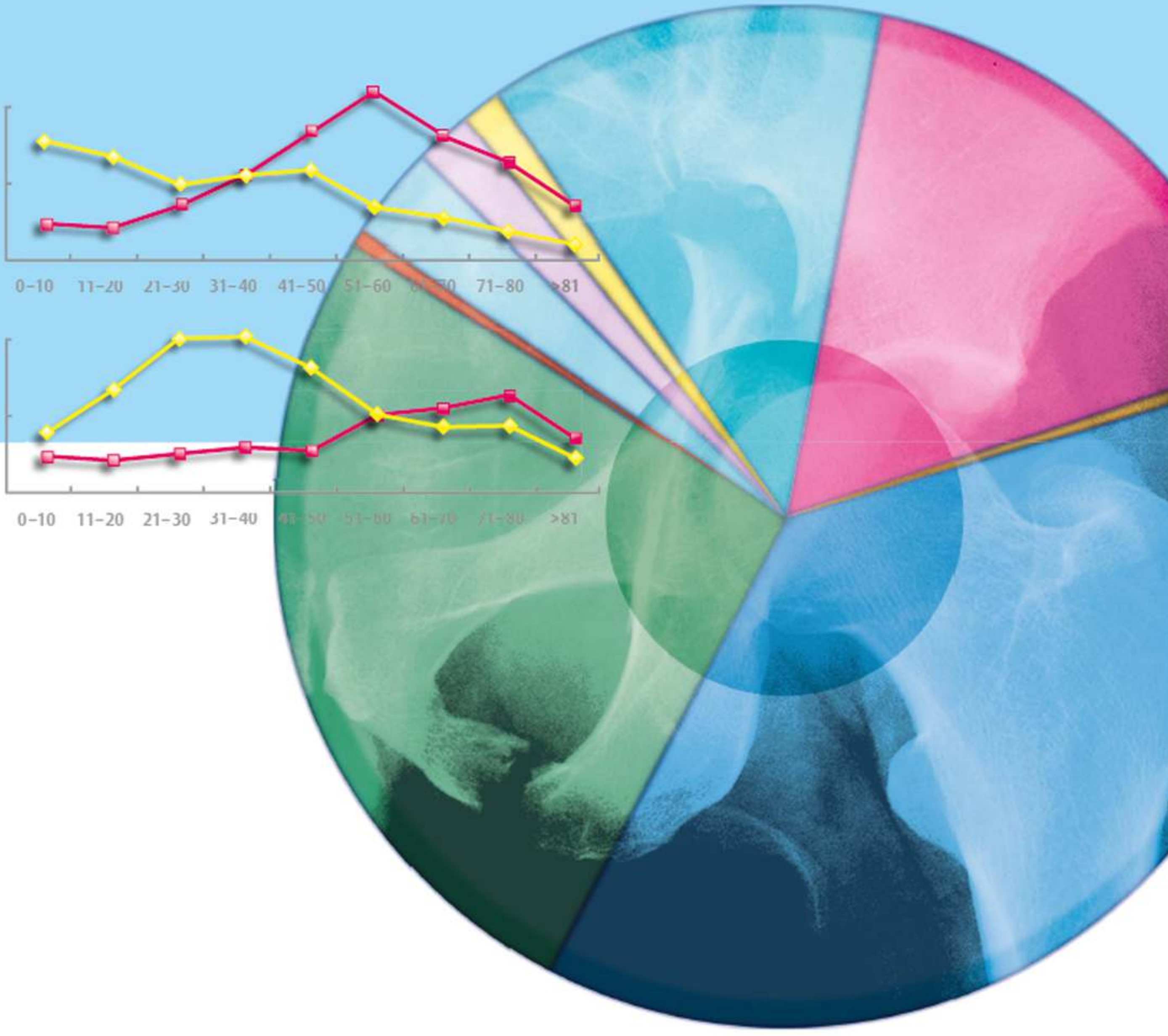
Clinical Epidemiology of Orthopaedic Trauma

Third Edition

Yingze Zhang



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Clinical Epidemiology of Orthopaedic Trauma

Third Edition

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I dedicate this third edition to my lovely wife, Yaling, for her support and inspiration, and to my sons, Qi and Yicheng, who bring happiness and joy to my life.

Contents

Foreword xiv
Liming Li

Foreword xv
Guixing Qiu

Foreword xvi
Robert D. D'Ambrosia

Foreword xvii
Roy W. Sanders

Preface xviii

Welcome to the Third Edition xix

Acknowledgments xxi

Contributors xxviii

How to Use This Book xxx

1. Introduction to Clinical Epidemiology of Orthopaedic Trauma 1
Yingze Zhang, Hongzhi Lv, and Xiaolin Zhang

Fractures Overview 1

Fracture Classification 1

Bones 3
Segments 3
Types 4
Group and Subgroup 4

Epidemiological Investigation and Analysis of Traumatic Fractures Incidence in China 4

Methods 5
The Content and Method of this Investigation 5
Quality Control and Evaluation 5
Data Statistics and Analysis 6

Epidemiological Study of Fractures 12

Incidence of Sex-Specific Fractures 15
Fracture Location 21
Fractures in Children 22

Suggested Readings 22

2. Fractures of the Humerus 23
Bo Liu, Qi Zhang, and Lin Jin

Overview of Humeral Fractures 23

Anatomic Features 23
AO Classification and Coding System for Humeral Fractures 24

Epidemiologic Features of Humeral Fractures in the China National Fracture Study 24

Humeral Fractures by Sex in CNFS 25
Humeral Fractures by Injury Side in CNFS 25
Humeral Fractures by Age Group and Sex in CNFS 26
Humeral Fractures by Location in CNFS 27
Humeral Fractures by Causal Mechanisms in CNFS 28

Clinical Epidemiologic Features of Humeral Fractures 29

Humeral Fractures by Sex 29
Humeral Fractures by Injured Side 30

Humeral Fractures by Age Group and Sex 31
Humeral Fractures by Location 33

Proximal Humeral Fractures (Segment 11) ... 34

Anatomic Features............................ 34
AO Classification of Proximal Humeral Fractures ... 34
Clinical Epidemiological Features of Proximal Humeral Fractures (Segment 11) 36
Injury Mechanism 50
Diagnosis 50
Treatment 51

Humeral Shaft Fractures (Segment 12) 52

Anatomic Features............................ 52
AO Classification for Humeral Shaft Fractures.... 52
Clinical Epidemiologic Features of Humeral Shaft Fractures (Segment 12).................. 53
Injury Mechanism 66
Diagnosis 66
Treatment 66

Distal Humeral Fractures (Segment 13) 67

Anatomical Features 67
AO Classification of Distal Humeral Fractures 68
Clinical Epidemiologic Features of Distal Humeral Fractures (Segment 13) 69
Injury Mechanism 82
Diagnosis 82
Treatment 82

Other Classifications of Humeral Fractures ... 82

The Neer Classification of Proximal Humeral Fractures 82
Classification of Humeral Fractures by Fracture Location 86

Clinical Epidemiologic Features of Medial Humeral Condylar Fractures 97

Suggested Readings 110

3. Fractures of the Ulna and Radius 111

Yingze Zhang, Song Liu, and Chenguang Du

Overview of Ulnar and Radial Fractures 111

Anatomic Features............................ 111
AO Classification and Coding System for Fractures of Ulna and Radius 111
Epidemiologic Features of Radial/Ulnar Fractures in the China National Fracture Study ... 111
Clinical Epidemiologic Features of Radial/Ulnar Fractures 117

Proximal Radial/Ulnar Fractures (Segment 21) 122

Anatomic Features............................ 122
AO Classification of Proximal Radial/Ulnar Fractures 122
Clinical Epidemiologic Features of the Proximal Radial/Ulnar Fractures (Segment 21)........... 123
Injury Mechanism 137
Diagnosis 137
Treatment 137

Fractures of the Radial/Ulnar Shaft (Segment 22) 138

Anatomic Features............................ 138
AO Classification of Fractures of Radial/Ulnar Shaft 138
Clinical Epidemiologic Features of the Radial/Ulnar Shaft Fractures (Segment 22) 139
Injury Mechanism 153
Diagnosis 153
Treatment 153

Distal Fractures of the Radius/Ulna (Segment 23) 153

Anatomic Features............................ 153
AO Classification of Distal Fractures of the Radius/Ulna................................ 153
Clinical Epidemiologic Features of Distal Fractures of the Radius/Ulna (Segment 23) 154
Injury Mechanism 169
Diagnosis 169
Treatment 169

Other Classifications of Ulnar and Radial Fractures 169

Monteggia Fractures.......................... 169
Galeazzi Fractures 176
Colles Fractures 180
Smith Fractures 184
Barton Fractures............................. 189

Suggested Readings 193

4. **Fractures of the Femur** 195

Yanbin Zhu, Yansen Li, and Enzeng Xing

Overview of Femoral Fractures 195

Anatomic Features........ 195
AO Classification and Coding System for Femoral Fractures 195
Epidemiologic Features of Femoral Fractures in the China National Fracture Study........ 195
Clinical Epidemiologic Features of Femoral Fractures 202

Proximal Femoral Fractures (Segment 31) ... 207

Anatomic Features........ 207
AO Classification of the Proximal Femoral Fractures 207
Clinical Epidemiologic Features of the Proximal Femoral Fractures (Segment 31)........ 207
Injury Mechanism........ 222
Diagnosis 222
Treatment 223

Diaphyseal Femoral Fractures (Segment 32) 223

Anatomic Features........ 223
AO Classification of Diaphyseal Femoral Fractures 223
Clinical Epidemiologic Features of Diaphyseal Femoral Fractures (Segment 32)........ 224
Injury Mechanism........ 240
Diagnosis 240
Treatment 240

Distal Femoral Fractures (Segment 33) 240

Anatomic Features........ 240
AO Classification of Distal Femoral Fractures.... 241
Clinical Epidemiologic Features of the Distal Femoral Fractures (Segment 33)........ 241
Injury Mechanism........ 257
Diagnosis 257
Treatment 257

Other Classifications of Femoral Fractures 257

Evans' Classification for Trochanteric Fractures of the Femur........ 257
The Garden Classification of Femoral Neck Fractures 261
The Pipkin Classification of Femoral Head Fractures 263

Suggested Readings 266

5. **Fractures of the Tibia and Fibula** 267

Juan Wang, Guang Yang, and Xiao Chen

Overview of Tibial/Fibular Fractures........ 267

Anatomic Features........ 267
AO Classification and Coding System of Tibial/Fibular Fractures 267
Epidemiologic Features of Fractures of the Tibia and Fibula in the China National Fracture Study 268
Clinical Epidemiologic Features of Tibial/Fibular Fractures 274

Proximal Tibial Fractures (Segment 41) 280

Anatomic Features........ 280
AO Classification of Proximal Tibial Fractures ... 281
Clinical Epidemiologic Features of Proximal Tibial Fractures (Segment 41) 281
Injury Mechanism........ 296
Diagnosis 296
Treatment 296

Tibial Diaphyseal Fractures (Segment 42) ... 297

Anatomic Features........ 297
AO Classification of Tibial Diaphyseal Fractures... 297
Clinical Epidemiologic Features of Tibial Diaphyseal Fractures (Segment 42) 297
Injury Mechanism........ 313
Diagnosis 313
Treatment 313

Distal Tibial Fractures (Segment 43)........ 313

Anatomical Features 313
AO Classification of Distal Tibial Fractures 313
Clinical Epidemiologic Features of Distal Tibial Fractures (Segment 43) 314
Injury Mechanism........ 328
Diagnosis 328
Treatment 328

Malleolar Injury (Segment 44)........ 328

Anatomical Features 328
AO Classification of Malleolar Injury 328
Clinical Epidemiologic Features of Malleolar Injury (Segment 44) 329
Injury Mechanism........ 345

Diagnosis ... 345
Treatment ... 345

Commonly Used Classifications for Fractures of the Tibia/Fibula ... 345

Tibial Plateau Fractures ... 345
Pilon Fractures ... 351

Suggested Readings ... 357

6. **Fractures of the Spine** ... 359
Wei Chen, Di Zhang, and Jiayuan Sun

Overview of Spinal Fractures ... 359

Anatomic Features ... 359
AO Classification and Coding System for Spinal Fractures ... 360
Epidemiologic Features of Spinal Fractures in the China National Fracture Study ... 360
Clinical Epidemiologic Features of Fractures of the Spinal Column ... 365

Cervical Fractures (Segment 51) ... 368

Anatomic Features ... 368
AO Classification of Cervical Spinal Fractures ... 369
Clinical Epidemiologic Features of Fractures of the Upper Cervical Spine (Segment 51.01–51.02) ... 369
Clinical Epidemiologic Features of Fractures of the Lower Cervical Spine (Segment 51.03–51.07) ... 378
Injury Mechanism ... 383
Diagnosis ... 383
Treatment ... 383
Further Classification of Cervical Spine Fractures ... 384

Thoracolumbar Fractures (Segments 52 and 53) ... 388

Anatomic Features ... 388
AO Classification of Thoracolumbar Spinal Fractures ... 388
Clinical Epidemiologic Features of Fractures of the Thoracolumbar Spine (Segments 52 and 53) ... 389
Injury Mechanism ... 397
Diagnosis ... 397
Treatment ... 397
Denis Classification of Thoracolumbar Spinal Fractures ... 398

Suggested Readings ... 400

7. **Fractures of the Pelvic Ring and Acetabulum** ... 403
Zhiyong Hou, Haili Wang, and Shiji Qin

Overview of Pelvic Ring and Acetabular Fractures ... 403

Anatomical Features ... 403
AO Classification and Coding System for Fractures of the Pelvic Ring and Acetabulum ... 404
Epidemiologic Features of Pelvic and Acetabular Fractures in the China National Fracture Study ... 405
Clinical Epidemiological Features of Fractures of the Pelvic Ring and Acetabulum ... 408

Pelvic Ring Fractures (Segment 61) ... 414

Anatomical Features ... 414
AO Classification of Pelvic Ring Fractures ... 414
Clinical Epidemiological Features of Pelvic Ring Fractures (Segment 61) ... 414
Injury Mechanism ... 429
Diagnosis ... 429
Treatment ... 429

Acetabular Fractures (Segment 62) ... 430

Anatomical Features ... 430
AO Classification of Acetabular Fractures ... 431
Clinical Epidemiological Features of Acetabular Fractures (Segment 62) ... 431
Injury Mechanism ... 445
Diagnosis ... 445
Treatment ... 445

Other Classifications for Fractures of the Pelvic Ring and Acetabulum ... 446

Tile Classification of Pelvic Ring Fractures ... 446
Young–Burgess Classification of Pelvic Ring Fractures ... 450
Letournel Classification of Pelvic Ring Fractures ... 458
Special Type of Pelvic Ring Fracture: Bilateral Sacroiliac Dislocation with an Intact Anterior Pelvic Ring ... 458

Letournel–Judet Classification of Acetabular Fractures 459
Tile Classification of Acetabular Fractures 464

Suggested Readings 465

8. Fractures of the Hand 467

Jialiang Guo, Lei Liu, and Chenni Ji

Overview of Hand Fractures 467

Anatomic Features........ 467
OTA Classification and Coding System for Hand Fractures........ 467
Epidemiologic Features of Hand Fractures in the China National Fracture Study 467
Clinical Epidemiologic Features of Hand Fractures 472

Carpal Fractures (Segments 71–76) 477

Anatomic Features........ 477
OTA Classification of Carpal Fractures........ 477
Clinical Epidemiologic Features of Carpal Fractures (71–76) 478
Injury Mechanism........ 493
Diagnosis 493
Treatment 493

Further Classification for Scaphoid Fractures 493

Anatomic Features and Coding System........ 493
Clinical Epidemiologic Features of Scaphoid Fractures in Adults 493
Injury Mechanism........ 501
Diagnosis 501
Treatment 501

Metacarpal Fractures (Segment 77) 501

Anatomic Features........ 501
OTA Classification of Metacarpal Fractures 501
Clinical Epidemiologic Features of Metacarpal Fractures in Adults (Segment 77) 501
Injury Mechanism........ 518
Diagnosis 518
Treatment 518

Further Classification of Base Fracture of the First Metacarpal Bone 518

Anatomic Features and Classification 518
Clinical Epidemiologic Features of Fractures of the Base of the First Metacarpal Bone 518
Injury Mechanism........ 524
Diagnosis 524
Treatment 525

Phalanx Fractures (Segment 78)........ 525

Anatomic Features........ 525
OTA Classification of Phalanx Fractures 525
Clinical Epidemiologic Features of Phalanx Fractures (Segment 78) 525
Injury Mechanism........ 542
Diagnosis 542
Treatment 542

Multiple Fractures (Segment 79) 542

OTA Classification of Multiple Fractures of the Hand........ 542
Clinical Epidemiologic Features of Multiple Fractures (Segment 79) 542

Suggested Readings 548

9. Fractures of the Foot 549

Fei Zhang, Ye Tian, Zongyou Yang, and Tao Liu

Overview of Foot Fractures........ 549

Anatomic Features........ 549
OTA Classification and Coding System for Foot Fractures 549
Epidemiologic Features of Foot Fractures in the China National Fracture Study........ 549
Clinical Epidemiologic Features of Foot Fractures 554

Talar Fractures (Segment 81)........ 560

Anatomic Features........ 560
OTA Classification of Talar Fractures 560
Clinical Epidemiologic Features of Talar Fractures 560
Injury Mechanism........ 574
Diagnosis 574
Treatment 574
Other Common Classifications of Talar Fractures 574

Calcaneal Fractures (Segment 82) 578

Anatomic Features........ 578

OTA Classification of Calcaneal Fractures 579
Clinical Epidemiologic Features of Calcaneal Fractures (Segment 82) 579
Injury Mechanism 591
Diagnosis 591
Treatment 592
Other Classifications for Calcaneal Fractures 592

Fractures of the Tarsal Navicular Bone (Segment 83) 597

Anatomic Features 597
OTA Classification of Tarsal Navicular Fractures 597
Clinical Epidemiologic Features of Tarsal Navicular (Segment 83) 597
Injury Mechanism 603
Diagnosis 603
Treatment 604

Cuboid Fractures (Segment 84) 604

Anatomic Features 604
OTA Classification of Cuboid Fractures 604
Clinical Epidemiologic Features of Cuboid Fractures 604
Injury Mechanism 610
Diagnosis 610
Treatment 611

Cuneiform Fractures (Segment 85) 611

Anatomic Features 611
OTA Classification of Cuneiform Fractures 611
Clinical Epidemiologic Features of Cuneiform Fractures (Segment 85) 612
Injury Mechanism 619
Diagnosis 619
Treatment 619

Metatarsal Fractures (Segment 87) 619

Anatomic Features 619
OTA Classification of Metatarsal Fractures 619
Clinical Epidemiologic Features of Metatarsal Fractures (Segment 87) 620
Injury Mechanism 638
Diagnosis 638
Treatment 638

Phalangeal Fractures (Segment 88) 638

Anatomic Features 638
OTA Classification of Phalangeal Fractures 638
Clinical Epidemiologic Features of Phalangeal Fractures (Segment 88) 639
Injury Mechanism 657
Diagnosis 657
Treatment 657

Multiple Fractures of the Foot (Segment 89) 657

Clinical Epidemiologic Features of Multiple Fractures of the Foot (Segment 89) by OTA Classification 657

Suggested Readings 660

10. Fractures of the Patella, Clavicle, and Scapula 661

Bing Yin, Shilun Li, and Zhaoyu Chen

Fractures of the Patella (Segment 34) 661

Anatomic Features 661
OTA Classification and Coding System for Patellar Fractures 661
Epidemiologic Features of Patellar Fractures in the China National Fracture Study 661
Clinical Epidemiologic Features of Patellar Fractures (Segment 34) 665
Injury Mechanism 677
Diagnosis 677
Treatment 677
Further Classifications of Patellar Fractures: The Regazzoni Classification 677

Clavicle Fractures (Segment 15) 682

Anatomic Features 682
Anatomic Features and Muscular Attachment of the Clavicle 683
OTA Classification and Coding System for Clavicle Fractures 684
Epidemiologic Features of Clavicle Fractures in the China National Fracture Study 684
Clinical Epidemiologic Features of Clavicle Fractures (Segment 15) 687
Injury Mechanism 695
Diagnosis 695
Treatment 695
Further Classifications of Clavicle Fractures 695

Scapular Fractures (Segment 14) 708

Anatomic Features 708
OTA Classification and Coding System for Scapular Fractures 709
Epidemiologic Features of Scapular Fractures in the China National Fracture Study 709

Epidemiologic Features of Scapular Fractures (Segment 14) 712
Injury Mechanism 727
Diagnosis 727
Treatment 727
Further Classifications of Scapular Fractures 728

Suggested Readings 754

11. Epidemiologic Features of Fractures in Taiwan Between 2011 and 2013 755
Tao Zhang, Pan Hu, Xiaodong Cheng, and Peizhi Yuwen

Introduction to the Taiwan Study 755

Fractures by Sex 755

Fractures by Age Group and Sex 758

Patients with Humeral Fractures 758
Patients with Ulnar and Radial Fractures 760
Patients with Femoral Fractures 762
Patients with Tibia and Fibula Fractures 764
Patients with Spinal Fractures 766
Patients with Fractures of the Pelvic Ring and Acetabulum 768
Patients with Hand Fractures 770
Patients with Foot Fractures 772
Patients with Patellar Fractures 774
Patients with Clavicle Fractures 776
Patients with Scapular Fractures 778

Fracture Location 780

Fractures in Children 780

Suggested Readings 781

Index 783

Foreword

Epidemiology's research field and application scope are expanding constantly as new methods of medical research are developed to study the distribution of disease and health status and their determinants, and to study the strategies and measures for preventing and treating diseases as well as promoting health. The epidemiology of orthopaedic trauma is an interdiscipline of epidemiology and orthopaedic trauma, using the principles and methods of epidemiology to study the incidence, prevalence, and constituents of traumatic fractures, and explore the possible causes of fractures, thus providing scientific basis for the prevention and treatment of traumatic fractures. The epidemiologic research of orthopaedic trauma can clearly describe the distribution of gender, age, location, time, and severity of fractures, as well as investigate the etiology of fracture by finding clues to possible cause and verifying the hypothesis, in order to provide scientific evidence for prevention and treatment of traumatic fractures in the population.

We are very pleased to see that Professor Yingze Zhang and his team have carried out an in-depth and detailed research work of the epidemiology of fractures in our country over 11 years. In 2009, they published *Clinical Epidemiology of Orthopaedic Trauma*, the first book of our country in this field, analyzing the distribution of age, sex, site, and severity of fracture over 60,000 patients (65,267 fractures), and systematically expounding the constituent ratio of various sites and types of fracture. The English translation was published by Thieme Medical Publishers in 2012. This book was well received by readers.

On this basis, Professor Zhang led the research group to carry out the national fracture epidemiological investigation. The difficulty of epidemiological study of a large sample population is selecting the representative sample and controlling the mixed factors effectively. Under the premise of considering the socioeconomic situation, urban-rural differentials, the level of hospital, and the ethnic distribution, the research group selected 83 hospitals with excellent representativeness from 31 provinces and autonomous regions (all except Hong Kong, Macao, and Taiwan) using multistage random sampling methods. The data of all traumatic fractures treated in those hospitals from January 2010 to December 2011 was collected, and epidemiological analysis of 431,822 fractures of 414,935 patients was performed, comprehensively reflecting the epidemiological characteristics of traumatic fracture in China. They have established an epidemiological database of the largest domestic and foreign sample volume of orthopaedic trauma. Their data collection and analysis of traumatic fracture in the whole country have revealed the common laws and the scientific foundation for prevention, diagnosis, and treatment of fractures.

This third edition of *Clinical Epidemiology of Orthopaedic Trauma* adds national incidence of traumatic fractures in China. They estimated incidence rates for traumatic fractures for the overall population and for subgroups by age and sex, as well as by demographic factors such as ethnic origin, occupation, geographical region, and residency category.

The data in this book are visually presented to the readers by means of pie charts, curve graphs, and histograms in order to minimize the description text. The text of fracture classification is supplemented by colored schematic diagrams and radiographs, making it easy to understand for clinical orthopaedic surgeons. The epidemiological characteristics of fractures are reflected intuitively and concisely in pictures with actual data. Furthermore, the new theory and new technology in the field of orthopaedic trauma in recent years are briefly introduced, which can expand readers' perspective and help young orthopaedic surgeons master the essentials of diagnosis and treatment of fractures.

Clinical Epidemiology of Orthopaedic Trauma is the most important achievement of large-scale epidemiological investigation of orthopaedic trauma in recent decades. It has filled the domestic gap in the epidemiological study of fracture, and improved the system of epidemiology of orthopaedic trauma in China.

I felt delighted after reading the first and second editions of *Clinical Epidemiology of Orthopaedic Trauma*, with great admiration for the author's hard work. Now, Professor Zhang and his team have completed this third edition, enriched by their insurmountably meticulous survey work in a wide region and with a large sample size. It is a great honor and pleasure for me to be invited to write this foreword.

Liming Li, MD
Vice-Chairman of China Preventive Medicine Association
Chairman of the China Association of Epidemics
College of Public Health of Peking University
Beijing, China

Foreword

At present, epidemiological data of fractures in Chinese literature mainly refer to foreign research, partially with unknown or unverifiable sources. As China is a huge country with such a large population, development levels vary greatly in different regions of the country, and the cause of injury is always complicated and variable. For this reason, foreign data is not able to reflect the characteristics and distribution of fractures in our country, especially when the incidence and types of the fractures in our country have changed greatly in recent years. Therefore, a large-scale domestic epidemiological investigation of fractures with large sample size is much needed.

Professor Yingze Zhang and his collaborators have done much research work on the epidemiological characteristics of the fractures in our country by stages since 2003. In the first stage, this team systemically analyzed the data of 65,267 fracture cases treated in The Third Hospital of Hebei Medical University from 2003 to 2007, according to the AO/OTA classification system and other commonly used or accepted classification. Their work was published by the People's Health Publishing House in 2009 as the first monograph of clinical epidemiology of traumatic fractures. This book was translated into an English edition and published by Thieme Medical Publisher in 2012, which introduced the great achievement of our country's fracture epidemiology to the whole world.

In the second stage, Professor Zhang led his team to extend the research to 31 provinces and autonomous regions in China. They investigated and analyzed 431,882 fractures of 414,935 patients from 83 hospitals, and built an epidemiological database of orthopaedic trauma with the world's largest sample size to date. The results have been included in the second edition of *Clinical Epidemiology of Orthopaedic Trauma*. Epidemiological characteristics of, as well as diagnosis and treatment techniques for fractures of the trunk and limbs in our country are comprehensively illustrated in this edition. Each chapter contains an overview of the diagnosis and treatment for fracture of various parts, accompanied by the latest technological progress, which is helpful to young orthopaedic surgeons' study of injury characteristics and essentials in diagnosis and treatment of various fractures. The second edition is also dominated by pictures and figures, consistent with the first edition in style and form. Age, gender, and type distributions of the fractures are displayed with charts, and the injury characteristics of various types of fractures are presented to the readers via a combination of color sketches and X-rays.

On this basis of this, Professor Zhang led the China National Fracture Study focusing on national incidence of traumatic fractures in the country. The study was done on the basis of the Sixth Population Census data and strictly followed the principle of epidemiological design and sampling method. A representative variety of people were field investigated with multistage stratified cluster random sampling. Under strict quality control, 512,187 effective questionnaires were got at last. They analyzed the population-weighted incidences of traumatic fractures by sex, age, part of fracture, and injury mechanism. The risk factors of different people were identified with multiple logistic regression analysis, and the biggest fracture epidemiological database in the world was established. On the basis of the first and second editions, they finished this third edition.

Clinical Epidemiology of Orthopaedic Trauma is an indispensable tool for orthopaedic surgeons, with abundant content, precise diction, detailed materials, excellent pictures and text, and comprehensive instruction. The new edition of this book makes our country's academic field more glorious and resplendent. I sincerely congratulate the authors for the publication of this book and hope it can play a proper role and be published in more foreign languages, so as to disseminate the new development of clinical epidemiology research of orthopaedic trauma in China to the orthopaedic surgeons and epidemiologists of other countries in the world.

Guixing Qiu, MD
Academician, China Academy of Engineering
Professor, Peking Union Medical College
Director, Department of Orthopedics
Peking Union Medical College Hospital
Beijing, China

Foreword

I am honored to write a foreword to this third edition of Professor Zhang's book, *Clinical Epidemiology of Orthopaedic Trauma*. He is well known to me personally and to orthopaedic academia in the United States. I was privileged to hear his presentations in Denver, Colorado; also at the "Current Concepts Course" in orthopaedics in Kauai, Hawaii, 2015; and at the Chinese Orthopedic Association meeting in Beijing, China, in 2016. Professor Zhang is president-elect of the Chinese Orthopaedic Association. He is an accomplished orthopaedic surgeon with a wide and varied experience in orthopaedic trauma in his position as chair of Orthopedic Trauma at Hebei University.

Professor Zhang's book is practical and well-illustrated, and will be an essential reference book for experienced orthopaedic surgeons, residents, and medical students. He has drawn upon his wide experience as an orthopaedic researcher who has been remarkably productive—authoring 22 books and over 400 publications. This book, in its third edition, includes 414,936 cases from 83 hospitals and 31 provinces across China. It is a comprehensive epidemiology study of orthopaedic trauma on a national scale, with a huge sample size, which has worldwide implications. His orthopaedic team, under his guidance, has done an outstanding job in the tedious work on AO/OTA classification of each fracture. The diagrams are easy to understand, and the illustrations demonstrate the superb results that could be obtained.

Through the study, the world now has a better understanding of fracture care in different areas of China, which will be very beneficial in allocating valuable resources accordingly. Professor Zhang and coworkers are to be congratulated for this valuable treatise in orthopaedic trauma that will serve as a reference and database for the present and well into the future. It is a monumental contribution to the world of orthopaedic surgery.

Robert D. D'Ambrosia, MD
Professor and Chair
Department of Orthopaedics
University of Colorado
Aurora, Colorado, USA

Foreword

Clinical Epidemiology of Orthopaedic Trauma, third edition, by Professor Yingze Zhang is an outstanding resource. This is one of the few books, if not the only, which collates this information into one volume. Comprehensive in nature and amply illustrated with diagrams, charts, and drawings, it evaluates every fracture seen and treated at a major international trauma center—complete with AO/OTA classification and demographic information, among other important data. Clearly and rationally organized, and in great detail, the authors lay out the individual fractures, their patterns, diagnosis, mechanism of injury, and treatment options. Beyond the orthopaedic surgeon's interest in such information, this book should be of inestimable value to researchers, residents, and students of all disciplines. In short, a must-have reference book for serious orthopaedic researchers. Professor Zhang is to be congratulated on this outstanding achievement.

Roy W. Sanders, MD
Editor-in-Chief
Journal of Orthopaedic Trauma
Tampa, Florida, USA

Preface

This book, *Clinical Epidemiology of Orthopaedic Trauma*, is the first monograph on fracture epidemiology. The first edition was published by People's Medical Publishing House in 2009, and translated into English by Thieme Medical Publishers and distributed worldwide in 2012. The book received extensive positive reviews for its unique writing style, which combined knowledge in both theory and practice. Prof. David E. Parker from North Carolina wrote a review of the book, considering it an excellent textbook with reasonable structure, abundant illustrations and pictures, and concise description.

The first edition was based on a retrospective review of 60,266 patients (65,267 fractures) treated at our trauma center over a 5-year period from 2003 to 2007. Given large differences in natural and social environments in China, we performed a large-scale, multicenter study to get a comprehensive understanding of the feature of orthopaedic trauma epidemiology. Based on the first edition, an advanced research throughout the nation was carried out.

Across the nation, 83 hospitals from 31 provinces were selected with a stratified multistage random sampling method and 414,835 patients (431,822 fractures) were identified from all levels of trauma center and included in the study. Our research teams comprise of orthopaedic surgeons, radiologists, and epidemiologists. Survey forms and data collection and analysis scheme were designed in detail.

All researchers were trained to classify the fractures accurately and consistently. The AO classification was adopted in this edition, as it had been widely recognized worldwide because of its practicality, uniformity, and comparability. Meanwhile, other special fracture classifications were adopted to reflect the feature of fracture comprehensively. Two senior orthopaedic surgeons and one radiologist were responsible for the high quality of the work. The second edition was completed after tallying the results.

This third edition of *Clinical Epidemiology of Orthopaedic Trauma* adds national incidence of traumatic fractures in China. The China National Fracture Study recruited a nationally representative sample from 8 provinces, 24 urban cities, and 24 rural counties in China using stratified random sampling and the probability proportional to size method. Under strict quality control, 512,187 effective questionnaires were got at last. We estimated incidence rates for traumatic fractures for the overall population and for subgroups by age and sex, as well as by demographic factors such as ethnic origin, occupation, geographical region, and residency category.

This book introduces the epidemiological feature of individual types of fracture concisely and yet comprehensively. The new trends and changes were documented as well. Although the structural organization is consistent with the last edition, the sample size is increased largely to reflect more authentic and accurate trends and changes in the epidemiological features of fractures in China as a nation. The easy-to-understand yet excellent graphics, with corresponding X-ray films and fracture line graphs are retained. Magnetic resonance imaging or computed tomography images are added for complicated fractures to fully illustrate the characteristics of the injuries. For the purpose of clinical and scientific research, the sections "Diagnosis" and "Treatment" were updated with the latest developments and progress. Omissions and mistakes are unavoidable due to the heavy workload and tight schedule. We are looking forward to your valuable comments and suggestions, which will be a generous help to our endeavors to create a consummate monograph.

All those who worked on the book have clinical and scientific research backgrounds. They made great efforts on this book, which made this publication possible. My deepest gratitude and respect to all of them!

Yingze Zhang, MD

Welcome to the Third Edition

My students told me, "Teacher, we have found that you have owned more than 100 patents in the Internet of State Intellectual Property Office of The Republic of China (http://www.sipo.gov.cn/), and more than 30 patents belong to invention patents; 5 patents applications in the USA have been into practical examination stage; 3 patents have certifications of FDA in America; 7 patents got the Chinese FDA's registration certificate. We have made a search in the Internet and found that you may be the doctor who has owned the most patents in China, also with the most registration certificates." When I heard the above news, I felt calm but proud. I got my first patent 20 years ago; since then I have been keeping up with it. The director of the State Patent Office has changed from Mr Jiang Yang, Mr Wang Jingchuan, Mr Tianli Pu, to Mr Shen Changyu now. Some of my patents came from instant burst of inspiration; some took more than 30 years from having an idea, experiments for improvement, to patent application and authorization. All these patents embody our research team's hard work and sweat. Today, it is rearranged into a book to commemorate the ups and downs during the past 30 years.

"The study without innovation cannot be called research." This was the motto of my instructor, Terayama Kazuo, professor of Shinshu University when I was a student in Japan, and it is my motivation to spur innovation. Western orthopaedics was introduced to China more than 150 years ago, but the real stage of rapid development started from the 1980s. Today, the rapid development of China's orthopaedic career is acknowledged worldwide, but orthopaedic fixation devices and products are imported from abroad, which are very expensive. Tens of billions of profits are earned by foreign companies easily each year! At the same time, there are a lot of poor people in remote areas living with permanent disability because they cannot afford the huge costs. This is another motivation for me to innovate.

I have vivid memories, in order to improve the quality of closed reduction of fracture, we used to go to aircraft manufacturing 20 km away from our hospital during holidays to do research on fracture traction equipment. After 32 years of continuous research, it granted patents on clinical application. But this time, some of our comrades were unable to share the joy with us. The turner and draftsman at that time had retired. The fitter died of illness a few years ago. Whenever thinking of these, I cannot avoid sentimentality. But what keeps me moving is that the fitter's son-in-law is fighting with us side by side.

Some of my patents belong to original results and have been used in clinical setting, such as "Intramedullary reduction device used for long bone fracture (golden key)" which has been used in the Denver Health Center, USA. Chinese products can be applied and promoted in the international arena. It is not only my personal glory, but also the pride of Chinese orthopaedic surgeons. There are also some products that are modification of the original, but the little bit of improvement not only allows doctors to operate more comfortably, but also effectively shorten the operation time, reducing trauma. As the saying goes: "Don't do nothing because the benefit is little, don't do it because the evil is little." As long as there is something good for the patients, then the small effort is worth it. There are some concepts, ideas, and designs for which, due to the current conditions, we can only first apply for a patent for reference of domestic and foreign counterparts.

China's President Xi Jinping said recently: "We cannot always use someone else's yesterday to dress our tomorrow; we cannot always expect to rely on scientific and technological achievements of others to improve our technological level; we cannot even do technical vassal of other countries, always followed the footsteps of others." We have to be not only first-class clinicians, but also first-class creative talent. We must dare to lead the orthopaedics trend in the world, and pursue excellence in tackling problems, to serve the motherland and the people and the world with innovative scientific achievements. "Not afraid of difficulties, not accepting failure, the courage to play, the courage to go beyond" is the motto of our team forever.

In the course of history, three decades are just a moment; but in my case, it is nearly half of my life. Looking back, bit by bit as vivid as if it happened yesterday, seeing the fruits of hard work, fills the heart with infinite emotions. These fruits have now been compiled into a book on the desk, to thumb through leisurely to enjoy. We also give these to our friends and colleagues, and invite everyone to join us to share the joy.

Yingze Zhang, MD

作者自序

一年前，我的学生告诉我：" 老师，从国家专利局网上查到您的专利已有100多项，发明专利就有30多项，在美国申请的5项已经进入实审阶段。另外有3项已经获得美国FDA认证，7项拿到了国家食品药品监督局的注册证。我们在网上搜了一下，您应该是国内医生中获得专利数量最多、拿到注册证最多的" 。得知这个消息，我的心情虽然平静，但自豪感还是油然而生。我最早的专利授权距今已经20多年了，期间的国家专利局长已经从姜颖、王景川、田力普换到了如今的申长雨。这些专利，有些来自灵感的瞬间迸发，一促而就；有些则从萌生思路、到实验改进、再到专利申报和授权历时30余年，都凝聚着我和科研团队的辛劳和汗水。今天重新整理，亦是对过去30多年酸甜苦辣的温习与纪念。

“没有创新的研究就不能称之为研究。” 这是我在日本留学时的导师信州大学寺山和雄教授的座右铭，也是鞭策我不断创新的动力。西医骨科传入中国已有150多年历史，但真正的快速发展阶段还是改革开放以后。如今，我国骨科事业的发展日新月异，但骨科器械和内固定的产品几乎还都是从国外引进，价格昂贵！每年成百上千亿的利润被外企轻易赚取！同时，还有很多偏远地区的贫困群众，因承担不起这巨额费用而留下终生残疾！这是激励我不断创新的又一动力。

还记得当年，为了提高骨折闭合复位质量，我们利用节假日，到20公里外的飞机制造厂一起研制骨折牵引复位器，反复实验、不断改进，历经32年终于获批发明专利并应用于临床。但此时，有些同志已经无法与我们一起分享喜悦了，当年的车工、绘图员都已退休，钳工前些年也因病去世了。每当想起这些，我都不免感伤，而更让我动容的是，钳工的女婿又和我们并肩奋斗。

我的专利有些是原创性成果，已经应用于临床，例如” 四肢长骨骨折髓内复位器（金钥匙）” ，已在美国Denver Health Center得到应用和认可。中国的产品能够在国际领域得到应用和推广，这不仅是我个人的荣耀，也是中国骨科医生的骄傲。也有一些产品只是在原有基础上的改良，但这一点点的改良，不仅能让医生操作起来更加得心应手，还能有效缩短手术时间、减小创伤。老话说的好：” 勿以恶小而为之，勿以善小而不为” 。只要有利于患者，再微小也值得我们为之努力。还有一些理念、构思和设计，由于目前条件所限，我们只能先将它们申报专利，以供国内外同行参考。

习近平总书记在最近的讲话中指出，” 不能总是用别人的昨天来装扮自己的明天。不能总是指望依赖他人的科技成果来提高自己的科技水平，更不能做其他国家的技术附庸，永远跟在别人的后面亦步亦趋。” 我们要做一流的临床医生，也要做一流的创新人才。我们要敢于引领世界骨科潮流，在攻坚克难中追求卓越，用创新的科学成果来服务于祖国人民和全世界。” 不怕困难、不言失败，敢于担当、勇于超越。” 是我们团队永远的座右铭！

在历史的长河中，三十年不过是瞬间；但于我而言，却是近一半的人生。回首从前，点点滴滴就像发生在昨天一样历历在目。每每看到这些我们用心血和汗水浇灌出来的果实，心中有不尽感慨。将这些血汗结晶汇编成册，放在案头，闲暇时随手翻阅，自得其乐；也送给朋友与同行，诚邀大家和我们一起共同分享这份喜悦。

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How to Use This Book

The authors of this book completed the China National Fracture Study (CNFS), which was a retrospective epidemiological study that recruited a nationally representative sample from 8 provinces, 24 urban cities, and 24 rural counties in China, using stratified random sampling and the probability proportional to size method. In the CNFS, 512,187 individuals participated, consisting of 259,649 boys and men and 252,538 girls and women. The national incidence rate of traumatic fractures of the trunk, arms, or legs for the overall population and for subgroups by age and sex, as well as by demographic factors such as ethnic origin, occupation, geographical region, and residency category were analyzed. The potential associations between fractures and various factors of interest, such as age, ethnic origin, education, smoking, alcohol drinking, sleep time per day, and history of previous fracture, were also studied.

The authors of this book also retrospectively reviewed radiographic images of 431,882 fractures in 414,935 patients obtained from 83 hospitals in 31 provinces of China, and performed fracture classification and statistical studies based on the AO/OTA system and other commonly used classification systems. The authors also reported the epidemiologic features of traumatic fractures in Taiwan province of China between 2011 and 2013 based on the analysis of data from a total of 390,133 patients with 424,645 fractures.

This book has 11 chapters. The first 10 chapters are organized according to the coding system proposed by AO/OTA fracture classification. The first chapter presents an outline of the book and provides an introduction to the coding of bones used by AO/OTA and to fracture classification principles. The remaining nine chapters deal with fractures occurring in different anatomic locations arranged in ascending order according to the AO/OTA coding system: humerus, radius/ulna, femur, tibia/fibula, spine, pelvic ring/acetabulum, hand, foot, and others (including patella, clavicle, and scapula). Each chapter is divided into sections that deal with segments within the bone. The final section of each chapter describes other commonly used fracture classification systems and their epidemiological characteristics. The 11th chapter describes the epidemiologic features of traumatic fractures in Taiwan province of China.

The epidemiological features of each type of fracture contain such information as the number of fractures and patients and gender and age distribution, which is displayed in tables, pie charts, bar charts, and so on.

Please note that percentages are displayed with two digits of precision after rounding up; therefore, the numbers in the tables may not always add up to 100% as a result of possible rounding differences.

1 Introduction to Clinical Epidemiology of Orthopaedic Trauma

Yingze Zhang, Hongzhi Lv, and Xiaolin Zhang

Fractures Overview

Bone fractures occur when there is a break in the continuity and integrity of the bone as a result of excessive force. Fractures usually begin with intensive pain and swelling at the site of injury, along with some degree of loss of function. Furthermore, fractures can also present with shock and fever as seen in severe cases. Characteristics of fractures include deformities, abnormal movement, bony crepitus, and perception of friction between fracture fragments. Fractures that result in a deformed limb and severe pain often require immediate surgical intervention. In severe fractures, the circulation may become disrupted and lead to a loss of pulse distal to the fracture site. Fractures involving articulation sites may result in subsequent dysfunction of the joint.

Fractures can be classified into different categories based on the impact of the fracture. For example, they can be classified as open or closed, depending on the integrity of the skin tissue and mucosa; as complete or incomplete, depending on the severity of the fracture; or as stable or unstable in terms of displacement, angulation, and shortening. Fractures can also be described as traumatic or nontraumatic, the latter more commonly seen as a pathologic fracture. Traumatic fractures are seen more frequently in clinical practice than nontraumatic fractures.

Radiographic examination should include anteroposterior (AP) and lateral views of the fractured bone, along with the nearest joint. Some fractures require additional radiographic views, such as AP and oblique views for metacarpus and metatarsus, lateral and axial views for calcaneus, and AP and ulnar views for scaphoid deviations. Sometimes, if the injury is difficult to determine, comparison views of the contralateral uninvolved side will be helpful in reaching an accurate diagnosis. In cases with a clinically suspected fracture and negative or inconclusive findings on initial radiography, a radiographic examination should be repeated 2 weeks later, when the fracture line will emerge as healed fragments, as seen in carpal scaphoid fractures. For fractures adjacent to a joint or a complex anatomic structure, as X-ray examination provides limited information, computed tomography (CT) or magnetic resonance imaging (MRI) is therefore highly recommended to provide a clear depiction of the fracture.

The overall principles of fracture management are: restoration of anatomy, stable fracture fixation, and early mobilization of the limb and patient. Fracture reduction is a procedure to restore anatomy by positioning displaced bone fragments in the correct alignment, and to encourage healing and normal use of the bone and limb. Fixation is an attempt to maintain proper alignment of the fracture site until the bone becomes strong enough to support the union. Functional exercise must be started as soon as possible, to restore the functional ability of muscle, tendon, and joint ligaments without compromising the fixation hardware.

Fracture Classification

To understand the injury mechanism, select proper treatment options, and compare the outcomes of different treatments regimes, it is important to have a system of fracture classification. Numerous fracture classification systems have been proposed in orthopaedics. A standardized and widely accepted fracture classification system would facilitate communication between physicians and assist documentation and research. For clinical relevance, it should reflect the complexity of treatment planning and have prognostic value for patient outcome. Maurice E. Müller indicated that a classification is useful only if it considers the severity of the bone lesion and serves as a basis for treatment and for evaluation of results. The AO classification is currently in use along with conventional classification. The latest version of the Müller AO classification was published in 1996 in the form of a supplement to Volume 10 of *The Journal of Orthopaedics Trauma*, where the classifications for the long bones, spine, and pelvis were comprehensive; however, smaller bones such as those of the hand and foot were listed only with numbers indicating location. The Müller AO classification has become widely accepted and applicable in practice not only because of the great impact the AO Foundation has had over the years in the field of orthopaedics, but also because of scientific validation of the classification system itself. The strength of Müller's system is that it provides a framework within which a surgeon can recognize, identify, and describe long bone injuries.

The Orthopaedic Trauma Association (OTA) has established its own classification system, with the AO system as a reference. Essentially, the OTA system added to the AO system by classifying those bones that were never classified in the AO system; this ultimately led to the formation of the AO/OTA system. The OTA published the latest version of fracture classification in December 2007 in a supplement to Volume 21 of *Journal of Orthopaedics Trauma*. The OTA adopted the AO system of classifying long bones, spine, and pelvis, and significantly revised the classification for the clavicle and scapula, foot and hand, and patella.

The AO Foundation should be mentioned whenever the AO fracture classification system is discussed. In 1958, a group of Swiss general and orthopaedic surgeons led by Maurice E. Müller, Martin Allgower, and Hands Willenegger established the AO Foundation. The AO “pioneers” proposed a method of absolute stability through compression between fracture fragments to achieve a goal of rigid internal fixation of fractures. This concept may be less than perfect by modern standards, but it caused a revolution in the treatment of fractures. The most important contribution of the AO Foundation is to promote these original principles, which not only are of great practical and scientific value but also can be continually refined and improved with use. Over the past 10 years, the AO principles of fracture management have evolved in various ways, and have begun to advance internal fixation methods. Today, 56 years after its establishment, the AO principles for operative fracture fixation and the bone-healing concept are accepted worldwide. As research in the biomechanics of fractures has advanced, the AO principles and the hardware for internal fixation have seen dramatic improvement, with emphasis shifting from strong internal fixation based on pure mechanics to fixation based on biomechanics. The latest AO principles stress the pathophysiology and biology of the bone-healing process rather than its mechanics.

The AO classification system adopted a five-element alphanumeric code to describe each fracture as the following: ■■-□□.□. The first two elements of the alphanumeric code describe the location (bone segment), followed by an alphabetic character for the fracture type (A, B, C), and lastly two numbers for morphological characteristics of the fracture (group and subgroup), as seen in ▶ Fig. 1.1.

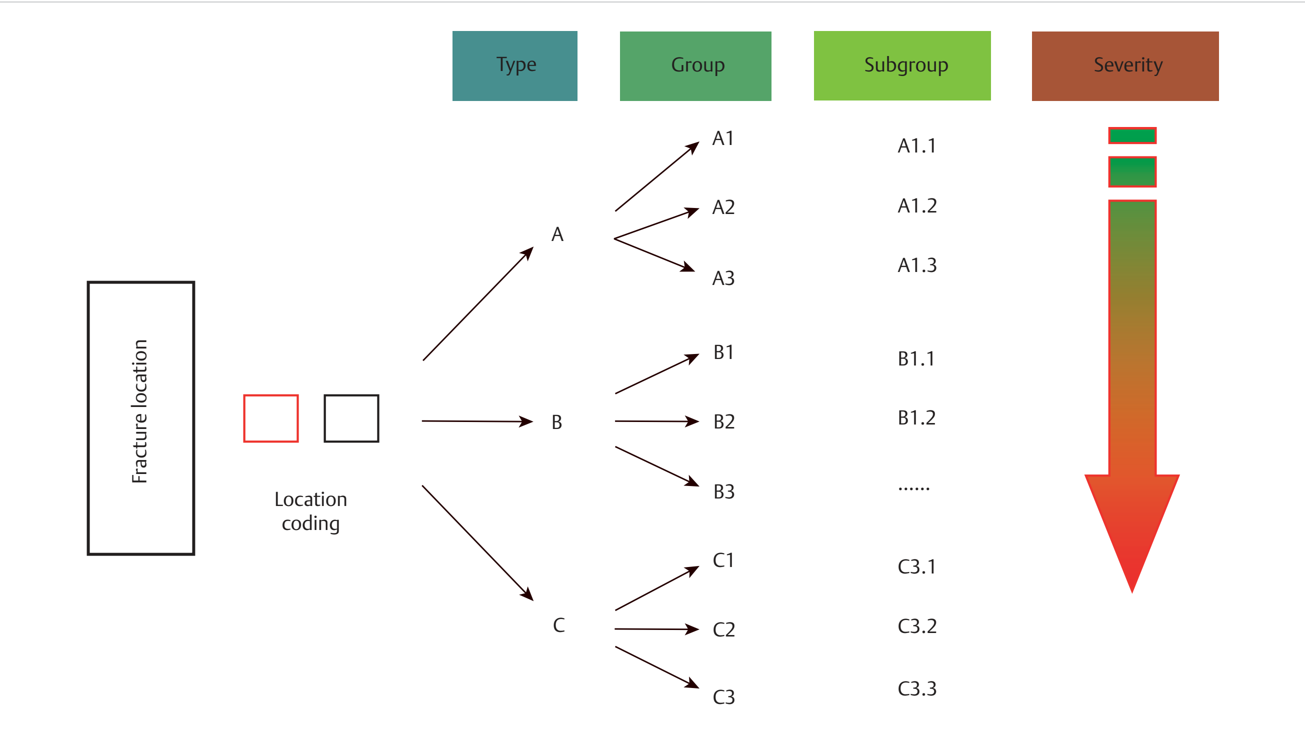

Fig. 1.1 AO classification of fractures.

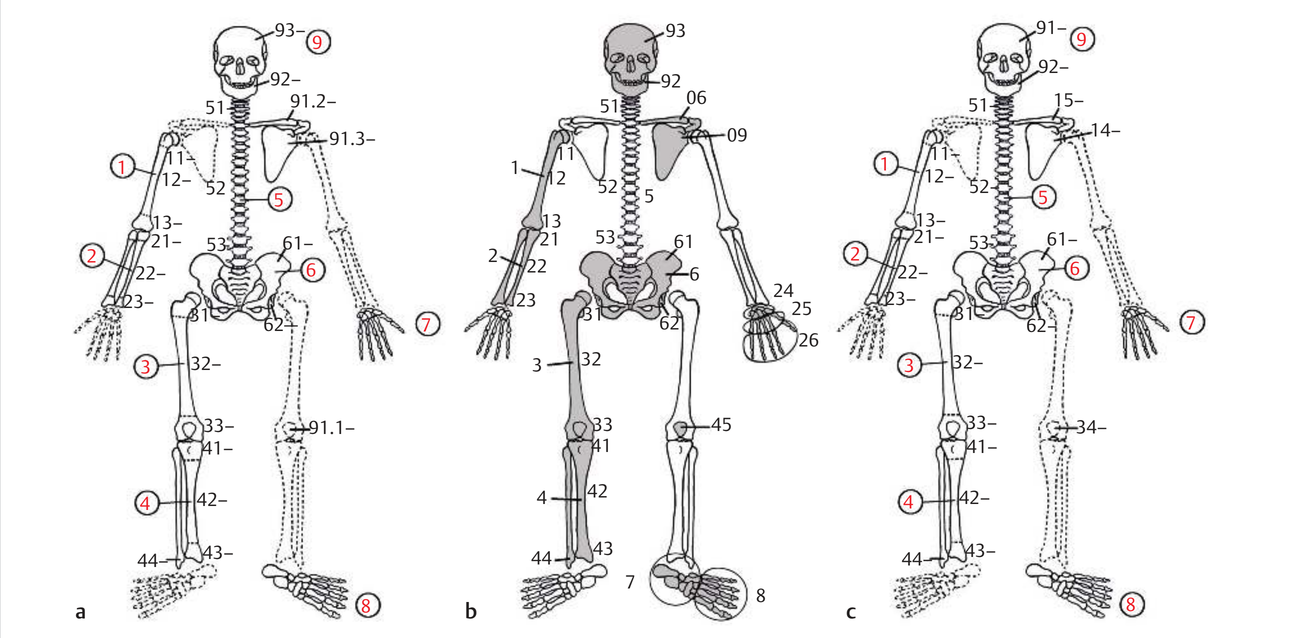

Fig. 1.2 Principles of the AO/OTA classification of fractures. All bones are coded by numbers that indicate the anatomical location. (a) The Müller AO classification system. (b) The OTA classification system. (c) The new unified classification system.

Bones

The numeric coding for every bone is seen in ▶ Fig. 1.2. It should be noted that the ulna/radius and tibia/fibula are each considered one long bone pair.

Segments

Each long bone is divided into three segments (proximal, diaphysis, and distal) which are numbered 1 to 3. Due to the complexity of a distal fracture of the tibia/fibula, the ankle joint is listed separately as segment 4. The anatomic delineation of the segments, proximal and distal, is performed according to "Heim's square" as shown in ▶ Fig. 1.3; a square whose lateral sides equal the maximum width of the epiphysis, and delineates the proximal and distal segments of each bone (except for 31 and 44).

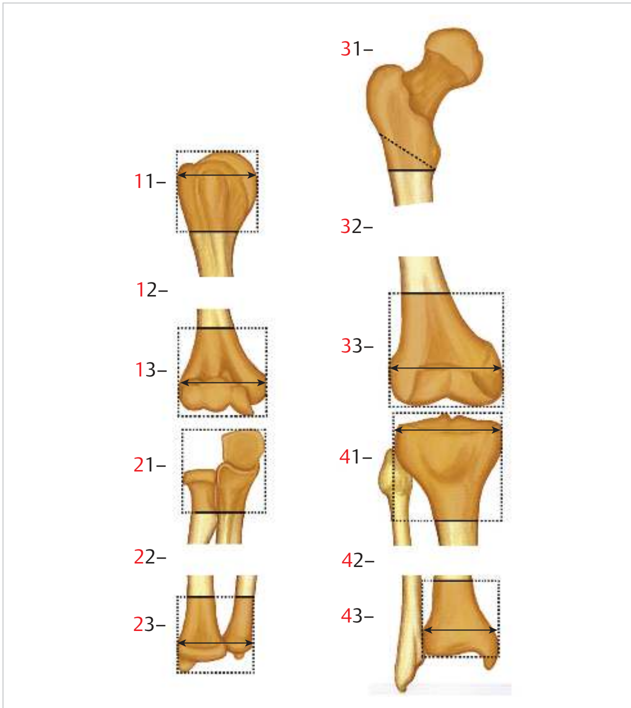

Fig. 1.3 Delineation of the proximal and distal segments of a long bone ("Heim's square").

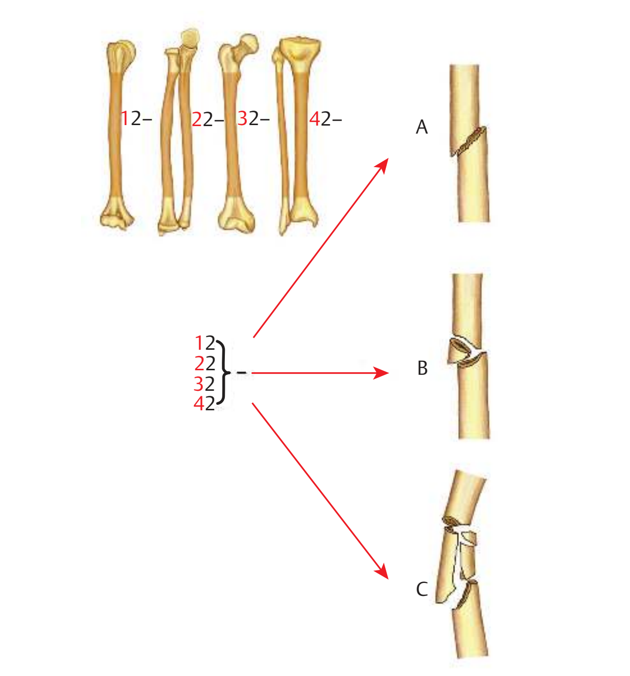

Fig. 1.4 Types of diaphyseal fractures of the long bones.

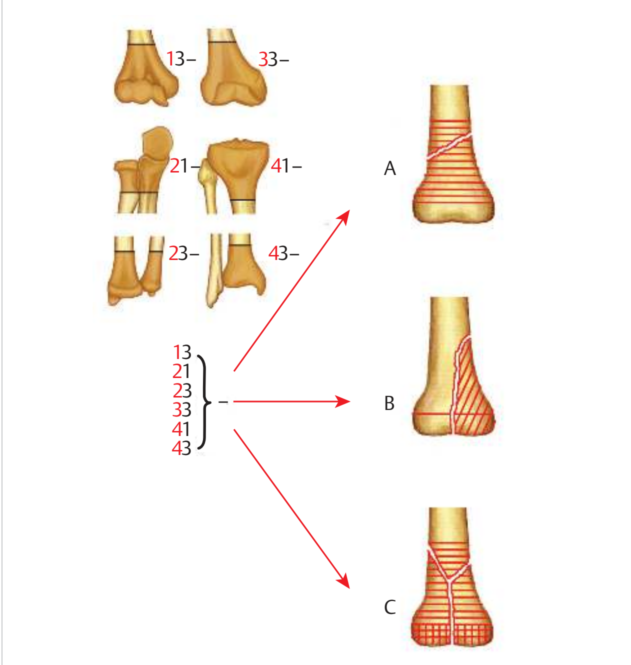

Fig. 1.5 Fracture types of the proximal and distal segments, and intra-articular fracture.

Types

Fractures are divided into three types and coded with the letters A, B, and C, indicating increasing severity.

- Diaphyseal fractures of the long bones (based on surface contact between the main fragments after the fracture is reduced) (▶ Fig. 1.4):
  - *Type A*: simple fracture; there is 90% surface contact between the main fragments
  - *Type B*: wedge fracture; there is minimal surface contact between the main fragments
  - *Type C*: complex fracture; there is no surface contact between the main fragments
- Fractures of the proximal and distal segments (based on the involvement of the articular surface) (▶ Fig. 1.5):
  - *Type A*: extra-articular (or nonarticular) fracture; the fracture line does not pass through the articular surface
  - *Type B*: partial articular fracture; the fracture line passes through the articular surface, with a portion of it still connected to the diaphysis
  - *Type C*: complete articular fracture; the fracture line passes through the articular surface and separates it completely from the diaphysis

Group and Subgroup

When fractures occur, they can be divided into groups based on morphologic features, once their location and fracture type are determined. Each group can then be further divided into subgroups, indicating increasing severity. The division of groups and subgroups varies at different segments of each bone, and will be discussed in detail in the corresponding chapters of this book. For clinical practice, division by group is sufficient for appropriate diagnosis and treatment, while division by subgroup would be needed for research investigation.

Epidemiological Investigation and Analysis of Traumatic Fractures Incidence in China

Traumatic injury is a major cause of global mortality and disability. Injuries also impose a substantial burden for China, being the fifth most common cause of death and resulting in more fatalities than diabetes and infectious disease. As we know, injury-related fractures constitute a major drain on health-care resources. In addition, the formulation/adjustment of relevant national policies and health works are based on the scientific analysis of the status of the fracture. However, national epidemiological data for fracture incidence rates are not investigated in our country. There is lack of epidemiology study on traumatic fractures in China based on population, incidence, and risk factor involved. Countries without such data must infer statistics based on results from other regions or some small sample size studies, which is highly problematic because of substantial variations in incidence rates. Therefore, China urgently needs to set up a database of traumatic fractures and elaborate the status and trauma mechanism, to provide scientific basis for disease prevention and treatment.

With a population in excess of 1.36 billion people, China is a vast country with substantial diversity in terms of economic development, cultural practices, health-care systems, climate, and topography. Moreover, the data of different grades of hospitals cannot be shared. It is difficult to carry out the epidemiological survey of fracture. The design of this study was on the basis of the Sixth Population Census data and strictly followed the principle of epidemiological design and sampling method. A representative variety of people were field investigated with multistage stratified cluster random sampling. Under strict quality control, 51,2187 effective questionnaires were got at last. We analyzed the population-weighted incidences of traumatic fracture by the sex, age, part of fracture, and injury mechanism. The risk factors of different people were identified with multiple logistic regression analysis, establishing the biggest fracture epidemiological database in the world.

Methods

Respondents

The respondents of this study are from China's 31 provinces, autonomous regions, and municipalities (except Taiwan, Hong Kong, and Macao). All eligible members in the selected families who had been living in their current residence for 6 months or more were invited to participate in the study, and single-member households were also included in the survey.

Sampling Method

A method of multistage stratified cluster random sampling was used in this study. Eight provinces and municipalities (three from the east region, two from the middle, and three from the west) were initially selected by stratified random sampling. According to the data of the sixth population census got in 2010, suitable sample size of each province was sampled by probability-proportional-to-size sampling method (PPS). Cities and counties of the chosen province were divided into large city, mid-sized city, small city, and rural area by the region type, population size, and level of economic development (▶ Fig. 1.6).

The Content and Method of this Investigation

1. For the field survey, a standardized questionnaire was administered by trained research teams. This questionnaire sought information about demographic characteristics such as age, sex, Chinese ethnic nationality, marital status, occupation, and residence.
2. Individuals who had traumatic fractures of the trunk, arms, or legs between January 1 and December 31, 2014 then answered a more detailed questionnaire between January 19 and May 16, 2015 regarding the date, fracture site, and injury mechanism. Participants were asked to provide medical records of their fractures, including radiographs, diagnostic reports, and medical reports. When such information was unavailable, the survey team paid the individual participants to obtain new radiographs of their reported fracture sites at a local hospital.

Quality Control and Evaluation

1. **Strengthen the leadership of quality control organizations**: In order to strengthen quality control organization's leadership and guarantee the quality of this survey, execution group, quality control team, expert advisory committee, and project office were put directly under the project leader (professor). A remarkable organizational chart can supply a better leadership, coordination, and guarantee the smooth conduct of the study.
2. **Set up working team system of three-level quality control system**:
   a) National quality control team led by epidemiological expert was responsible for the quality control method, the unified survey methods and survey form, the training of investigator, on-the-spot guidance, and the quality control of investigation process.
   b) Eight quality control teams were established (one per province), and quality controller was appointed in accordance with sampling, field survey, imaging test, and data management. The quality controller cooperated with national quality control team to complete the quality control, according to the project quality control standards and methods.
   c) A specialized quality controller was responsible for quality control in every investigation point. This quality controller was under the leadership of the provincial quality control working group to do a good job of quality control of the site.
3. **Repeated program demonstration**: The quality control methods in the phases of sampling, questionnaire survey, radiological examination, and data cleaning were determined. In order to ensure the quality of the investigation, we invited professor Derek Smith from James Cook University Australia, professors Guang Zeng and Ruotao Wang from the National Centers for Disease Control and Prevention, professor Qubing Shen from Nanjing Medical University, professor Changqing Zhang from Anhui Medical University, professors Dianwu Liu, Qingbao Tian, and Xu Liu from Hebei Medical University, professor Yichong Li from Beijing Medical University, and other famous epidemiologists in China to participate in our program. A pilot phase was undertaken to ameliorate this program in general in two urban communities and three administrative villages in Hebei Province.
4. **Investigator training**: All the investigators had to participate in the unified training and obtain the certificate at the

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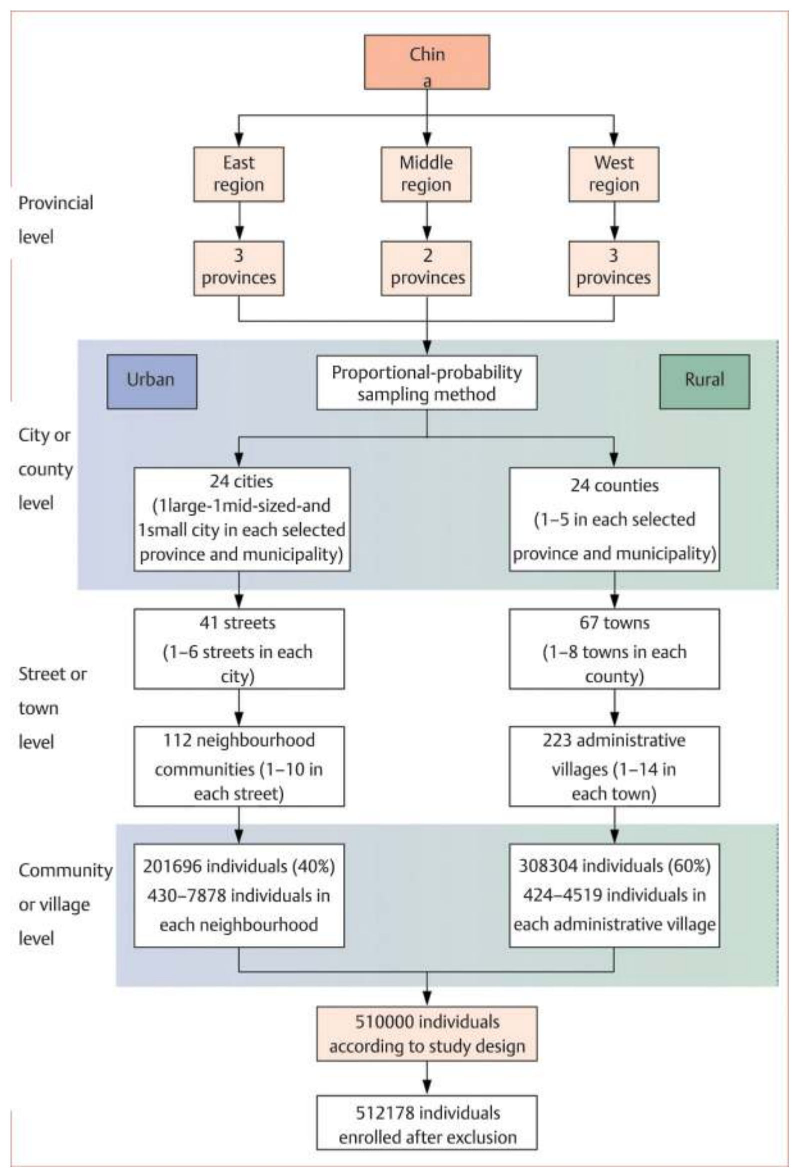

Fig. 1.6 China National Fracture Study (CNFS) profile.

project initiation. Each investigator had a clear understanding of the significance of the survey, principles of design, content of questionnaire, and method of inquiry.

5. **Establish supervision system of quality control**: The supervision team supervised the national quality control section and subgroups of each province; the leading group invited specialist experts to supervise the implementation process of the project.
6. **Enhance quality control of data input**: Project office conducted centralized training of the data entry keyers, and the content of this training included the principle of questionnaire reorganization, method of input, and management of database. In order to ensure the quality of data input, each provincial unit conducted the data entry independently. All data were recorded on a written survey at each selected household and later entered into the EpiData 3.1 software program using the dual import program. Eight quality control teams were established (one per province), with 10% of all questionnaires collected in the field being sampled by the quality control team to check for omissions and errors. Participants reporting traumatic fractures had their clinical records, medical history, and radiographs interpreted by independent orthopaedic surgeons and radiologists to ensure the accuracy of the original diagnosis.

Data Statistics and Analysis

During the main sampling phase, 31 provinces (municipalities or autonomous regions) in mainland China were categorized into three regions (east, central, and west) according to socioeconomic development and climate, similar to the method used by the Chinese Statistical Bureau. Eight provinces and municipalities were initially selected by stratified random sampling: three from the east region (Hebei, Guangdong, Shanghai), two from the middle (Jilin, Hubei), and three from the west (Yunnan, Sichuan, Gansu) (▶ Fig. 1.7).

Twenty-four cities (large, mid-sized, and small cities), 41 streets and 112 community committees, and 24 counties, 67 towns, and 223 villages were selected from these 8 provinces were selected. A total of 535,836 questionnaires were collected. Following exclusions, 512,187 (96%) individuals participated in the China National Fracture Study (CNFS): 259,649 (51%) boys and men and 252,538 (49%) girls and women. The age and gender distributions of these patients in this national epidemiology of fracture survey are shown in ▶ Table 1.1.

The national epidemiological survey of fracture shows: 1,763 individuals (990 men and 773 women, mean age of 48.2 years [SD 18.9]) reported 1,833 traumatic fractures that had occurred in 2014. Among them were 117 (6%) children with 117 fractures, 1,303 (74%) young and middle-aged adults with 1,350 fractures, and 343 (19%) older individuals with 366 fractures. The population-weighted incidence rate of traumatic fractures of the trunk, arms, and legs in China was 3.21 per 1,000 population (▶ Table 1.2). It is estimated that about 4.4 million people in China suffered fractures of limbs and trunk in 2014.

Fig. 1.7 Distribution map of the selected provinces in this survey.

We also analyzed the population-weighted incidences of traumatic fracture by individual characteristics and regions. There was no significant difference in incidence between those of Han ethnicity and all other ethnicities combined, nor was there any significant difference according to geographical region or urbanization. Stratified by occupation, retired and unemployed individuals had the highest incidence rates (5.86 and 5.24 per 1,000 people, respectively), and the preschool and students had low incidence rates (1.76 and 0.79 per 1,000 people, respectively). According to education level, illiterate individuals had the highest incidence rate, 5.46 per 1,000 population (▶ Table 1.3).

The incidence of distal radial and ulnar fractures among all fractures is the highest in children (male 0.58%, female 0.51%). The incidence of tibiofibular fractures is the highest among middle-aged male (1.02%) and female (0.63%). The incidence of tibiofibular fractures is the highest among old male (1.30%). The incidence of distal ulnar and radius fracture is the highest among old female (1.72%; ▶ Table 1.4).

According to the causal mechanism, fracture patients are divided into six subgroups. Slip, trip, or fall is the most common injury mechanism in this investigation, accounting for 57.72% of all fractures. Traffic accidents, crushing injuries, and falls from heights accounted for 20.37%, 9.66%, and 20.37%, respectively. Analysis of risk factors shows that slip, trip, or fall is the most common injury mechanism among old women accounting for 83.03% of all fractures. The proportion of slip, trip, or fall is lower than 50% while the proportion of traffic accident is more than 25% in young and middle-aged males (▶ Table 1.5).

Five separate design-based multiple logistic regression models were constructed to explore the potential risk factors for traumatic fractures among children, young and middle-aged adults, and older people. In view of the complexity of the study's sample design, weights were calculated for all analyses to reflect the entire population of China. Sample weighting comprised two components: sampling weight, which accounts

Table 1.1 Gender and age distribution of patients in the epidemiological survey of fracture (case)

Age (years)	National census*			Our survey			Fracture patients		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
0–4	41,062,566	34,470,044	75,532,610	14,679	12,161	26,840	12	10	22
5–14	78,731,942	67,058,069	145,790,011	29,554	24,772	54,326	63	32	95
15–24	115,913,403	111,388,229	227,301,632	31,082	30,938	62,020	67	34	101
25–34	100,358,860	97,793,195	198,152,055	46,048	47,146	93,194	142	52	194
35–44	123,999,782	118,780,141	242,779,923	41,017	39,975	80,992	175	79	254
45–54	94,139,652	90,208,072	184,347,724	40,245	39,320	79,565	209	152	361
55–64	70,917,364	69,062,392	139,979,756	28,894	30,074	58,968	177	216	393
65–74	37,151,924	36,933,755	74,085,679	19,321	19,424	38,745	99	132	231
≥75	20,053,611	24,787,868	44,841,479	8,809	8,728	17,537	46	66	112
Total	682,329,104	650,481,765	1,332,810,869	259,649	252,538	512,187	990	773	1763

*National census indicated the data of sixth population census got in 2010 in China.

Table 1.2 National incidence of traumatic fractures in China in 2014 (per 1,000)

Age (years)	Sample size	Sample size incidence rate per 1,000 population (95% CI)		
		Male	Female	Total
0–4	26,840	0.72 (0.14–1.30)	0.68 (0.11–1.25)	0.70 (0.21–1.19)
5–14	54,326	2.26 (1.48–3.05)	1.23 (0.85–1.61)	1.79 (1.31–2.26)
15–24	62,020	2.22 (1.66–2.78)	1.13 (0.78–1.48)	1.69 (1.36–2.02)
25–34	93,194	3.04 (2.55–3.53)	1.03 (0.78–1.28)	2.05 (1.74–2.36)
35–44	80,992	4.25 (3.52–4.98)	1.92 (1.32–2.51)	3.11 (2.60–3.61)
45–54	79,565	5.09 (3.91–6.27)	3.61 (2.87–4.36)	4.37 (3.51–5.22)
55–64	58,968	6.01 (4.67–7.34)	7.04 (6.06–8.01)	6.52 (5.60–7.43)
65–74	38,745	5.19 (3.90–6.47)	6.60 (5.16–8.04)	5.89 (4.91–6.87)
≥ 75	17,537	4.90 (3.09–6.72)	6.89 (4.67–9.11)	6.00 (4.37–7.63)
Total	**512,187**	**3.65 (3.12–4.18)**	**2.75 (2.46–3.04)**	**3.21 (2.83–3.59)**

Table 1.3 National incidence rate per 1,000 population in 2014 according to the demographic characteristics and urbanization

	Sample size	Sample size incidence rate per 1,000 population (95% CI)		
		Male	Female	Total
Ethnic origin				
Han	477,508	3.65 (3.10–4.20)	2.83 (2.51–3.14)	3.25 (2.86–3.64)
Other	34,679	3.87 (3.23–4.51)	2.06 (1.28–2.83)	2.98 (2.33–3.63)
Region				
East	232,998	3.75 (3.11–4.38)	3.26 (2.79–3.72)	3.51 (3.02–4.00)
Central	99,109	3.02 (2.14–3.89)	2.54 (1.91–3.18)	2.78 (2.13–3.43)
West	180,080	3.93 (2.88–4.98)	2.35 (1.80–2.91)	3.15 (2.39–3.92)
Urbanization				
Urban area	203,101	3.29 (2.76–3.81)	2.62 (2.12–3.13)	2.96 (2.50–3.43)
Rural area	309,086	3.89 (3.16–4.61)	2.85 (2.47–3.23)	3.38 (2.88–3.89)
Occupation				
Office worker	61,919	3.24 (2.29–4.19)	2.20 (1.55–2.86)	2.76 (2.10–3.42)
Farmer	106,484	5.18 (4.35–6.02)	4.38 (3.75–5.02)	4.75 (4.21–5.30)
Manual worker	148,650	4.03 (3.30–4.76)	1.79 (1.36–2.22)	3.05 (2.54–3.57)
Retired	30,366	4.80 (3.41–6.19)	6.82 (5.21–8.42)	5.86 (4.80–6.92)
Unemployed	32,770	7.45 (5.04–9.87)	4.32 (3.29–5.36)	5.24 (4.11–6.37)
Preschool children	35,581	0.77 (0.27–1.27)	0.81 (0.29–1.34)	0.79 (0.37–1.21)
Students	80,443	2.22 (1.68–2.75)	1.27 (0.91–1.62)	1.76 (1.39–2.13)
Other	15,974	3.76 (2.53–4.99)	4.67 (2.35–6.99)	4.14 (3.01–5.26)
Education (preschool children and students excluded; *n* = 396,163)				
Illiterate	74,937	6.03 (4.85–7.20)	4.98 (4.38–5.59)	5.46 (4.79–6.14)
Primary school	158,970	5.09 (4.17–6.01)	3.33 (2.69–3.97)	4.23 (3.54–4.92)
Junior high school	121,415	2.94 (2.14–3.74)	2.69 (1.88–3.50)	2.82 (2.12–3.52)
Senior high school or above	40,841	3.26 (2.40–4.11)	1.74 (1.25–2.23)	2.56 (1.98–3.13)

Table 1.4 National incidence rate per 1,000 population of traumatic fractures in China by body site in 2014

	Children (0–14 years)		Young and middle-aged adults (15–64 years)		Older people (≥ 65 years)		Total
	Boys	Girls	Male	Female	Male	Female	
Humerus	0.38 (0.17–0.58)	0.07 (0.00–0.16)	0.21 (0.13–0.29)	0.13 (0.07–0.18)	0.18 (0.00–0.41)	0.47 (0.16–0.79)	0.20 (0.15–0.24)
Radius and ulna	0.58 (0.34–0.82)	0.51 (0.27–0.75)	0.57 (0.47–0.68)	0.61 (0.48–0.75)	0.53 (0.22–0.84)	1.72 (1.18–2.26)	0.63 (0.55–0.72)
Femur	0.07 (0.00–0.15)	0.01 (0.00–0.03)	0.44 (0.28–0.60)	0.17 (0.10–0.23)	1.11 (0.76–1.46)	1.39 (0.87–1.91)	0.35 (0.27–0.43)
Tibia and fibula	0.29 (0.11–0.47)	0.19 (0.00–0.37)	1.02 (0.85–1.19)	0.63 (0.51–0.74)	1.30 (0.81–1.80)	1.13 (0.76–1.50)	0.76 (0.66–0.86)
Spine	0.06 (0.00–0.17)	0.02 (0.00–0.05)	0.33 (0.20–0.47)	0.23 (0.15–0.30)	0.79 (0.44–1.13)	0.82 (0.38–1.27)	0.29 (0.21–0.37)
Pelvic ring and acetabulum		0.02 (0.00–0.06)	0.09 (0.01–0.18)	0.07 (0.04–0.10)	0.17 (0.01–0.32)	0.51 (0.22–0.80)	0.09 (0.05–0.13)
Hand	0.06 (0.00–0.14)	0.12 (0.00–0.23)	0.37 (0.24–0.49)	0.24 (0.17–0.31)	0.29 (0.07–0.50)	0.34 (0.09–0.59)	0.27 (0.21–0.32)
Foot	0.23 (0.06–0.40)	0.03 (0.00–0.08)	0.57 (0.44–0.70)	0.29 (0.20–0.39)	0.45 (0.12–0.78)	0.30 (0.02–0.57)	0.38 (0.29–0.47)
Scapula			0.08 (0.03–0.13)	0.04 (0.01–0.07)	0.15 (0.00–0.32)	0.06 (0.00–0.14)	0.05 (0.02–0.08)
Clavicle	0.05 (0.00–0.13)	0.05 (0.00–0.12)	0.25 (0.17–0.33)	0.13 (0.08–0.18)	0.12 (0.00–0.30)	0.13 (0.00–0.25)	0.16 (0.13–0.20)
Patella	0.02 (0.00–0.06)	0.03 (0.00–0.07)	0.14 (0.07–0.21)	0.11 (0.05–0.17)	0.27 (0.08–0.46)	0.31 (0.08–0.55)	0.13 (0.08–0.17)

Table 1.5 Proportion of traumatic fractures by causal mechanisms in China in 2014 (% of total)

	Children (0–14 years)	Young and middle-aged adults (15–64 years)		Older people (≥ 65 years)		Total
		Male	Female	Male	Female	
Traffic accident	11.31 (3.47–19.15)	25.20 (21.90–28.50)	19.35 (15.47–23.22)	16.48 (11.28–21.67)	9.85 (6.44–13.26)	20.37 (18.60–22.14)
Slip, trip, or fall	71.70 (61.39–82.01)	43.14 (37.71–48.58)	66.99 (62.91–71.07)	66.13 (57.57–74.69)	83.03 (78.02–88.04)	57.72 (54.25–61.18)
Fall from height	8.67 (3.66–13.67)	12.85 (10.48–15.22)	5.83 (3.52–8.15)	7.32 (1.05–13.59)	3.49 (1.01–5.97)	9.18 (7.68–10.68)
Crushing injury	5.59 (0.00–12.09)	14.35 (11.37–17.32)	5.37 (3.05–7.69)	10.07 (2.87–17.28)	3.06 (0.33–5.79)	9.66 (7.87–11.46)
Sharp trauma		1.76 (0.46–3.05)	1.68 (0.74–2.61)			1.32 (0.56–2.07)
Blunt force trauma	2.73 (0.00–5.75)	2.70 (1.11–4.30)	0.79 (0.07–1.51)		0.57 (0.00–1.70)	1.75 (0.73–2.76)

for unequal probability of sample selection in each sampling stage, and poststratification weight, which harmonizes the sample structure of the survey with that of the standard Chinese population based on the most recent (2010) census. We specifically considered the age (5-year increments), sex, and geographical region simultaneously when undertaking the poststratification process. For 95% CIs, we estimated sampling error using Taylor series linearization, considering multistage sampling design. All statistical analyses were done with SAS (version 9.3) and Sudaan (version 11.01).

► Table 1.6 summarizes risk factors for traumatic fractures in children aged 14 years and younger. When compared with boys, girls had a lower risk of sustaining a fracture. When compared with preschool children, primary school students had a higher risk of fractures. Sleeping less than 7 hours per day also increased the risk of traumatic fractures among children.

Table 1.6 Risk factors for traumatic fractures in Chinese children (≤ 14 years)

Risk factors	OR (95%CI)
Age (years)	
• 0–4	Reference
• 5–14	1.02 (0.39–2.68)
Sex	
• Boy	Reference
• Girl	0.63 (0.41–0.97)
Ethnic origin	
• Han	Reference
• Other	1.34 (0.77–2.35)
Education	
• Preschool	Reference
• Primary school	2.28 (1.07–4.88)
• Junior high school or above	2.28 (0.88–5.93)
Calcium or vitamin D supplement	
• No	Reference
• Yes	1.12 (0.47–2.69)
Average sleep time per day (h)	
• ≥ 7	Reference
• < 7	2.70 (1.28–5.70)
Urbanization	
• Rural area	Reference
• Urban area	0.78 (0.39–1.54)
Region	
• West Region	Reference
• Central Region	0.95 (0.44–2.05)
• East Region	1.51 (0.78–2.91)

▶ Table 1.7 summarizes risk factors for traumatic fractures in young and middle-aged adults aged between 15 and 64 years by sex. Compared with women aged 15–24 years, those aged 45–54 years and 55–64 years were more likely to experience fractures. Compared with Han Chinese ethnicity, being another ethnicity had a protective effect for women. Having junior high school as the highest education level compared with illiterate participants acted as a protective factor for men (odds ratio [OR] 0.68, 95% CI 0.47–0.99). When unemployment was used as the occupational referent, being an office worker, manual worker, farmer, retired, or having another job were protective factors for men, while only being a manual worker was found to be a protective factor for women. Cigarette smoking was a risk factor for men. For both men and women, alcohol consumption, having a previous history of fracture, and an average sleep time of less than 7 hours were strong risk factors for traumatic fractures. Compared with a normal BMI, having a BMI of less than 18.5 kg/m^2 implied a risk factor for men, whereas a BMI of more than 28 kg/m^2 was a risk factor for women (▶ Table 1.7).

▶ Table 1.8 shows risk factors for traumatic fractures in older people aged 65 years or more by sex. Drinking alcohol, sleeping less than 7 hours per day, and having a previous fracture history were identified as strong risk factors for men. Having a highest education level of primary school or junior high school was a protective factor for men. For elderly women, sleeping less than 7 hours per day, having a previous history of fracture, and having two or more children were strong risk factors for traumatic fractures. Living in the central and east regions of China were

Table 1.7 Risk factors for traumatic fractures among young and middle-aged Chinese adults (aged 15–64 years)

Risk factors	OR (95%CI)	
	Male	Female
Age (years)		
• 15–24	Reference	Reference
• 25–34	1.11 (0.73–1.70)	0.85 (0.52–1.40)
• 35–44	1.50 (0.98–2.30)	1.46 (0.82–2.60)
• 45–54	1.55 (0.93–2.58)	1.92 (1.08–3.42)
• 55–64	1.62 (0.96–2.73)	2.54 (1.41–4.57)
Ethnic origin		
• Han	Reference	Reference
• Other	1.04 (0.82–1.31)	0.62 (0.47–0.82)
Education		
• Illiterate	Reference	Reference
• Primary school	1.07 (0.85–1.36)	1.09 (0.86–1.39)
• Junior high school	0.68 (0.47–0.99)	0.92 (0.63–1.34)
• Senior high school or above	0.88 (0.65–1.20)	1.12 (0.80–1.56)
Occupation		
• Unemployed	Reference	Reference
• Office worker	0.43 (0.32–0.58)	0.75 (0.53–1.06)
• Manual worker	0.51 (0.36–0.74)	0.64 (0.50–0.81)
• Farmer	0.51 (0.32–0.83)	0.83 (0.64–1.08)
• Retired	0.46 (0.26–0.80)	0.95 (0.60–1.52)
• Student	0.64 (0.36–1.11)	1.03 (0.53–1.98)
• Other	0.47 (0.28–0.77)	0.70 (0.38–1.29)
Cigarette smoking		
• No	Reference	Reference
• Yes	1.47 (1.24–1.74)	0.87 (0.45–1.70)
Alcohol consumption		
• No	Reference	Reference
• Yes	2.27 (1.87–2.75)	2.75 (2.23–3.40)
Calcium or vitamin D supplement		
• No	Reference	Reference
• Yes	1.25 (0.90–1.74)	0.81 (0.55–1.19)
Urbanization		
• Rural area	Reference	Reference
• Urban area	0.93 (0.69–1.25)	1.00 (0.75–1.34)
Region		
• West Region	Reference	Reference
• Central Region	0.89 (0.53–-1.47)	1.05 (0.66–1.66)
• East Region	1.06 (0.75–1.50)	1.11 (0.81–1.51)

(Continued)

Table 1.7 (*Continued*)

Risk factors	OR (95%CI)	
	Male	Female
BMI (kg/m²)		
• 18.5–23.9	Reference	Reference
• 24–27.9	1.00 (0.80–1.23)	1.19 (0.97–1.47)
• ≥28	1.09 (0.75–1.58)	1.39 (1.04–1.88)
• <18.5	1.47 (1.02–2.13)	0.91 (0.60–1.37)
Average sleep time per day (h)		
• ≥7	Reference	Reference
• <7	1.88 (1.65–2.15)	1.82 (1.52–2.17)
House facing the sun		
• No	Reference	Reference
• Yes	1.07 (0.42–2.72)	1.68 (0.41–6.96)
Previous history of fracture		
• No	Reference	Reference
• Yes	2.52 (1.52–4.18)	3.19 (1.85–5.49)
Children		
• 0	/	Reference
• 1	/	0.66 (0.39–1.13)
• 2	/	1.60 (0.97–2.64)
• 3	/	1.75 (0.97–3.16)
• ≥4	/	1.11 (0.38–3.24)
Menopause age (years)		
• >50	/	Reference
• 46–50	/	1.13 (0.80–1.58)
• <46	/	0.74 (0.40–1.34)
• Premenopausal	/	0.85 (0.53–1.35)

also strong risk factors for women when compared with living in the west region. Additionally, a BMI ranging between 24 and 27 kg/m² incurred a risk effect for elderly women (▶ Table 1.8).

The CNFS represents the first detailed epidemiological investigation of traumatic fractures ever done across the entire Chinese population based on the sufficiently scientifically appraised unified design and implementation. This investigation had rigorous design, big sample size, wide coverage, favorable representative, extensive content, normative method, and abundant data. Through the investigation, we can not only understand the fracture incidence, variation tendency, damage mechanism, and its risk factors of our country, but also provide timely, accurate, and reliable data to formulate and evaluate the national policies and development plan. Based on these data, the health sector can make better damage control policies and take precautionary measures, and orthopaedic surgeons can not only understand the different kinds of fracture accurately, but also improve the diagnosis and treatment outcome and save medical resources, leading to tremendous social benefits.

Epidemiological Study of Fractures

A number of large-scale epidemiologic studies of fractures have been conducted in several countries over recent years. With the help of the AO Foundation, a group of talented orthopaedic surgeons based in Spain conducted a retrospective review of 54,280 fractures obtained from the AO database over a 5-year period. All 54,280 fractures were updated using the AO classification system. A statistical study of fracture incidence according to each type and subdivision was also conducted. However, this study was limited by using the AO system exclusively throughout, while other classification systems commonly used in clinical practice were barely referenced. In the current Chinese literature, there are few systemic studies or reports on the incidence of fractures based on a large sample size. The statistical data referred to in China are mostly from publications from

Table 1.8 Risk factors for traumatic fractures in older Chinese people (≥ 65 years)

Risk factors	OR (95%CI)	
	Male	Female
Age (years)		
• 65–74	Reference	Reference
• ≥ 75	1.18 (0.73–1.91)	1.10 (0.75–1.62)
Ethnic origin		
• Han	Reference	Reference
• Other	0.52 (0.25–1.08)	1.18 (0.56–2.50)
Education		
• Illiterate	Reference	Reference
• Primary school	0.69 (0.48–0.99)	1.31 (0.89–1.93)
• Junior high school	0.43 (0.19–0.98)	0.70 (0.37–1.32)
• Senior high school or above	0.17 (0.02–1.50)	1.05 (0.40–2.77)
Occupation		
• Unemployed	Reference	Reference
• Office worker	0.24 (0.03–1.92)	1.70 (0.58–5.00)
• Manual worker	0.85 (0.44–1.61)	0.50 (0.23–1.12)
• Farmer	1.01 (0.65–1.58)	0.85 (0.55–1.31)
• Retired	1.07 (0.62–1.83)	0.75 (0.46–1.22)
• Other	0.79 (0.33–1.94)	0.97 (0.48–1.96)
Cigarette smoking		
• No	Reference	Reference
• Yes	0.81 (0.54–1.23)	0.78 (0.33–1.83)
Alcohol consumption		
• No	Reference	Reference
• Yes	3.29 (1.92–5.64)	1.67 (0.66–4.23)
Calcium or vitamin D supplement		
• No	Reference	Reference
• Yes	0.94 (0.50–1.77)	0.80 (0.46–1.40)
Urbanization		
• Rural area	Reference	Reference
• Urban area	0.81 (0.55–1.20)	0.87 (0.59–1.27)
Region		
• West Region	Reference	Reference
• Central Region	1.32 (0.72–2.41)	2.09 (1.24–3.53)
• East Region	1.27 (0.78–2.07)	2.45 (1.45–4.13)
BMI (kg/m^2)		
• 18.5–23.9	Reference	Reference
• 24–27.9	1.00 (0.65–1.55)	1.36 (1.02–1.81)
• ≥ 28	0.35 (0.08–1.53)	1.19 (0.68–2.10)
• < 18.5	1.68 (0.93–3.03)	1.32 (0.76–2.31)

(Continued)

Table 1.8 (*Continued*)

Risk factors	OR (95%CI)	
	Male	Female
Average sleep time per day (h)		
• ≥7	Reference	Reference
• <7	1.75 (1.18–2.61)	2.81 (1.90–4.17)
House facing the sun		
• No	Reference	Reference
• Yes	0.63 (0.15–2.64)	2.45 (0.25–23.64)
Previous history of fracture		
• No	Reference	Reference
• Yes	4.27 (2.72–6.70)	2.30 (1.27–4.18)
Children		
• ≤1	/	Reference
• 2	/	4.97 (2.08–11.85)
• 3	/	3.22 (1.37–7.61)
• ≥4	/	4.28 (1.59–11.56)
Menopause age (years)		
• >50	/	Reference
• 46–50	/	1.08 (0.74–1.58)
• <46	/	1.09 (0.45–2.65)

other countries. A handful of similar studies conducted in China have been limited either by a small sample size or by overgeneralization due to specific targeting of particular populations or a specific fracture location.

The Chinese research study of fracture incidence with the largest sample size to date was conducted by Dr. Liu Li-ke at Huaxi Medical University in Sichuan province. The author randomly selected 10,930 residents of Chengdu city aged over 50 years, and conducted a retrospective review of their past fracture history. Risk factor analysis of fractures performed on 1,639 of the 10,930 residents concluded that the highest incidence of fracture was found in the forearm, followed by the spine, and finally the femoral neck; and the incidence of fracture is higher among women than men and in urban areas more than rural areas. Factors such as the level of physical work, amount of sleep a person has, and hereditary may have an impact on the occurrence of fractures. Dr. Chen Wenchang at the FuJian Provincial Hospital examined 3,688 patients with fractures or joint injury, the largest study, to date, of patients with fractures. Statistical analysis of the injury mechanism, fracture location, age, and treatment led to the conclusion that fractures are most likely to occur at the wrist, ulna/radius, tibia/fibula, and distal radius. At the end of the 20th century, a project named “An investigation on the current status and characteristics of common health conditions resulting from aging” was performed in China. However, the results of this project cannot be applied to the general population as it solely targeted osteoporosis in the elderly population. The studies and investigations mentioned above fail to accurately reflect the incidence and features of fracture among the general population, due to limited sample size, age-restricted target population, and lack of analysis on the variation of fracture incidence.

The Third Hospital of Hebei Medical University is a Grade III Class A hospital according to the grading system in China. As a full-service hospital, it specializes in orthopaedic medicine and draws patients mainly from the local, surrounding area. The authors reviewed radiographic images of 65,267 fractures treated at this hospital over a 5-year period from 2003 to 2007. Fracture classification and statistical studies were performed based on the AO/OTA system, with application of the picture archiving and communication systems (PACS). This extensive review also permitted statistical studies on fracture incidence based on commonly used classifications other than the AO/OTA system, which involve fractures occurring in bones of the extremities, spine and pelvis. In 2009, we published a book to describe the epidemiological characteristics of 65,267 fractures. Based upon the abovementioned work, we conducted a nationwide survey to investigate the epidemiological characteristics of fractures of the trunk and four extremities of China. The current study consisted of 414,935 patients (431,822 fractures) obtained from 83 hospitals across China. To the best of our knowledge, this is a comprehensive epidemiological study on fracture incidence on a national scale, with the largest sample size to date. It reflects the epidemiological status of fractures in China.

Statistical studies were conducted after fractures of long bones in the extremities, spine, and pelvis, which had also been coded according to the AO classification system, while the remaining fractures were also classified based on the OTA classification system. In an effort to secure accurate diagnoses and appropriate treatment, statistical analyses were also performed on the incidence of fracture in a specific location based on other commonly used classifications, such as the Robinson classification for clavicle fractures and the Denis classification for thoracolumbar spine fractures.

Currently, the AO/OTA classification system is widely accepted and used for fracture classification in adults, while its pediatric system is still in development. Consequently, all statistical data were collected from patients aged over 16 years when the AO/OTA system was indicated, whereas the incidence of pediatric fractures was analyzed by other classification systems.

A patient can sustain one or more fractures when an injury occurs; therefore, the total number of fractures is greater than the total number of injured patients. To achieve scientific statistical analysis, the numbers of patients and of fractures (fracture location) are discussed separately. All fractures are classified and analyzed based on the number (location) of fractures. For example, if a patient received an injury that resulted in a unilateral humeral fracture and bilateral tibia/fibula fractures, the number of fractures is counted as three, while the number of patients is one.

The present statistical study is based on a total of 414,935 patients (431,822 fractures), 257,764 males and 157,171 females, including 360,300 adults (374,396 fractures) and 54,635 children (57,426 fractures), obtained between January 2010 and December 2011 from 83 hospitals selected from 31 provinces of China. A summary of key points found in this book follows.

Incidence of Sex-Specific Fractures

- In general, the incidence of fracture is higher in males than in females (▶ Fig. 1.8).
- Line charts of age and sex distribution of fractures of the trunk and four extremities (▶ Fig. 1.9; ▶ Fig. 1.10; ▶ Fig. 1.11; ▶ Fig. 1.12; ▶ Fig. 1.13; ▶ Fig. 1.14; ▶ Fig. 1.15; ▶ Fig. 1.16; ▶ Fig. 1.17; ▶ Fig. 1.18; ▶ Fig. 1.19).

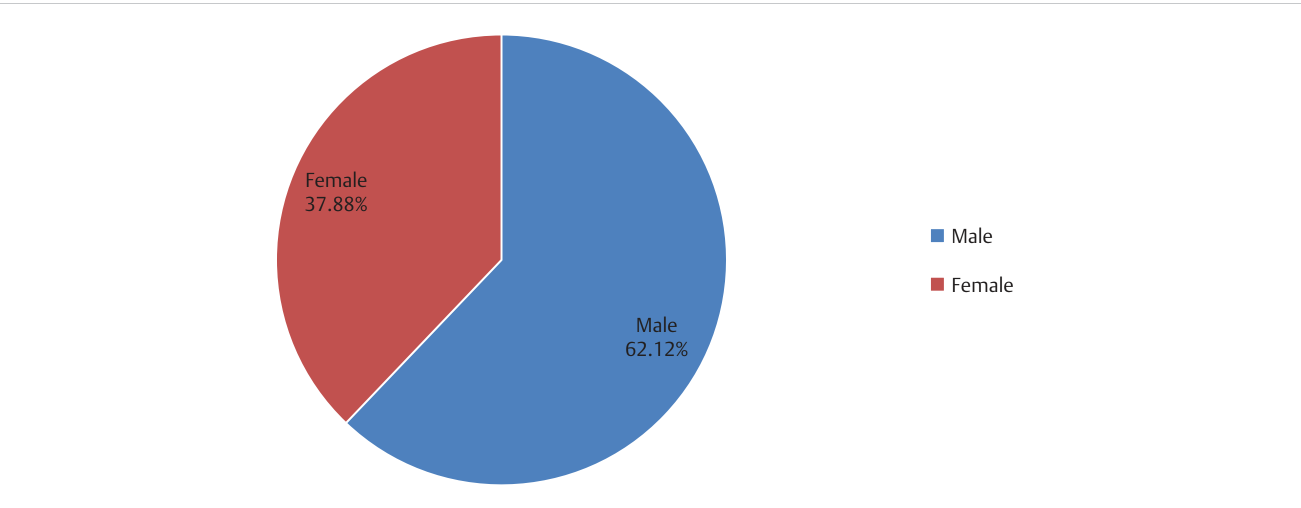

Fig. 1.8 Sex distribution of 414,935 patients with fractures treated from 2010 to 2011 at 83 hospitals of China.

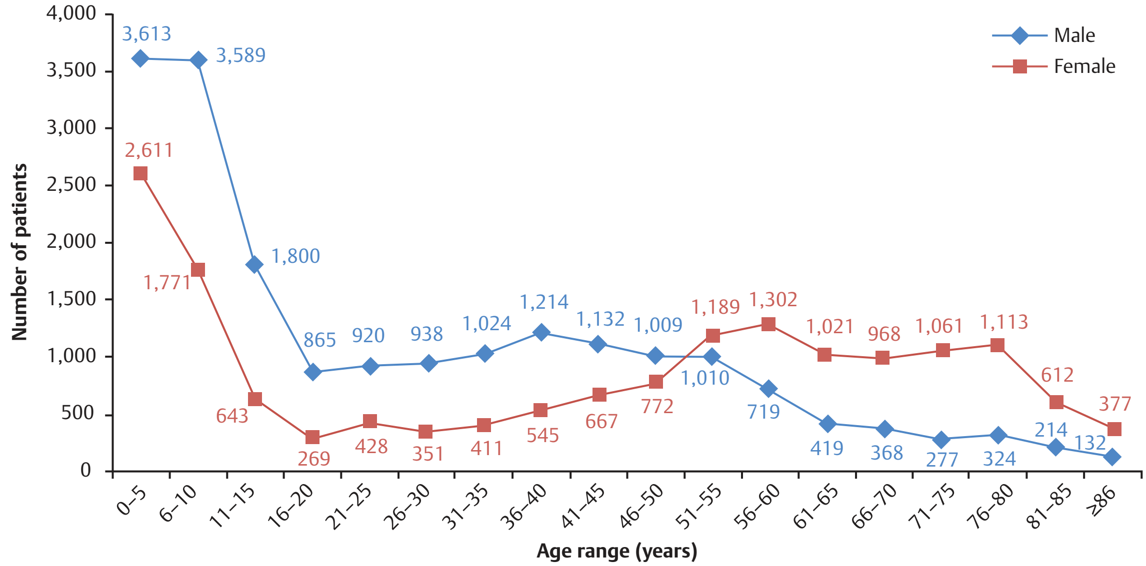

Fig. 1.9 Age and sex distribution of 35,678 patients with humeral fractures.

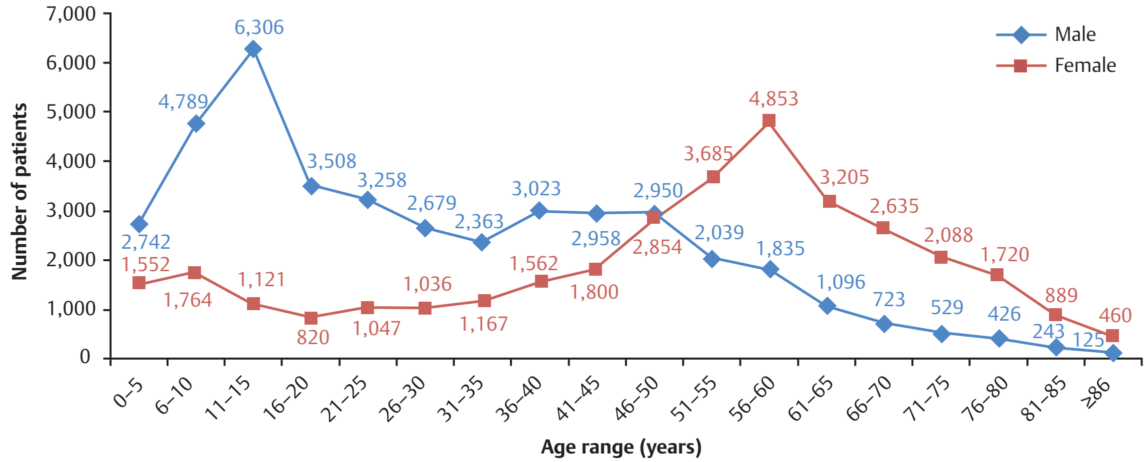

Fig. 1.10 Age and sex distribution of 75,850 patients with radius/ulnar fractures.

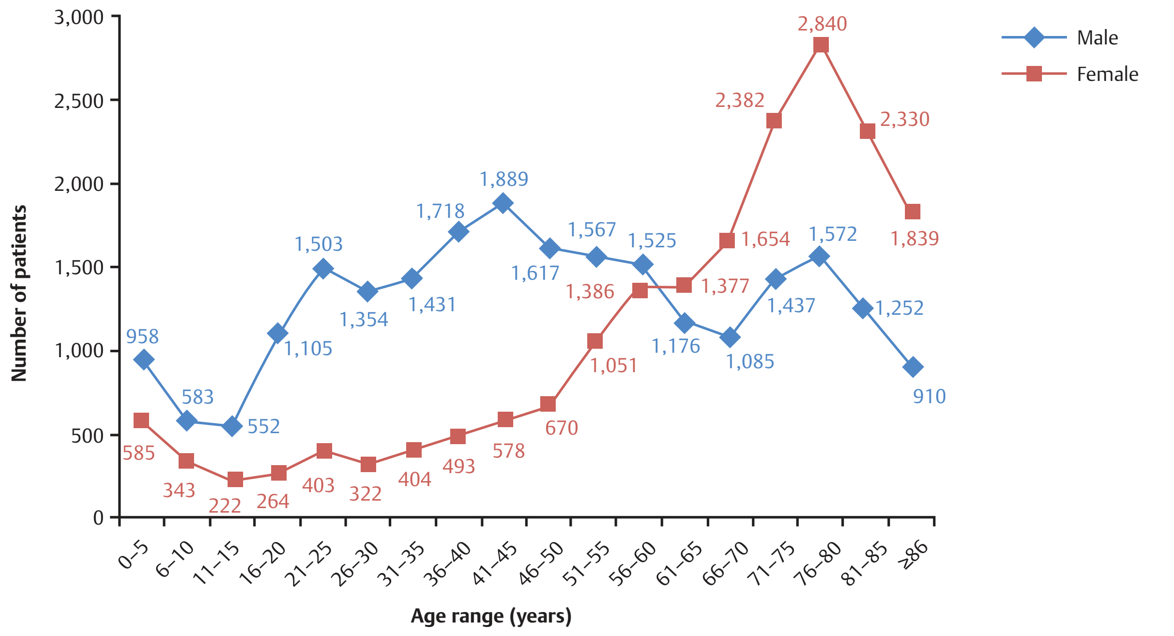

Fig. 1.11 Age and sex distribution of 42,377 patients with femur fractures.

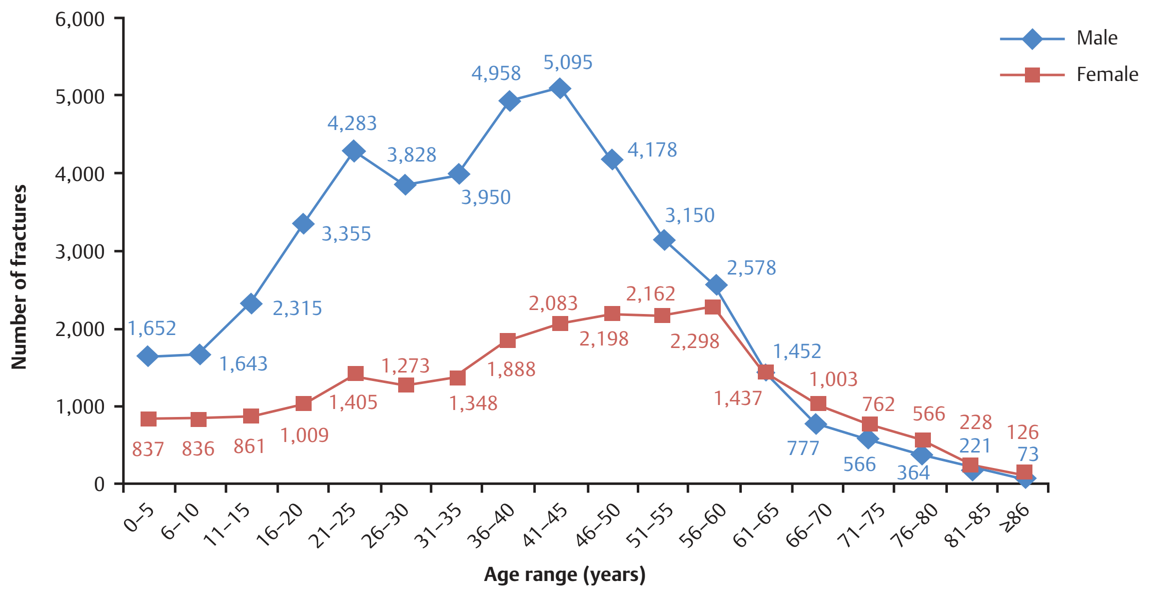

Fig. 1.12 Age and sex distribution of 66,758 patients with tibia/fibula fractures.

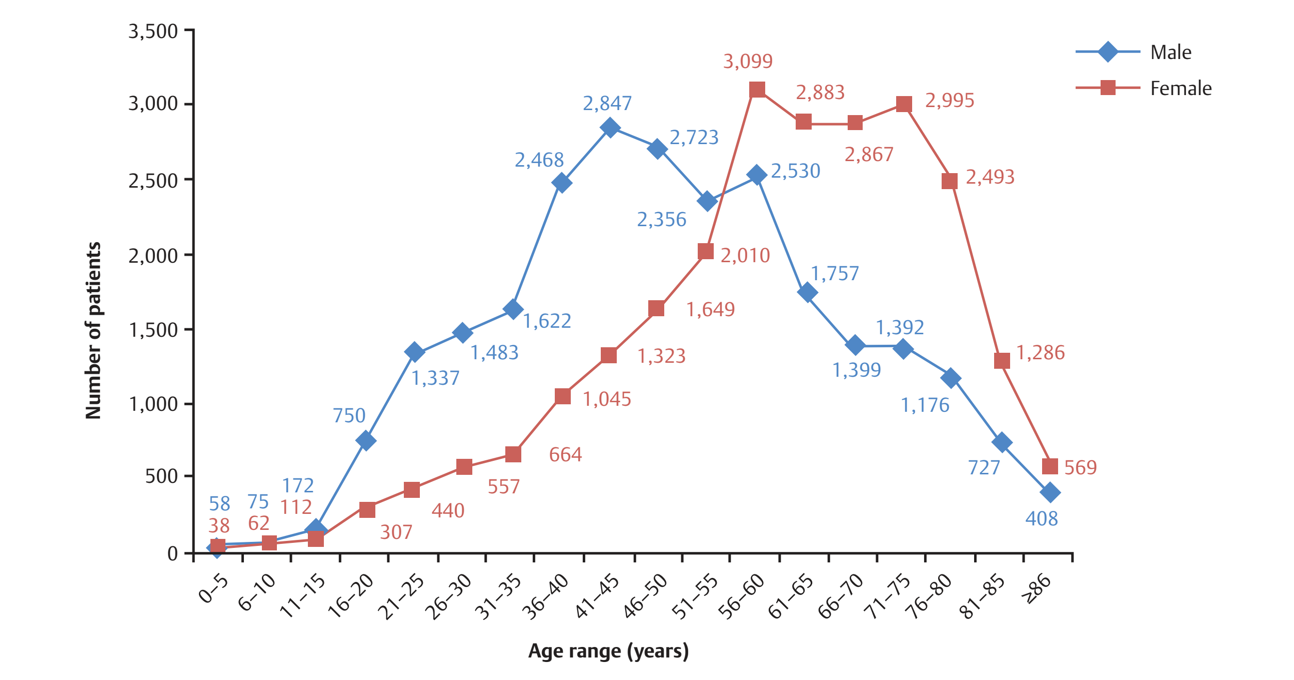

Fig. 1.13 Age and sex distribution of 49,679 patients with spinal column fractures.

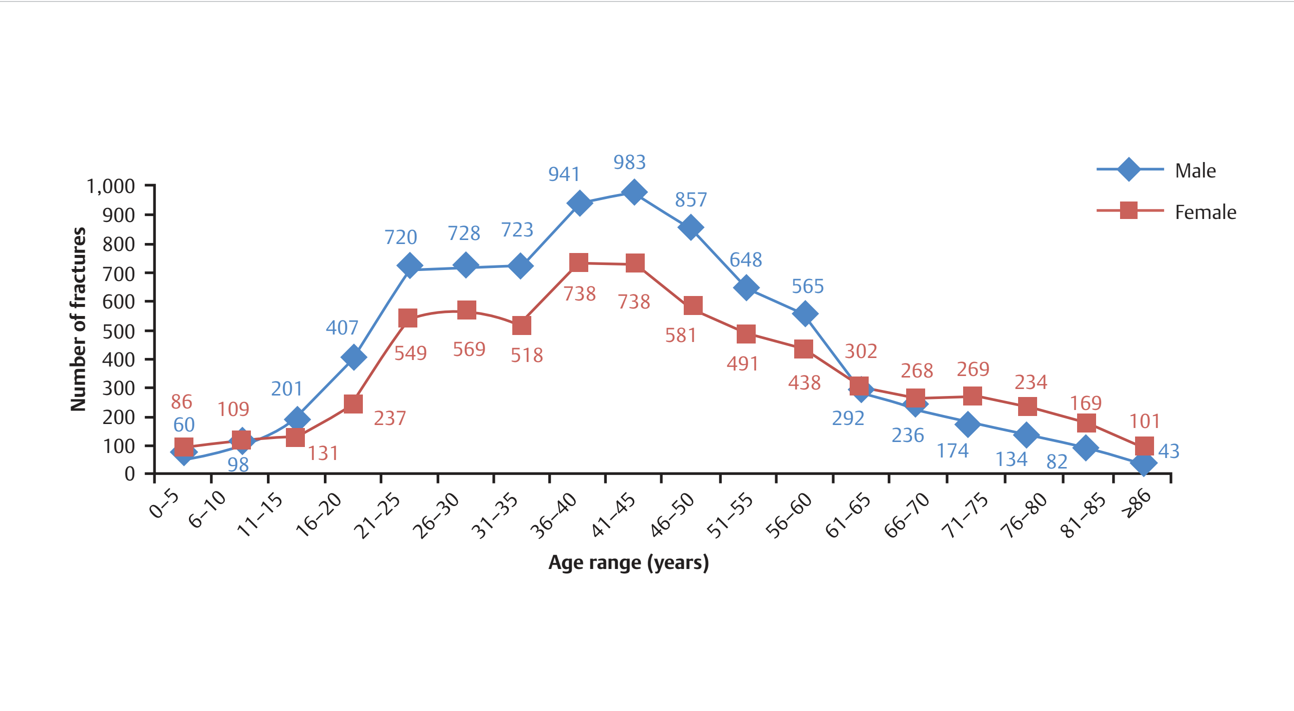

Fig. 1.14 Age and sex distribution of 14,420 patients with fractures of the pelvic ring and acetabulum.

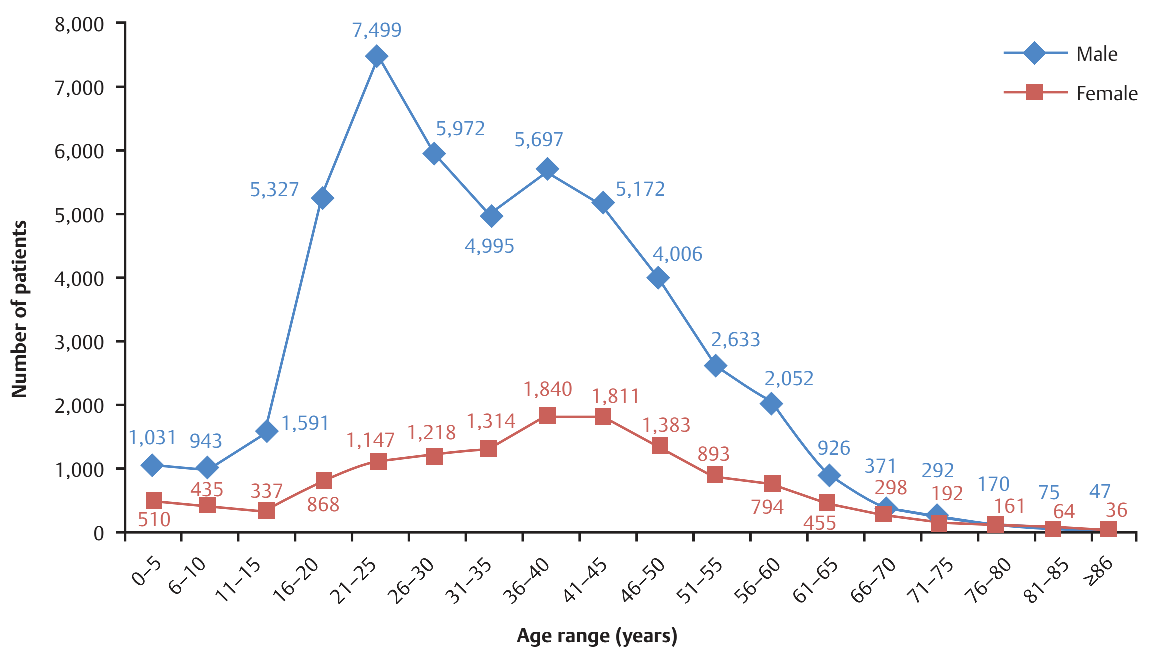

Fig. 1.15 Age and sex distribution of 62,555 patients with hand fractures.

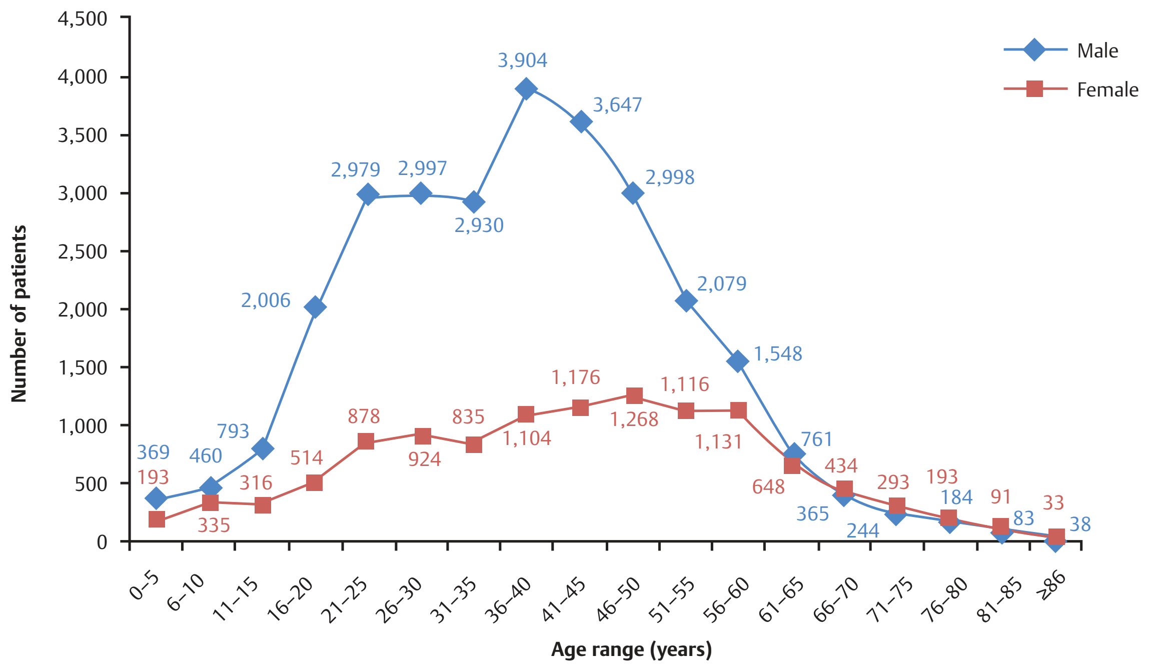

Fig. 1.16 Age and sex distribution of 39,867 patients with foot fractures.

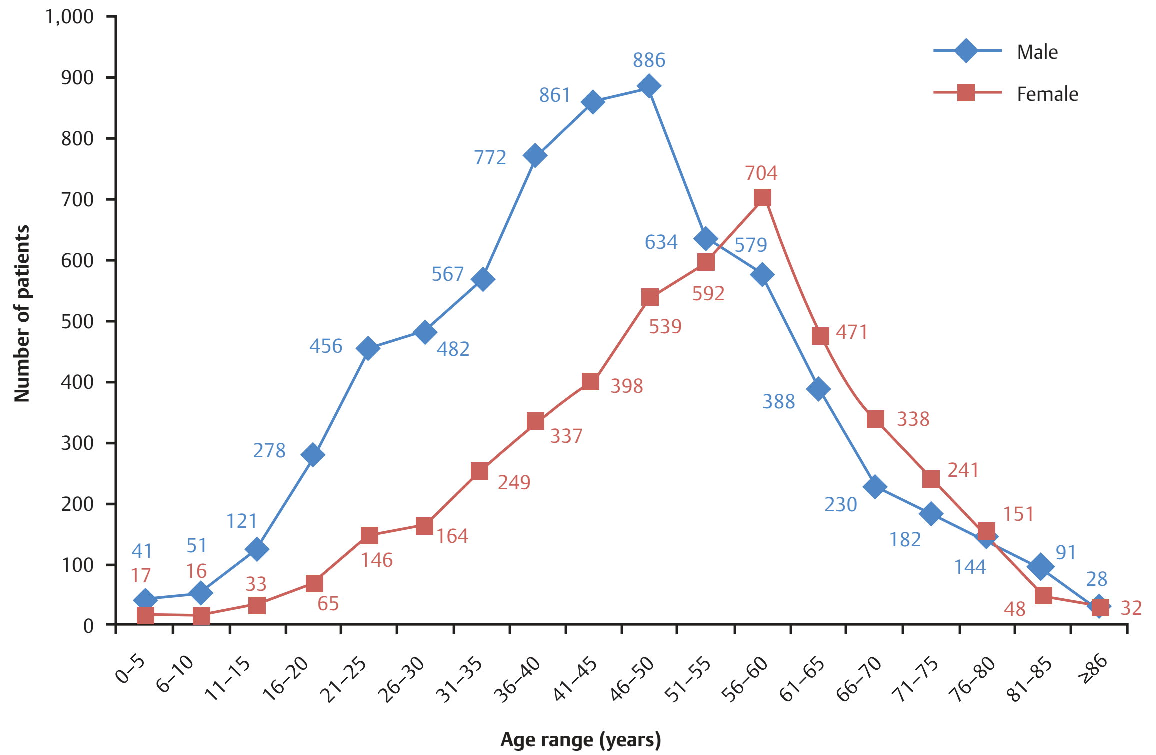

Fig. 1.17 Age and sex distribution of 11,332 patients with patellar fractures.

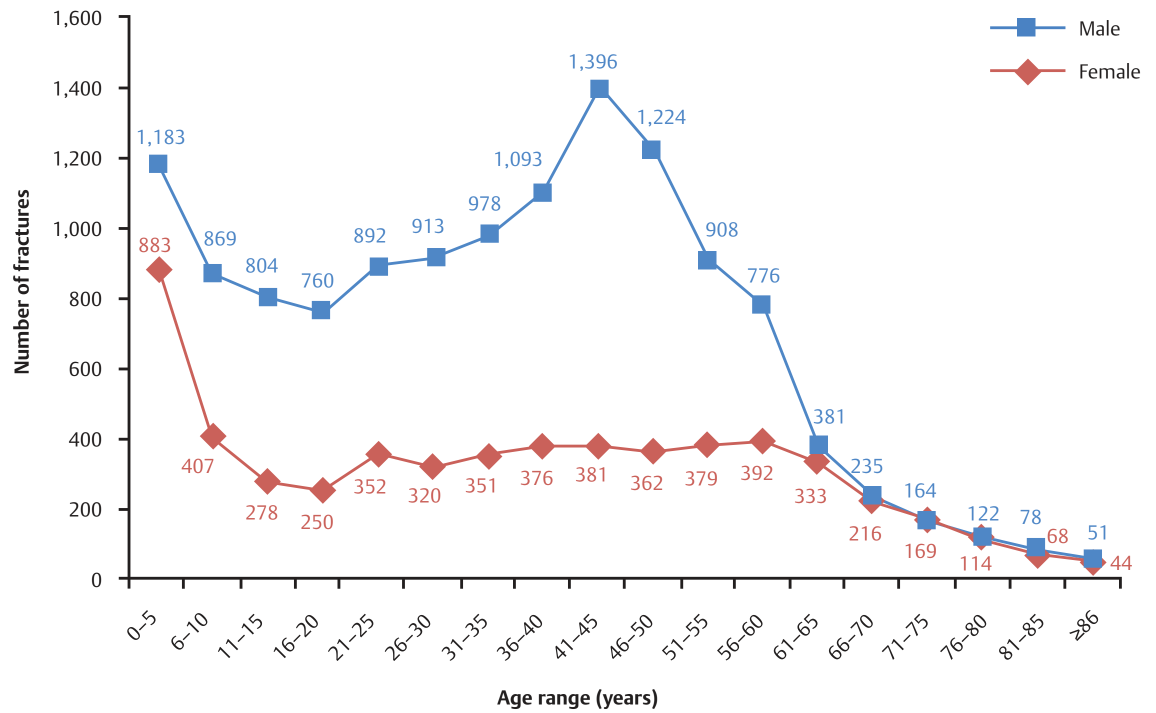

Fig. 1.18 Age and sex distribution of 18,502 patients with clavicle fractures.

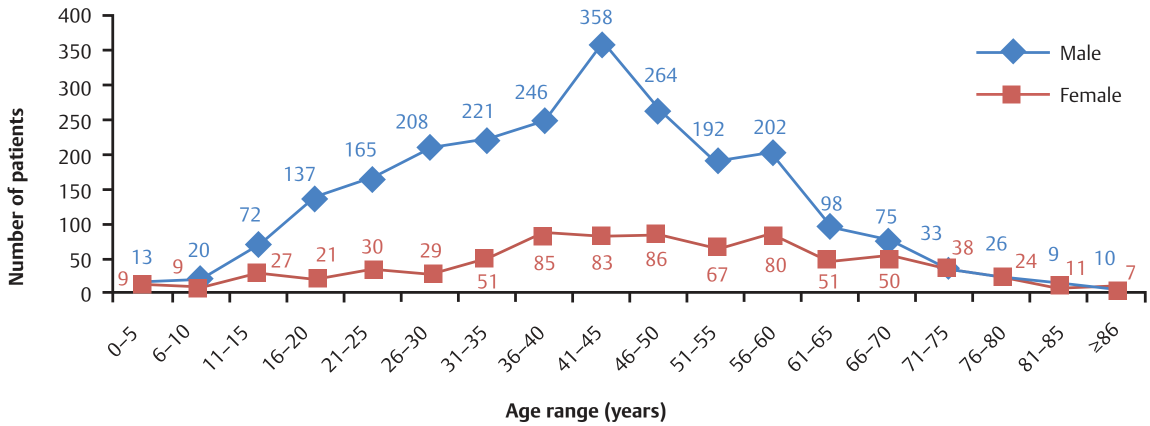

Fig. 1.19 Age and sex distribution of 3,107 patients with scapular fractures.

Fracture Location

Fractures more frequently occur in tibia/fibula, ulna/radius, and hand (▶ Table 1.9; ▶ Fig. 1.20).

Table 1.9 Distribution of 420,125 patients by fracture locations and by gender (unit: patient)

Location	Humerus	Ulna/ Radius	Femur	Tibia/ Fibula	Spine	Foot/ Ankle	Hand	Pelvis/ Acetabulum	Clavicle	Scapula	Patella	Total
Male	19,567	41,592	23,234	44,438	25,280	28,385	48,799	7,892	12,827	2,349	6,791	261,154
Female	16,111	34,258	19,143	22,320	24,399	11,482	13,756	6,528	5,675	758	4,541	158,971
Total	35,678	75,850	42,377	66,758	49,679	39,867	62,555	14,420	18,502	3,107	11,332	420,125
Percentage (%)	8.49	18.05	10.09	15.89	11.82	9.49	14.89	3.43	4.40	0.74	2.70	100.00

Note: Since a patient may sustain one or more fractures of different locations, the total number of patients summarized according to locations is 420,125, greater than the total number of 414,935 patients.

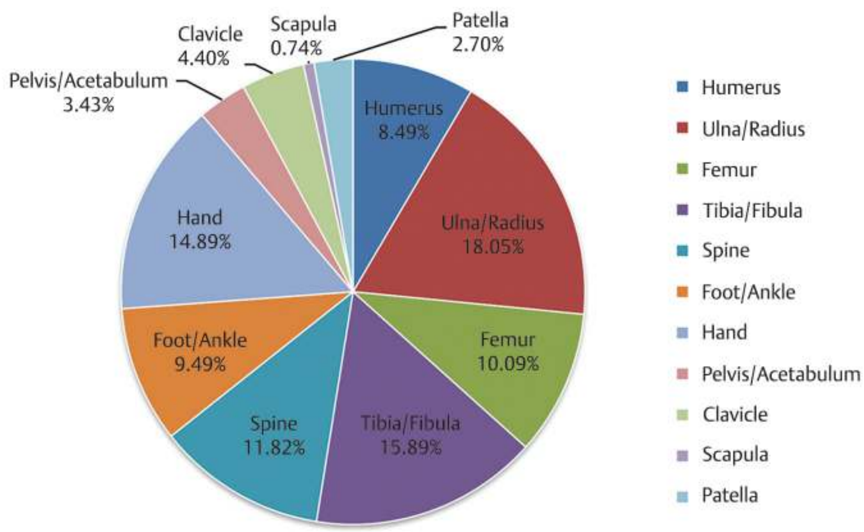

Fig. 1.20 Fracture distribution of the 420,125 patients summarized according to locations.

1

Fractures in Children

Fracture characteristics in children are different from adults, with ulna/radius, humerus, and tibia/fibula being bones with the highest fracture incidence. The locations with the highest risk of fractures are distal humerus, distal ulna/radius, clavicle, and diaphysis of tibia (▶ Table 1.10).

Table 1.10 Distribution of fracture locations in children and adults

Location	Humerus	Ulna/ Radius	Femur	Tibia/ Fibula	Spine	Foot/ Ankle	Hand	Pelvis/ Acetabulum	Clavicle	Scapula	Patella	Total
Children	14,041	18,334	3,282	8,264	564	2,502	4,881	687	4,430	151	290	57,426
Adults	21,769	58,216	39,696	60,614	54,533	38,634	58,849	13,868	14,157	2,972	11,088	374,396
Total	35,810	76,550	42,978	68,878	55,097	41,136	63,730	14,555	18,587	3,123	11,378	431,822

Suggested Readings

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2 Fractures of the Humerus

Bo Liu, Qi Zhang, and Lin Jin

Overview of Humeral Fractures

Anatomic Features

The humerus (▶ Fig. 2.1) is the longest and largest bone of the arm; it is divided into a body and two extremities. The proximal humerus is part of the radiographic anatomy of the shoulder. The humeral head is nearly hemispheric in shape, and articulates with the glenoid cavity of the scapula. The greater tubercle, situated lateral to the head, has three areas of muscle insertion: the supraspinatus superiorly, the infraspinatus in the middle, and the teres minor inferiorly. Situated in front of the head is the lesser tubercle, into which the tendon of the subscapularis inserts. The tubercles are separated from each other by a deep groove named the intertubercular groove, which contains the long tendon of the biceps brachii.

The articular surface of the head is called the anatomic neck, and provides attachment for the articular capsule of the shoulder joint. The surgical neck is the narrowing below the tubercles and is frequently the site of fracture of the proximal humerus. The body runs from the tubercles, is almost cylindric in its upper half, and gradually flattens and gains a prismatic shape. The radial nerve winds around the posterior aspect of the humerus, running laterally in the radial sulcus toward the forearm. The lower extremities are flattened, broad, and thin proximally, while they are thicker at the two tuberculated eminences (lateral and medial epicondyles). The trochlea and the capitulum of the humerus articulate with the semilunar notch of the ulna and the margin of the radial head, respectively, to form the humeroulnar articulation and the humeroradial articulation.

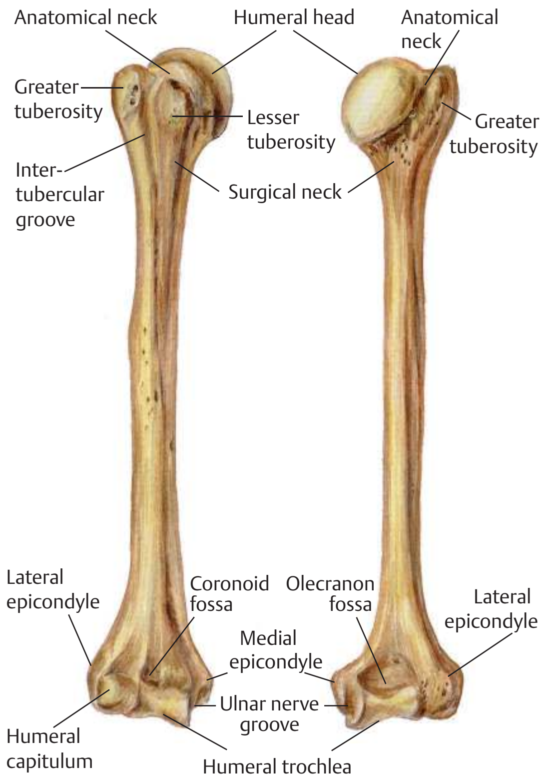


Fig. 2.1 Anterior and posterior aspects of the humerus.

AO Classification and Coding System for Humeral Fractures

The humerus is assigned the number "1" based on the AO system and is further divided into three zones: 11, proximal fracture; 12, shaft fracture; and 13, distal fracture (▶ Fig. 2.2; ▶ Fig. 2.3).

Fig. 2.2 AO codes for humeral fractures.

Epidemiologic Features of Humeral Fractures in the China National Fracture Study

A total of 106 patients with 106 humeral fractures were investigated in the China National Fracture Study (CNFS). The fractures accounted for 6.01% of all patients with fractures and 5.78% of all types of fractures. The population-weighted incidence rate of humeral fractures was 20 per 100,000 population in 2014.

The epidemiologic features of humeral fractures in the CNFS are as follows:

- More males than females
- More right-side injuries than left-side injuries
- The highest risk age group is 15–64 years
- The proximal humeral fracture is the most common humeral fracture
- Injuries occurred most commonly via slips, trips, or falls

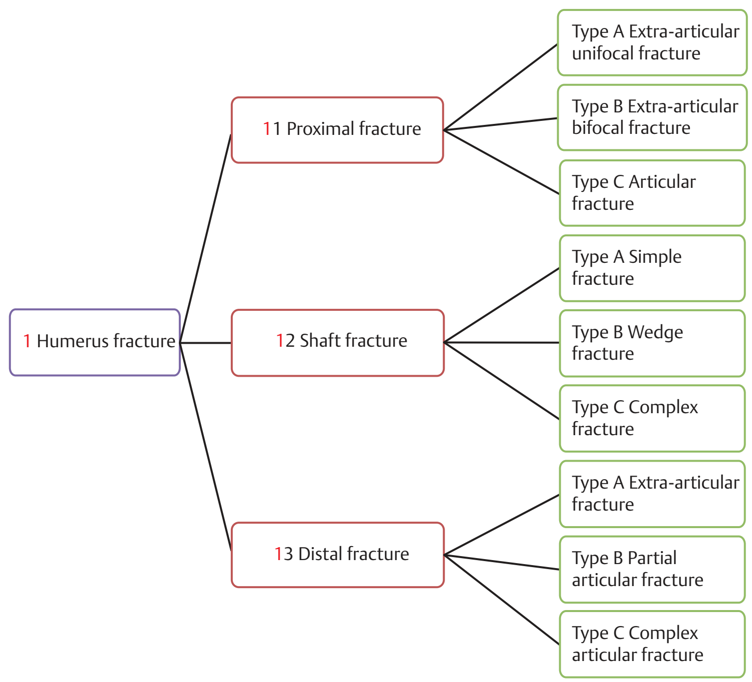


Fig. 2.3 Algorithm.

Humeral Fractures by Sex in CNFS

Sex distribution of 106 patients with humeral fractures in CNFS is shown in ▶ Table 2.1 and ▶ Fig. 2.4.

Table 2.1 Sex distribution of 106 patients with humeral fractures in CNFS

Sex	Number of patients	Percentage
Male	64	60.38
Female	42	39.62
Total	106	100.00

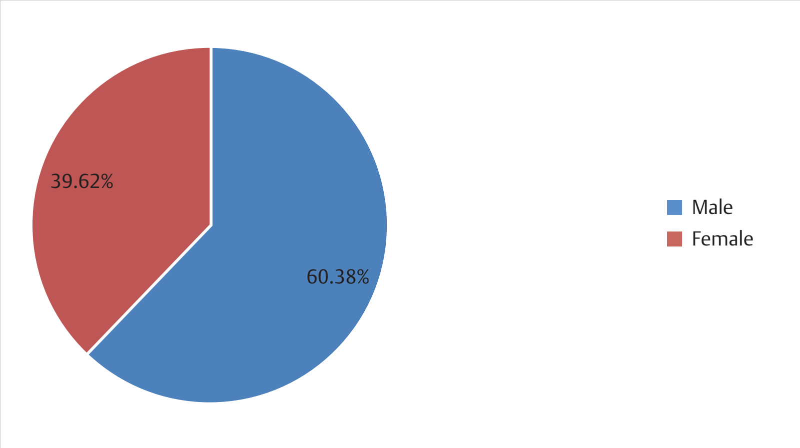


Fig. 2.4 Sex distribution of 106 patients with humeral fractures in China National Fracture Study (CNFS).

Humeral Fractures by Injury Side in CNFS

Injury side distribution of 106 patients with humeral fractures in CNFS is shown in ▶ Table 2.2 and ▶ Fig. 2.5.

Table 2.2 Injury side distribution of 106 patients with humeral fractures in CNFS

Injured side	Number of patients	Percentage
Left	51	48.11
Right	55	51.89
Total	106	100.00

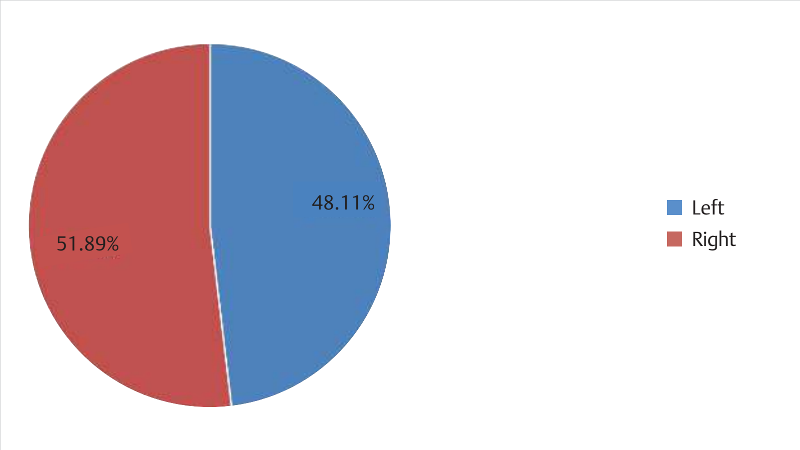


Fig. 2.5 Injury side distribution of 106 patients with humeral fractures in China National Fracture Study (CNFS).

■ Humeral Fractures by Age Group and Sex in CNFS

Age and sex distribution of 106 patients with humeral fractures in CNFS are shown in ▶ Table 2.3 and ▶ Fig. 2.6.

Table 2.3 Age and sex distribution of 106 patients with humeral fractures in CNFS

Age group (years)	Male	Female	Total	Percentage
0–14	17	2	19	17.92
15–64	42	26	68	64.15
≥ 65	5	14	19	17.92
Total	64	42	106	100.00

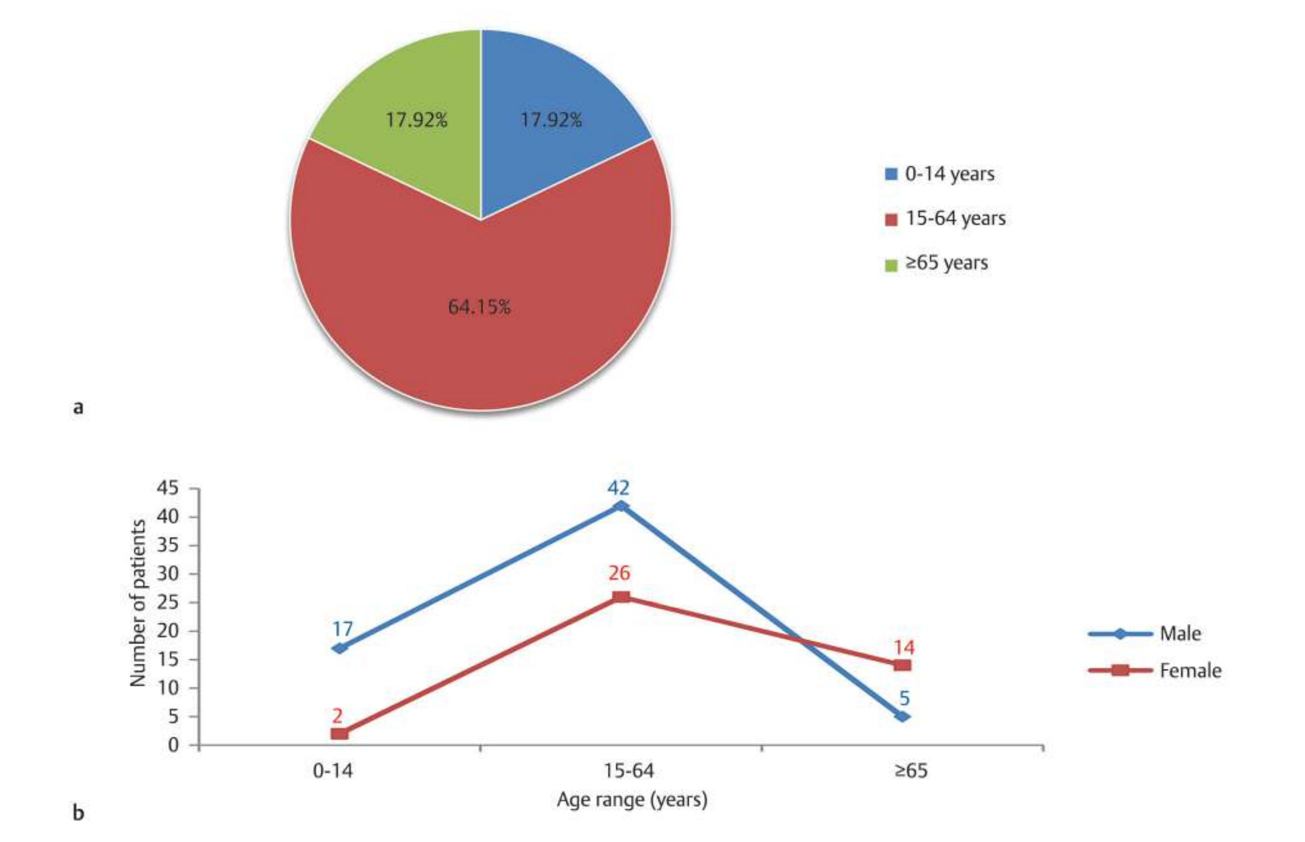


Fig. 2.6 (**a**) Age distribution of 106 patients with humeral fractures in China National Fracture Study (CNFS). (**b**) Age and sex distribution of 106 patients with humeral fractures in CNFS.

Humeral Fractures by Location in CNFS

Segment distribution of 106 patients with humeral fractures in CNFS based on AO classification is shown in ▶ Table 2.4 and ▶ Fig. 2.7.

Table 2.4 Segment distribution of 106 patients with humeral fractures in CNFS based on AO classification

Segment	Male	Female	Total	Percentage
11	19	23	42	39.62
12	25	12	37	34.91
13	20	7	27	25.47
Total	64	42	106	100.00

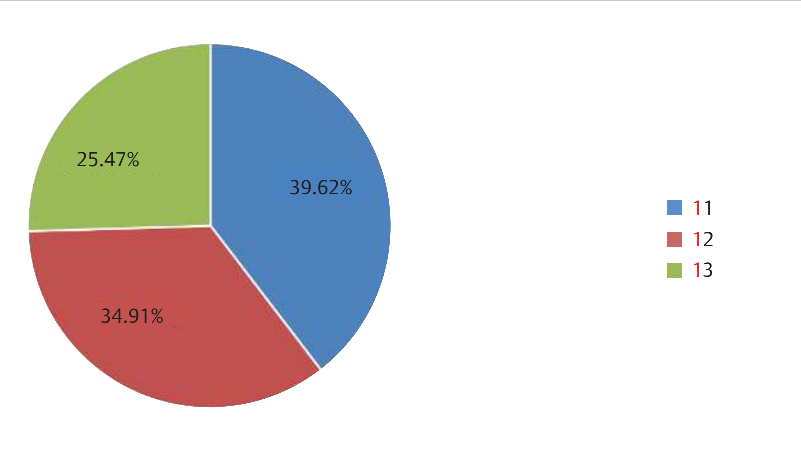


Fig. 2.7 Segment distribution of 106 patients with humeral fractures in China National Fracture Study (CNFS) based on AO classification.

Humeral Fractures by Causal Mechanisms in CNFS

Causal mechanisms distribution of 106 patients with humeral fractures in CNFS is shown in ▶ Table 2.5 and ▶ Fig. 2.8.

Table 2.5 Causal mechanisms distribution of 106 patients with humeral fractures in CNFS

Causal mechanisms	Male	Female	Total	Percentage
Traffic accident	24	11	35	33.02
Slip, trip, or fall	31	28	59	55.66
Fall from heights	2	1	3	2.83
Crushing injury	6	2	8	7.55
Blunt force trauma	1	0	1	0.94
Total	64	42	106	100.00

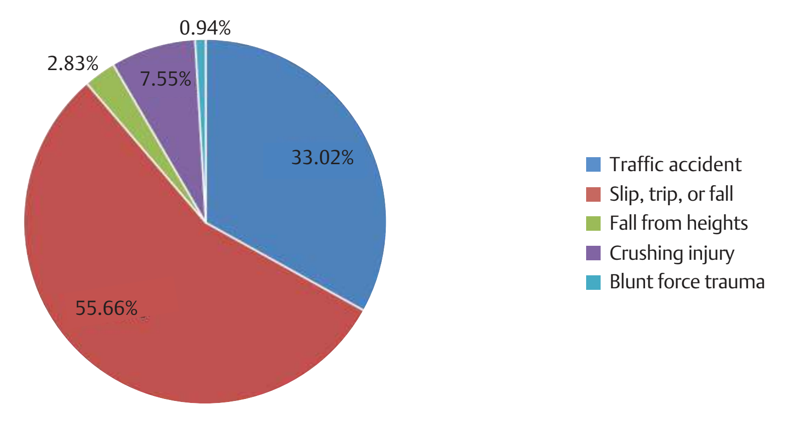


Fig. 2.8 Causal mechanisms distribution of 106 patients with humeral fractures in China National Fracture Study (CNFS).

Clinical Epidemiologic Features of Humeral Fractures

A total of 35,678 patients with 35,810 humeral fractures were treated in 83 hospitals of China over a two-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 8.60% of all patients with fractures and 8.29% of all types of fractures. Among 35,678 patients, 14,027 were children with 14,041 fractures, and 21,651 were adults with 21,769 fractures.

The epidemiologic features of humeral fractures are as follows:

- More males than females
- More left sides involved than right sides
- The highest-risk age groups are 0–5 years and 6–10 years
- In adults, fractures occur most frequently in the proximal humerus; in children they occur most frequently in distal humerus

Humeral Fractures by Sex

Sex distribution of 35,678 patients with humeral fractures is shown in ▶ Table 2.6 and ▶ Fig. 2.9.

Table 2.6 Sex distribution of 35,678 patients with humeral fractures

Sex	Number of patients	Percentage
Male	19,567	54.84
Female	16,111	45.16
Total	35,678	100.00

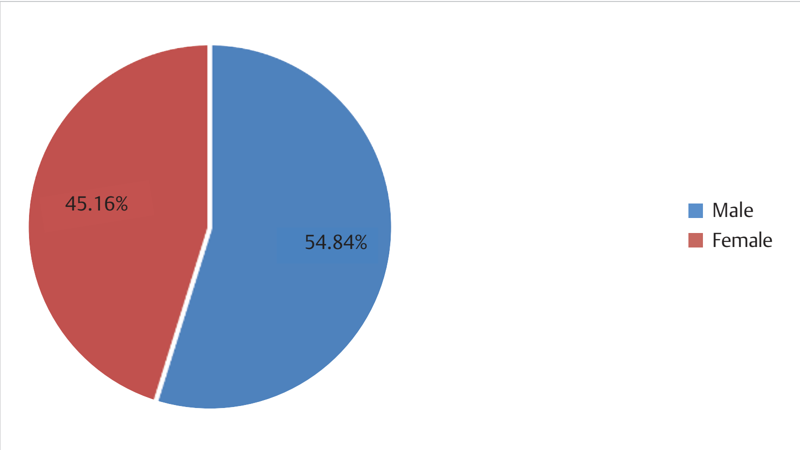


Fig. 2.9 Sex distribution of 35,678 patients with humeral fractures.

Humeral Fractures by Injured Side

Injury side distribution of 35,678 patients with humeral fractures is shown in ▶ Table 2.7 and ▶ Fig. 2.10.

Table 2.7 Injury side distribution of 35,678 patients with humeral fractures

Injured side	Number of patients	Percentage
Left	18,809	52.72
Right	16,827	47.16
Bilateral	42	0.12
Total	35,678	100.00

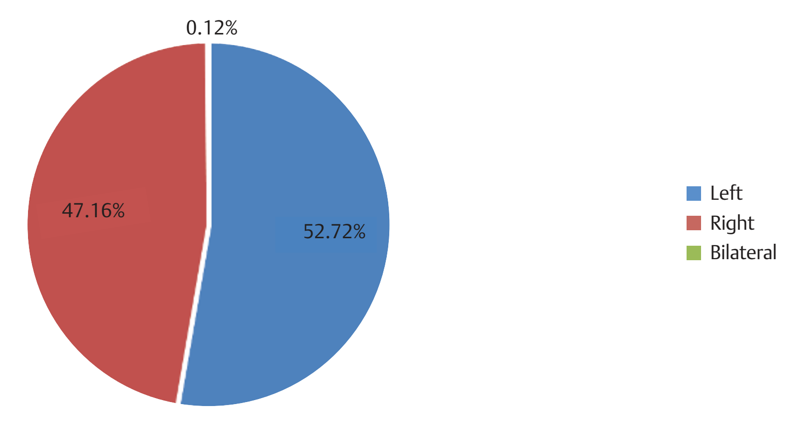


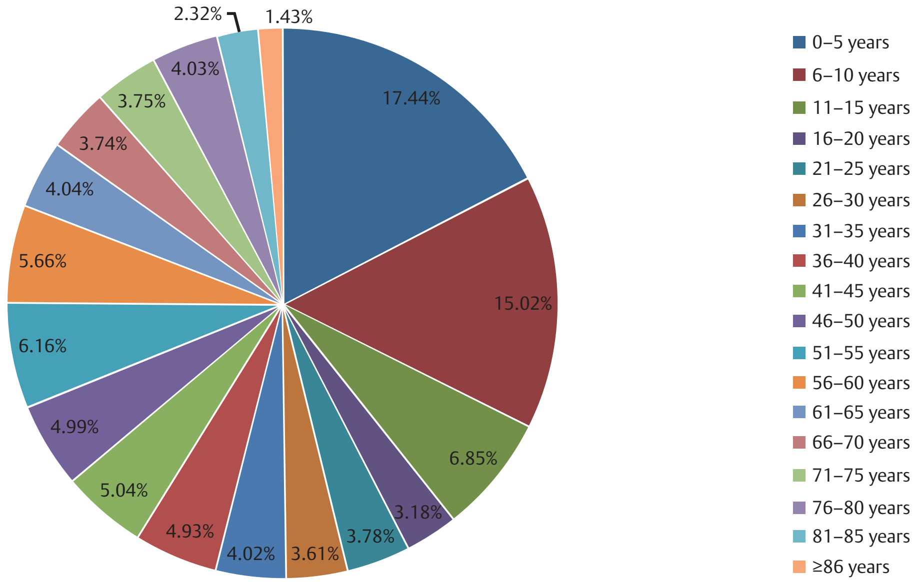
Fig. 2.10 Injury side distribution of 35,678 patients with humeral fractures.

Humeral Fractures by Age Group and Sex

Age and sex distribution of 35,678 patients with humeral fractures are shown in ▶ Table 2.8 and ▶ Fig. 2.11.

Table 2.8 Age and sex distribution of 35,678 patients with humeral fractures

Age group (years)	Male	Female	Total	Percentage
0–5	3,613	2,611	6,224	17.44
6–10	3,589	1,771	5,360	15.02
11–15	1,800	643	2,443	6.85
16–20	865	269	1,134	3.18
21–25	920	428	1,348	3.78
26–30	938	351	1,289	3.61
31–35	1,024	411	1,435	4.02
36–40	1,214	545	1,759	4.93
41–45	1,132	667	1,799	5.04
46–50	1,009	772	1,781	4.99
51–55	1,010	1,189	2,199	6.16
56–60	719	1,302	2,021	5.66
61–65	419	1,021	1,440	4.04
66–70	368	968	1,336	3.74
71–75	277	1,061	1,338	3.75
76–80	324	1,113	1,437	4.03
81–85	214	612	826	2.32
≥ 86	132	377	509	1.43
Total	19,567	16,111	35,678	100.00



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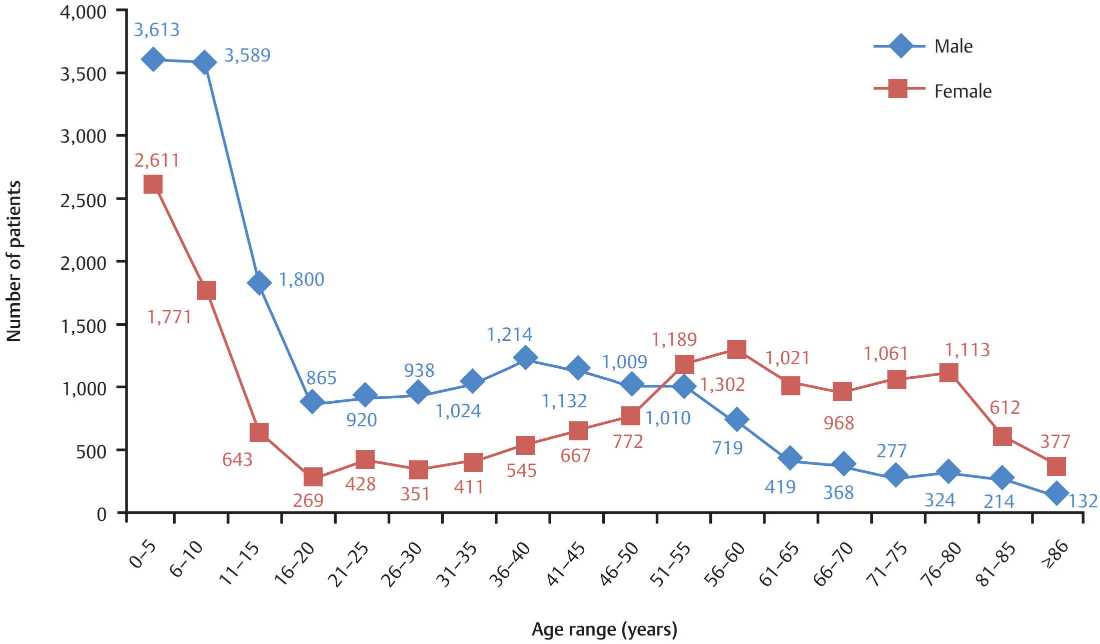

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Fig. 2.11 (**a**) Age distribution of 35,678 patients with humeral fractures. (**b**) Age and sex distribution of 35,678 patients with humeral fractures.

Humeral Fractures by Location

The Distribution of Humeral Fractures by Segments in Adults Based on AO Classification

Segment distribution of 21,769 humeral fractures in adults based on AO classification is shown in ▶ Table 2.9 and ▶ Fig. 2.12.

Table 2.9 Segment distribution of 21,769 humeral fractures in adults based on AO classification

Segment	Number of fractures	Percentage
11	12,959	59.53
12	5,049	23.19
13	3,761	17.28
Total	21,769	100.00

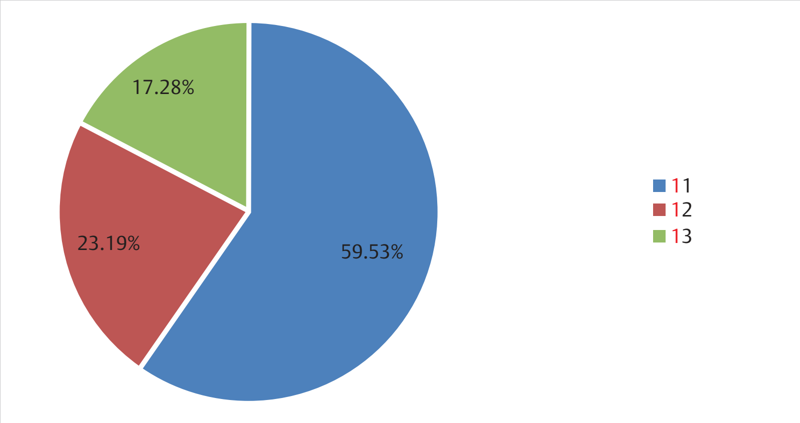


Fig. 2.12 Segment distribution of 21,769 humeral fractures in adults based on AO classification.

The Distribution of Humeral Fractures by Segments in Children

Segment distribution of 14,041 humeral fractures in children is shown in ▶ Table 2.10 and ▶ Fig. 2.13.

Table 2.10 Segment distribution of 14,041 humeral fractures in children

Segment	Number of fractures	Percentage
Proximal	1,618	11.52
Diaphysis	923	6.57
Distal	11,500	81.90
Total	14,041	100.00

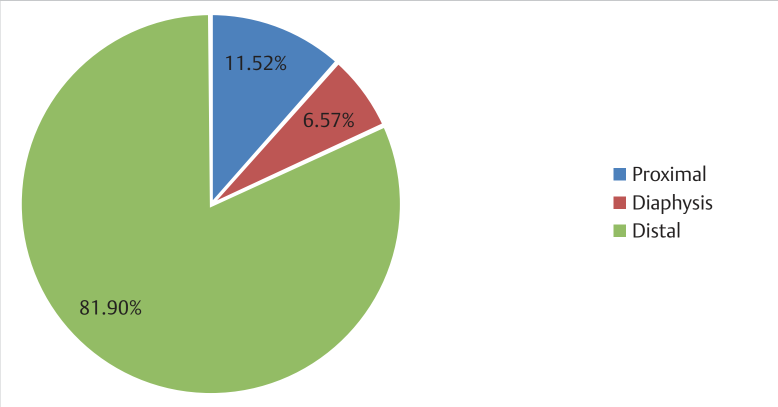


Fig. 2.13 Segment distribution of 14,041 humeral fractures in children.

2

Proximal Humeral Fractures (Segment 11)

Anatomic Features

The proximal part of the humerus consists of the head, two eminences, the greater and lesser tubercles, and the surgical neck (▶ Fig. 2.14). The humeral head has a hemispherical shape, which has superior, medial, and posterior aspects. The narrow groove separating the head from the tubercles is the anatomic neck, where fractures rarely occur but there is a high incidence of avascular necrosis due to the disruption of blood supply to the main head fragment. The narrowing below the tubercles, called the surgical neck, is the junction of the two tubercles with the cylindric shaft. It is frequently fractured because the cortex at this part of the bone abruptly becomes quite thin. The greater tubercle is situated laterally and posteriorly to the proximal humerus, and provides insertion points for the supraspinatus, infraspinatus, and teres minor. The ridge descending down the shaft from the root of the greater tubercle is called the crest of the greater tubercle, into which the pectoralis major muscle inserts. The lesser tubercle, situated anteriorly, represents the center of the humeral head and provides an insertion point for the subscapularis. The crest descending from the lesser tubercle has attachments to the latissimus dorsi and the teretiscapularis. The intertubercular groove lodges the long tendon of the biceps brachii (▶ Fig. 2.15; ▶ Fig. 2.16).

AO Classification of Proximal Humeral Fractures

Based on AO classification, the proximal end of the humerus is delineated by a square with its lateral side equal to the maximum width of the epiphysis. The AO coding of proximal humeral fracture is “11,” and is further divided into three categories based on the severity of injury: types A, B, and C (▶ Fig. 2.17).

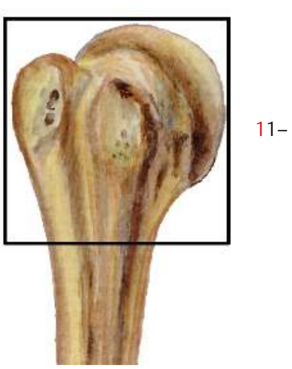


Fig. 2.14 The proximal part of the humerus.

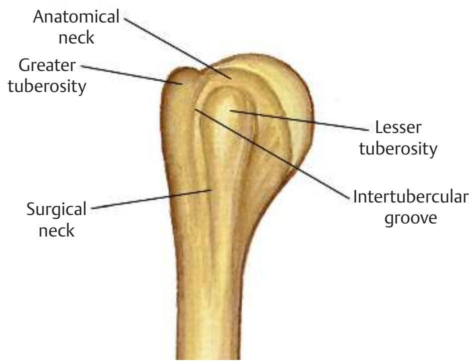


Fig. 2.15 Features of the proximal part of the humerus.

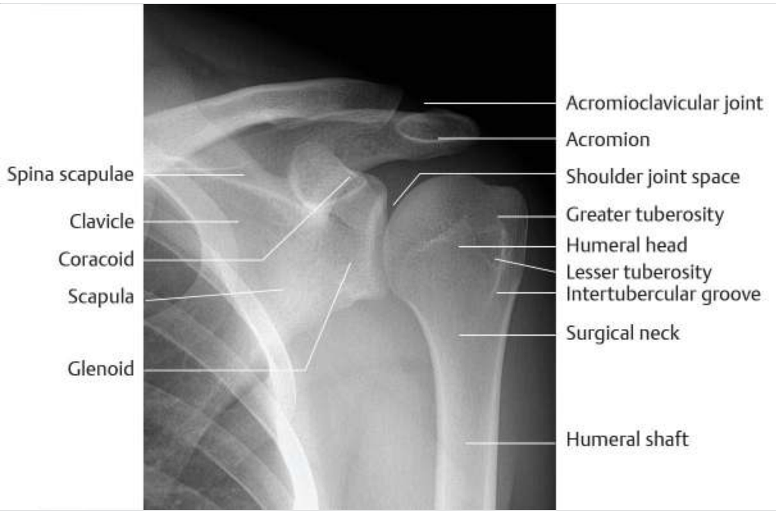


Fig. 2.16 Radiographic anatomy of the shoulder.

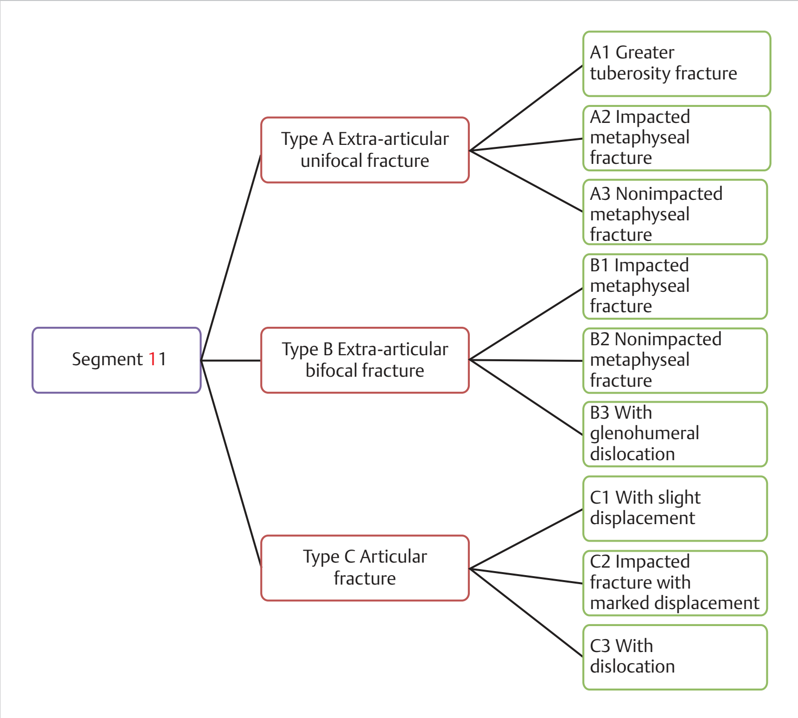


Fig. 2.17 Algorithm.

Clinical Epidemiological Features of Proximal Humeral Fractures (Segment 11)

A total of 12,959 adult proximal humeral fractures (segment 11) were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. Each case was reviewed and statistically studied; the fractures accounted for 59.53% of adult humeral fractures. The epidemiologic features are as follows:

- More females than males
- The high-risk age group is 51–55 years, specifically 51–55 years for males and 56–60 years for females
- The high-incidence type is 11-A, and is the same for both males and females
- The high-incidence group is 11-A1, and is the same for both males and females.

Fractures of Segment 11 by Sex

Sex distribution of 12,959 fractures of segment 11 is shown in ▶ Table 2.11 and ▶ Fig. 2.18.

Table 2.11 Sex distribution of 12,959 fractures of segment 11

Sex	Number of fractures	Percentage
Male	5,247	40.49
Female	7,712	59.51
Total	12,959	100.00

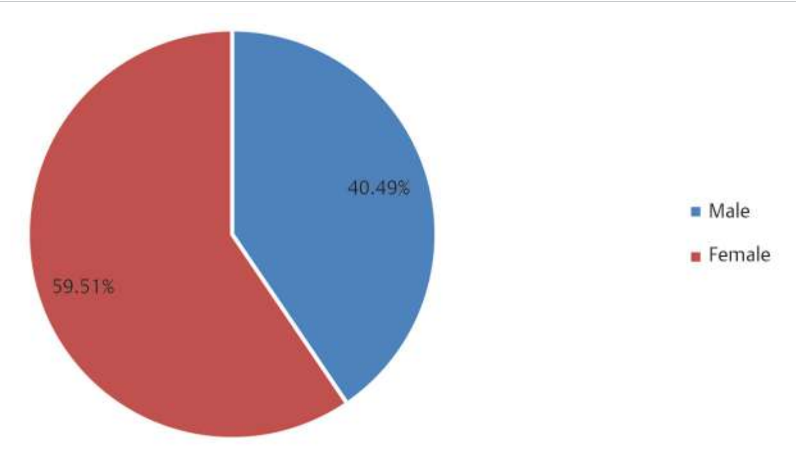


Fig. 2.18 Sex distribution of 12,959 fractures of segment 11.

■ Fractures of Segment 11 by Age Group

Age and sex distribution of 12,959 fractures of segment 11 are shown in ▶ Table 2.12 and ▶ Fig. 2.19.

Table 2.12 Age and sex distribution of 12,959 fractures of segment 11

Age group (years)	Male	Female	Total	Percentage
16–20	236	86	322	2.48
21–25	218	153	371	2.86
26–30	334	164	498	3.84
31–35	448	197	645	4.98
36–40	568	295	863	6.66
41–45	582	401	983	7.59
46–50	574	526	1,100	8.49
51–55	634	920	1,554	11.99
56–60	411	977	1,388	10.71
61–65	273	779	1,052	8.12
66–70	255	752	1,007	7.77
71–75	204	837	1,041	8.03
76–80	235	863	1,098	8.47
81–85	174	482	656	5.06
≥ 86	101	280	381	2.94
Total	5,247	7,712	12,959	100.00

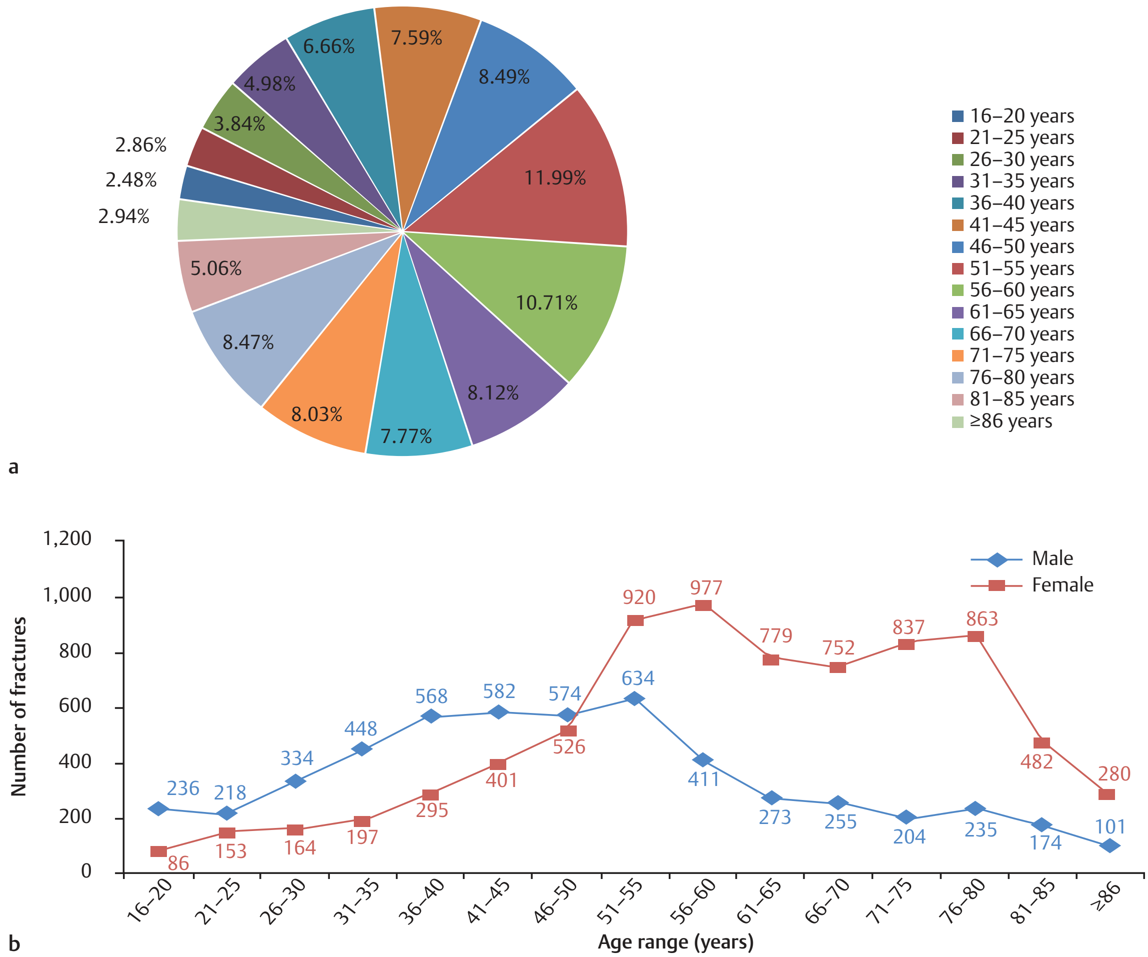


Fig. 2.19 (a) Age distribution of 12,959 fractures of segment 11. (**b**) Age and sex distribution of 12,959 fractures of segment 11.

■ Fractures of Segment 11 by Fracture Type

Sex and fracture type distribution of 12,959 fractures of segment 11 are shown in ▶ Table 2.13, ▶ Table 2.14, ▶ Fig. 2.20, and ▶ Fig. 2.21.

Table 2.13 Sex and fracture type distribution of 12,959 fractures of segment 11

Fracture type	Male	Female	Total	Percentage of segment 11 fractures	Percentage of adult humeral fractures
11-A	3,718	5,085	8,803	67.93	40.44
11-B	1,038	1,801	2,839	21.91	13.04
11-C	491	826	1,317	10.16	6.05
Total	5,247	7,712	12,959	100.00	59.53

Table 2.14 Sex and fracture group distribution of 12,959 fractures of Segment 11

Fracture group	Male	Female	Total	Percentage of segment 11 fractures	Percentage of adult humeral fractures
11-A1	2,302	2,841	5,143	39.69	23.63
11-A2	865	1,468	2,333	18.00	10.72
11-A3	551	776	1,327	10.24	6.10
11-B1	524	960	1,484	11.45	6.82
11-B2	385	616	1,001	7.72	4.60
11-B3	129	225	354	2.73	1.63
11-C1	169	295	464	3.58	2.13
11-C2	166	291	457	3.53	2.10
11-C3	156	240	396	3.06	1.82
Total	5,247	7,712	12,959	100.00	59.53

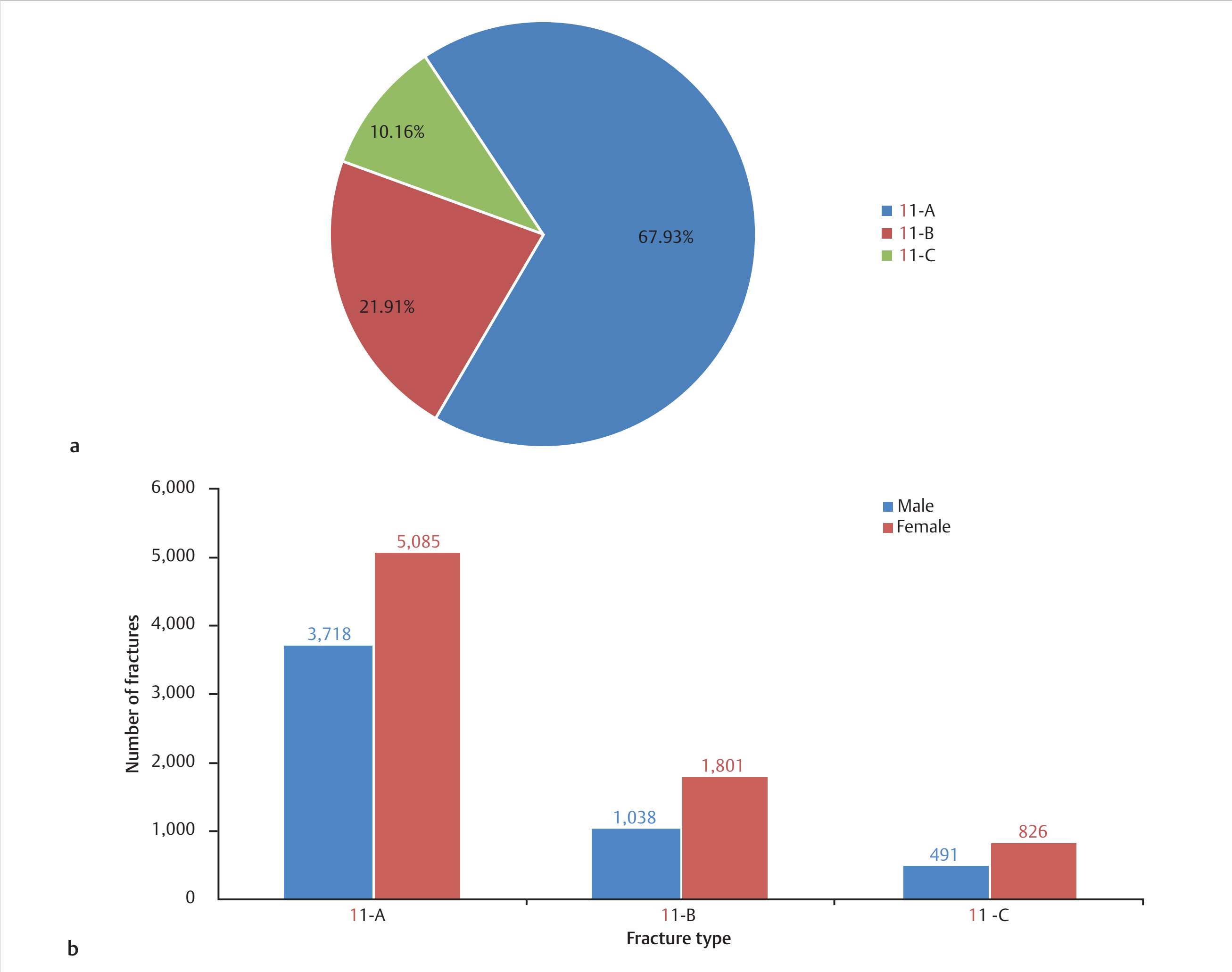


Fig. 2.20 (**a**) Fracture type distribution of 12,959 fractures of segment 11. (**b**) Sex and fracture type distribution of 12,959 fractures of segment 11.

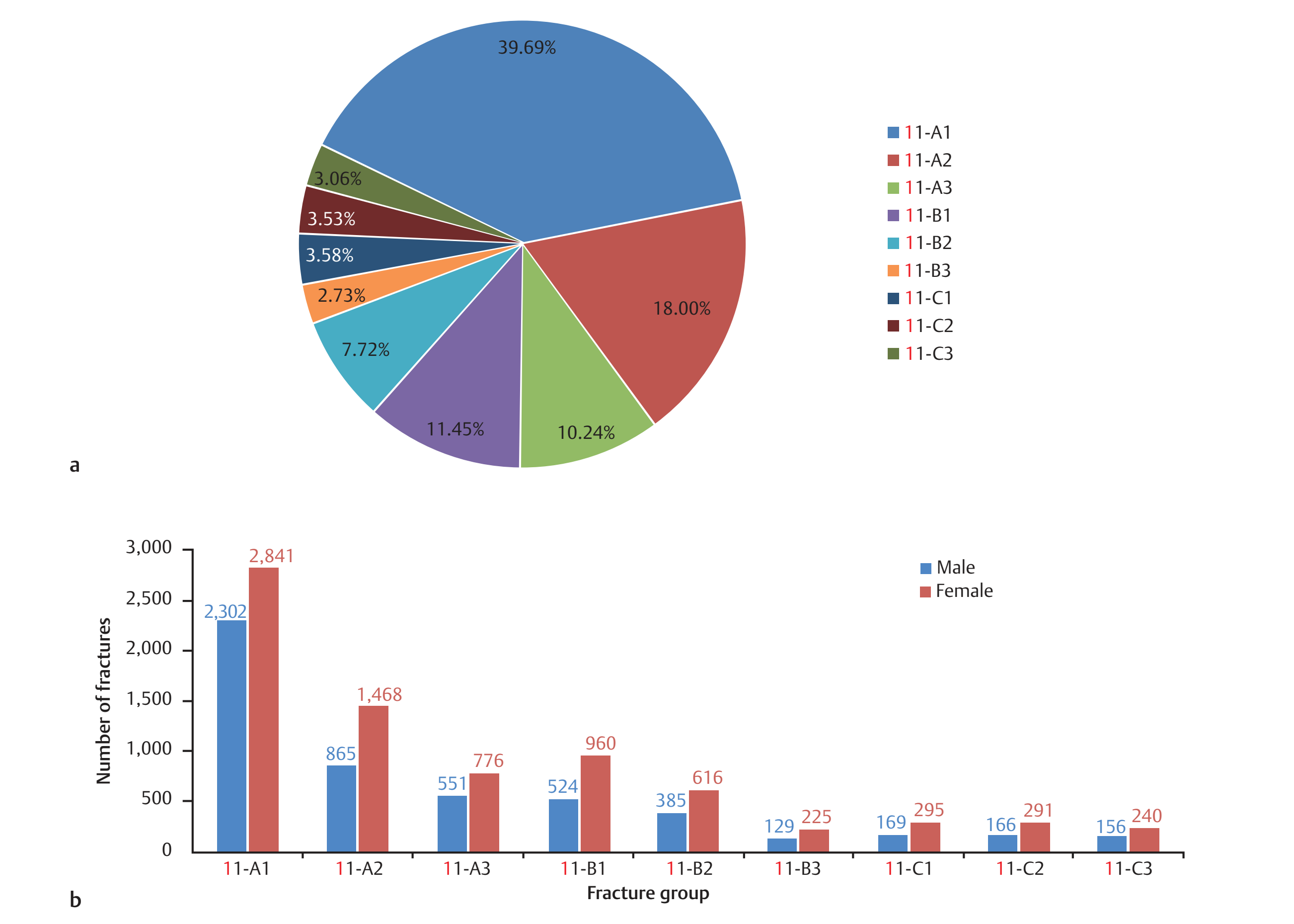
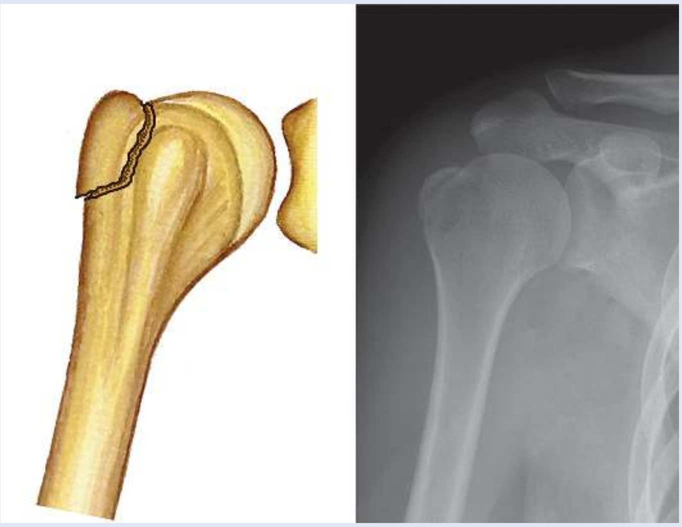


Fig. 2.21 (a) Fracture group distribution of 12,959 fractures of segment 11. (b) Sex and fracture group distribution of 12,959 fractures of segment 11.

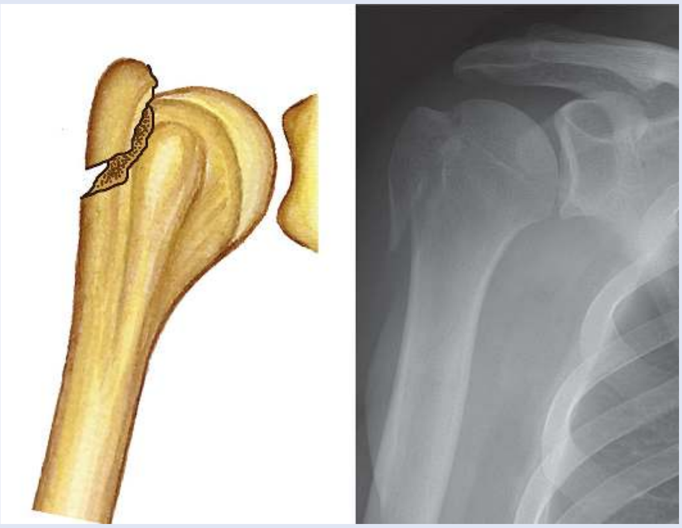
11-A Humerus, proximal, extra-articular fractures, unifocal

11-A1 Humerus, proximal, extra-articular, greater tuberosity fracture
5,143 fractures
M: 2,302 (44.76%)
F: 2,841 (55.24%)
1.37% of total adult fractures
23.63% of adult humeral fractures
39.69% of segment 11
58.42% of type 11-A

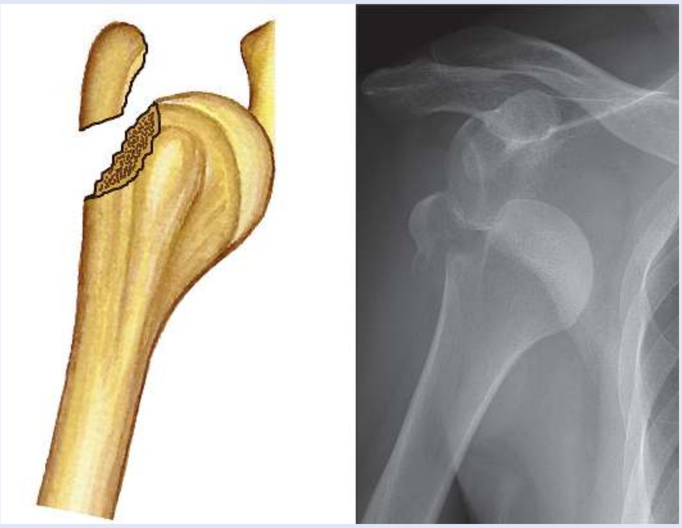
11-A1.1 Greater tuberosity fracture without displacement



11-A1.2 Greater tuberosity fracture with displacement



11-A1.3 Greater tuberosity fracture with glenohumeral dislocation

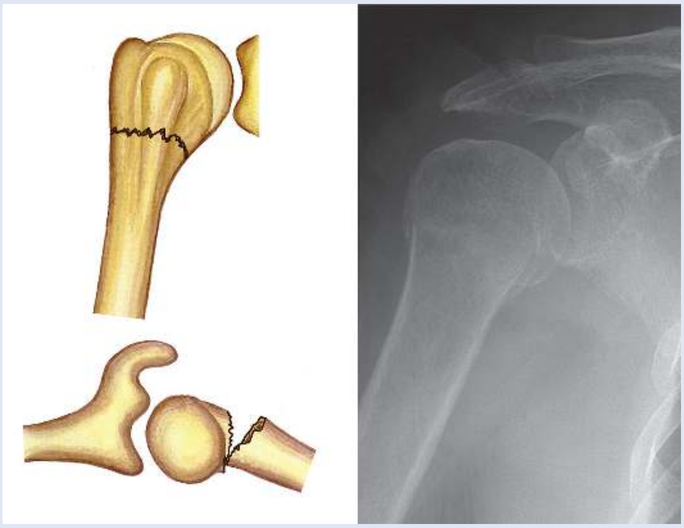


11-A Humerus, proximal, extra-articular fractures, bifocal

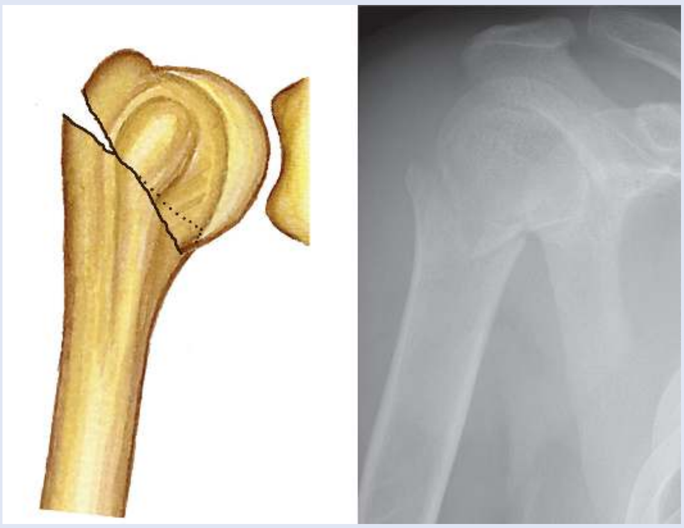
11-A2 Humerus, proximal, extra-articular fracture with impacted metaphysis

2,333 fractures
M: 865 (37.08%)
F: 1,468 (62.92%)
0.62% of total adult fractures
10.72% of adult humeral fractures
18.00% of segment 11
26.50% of type 11-A

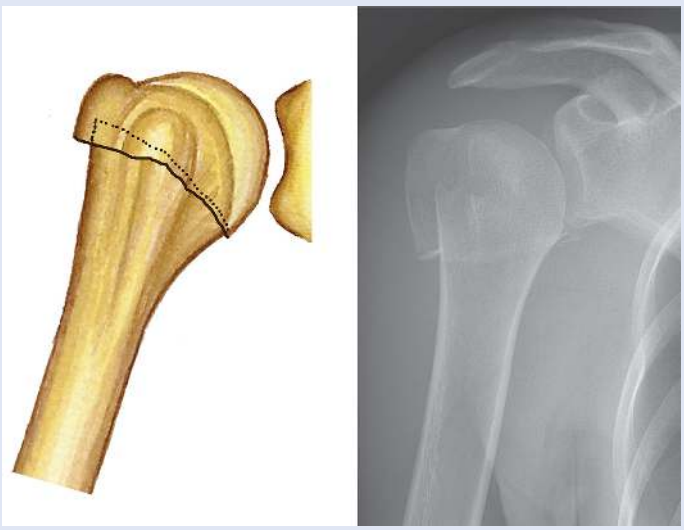
11-A2.1 With frontal malalignment



11-A2.2 With varus malalignment



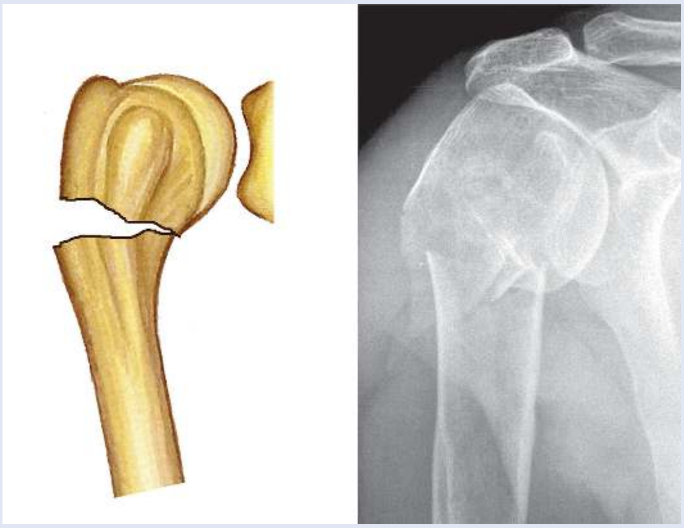
11-A2.3 With valgus malalignment



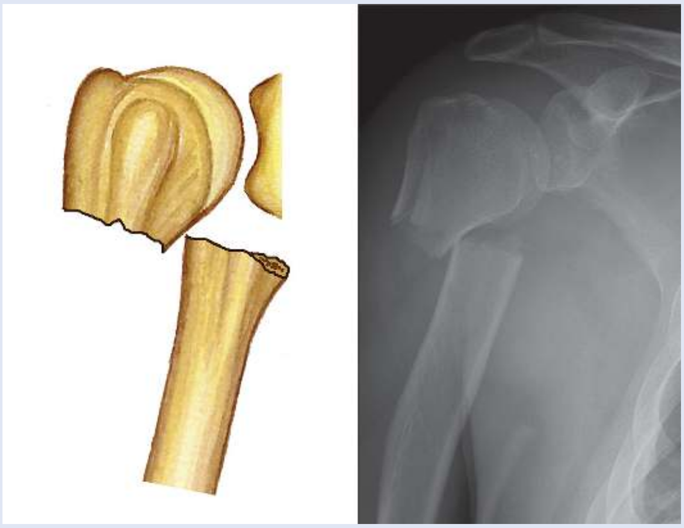
11-A Humerus, proximal, extra-articular fractures, bifocal

11-A3 Humerus, proximal, extra-articular fracture without impacted metaphysis
1,327 fractures
M: 551 (41.52%)
F: 776 (58.48%)
0.35% of total adult fractures
6.10% of adult humeral fractures
10.24% of segment 11
15.07% of type 11-A

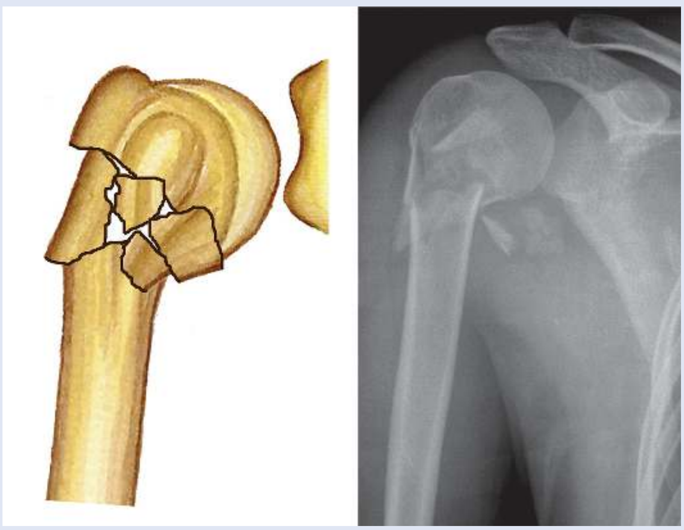
11-A3.1 With angulation



11-A3.2 With translation



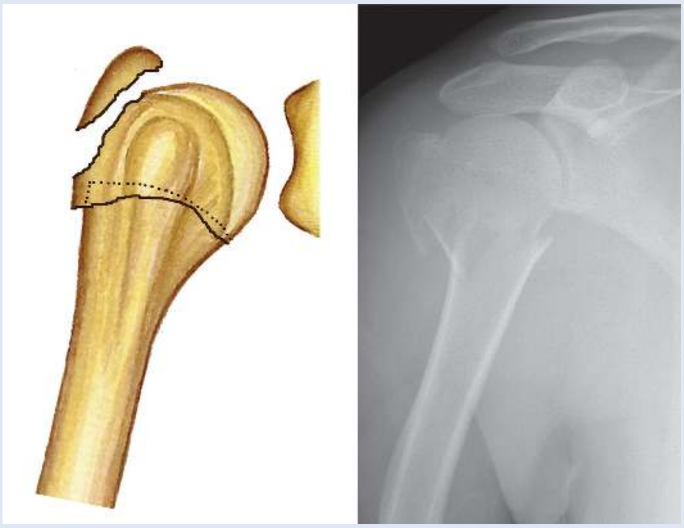
11-A3.3 Multiple fragments



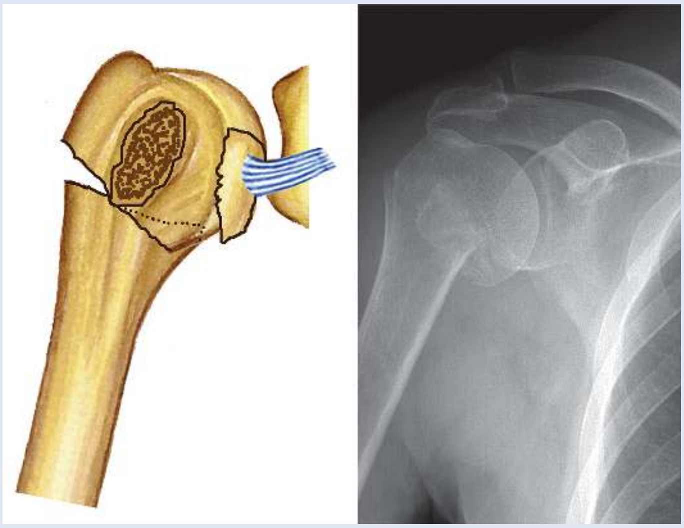
11-B Humerus, proximal, extra-articular fractures, bifocal

11-B1 Humerus, proximal, extra-articular, bifocal fracture with impacted metaphysis
1,484 fractures
M: 524 (35.31%)
F: 960 (64.69%)
0.40% of total adult fractures
6.82% of adult humeral fractures
11.45% of segment 11
52.27% of type 11-B

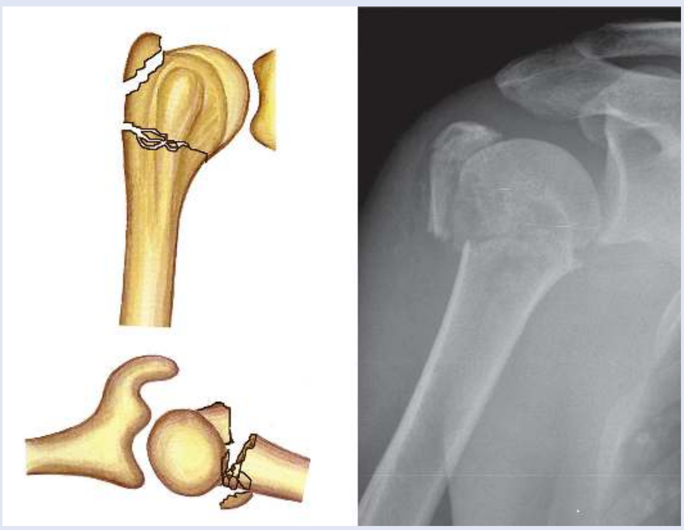
11-B1.1 Lateral and greater tuberosity fractures



11-B1.2 Medial and lesser tuberosity fractures



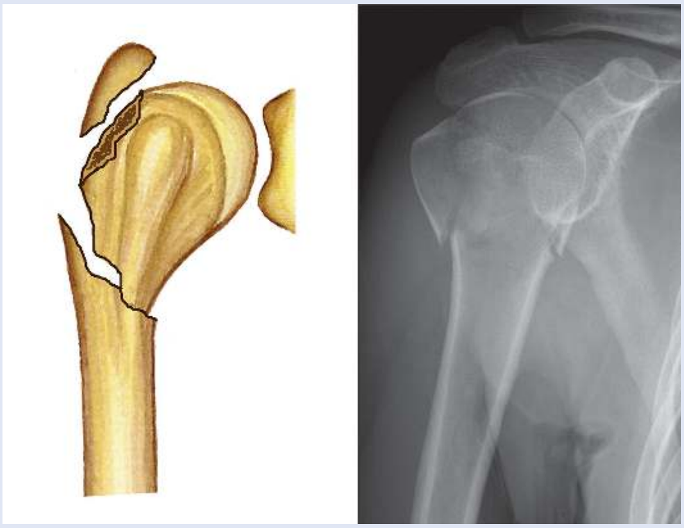
11-B1.3 Posterior and greater tuberosity fractures



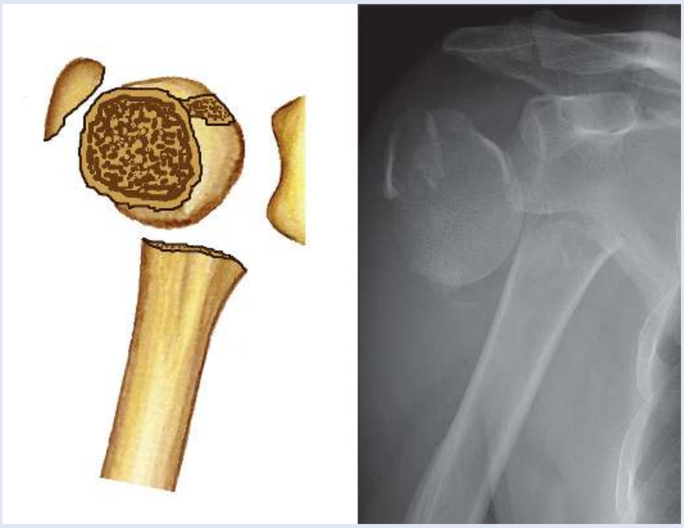
11-B Humerus, proximal, extra-articular fractures, bifocal

11-B2 Humerus, proximal, extra-articular, bifocal fracture without impacted metaphysis
1,001 fractures
M: 385 (38.46%)
F: 616 (61.54%)
0.27% of total adult fractures
4.60% of adult humeral fractures
7.72% of segment 11
35.26% of type 11-B

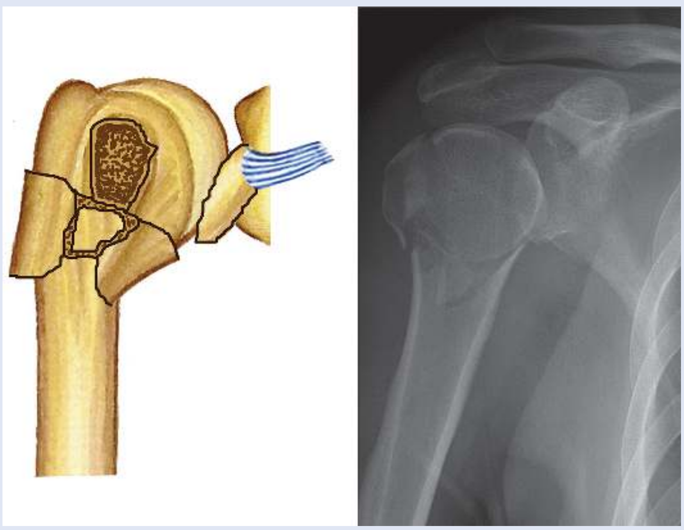
11-B2.1 Without rotatory displacement of the epiphyseal fragment



11-B2.2 With rotatory displacement of the epiphyseal fragment



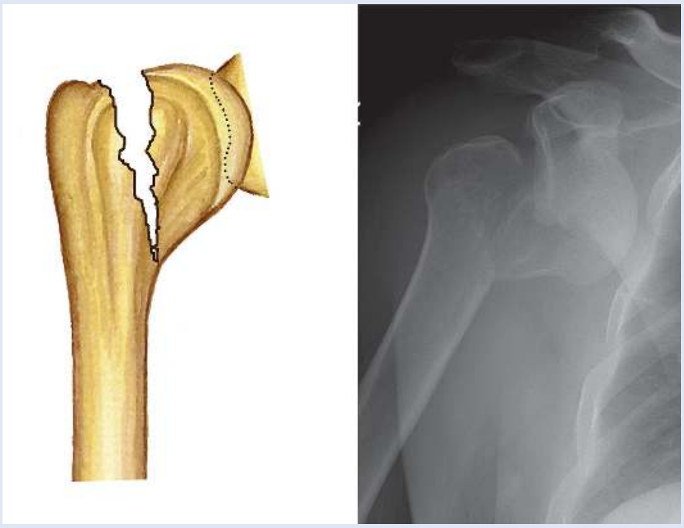
11-B2.3 Multiple fragments with fracture of one tuberosity



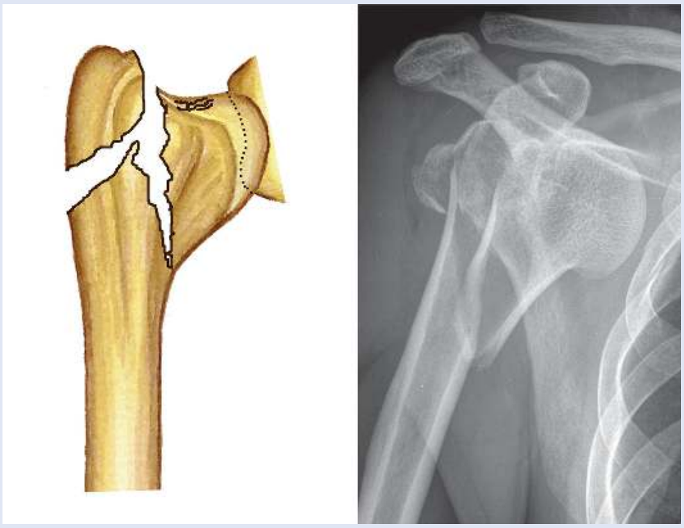
11-B Humerus, proximal, extra-articular fractures, bifocal

11-B3 Humerus, proximal, extra-articular, bifocal fracture with glenohumeral dislocation
354 fractures
M: 129 (36.44%)
F: 225 (63.56%)
0.09% of total adult fractures
1.63% of adult humeral fractures
2.73% of segment 11
12.47% of type 11-B

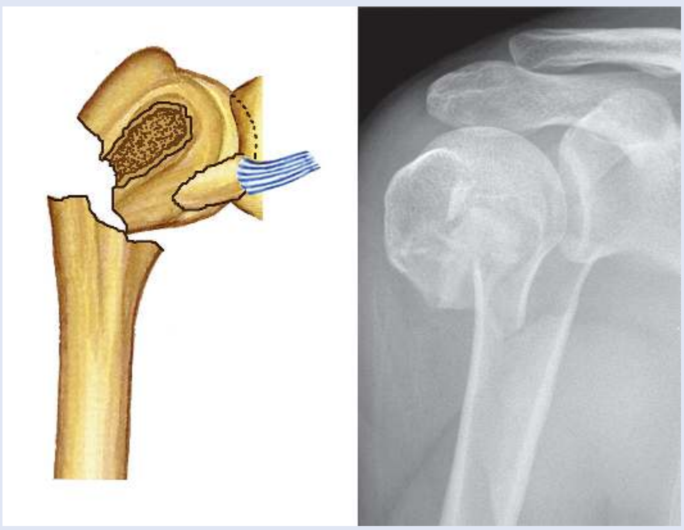
11-B3.1 Vertical cervical line; greater tuberosity intact; anterior medial dislocation



11-B3.2 Vertical cervical line; anterior medial dislocation; greater tuberosity fractured



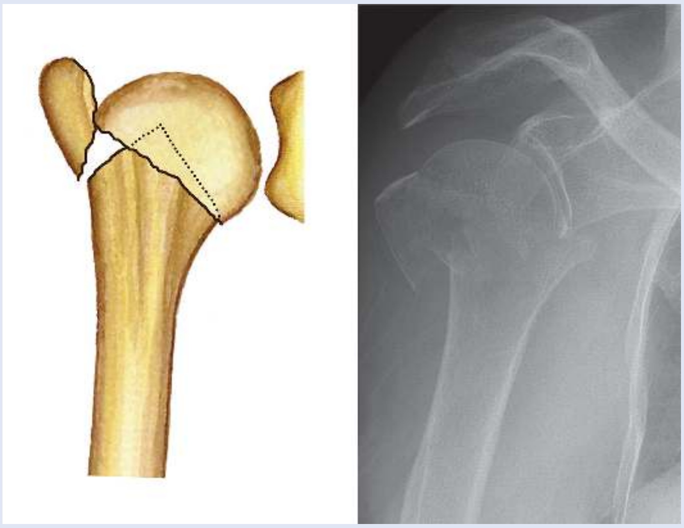
11-B3.3 Posterior dislocation; lesser tuberosity fractured



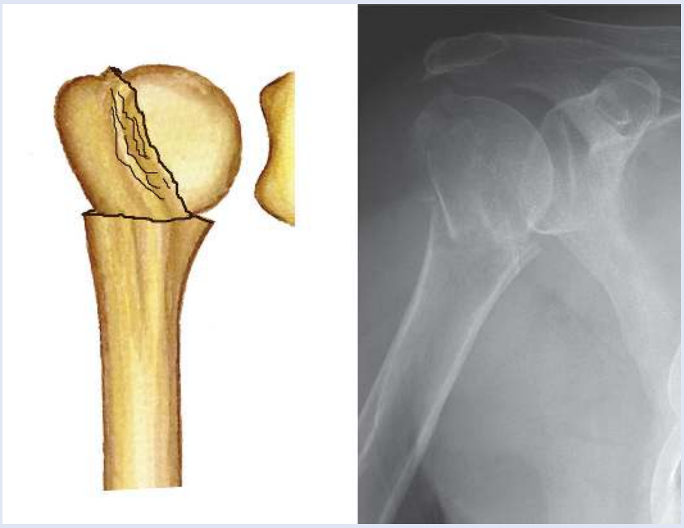
11-C Humerus, proximal, articular fractures

11-C1 Humerus, proximal, articular fracture with slight dislocation
464 fractures
M: 169 (36.42%)
F: 295 (63.58%)
0.12% of total adult fractures
2.13% of adult humeral fractures
3.58% of segment 11
35.23% of type 11-C

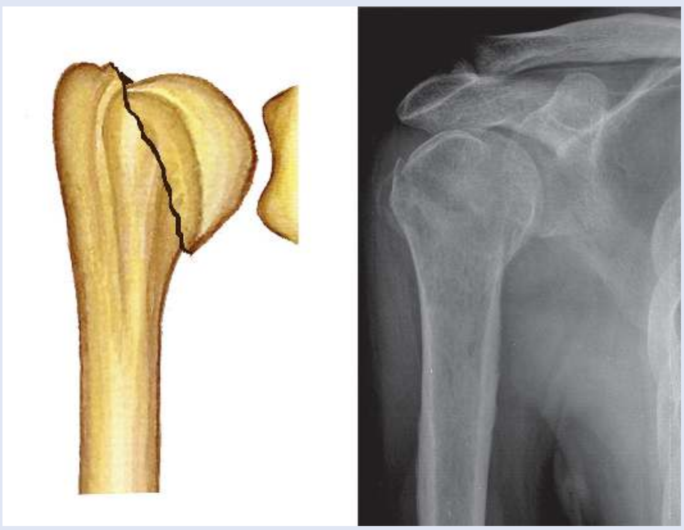
11-C1.1 Cephalotubercular, with valgus malalignment



11-C1.2 Cephalotubercular, with varus malalignment



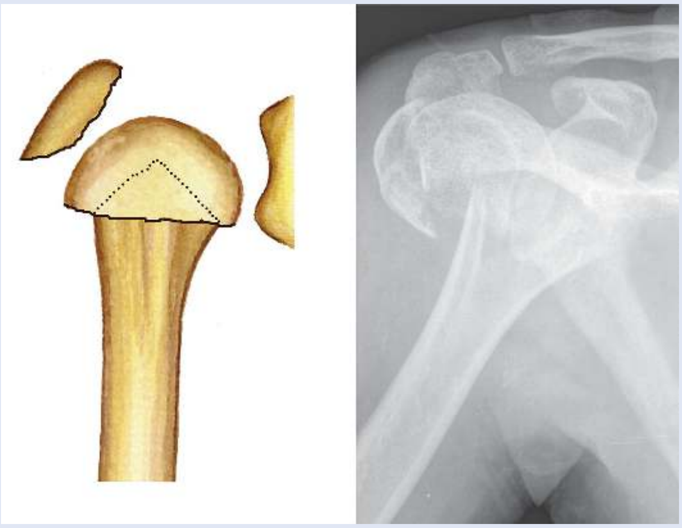
11-C1.3 Anatomical neck



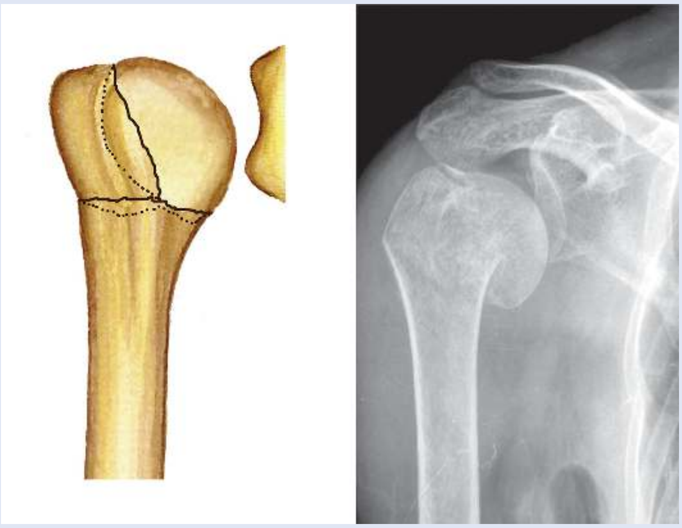
11-C Humerus, proximal, articular fractures

11-C2 Humerus, proximal, articular fracture, impacted with marked displacement
457 fractures
M: 166 (36.32%)
F: 291 (63.68%)
0.12% of total adult fractures
2.10% of adult humeral fractures
3.53% of segment 11
34.70% of type 11-C

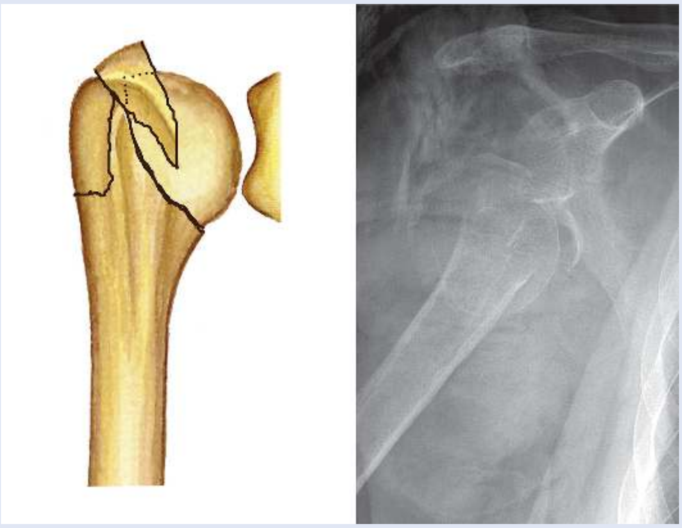
11-C2.1 Cephalotubercular, with valgus malalignment



11-C2.2 Cephalotubercular, with varus malalignment



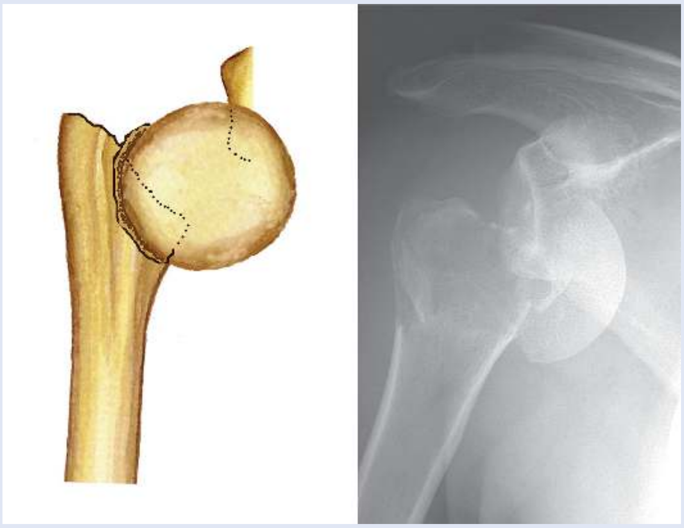
11-C2.3 Transcephalic and tubercular, with varus malalignment



11-C Humerus, proximal, articular fractures

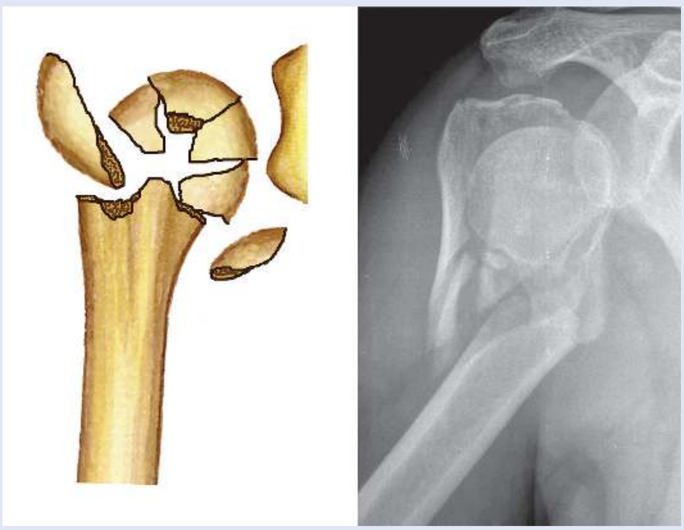
11-C3 Humerus, proximal, articular fracture with dislocation
396 fractures
M: 156 (39.39%)
F: 240 (60.61%)
0.11% of total adult fractures
1.82% of adult humeral fractures
3.06% of segment 11
30.07% of type 11-C

11-C3.1 Anatomical neck



11-C3.2 Anatomical neck and tuberosities

11-C3.3 Cephalotubercular fragmentation



2

Injury Mechanism

Proximal humeral fractures are often caused by indirect force. In elderly patients, fractures are usually associated with osteoporosis, and can be caused by low or moderate force, such as that seen in falls from a standing position. For example, during a fall with an upper extremity in the outstretched position, when one's hand touches the ground, the lateral shoulder is subjected to an upward-directed force, and this results in a proximal humeral fracture. Young patients often receive fractures from high-energy and direct-force impact to the proximal humerus.

When fractures occur, the greater tuberosity fragment is usually pulled superoposteriorly by the supraspinatus, infraspinatus, and teres minor. In contradistinction, the lesser tuberosity fragment usually moves medially due to traction from the subscapularis. When surgical neck fractures occur, the proximal fragment is usually shortened and displaced due to traction from the deltoid, and the distal fragment is pulled medially by the pectoralis major.

The black arrows in ▶ Fig. 2.22 indicate the directions of displacement of four anatomic structures (1, greater tuberosity; 2, lesser tuberosity; 3, humeral shaft; and 4, humeral head) after fracture, under traction of the rotator cuff muscles, deltoid, and pectoralis major.

Diagnosis

Pain, swelling, and restricted motion are usually present when fracture of the proximal humerus occurs. If the fracture involves the articulation site, with minimal or no displacement, then the swelling and deformity may not be visible, due to protection from thick soft tissue around the shoulder. Tenderness of the shoulder and bone crepitus indicates a fracture. If a fracture fragment becomes displaced, then a palpable cavity in the glenohumeral joint will be noted. It is essential to determine the presence of any associated neurovascular injury. The axillary artery and axillary nerve are most commonly injured in proximal humeral fractures.

The trauma series of radiographic evaluation for suspected proximal humeral fractures consists of anteroposterior (AP) and lateral views in the scapular plane and an axillary view.

When obtaining an *AP view* (▶ Fig. 2.23), the patient stands in a position with the shoulder to be examined in contact with the examining table. The scapula should lie parallel to the cassette and the X-ray beam must be tilted 40 degrees to the plane of the thorax. Good visualization of the subacromial space should be obtained with no overlap of the humeral head and glenoid cavity, resulting in the anterior and posterior rim of the glenoid fossa being superimposed.

To obtain an *outlet view* (▶ Fig. 2.24), the patient stands in an anterior oblique position, with the anterior aspect of the examined shoulder in contact with the cassette, and the X-ray beam parallel to the scapular spine with the body tilted 40 degrees.

Since the plane of the scapula is 30 to 40 degrees anterior to the coronal plane of the body, the glenohumeral joint inclines anteriorly, and the glenoid fossa directly faces the humeral head

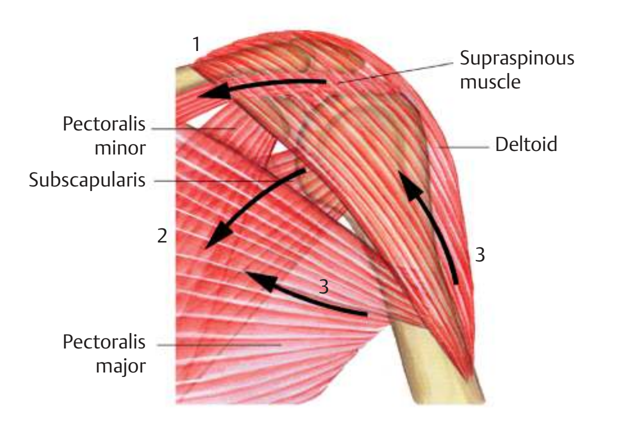


Fig. 2.22 The black arrows indicate the directions of displacement of (1) greater tuberosity, (2) lesser tuberosity, (3) humeral shaft, and (4) humeral head after fracture, under traction of the rotator cuff muscles, deltoid, and pectoralis major.

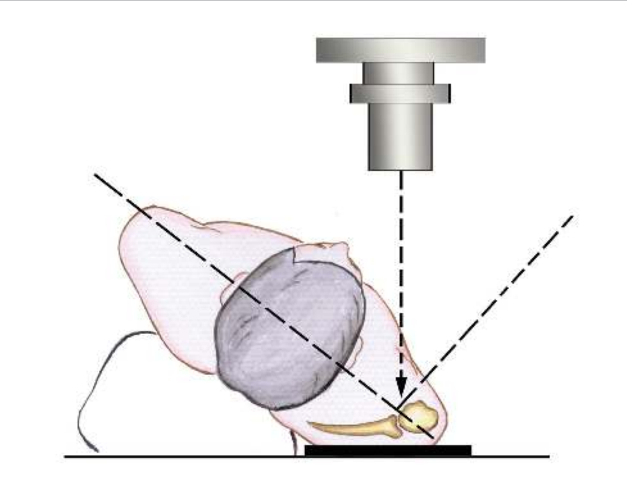


Fig. 2.23 Radiographic evaluation: anteroposterior (AP) view of scapula.

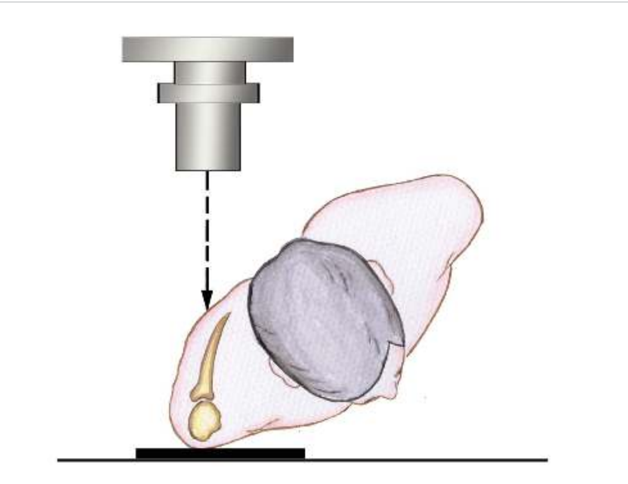


Fig. 2.24 Radiographic evaluation: outlet view of scapula.

posteriorly. The common AP view and transthoracic lateral projection of the shoulder both provide a lateral view of the shoulder joint, neither of which are true reflections of the displacement, angulation, or dislocation of the proximal humeral fracture (▶ Fig. 2.25).

To obtain an *axillary view* (▶ Fig. 2.26), the patient is placed in a supine position with his or her arm abducted 70–90 degrees. The cassette is placed on the superior aspect of the shoulder and the beam can be centered on the axilla.

Since abduction of the shoulder is markedly restricted due to the pain, nowadays a modified axillary view, known as a Velpeau view (▶ Fig. 2.27), is used. In this view, the patient is in a standing position and is tilted backwards ~30 degrees over the cassette on the table. The X-ray beam is then projected vertically from above the shoulder onto the cassette. This view is limited by unavoidable overlapping of structures; thus, a supine projection is the recommended choice of imaging in practice.

If the radiographic evaluation is equivocal or if there is soft-tissue damage, then computed tomography (CT) or magnetic resonance imaging (MRI) can be a good imaging choice to provide more accurate information for early diagnosis and proper treatment. Doppler ultrasound or angiography can be of great assistance if the proximal humeral fracture is associated with dislocation or with vascular injury.

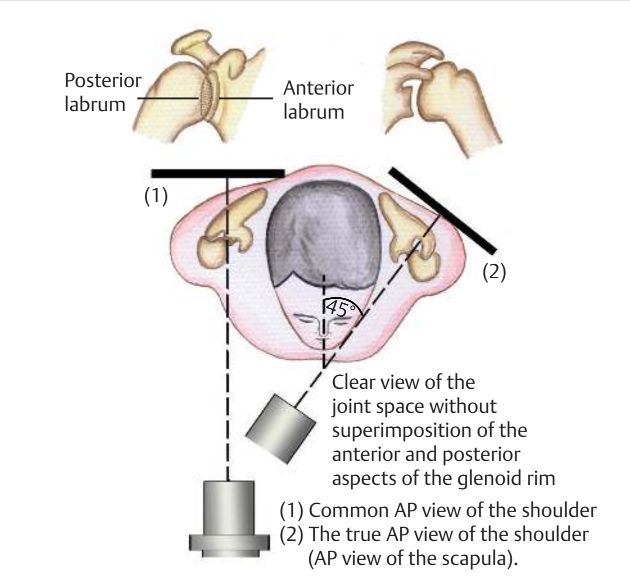


Fig. 2.25 Anteroposterior (AP) view and transthoracic lateral projection of the shoulder.

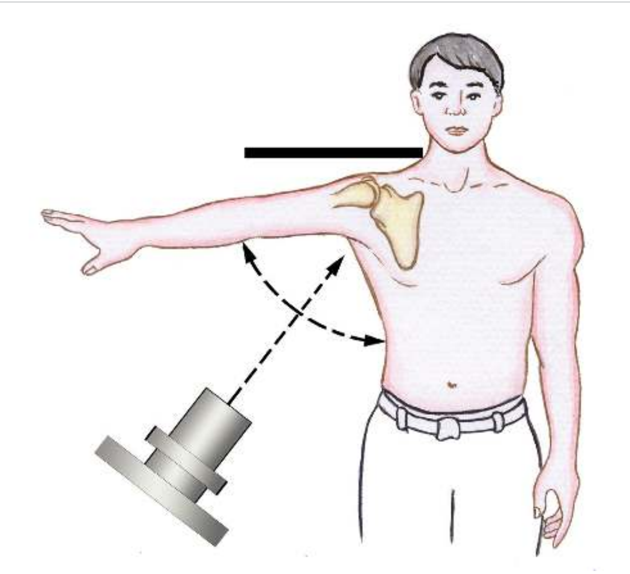


Fig. 2.26 Radiographic evaluation: axillary view of scapula.

Treatment

Proximal humeral fracture with minimal or no displacement may be treated nonoperatively with satisfactory results. For patients older than 50 years, however, minimally invasive surgery for internal fixation is recommended to avoid the occurrence of traumatic periarthritis of the shoulder joint. An unstable fracture, or one with marked displacement, requires surgical stabilization. Surgical management in patients with osteoporosis or severely comminuted fractures cannot achieve satisfactory results by reduction and stabilization; therefore, prosthetic replacement for the joint should be applied for such patients.

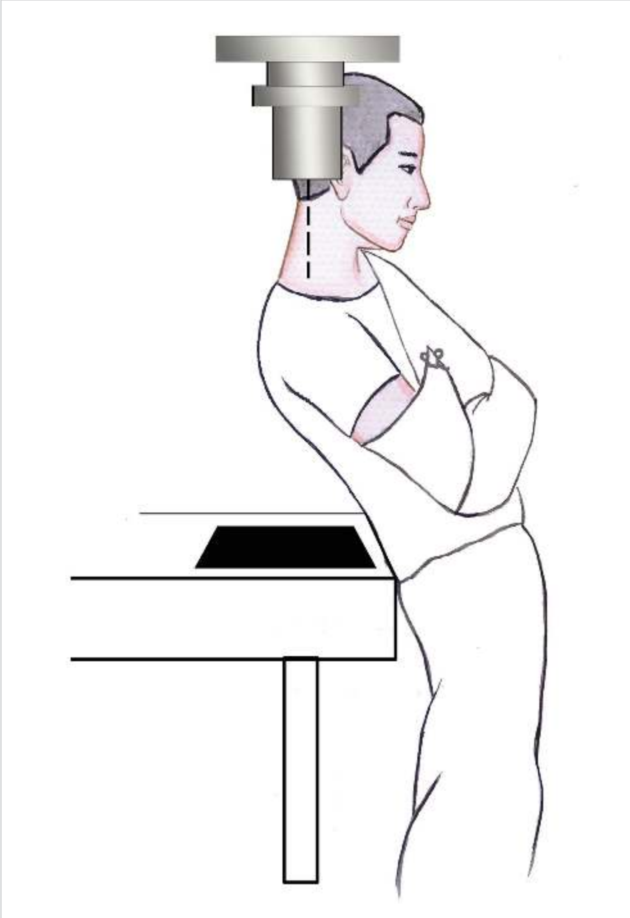


Fig. 2.27 Radiographic evaluation: Velpeau view.

Humeral Shaft Fractures (Segment 12)

■ Anatomic Features

The shaft of the humerus (▶ Fig. 2.28) extends from the upper border of the pectoralis major insertion site to the supracondylar ridge distally. The proximal aspect of the humeral shaft is cylindric on cross-section; distally, its anterior–posterior diameter narrows. The medial and lateral intermuscular septa divide the arm into anterior and posterior compartments. The anterior compartment contains the biceps brachii, coracobrachialis, and brachialis muscles. The brachial artery and vein, and median, musculocutaneous, and ulnar nerves course along the medial border of the biceps. The triceps brachii muscle and radial nerve are contained in the posterior compartment. The radial nerve winds around the radial sulcus in between the medial and lateral heads of the triceps brachii, perforating the lateral intermuscular septum at the junction of the middle and distal thirds of the humeral shaft and entering the anterior aspect of the arm, which makes it an easy target when fractures and dislocations occur at this location.

■ AO Classification for Humeral Shaft Fractures

The humeral shaft segment is coded as number "12" based on the AO classification, and is further divided into three main types depending on fracture morphology: types A, B, and C (▶ Fig. 2.29).

Fig. 2.28 The humeral shaft.

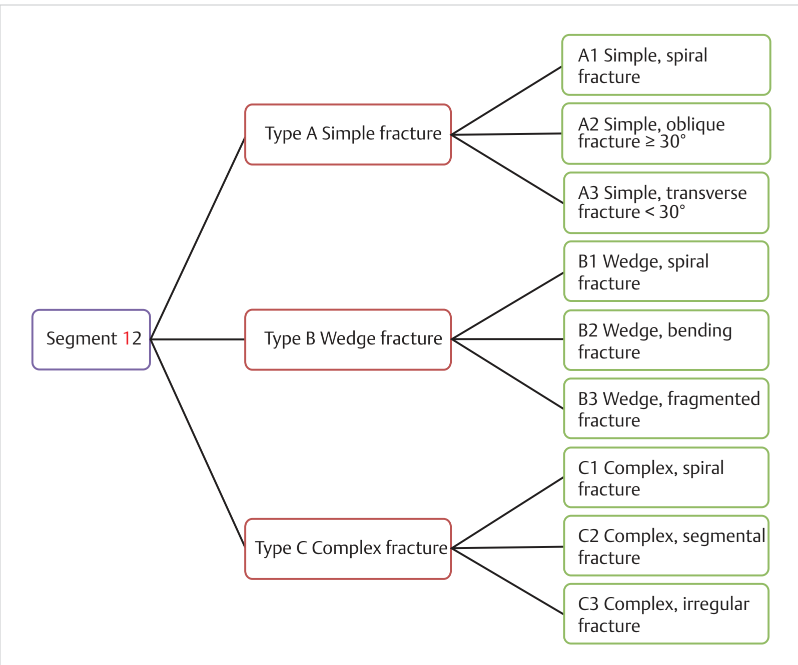


Fig. 2.29 Algorithm.

Clinical Epidemiologic Features of Humeral Shaft Fractures (Segment 12)

A total of 5,049 adult fractures of the humeral shaft (segment 12) were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 23.19% of adult humeral fractures.

See ▶ Table 2.15 and ▶ Fig. 2.30.

The epidemiologic features are as follows:

- More males than females
- The high-risk age group is 21–25 years; 21–25 years for males, 41–45 years for females
- The high-incidence fracture type is 12-A, and is the same for both males and females
- The high-incidence fracture group is 12-A3; 12-A3 for males, 12-A1 for females

Table 2.15 Sex distribution of 5,049 fractures of segment 12

Sex	Number of fractures	Percentage
Male	3,267	64.71
Female	1,782	35.29
Total	5,049	100.00

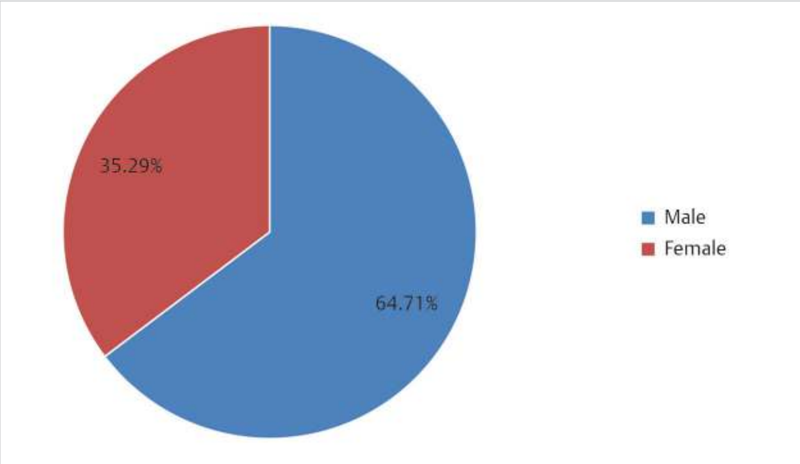


Fig. 2.30 Sex distribution of 5,049 fractures of segment 12.

■ Fractures of Segment 12 by Sex

See ► Table 2.16 and ► Fig. 2.31.

Table 2.16 Age and sex distribution of 5,049 fractures of segment 12

Age group (years)	Male	Female	Total	Percentage
16–20	252	75	327	6.48
21–25	434	155	589	11.67
26–30	388	121	509	10.08
31–35	364	117	481	9.53
36–40	414	152	566	11.21
41–45	382	160	542	10.73
46–50	294	148	442	8.75
51–55	231	139	370	7.33
56–60	208	152	360	7.13
61–65	95	120	215	4.26
66–70	69	99	168	3.33
71–75	47	106	153	3.03
76–80	52	147	199	3.94
81–85	21	52	73	1.45
≥ 86	16	39	55	1.09
Total	3,267	1,782	5,049	100.00

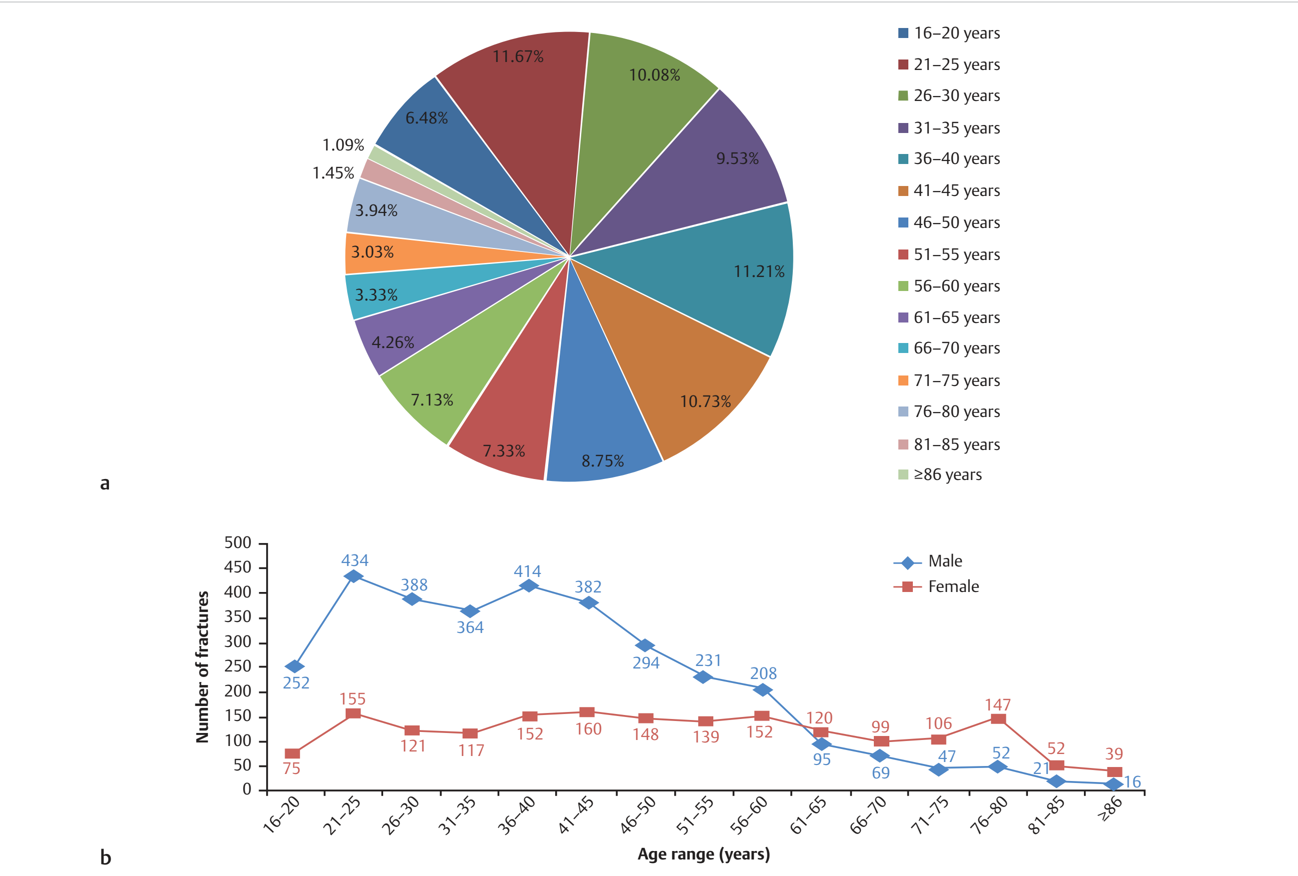


Fig. 2.31 (a) Age distribution of 5,049 fractures of segment 12. (b) Age and sex distribution of 5,049 fractures of segment 12.

■ Fractures of Segment 12 by Age Group

See ▶ Table 2.17 and ▶ Fig. 2.32.

Table 2.17 Sex and fracture type distribution of 5,049 fractures of segment 12

Fracture type	Male	Female	Number of fractures	Percentage of segment 12 fractures	Percentage of adult humeral fractures
12-A	1,721	945	2,666	52.80	12.25
12-B	1,249	657	1,906	37.75	8.76
12-C	297	180	477	9.45	2.19
Total	3,267	1,782	5,049	100.00	23.19

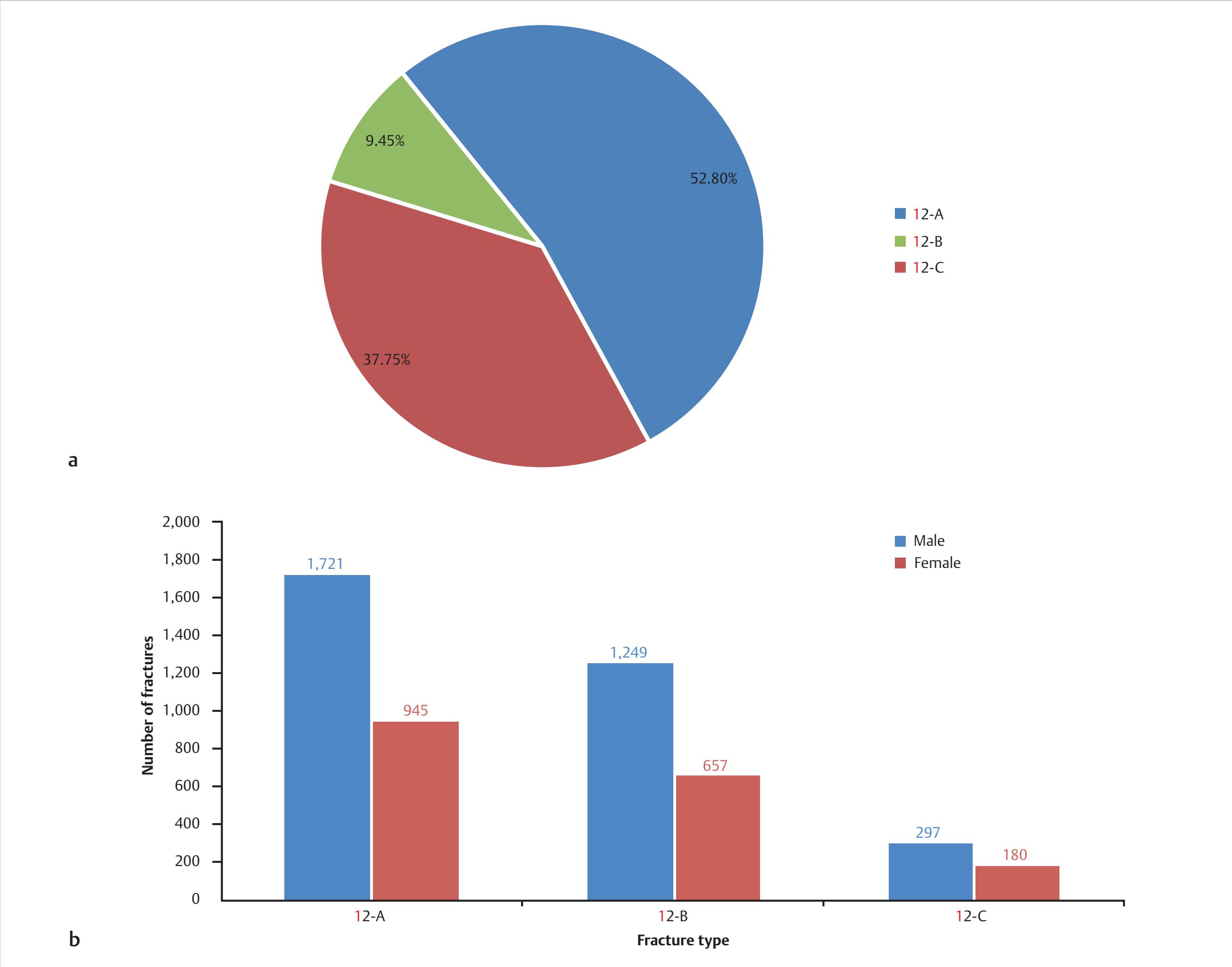


Fig. 2.32 (**a**) Fracture type distribution of 5,049 fractures of segment 12. (**b**) Sex and fracture type distribution of 5,049 fractures of segment 12.

■ Fractures of Segment 12 by Fracture Type

See ▶ Table 2.18 and ▶ Fig. 2.33.

Table 2.18 Sex and fracture group distribution of 5,049 fractures of segment 12

Fracture group	Male	Female	Total	Percentage of segment 12 fractures	Percentage of adult humeral fracture
12-A1	408	378	786	15.57	3.61
12-A2	609	275	884	17.51	4.06
12-A3	704	292	996	19.73	4.58
12-B1	418	285	703	13.92	3.23
12-B2	609	282	891	17.65	4.09
12-B3	222	90	312	6.18	1.43
12-C1	126	107	233	4.61	1.07
12-C2	62	26	88	1.74	0.40
12-C3	109	47	156	3.09	0.72
Total	3,267	1,782	5,049	100.00	23.19

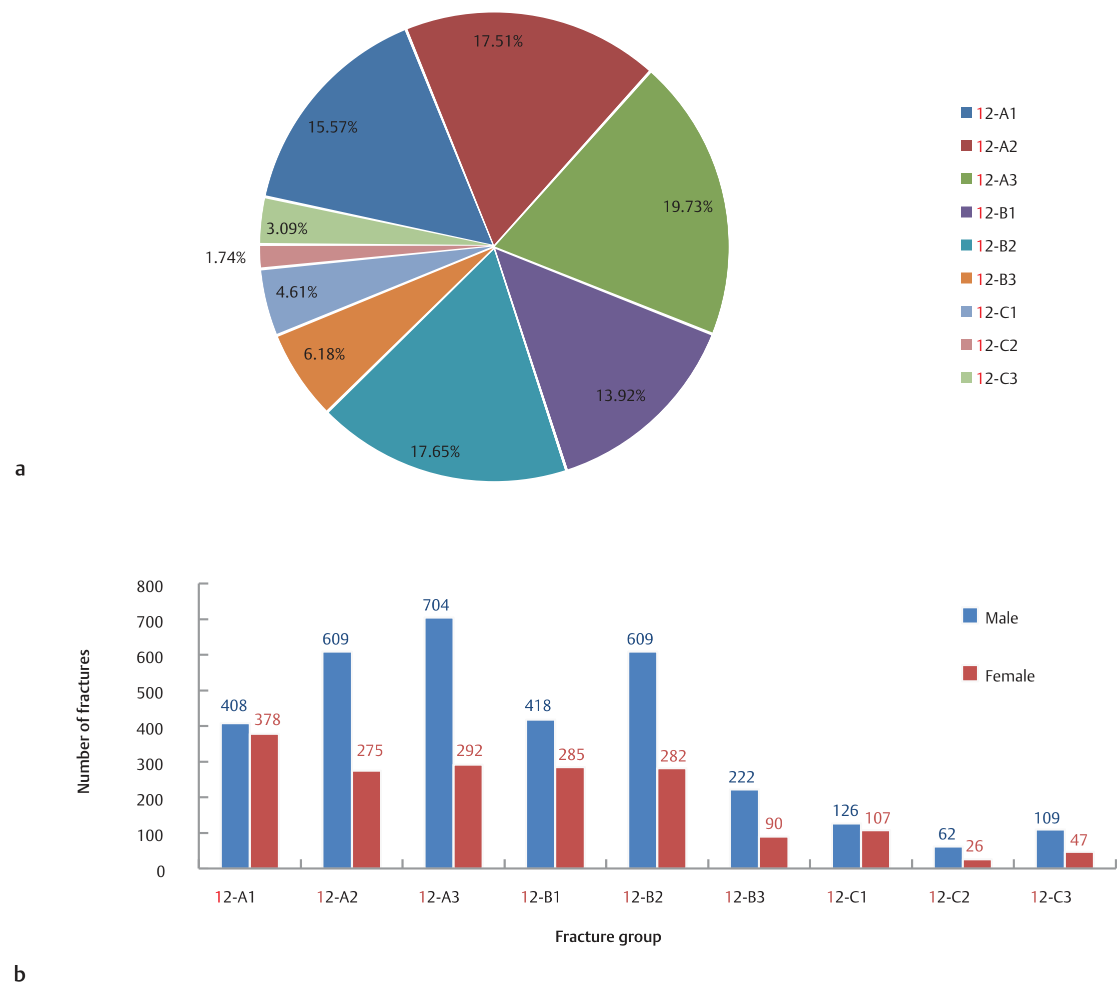
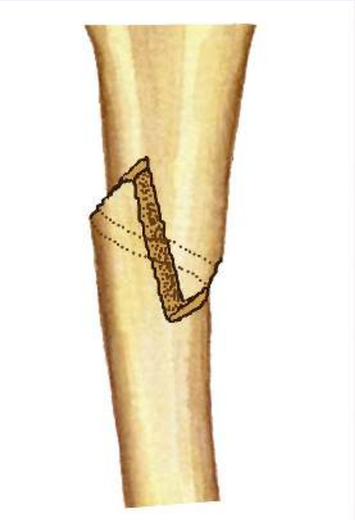


Fig. 2.33 (**a**) Fracture group distributions of 5,049 fractures of segment 12. (**b**) Sex and fracture group distribution of 5,049 fractures of segment 12.

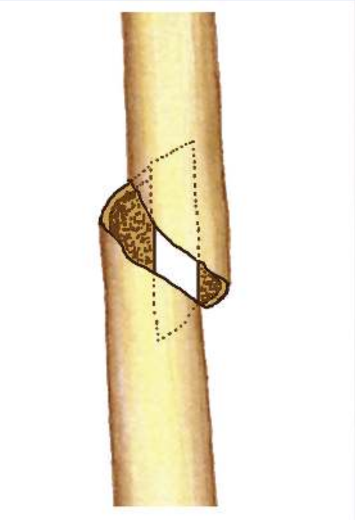
12-A Humerus, diaphysis, simple fractures

12-A1 Humerus, diaphysis, simple fracture, spiral fracture
786 fractures
M: 408 (51.91%)
F: 378 (48.09%)
0.21% of total adult fractures
3.61% of adult humeral fractures
15.57% of segment 12
29.48% of 12-A

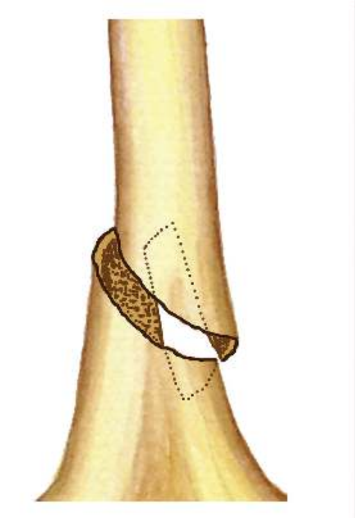
12-A1.1 Proximal third



12-A1.2 Middle third



12-A1.3 Distal third

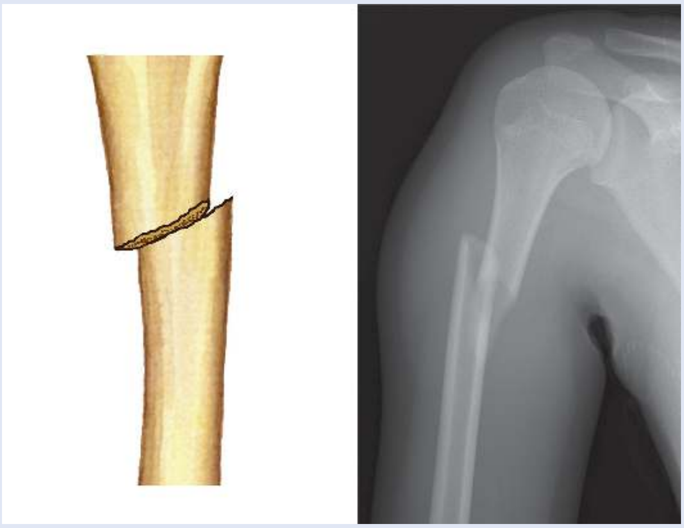


12-A Humerus, diaphysis, simple fractures

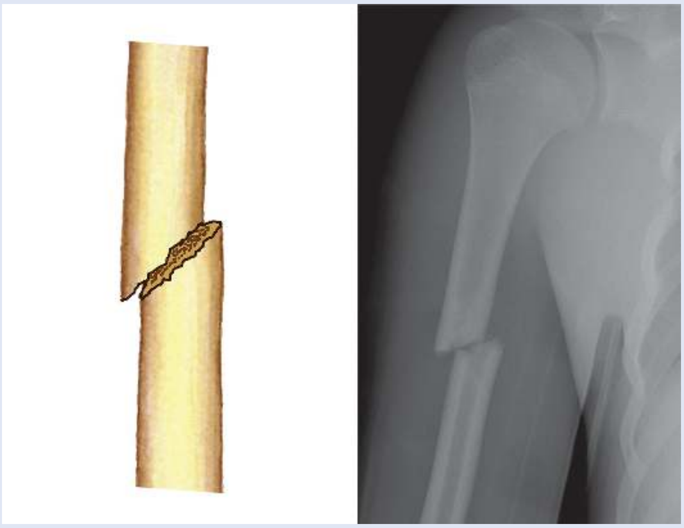
12-A2 Humerus, diaphysis, simple fracture, oblique fracture (≥ 30 degrees)

884 fractures
M: 609 (68.89%)
F: 275 (31.11%)
0.24% of total adult fractures
4.06% of adult humeral fractures
17.51% of segment 12
33.16% of 12-A

12-A2.1 Proximal third



12-A2.2 Middle third

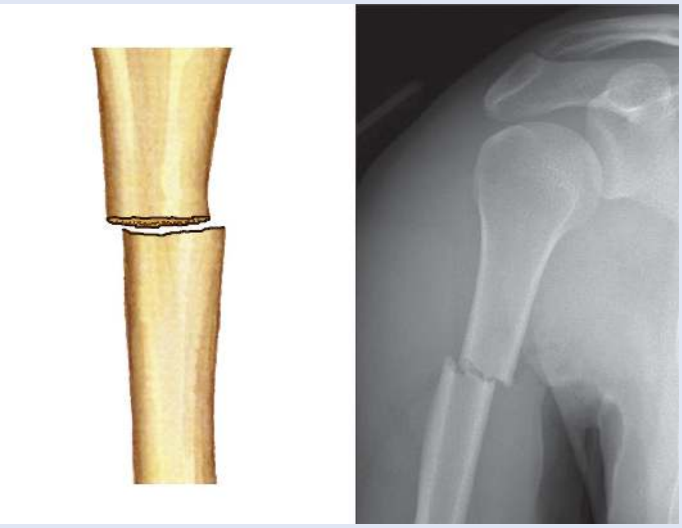


12-A2.3 Distal third

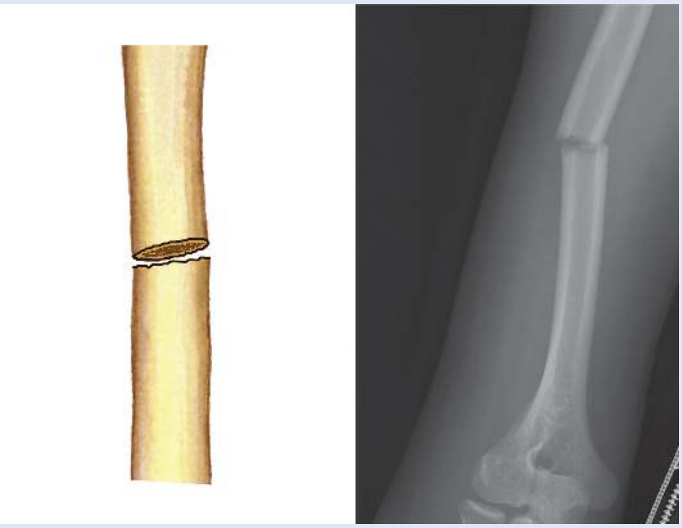
12-A Humerus, diaphysis, simple fractures

12-A3 Humerus, diaphysis, simple fracture, transverse fracture (<30 degrees)
996 fractures
M: 704 (70.68%)
F: 292 (29.32%)
0.27% of total adult fractures
4.58% of adult humeral fractures
19.73% of segment 12
37.36% of 12-A

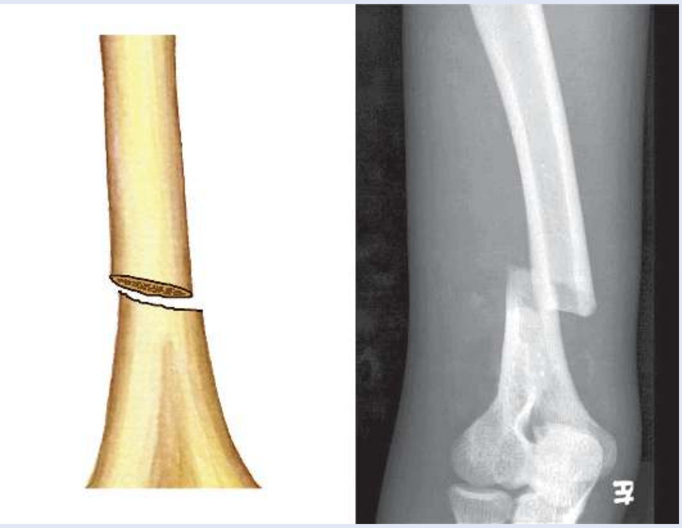
12-A3.1 Proximal third



12-A3.2 Middle third



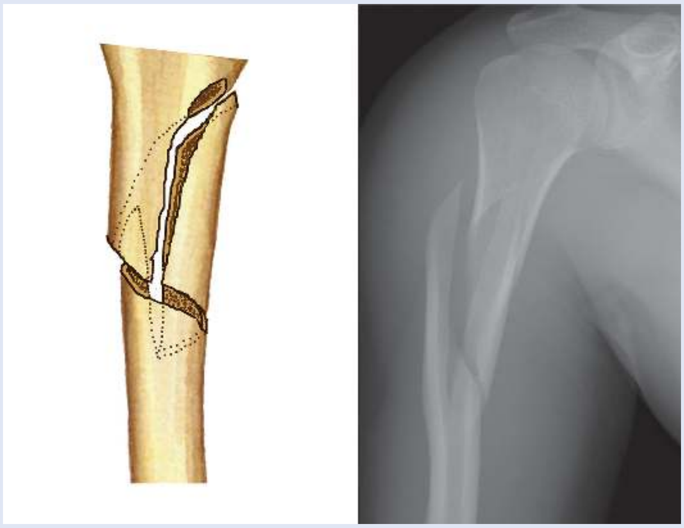
12-A3.3 Distal third



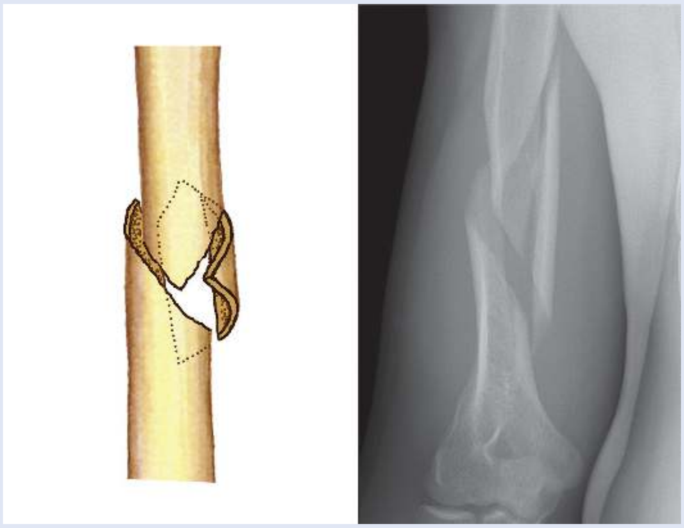
12-B Humerus, diaphysis, wedge fractures

12-B1 Humerus, diaphysis, wedge fracture, spiral fracture
703 fractures
M: 418 (59.46%)
F: 285 (40.54%)
0.19% of total adult fractures
3.23% of adult humeral fractures
13.92% of segment 12
36.88% of 12-B

12-B1.1 Proximal third



12-B1.2 Middle third

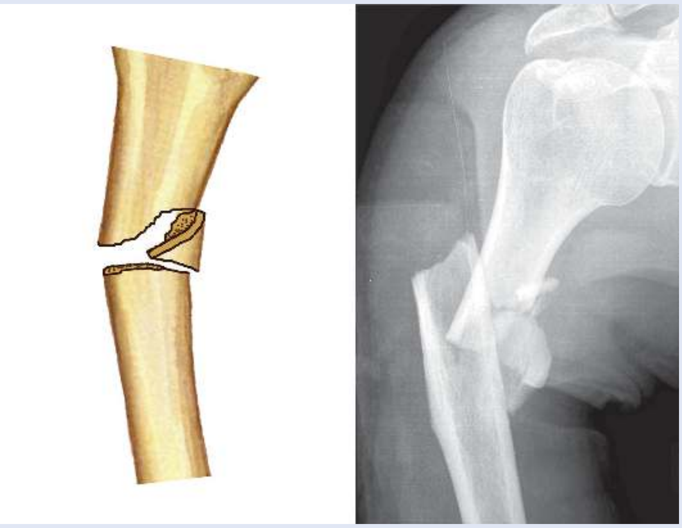


12-B1.3 Distal third

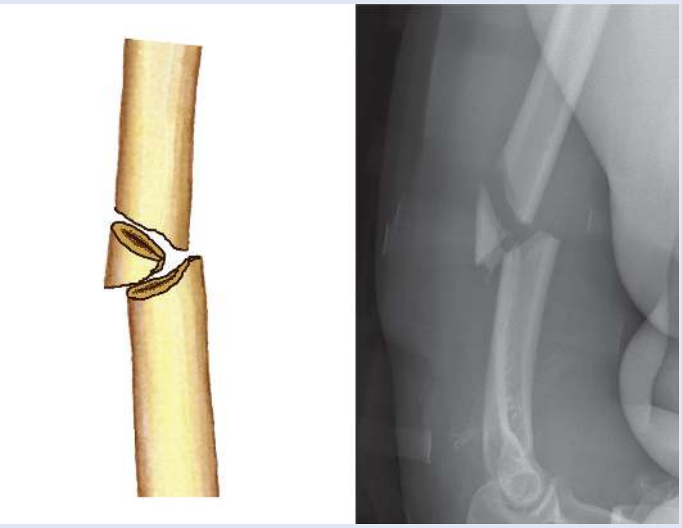
12-B Humerus, diaphysis, wedge fracture

12-B2 Humerus, diaphysis, wedge fracture, bending fracture
891 fractures
M: 609 (68.35%)
F:282 (31.65%)
0.24% of total adult fractures
4.09% of adult humeral fractures
17.65% of segment 12
46.75% of type 12-B

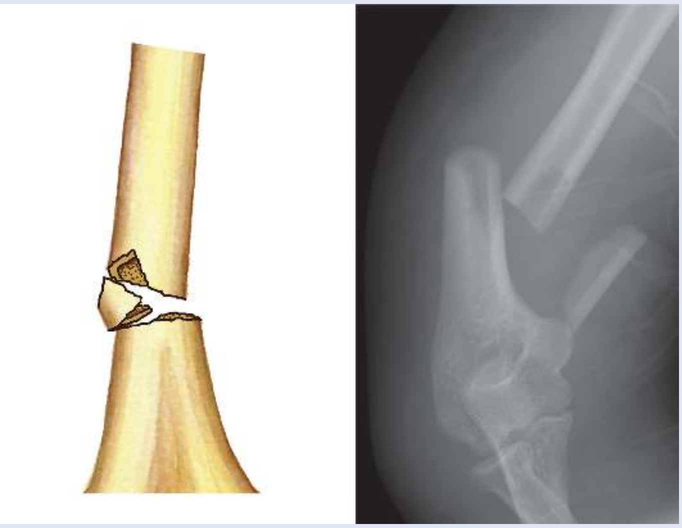
12-B2.1 Proximal third



12-B2.2 Middle third



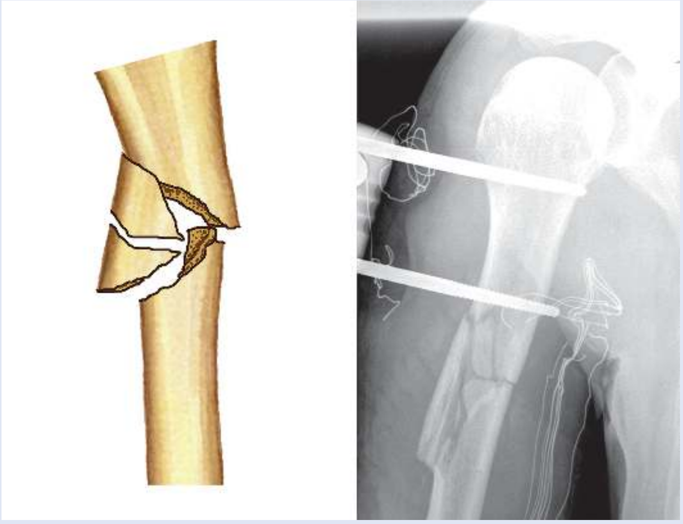
12-B2.3 Distal third



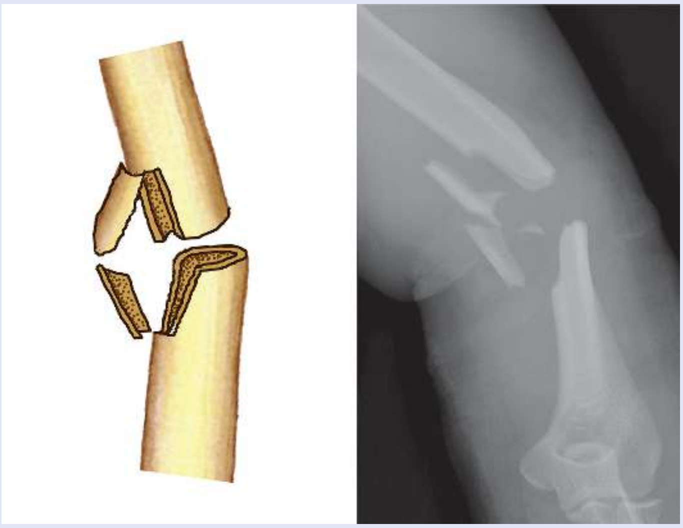
12-B Humerus, diaphysis, wedge fractures

12-B3 Humerus, diaphysis, wedge fracture, fragmented fracture
312 fractures
M: 222 (71.15%)
F: 90 (28.85%)
0.08% of total adult fractures
1.43% of adult humeral fractures
6.18% of segment 12
16.37% of 12-B

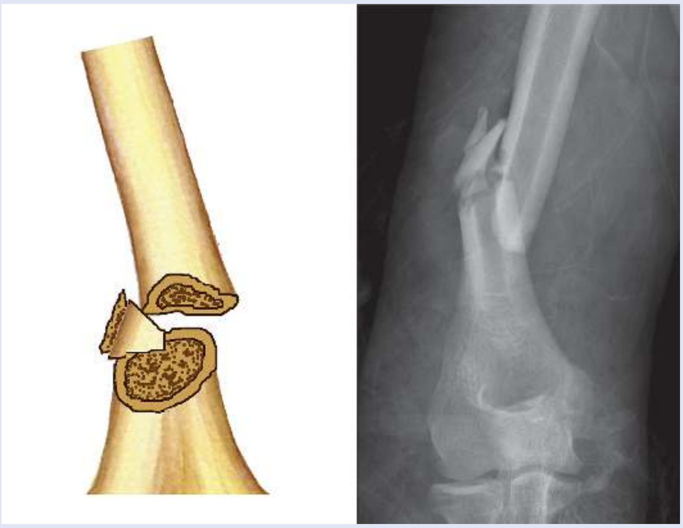
12-B3.1 Proximal third



12-B3.2 Middle third



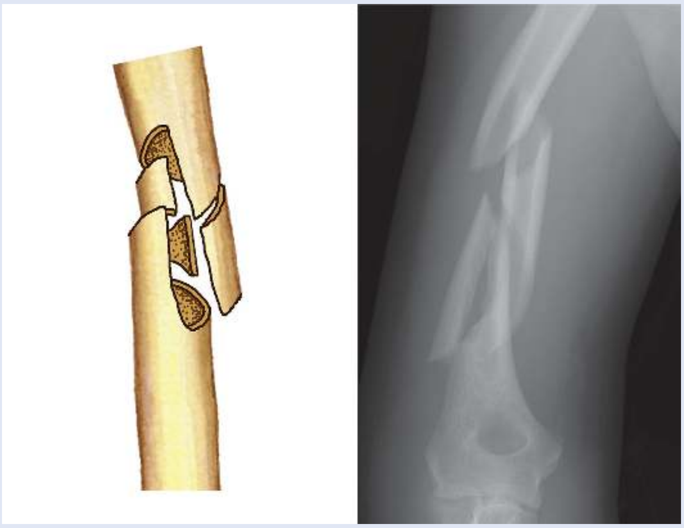
12-B3.3 Distal third



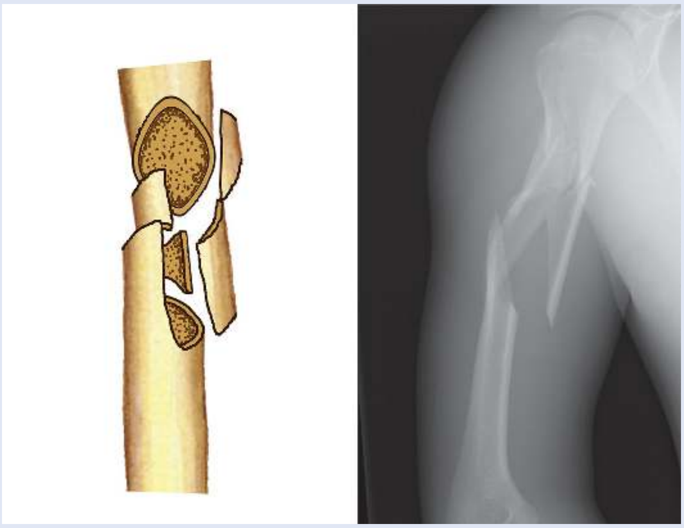
12-C Humerus, diaphysis, complex fractures

12-C1 Humerus, diaphysis, complex fracture, spiral fracture
233 fractures
M: 126 (54.08%)
F: 107 (45.92%)
0.06% of total adult fractures
1.07% of adult humeral fractures
4.61% of segment 12
48.85% of 12-C

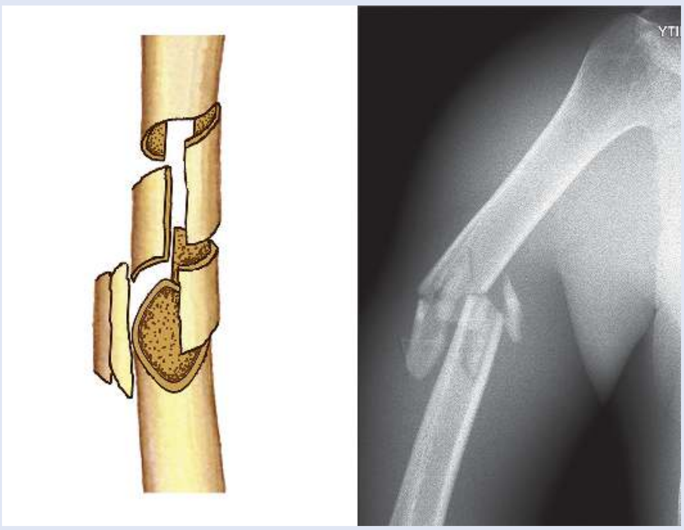
12-C1.1 With two intermediate fragments



12-C1.2 With three intermediate fragments



12-C1.3 With more than three intermediate fragments

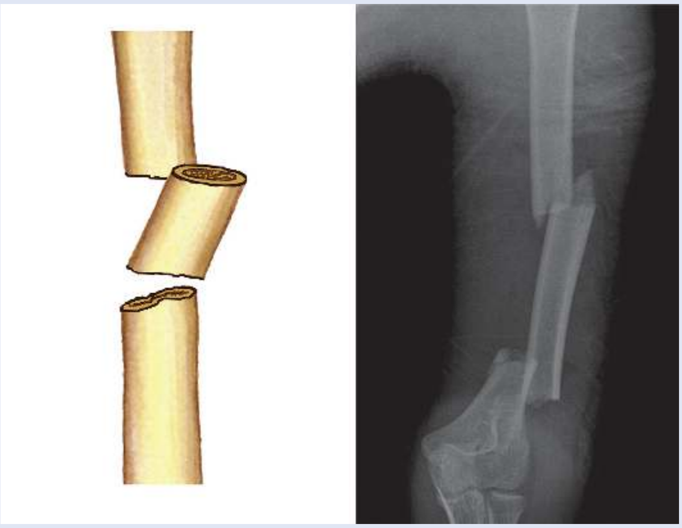


2

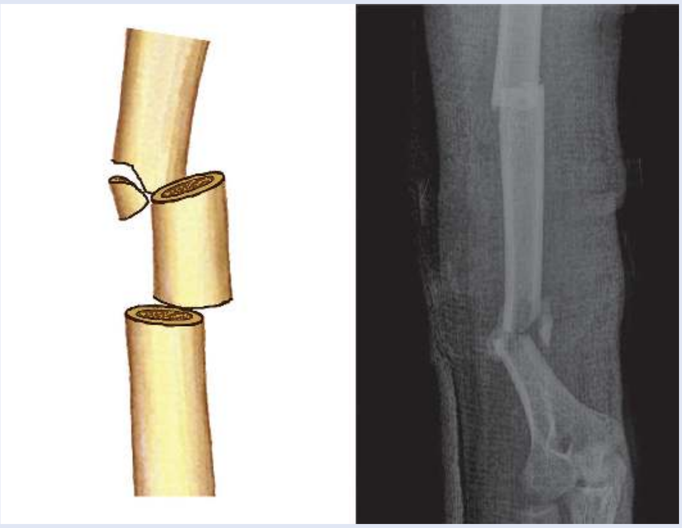
12-C Humerus, diaphysis, complex fractures

12-C2 Humerus, diaphysis, complex fracture, segmental fracture
88 fractures
M: 62 (70.45%)
F: 26 (29.55%)
0.02% of total adult fractures
0.40% of adult humeral fractures
1.74% of segment 12
18.45% of 12-C

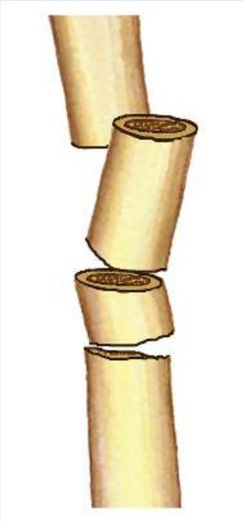
12-C2.1 With one intermediate segment



12-C2.2 With one intermediate segment and additional wedge fragment



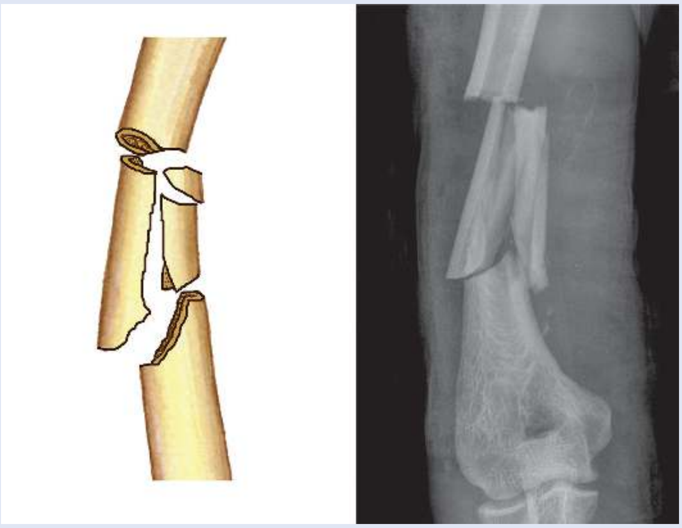
12-C2.3 With two intermediate segments



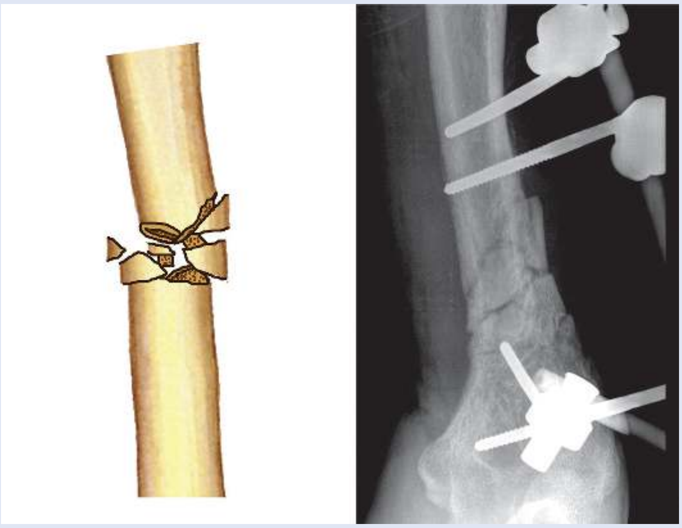
12-C Humerus, diaphysis, complex fractures

12-C3 Humerus, diaphysis, complex fracture, irregular fracture
156 fractures
M: 109 (69.87%)
F: 47 (30.13%)
0.04% of total adult fractures
0.72% of adult humeral fractures
3.09% of segment 12
32.70% of 12-C

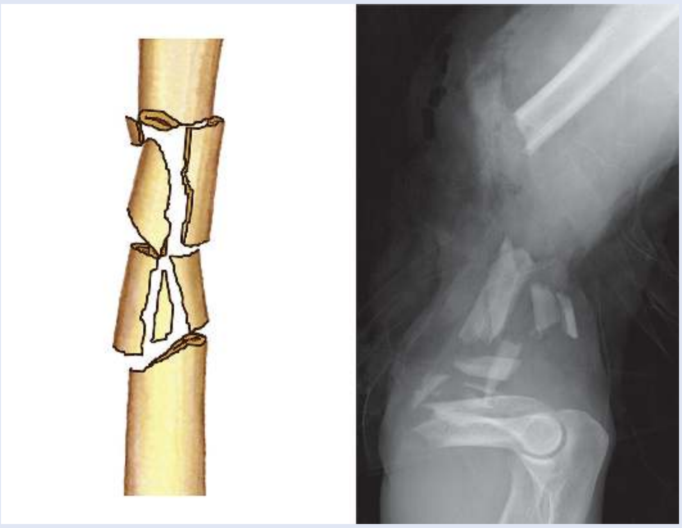
12-C3.1 With two or three intermediate fragments



12-C3.2 With limited shattering (<4 cm)



12-C3.3 With extensive shattering (>4 cm)



2

Injury Mechanism

There are several mechanisms that result in humeral shaft fractures:

- Direct force is the most common mechanism of injury, such as in a direct blow, a compression force, or a gunshot, all of which usually produce transverse, comminuted, or open fractures.
- Indirect mechanisms involve a fall where the hand or elbow touches the ground. The fall usually involves a twisting motion to the remainder of the body, or the attached muscles may contract asymmetrically, leading to a greater incidence of spiral or oblique fractures.
- Spiral injuries typically occur in the junction of the middle, distal third of the humeral shaft, caused by military training or athletic activities such as throwing or arm wrestling. When engaged in such activities, the attached muscle contracts abruptly and the axial load increases, leading to a spiral fracture.

The fractured arm usually presents with typical deformity under the influence of the attached muscle. For example, when the fracture line is proximal to the insertion of the pectoralis major, the traction of the rotator cuff muscles results in abduction and internal rotation of the proximal fragment, while the distal fragment is displaced medially by the pectoralis major. When fractures occur between insertions of the pectoralis major and deltoid, the distal fragment is displaced laterally by the deltoid, while the proximal fragment is pulled medially by the pectoralis major, latissimus dorsi, and teres major. Fractures below the deltoid insertion will result in abduction and flexion of the proximal fragment, and the proximal displacement of the distal fragment (▶ Fig. 2.34).

Diagnosis

Patients with humeral shaft fractures present with arm pain, swelling, and deformity. Abnormal movement and crepitus can be observed. A careful neurovascular evaluation of the affected limb should be performed, especially checking for compartmental pressure and the presence of the distal pulse if the limb is swollen. A test for sensory and motor function should be performed as well.

The radiographic evaluation for humeral shaft fractures should include an AP and a lateral view of the entire humerus to clarify fracture locations and types.

Treatment

The treatment of choice for humeral shaft fractures depends on several factors, including the patient's physical status, age, comorbidities, soft-tissue damage, and fracture type. Most humeral shaft fractures can be treated successfully with nonoperative management. Multiple closed techniques are available, including use of the hanging arm cast, U plaster, sling/swathe, abduction humeral/shoulder spica cast, and functional brace, as well as the use of skeletal traction.

Operative intervention is indicated in special circumstances, including failure of closed treatment, open fracture, vascular injury, floating elbow, segmental fractures, bilateral fractures of the humerus, and polytrauma such as multiple fractures. Radial nerve injury can be seen in 18% of humeral fractures, and is

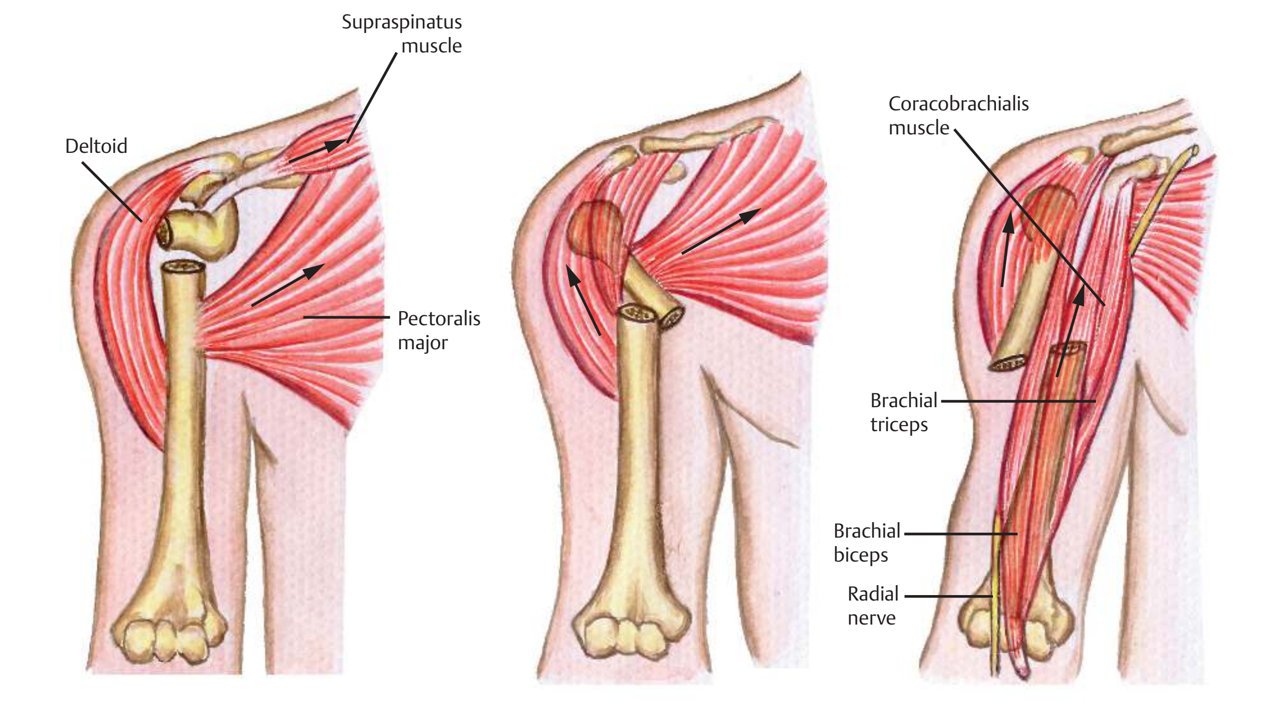


Fig. 2.34 Humeral shaft fractures.

often caused by traction injury, 90% of which resolve to normal function in 3 to 4 months. Nerve exploration is required for the unresolved radial nerve injury. An indication for early nerve exploration also includes compromised radial nerve function associated with the treatment of closed manipulation itself. It is generally accepted that up to 3 cm of shortening and 20 to 30 degrees of varus, anterior, or rotational deformity will result in an acceptable upper-extremity function. The fracture-fixation devices include intramedullary nails, plates, and external fixators; the choice of which to use is most often is based on clinical experience and the fracture type.

Distal Humeral Fractures (Segment 13)

Anatomical Features

The distal end of the humerus is flattened and bears two articulations: the trochlea for the ulna and the capitellum for the radius (▶ Fig. 2.35). There are three depressions: the radial fossa and coronoid fossa above the anterior part of the trochlea receive the radial head and coronoid process of the ulna during the flexion of the forearm, while posteriorly the back part of the trochlea is the olecranon fossa, which receives the olecranon during extension of the forearm (▶ Fig. 2.36).

The lateral epicondyle is a tuberculated eminence and provides an attachment site for the extensor muscle of the forearm. The medial epicondyle, larger and more prominent than the lateral one, provides an attachment site for the flexor muscles of the forearm, while the ulnar nerve runs in a groove on the back of this epicondyle. The capitulum of the humerus, a portion of the articular surface that extends lower than the lateral epicondyle, articulates with the cup-shaped depression on the head of the radius (▶ Fig. 2.37).

The grooved portion on the trochlea's articular surface fits precisely within the ulna's semilunar notch, a large depression formed by the coronoid process anteriorly and the olecranon process posteriorly (▶ Fig. 2.38). When the arm is extended with the palm facing up, the supplementary angle to that between the longitudinal axis of the arm and of the forearm is called the carrying angle or the valgus angle. Malreduction of fractures in the distal humerus can lead to changes in the carrying angle, and consequently a valgus or varus deformity of the elbow.

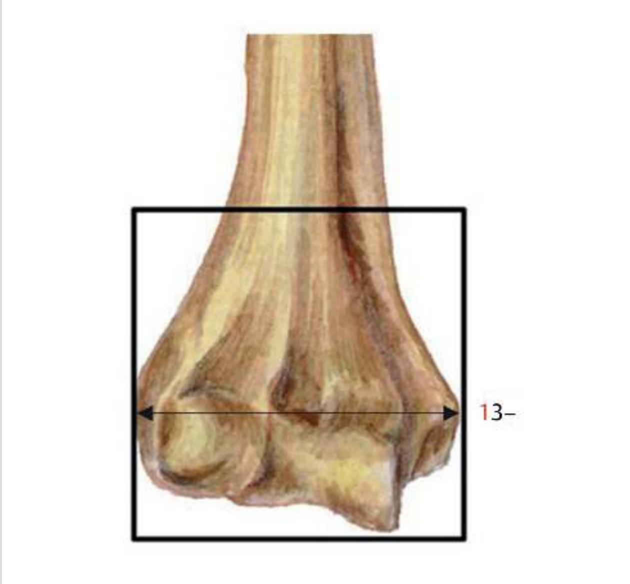


Fig. 2.35 Distal end of the humerus.

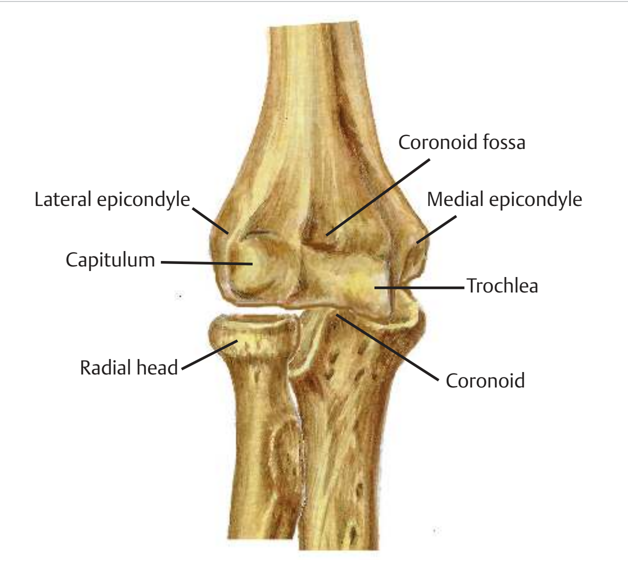


Fig. 2.36 Anterior view of the elbow joint.

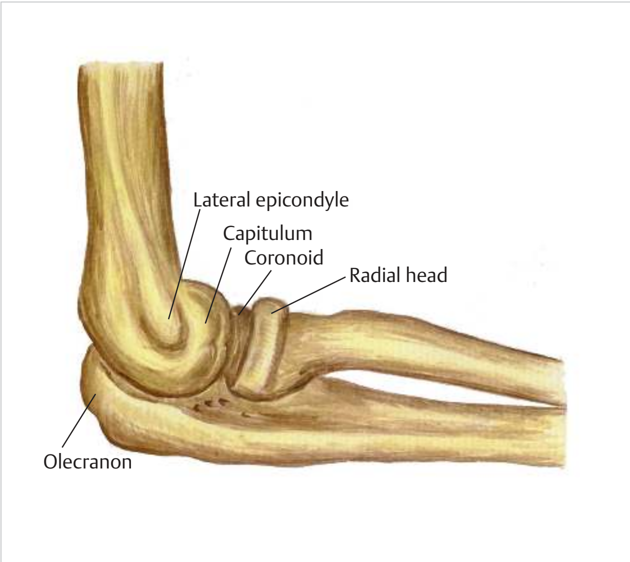


Fig. 2.37 Lateral view of the elbow joint.

AO Classification of Distal Humeral Fractures

The distal end of the humerus is delineated by a square whose side is equal to the maximum width of the distal humerus based on the AO classification, and the location coded as number “13.” It is classified into three types, depending on the involvement of the articulation: 13-A: extra-articular fracture; 13-B: partial articular fracture; and 13-C: complete articular fracture (▶ Fig. 2.39).

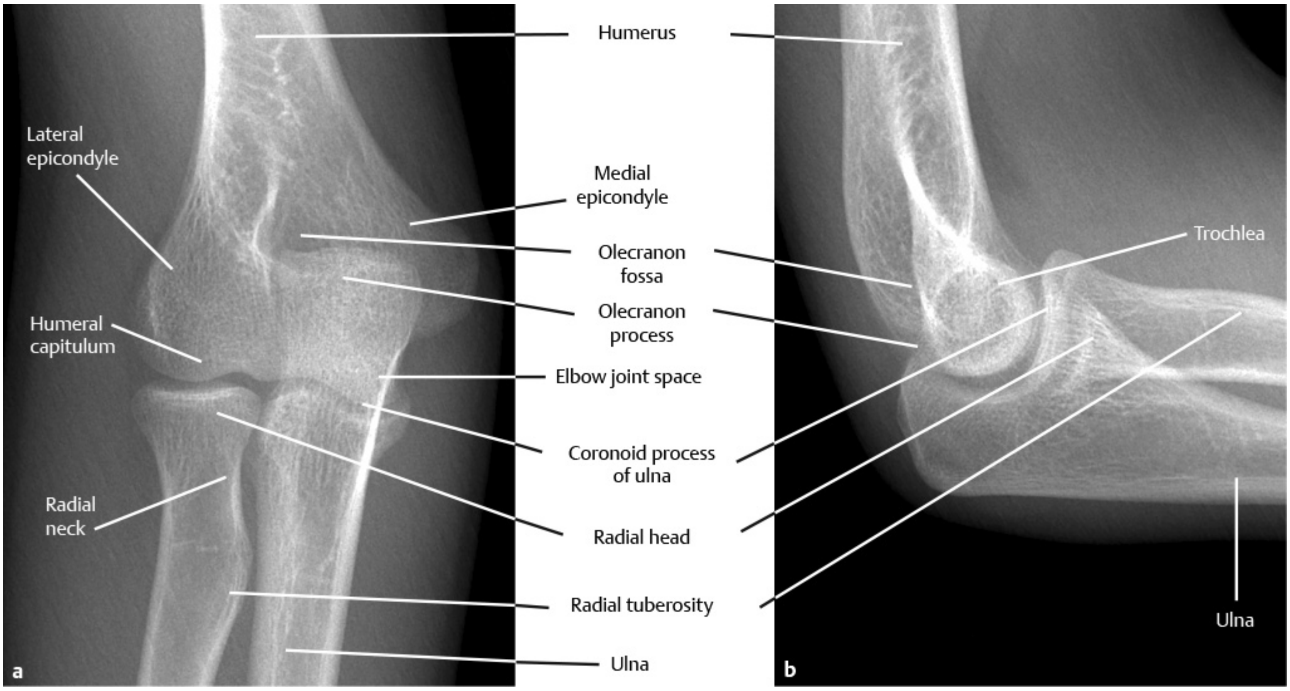


Fig. 2.38 (**a, b**) Radiographic anatomy of the elbow joint.

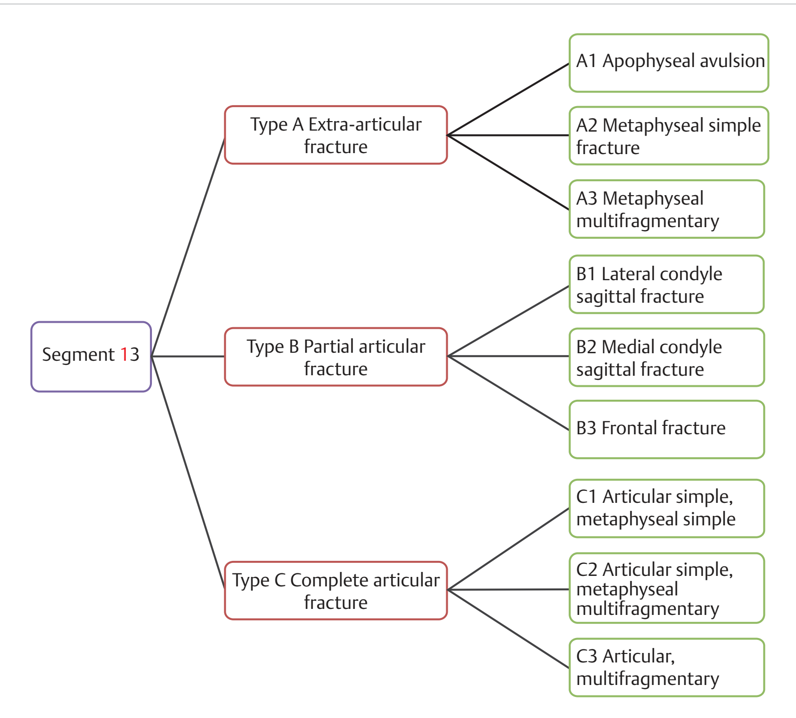


Fig. 2.39 Algorithm.

Clinical Epidemiologic Features of Distal Humeral Fractures (Segment 13)

A total of 3,761 adult fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 17.28% of all humeral fractures in adults. The epidemiologic features are as follows:

- More males than females
- The high-risk age group is 16–20 years for males, 56–60 years for females
- The high-risk fracture type is 13-A, and is the same for both males and females
- The high-risk fracture group is 13-A1, and is the same for both males and females

Fractures of Segment 13 by Sex

See ▶ Table 2.19 and ▶ Fig. 2.40.

Table 2.19 Sex distribution of 3,761 fractures of segment 13

Sex	Number of fractures	Percentage
Male	2,114	56.21
Female	1,647	43.79
Total	3,761	100.00

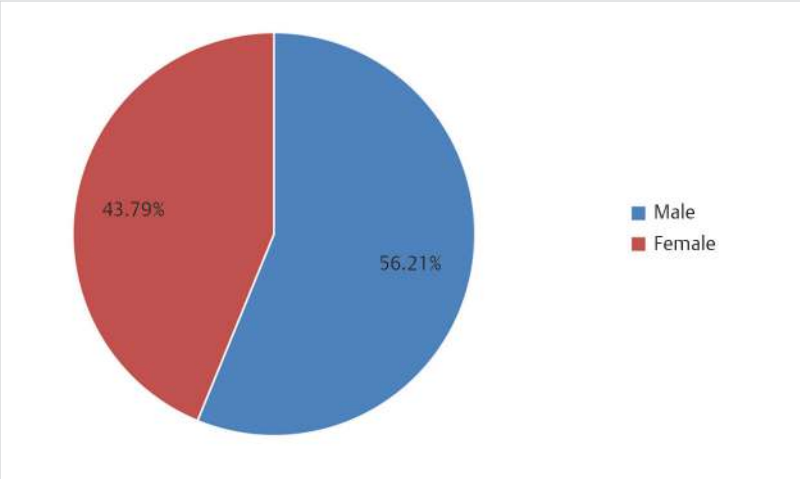


Fig. 2.40 Sex distribution of 3,761 fractures of segment 13.

■ Fractures of Segment 13 by Age Group

See ▸ Table 2.20 and ▸ Fig. 2.41.

Table 2.20 Age and sex distribution of 3,761 fractures of segment 13

Age group (years)	Male	Female	Total	Percentage
16–20	381	111	492	13.08
21–25	275	123	398	10.58
26–30	229	68	297	7.90
31–35	218	97	315	8.38
36–40	236	98	334	8.88
41–45	177	110	287	7.63
46–50	145	102	247	6.57
51–55	149	142	291	7.74
56–60	107	178	285	7.58
61–65	51	128	179	4.76
66–70	45	121	166	4.41
71–75	27	120	147	3.91
76–80	37	111	148	3.94
81–85	20	79	99	2.63
≥ 86	17	59	76	2.02
Total	2,114	1,647	3,761	100.00

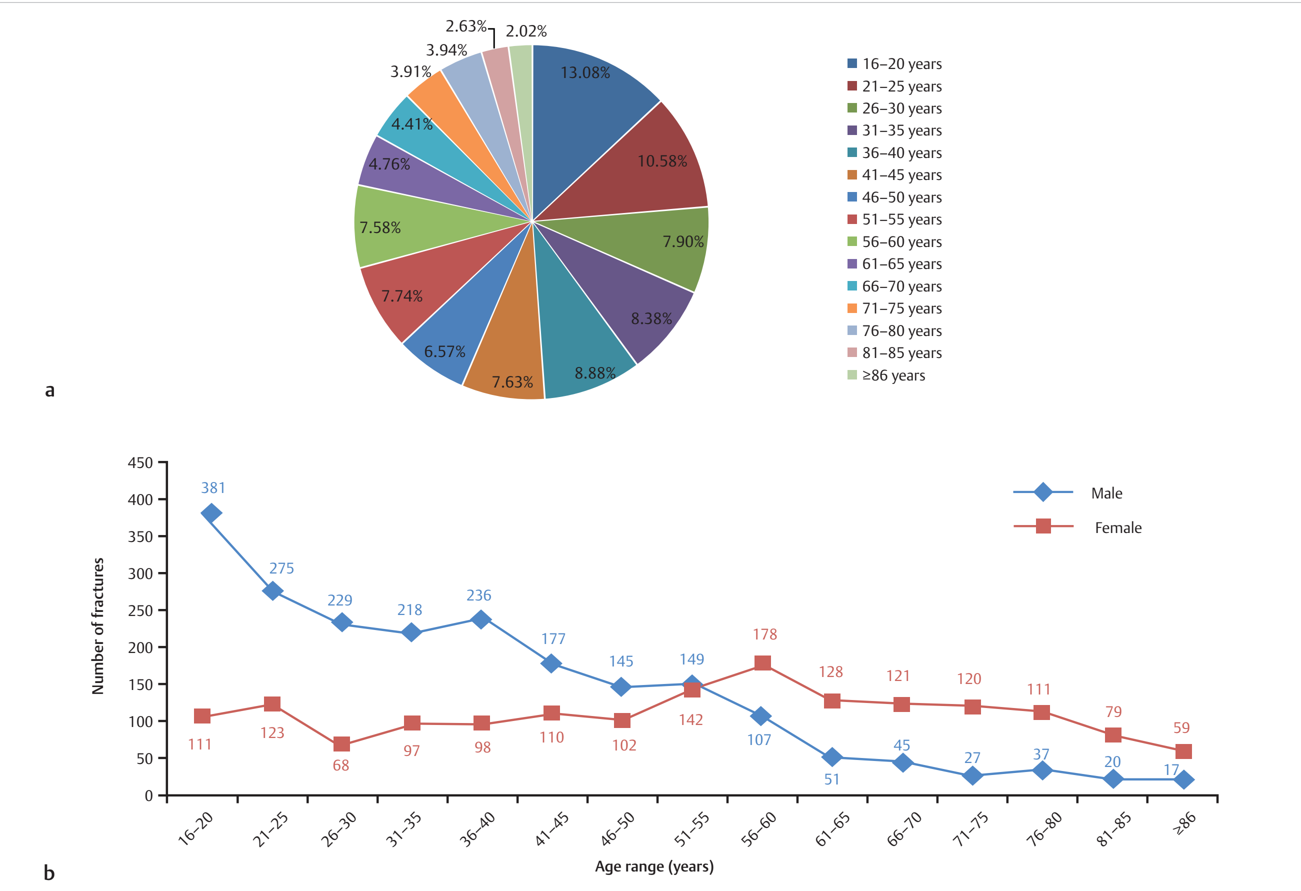


Fig. 2.41 (a) Age distribution of 3,761 fractures of segment 13. (b) Age and sex distribution of 3,761 fractures of segment 13.

■ Fractures of Segment 13 by Fracture Type

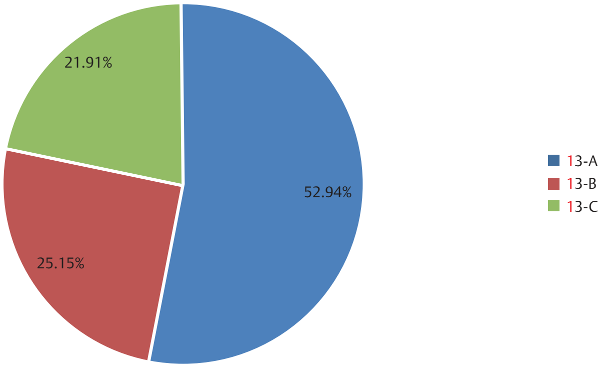
See ► Table 2.21, ► Table 2.22, ► Fig. 2.42, and ► Fig. 2.43.

Table 2.21 Sex and fracture distribution of 3,761 fractures of segment 13

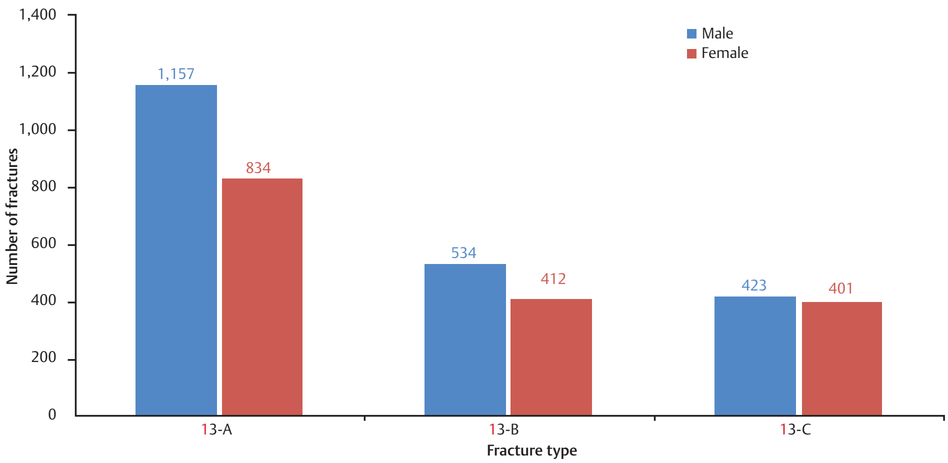
Fracture type	Male	Female	Number of fractures	Percentage of segment 13 fractures	Percentage of adult humeral fracture
13-A	1,157	834	1,991	52.94	9.15
13-B	534	412	946	25.15	4.35
13-C	423	401	824	21.91	3.79
Total	2,114	1,647	3,761	100.00	17.28

Table 2.22 Sex and fracture group distribution of 3,761 fractures of segment 13

Fracture group	Male	Female	Total	Percentage of segment 13 fractures	Percentage of adult humeral fracture
13-A1	687	373	1,060	28.18	4.87
13-A2	349	346	695	18.48	3.19
13-A3	121	115	236	6.27	1.08
13-B1	291	208	499	13.27	2.29
13-B2	174	141	315	8.38	1.45
13-B3	69	63	132	3.51	0.61
13-C1	117	128	245	6.51	1.13
13-C2	149	144	293	7.79	1.35
13-C3	157	129	286	7.60	1.31
Total	2,114	1,647	3,761	100.00	17.28

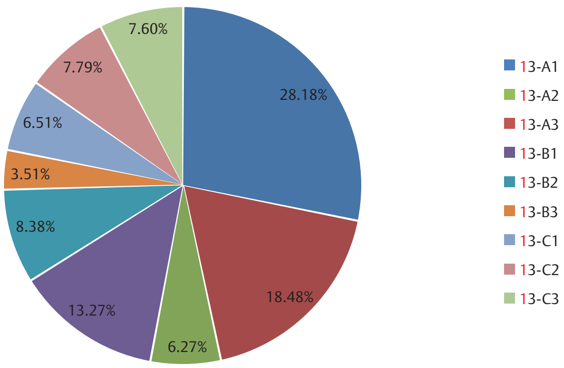


a



b

Fig. 2.42 (a) Fracture type distribution of 3,761 fractures of segment 13. (b) Sex and fracture type distribution of 3761 fractures of segment 13.



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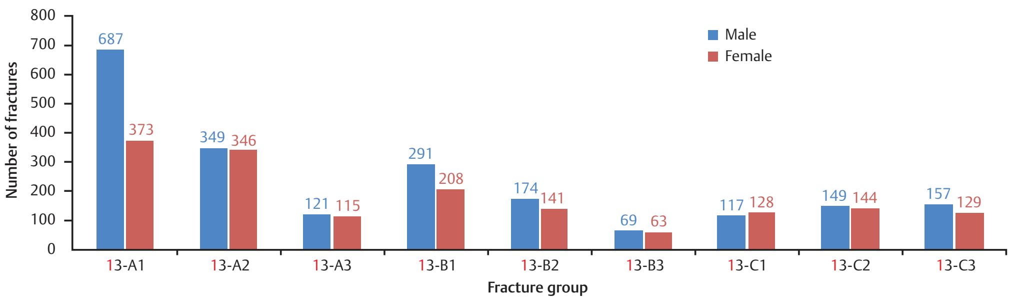


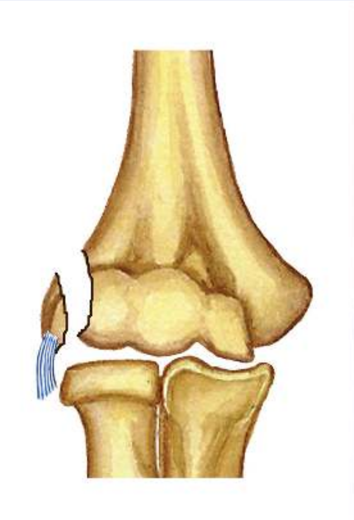
b

Fig. 2.43 (a) Fracture group distribution of 3,761 fractures of segment 13. (b) Sex and fracture group distribution of 3,761 fractures of segment 13.

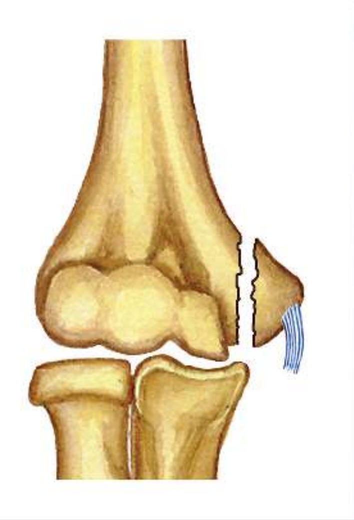
13-A Humerus, distal, extra-articular fractures

13-A1 Humerus, distal, extra-articular fracture, apophyseal avulsion
1,060 fractures
M: 687 (64.81%)
F: 373 (35.19%)
0.28% of total adult fractures
4.87% of adult humeral fractures
28.18% of segment 13
53.24% of type 13-A

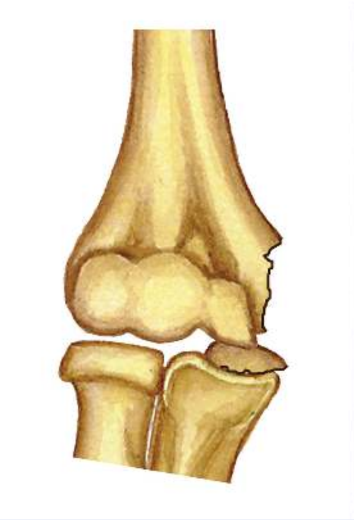
13-A1.1 Lateral epicondyle



13-A1.2 Medial epicondyle with no incarcerated fragment



13-A1.3 Medial epicondyle with incarcerated fragment

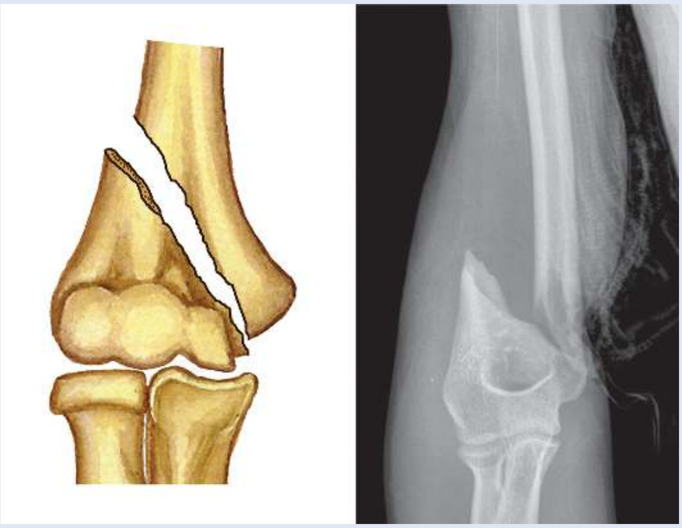


2

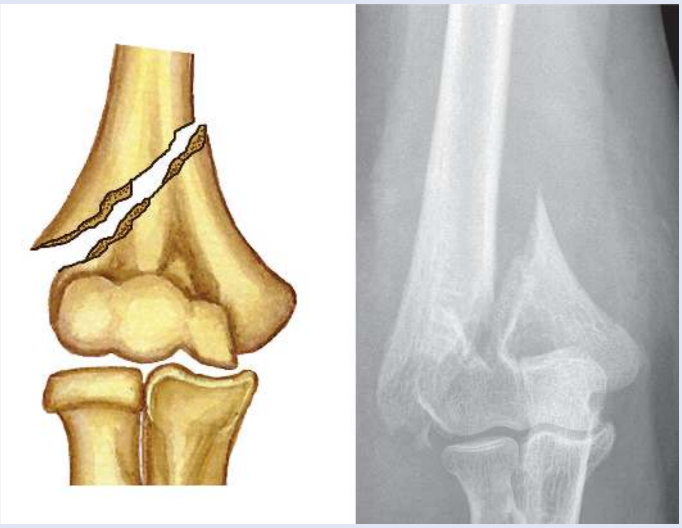
13-A Humerus, distal, extra-articular fractures

13-A2 Humerus, distal, extra-articular fracture, metaphyseal simple fracture
695 fractures
M: 349 (50.22%)
F: 346 (49.78%)
0.19% of total adult fractures
3.19% of adult humeral fractures
18.48% of segment 13
34.91% of type 13-A

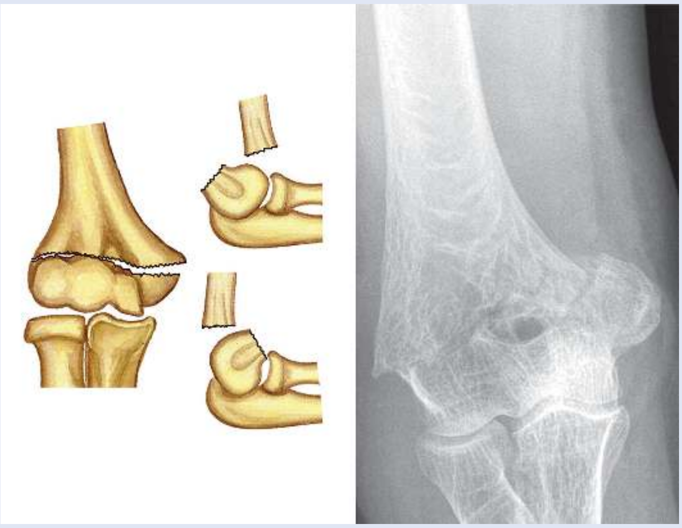
13-A2.1 Oblique downward and inward



13-A2.2 Oblique downward and outward



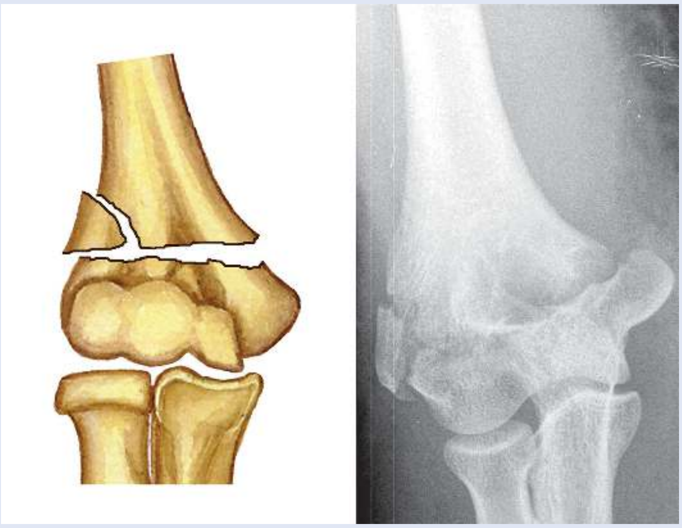
13-A2.3 Transverse



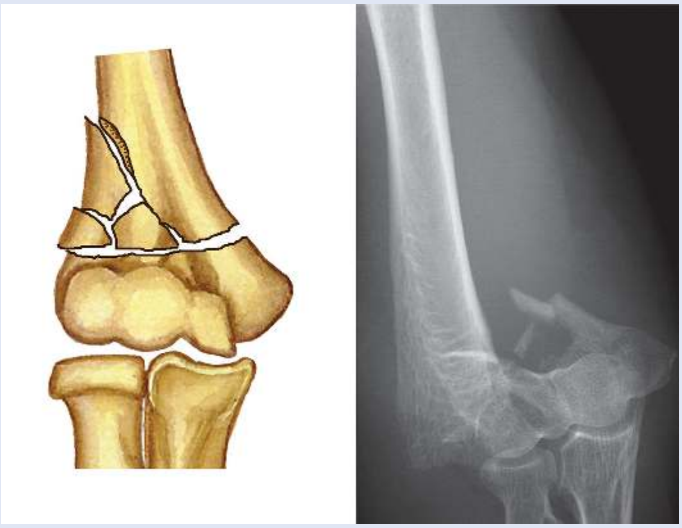
13-A Humerus, distal, extra-articular fractures

13-A3 Humerus, distal, extra-articular fracture, metaphyseal multifragmentary fracture
236 fractures
M: 121 (51.27%)
F: 115 (48.73%)
0.06% of total adult fractures
1.08% of adult humeral fractures
6.27% of segment 13
11.85% of type 13-A

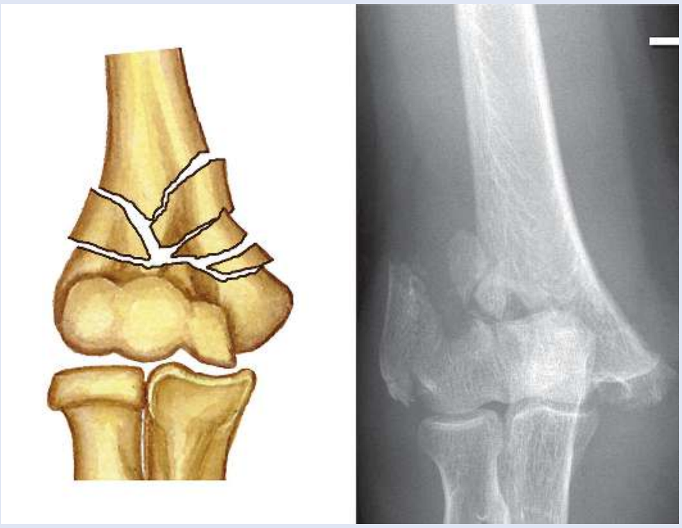
13-A3.1 With intact wedge



13-A3.2 With a fragmented wedge



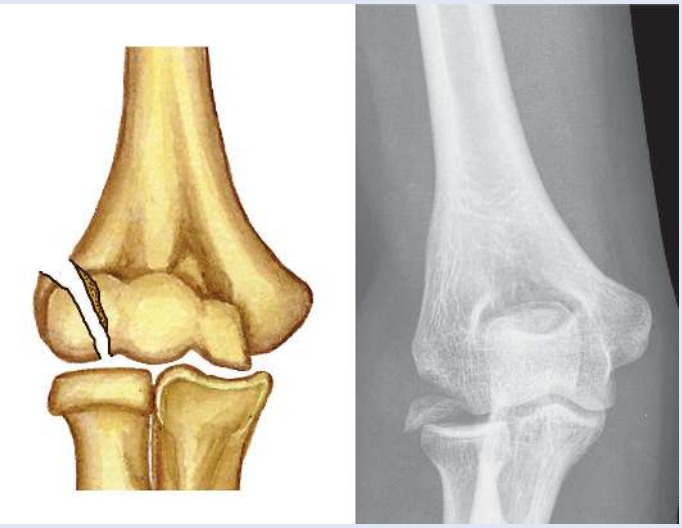
13-A3.3 Complex



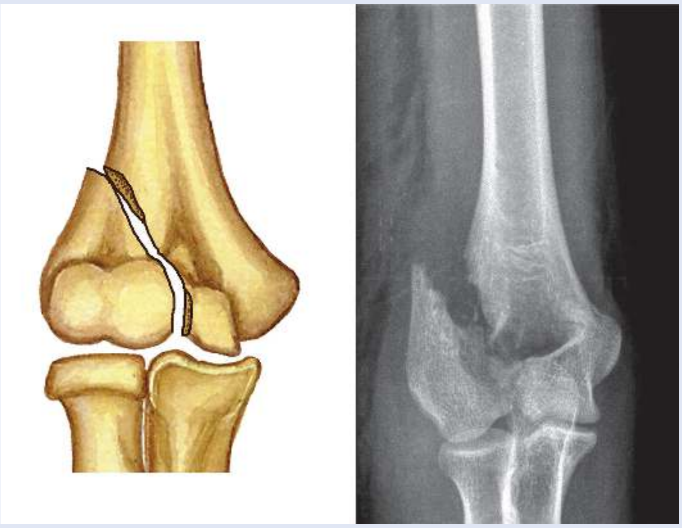
13-B Humerus, distal, partial articular fractures, single condyle

13-B1 Humerus, distal, partial articular fracture, lateral condyle sagittal fracture
499 fractures
M: 291 (58.32%)
F: 208 (41.68%)
0.13% of total adult fractures
2.29% of adult humeral fractures
13.27% of segment 13
52.75% of type 13-B

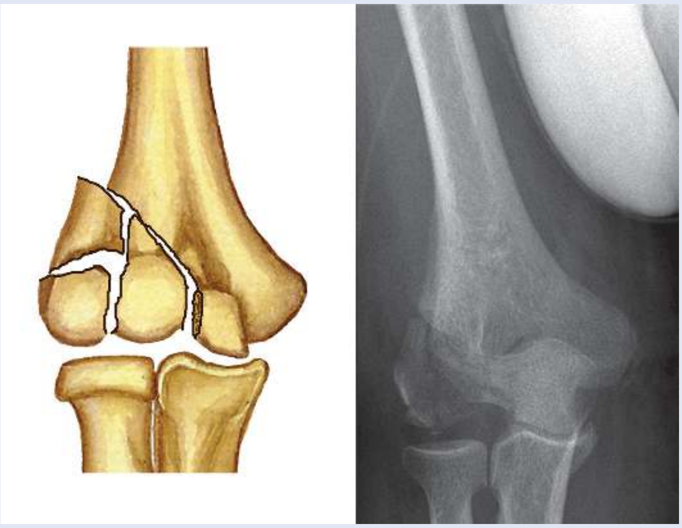
13-B1.1 Capitellum



13-B1.2 Transtrochlear simple



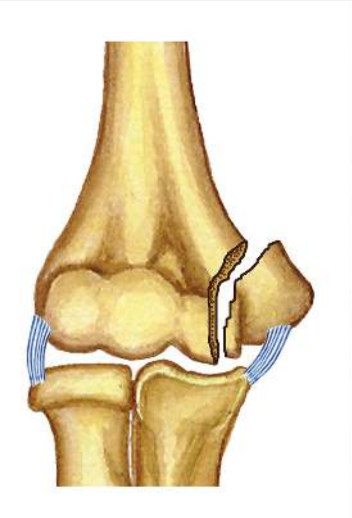
13-B1.3 Transtrochlear multifragmentary



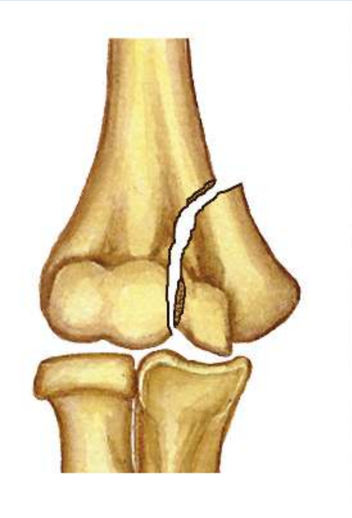
13-B Humerus, distal, partial articular fractures, single condyle

13-B2 Humerus, distal, partial articular fracture, medial condyle sagittal fracture
315 fractures
M: 174 (55.24%)
F: 141 (44.76%)
0.08% of total adult fractures
1.45% of adult humeral fractures
8.38% of segment 13
33.30% of type 13-B

13-B2.1 Transtrochlear simple, through the medial condyle



13-B2.2 Transtrochlear simple, through the groove



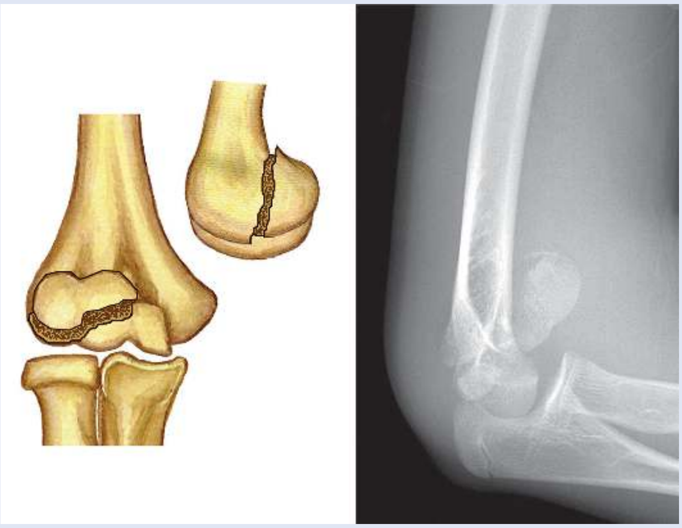
13-B2.3 Transtrochlear complex

13-B Humerus, distal, partial articular fractures, single condyle

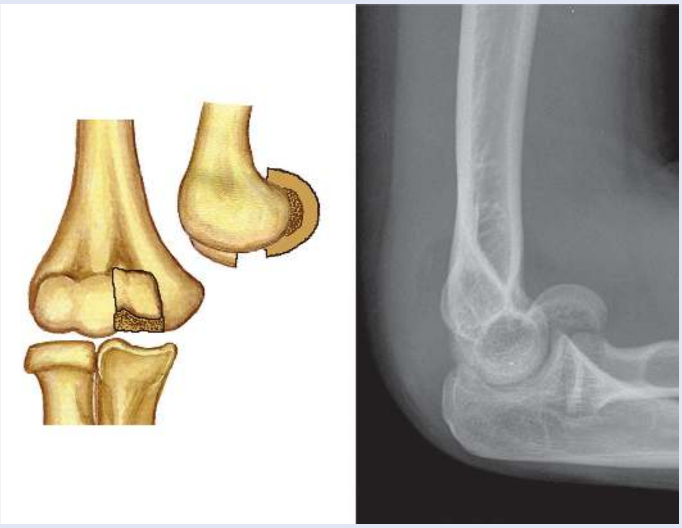
13-B3 Humerus, distal, partial articular fracture, single condyle, frontal fracture

132 fractures
M: 69 (52.27%)
F: 63 (47.73%)
0.04% of total adult fractures
0.61% of adult humeral fractures
3.51% of segment 13
13.95% of type 13-B

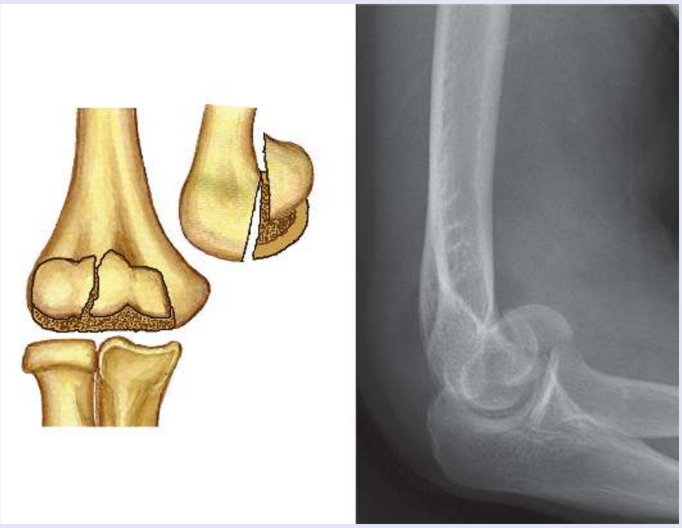
13-B3.1 Capitellum



13-B3.2 Trochlea



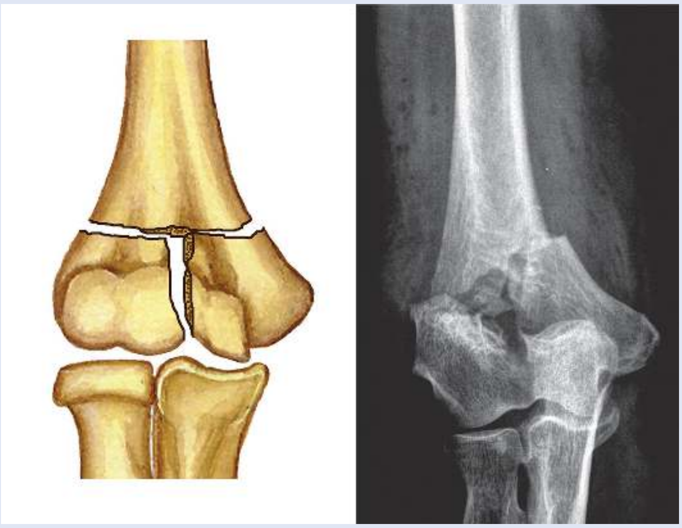
13-B3.3 Capitellum and trochlea



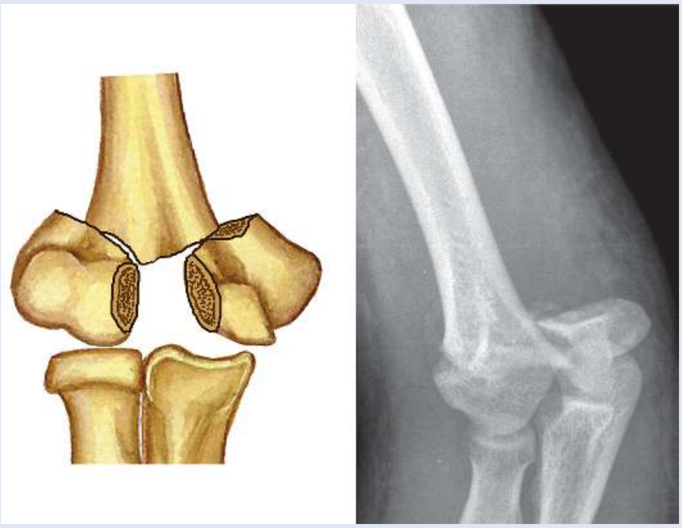
13-C Humerus, distal, complete articular fractures

13-C1 Humerus, distal, complete articular fracture, simple, metaphyseal simple
245 fractures
M: 117 (47.76%)
F: 128 (52.24%)
0.07% of total adult fractures
1.13% of adult humeral fractures
6.51% of segment 13
29.73% of type 13-C

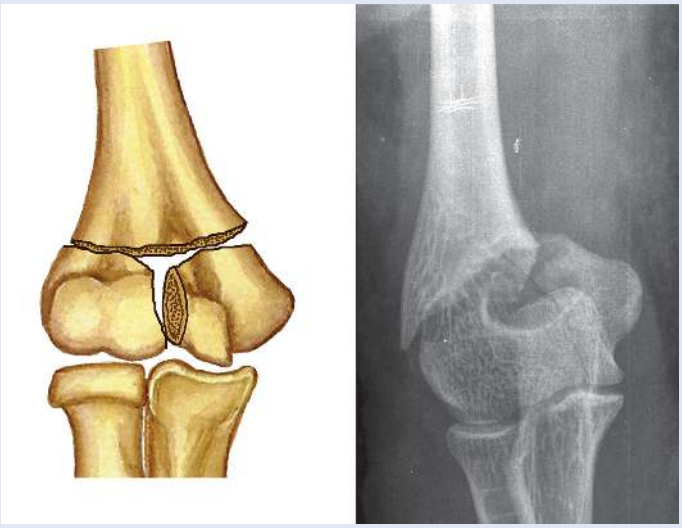
13-C1.1 With slight displacement



13-C1.2 With marked displacement



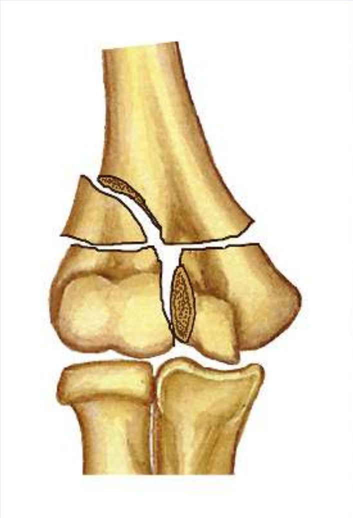
13-C1.3 T-shaped epiphyseal



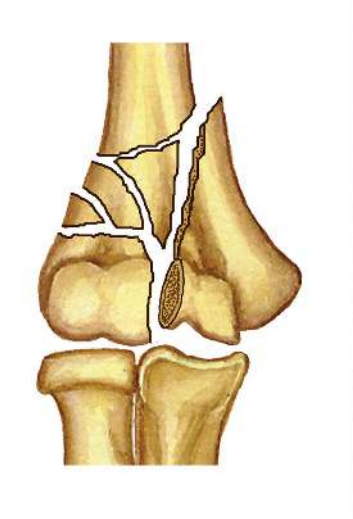
13-C Humerus, distal, complete articular fractures

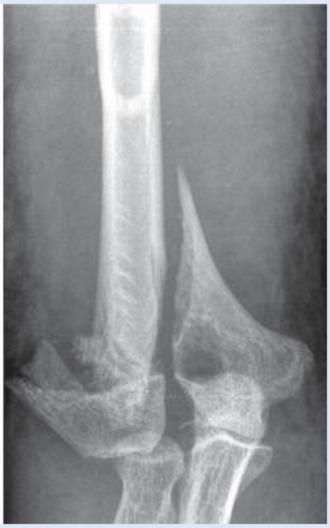
13-C2 Humerus, distal, complete articular fracture, simple, metaphyseal, multifragmentary
293 fractures
M: 149 (50.85%)
F: 144 (49.15%)
0.08% of total adult fractures
1.35% of adult humeral fractures
7.79% of segment 13
35.56% of type 13-C

13-C2.1 With an intact wedge

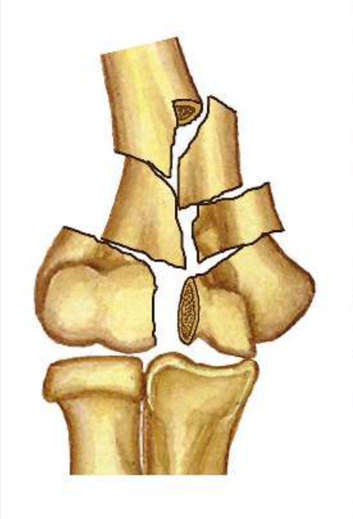


13-C2.2 With a fragmented wedge





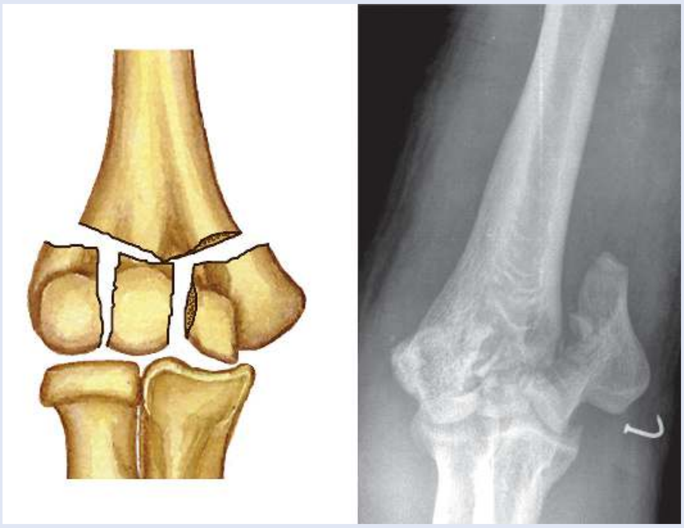
13-C2.3 Complex



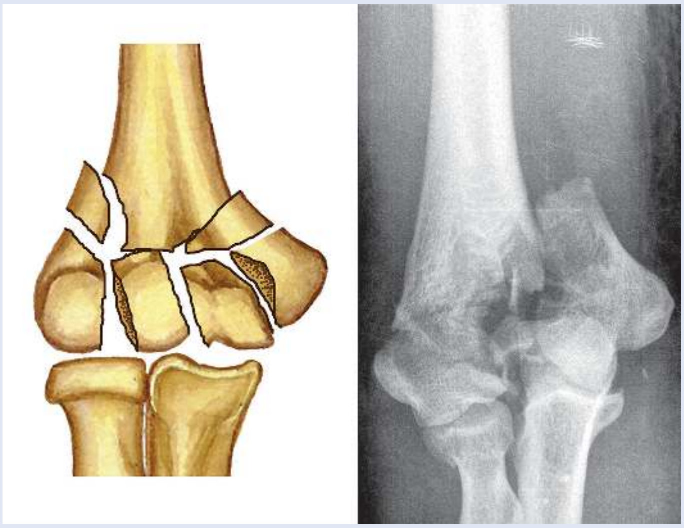
13-C Humerus, distal, complete articular fractures

13-C3 Humerus, distal, complete articular fracture, multifragmentary
286 fractures
M: 157 (54.90%)
F:129 (45.10%)
0.08% of total adult fractures
1.31% of adult humeral fractures
7.60% of segment 13
34.71% of type 13-C

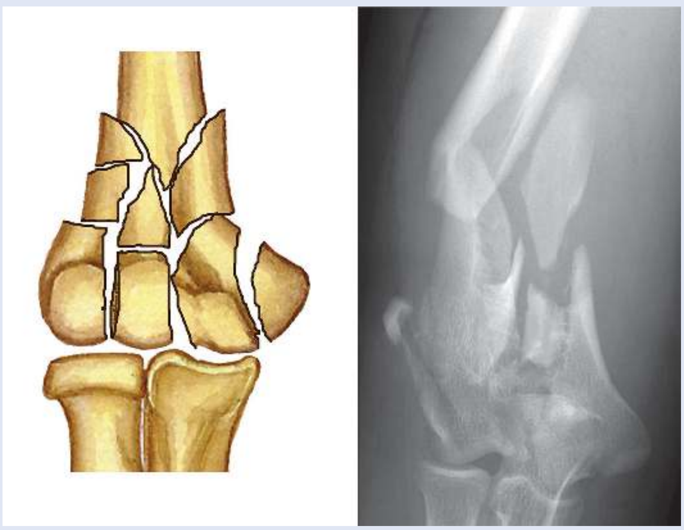
13-C3.1 Metaphyseal simple



13-C3.2 Metaphyseal wedge



13-C3.3 Metaphyseal multifragmentary



Injury Mechanism

Injury mechanism is as follows:

- *Supracondylar fractures*: There are two types of supracondylar fractures: extension and flexion. The extension type accounts for most cases, and is often caused by a fall on the outstretched hand with hyperextension of the elbow, in which case the distal fragment is displaced posteriorly. The flexion type occurs less frequently, usually from a fall with the elbow flexed as it hits the ground, resulting in a fracture with anterior displacement of the distal fragment.
- *Single condylar fracture*: Commonly occurs from a fall on the outstretched arm, with the elbow forced into valgus or varus position. A direct blow can also lead to single condylar fracture.
- *Capitellar fracture*: Fractures of the capitellum are rare, usually caused by an axial load on the capitellum through the radius, and may be associated with radial head fractures and posterior dislocation of the elbow.
- *Bicondylar fractures*: This type of fracture is caused by a direct force applied to the elbow, especially on the olecranon when the joint is flexed about 90 degrees.

Diagnosis

The patient with a fracture of the distal humerus presents with pain, swelling, and restricted motion. Deformity of the elbow may be present if there has been marked displacement. Thorough examination of the limb should be performed, including a neurovascular examination and X-rays, since such fractures may be associated with an injury of the median nerve, ulna, or brachial artery.

Radiographic evaluation for distal humeral fracture includes AP and lateral views of the elbow. CT or MRI will be required to clarify the diagnosis if there are complex fractures or severe soft-tissue injuries surrounding the affected area. Angiogram or Doppler ultrasonography for evaluation of arterial injury may be indicated if Doppler pulses are absent or greatly diminished compared with the normal side and swelling is present around the fractured area.

Treatment

Most fractures with minimal or no displacement can be treated with a nonoperative approach. Closed reduction can be attempted as a first step to treat displaced fractures, and should be performed with slow, gentle, sustained maneuvers. Multiple attempts at closed reduction may be associated with a high risk of neurovascular impairment, and therefore should be avoided. Emergent operation must be performed if there is impaired circulation. For unstable fractures or after multiple failed attempts at closed treatment, surgical management should be considered, such as percutaneous pin fixation, external fixation, or open reduction with internal fixation. Since the region of the elbow is the commonest site to develop myositis ossificans and malfunction postoperatively, minimal invasive surgery and internal fixation is highly recommended. In elderly patients with osteoporosis, total elbow replacement as a primary or secondary procedure has been suggested if fractures are severe.

Other Classifications of Humeral Fractures

The Neer Classification of Proximal Humeral Fractures

Overview

In 1970, Neer described his classification system for fractures of the proximal humerus into four segments of classification depending on the segment involved in fractures and the degree of displacement, and his classification system is the most commonly used for proximal humeral fracture.

Based on the presence or absence of significant displacement of one or more of the four major bone segments (humeral head, shaft, greater tuberosity, and lesser tuberosity), the Neer system classifies fractures of the proximal humerus into four types. According to Neer, a fracture is displaced when there is more than 1 cm of displacement and 45 degrees of angulation between any of the four segments in relation to one another. The Neer classification addresses the number of displaced fragments, instead of fracture lines. For example, a fracture with less than a 1 cm displacement and 45 degrees of angulation is considered as a one-part fracture. The Neer system is based on several factors such as the anatomic structure where fractures occur, degree of displacement, and different combinations of displacement; therefore, the system is able to identify all possible types of proximal humeral fractures. In addition, the Neer system can help show the impact of the attached muscle on the fracture displacement and assess the blood supply to the humeral head to provide better guidance in treatment and estimate the prognosis of patients with proximal humeral fractures.

- *Type I*: One or more fractures occur in one or more of the four segments, but with minimal or no displacement, in which a segment is displaced < 1 cm or angulated/rotated < 45 degrees. Though the soft tissue and blood supply to the fragment remain intact, this group accounts for the majority of all proximal humeral fractures (▶ Fig. 2.44).
- *Type II*: Fractures occur in one or more of the four segments, with one fracture fragment displaced > 1 cm and angulated/rotated > 45 degrees. In this group, displaced surgical neck fractures are most commonly seen (▶ Fig. 2.45).
- *Type III*: Fractures occur in one or more of the four segments, with two fracture fragments displaced > 1 cm, and angulated/rotated > 45 degrees. Glenohumeral dislocation (fracture-dislocation) is included in this group (▶ Fig. 2.46).
- *Type IV*: All the humeral segments are displaced, including dislocation of the humeral head. In this group, the humeral head is isolated and its main blood supply is disrupted (▶ Fig. 2.47).

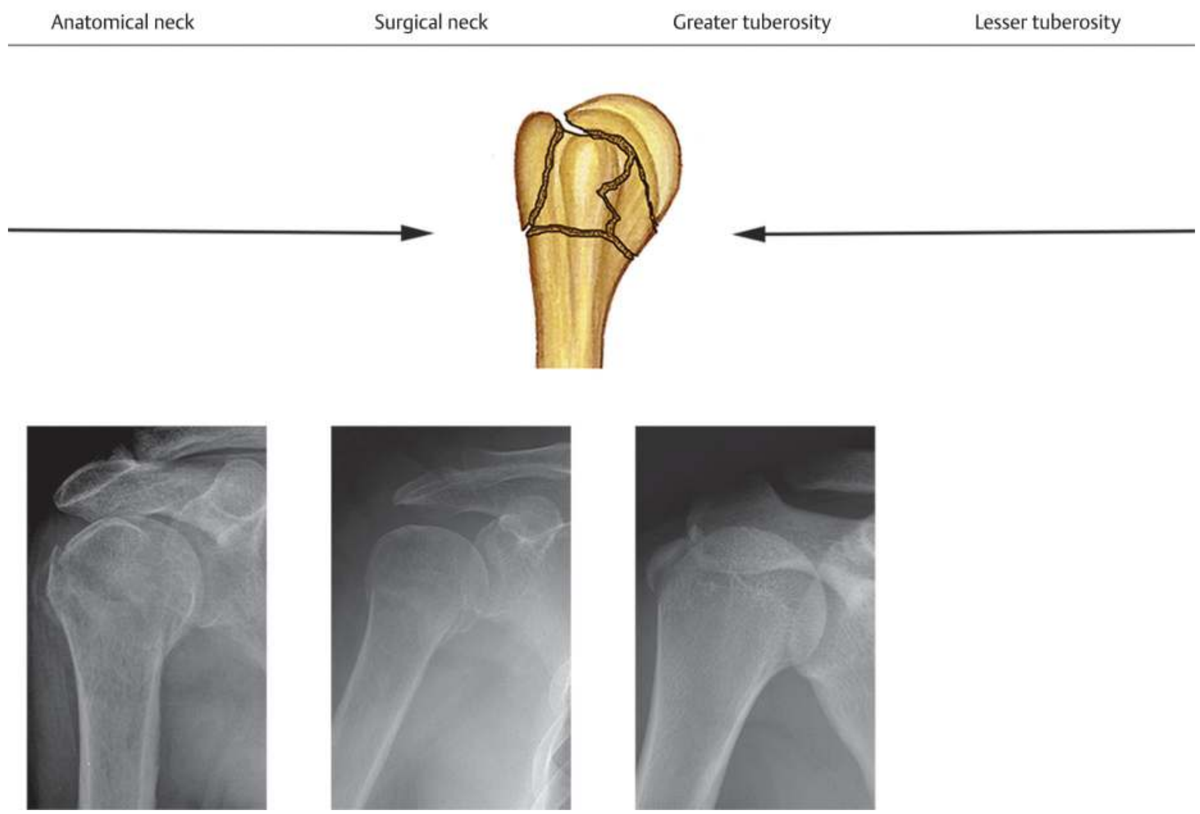


Fig. 2.44 Neer Type I humeral fractures.

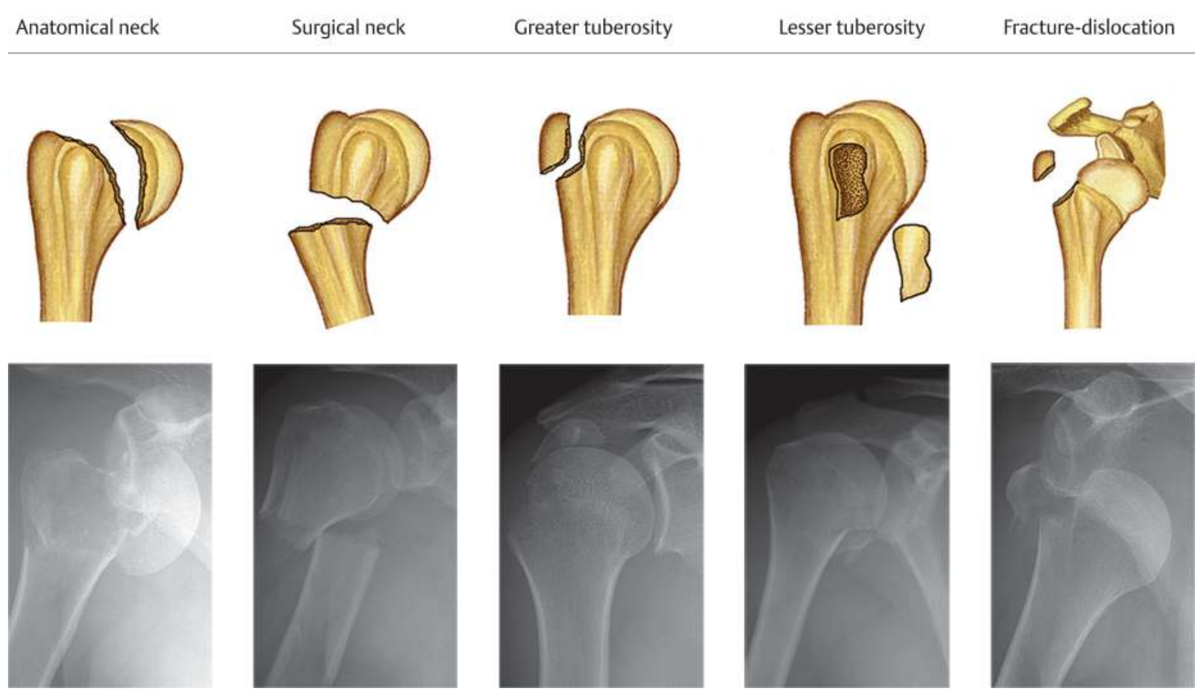


Fig. 2.45 Neer Type II humeral fractures.

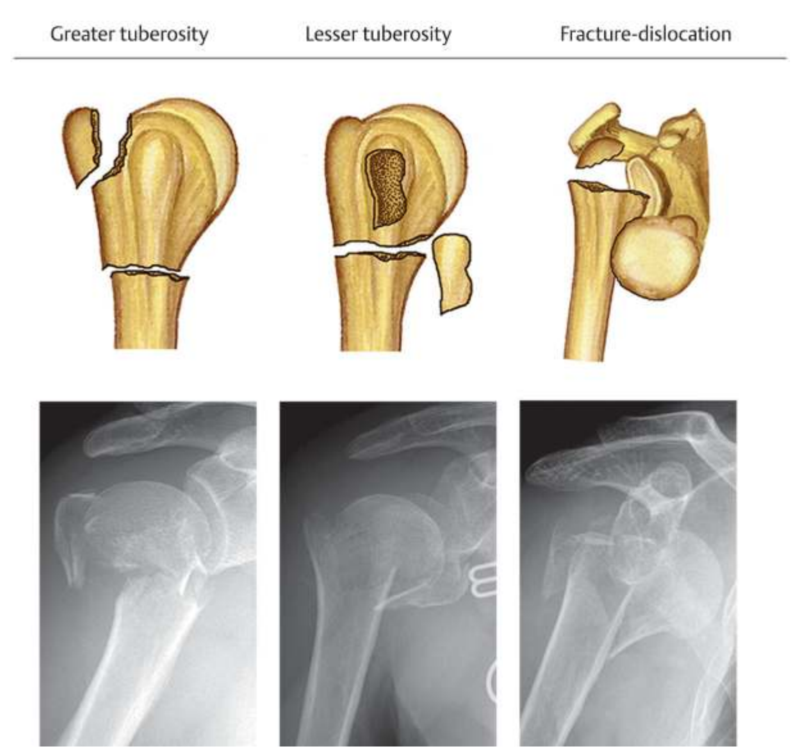


Fig. 2.46 Neer Type III humeral fractures.

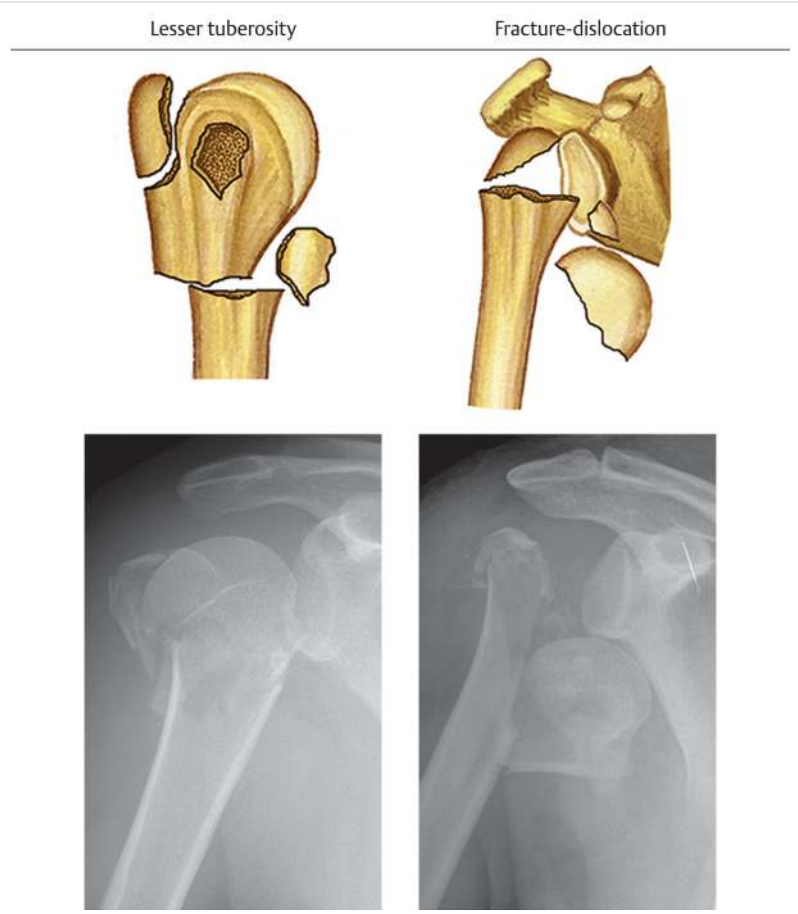


Fig. 2.47 Neer Type IV humeral fractures.

■ Clinical Epidemiologic Features for Neer Classification

A total of 13,361 proximal humeral fractures based on the Neer classification were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistical studies were performed; the fractures accounted for 91.66% of all the proximal humeral fractures. The epidemiologic features are as follows:

- More females than males
- Type I fractures account for most cases

See ▶ Table 2.23 and ▶ Fig. 2.48.

Table 2.23 Sex and fracture type distribution of 13,361 proximal humeral fractures by Neer classification

Fracture type	Male	Female	Number of fractures	Percentage
Type I	2,958	3,969	6,927	51.84
Type II	1,781	2,469	4,250	31.81
Type III	620	1,065	1,685	12.61
Type IV	212	287	499	3.73
Total	5,571	7,790	13,361	100.00

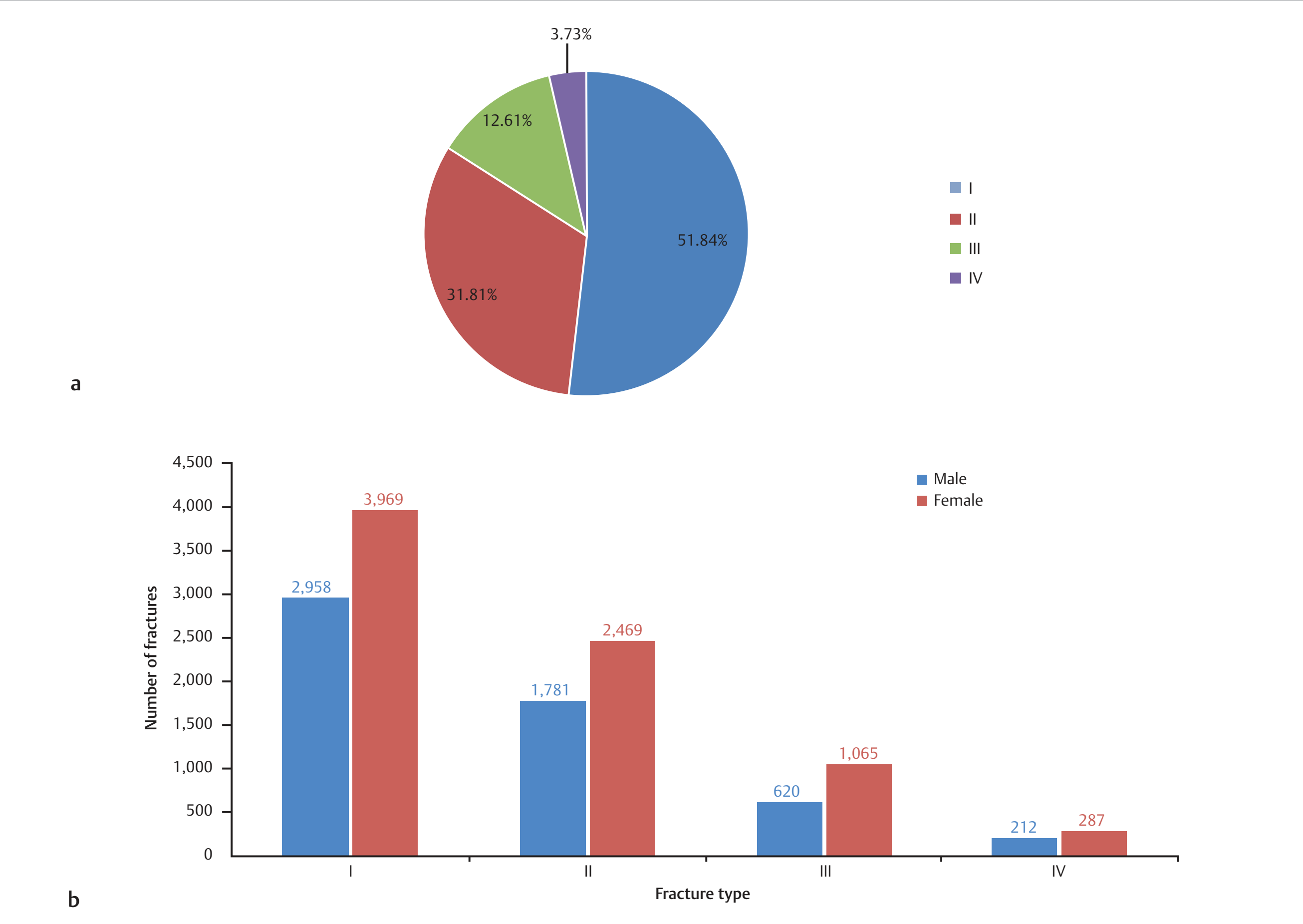


Fig. 2.48 (**a**) Fracture type distribution of 13,361 proximal humeral fractures by Neer classification. (**b**) Sex and fracture type distribution of 13,361 proximal humeral fractures by Neer classification.

Classification of Humeral Fractures by Fracture Location

Supracondylar Humeral Fractures

2

Overview

Supracondylar humeral fracture is mostly caused by indirect force on the elbow, with various injury mechanisms and fracture patterns. There are two types of supracondylar fractures, namely extension and flexion, both based on the mechanism of the injury.

Extension Type

The extension type fracture is caused by a fall on an outstretched hand when the elbow is hyperextended. When a fall occurs, the impact force from the ground transmits to the elbow through the forearm and results in a fracture. The distal fragment of the humerus will displace posteriorly, with anterior displacement of the proximal fragment. The fracture line runs obliquely downward from posterior to anterior. When the displacement is severe, the proximal fracture fragment often injures the brachial muscle, median nerve, and brachial artery (▶ Fig. 2.49).

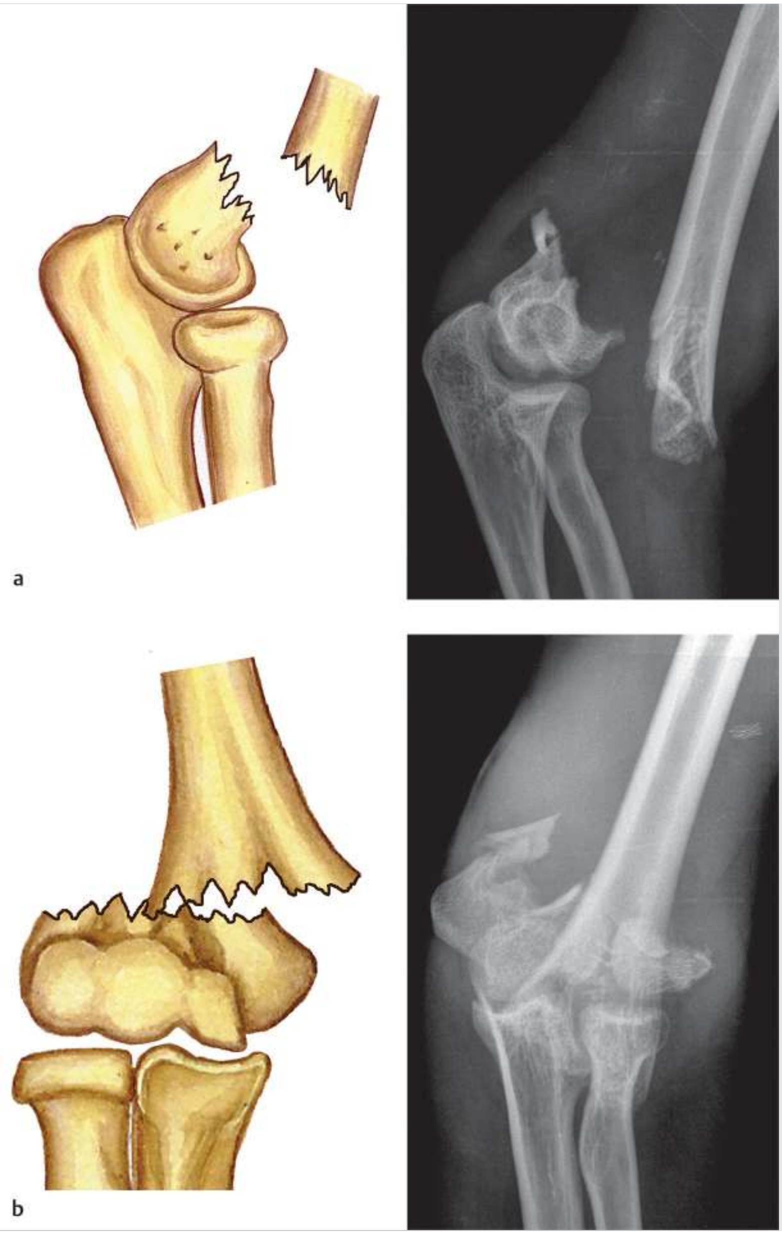


Fig. 2.49 Extension type supracondylar humeral fractures: lateral (**a**) and anterior (**b**) views.

Flexion Type

The flexion type of fracture is rare, and is caused by a fall on the olecranon when the elbow is flexed. The impact force on the olecranon transmitted vertically to the condyle can result in supracondylar fractures. The distal fragment will displace anteriorly, and the proximal fragment posteriorly. The fracture line runs obliquely downward from anterior to posterior (▶ Fig. 2.50).

Clinical Epidemiologic Features of Supracondylar Humeral Fractures

A total of 6,323 supracondylar fractures of the humerus were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 17.66% of all humeral fractures. The epidemiologic features are as the follows:

- More males than females
- The high-risk age group is 0–5 years
- Extension type of fractures account for the majority of cases

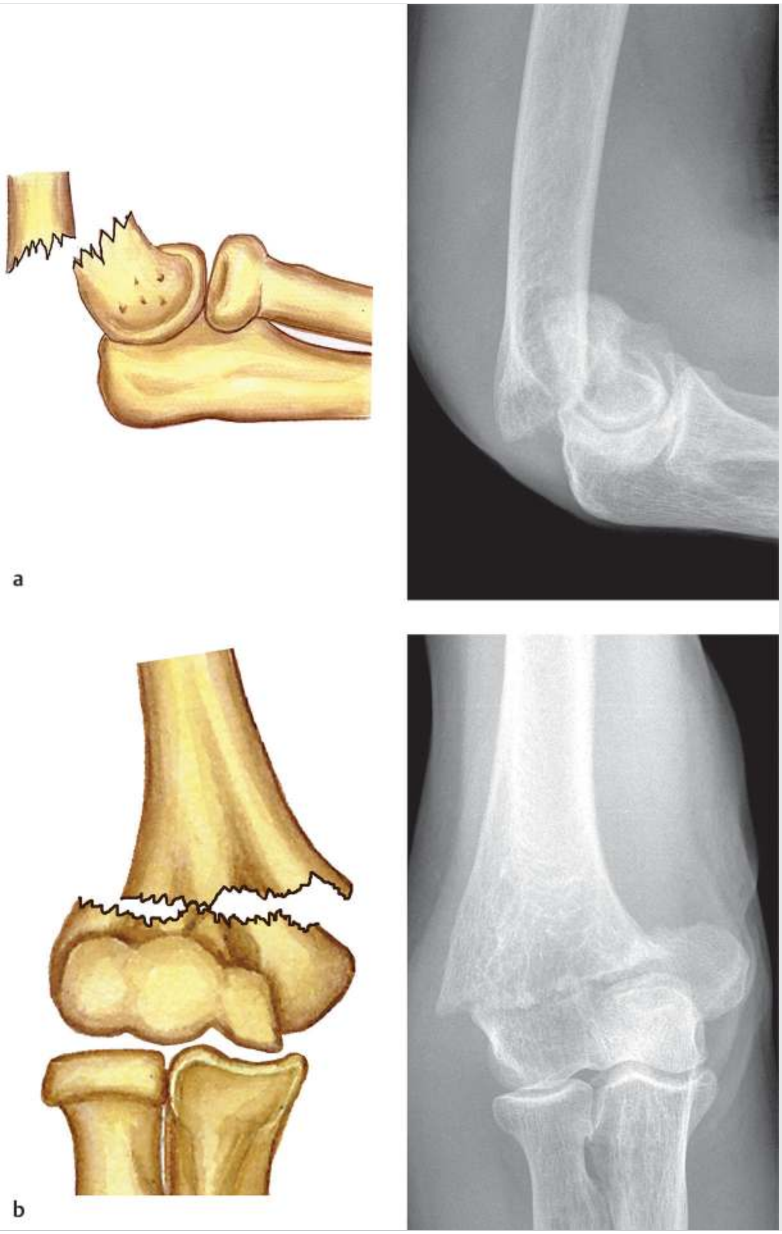


Fig. 2.50 Flexion type supracondylar humeral fractures: lateral (**a**) and anterior (**b**) views.

Supracondylar Humeral Fractures by Sex

See ▶ Table 2.24 and ▶ Fig. 2.51.

Table 2.24 Sex distribution of 6,323 supracondylar fractures of the humerus

Sex	Number of fractures	Percentage
Male	3,865	61.13
Female	2,458	38.87
Total	6,323	100.00

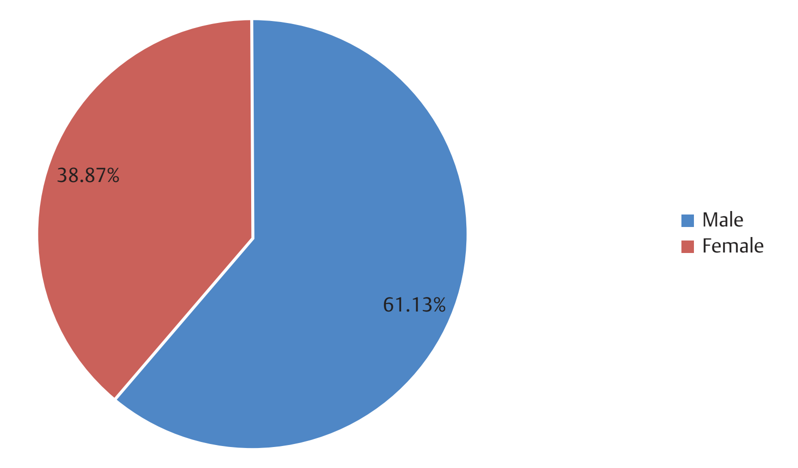


Fig. 2.51 Sex distribution of 6,323 supracondylar fractures of the humerus.

Supracondylar Humeral Fractures by Age Group

See ▶ Table 2.25 and ▶ Fig. 2.52.

Table 2.25 Age and sex distribution of 6,323 supracondylar fractures of the humerus

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	1,500	1,174	2,674	42.29
6–10	1,561	761	2,322	36.72
11–15	441	146	587	9.28
16–20	53	19	72	1.14
21–25	29	26	55	0.87
26–30	37	15	52	0.82
31–35	36	21	57	0.90
36–40	38	20	58	0.92
41–45	21	14	35	0.55
46–50	29	10	39	0.62
51–55	48	30	78	1.23
56–60	23	38	61	0.96
61–65	12	25	37	0.59
66–70	9	27	36	0.57
71–75	5	30	35	0.55
76–80	13	39	52	0.82
81–85	6	38	44	0.70
≥ 86	4	25	29	0.46
Total	3,865	2,458	6,323	100.00

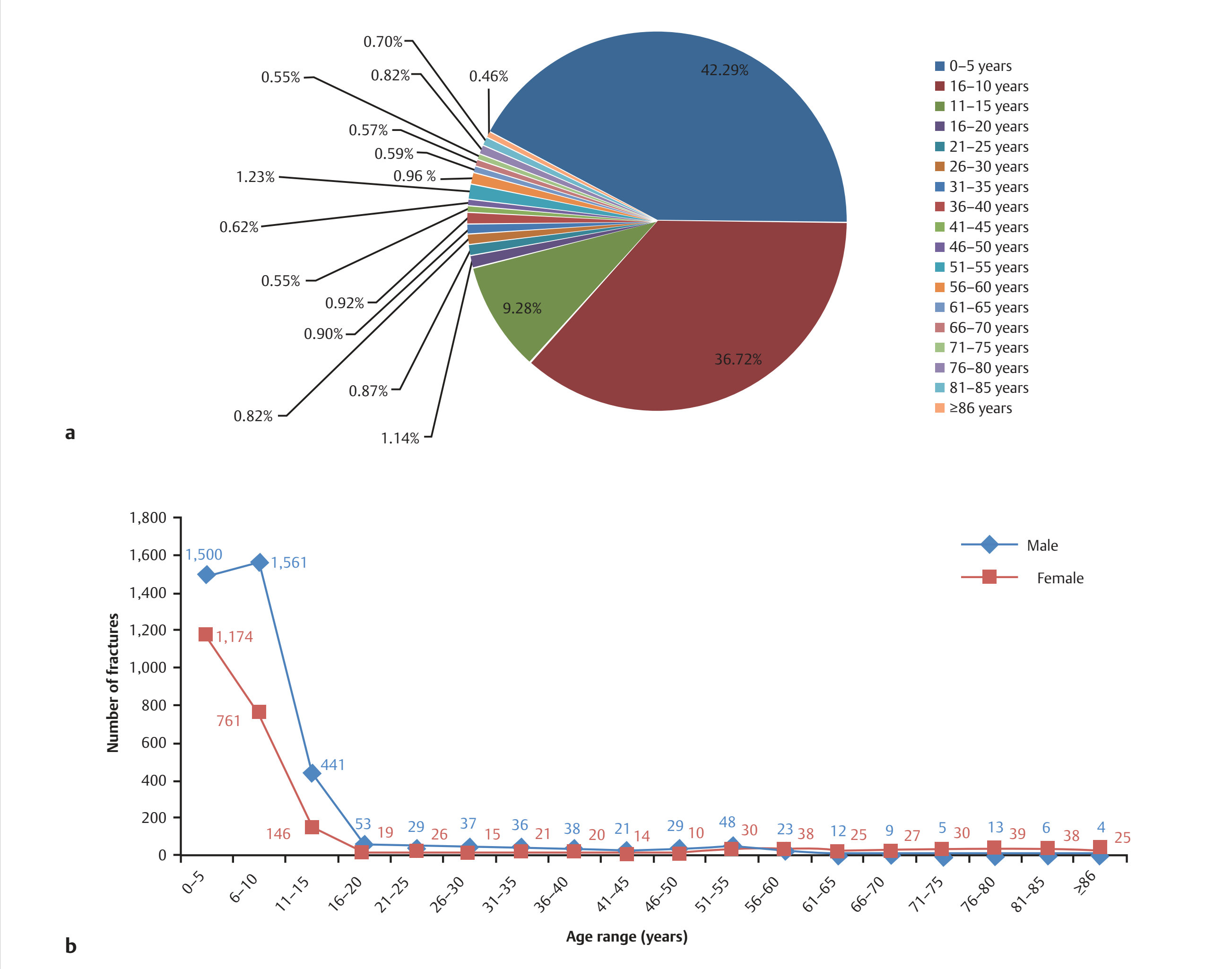


Fig. 2.52 (**a**) Age distribution of 6,323 supracondylar fractures of the humerus. (**b**) Age and sex distribution of 6,323 supracondylar fractures of the humerus.

Supracondylar Humeral Fractures by Fracture Pattern

See ▶ Table 2.26 and ▶ Fig. 2.53.

Table 2.26 Sex and fracture pattern distribution of 6,323 supracondylar fractures of the humerus

Fracture pattern	Male	Female	Number of fractures	Percentage
Extension	2,914	1,859	4,773	78.41
Flexion	792	522	1,314	21.59
Total	3,706	2,381	6,087	100.00

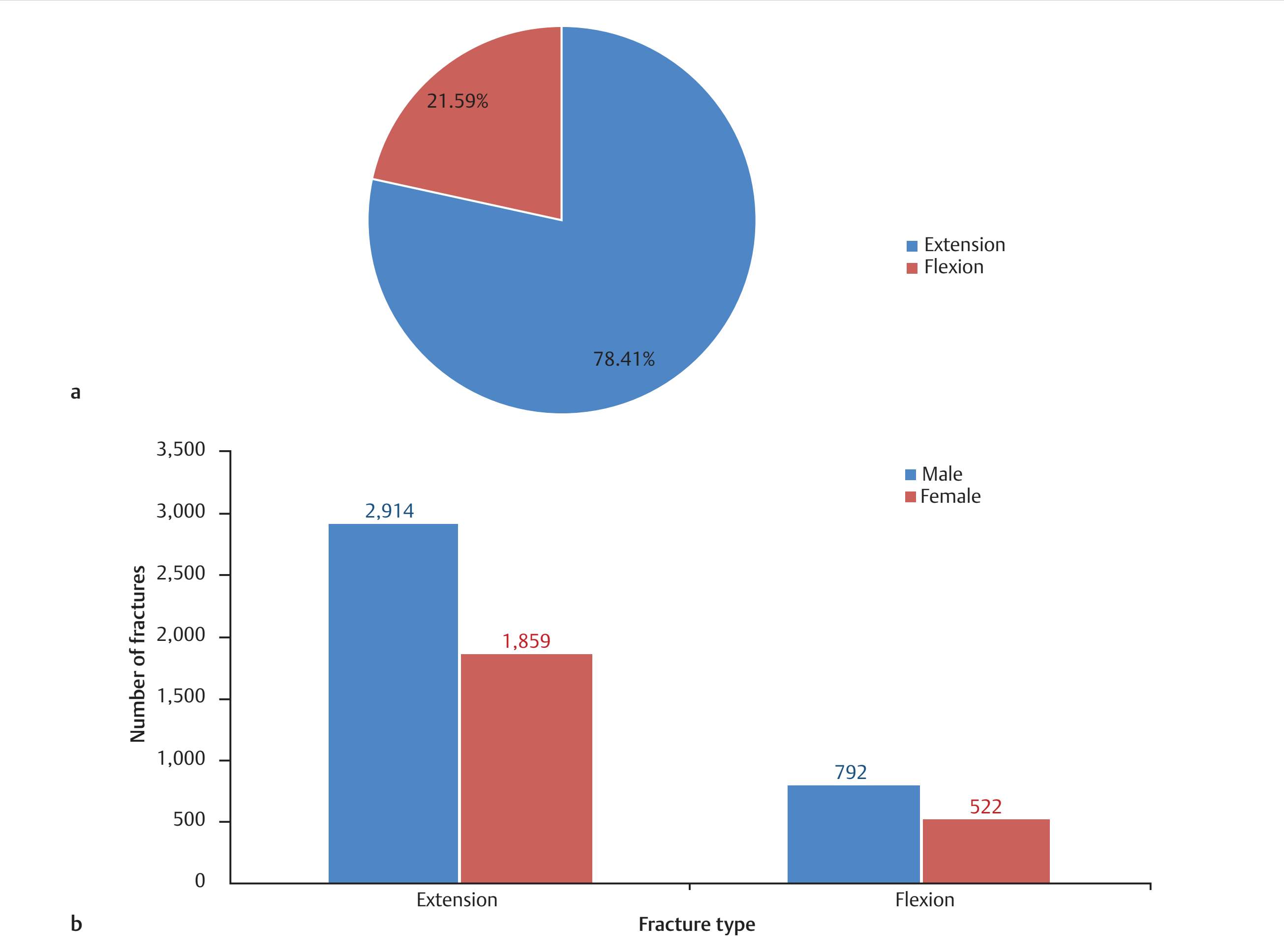


Fig. 2.53 (**a**) Fracture pattern distribution of 6,323 supracondylar fractures of the humerus. (**b**) Sex and fracture pattern distribution of 6,323 supracondylar fractures of the humerus.

■ Intercondylar Humeral Fractures

Overview

Rise classified intercondylar fractures of the humerus into four types, based on the degree of fracture displacement.

- *Type I*: with minimal or no displacement, congruity of the articular surface remains (▶ Fig. 2.54)
- *Type II*: displacement between the trochlea and capitellum; the articular surface is nearly intact with no rotation of either fracture fragment (▶ Fig. 2.55)
- *Type III*: displacement and separation of fragments with rotation; congruity of the articular surface is compromised (▶ Fig. 2.56)
- *Type IV*: multifragmentary fractures with significant displacement and severely damaged articular surface; the fracture fragment may penetrate through the skin to form open fractures (▶ Fig. 2.57)

Clinical Epidemiologic Features of Intercondylar Humeral Fractures

A total of 1,318 intercondylar fractures of the humerus were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 3.68% of all humeral fractures. The epidemiologic features are as follows:

- More males than females
- The high-risk age groups are 0–5 years and 6–10 years; 0–5 years and 6–10 years for males, 0–5 years for females.

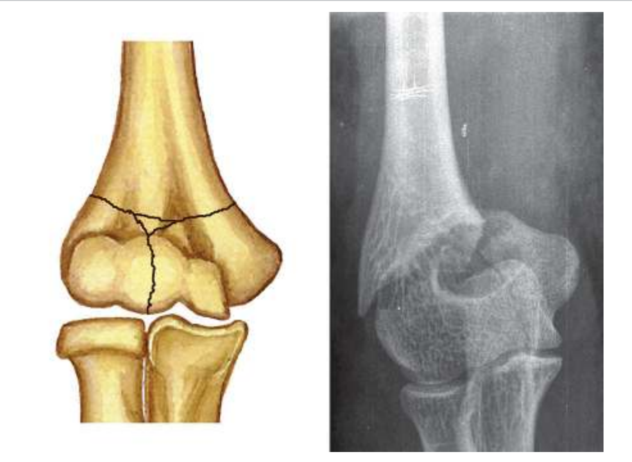


Fig. 2.54 Rise Type I intercondylar humeral fractures.

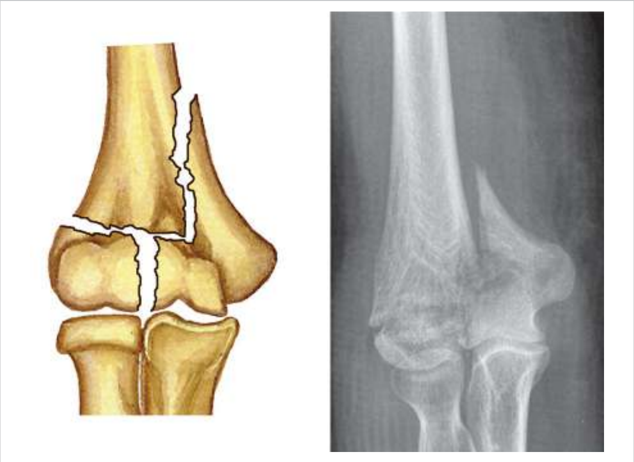


Fig. 2.55 Rise Type II intercondylar humeral fractures.

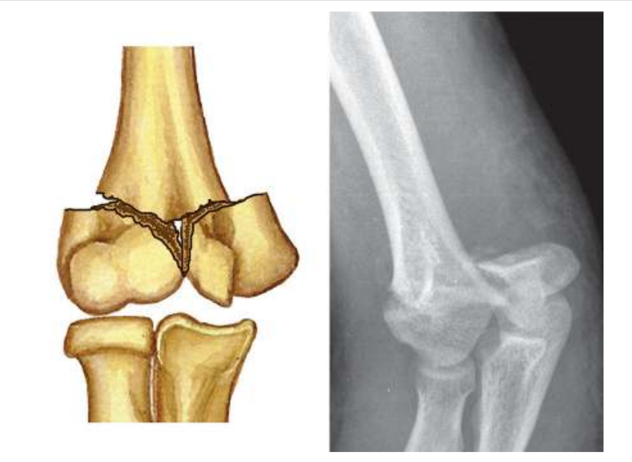


Fig. 2.56 Rise Type III intercondylar humeral fractures.

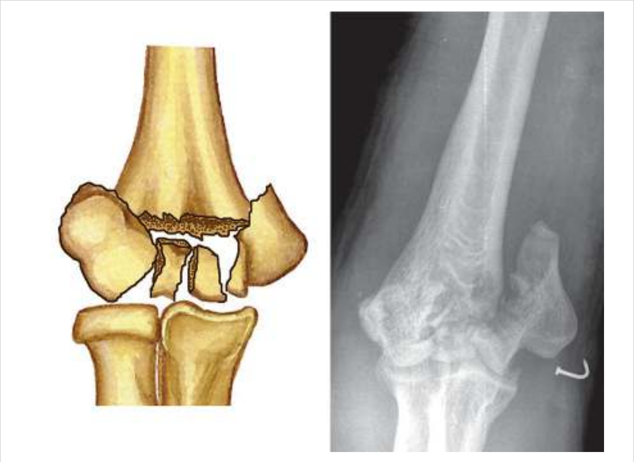


Fig. 2.57 Rise Type IV intercondylar humeral fractures.

Intercondylar Humeral Fractures by Sex

See ▶ Table 2.27 and ▶ Fig. 2.58.

Table 2.27 Sex distribution of 1,318 intercondylar fractures of the humerus

Sex	Number of fractures	Percentage
Male	752	57.06
Female	566	42.94
Total	1,318	100.00

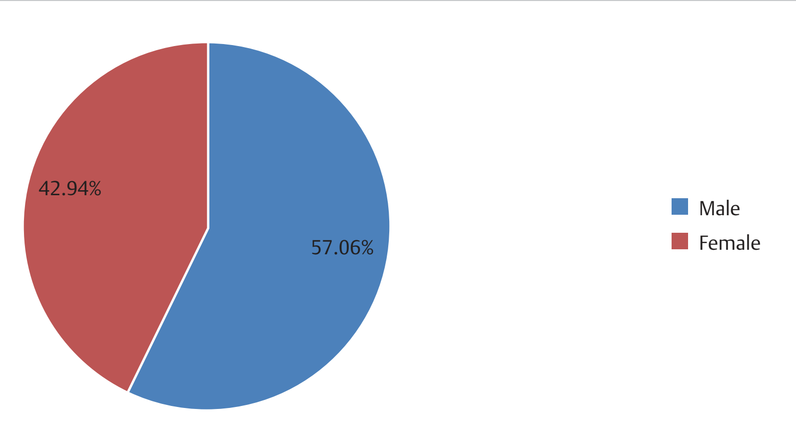


Fig. 2.58 Sex distribution of 1,318 intercondylar fractures of the humerus.

Intercondylar Humeral Fractures by Age Group

See ▶ Table 2.28 and ▶ Fig. 2.59.

Table 2.28 Age and sex distribution of 1,318 intercondylar fractures of the humerus

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	132	105	237	17.98
6–10	134	55	189	14.34
11–15	68	33	101	7.66
16–20	46	24	70	5.31
21–25	39	35	74	5.61
26–30	38	10	48	3.64
31–35	61	19	80	6.07
36–40	58	17	75	5.69
41–45	44	23	67	5.08
46–50	38	18	56	4.25
51–55	29	28	57	4.32
56–60	30	38	68	5.16
61–65	14	43	57	4.32
66–70	7	31	38	2.88
71–75	4	31	35	2.66
76–80	4	29	33	2.50
81–85	2	17	19	1.44
≥ 86	4	10	14	1.06
Total	752	566	1,318	100.00

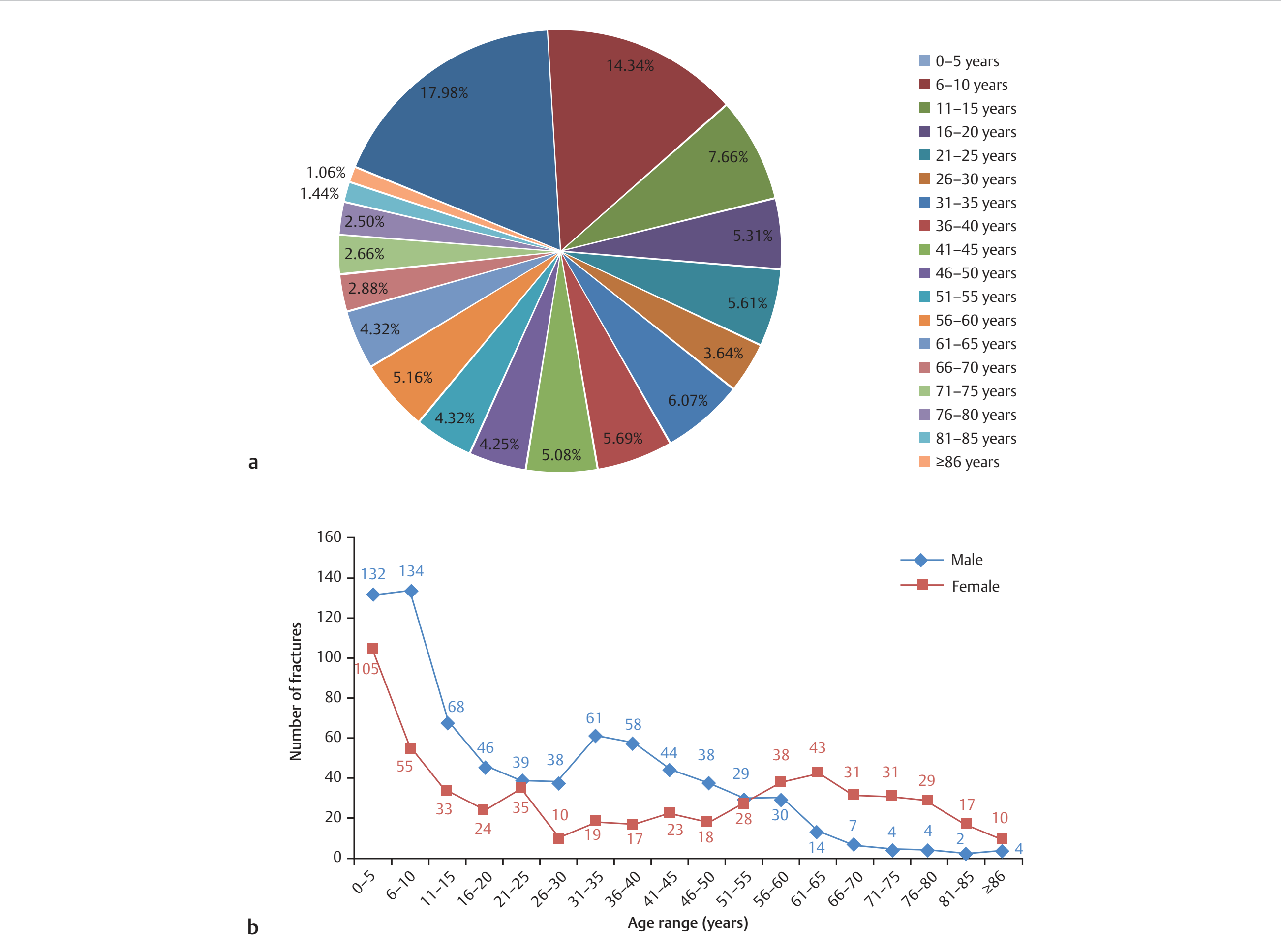


Fig. 2.59 (**a**) Age distribution of 1,318 intercondylar fractures of the humerus. (**b**) Age and sex distribution of 1,318 intercondylar fractures of the humerus.

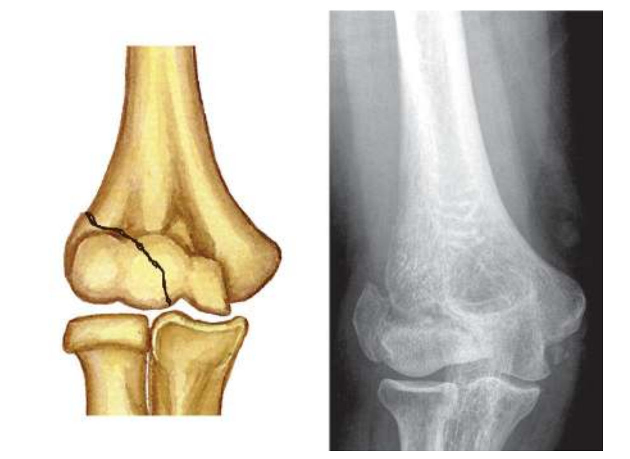


Fig. 2.60 Type I lateral humeral condylar fractures.

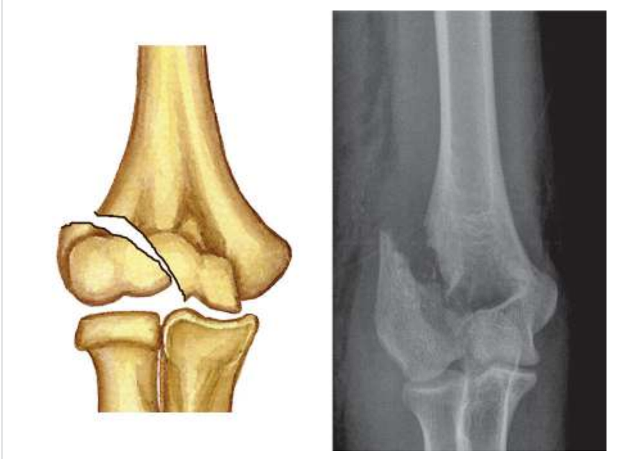


Fig. 2.61 Type II lateral humeral condylar fractures.

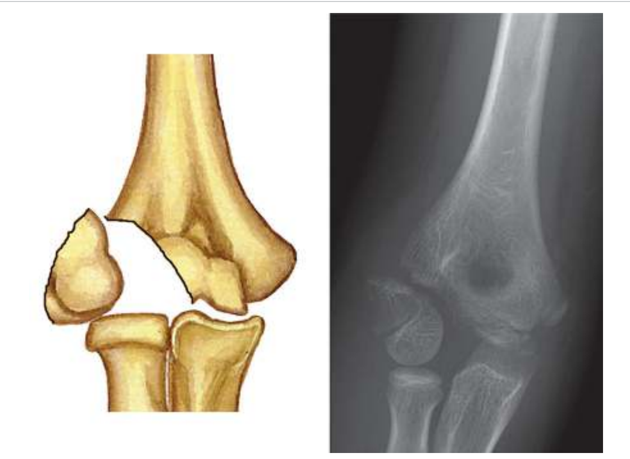


Fig. 2.62 Type III lateral humeral condylar fractures.

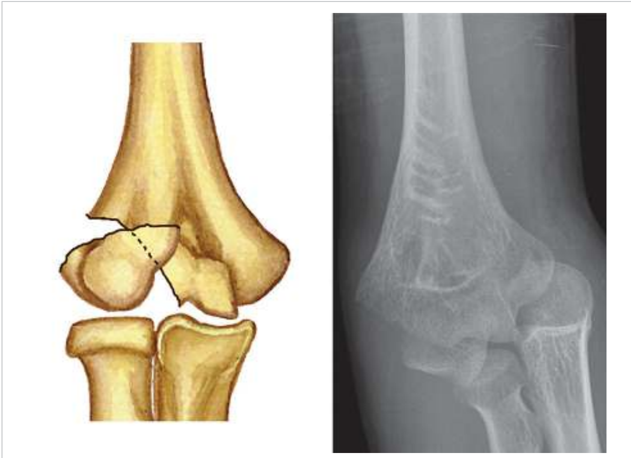


Fig. 2.63 Type IV lateral humeral condylar fractures.

■ Lateral Humeral Condylar Fractures

Overview

Lateral condylar fracture of the humerus is often caused by a fall on the outstretched arm with the forearm in abduction, which transmits a force through the forearm extensor musculature to its attachment on the lateral condyle. This type of fracture may also result from a fall onto the extended hand, leading to impaction of the radial head into the lateral condyle. The same force may also lead to impaction of the coronoid process of the ulna into the trochlea, and consequently result in fractures in the lateral aspect of the trochlea. Because the elbow position varies as the injury occurs, the direction of fracture displacement and size of the fragment is markedly different from each other.

Lateral humeral condylar fracture is classified into four types, based on the degree of fracture displacement:

- *Type I* (nondisplaced): with minimal or no displacement (▶ Fig. 2.60)
- *Type II* (lateral displacement): the fracture fragment is displaced laterally and posteriorly without rotation (▶ Fig. 2.61)
- *Type III* (rotatory displacement): complete displacement with rotation; the rotation of the fragment can be 90 or 180 degrees in severe fractures (▶ Fig. 2.62)
- *Type IV* (fracture dislocation): the lateral condylar fragment is displaced laterally, often associated with dislocation of the elbow, which may be medial, lateral, or posterior (▶ Fig. 2.63)

Clinical Epidemiologic Features of Lateral Humeral Condylar Fractures

A total of 1,971 lateral humeral condylar fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 5.50% of all humeral factures. The epidemiologic features are as follows:

- More males than females
- The high-risk age groups are 0–5 years and 6–10 years

Lateral Humeral Condylar Fractures by Sex

See ▶ Table 2.29 and ▶ Fig. 2.64.

Table 2.29 Sex distribution of 1,971 lateral condylar fractures of the humerus

Sex	Number of fractures	Percentage
Male	1,326	67.28
Female	645	32.72
Total	1,971	100.00

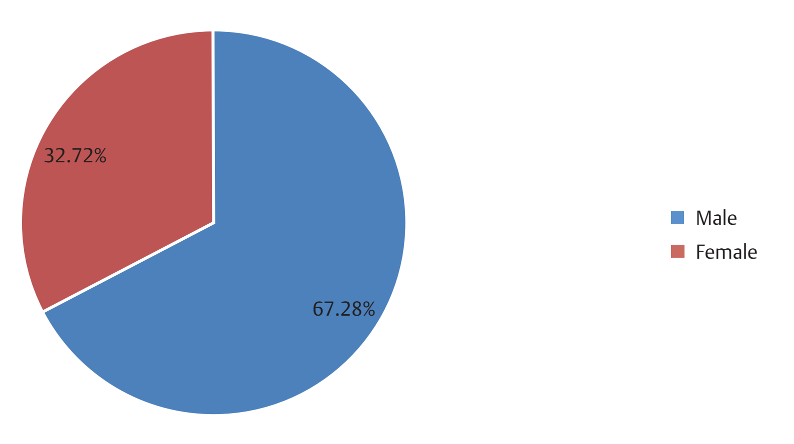


Fig. 2.64 Sex distribution of 1,971 lateral condylar fractures of the humerus.

Lateral Humeral Condylar Fractures by Age Group

See ▶ Table 2.30 and ▶ Fig. 2.65.

Table 2.30 Age and sex distribution of 1,971 lateral condylar fractures of the humerus

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	557	310	867	43.99
6–10	423	119	542	27.50
11–15	111	27	138	7.00
16–20	39	9	48	2.44
21–25	41	4	45	2.28
26–30	30	11	41	2.08
31–35	22	13	35	1.78
36–40	25	13	38	1.93
41–45	21	17	38	1.93
46–50	20	17	37	1.88
51–55	18	22	40	2.03
56–60	5	25	30	1.52
61–65	3	13	16	0.81
66–70	5	18	23	1.17
71–75	1	15	16	0.81
76–80	2	6	8	0.41
81–85	1	3	4	0.20
≥ 86	2	3	5	0.25
Total	1,326	645	1,971	100.00

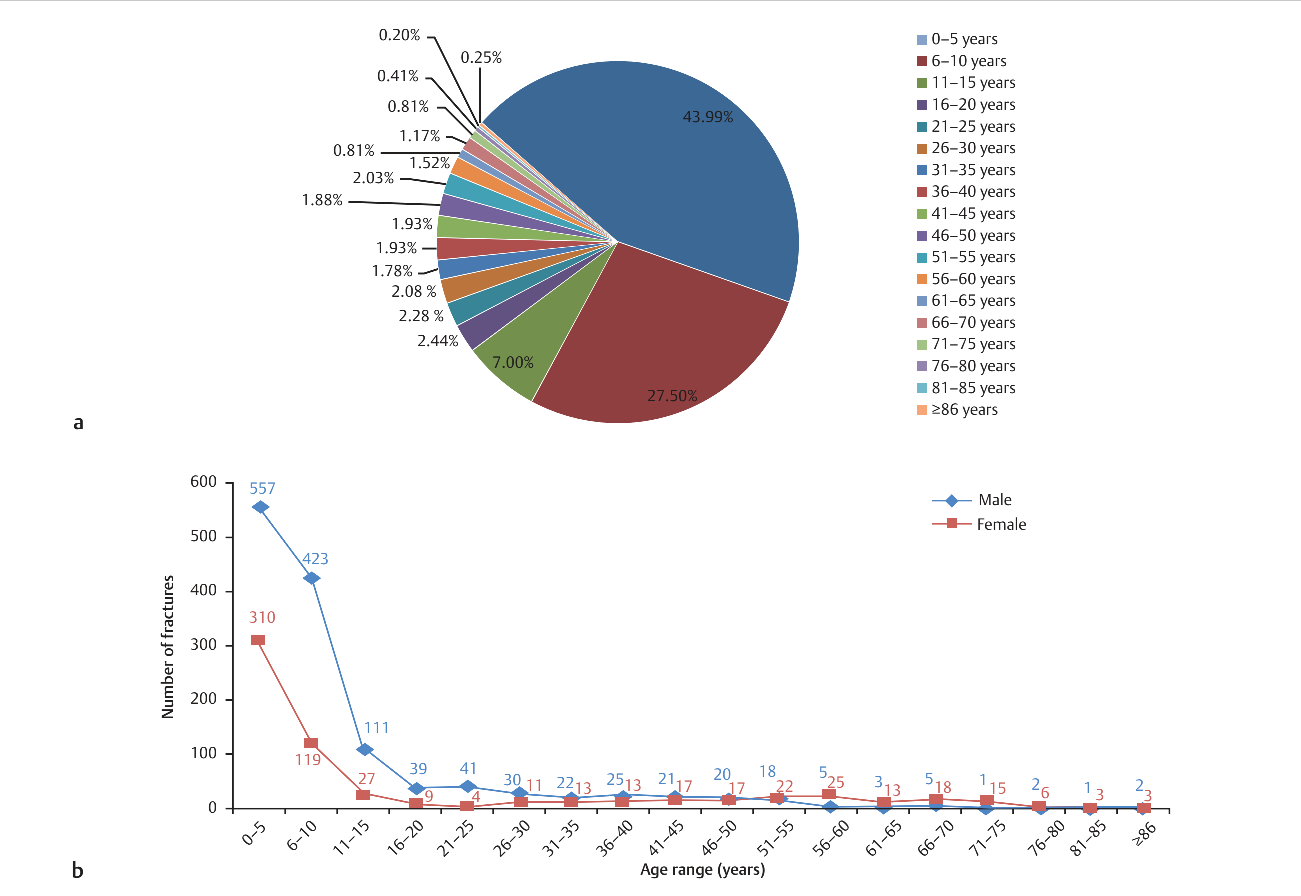


Fig. 2.65 (a) Age distribution of 1,971 lateral condylar fractures of the humerus. (b) Age and sex distribution of 1,971 lateral condylar fractures of the humerus.

■ Medial Humeral Condylar Fractures

Overview

The true mechanism of injury for medial condylar fracture of the humerus remains unclear. It is likely to occur when violent force transmits to or directly acts on the elbow. In effect, the trochlear (semilunar) notch of the ulna strikes on the medial condyle and leads to fracture of medial condyle.

Depending on the course of the fracture line and the displacement of medial condylar fragment, medial humeral condylar fracture is classified into three types:

- *Type I*: with minimal or no displacement between fragments; the fracture line runs obliquely downward and outward from the medial epicondyle up to the trochlear articulation surface (▶ Fig. 2.66)
- *Type II*: similar fracture line course as in Type I, but the fragment is displaced either laterally or slightly upward, with no rotation (▶ Fig. 2.67)
- *Type III*: the fracture line is the same as seen in Type II; however, here the fragment is displaced ulnarly or anteriorly, with rotary dislocation (▶ Fig. 2.68)

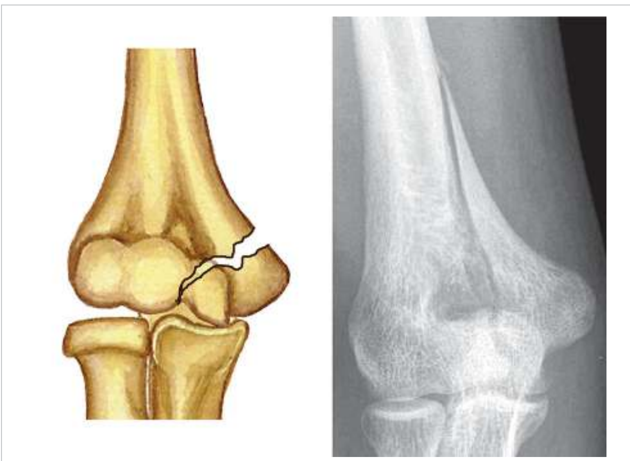


Fig. 2.66 Type I medial humeral condylar fractures.

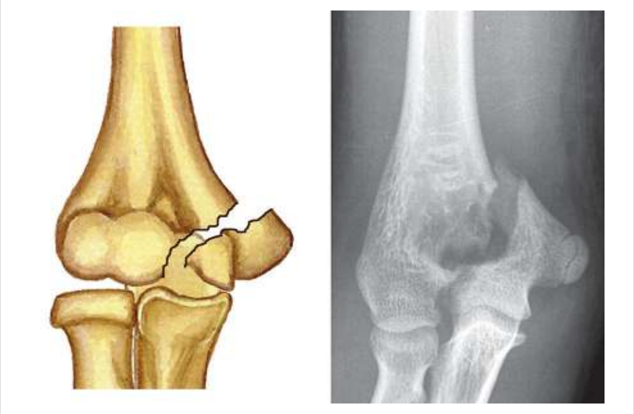


Fig. 2.67 Type II medial humeral condylar fractures.

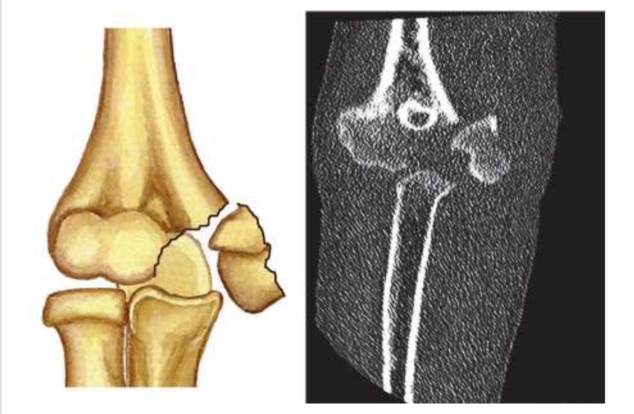


Fig. 2.68 Type III medial humeral condylar fractures.

Clinical Epidemiologic Features of Medial Humeral Condylar Fractures

A total of 895 medial humeral condylar fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011; the fractures accounted for 2.50% of all humeral fractures.

The epidemiologic features are as follows:

- More males than females
- The high-risk age groups are 0–5 years and 6–10 years

Medial Humeral Condylar Fractures by Sex

See ▶ Table 2.31 and ▶ Fig. 2.69.

Table 2.31 Sex distribution of 895 medial condylar fractures of the humerus

Sex	Number of fractures	Percentage
Male	560	62.57
Female	335	37.43
Total	895	100.00

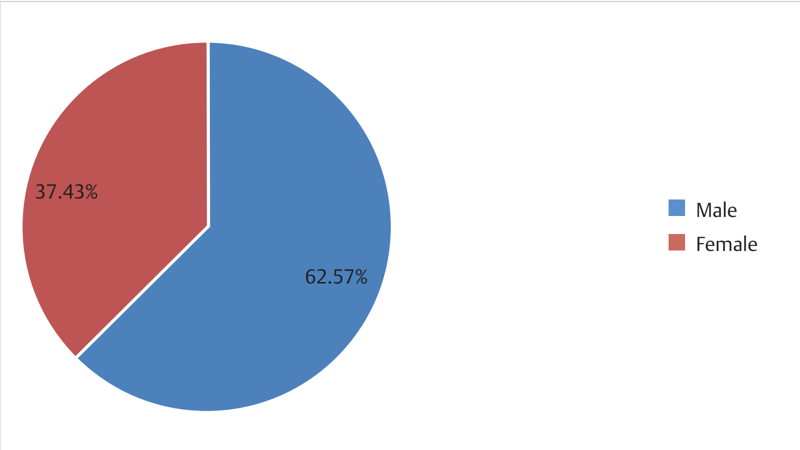


Fig. 2.69 Sex distribution of 895 medial condylar fractures of the humerus.

Medial Humeral Condylar Fractures by Age Group

See ▶ Table 2.32 and ▶ Fig. 2.70.

Table 2.32 Age and sex distribution of 895 medial condylar fractures of the humerus

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	212	113	325	36.31
6–10	114	64	178	19.89
11–15	67	23	90	10.06
16–20	39	12	51	5.70
21–25	12	11	23	2.57
26–30	19	8	27	3.02
31–35	14	7	21	2.35
36–40	14	10	24	2.68
41–45	23	8	31	3.46
46–50	17	8	25	2.79
51–55	8	9	17	1.90
56–60	7	17	24	2.68
61–65	0	12	12	1.34
66–70	4	9	13	1.45
71–75	2	8	10	1.12
76–80	7	7	14	1.56
81–85	1	4	5	0.56
≥ 86	0	5	5	0.56
Total	560	335	895	100.00

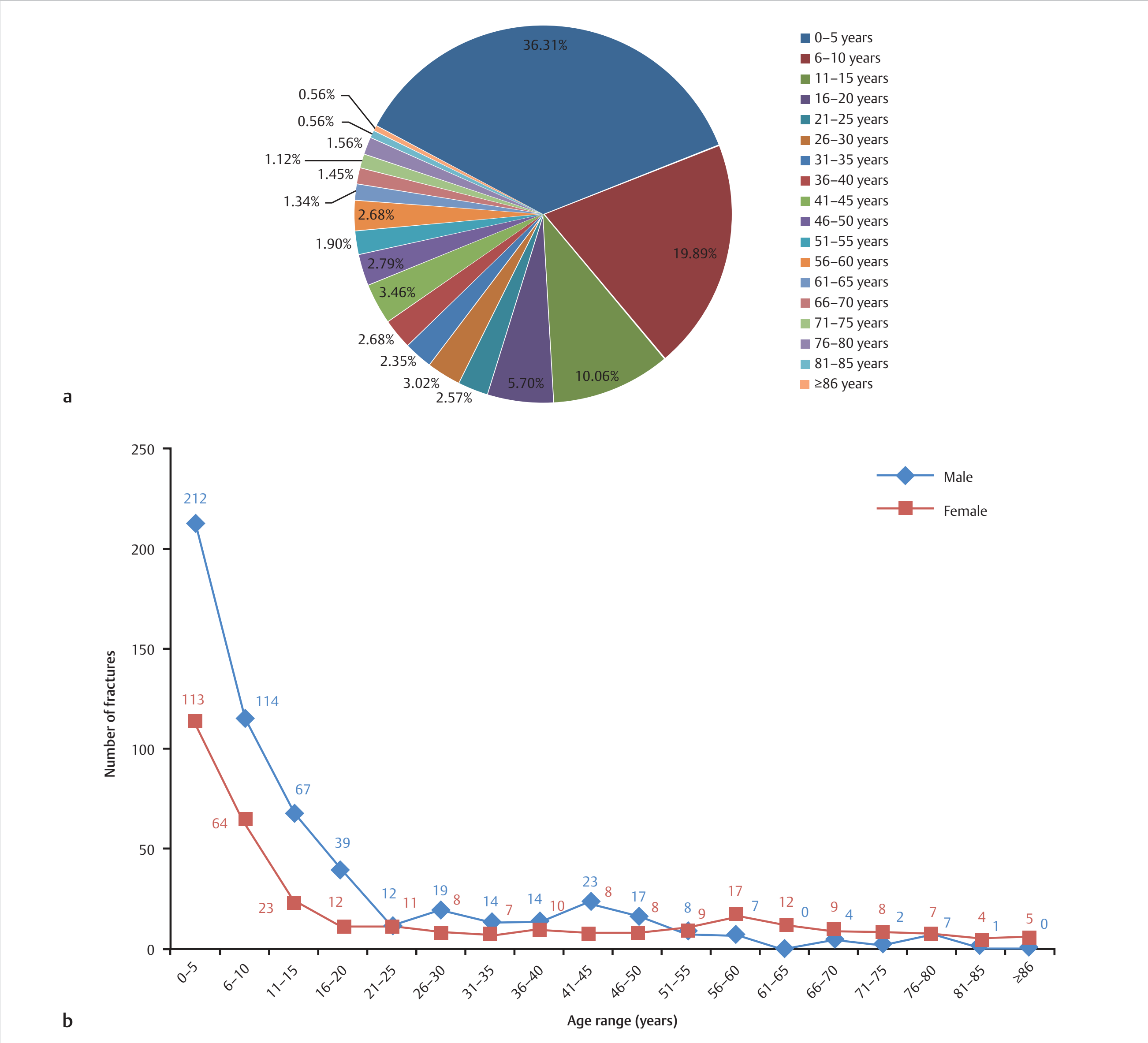


Fig. 2.70 (**a**) Age distribution of 895 medial condylar fractures of the humerus. (**b**) Age and sex distribution of 895 medial condylar fractures of humerus.

■ Lateral Humeral Epicondyle Fractures

Overview

This type of injury is often seen as an avulsion fracture due to violent contraction of the extensor muscle; the mechanism involves a fall on an outstretched hand with the forearm in excessive pronation and adduction. Fragments may be slightly displaced or may have 60 to 180 degrees of rotary dislocation (▶ Fig. 2.71).

Clinical Epidemiologic Features of Lateral Humeral Epicondyle Fractures

A total of 756 lateral humeral epicondyle fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 2.11% of all humeral fractures. Their epidemiologic features are as follows:

- More males than females
- The high-risk age groups are 0–5 years and 6–10 years

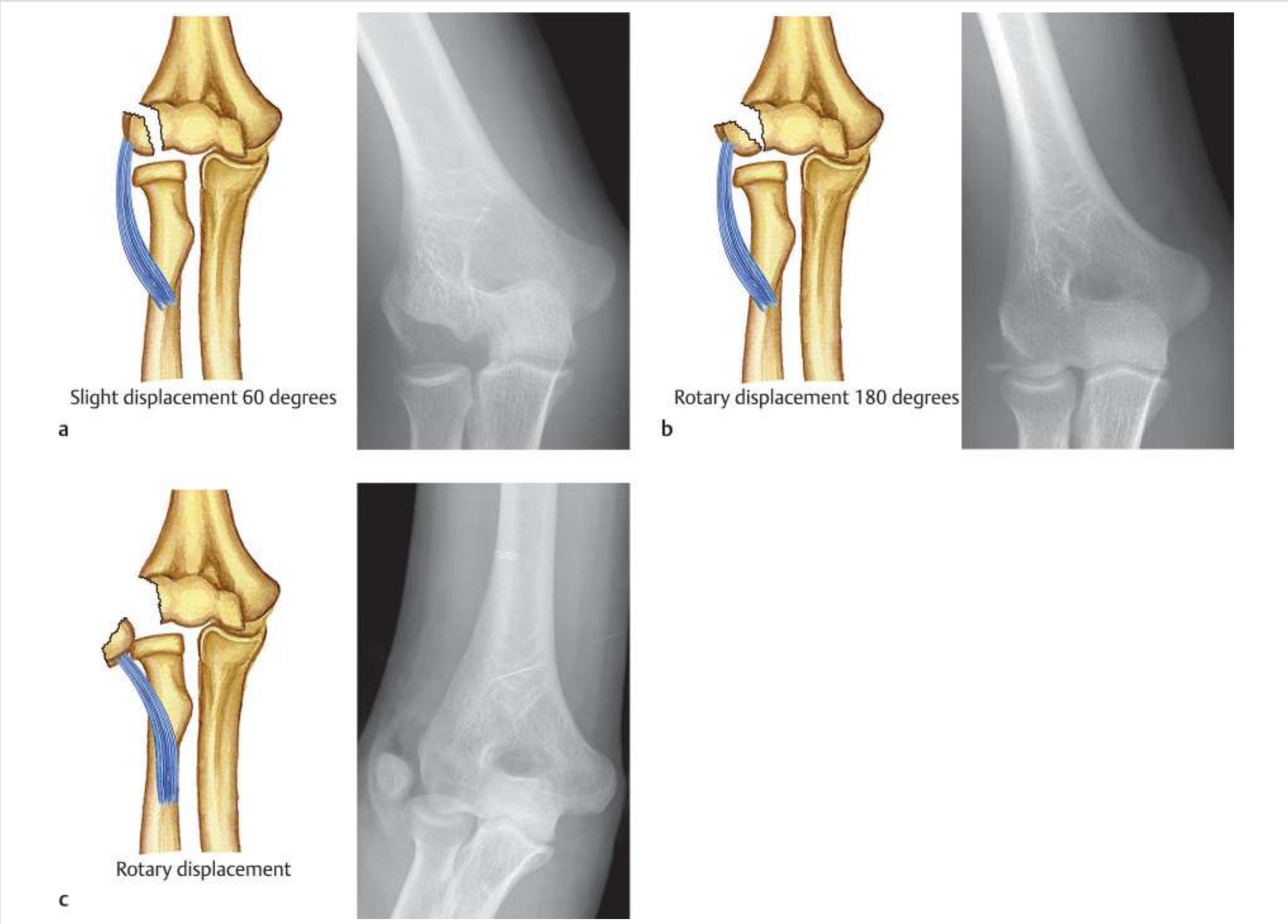


Fig. 2.71 (a–c) Lateral humeral epicondyle fractures.

Lateral Humeral Epicondyle Fractures by Sex

See ▶ Table 2.33 and ▶ Fig. 2.72.

Table 2.33 Sex distribution of 756 lateral epicondyle fractures of the humerus

Sex	Number of fractures	Percentage
Male	481	63.62
Female	275	36.38
Total	756	100.00

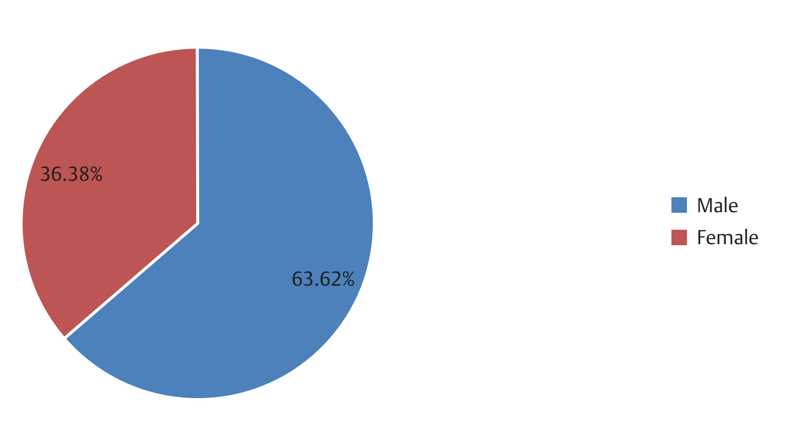


Fig. 2.72 Sex distribution of 756 lateral epicondyle fractures of the humerus.

Lateral Humeral Epicondyle Fractures by Age Group

See ▶ Table 2.34 and ▶ Fig. 2.73.

Table 2.34 Age and sex distribution of 756 lateral epicondyle fractures of the humerus

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	80	43	123	16.27
6–10	72	31	103	13.62
11–15	47	20	67	8.86
16–20	47	22	69	9.13
21–25	56	16	72	9.52
26–30	47	3	50	6.61
31–35	23	15	38	5.03
36–40	41	14	55	7.28
41–45	18	10	28	3.70
46–50	13	15	28	3.70
51–55	10	20	30	3.97
56–60	12	22	34	4.50
61–65	5	8	13	1.72
66–70	4	18	22	2.91
71–75	4	5	9	1.19
76–80	0	6	6	0.79
81–85	1	6	7	0.93
≥ 86	1	1	2	0.26
Total	481	275	756	100.00

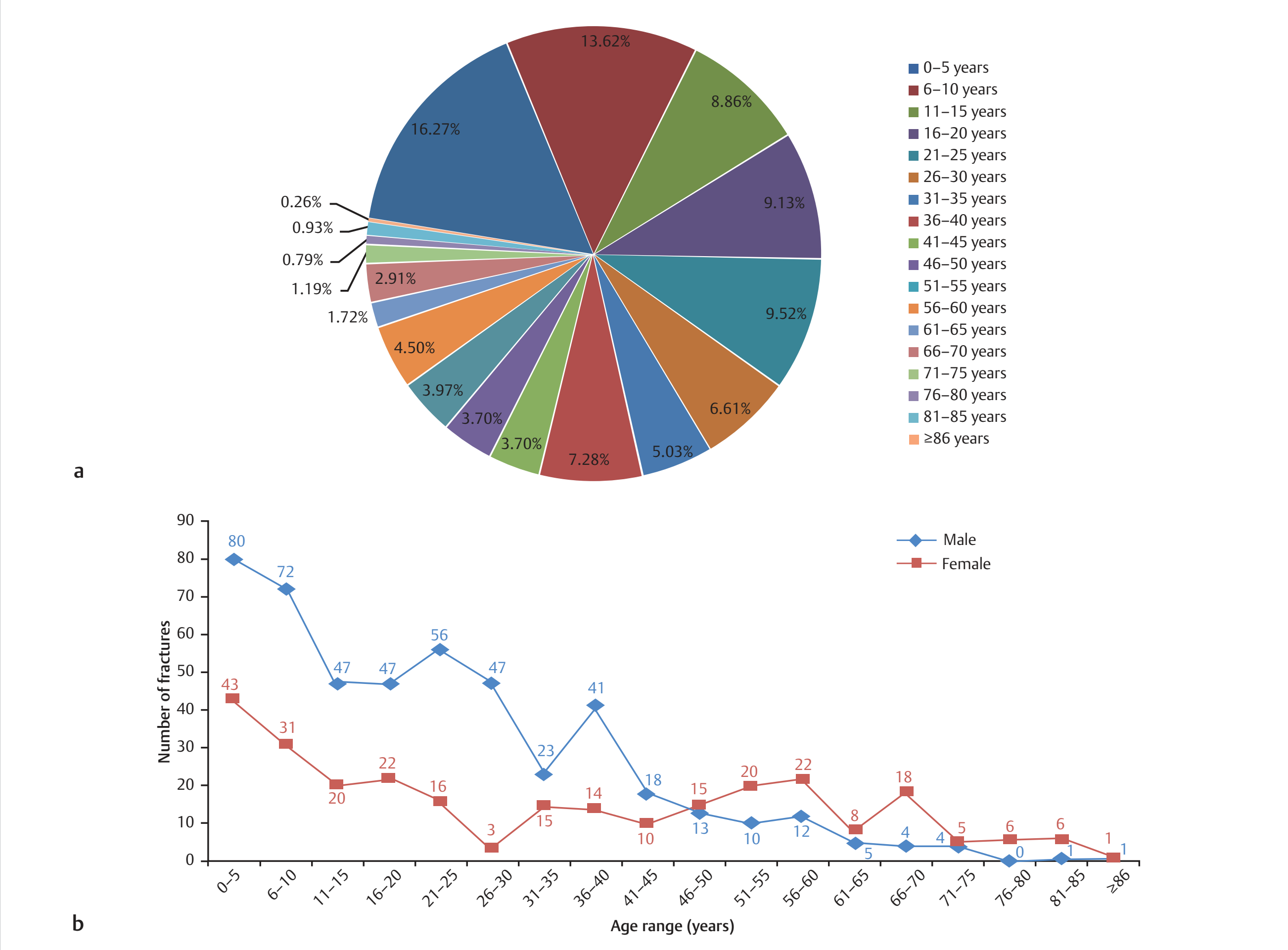


Fig. 2.73 (**a**) Age distribution of 756 lateral epicondyle fractures of the humerus. (**b**) Age and sex distribution of 756 lateral epicondyle fractures of the humerus.

Medial Humeral Epicondyle Fractures

Overview

This type of injury is often caused by a fall on flat ground or a sports-related injury such as throwing a ball. It produces a muscular avulsion fracture secondary to contraction of the forearm flexor musculature, due to a fall with the forearm in backward extension and abduction. The avulsion fragment displaces anteriorly and distally, and with possible rotation. Based on the degree of fragment displacement and the alteration in the elbow joint, medial epicondyle humeral fracture is classified into four types:

- *Type I*: with minimal fragment displacement (▶ Fig. 2.74)
- *Type II*: the fragment is markedly displaced by traction of the muscle, and may reach the same level as the elbow joint, with possible rotation (< 30 degrees) (▶ Fig. 2.75)
- *Type III*: the fragment is detached and stuck within the elbow joint space, with the elbow in semi-dislocation (▶ Fig. 2.76)
- *Type IV*: the fragment is detached and stuck within the articulation site, with posterior or posterolateral elbow dislocation (▶ Fig. 2.77)

Clinical Epidemiologic Features of Medial Epicondyle Fractures

A total of 865 medial epicondyle humeral fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 2.42% of all humeral fractures. The epidemiologic features are as follows:

- More males than females
- The high-risk age group is 11–15 years

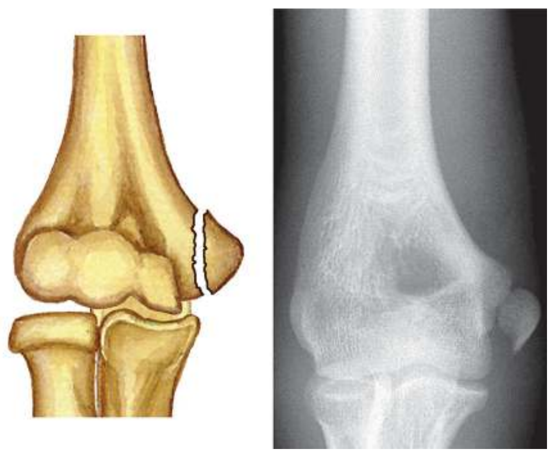


Fig. 2.74 Type I medial humeral epicondyle fractures.

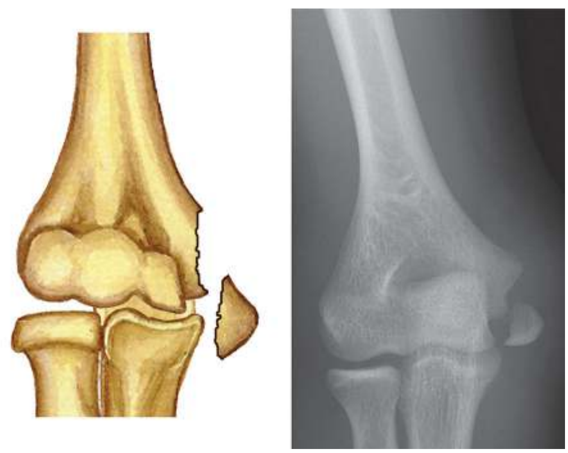


Fig. 2.75 Type II medial humeral epicondyle fractures.

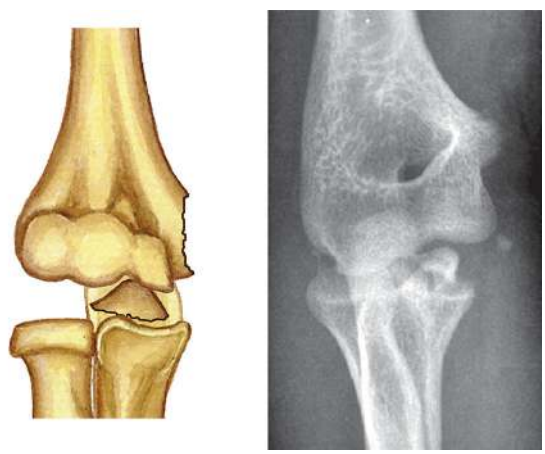


Fig. 2.76 Type III medial humeral epicondyle fractures.

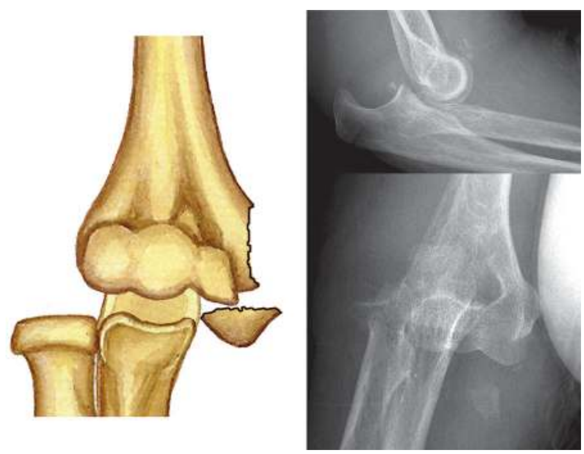


Fig. 2.77 Type IV medial humeral epicondyle fractures.

Medial Humeral Epicondyle Fractures by Sex

See ▶ Table 2.35 and ▶ Fig. 2.78.

Table 2.35 Sex distribution of 865 medial epicondyle fractures of the humerus

Sex	Number of fractures	Percentage
Male	568	65.66
Female	297	34.34
Total	865	100.00

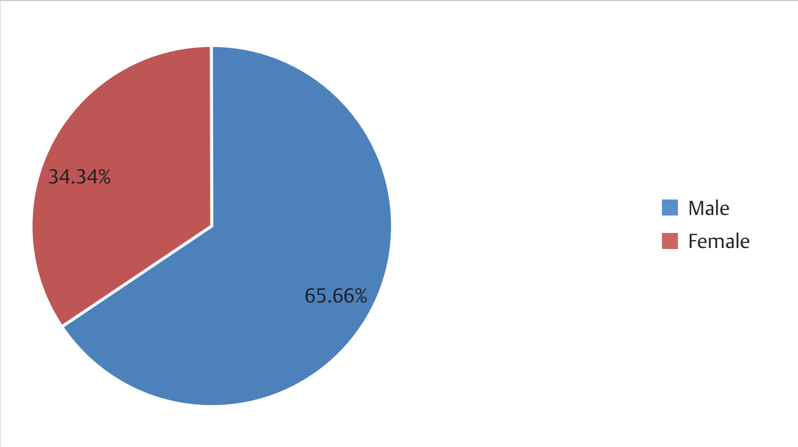


Fig. 2.78 Sex distribution of 865 medial epicondyle fractures of the humerus.

Medial Humeral Epicondyle Fractures by Age Group

See ▶ Table 2.36 and ▶ Fig. 2.79.

Table 2.36 Age and sex distribution of 865 medial epicondyle fractures of the humerus

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	42	40	82	9.48
6–10	73	54	127	14.68
11–15	117	52	169	19.54
16–20	98	12	110	12.72
21–25	58	8	66	7.63
26–30	30	9	39	4.51
31–35	28	13	41	4.74
36–40	25	15	40	4.62
41–45	19	16	35	4.05
46–50	15	13	28	3.24
51–55	20	16	36	4.16
56–60	18	15	33	3.82
61–65	8	11	19	2.20
66–70	6	8	14	1.62
71–75	5	10	15	1.73
76–80	5	2	7	0.81
81–85	1	2	3	0.35
≥ 86	0	1	1	0.12
Total	568	297	865	100.00

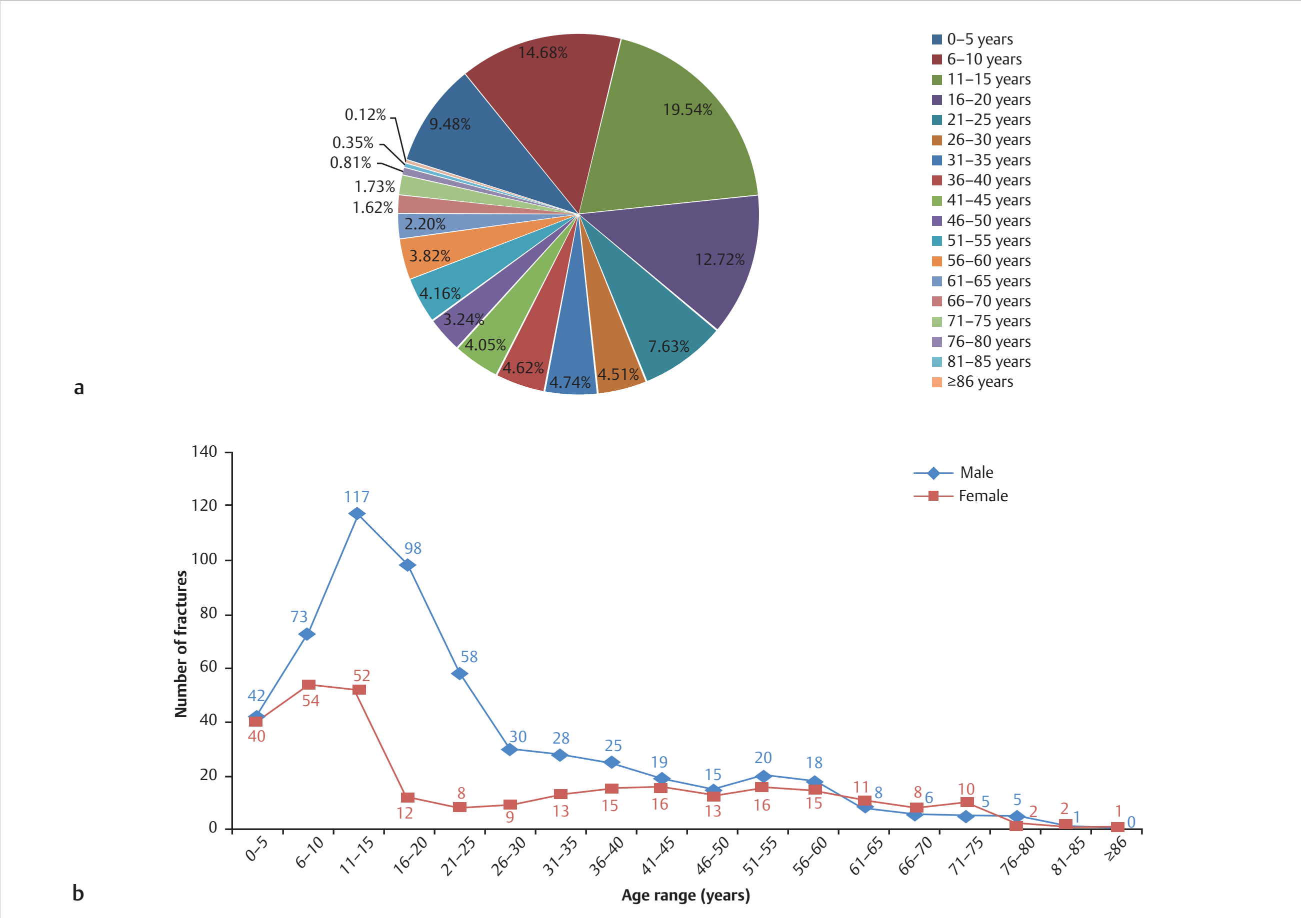


Fig. 2.79 (**a**) Age distribution of 865 medial epicondyle fractures of the humerus. (**b**) Age and sex distribution of 865 medial epicondyle fractures of the humerus.

■ Humeral Capitellum Fractures

Overview

The most frequently reported mechanism of injury to the humeral capitellum is a fall on an outstretched hand, with axial compression and the elbow in slight flexion. The resulting axial force shears the capitellum from the distal humerus through the radial head.

Based on the size of the fracture fragment and extent of the fracture line, capitellum fracture can be classified into three types:

- *Type I (Hahn-Steinthal fracture)*: complete fracture with fragments containing capitellum and the adjacent lip of the trochlea (▶ Fig. 2.80)
- *Type II (Kocher-Lorenz fracture)*: simple complete capitellum fracture with minimal fragmentation, which is difficult to detect on X-ray film (▶ Fig. 2.81)
- *Type III*: the capitellum is comminuted with separate trochlear fragments (▶ Fig. 2.82)

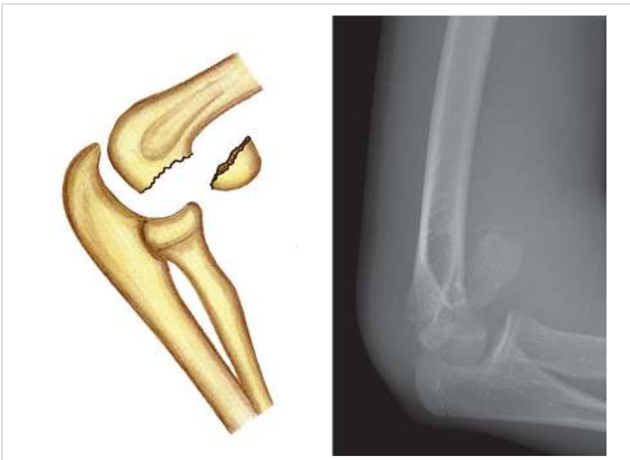


Fig. 2.80 Type I humeral capitellum fractures.

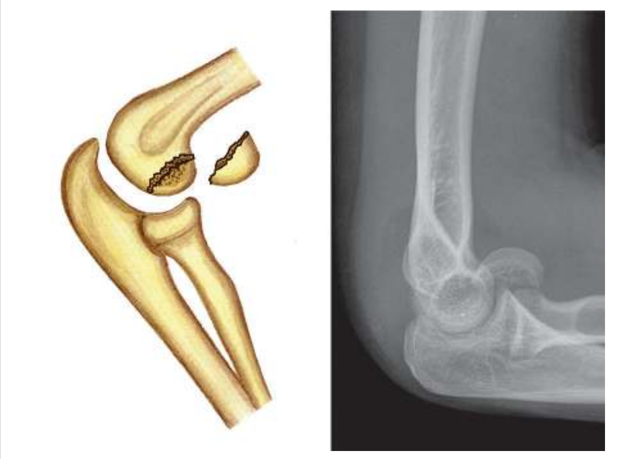


Fig. 2.81 Type II humeral capitellum fractures.

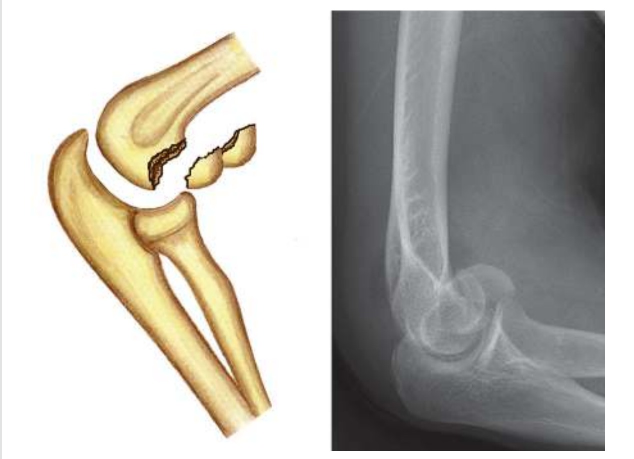


Fig. 2.82 Type III humeral capitellum fractures.

Clinical Epidemiologic Features of Humeral Capitellum Fractures

A total 196 capitellum fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 0.55% of all humeral fractures. The epidemiologic features are as follows:

- More males than females
- The high-risk age group is 6–10 years

Humeral Capitellum Fractures by Sex

See ▶ Table 2.37 and ▶ Fig. 2.83.

Table 2.37 Sex distribution of 196 capitellum fractures of the humerus

Sex	Number of fractures	Percentage
Male	122	62.24
Female	74	37.76
Total	196	100.00

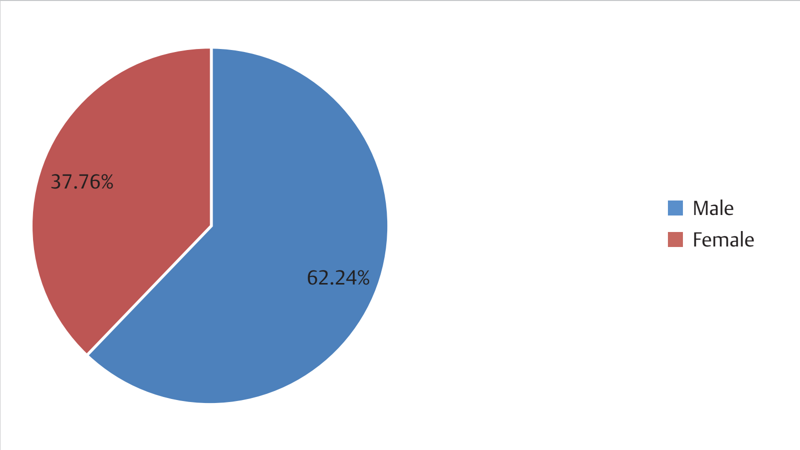


Fig. 2.83 Sex distribution of 196 capitellum fractures of the humerus.

Humeral Capitellum Fractures by Age Group

See ▶ Table 2.38 and ▶ Fig. 2.84.

Table 2.38 Age and sex distribution of 196 capitellum fractures of the humerus

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	18	8	26	13.27
6–10	21	14	35	17.86
11–15	8	2	10	5.10
16–20	15	6	21	10.71
21–25	11	8	19	9.69
26–30	8	2	10	5.10
31–35	12	3	15	7.65
36–40	6	3	9	4.59
41–45	5	5	10	5.10
46–50	4	4	8	4.08
51–55	5	4	9	4.59
56–60	1	4	5	2.55
61–65	2	4	6	3.06
66–70	1	0	1	0.51
71–75	3	3	6	3.06
76–80	1	3	4	2.04
81–85	1	1	2	1.02
≥ 86	0	0	0	0.00
Total	122	74	196	100.00

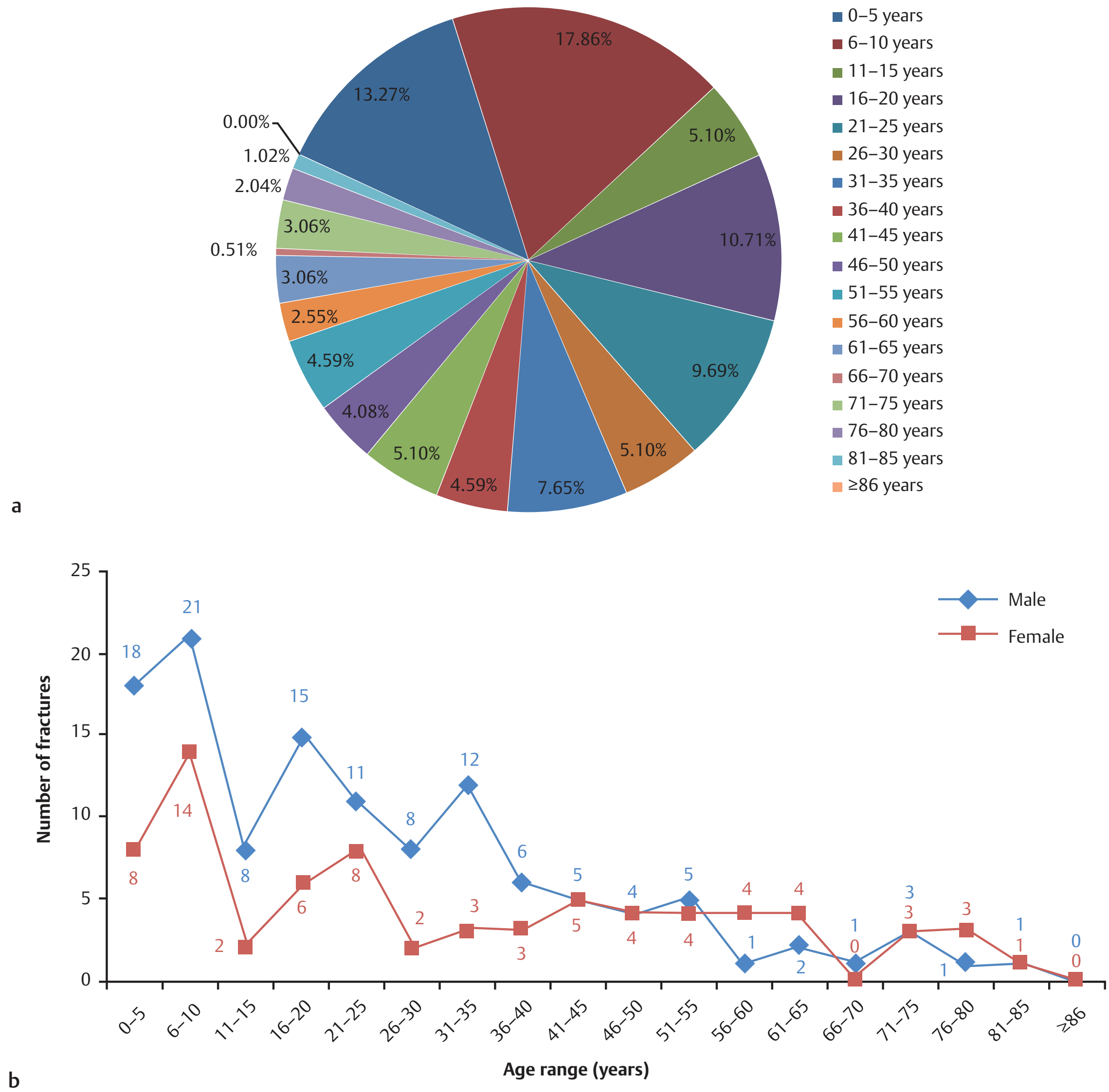


Fig. 2.84 (**a**) Age distribution of 196 capitellum fractures of the humerus. (**b**) Age and sex distribution of 196 capitellum fractures of the humerus.

Suggested Readings

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3 Fractures of the Ulna and Radius

Yingze Zhang, Song Liu, and Chenguang Du

Overview of Ulnar and Radial Fractures

Anatomic Features

The ulna and radius are the bony structures of the forearm that form the elbow joint proximally with the humerus and the wrist joint distally with the carpals. The radius and ulna are joined by the proximal and distal radioulnar joints and by the interosseous membrane (IOM). The radioulnar joints are pivot joints where movements of supination and pronation take place. If one bone shows a fracture with displacement or angulation, usually the other bone will also have a fracture or displacement. Both the radius and ulna are long bones, prismatic in form, and lie roughly parallel to each other when the forearm is supinated. The ulna is relatively straight, while the radius is slightly curved longitudinally (▶ Fig. 3.1).

AO Classification and Coding System for Fractures of Ulna and Radius

Based on the AO classification, the ulna/radius should be considered as one unit of bone, with the location coding number "2." The anatomic delineation of the segments, proximal, shaft, and distal, is performed according to the "Heim's Square," with assigned numbers of "21, 22, and 23," respectively (▶ Fig. 3.2; ▶ Fig. 3.3).

Epidemiologic Features of Radial/Ulnar Fractures in the China National Fracture Study

A total of 355 patients with 356 radial/ulnar fractures were investigated in the China National Fracture Study (CNFS). The fractures accounted for 20.14% of all patients with fractures and 19.42% of all types of fractures. The population-weighted incidence rate of radial/ulnar fractures was 63 per 100,000 population in 2014. The epidemiologic features of radial/ulnar fractures in the CNFS are as follows:

- More females than males
- More right-side injuries than left-side injuries
- The highest-risk age group is 15–64 years
- Distal fracture of the radius/ulna is the most common forearm fracture
- Injuries occurred most commonly via slips, trips, or falls

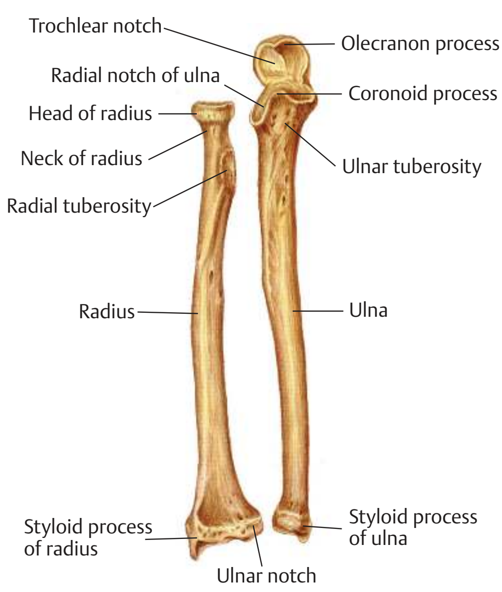

Fig. 3.1 Anterior view of the ulna and radius.

Fig. 3.2 AO coding for the ulna and radius.

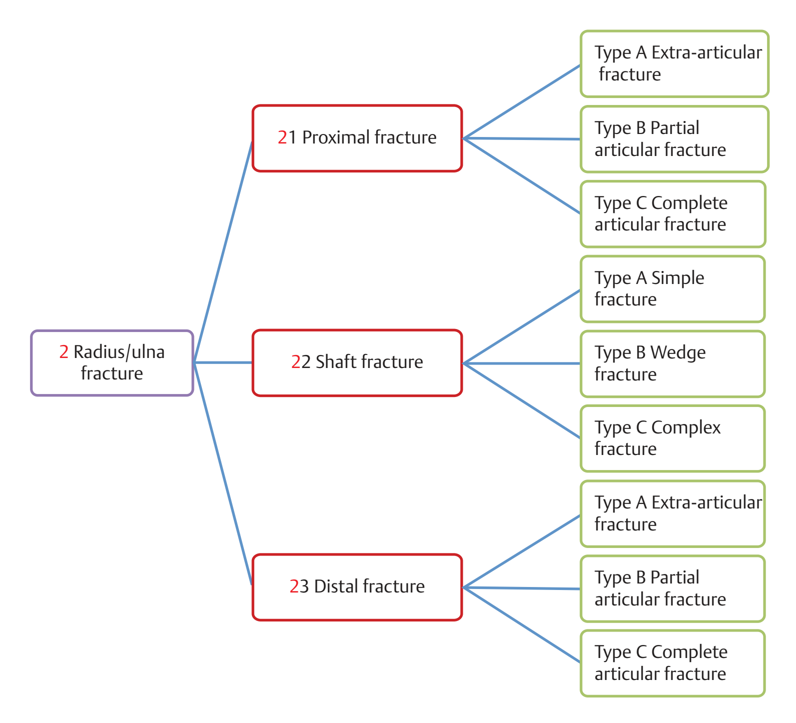

Fig. 3.3 Algorithm.

■ Radial/Ulnar Fracture by Sex

See ▶ Table 3.1 and ▶ Fig. 3.4.

Table 3.1 Sex distribution of 355 patients with radial/ulnar fractures in the China National Fracture Study

Sex	Number of patients	Percentage
Male	153	43.10
Female	202	56.90
Total	355	100.00

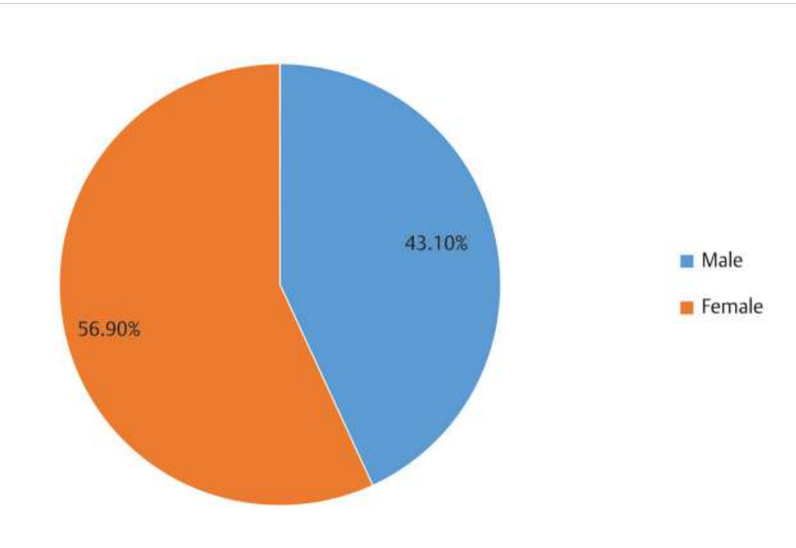

Fig. 3.4 Sex distribution of 355 patients with radial/ulnar fractures in the China National Fracture Study (CNFS).

■ Radial/Ulnar Fracture by Injury Side

See ▶ Table 3.2 and ▶ Fig. 3.5.

Table 3.2 Injury side distribution of 355 patients with radial/ulnar fractures in the China National Fracture Study

Injured side	Number of patients	Percentage
Left	169	47.61
Right	185	52.11
Bilateral	1	0.28
Total	355	100.00

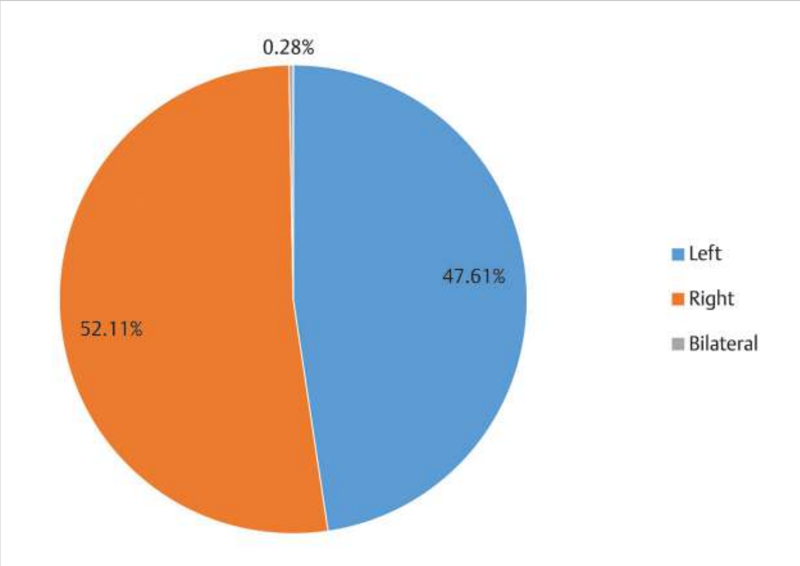

Fig. 3.5 Injury side distribution of 355 patients with radial/ulnar fractures in the China National Fracture Study (CNFS).

■ Radial/Ulnar Fracture by Age Group and Sex

See ▶ Table 3.3 and ▶ Fig. 3.6.

Table 3.3 Age and sex distribution of 355 patients with radial/ulnar fractures in the China National Fracture Study

Age group (years)	Male	Female	Total	Percentage
0–14	26	20	46	12.96
15–64	113	129	242	68.17
≥65	14	53	67	18.87
Total	153	202	355	100.00

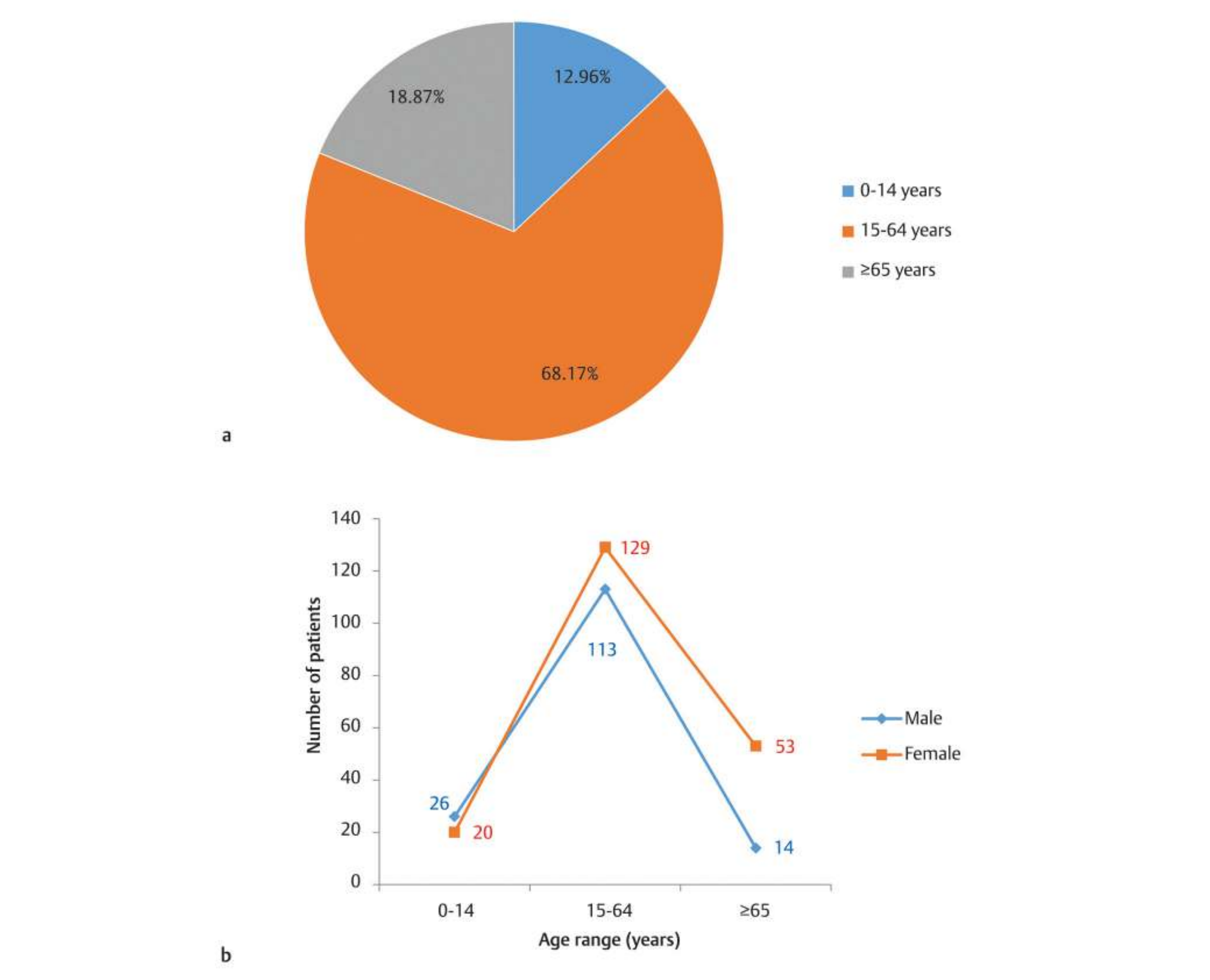

Fig. 3.6 (**a**) Age distribution of 355 patients with radial/ulnar fractures in the China National Fracture Study (CNFS). (**b**) Age and sex distribution of 355 patients with radial/ulnar fractures in the CNFS.

■ Radial/Ulnar Fracture by Location

See ▶ Table 3.4 and ▶ Fig. 3.7.

Table 3.4 Segment distribution of 355 patients with radial/ulnar fractures in the China National Fracture Study based on AO classification

Segment	Male	Female	Total	Percentage
21	27	27	54	15.17
22	47	34	81	22.75
23	80	141	221	62.08
Total	154	202	356	100.00

3

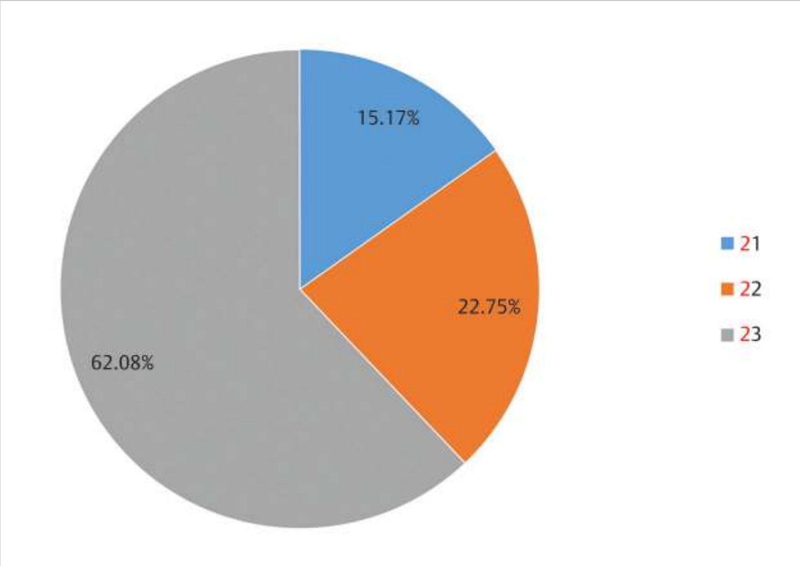

Fig. 3.7 Segment distribution of 355 patients with radial/ulnar fractures in the China National Fracture Study (CNFS) based on AO classification.

■ Radial/Ulnar Fracture by Causal Mechanisms

See ▶ Table 3.5 and ▶ Fig. 3.8.

Table 3.5 Causal mechanisms distribution of 355 patients with radial/ulnar fractures in the China National Fracture Study

Causal mechanisms	Male	Female	Total	Percentage
Traffic accident	20	22	42	11.83
Slip, trip, or fall	101	175	276	77.75
Fall from heights	14	3	17	4.79
Crushing injury	8	2	10	2.82
Sharp trauma	3	0	3	0.85
Blunt force trauma	7	0	7	1.97
Total	153	202	355	100.00

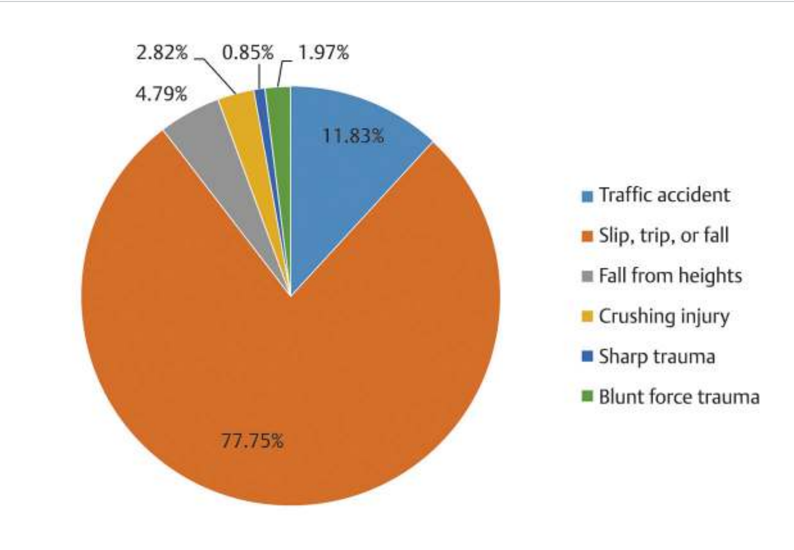

Fig. 3.8 Causal mechanisms distribution of 355 patients with radial/ulnar fractures in the China National Fracture Study.

Clinical Epidemiologic Features of Radial/Ulnar Fractures

A total of 75,850 patients with 76,550 radial/ulnar fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 18.28% of all patients with fractures and 17.73% of all types of fractures, respectively. Among these 75,850 patients, 18,274 were children with 18,334 fractures, and 57,576 were adults with 58,216 fractures. Epidemiologic features of radial/ulnar fractures are as follows:

- More males than females
- More left sides involved than right sides
- The highest-risk age group is 11–15 years; the most affected female age group is 56–60 years, while males between the ages of 11 and 15 years have the highest risk
- Distal fracture of the radius/ulna is the most common forearm fracture

Radial/Ulnar Fractures by Sex

See ▶ Table 3.6 and ▶ Fig. 3.9.

Table 3.6 Sex distribution of 75,850 patients with radial/ulnar fractures

Sex	Number of patients	Percentage
Male	41,592	54.83
Female	34,258	45.17
Total	75,850	100.00

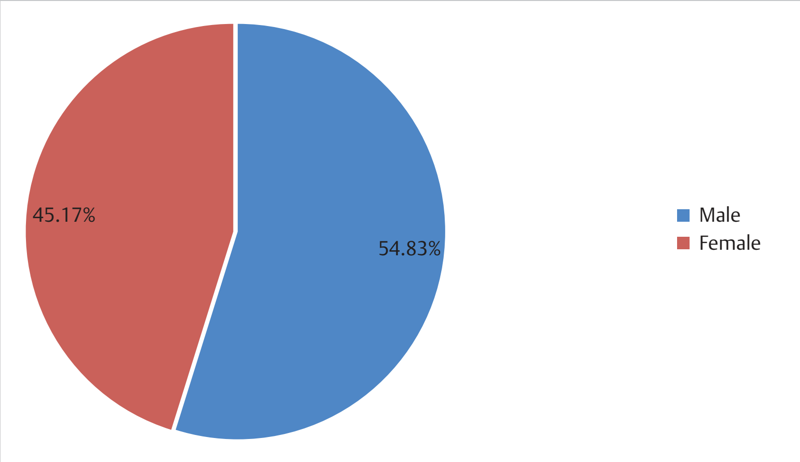

Fig. 3.9 Sex distribution of 75,850 patients with radial/ulnar fractures.

■ Radial/Ulnar Fractures by Injured Side

See ► Table 3.7 and ► Fig. 3.10.

Table 3.7 Injury side distribution of 75,850 patients with radial/ulnar fractures

Injury side	Number of patients	Percentage
Left	40,576	53.50
Right	34,936	46.06
Bilateral	338	0.45
Total	75,850	100.00

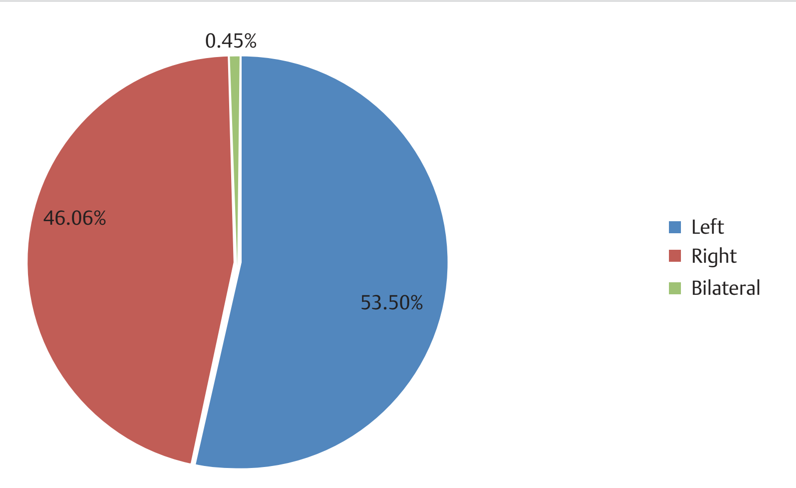

Fig. 3.10 Injury side distribution of 75,850 patients with radial/ulnar fractures.

■ Radial/Ulnar Fractures by Age Group

See ▶ Table 3.8 and ▶ Fig. 3.11.

Table 3.8 Age and sex distribution of 75,850 patients with radial/ulnar fractures

Age group (years)	Male	Female	Number of patients	Percentage
0–5	2,742	1,552	4,294	5.66
6–10	4,789	1,764	6,553	8.64
11–15	6,306	1,121	7,427	9.79
16–20	3,508	820	4,328	5.71
21–25	3,258	1,047	4,305	5.68
26–30	2,679	1,036	3,715	4.90
31–35	2,363	1,167	3,530	4.65
36–40	3,023	1,562	4,585	6.04
41–45	2,958	1,800	4,758	6.27
46–50	2,950	2,854	5,804	7.65
51–55	2,039	3,685	5,724	7.55
56–60	1,835	4,853	6,688	8.82
61–65	1,096	3,205	4,301	5.67
66–70	723	2,635	3,358	4.43
71–75	529	2,088	2,617	3.45
76–80	426	1,720	2,146	2.83
81–85	243	889	1,132	1.49
≥ 86	125	460	585	0.77
Total	41,592	34,258	75,850	100.00

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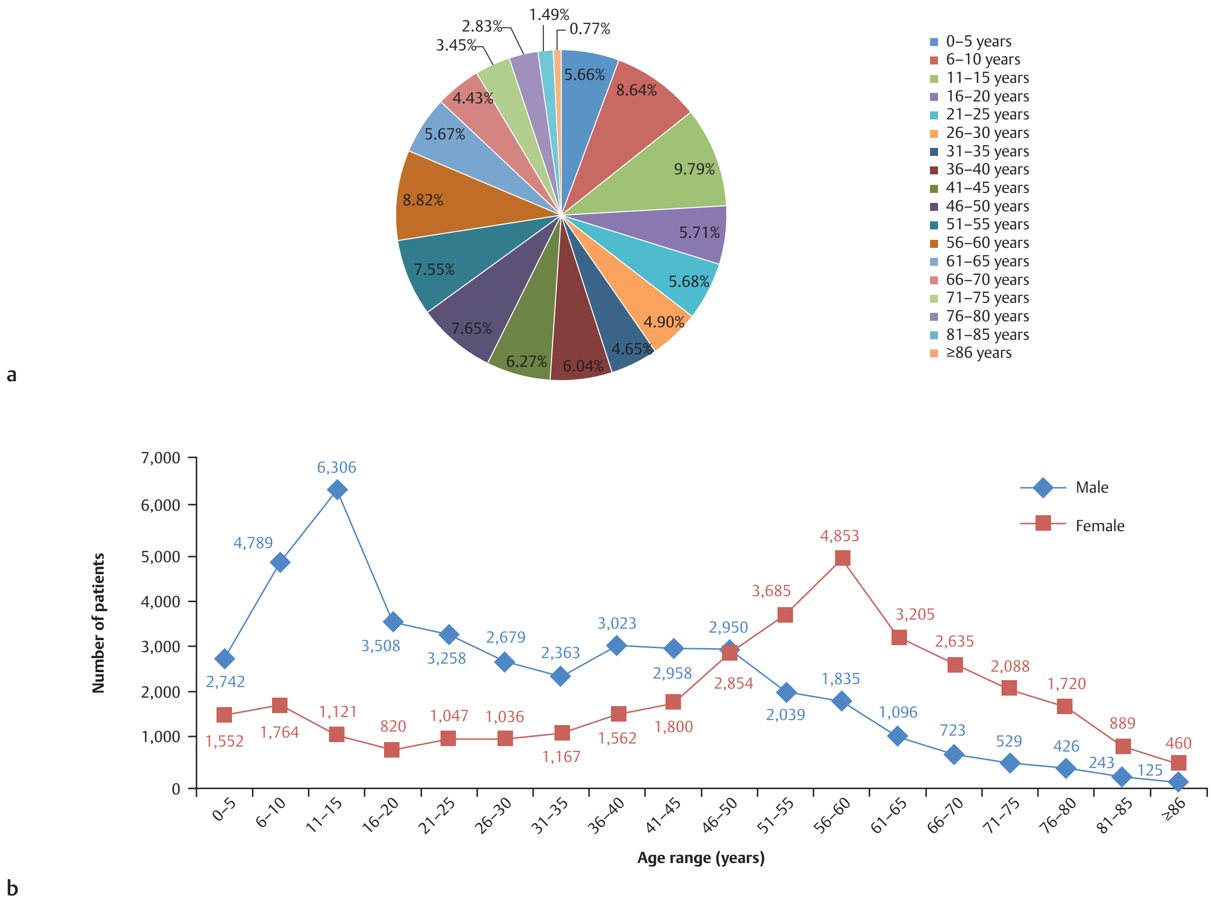


Fig. 3.11 (a) Age distribution of 75,850 patients with radial/ulnar fractures. (b) Age and sex distribution of 75,850 patients with radial/ulnar fractures.

Radial/Ulnar Fractures by Location

Radial/Ulnar Fractures in Adults by Segment Based on AO Classification

See ▶ Table 3.9 and ▶ Fig. 3.12.

Table 3.9 Segment distribution of 58,216 radial/ulnar fractures in adults based on AO classification

Segment	Number of fractures	Percentage
21	7,202	12.37
22	7,594	13.04
23	43,420	74.58
Total	58,216	100.00

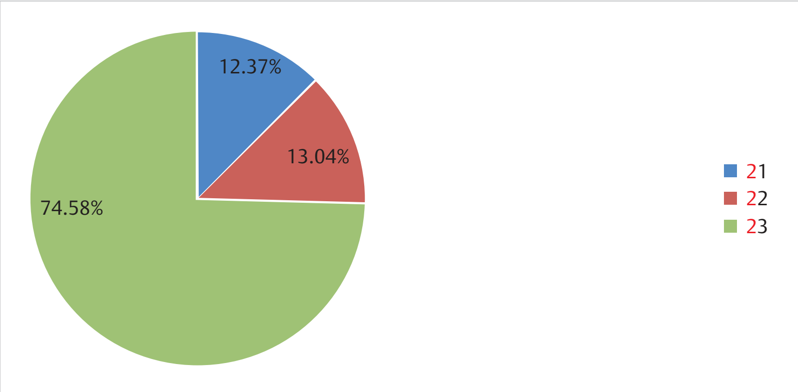


Fig. 3.12 Segment distribution of 58,216 radial/ulnar fractures in adults based on AO classification.

Radial/Ulnar Fractures in Children by Segment

See ▶ Table 3.10 and ▶ Fig. 3.13.

Table 3.10 Segment distribution of 18,334 radial/ulnar fractures in children

Segment	Number of fractures	Percentage
Proximal	3,427	18.69
Diaphysis	6,113	33.34
Distal	8,794	47.97
Total	18,334	100.00

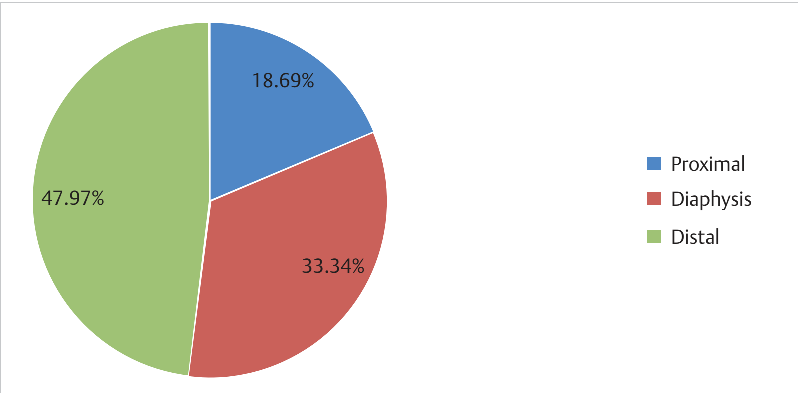


Fig. 3.13 Segment distribution of 18,334 radial/ulnar fractures in children.

Proximal Radial/Ulnar Fractures (Segment 21)

Anatomic Features

The bony structures of the proximal part of the radius/ulna consist of the olecranon, coronoid process, radial head, radial neck, and part of the metaphysis. The bony surfaces of the humeroradial joint constitute an enarthrosis or ball and socket joint, between the radial head and the capitulum of the humerus, while the proximal radioulnar joint is a trochoid or pivot joint

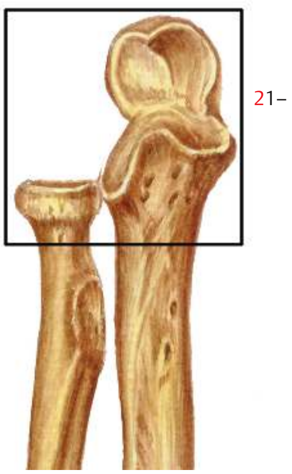


Fig. 3.14 AO coding for the proximal ulna/radius.

between the radial head and the ring formed by the radial notch of the ulna and the annular ligament. These two joints play an important role in the complex action of turning the forearm over as in pronation or supination. The humeroradial joint is considered similar to a lateral column that provides stability to the elbow joint during its motion in flexion or extension.

The articular surfaces of the elbow joint are connected by a capsule that is attached to the radial neck, 1.5 cm distal to the humeroradial joint. The radial tuberosity, also known as the bicipital tuberosity, is the main insertion of the biceps brachii muscle.

The olecranon and the coronoid process form a large depression called the semilunar notch that serves as an articulation site with the trochlea of the humerus. The humeroulnar joint is a simple hinge joint that allows for flexion and extension. The tendon of the triceps brachii muscle inserts into the posterior portion of the upper surface of the olecranon, while the ulnar nerve winds along the olecranon or epicondylar groove.

AO Classification of Proximal Radial/Ulnar Fractures

Based on AO classification, the delineation of the proximal radius/ulna is illustrated by a square whose lateral sides are parallel to the axis of the bone and their length equal to the maximum width of the epiphysis. According to this formula, the proximal radius/ulna is coded as the number 21 (▶ Fig. 3.14).

On the basis of articular surface involvement, the radial/ulnar fracture is further divided into three types: 21-A: extra-articular fracture; 21-B: partial articular fracture; and 21-C: complex articular fracture (▶ Fig. 3.15).

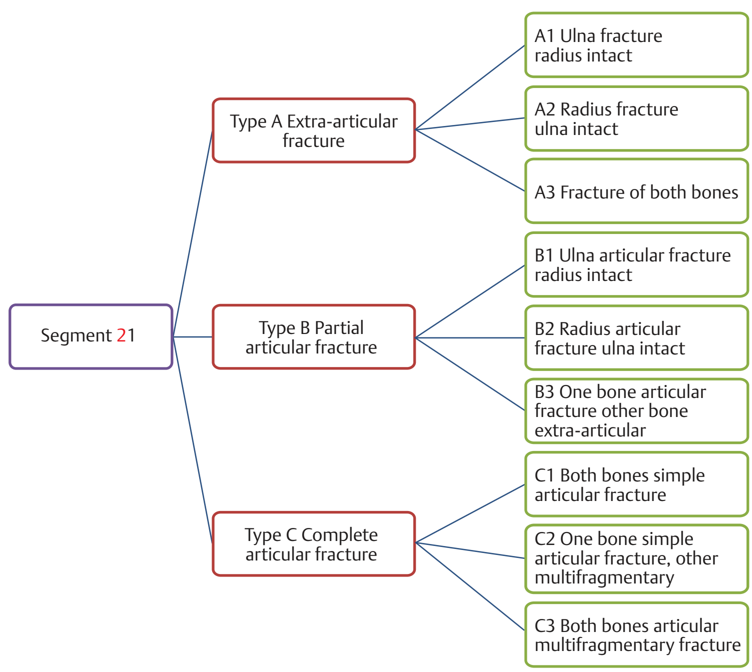


Fig. 3.15 Algorithm.

Clinical Epidemiologic Features of the Proximal Radial/Ulnar Fractures (Segment 21)

A total of 7,202 adult proximal radial/ulnar fractures (segment 21) were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 12.37% of all fractures of the radius/ulna in adult. Their epidemiologic features are as follows:

- More males than females
- The high-risk age group is 21–25 years: the same age group for males, while the most affected female age group is 46–50 years.
- The most common fracture type among segment 21 fractures is type 21-B: the same fracture type for both males and females
- The most common fracture group among segment 21 fractures is group 21-B1: the same fracture group for both males and females

3

Fractures of Segment 21 by Sex

See ▶ Table 3.11 and ▶ Fig. 3.16.

Table 3.11 Sex distribution of 7,202 fractures of segment 21

Sex	Number of fractures	Percentage
Male	4,526	62.84
Female	2,676	37.16
Total	7,202	100.00

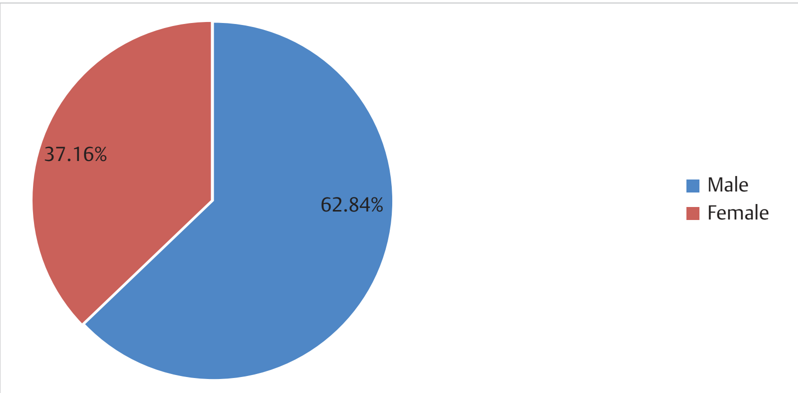


Fig. 3.16 Sex distribution of 7,202 fractures of segment 21.

■ Fractures of Segment 21 by Age Group

See ▶ Table 3.12 and ▶ Fig. 3.17.

Table 3.12 Age and sex distribution of 7202 fractures of segment 21

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	521	133	654	9.08
21–25	667	240	907	12.59
26–30	602	202	804	11.16
31–35	520	173	693	9.62
36–40	602	233	835	11.59
41–45	501	292	793	11.01
46–50	402	317	719	9.98
51–55	232	289	521	7.23
56–60	193	258	451	6.26
61–65	103	164	267	3.71
66–70	57	137	194	2.69
71–75	53	93	146	2.03
76–80	45	73	118	1.64
81–85	21	55	76	1.06
≥ 86	7	17	24	0.33
Total	4,526	2,676	7,202	100.00

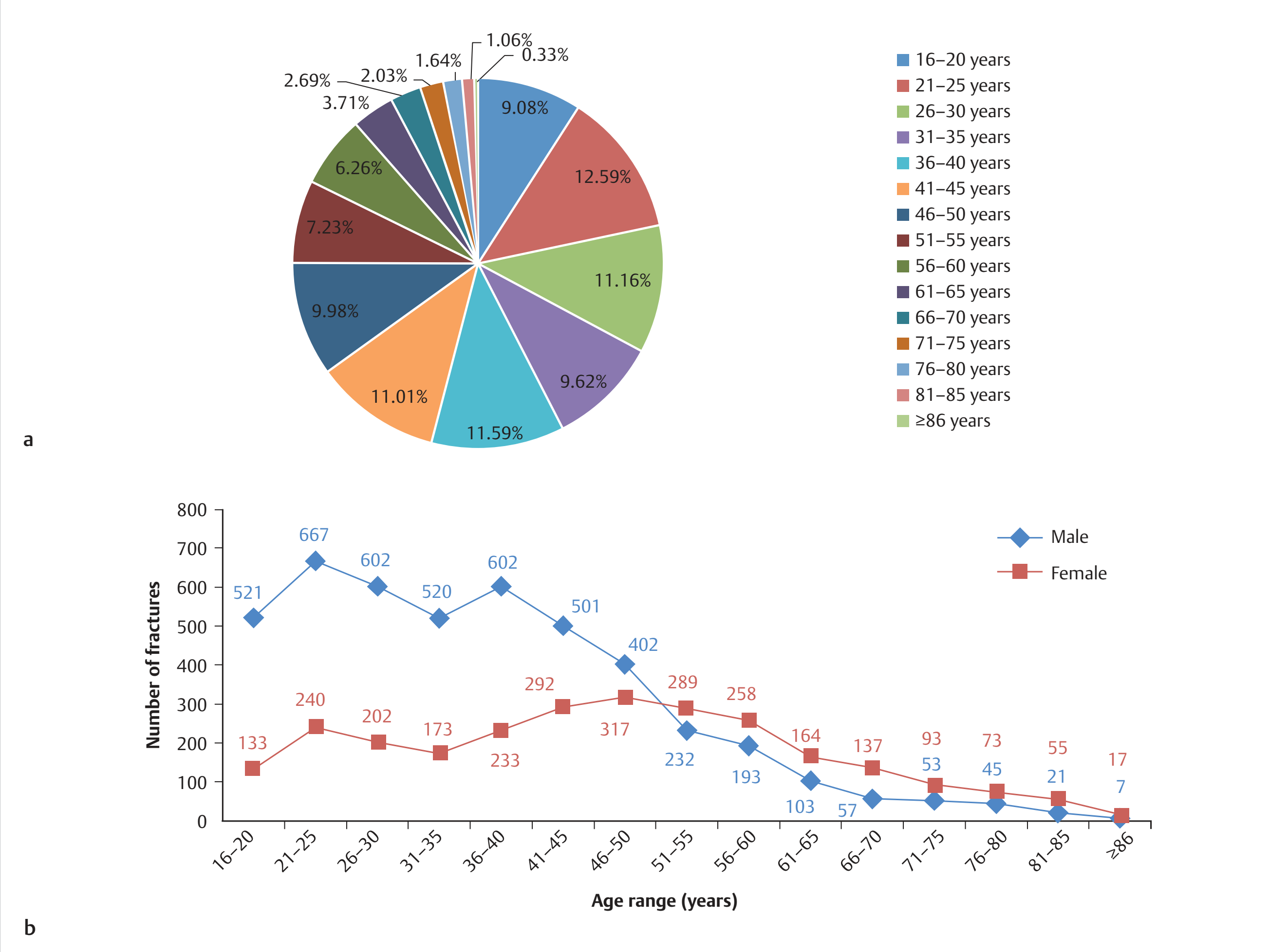


Fig. 3.17 (a) Age distribution of 7,202 fractures of segment 21. (b) Age and sex distribution of 7,202 fractures of segment 21.

■ Fractures of Segment 21 by Fracture Type

See ▶ Table 3.13, ▶ Table 3.14, ▶ Fig. 3.18, and ▶ Fig. 3.19.

Table 3.13 Sex and fracture type distribution of 7,202 fractures of segment 21

Fracture type	Male	Female	Number of fractures	Percentage
21-A	972	678	1,650	22.91
21-B	3,364	1,903	5,267	73.13
21-C	190	95	285	3.96
Total	4,526	2,676	7,202	100.00

Table 3.14 Sex and fracture group distribution of 7,202 fractures of segment 21

Fracture group	Male	Female	Number of fractures	Percentage of segment 21 fractures	Percentage of radial/ulnar fractures
21-A1	521	256	777	10.79	1.33
21-A2	412	394	806	11.19	1.38
21-A3	39	28	67	0.93	0.12
21-B1	1,809	964	2,773	38.50	4.76
21-B2	1,426	866	2,292	31.82	3.94
21-B3	129	73	202	2.80	0.35
21-C1	76	49	125	1.74	0.21
21-C2	66	24	90	1.25	0.15
21-C3	48	22	70	0.97	0.12
Total	4,526	2,676	7,202	100.00	12.37

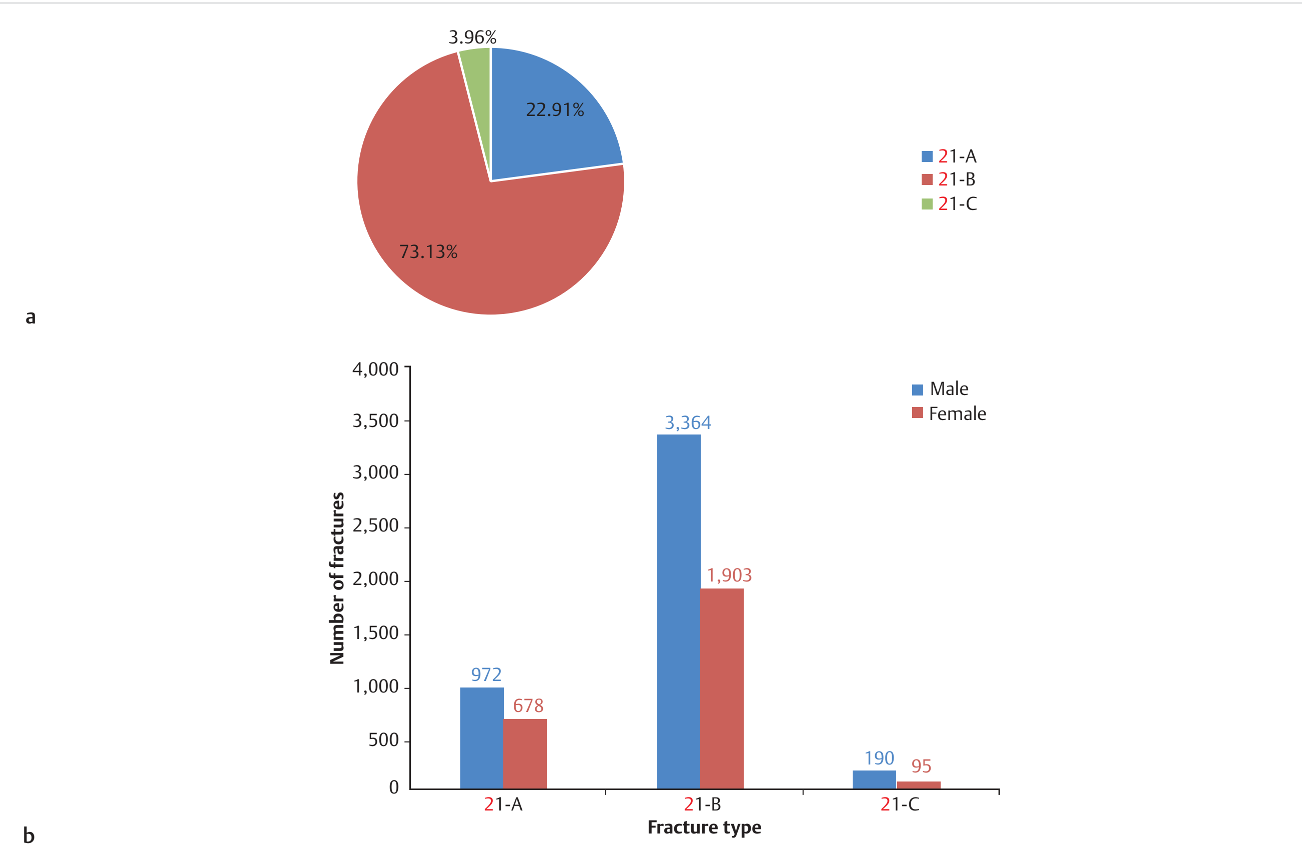


Fig. 3.18 (a) Fracture type distribution of 7,202 fractures of segment 21. (b) Sex and fracture type distribution of 7,202 fractures of segment 21.

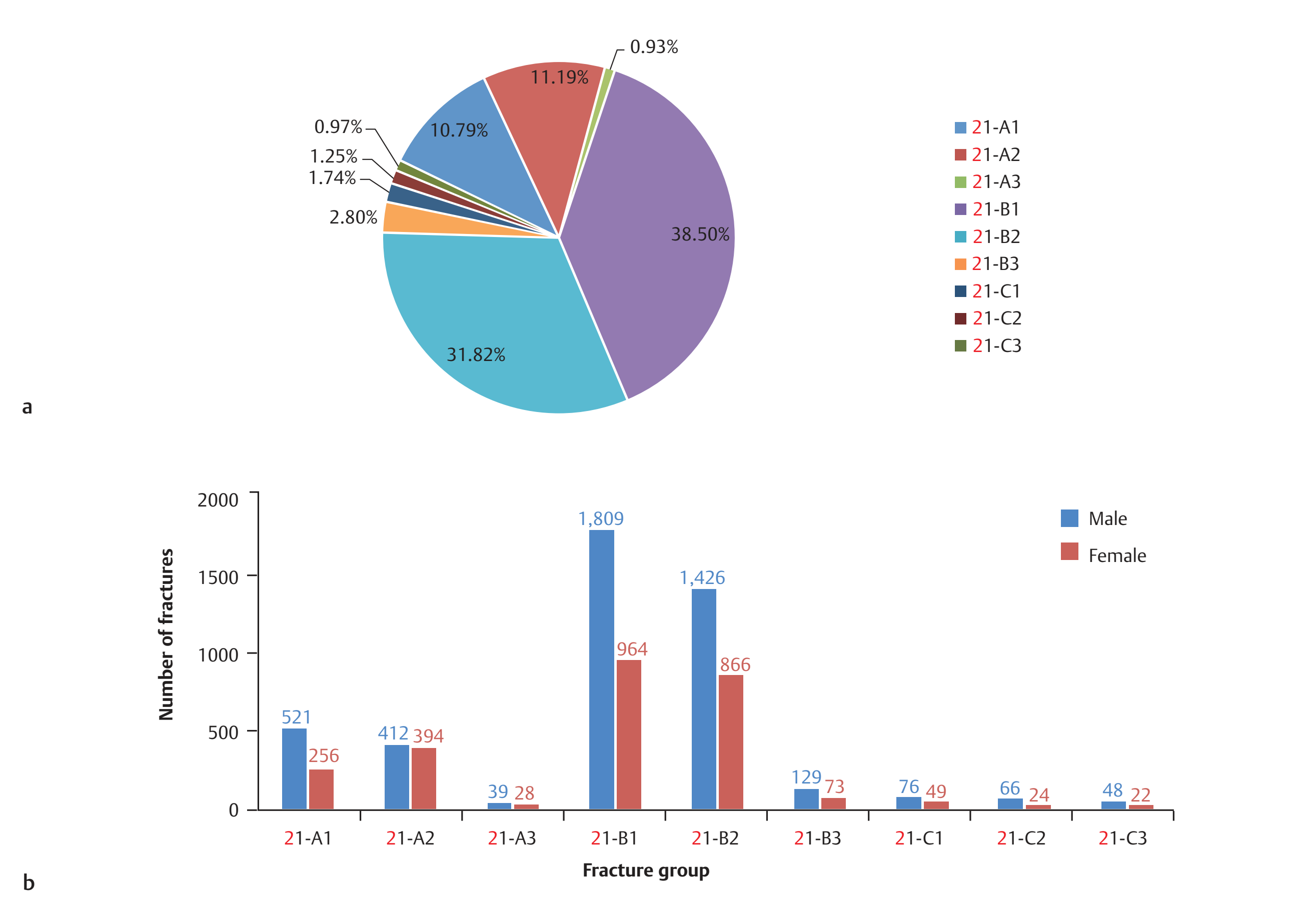
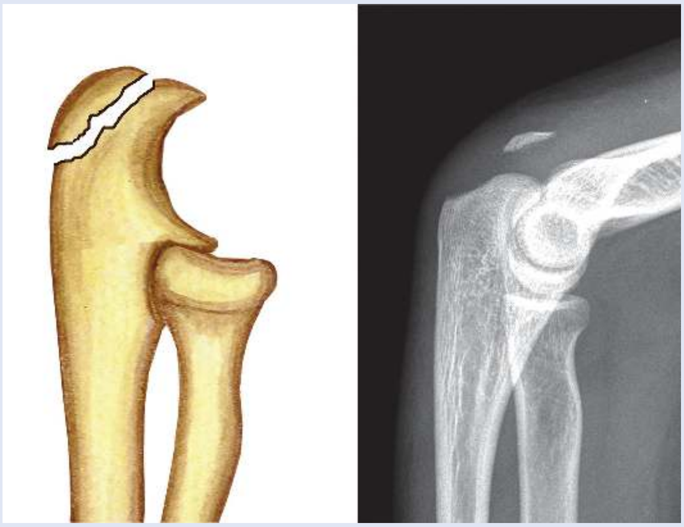


Fig. 3.19 (a) Fracture group distribution of 7,202 fractures of segment 21. (b) Sex and fracture group distribution of 7,202 fractures of segment 21.

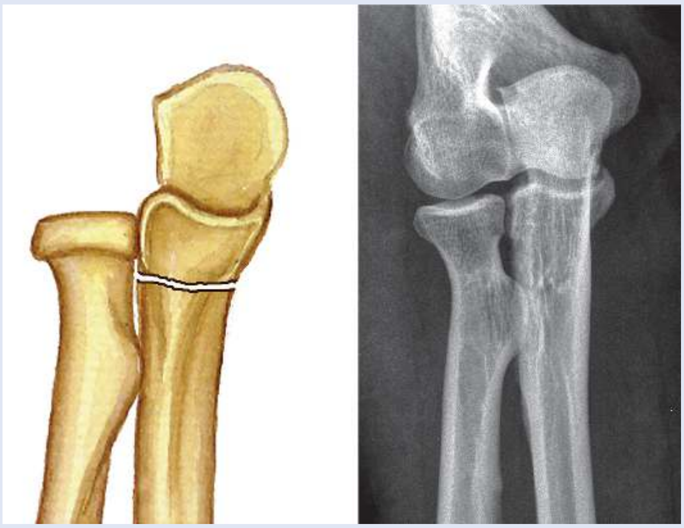
21-A Radius/ulna, proximal, extra-articular fractures

21-A1 Ulna, radius intact
777 fractures
M: 521 (67.05%)
F: 256 (32.95%)
0.21% of total adult fractures
1.33% of adult radius/ulna
10.79% of segment 21
47.09% of type 21-A

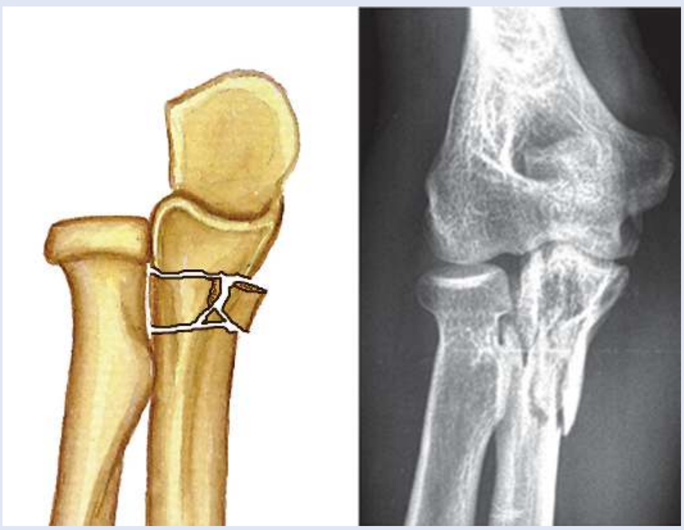
21-A1.1 Avulsion of triceps insertion from the olecranon



21-A1.2 Metaphyseal simple fracture



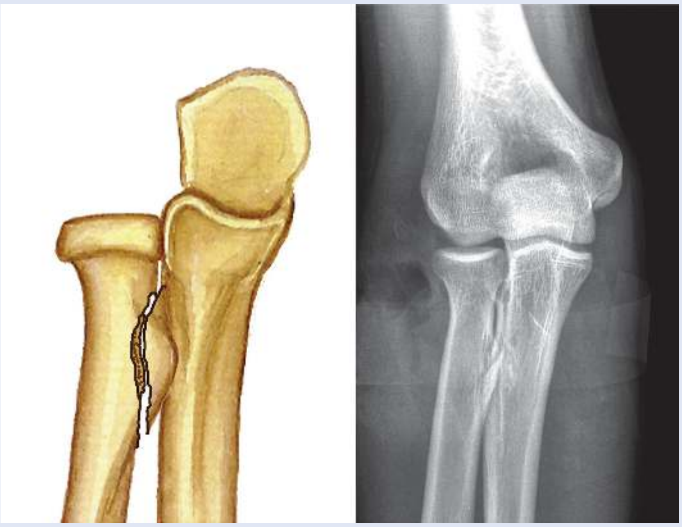
21-A1.3 metaphyseal multifragmentary fracture



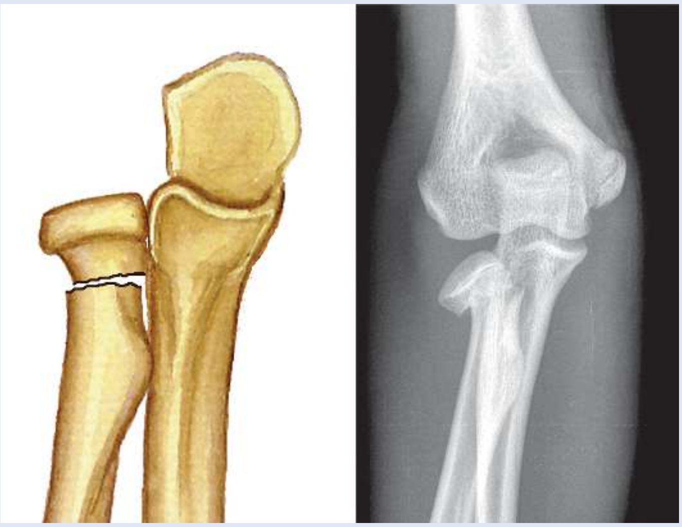
21-A Radius/ulna, proximal, extra-articular fractures

21-A2 Radius, ulna intact
806 fractures
M: 412 (52.12%)
F: 394 (48.88%)
0.22% of total adult fractures
1.38% of adult radius/ulna
11.19% of segment 21
48.85% of type 21-A

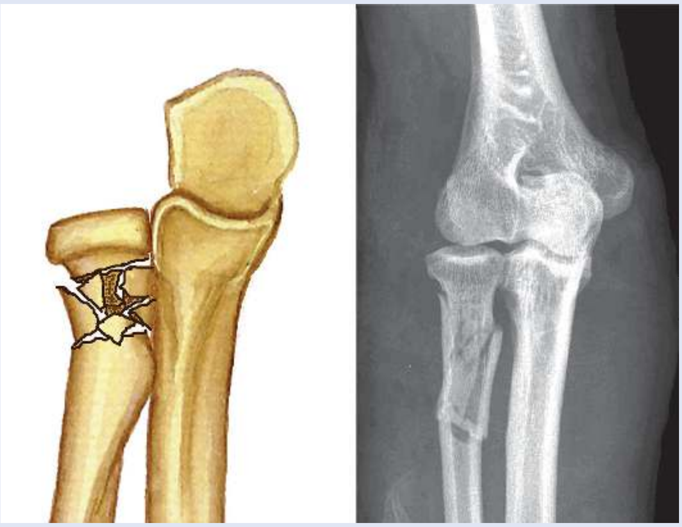
21-A2.1 Avulsion of biceps insertion from the radial tuberosity



21-A2.2 Radial neck simple fracture



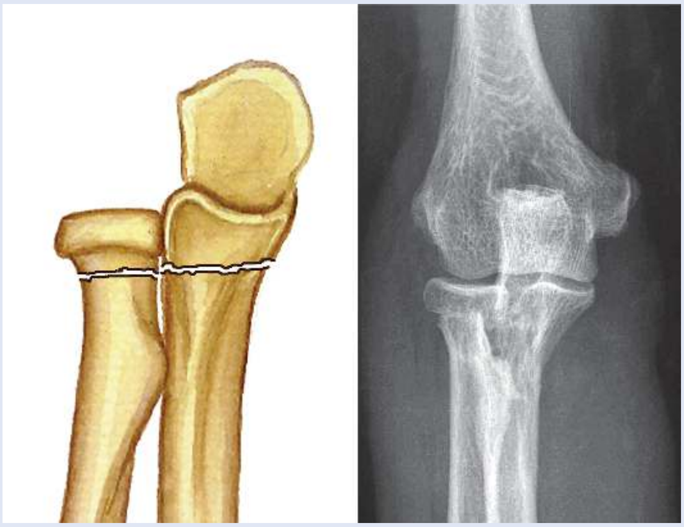
21-A2.3 Radial neck multifragmentary fracture



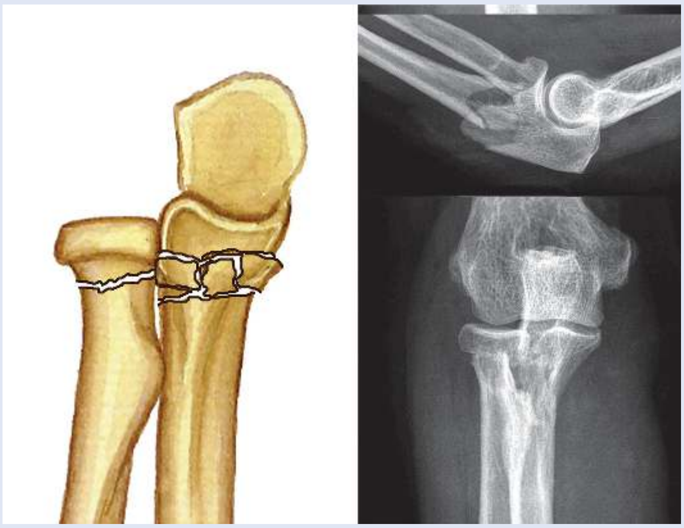
21-A Radius/ulna, proximal, extra-articular fractures

21-A3 Both bones
67 fractures
M: 39 (58.21%)
F: 28 (41.79%)
0.22% of total adult fractures
0.12% of adult radius/ulna
0.93% of segment 21
4.06% of type 21-A

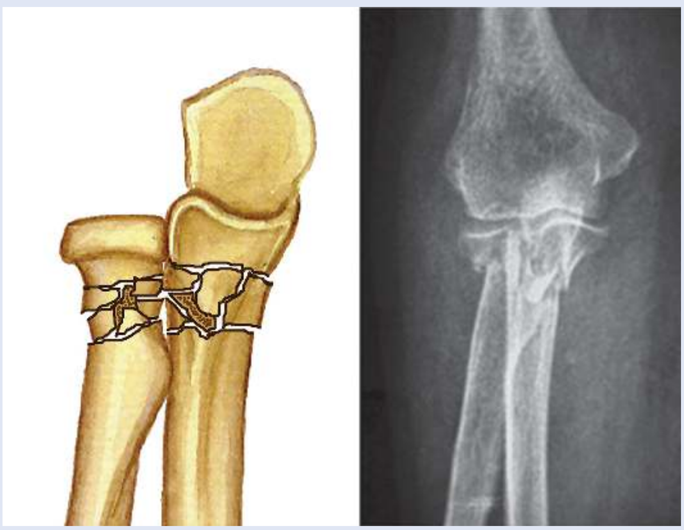
21-A3.1 Both bones simple fracture

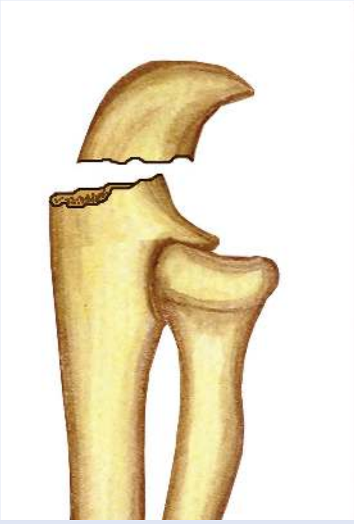
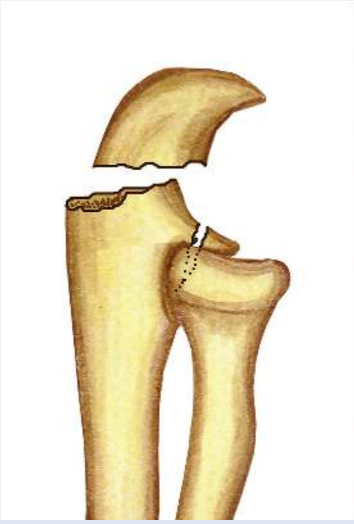
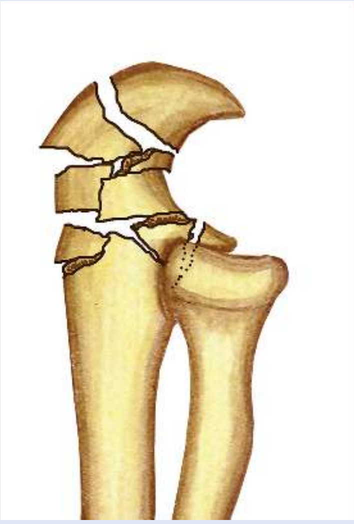


21-A3.2 One bone simple fracture, other bone multifragmentary fracture



21-A3.3 Both bones multifragmentary

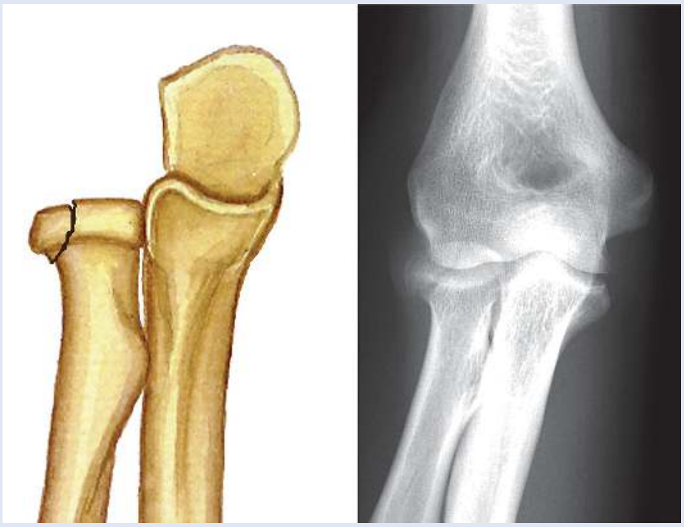


21-B Radius/ulna, proximal, partial articular fractures	
21-B1 Ulna, radius intact 2,773 fractures M: 1,809 (65.24%) F: 964 (34.76%) 0.74% of total adult fractures 4.76% of adult radius/ulna 38.50% of segment **21** 52.65% of type **21-B**	**21-B1.1** Unifocal simple fracture   **21-B1.2** Bifocal simple fracture   **21-B1.3** Bifocal multifragmentary  

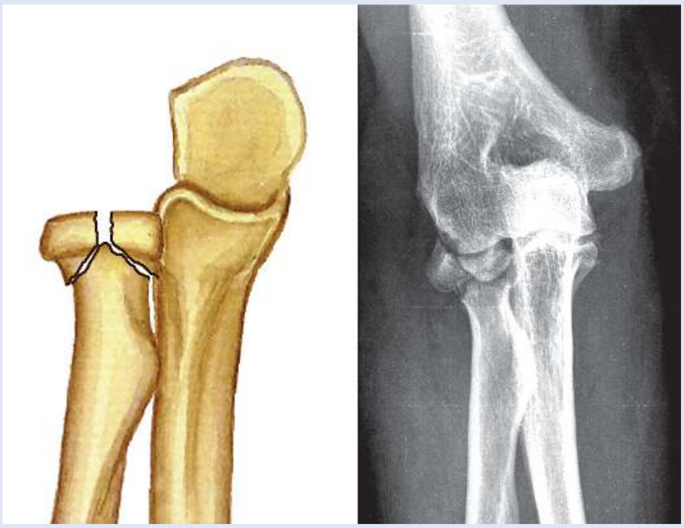
21-B Radius/ulna, proximal, partial articular fractures

21-B2 Radius, ulna intact
2,292 fractures
M: 1,426 (62.22%)
F: 866 (37.78%)
0.61% of total adult fractures
3.94% of adult radius/ulna
31.82% of segment 21
43.52% of type 21-B

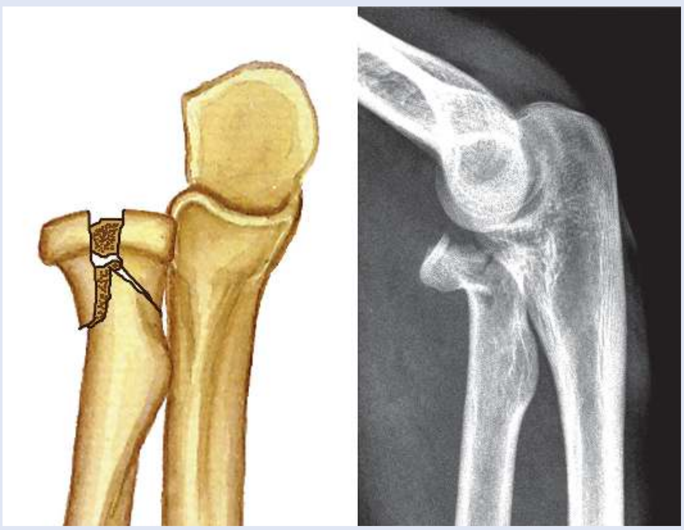
21-B2.1 Simple fracture with minimal or no displacement



21-B2.2 Multifragmentary without depression



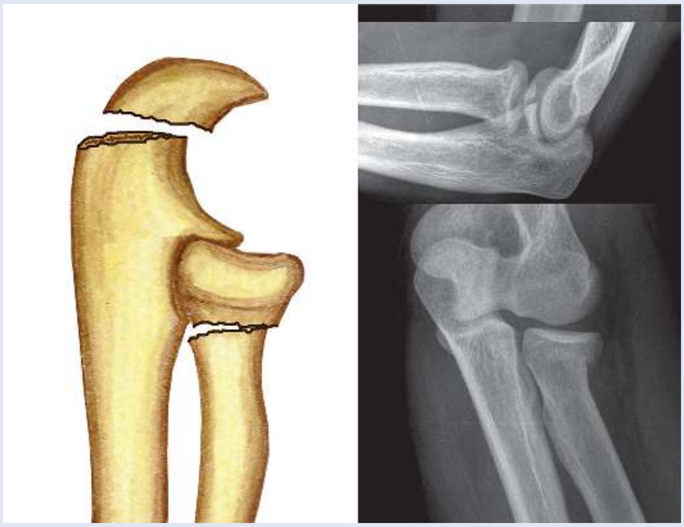
21-B2.3 Multifragmentary with depression



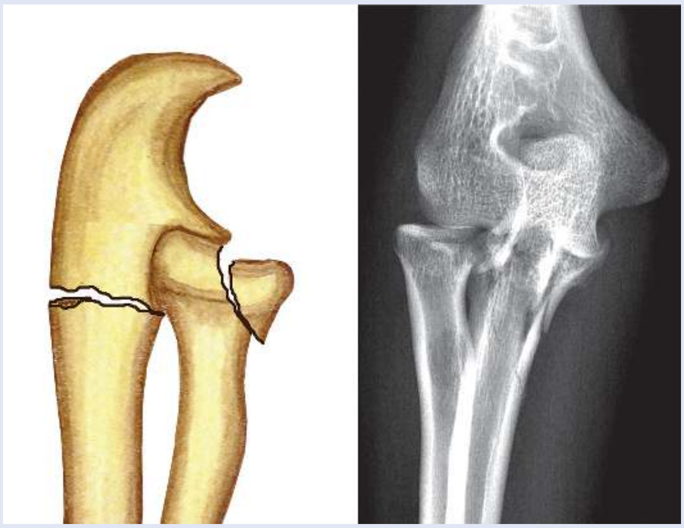
21-B Radius/ulna, proximal, partial articular fractures

21-B3 One bone articular, other bone extra-articular
202 fractures
M: 129 (63.86%)
F: 73 (36.14%)
0.05% of total adult fractures
0.35% of adult radius/ulna
2.80% of segment **21**
3.84% of type **21-B**

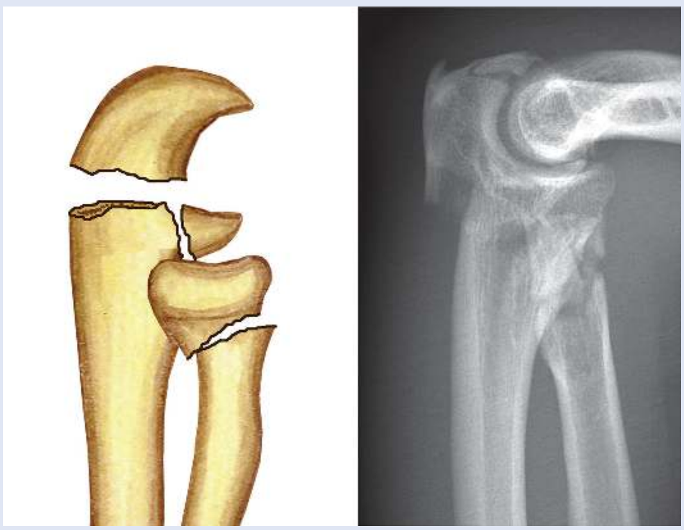
21-B3.1 Ulna articular simple, radius extra-articular fracture



21-B3.2 Radius articular simple, ulna extra-articular fracture



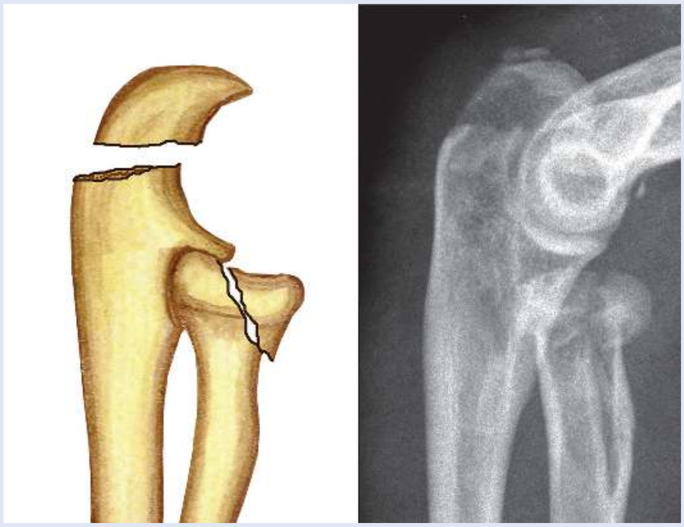
21-B3.3 One bone articular multifragmentary, other bone extra-articular fracture



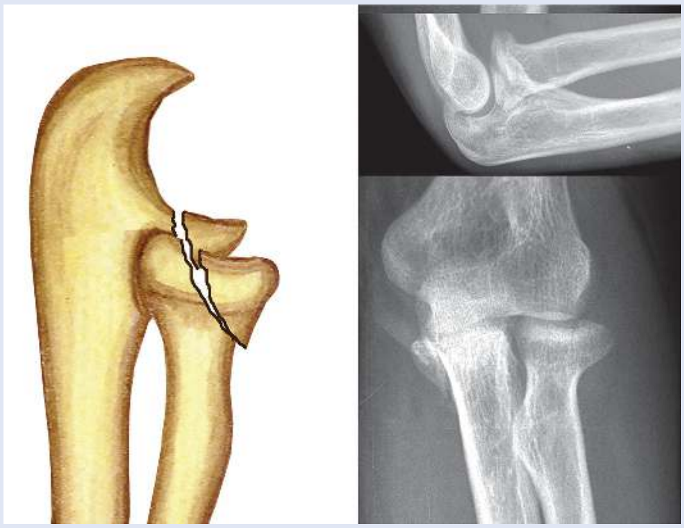
21-C Radius/ulna, proximal, complete articular fractures

21-C1 Both bones, simple fracture
125 fractures
M: 76 (60.80%)
F: 49 (39.20%)
0.03% of total adult fractures
0.21% of adult radius/ulna
1.74% of segment 21
43.86% of type 21-C

21-C1.1 Olecranon and radial head



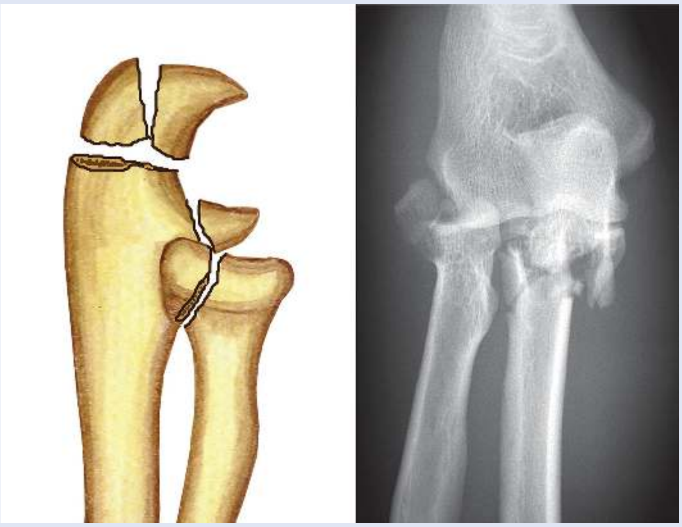
21-C1.2 Coronoid process and radial head



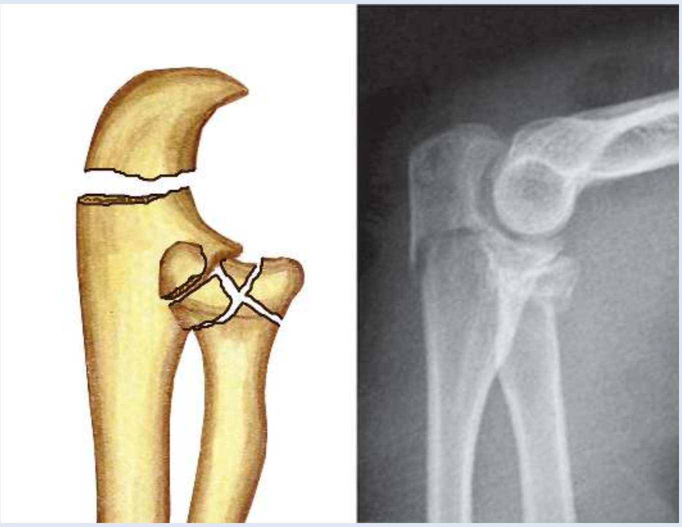
21-C Radius/ulna, proximal, complete articular fractures

21-C2 Both bones, one articular simple, the other articular multifragmentary
90 fractures
M: 66 (73.33%)
F: 24 (26.67%)
0.02% of total adult fractures
0.15% of adult radius/ulna
1.25% of segment 21
31.58% of type 21-C

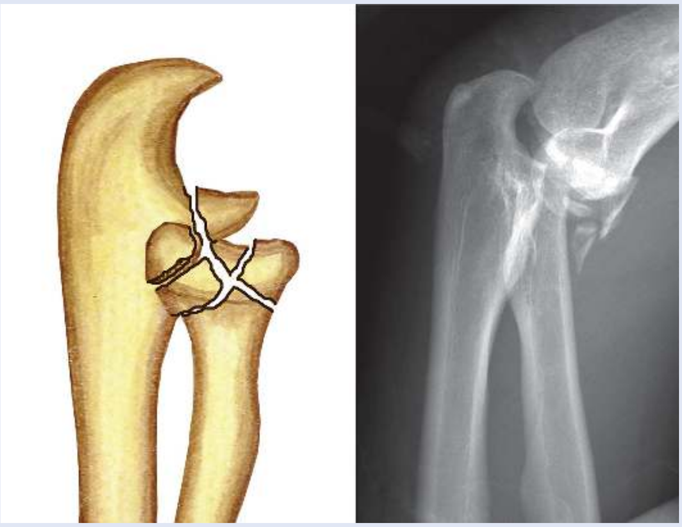
21-C2.1 Olecranon multifragmentary, radial head simple split



21-C2.2 Olecranon simple, radial head multifragmentary



21-C2.3 Coronoid process simple, radial head multifragmentary

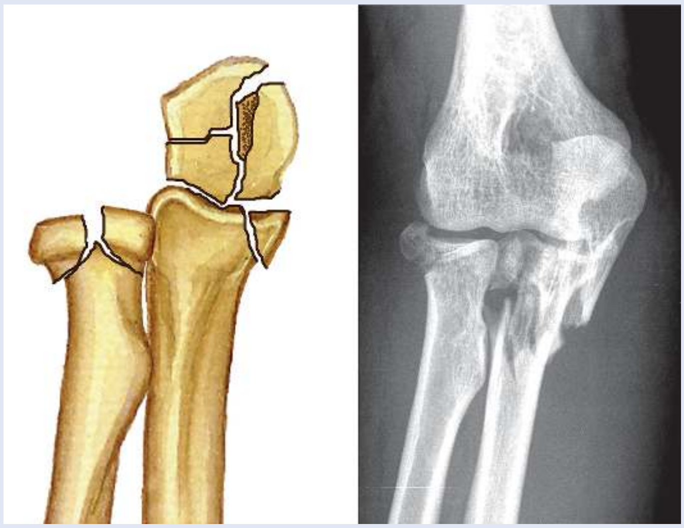


21-C Radius/ulna, proximal, complete articular fractures

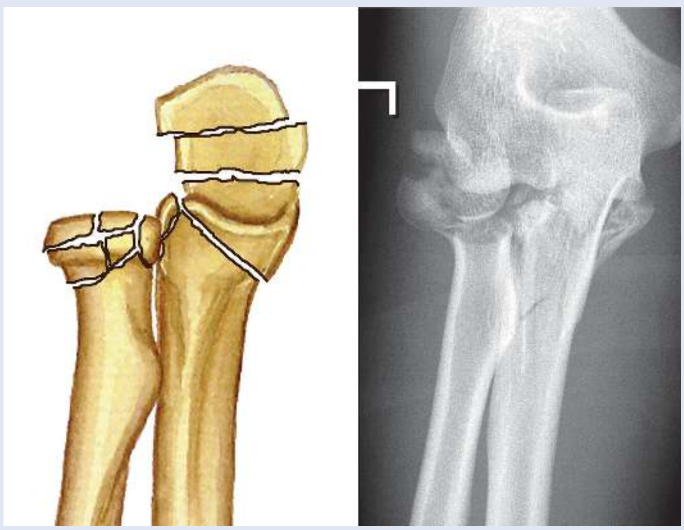
21-C3 Both bones, articular multifragmentary
70 fractures
M: 48 (68.57%)
F: 22 (31.43%)
0.02% of total adult fractures
0.12% of adult radius/ulna
0.97% of segment 21
24.56% of type 21-C

21-C3.1 Three fragments each bone

21-C3.2 Ulna more than three fragments, radius three or more fragments



21-C3.3 Radius more than three fragments, ulna three or more fragments



Injury Mechanism

Olecranon Fractures

Olecranon multifragmentary fracture can be caused by direct trauma, as in falls on or blows to the point of the elbow. Such types of fractures also occur during a fall on the semiflexed supinated forearm with the hand striking the ground, and the pull of the triceps muscle leading to a transverse or wedge fracture of the olecranon.

Fractures of Radial Head or Neck of the Radius

This type of injury is usually from a fall on an outstretched arm with the force of impact transmitted up the hand through the forearm to the radial head, which is forced to the capitellum and often causes fractures in the anterolateral aspect of the radial head or neck of the radius. Multifragmentary fractures or dislocation may occur by high energy trauma.

Coronoid Fractures

Coronoid fracture, rarely seen in isolation, usually occurs in combination with olecranon fracture; this type of fracture results from an avulsion fracture of the bony structure of the coronoid, by contraction of the joint capsule with the elbow in hyperextension.

Diagnosis

The insertion of the triceps muscle on the olecranon is usually compromised when olecranon fractures occur. In most cases, patients cannot fully strengthen their arm due to the pain and are unable to overcome any resistance. The movement of supination aggravates the pain from fractures in the radial head or neck of the radius and limits the range of motion.

The radiographic examination should include anteroposterior (AP) and lateral views of the elbow. If the patient has marked physical signs but inconclusive X-rays, then computed tomography (CT) or magnetic resonance imaging (MRI) scans may be required to clarify the nature and extent of the injury. Note that the individual will be unable to fully extend the forearm when taking the AP view of the elbow, so the beam must be placed perpendicularly to the radial head (▶ Fig. 3.20).

Treatment

Olecranon fractures are unstable fractures, usually requiring surgical intervention. Plate fixation, tension band wiring, and other internal fixators can be utilized in stabilizing the fracture, depending on the fracture type. Stable fractures of the radial head or the neck of radius with no displacement can be managed nonsurgically, but with close monitoring of fracture progression within 4 weeks. Minimal invasive internal fixation is preferable for fractures with dislocation or when nonsurgical treatment fails. Based on fracture type, patient's age, and general condition, various internal fixators can be selected, including screws, absorbable screws, and Kirschner wires (K-wires). Anatomic reduction to the utmost, rigid fixation, and early mobilization are applied even for complex fractures. Excision of the radial head and replacement with a prosthesis should be considered only as a last resort.

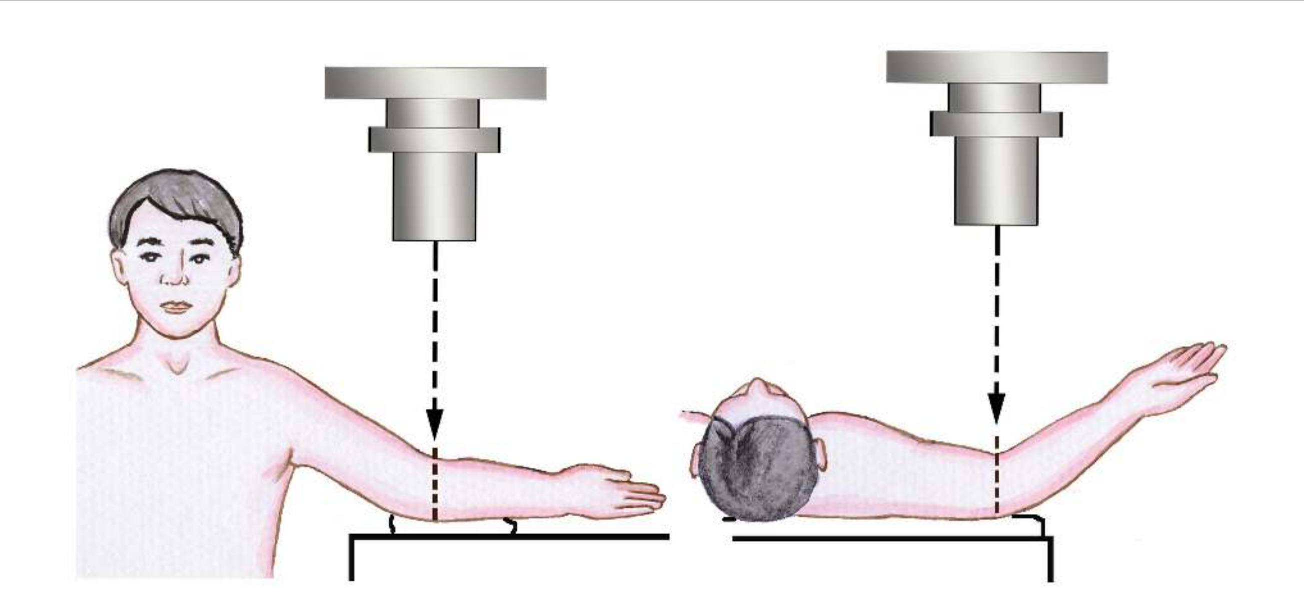


Fig. 3.20 Radiographic examination of the elbow: the correct projection position is shown to the left, while the wrong position commonly seen in practice is shown on the right.

Fractures of the Radial/Ulnar Shaft (Segment 22)

Anatomic Features

The ulna is relatively straight while the radius is slightly curved. In the anatomic position, the width of the space between the ulna and radius is variable, with a maximum width of 1.5 to 2.0 cm. The IOM, which connects the radius and ulna along their entire length, bears loads with the forearm in neutral position and is slackened when the forearm is in pronated position. The fibers of IOM run obliquely upward and lateral from the interosseous crest of the ulna to that of the radius. When one of the bones is fractured, energy is transmitted along the IOM, causing fractures on the other bone in a different plane and a dislocated proximal radioulnar joint. Many muscles are attached to the radius and ulna with their insertion points spread around their shafts. Consequently, complex fractures with marked displacement usually occur due to contraction of multiple muscles, which make the reduction very difficult.

AO Classification of Fractures of Radial/Ulnar Shaft

The numeric code for shaft of the radius and ulna is “22” based on AO classification (▶ Fig. 3.21). Fracture of the radial/ulnar shaft is divided into three types: 22-A: simple fracture; 22-B: wedge fracture; and 22-C: complex fracture (▶ Fig. 3.22).

Fig. 3.21 AO code for the shaft of the ulna and radius.

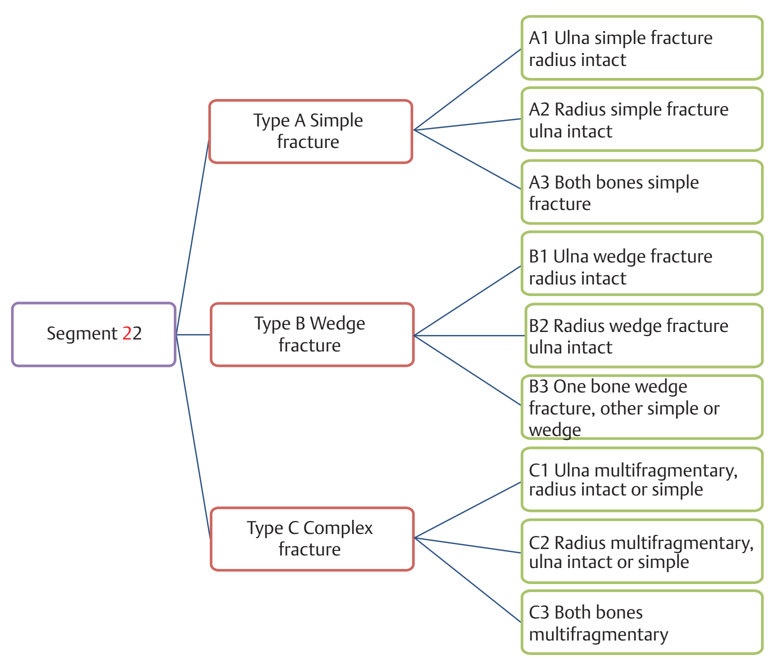


Fig. 3.22 Algorithm.

Clinical Epidemiologic Features of the Radial/Ulnar Shaft Fractures (Segment 22)

A total of 7,594 adult radial/ulnar shaft fractures (segment 22) were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 13.04% of all adult fractures of the radius/ulna. Their epidemiologic features are as follows:

- More males than females
- The high-risk age group is 21–25 years; the age group 21–25 years is the high-risk group for males; for females, it is 36–40 years
- The most common fracture type among segment 22 fractures is type 22-A, the same fracture type for both males and females
- The most common fracture group among segment 22 fractures is group 22-A1, the same fracture group for both males and females

Fractures of Segment 22 by Sex

See ▶ Table 3.15 and ▶ Fig. 3.23.

Table 3.15 Sex distribution of 7,594 fractures of segment 22

Sex	Number of fractures	Percentage
Male	5,709	75.18
Female	1,885	24.82
Total	7,594	100.00

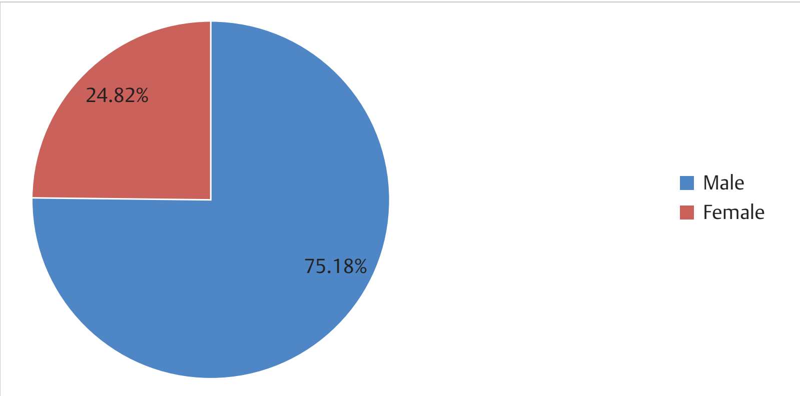


Fig. 3.23 Sex distribution of 7,594 fractures of segment 22.

■ Fractures of Segment 22 by Age Group

See ▶ Table 3.16 and ▶ Fig. 3.24.

Table 3.16 Age and sex distribution of 7,594 fractures of segment 22

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	826	148	974	12.83
21–25	865	161	1,026	13.51
26–30	683	182	865	11.39
31–35	528	175	703	9.26
36–40	674	257	931	12.26
41–45	623	227	850	11.19
46–50	587	242	829	10.92
51–55	346	122	468	6.16
56–60	272	86	358	4.71
61–65	147	88	235	3.09
66–70	70	66	136	1.79
71–75	30	56	86	1.13
76–80	34	47	81	1.07
81–85	14	19	33	0.43
≥ 86	10	9	19	0.25
Total	5,709	1,885	7,594	100.00

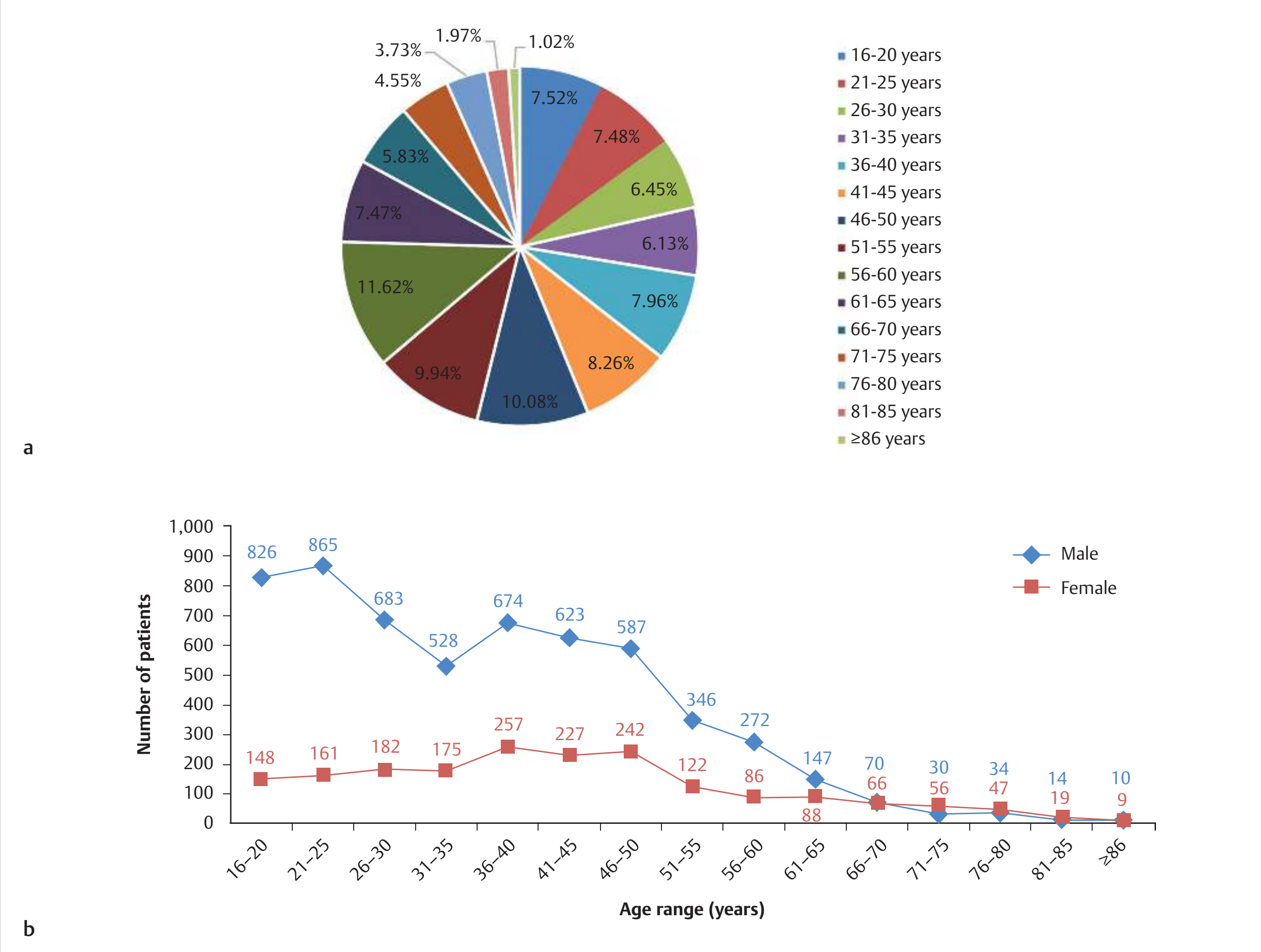


Fig. 3.24 (a) Age distribution of 7,594 fractures of segment 22. (b) Age and sex distribution of 7,594 fractures of segment 22.

■ Fractures of Segment 22 by Fracture Type

See ▶ Table 3.17, ▶ Table 3.18, ▶ Fig. 3.25, and ▶ Fig. 3.26.

Table 3.17 Sex and fracture type distribution of 7,594 fractures of segment 22

Fracture type	Male	Female	Number of fractures	Percentage of radial/ulnar fractures
22-A	3,456	1,201	4,657	61.32
22-B	1,785	538	2,323	30.59
22-C	468	146	614	8.09
Total	5,709	1,885	7,594	100.00

Table 3.18 Sex and fracture group distribution of 7,594 fractures of segment 22

Fracture group	Male	Female	Number of fractures	Percentage of segment 22 fractures	Percentage of radial/ulnar fractures
22-A1	1,268	463	1,731	22.79	2.97
22-A2	1,188	367	1,555	20.48	2.67
22-A3	1,000	371	1,371	18.05	2.36
22-B1	694	156	850	11.19	1.46
22-B2	469	133	602	7.93	1.03
22-B3	622	249	871	11.47	1.50
22-C1	178	55	233	3.07	0.40
22-C2	154	48	202	2.66	0.35
22-C3	136	43	179	2.36	0.31
Total	5,709	1,885	7,594	100.00	13.04

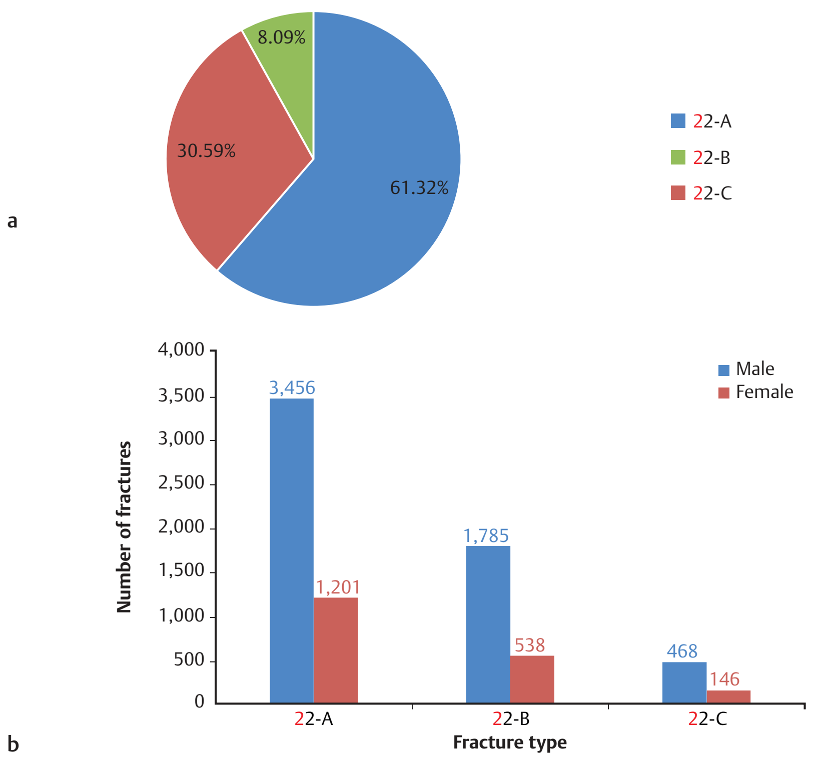
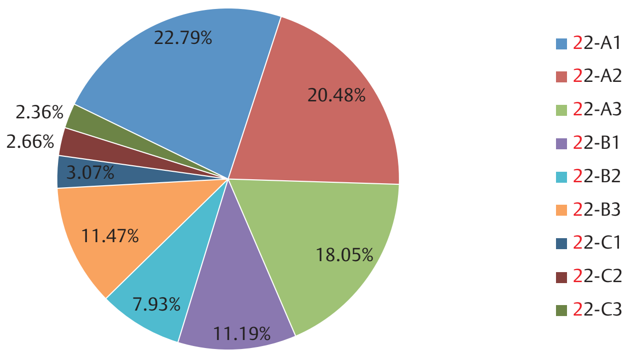
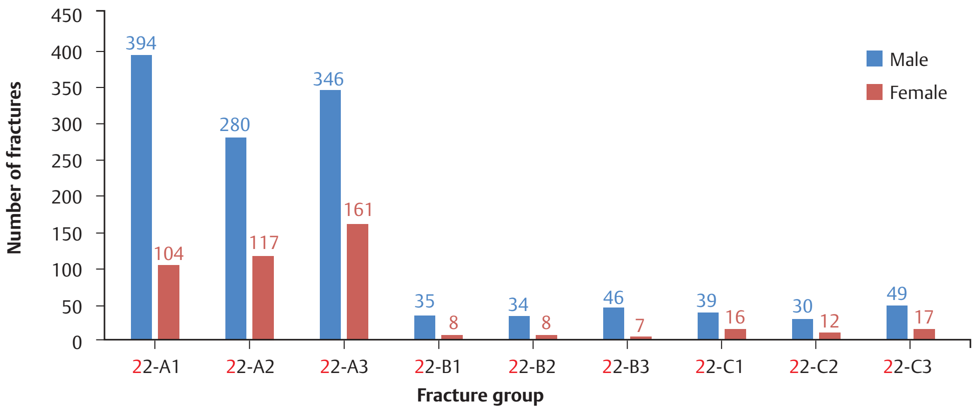


Fig. 3.25 (a) Fracture type distribution of 7,594 fractures of segment 22. (b) Sex and fracture type distribution of 7,594 fractures of segment 22.



a



b

Fig. 3.26 (**a**) Fracture group distribution of 7,594 fractures of segment 22. (**b**) Sex and fracture group distribution of 7,594 fractures of segment 22.

22-A Radial/ulnar shaft simple fractures

22-A1 Ulna, radius intact
1,731 fractures
M: 1,268 (73.25%)
F: 463 (26.75%)
0.46% of total adult fractures
2.97% of adult radius/ulna
22.79% of segment **22**
37.17% of type **22-A**

22-A1.1 Oblique

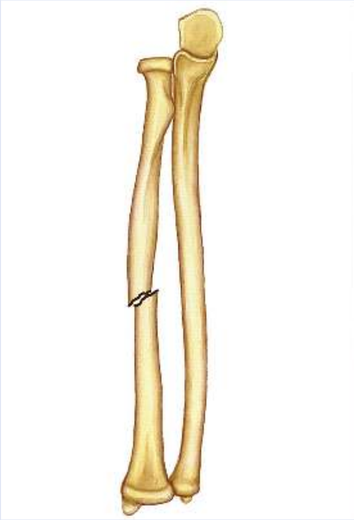
22-A1.2 Transverse

22-A1.3 With radial head dislocation (Monteggia)

22-A Radial/ulnar shaft simple fractures

22-A2 Radius, ulna intact
1,555 fractures
M: 1,188 (76.40%)
F: 367 (23.60%)
0.42% of total adult fractures
2.67% of adult radius/ulna
20.48% of segment 22
33.39% of type 22-A

22-A2.1 Oblique



22-A2.2 Transverse

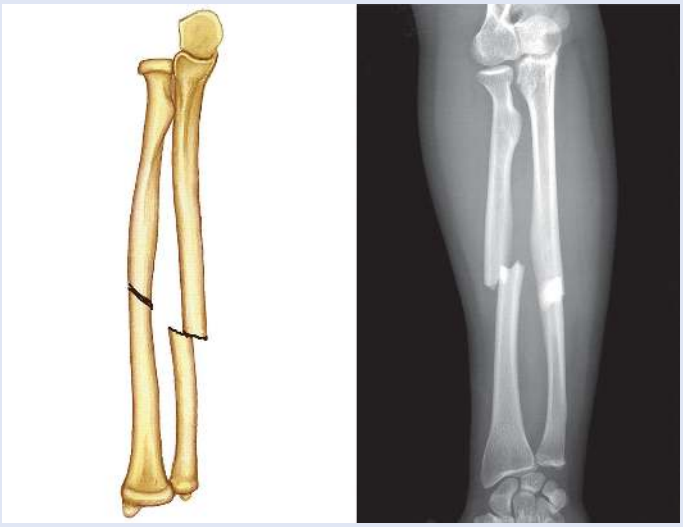
22-A2.3 With distal radioulnar joint dislocation (Galeazzi)

22-A Radial/ulnar shaft simple fractures

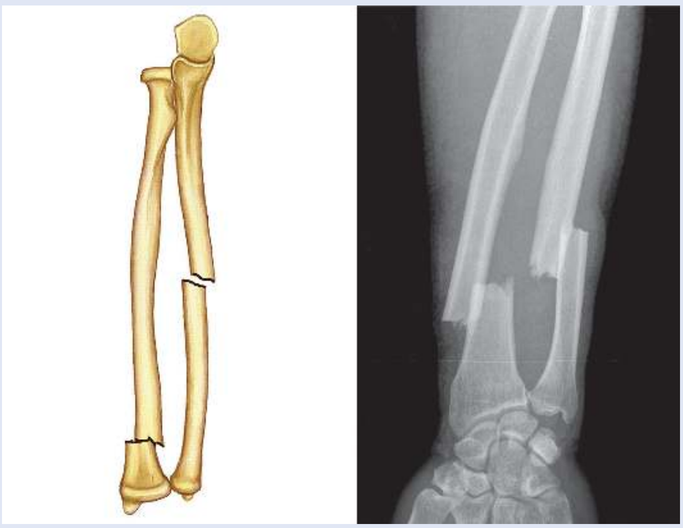
22-A3 Both bones
1,371 fractures
M: 1,000 (72.94%)
F: 371 (27.06%)
0.37% of total adult fractures
2.36% of adult radius/ulna
18.05% of segment 22
29.44% of type 22-A

22-A3.1 Radius, proximal section

22-A3.2 Radius, middle section



22-A3.3 Radius, distal section

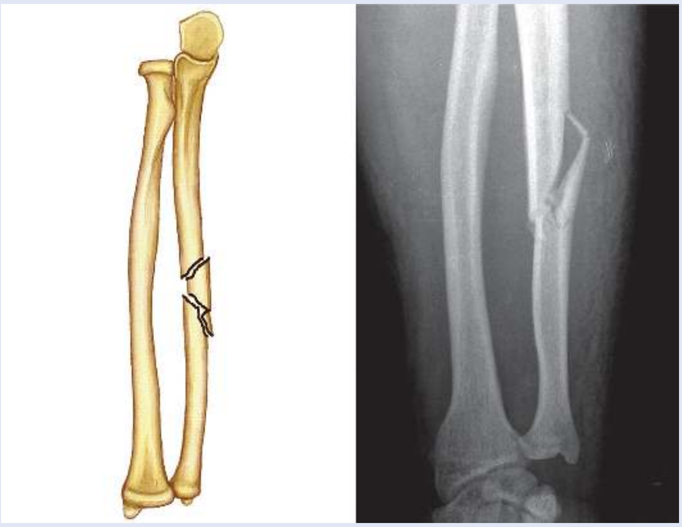


22-B Radial/ulnar shaft wedge fractures

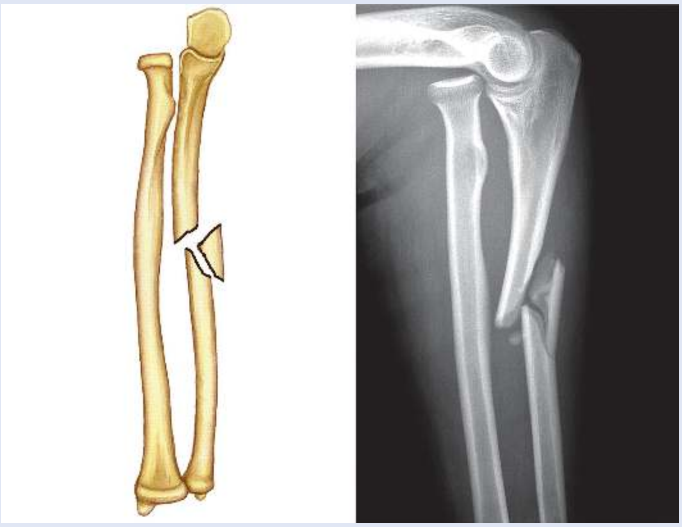
22-B1 Ulna, radius intact
850 fractures
M: 694 (81.65%)
F: 156 (18.35%)
0.23% of total adult fractures
1.46% of adult radius/ulna
11.19% of segment **22**
36.59% of type **22-B**

22-B1.1 Intact wedge

22-B1.2 Fragmented wedge



22-B1.3 With radial head dislocation (Monteggia)

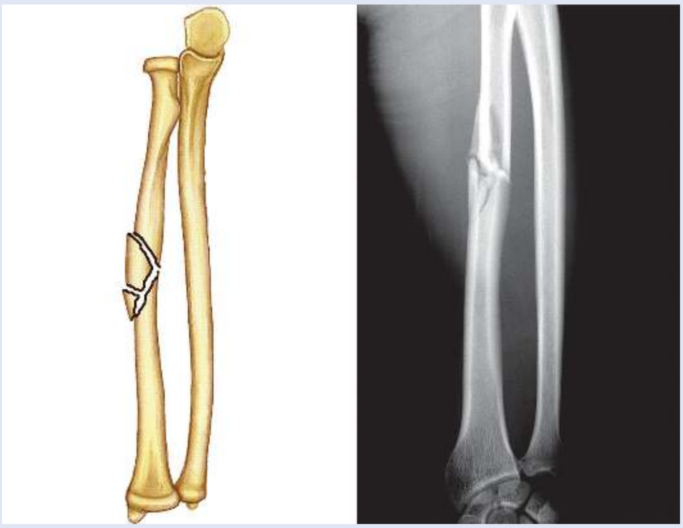


22-B Radial/ulnar shaft wedge fractures

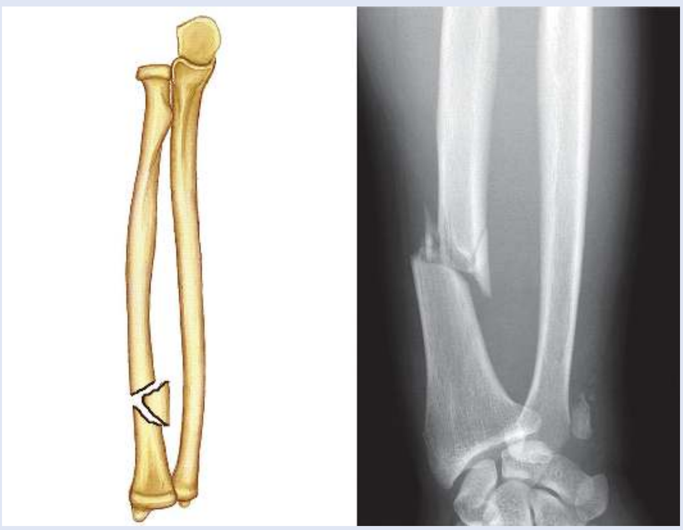
22-B2 Radius, ulna intact
602 fractures
M: 469 (77.91%)
F: 133 (22.09%)
0.16% of total adult fractures
1.03% of adult radius/ulna
7.93% of segment **22**
25.91% of type **22-B**

22-B2.1 Intact wedge

22-B2.2 Fragmented wedge



22-B2.3 With distal radioulnar joint dislocation (Galeazzi)



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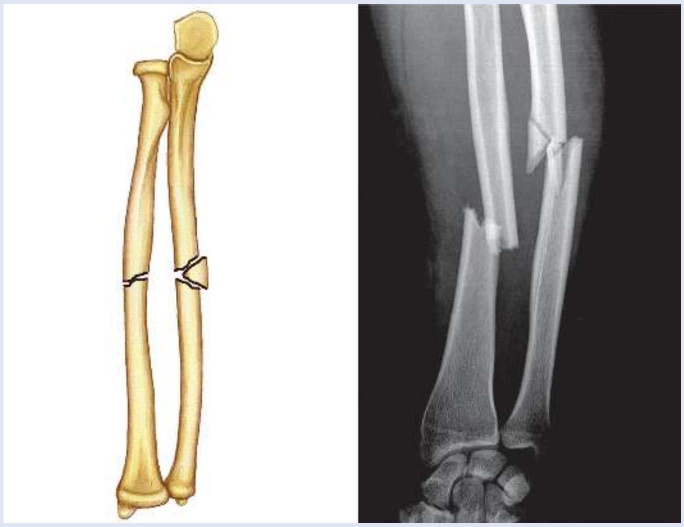
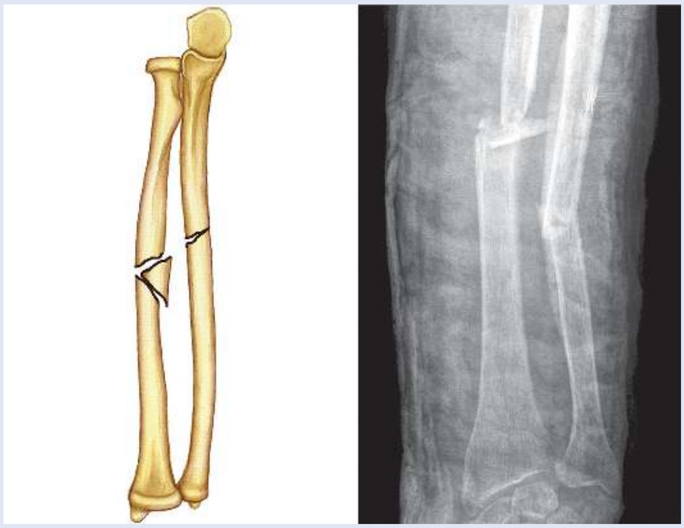
22-B Radial/ulnar shaft wedge fractures

22-B3 One bone wedge, the other simple or wedge
871 fractures
M: 622 (71.41%)
F: 249 (28.59%)
0.23% of total adult fractures
1.50% of adult radius/ulna
11.47% of segment 22
37.49% of type 22-B

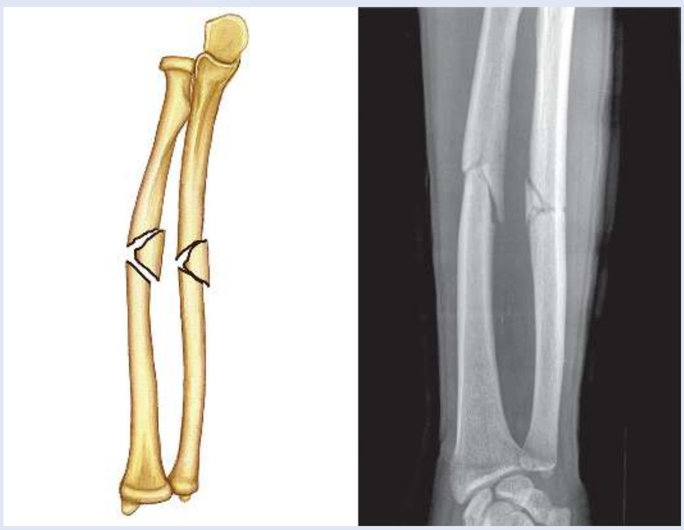
22-B3.1 Ulna wedge, radius simple



22-B3.2 Radius wedge, ulna simple



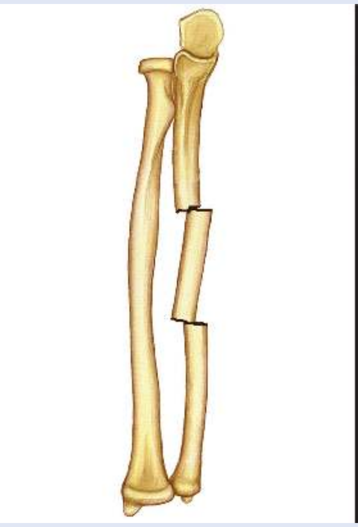
22-B3.3 Both bones wedge



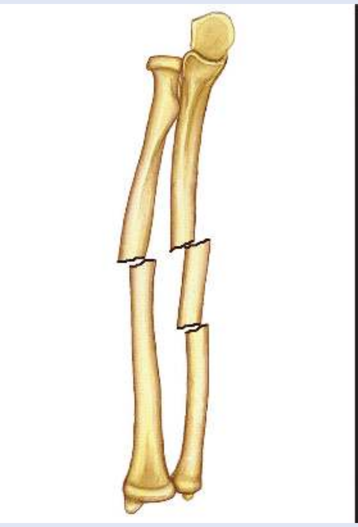
22-C Radial/ulnar shaft complex fractures

22-C1 Ulna multifragmentary, radius intact or simple
233 fractures
M: 178 (76.39%)
F: 55 (23.61%)
0.06% of total adult fractures
0.40% of adult radius/ulna
3.07% of segment 22
37.95% of type 22-c

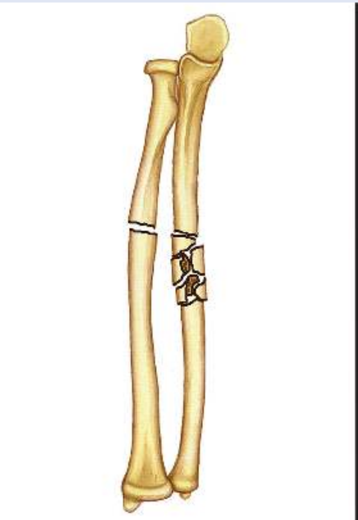
22-C1.1 Ulna segmental, radius intact or dislocation



22-C1.2 Ulna segmental, radius simple or wedge



22-C1.3 Ulna complex, radius intact, simple or wedge

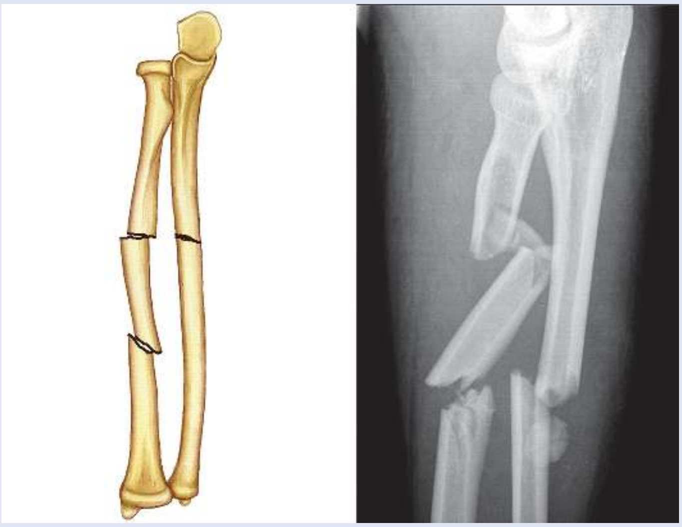


22-C Radial/ulnar shaft complex fractures

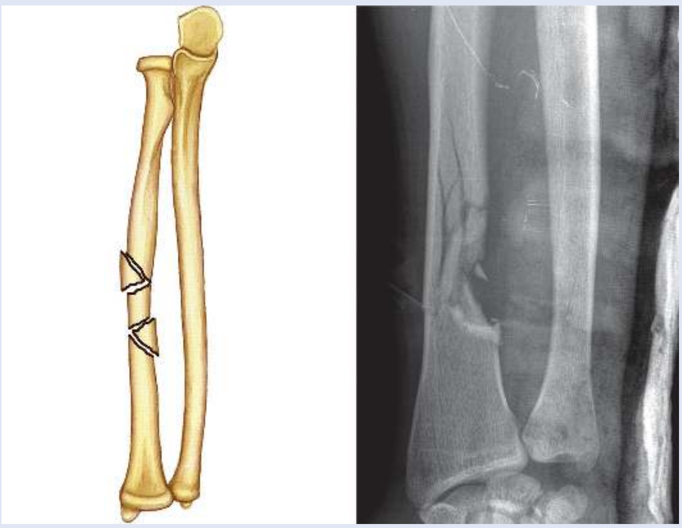
22-C2 Radius multifragmentary, ulna intact or simple
202 fractures
M: 154 (76.24%)
F: 48 (23.76%)
0.05% of total adult fractures
0.35% of adult radius/ulna
2.66% of segment **22**
32.90% of type **22-c**

22-C2.1 Radius segmental, ulna intact without dislocation or with dislocation of distal radioulnar (Galeazzi)

22-C2.2 Radius segmental, simple or wedge ulna fracture



22-C2.3 Radius complex, ulna intact or simple



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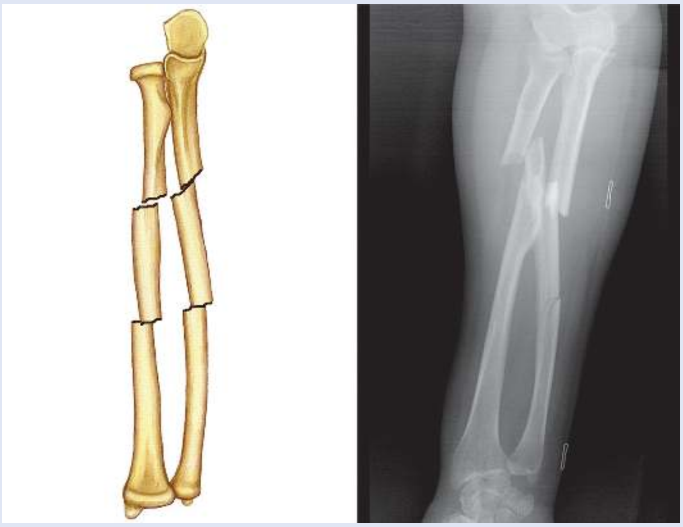
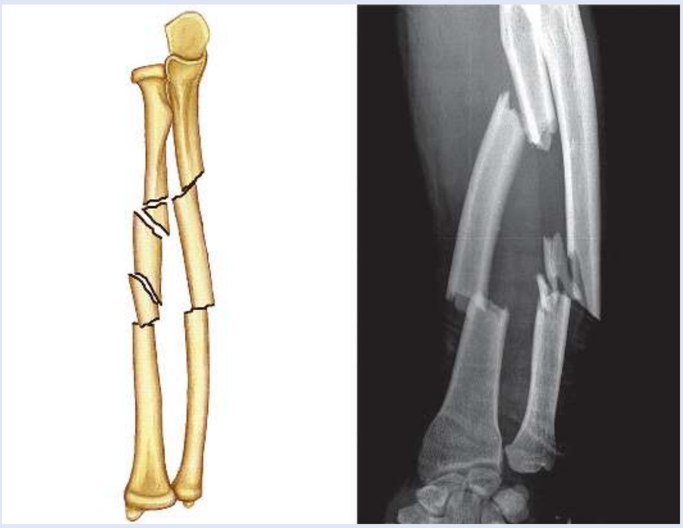
22-C Radial/ulnar shaft complex fractures

22-C3 Both bones multifragmentary
179 fractures
M: 136 (75.98%)
F: 43 (24.02%)
0.05% of total adult fractures
0.31% of adult radius/ulna
2.36% of segment 22
29.15% of type 22-c

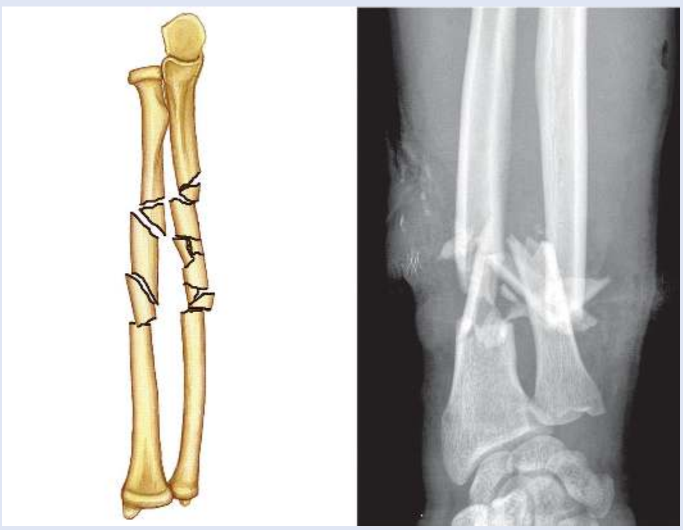
22-C3.1 Both bones segmental



22-C3.2 One bone segmental, the other complex



22-C3.3 Both bones complex



Injury Mechanism

Radial Shaft Fractures

This type of injury is usually caused by a direct blow on the forearm.

Ulnar Shaft Fractures

This fracture type most commonly occurs from direct trauma along the ulnar subcutaneous border, classically described as a “nightstick fracture,” when the forearm is used to block a blow. The fracture may also be caused by indirect force with the forearm in hypersupination or hyperpronation.

Fractures of the Shaft of the Radius and Ulna

This type of injury commonly results from a direct blow, such as in a fall from a height with the axial force transmitted through the ulna and radius.

Diagnosis

Patients with isolated fractures of the ulna or radius usually do not present with marked deformity, but there may be limited or partially limited rotation of the forearm. Physical examination reveals fracture pain that is aggravated by palpation over the injured region or when an increased axial load is applied. When both bones fracture, diagnosis is easily made based on physical signs like obvious deformity, bony crepitus, and limited rotation of the forearm. In patients with fractures of the radius and ulna or with semi-dislocation or dislocation of the proximal or distal radioulnar joint, physical examination indicates focal tenderness to palpation and limited or partially limited rotational function of the forearm.

The radiographic examination must include an AP view of the elbow or wrist depending upon the clinical indication. An oblique view may be required if there is suspected articular involvement or an inconclusive AP view.

It should be noted that fractures of the proximal third of the ulna often accompany radial head dislocation (Monteggia), while fractures of the distal third of the radius are often associated with a distal radioulnar joint (DRUJ) dislocation (Galeazzi).

Treatment

Ulnar shaft fractures can usually be managed by nonsurgical treatment, and should be immobilized with the forearm in a neutral position to minimize the contracture of the IOM between the radius and ulna. Radial shaft fractures often require surgical intervention. Monteggia and Galeazzi fractures include not only bony fractures but also joint dislocations, and consequently should be managed by surgical treatment. Fractures of both bones in the middle third of the forearm in an adult should be treated by surgical approach. In this scenario, the surgeon should avoid managing both bone fractures from the same incision, to minimize the chance of osseous bridge formation after the operation.

Distal Fractures of the Radius/Ulna (Segment 23)

Anatomic Features

The bony structures of the distal radius and ulna include the articular surface of the distal radius, DRUJ, and styloid processes of the radius and ulna. The area where bony substance changes from cancellous bone to compact bone in the distal end of the radius and ulna is an anatomically weak spot, and often a seat of fractures occurrence.

The slope of the dorsal to palmar surface of the distal radius and the slope volarly from the radius to the ulna form a palmar tilt angle and a radial inclination angle, respectively.

The distal radioulnar articulation, formed between the head of the ulna and the ulnar notch on the distal radius, is the anatomic foundation for the rotation of the forearm. The radial styloid process is 1.0 to 1.5 cm below the styloid process of the ulna.

The radiocarpal joint or wrist joint is an ellipsoid joint, formed by the distal portion of radius and the proximal portion of the carpal bone. The proximal articular surface of the scaphoid, lunate, and triquetrum forms a smooth convex surface, which rests in the concavity formed by the articular surface of the radius and the under-surface of the articular disk. The capsule of the wrist joint, which is lax and unbranched, is strengthened by numerous ligaments anteriorly–posteriorly and laterally.

AO Classification of Distal Fractures of the Radius/Ulna

Based on AO classification, the delineation of the distal radius/ulna is illustrated by a square whose lateral sides are parallel to the axis of the bone and their length equal to the maximum width of the epiphysis. According to this formula, the distal radius/ulna is coded as 23 (▶ Fig. 3.27; ▶ Fig. 3.28). On the basis of articular surface involvement, the distal radial/ulnar fracture (23) is further divided into three types: 23-A: extra-articular fracture; 23-B: partial articular fracture; and 23-C: complex articular fracture.

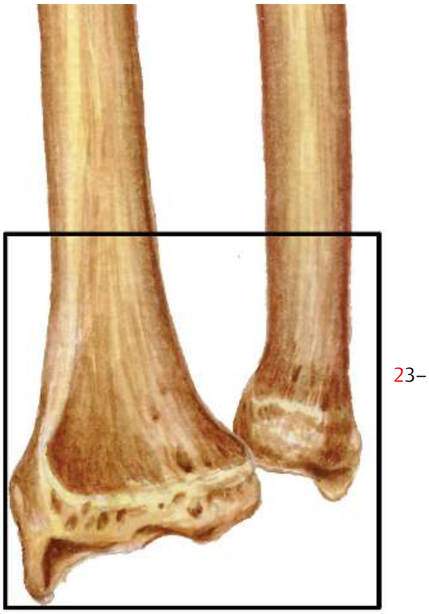


Fig. 3.27 AO code for the distal ulna and radius.

Clinical Epidemiologic Features of Distal Fractures of the Radius/Ulna (Segment 23)

A total of 43,420 adult distal radial/ulnar fractures (segment 23) were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 74.58% of all fractures of the radius/ulna in adults. Their epidemiologic features are as follows:

- More females than males
- The high-risk age group is 56–60 years; females are in this same age group, while males between the ages of 16 and 20 are most affected
- The most common fracture type among segment 23 fractures is type 23-A—the same fracture type for both males and females
- The most common fracture group among segment 23 fractures is group 23-A2—the same fracture group for both males and females

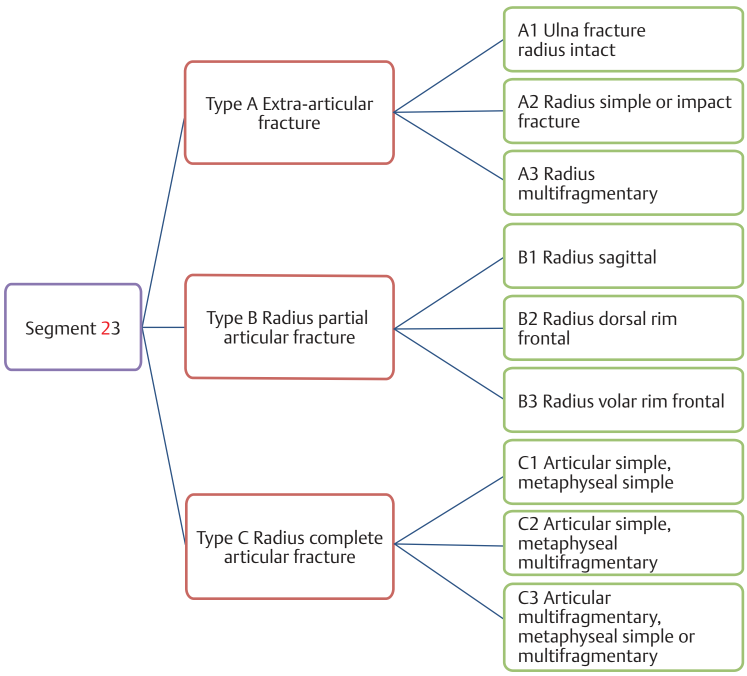


Fig. 3.28 Algorithm.

■ Fractures of Segment 23 by Sex

See ▶ Table 3.19 and ▶ Fig. 3.29.

Table 3.19 Sex distribution of 43,420 fractures of segment 23

Sex	Number of fractures	Percentage
Male	18,009	41.48
Female	25,411	58.52
Total	43,420	100.00

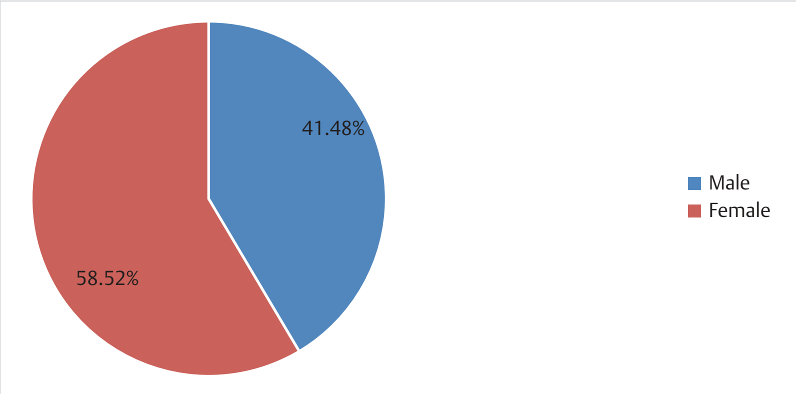


Fig. 3.29 Sex distribution of 43,420 fractures of segment 23.

■ Fractures of Segment 23 by Age Group

See ▶ Table 3.20 and ▶ Fig. 3.30.

Table 3.20 Age and sex distribution of 43,420 fractures of segment 23

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	2,216	533	2,749	6.33
21–25	1,791	656	2,447	5.64
26–30	1,450	660	2,110	4.86
31–35	1,364	822	2,186	5.03
36–40	1,808	1,082	2,890	6.66
41–45	1,914	1,301	3,215	7.40
46–50	2,005	2,310	4,315	9.94
51–55	1,490	3,286	4,776	11.00
56–60	1,390	4,539	5,929	13.65
61–65	863	2,964	3,827	8.81
66–70	602	2,443	3,045	7.01
71–75	447	1,951	2,398	5.52
76–80	352	1,610	1,962	4.52
81–85	209	818	1,027	2.37
≥ 86	108	436	544	1.25
Total	18,009	25,411	43,420	100.00

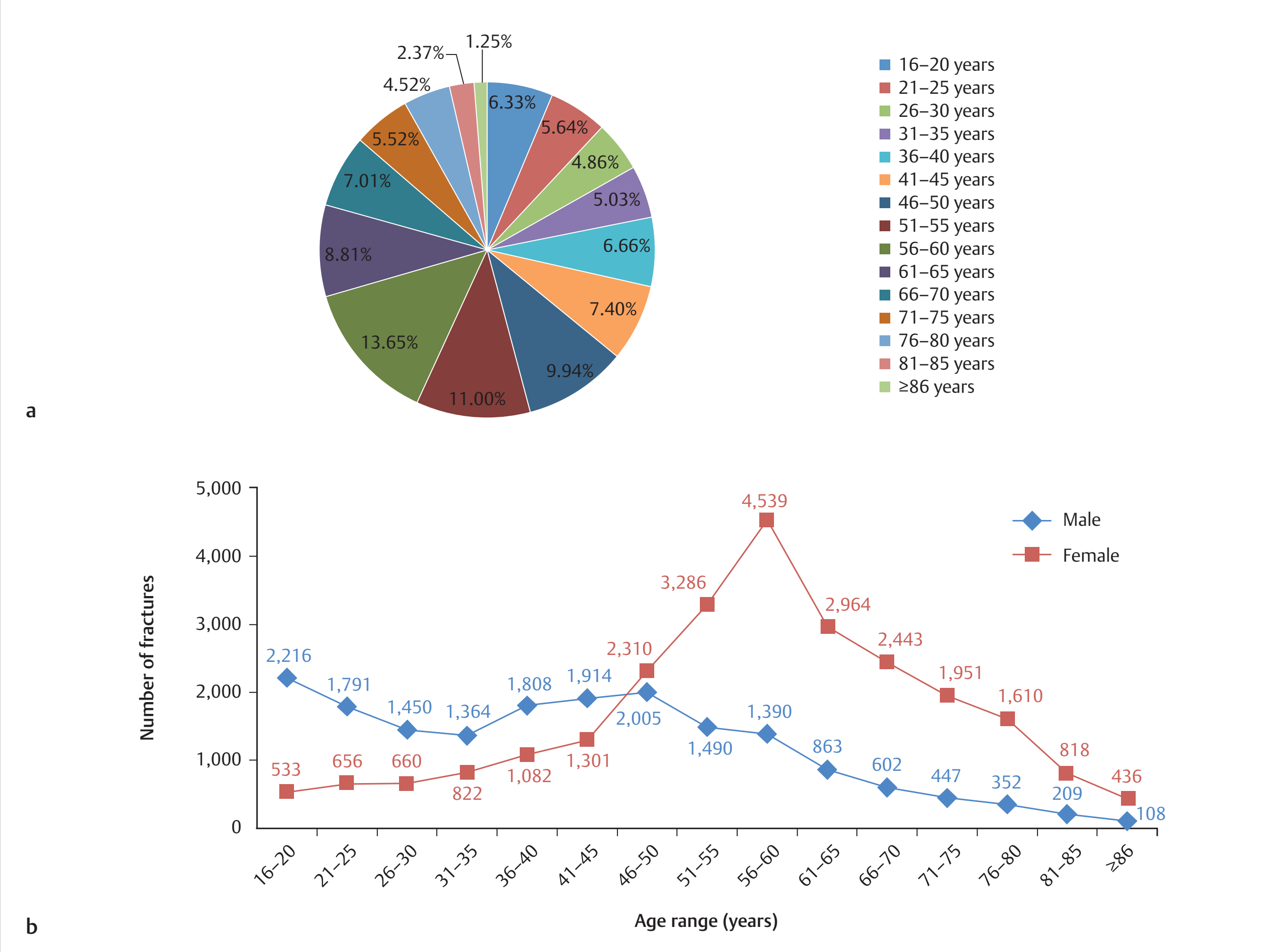


Fig. 3.30 (a) Age distribution of 43,420 fractures of segment 23. (b) Age and sex distribution of 43,420 fractures of segment 23.

■ Fractures of Segment 23 by Fracture Type

See ▶ Table 3.21, ▶ Table 3.22, ▶ Fig. 3.31, and ▶ Fig. 3.32.

Table 3.21 Sex and fracture type distributions of 43,420 fractures of segment 23

Fracture type	Male	Female	Number of fractures	Percentage
23-A	9,423	16,148	25,571	58.89
23-B	4,246	3,527	7,773	17.90
23-C	4,340	5,736	10,076	23.21
Total	18,009	25,411	43,420	100.00

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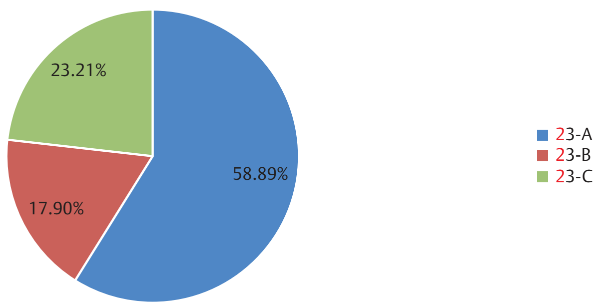
Table 3.22 Sex and fracture group distribution of 43,420 fractures of segment 23

Fracture group	Male	Female	Number of fractures	Percentage of segment 23 fractures	Percentage of radial/ulnar fractures
23-A1	1,598	852	2,450	5.64	4.21
23-A2	6,038	11,706	17,744	40.87	30.48
23-A3	1,787	3,590	5,377	12.38	9.24
23-B1	2,929	2,072	5,001	11.52	8.59
23-B2	662	759	1,421	3.27	2.44
23-B3	655	696	1,351	3.11	2.32
23-C1	1,997	2,958	4,955	11.41	8.51
23-C2	978	1,226	2,204	5.08	3.79
23-C3	1,365	1,552	2,917	6.72	5.01
Total	18,009	25,411	43,420	100.00	74.58



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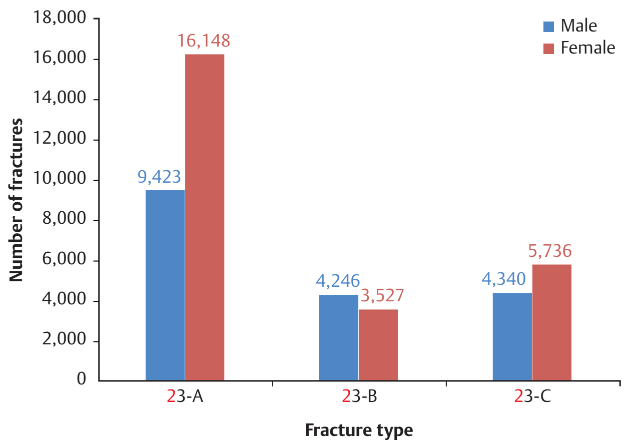


b

Fig. 3.31 (**a**) Fracture type distribution of 43,420 fractures of segment 23. (**b**) Sex and fracture type distribution of 43,420 fractures of segment 23.

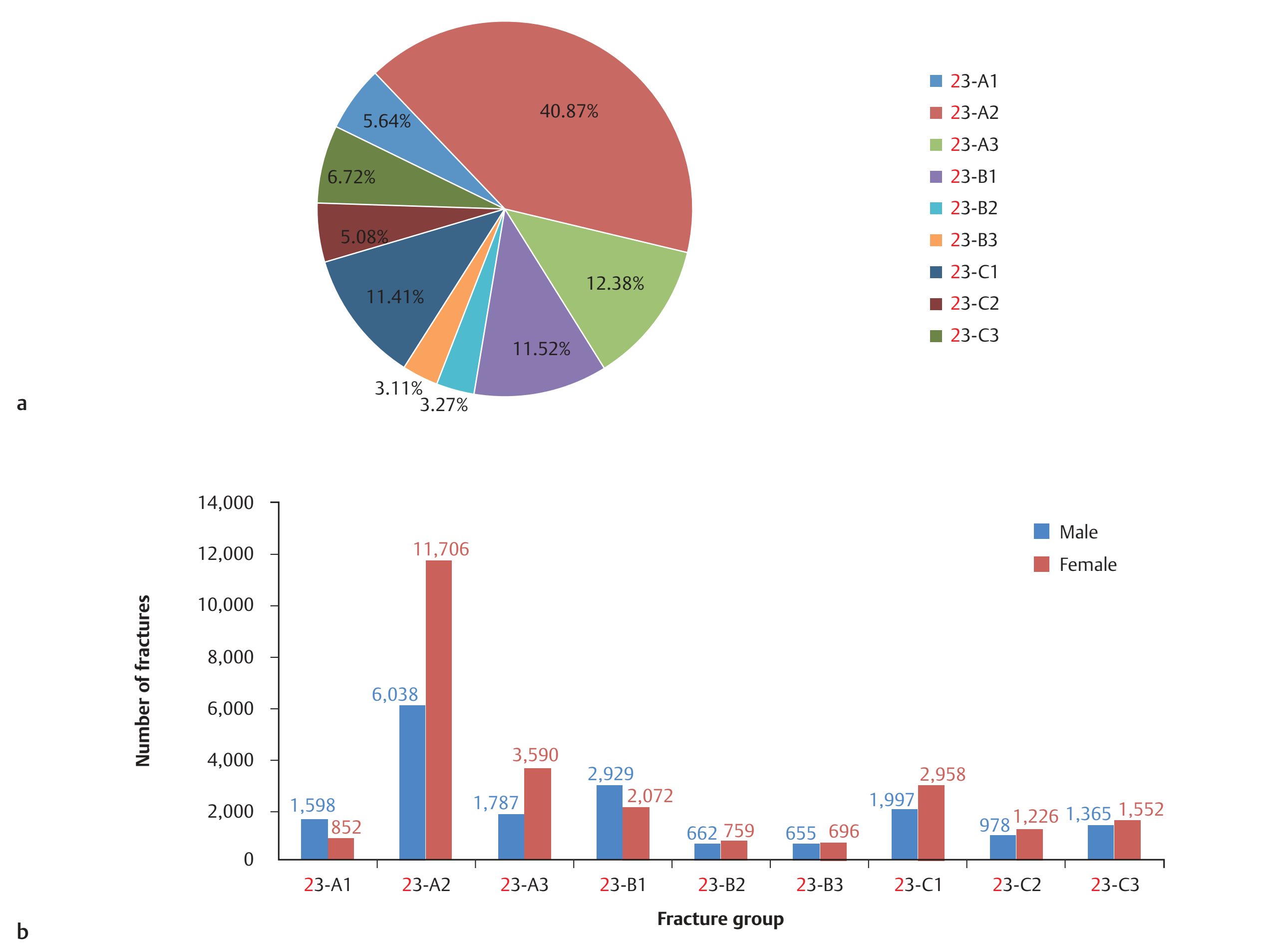
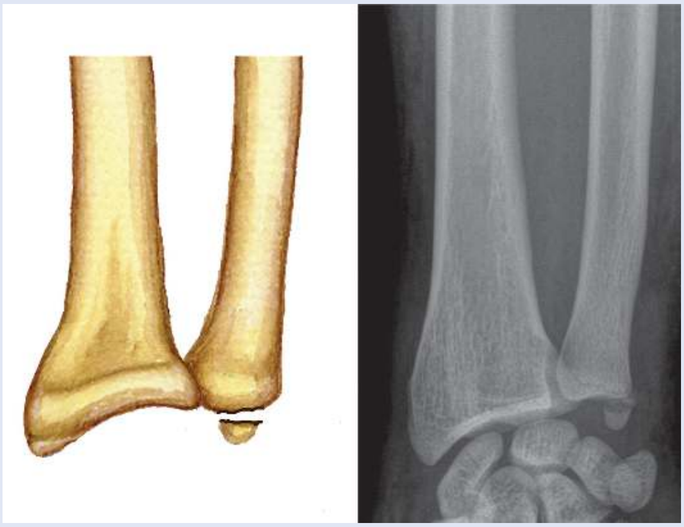


Fig. 3.32 (**a**) Fracture group distribution of 43,420 fractures of segment 23. (**b**) Sex and fracture group distribution of 43,420 fractures of segment 23.

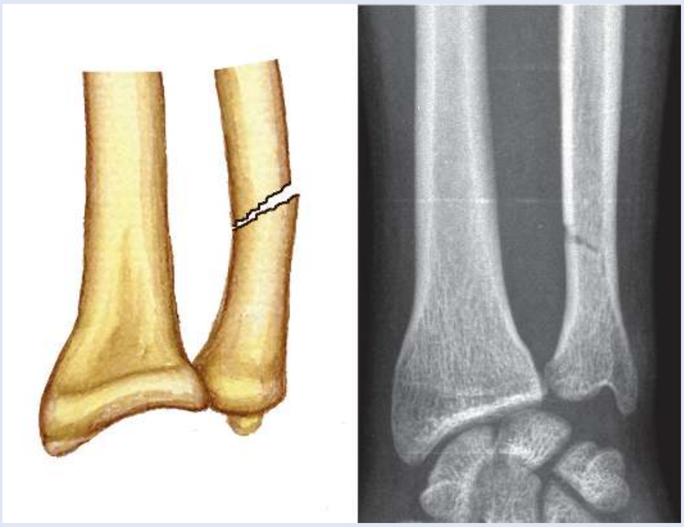
23-A Radius/ulna, distal, extra-articular fractures

23-A1 Ulna, radius intact
2,450 fractures
M: 1,598 (65.22%)
F: 852 (34.78%)
0.65% of total adult fractures
4.21% of adult radius/ulna
5.64% of segment **23**
9.58% of type **23-A**

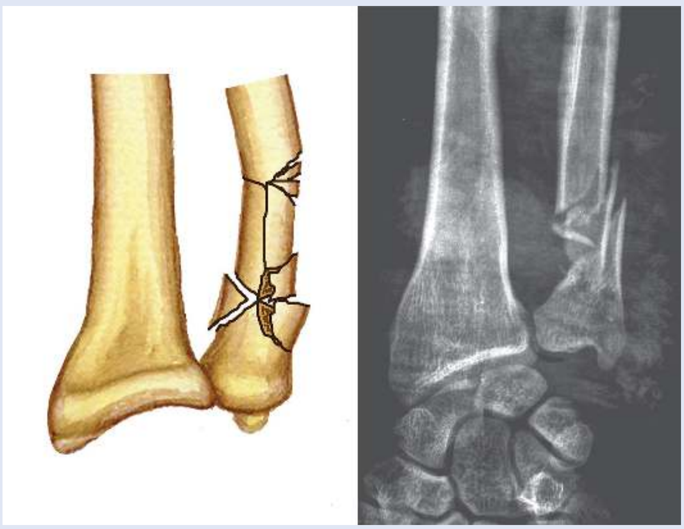
23-A1.1 Styloid process



23-A1.2 Metaphyseal simple



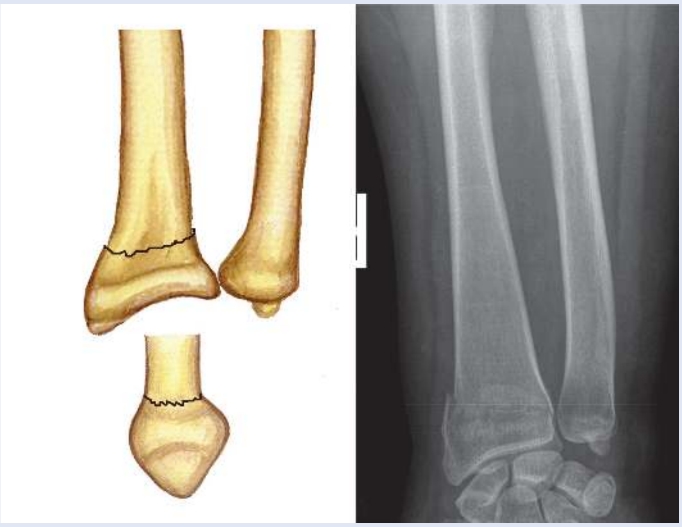
23-A1.3 Metaphyseal multifragmentary



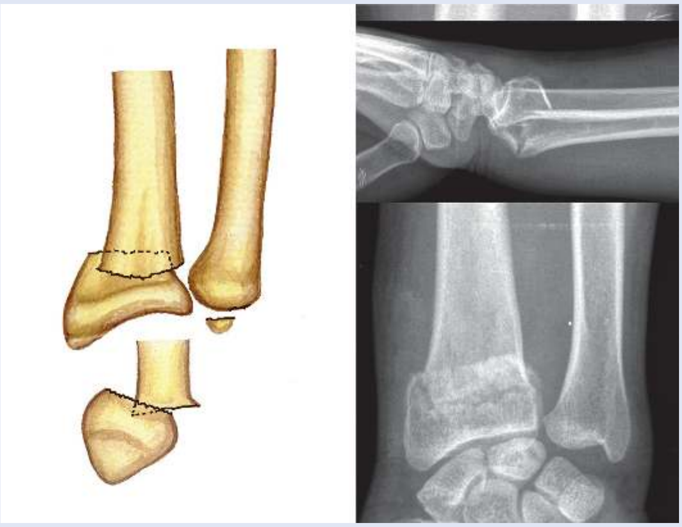
23-A Radius/ulna, distal, extra-articular fractures

23-A2 Radius simple or impact
17,744 fractures
M: 6,038 (34.03%)
F: 11,706 (65.97%)
4.74% of total adult fractures
30.48% of adult radius/ulna
40.87% of segment 23
69.39% of type 23-A

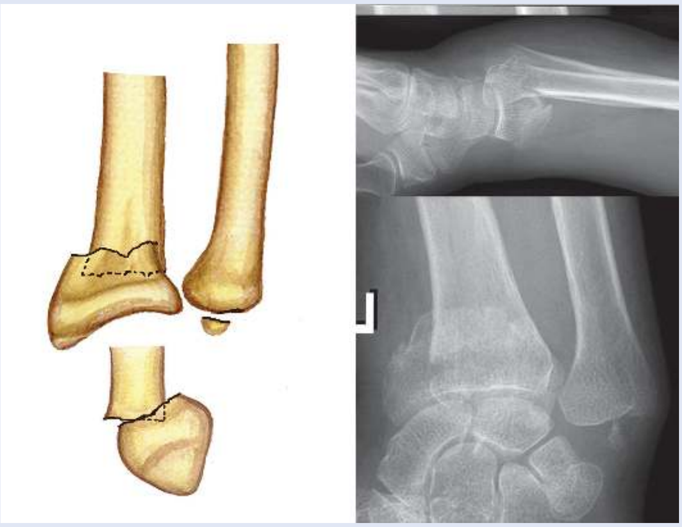
23-A2.1 Without displacement



23-A2.2 With dorsal displacement (Colles fracture)



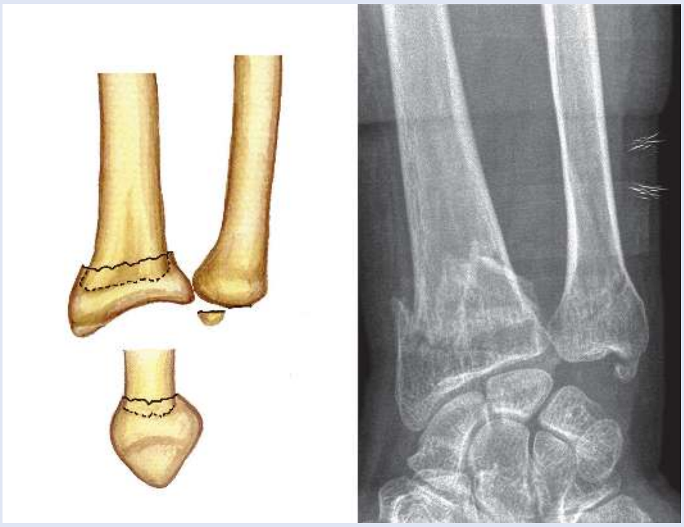
23-A2.3 With volar displacement (Smith fracture)



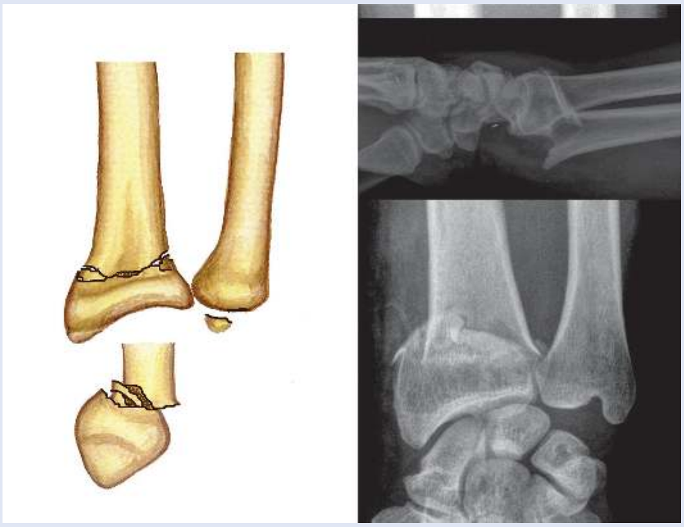
23-A Radius/ulna, distal, extra-articular fractures

23-A3 Radius multifragmentary
5,377 fractures
M: 1,787 (33.23%)
F: 3,590 (66.77%)
1.44% of total adult fractures
9.24% of adult radius/ulna
12.38% of segment 23
21.03% of type 23-A

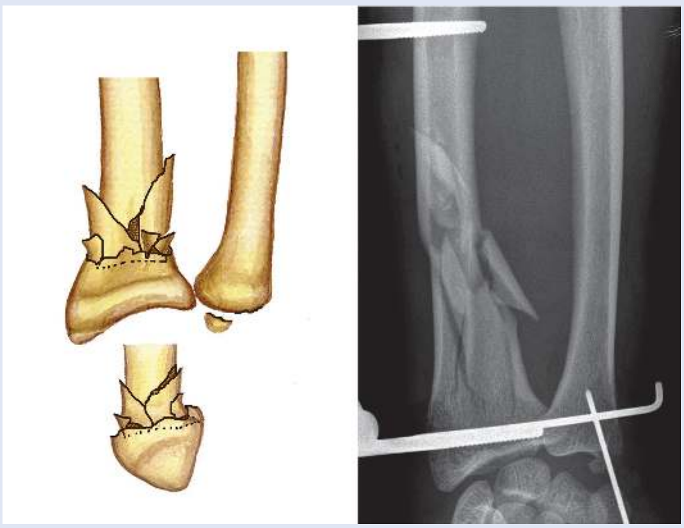
23-A3.1 Impacted with axial shortening



23-A3.2 Impacted with wedge fragments



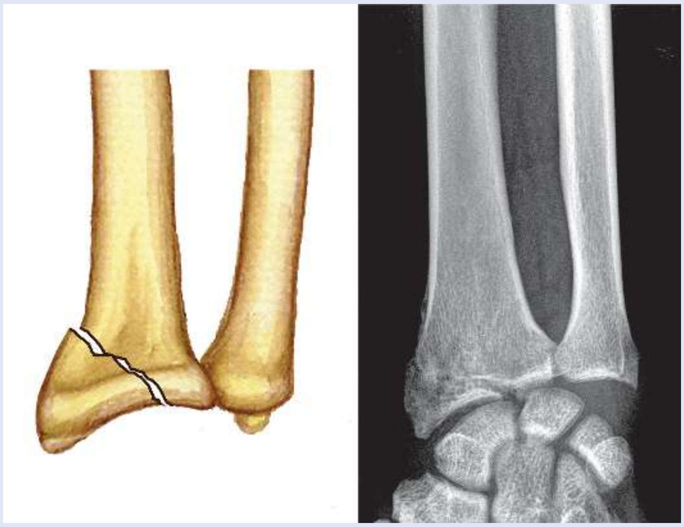
23-A3.3 Complex



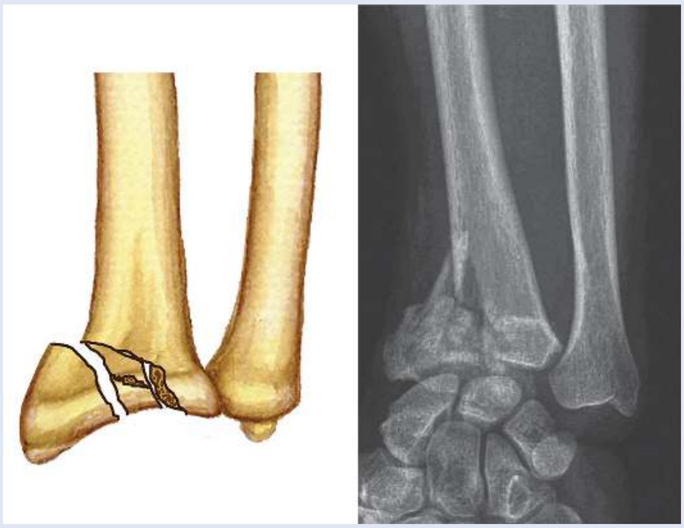
23-B Radius/ulna, distal, partial articular fractures

23-B1 Radius, sagittal
5,001 fractures
M: 2,929 (58.57%)
F: 2,072 (41.43%)
1.34% of total adult fractures
8.59% of adult radius/ulna
11.52% of segment **23**
64.34% of type **23-B**

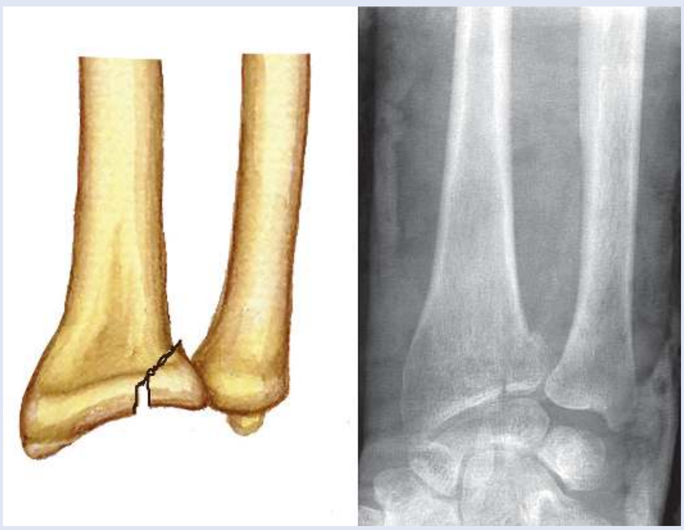
23-B1.1 Lateral simple



23-B1.2 Lateral multifragmentary



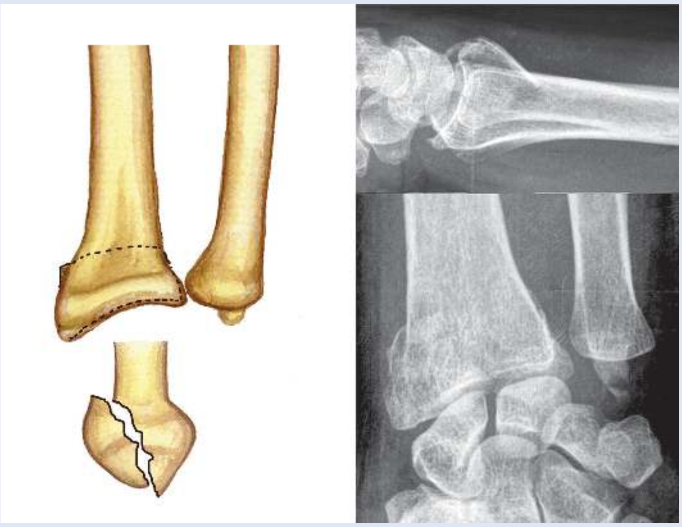
23-B1.3 Medial



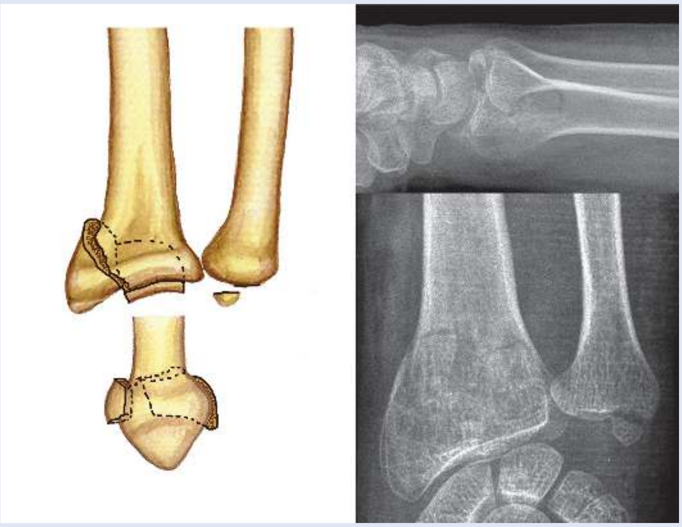
23-B Radius/ulna, distal, partial articular fractures

23-B2 Radius dorsal rim frontal
1,421 fractures
M: 662 (46.59%)
F: 759 (53.41%)
0.38% of total adult fractures
2.44% of adult radius/ulna
3.27% of segment 23
18.28% of type 23-B

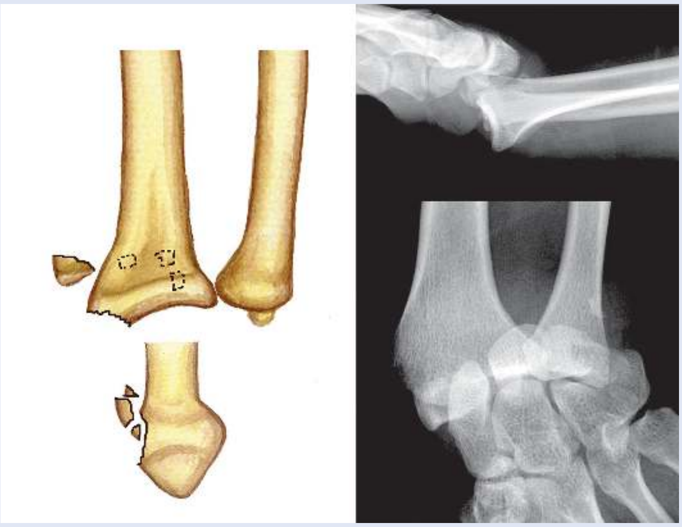
23-B2.1 Simple



23-B2.2 With lateral sagittal fracture line



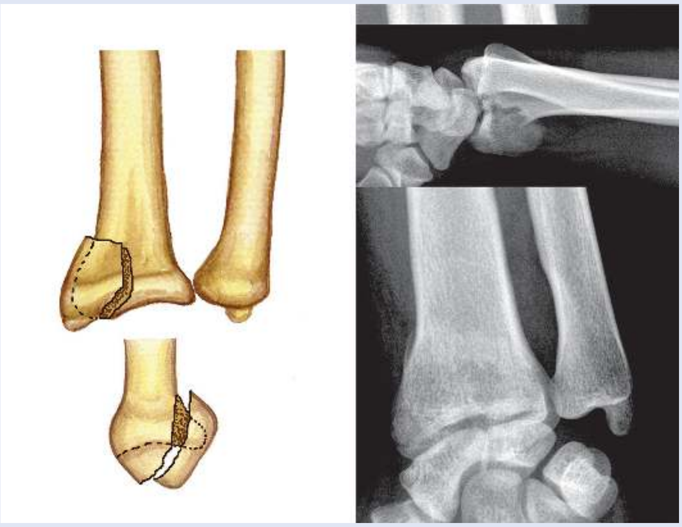
23-B2.3 With dorsal displacement of carpus



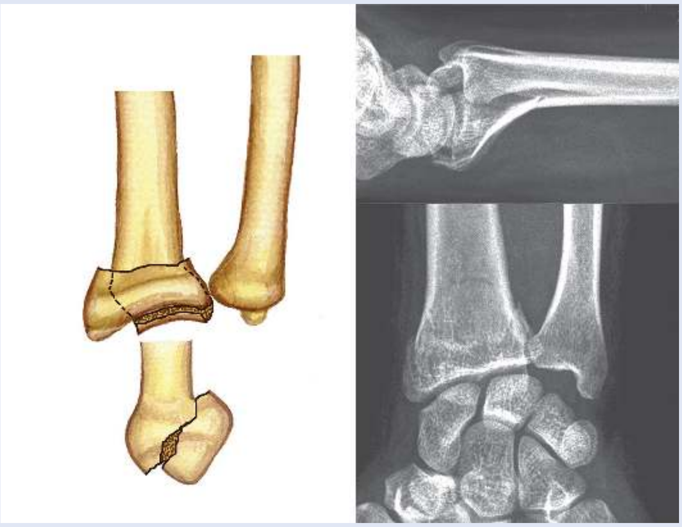
23-B Radius/ulna, distal, partial articular fractures

23-B3 Radius volar rim frontal
1,351 fractures
M: 655 (48.48%)
F: 696 (51.52%)
0.36% of total adult fractures
2.32% of adult radius/ulna
3.11% of segment 23
17.38% of type 23-B

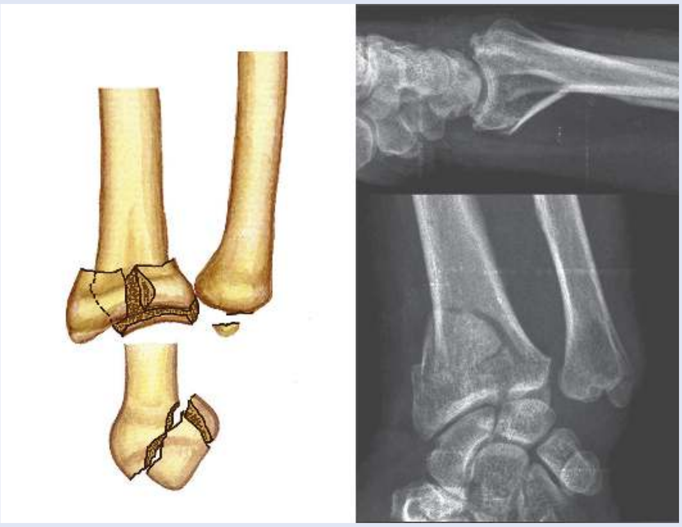
23-B3.1 Simple with small fragment



23-B3.2 Simple with large fragment



23-B3.3 Multifragmentary

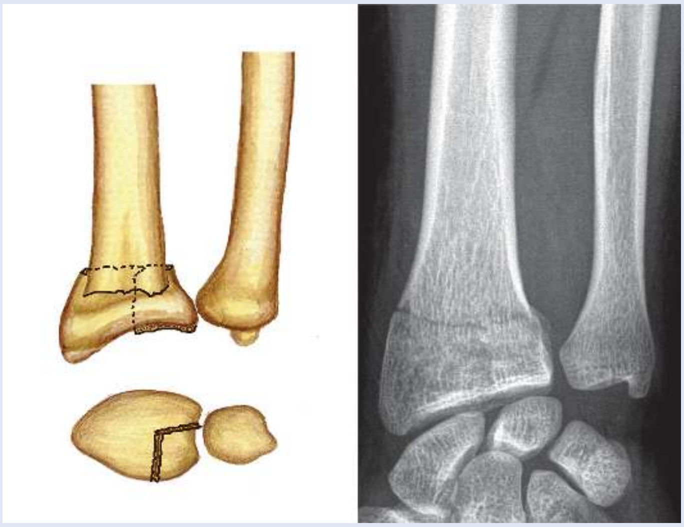


3

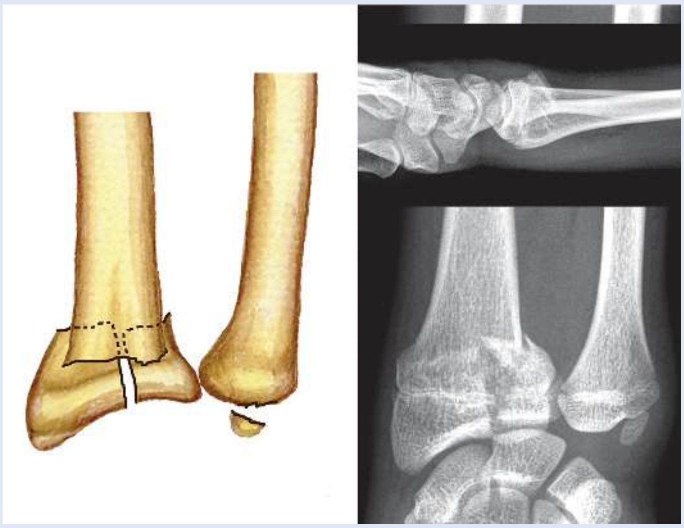
23-C Radius/ulna, distal, complete articular fractures

23-C1 Radius articular simple, metaphyseal simple
4,955 fractures
M: 1,997 (40.30%)
F: 2,958 (59.70%)
1.32% of total adult fractures
8.51% of adult radius/ulna
11.41% of segment 23
49.18% of type 23-C

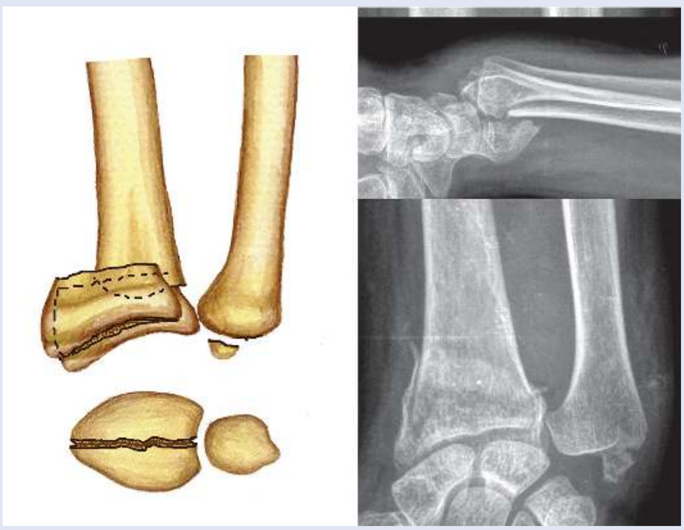
23-C1.1 Posteromedial articular fragment



23-C1.2 With sagittal articular fracture line



23-C1.3 With frontal articular fracture line

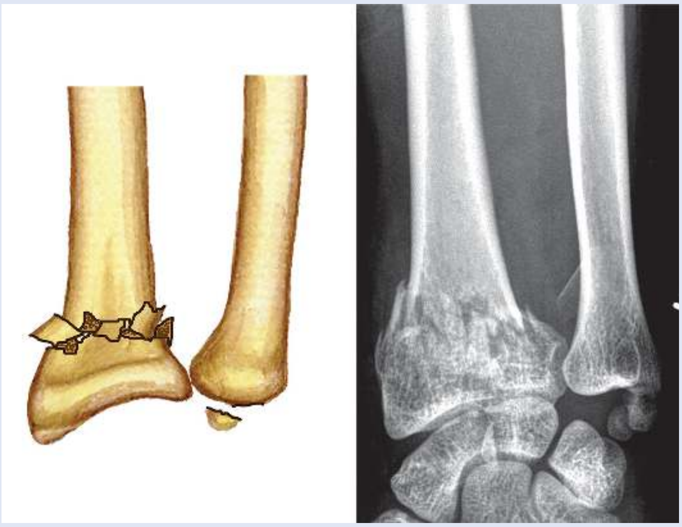


3

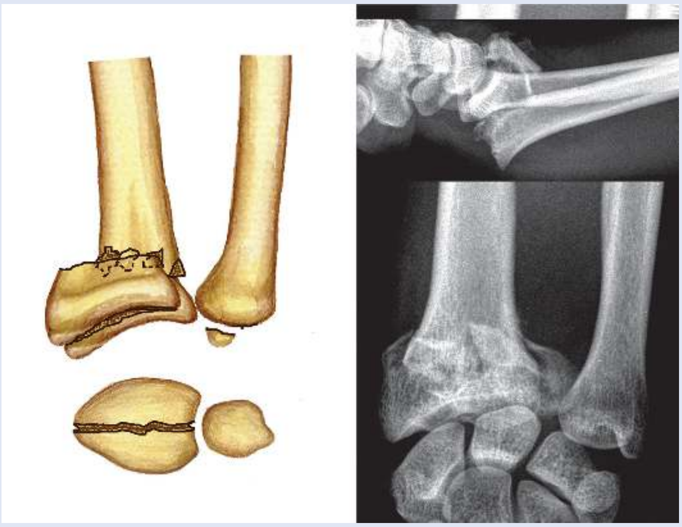
23-C Radius/ulna, distal, complete articular fractures

23-C2 Radius articular simple, metaphyseal multifragmentary
2,204 fractures
M: 978 (44.37%)
F: 1,226 (55.63%)
0.59% of total adult fractures
3.79% of adult radius/ulna
5.08% of segment 23
21.87% of type 23-C

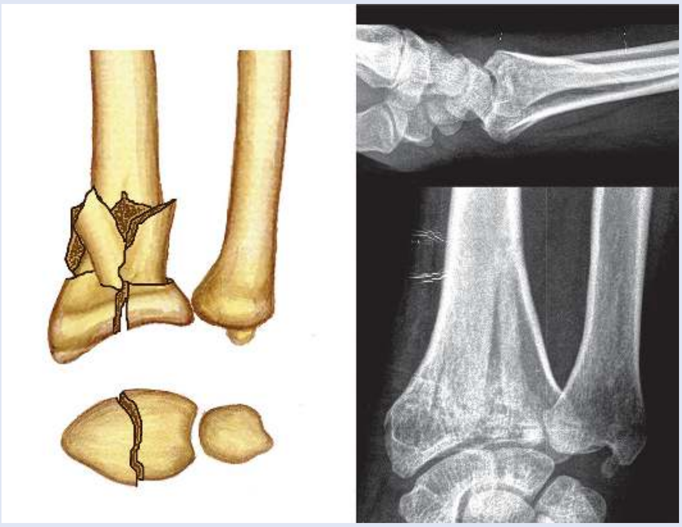
23-C2.1 With sagittal articular fracture line



23-C2.2 With frontal articular fracture line



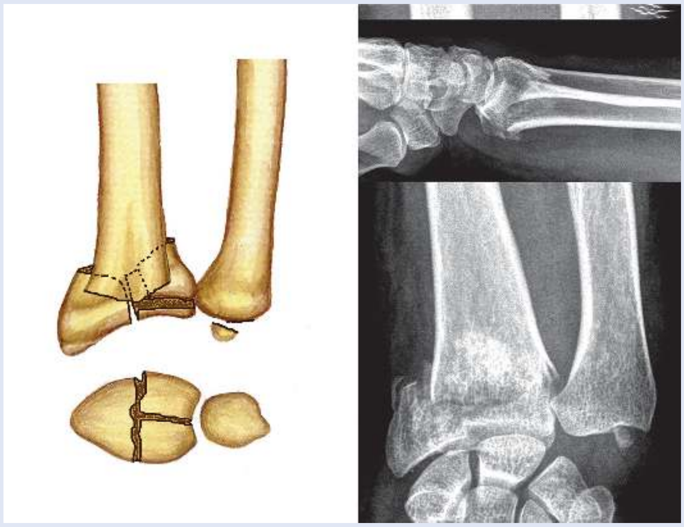
23-C2.3 Fracture line extending from articulation into the diaphysis



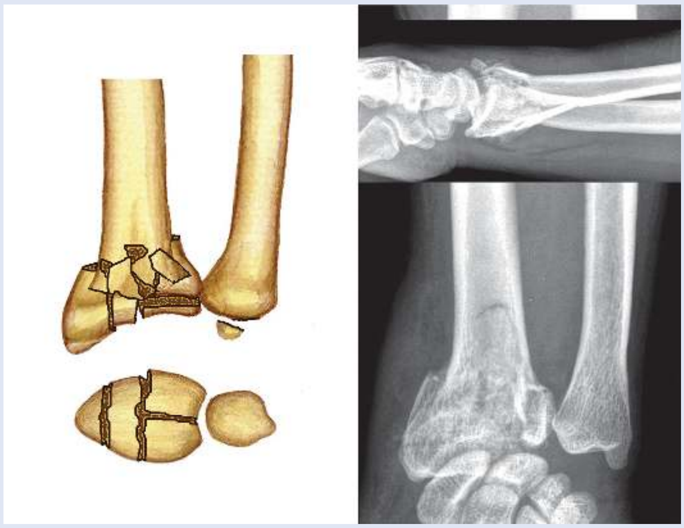
23-C Radius/ulna, distal, complete articular fractures

23-C3 Radius articular multifragmentary, metaphyseal simple or multifragmentary
2,917 fractures
M: 1,365 (46.79%)
F: 1,552 (53.21%)
0.78% of total adult fractures
5.01% of adult radius/ulna
6.72% of segment **23**
28.95% of type **23-C**

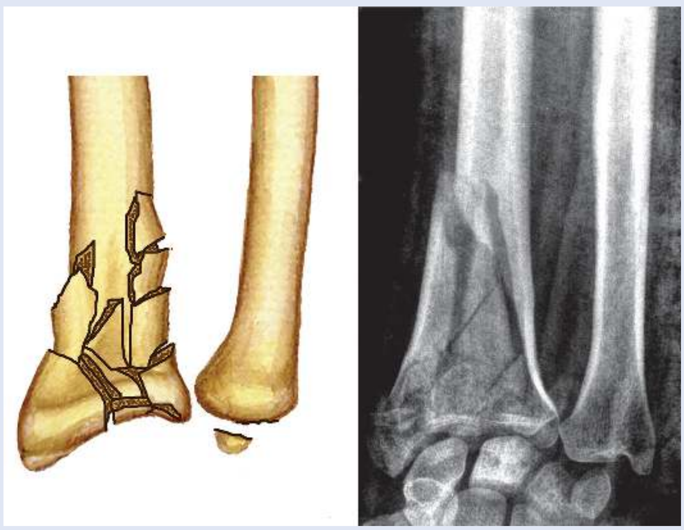
23-C3.1 Metaphyseal simple



23-C3.2 Metaphyseal multifragmentary



23-C3.3 Fracture line extending from articulation into the diaphysis



3

Injury Mechanism

The distal radial/ulnar fracture results from force transmitted through the hand and wrist to the distal radius/ulna, which often occurs from a fall on an outstretched hand. Fractures of the distal radius/ulna can be further divided into extension fractures, flexion fractures, and intra-articular fractures, associated with a dislocation of the wrist joint depending on different injury mechanisms. Extension fractures result from a fall on an outstretched pronated hand with impact on the palm and subsequent forced dorsiflexion and hyperextension. A fall onto the back of the hand with the hand and carpus in hyperflexion can result in flexion fractures.

Diagnosis

Patients with fractures of the distal radius/ulna may present with pain and a swollen distal forearm with localized tenderness. If fractures are accompanied by significant displacement or angulation, then a typical deformity will appear, such as a "dinner-fork" deformity of the wrist. A detailed neurovascular examination is imperative.

Imaging studies should include an AP and lateral view of the wrist joint, which are both helpful in assessing the fracture type of the distal forearm and the degree of the displacement. A CT scan may be required to provide better visualization for complex or intra-articular fractures, or when the initial X-ray fails to indicate the position of the fragment.

Treatment

Intra- or extra-articular fractures with minimal or no displacement, and stable, impacted fractures with minimal or no shortening can be managed by closed reduction and cast or splint immobilization. Surgical fixation should be considered in patients with unstable fractures of the distal radius/ulna, and intra-articular fractures with marked displacement.

Other Classifications of Ulnar and Radial Fractures

Monteggia Fractures

Overview

The Monteggia fracture is a fracture of the proximal third of the ulna with dislocation of the radial head. It is named after Giovanni Monteggia, who first described this injury in 1814. In 1967, Bado further divided Monteggia fractures into four types depending upon displacement of radial head. The types of Monteggia fractures (Bado type) and their injury mechanisms are as follows:

- *Type I*: anterior dislocation of the radial head with associated anteriorly angulated fracture of the ulna, which usually occurs with the hand in forced pronation.
- *Type II*: posterior/posterolateral dislocation of the radial head with associated posteriorly angulated fracture of the ulnar shaft. This typically occurs from axial loading of the forearm with a flexed elbow.
- *Type III*: lateral/anterolateral dislocation of the radial head with fracture of the ulnar metaphysis. This typically occurs from forced abduction of the elbow. The radial head will dislocate posterolaterally if the hand is in forced supination, or anterolaterally if the hand is in forced pronation.
- *Type IV*: anterior dislocation of the radial head with fractures of both the radius and ulna within the proximal third at the same level. This typically occurs from a mechanism similar to type I but combined with a radial shaft fracture.

The typical presentation for a Monteggia fracture is a painful, swollen, and deformed elbow with bony crepitus and an abnormal range of motion of the injured area. Particular attention should be paid to the posterior interosseous branch of the radial nerve, which courses around the radial neck, and is especially at risk in Monteggia fractures. Imaging studies must include AP and lateral views of the elbow joint. Determining whether or not the extension of the long axis of the radius points directly at the capitellum can be helpful in assessing the radiocapitellar joint, which can be better visualized on the lateral projection of the elbow (▶ Fig. 3.33).

Compared with other fracture types of the forearm, Monteggia fractures are more likely to cause unstable fractures and stiffness of the elbow joint. Most pediatric fracture patterns can be managed conservatively with closed reduction and casting, but may require open reduction if the closed reduction fails due to an impacted or torn annular ligament. However, most adult fractures require surgical treatment. Fractures with radial nerve injuries should be treated with open reduction and internal fixation, and exploration of the radial nerve should be performed as well.

Fig. 3.33 Anteroposterior (AP) and lateral views of the elbow joint.

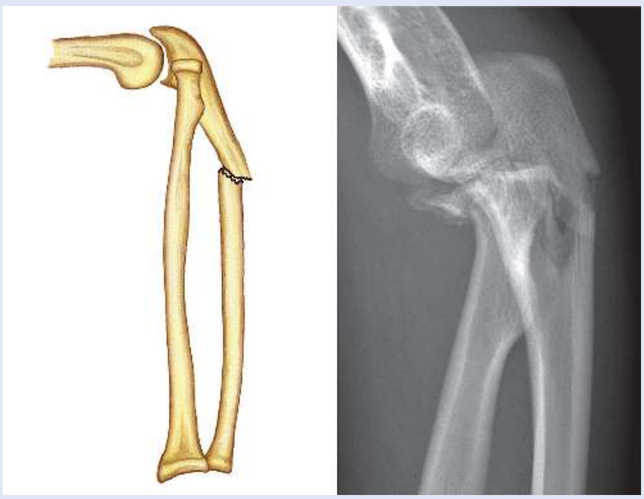
■ Monteggia Fracture Types

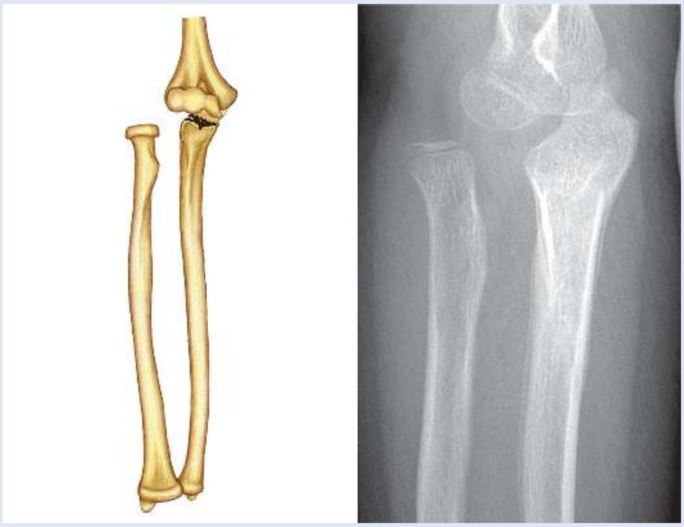
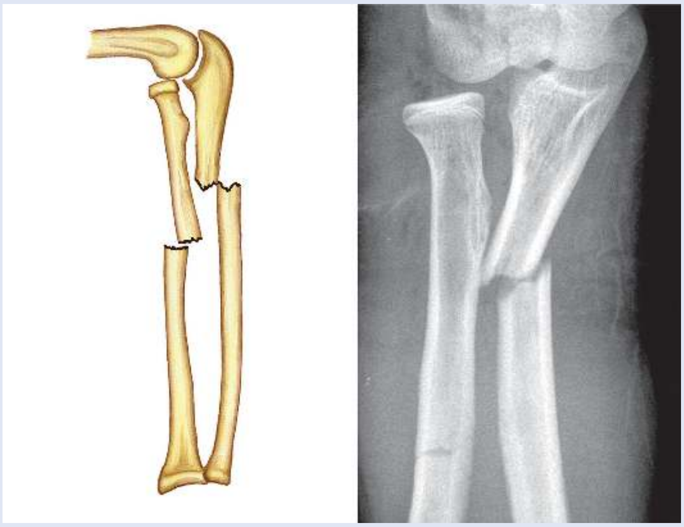
Type I: Anterior dislocation of the radial head with associated anteriorly angulated fracture of the ulnar shaft
450 fractures
M: 297 (66.00%)
F: 153 (34.00%)
0.10% of total
0.59% of radius/ulna
47.87% of Monteggia fractures

Monteggia Type I

Type II: Posterolateral dislocation of the radial head with associated posteriorly angulated fracture of the ulnar shaft
129 fractures
M: 90 (69.77%)
F: 39 (30.23%)
0.03% of total
0.17% of radius/ulna
13.72% of Monteggia fractures

Monteggia Type II



Type III: Lateral/anterolateral dislocation of the radial head with fracture of ulnar metaphysis 276 fractures M: 215 (77.90%) F: 61 (22.10%) 0.06% of total 0.36% of radius/ulna 29.36% of Monteggia fractures	Monteggia Type III 
Type IV: Anterior dislocation of radial head with fractures of both the radius and ulna within proximal third at the same level 85 fractures M: 66 (77.65%) F: 19 (22.35%) 0.02% of total 0.11% of radius/ulna 9.04% of Monteggia fractures	Monteggia Type IV 

■ Clinical Epidemiologic Features of Monteggia Fractures

A total of 940 Monteggia fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 0.22% of all fractures and 1.23% of fractures of the radius/ulna. The epidemiologic features of Monteggia fracture are as follows:

- More males than females
- The high-risk age group is 6–10 years
- The most common Monteggia fracture type by Bado classification is Type I

Monteggia Fractures by Sex

See ▶ Table 3.23 and ▶ Fig. 3.34.

Table 3.23 Sex distribution of 940 Monteggia fractures

Sex	Number of fractures	Percentage
Male	668	71.06
Female	272	28.94
Total	940	100.00

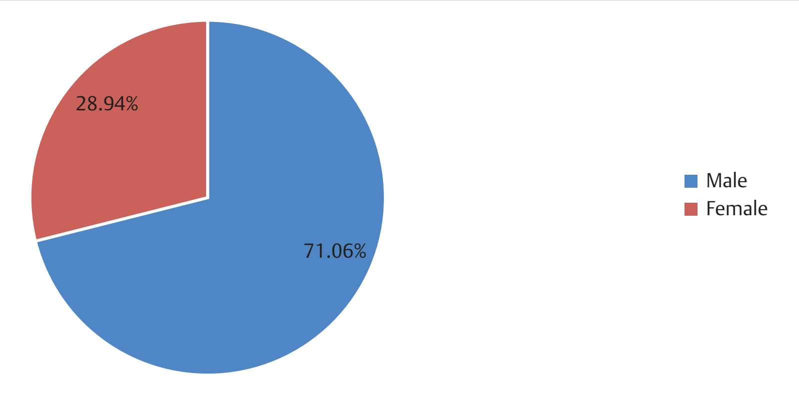


Fig. 3.34 Sex distribution of 940 Monteggia fractures.

Monteggia Fractures by Age Group

See ▶ Table 3.24 and ▶ Fig. 3.35.

Table 3.24 Age and sex distribution of 940 Monteggia fractures

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	92	62	154	16.38
6–10	110	55	165	17.55
11–15	55	5	60	6.38
16–20	45	13	58	6.17
21–25	51	22	73	7.77
26–30	49	16	65	6.91
31–35	61	24	85	9.04
36–40	57	7	64	6.81
41–45	56	20	76	8.09
46–50	40	17	57	6.06
51–55	23	9	32	3.40
56–60	15	5	20	2.13
61–65	10	3	13	1.38
66–70	3	4	7	0.74
71–75	0	8	8	0.85
76–80	0	1	1	0.11
81–85	1	1	2	0.21
≥ 86	0	0	0	0.00
Total	668	272	940	100.00

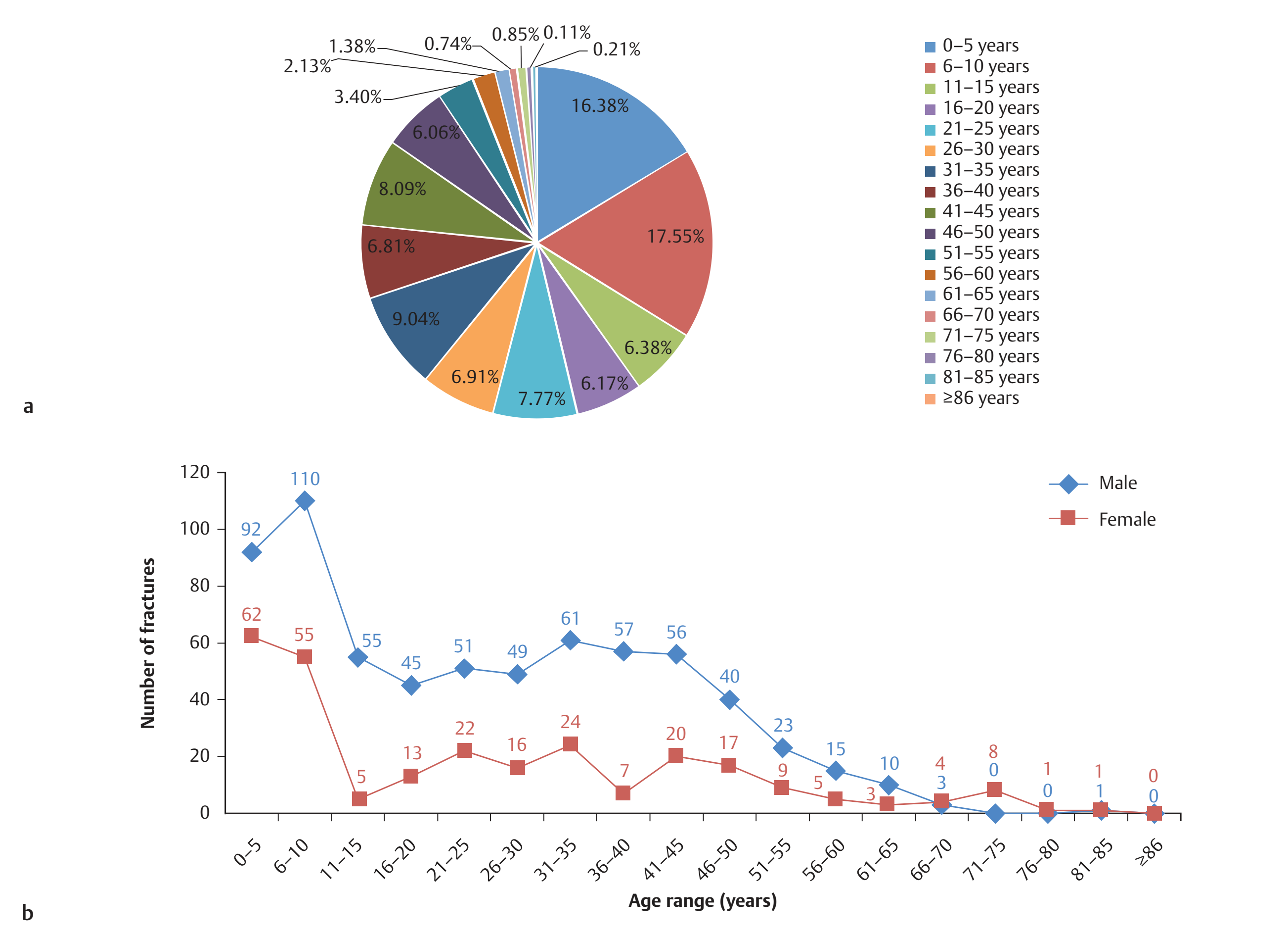


Fig. 3.35 (**a**) Age distribution of 940 Monteggia fractures. (**b**) Age and sex distribution of 940 Monteggia fractures.

Monteggia Fractures by Type

See ▶ Table 3.25 and ▶ Fig. 3.36.

Table 3.25 Sex and fracture type distribution of 940 Monteggia fractures

Fracture type	Male	Female	Number of fractures	Percentage
I	297	153	450	47.87
II	90	39	129	13.72
III	215	61	276	29.36
IV	66	19	85	9.04
Total	668	272	940	100.00

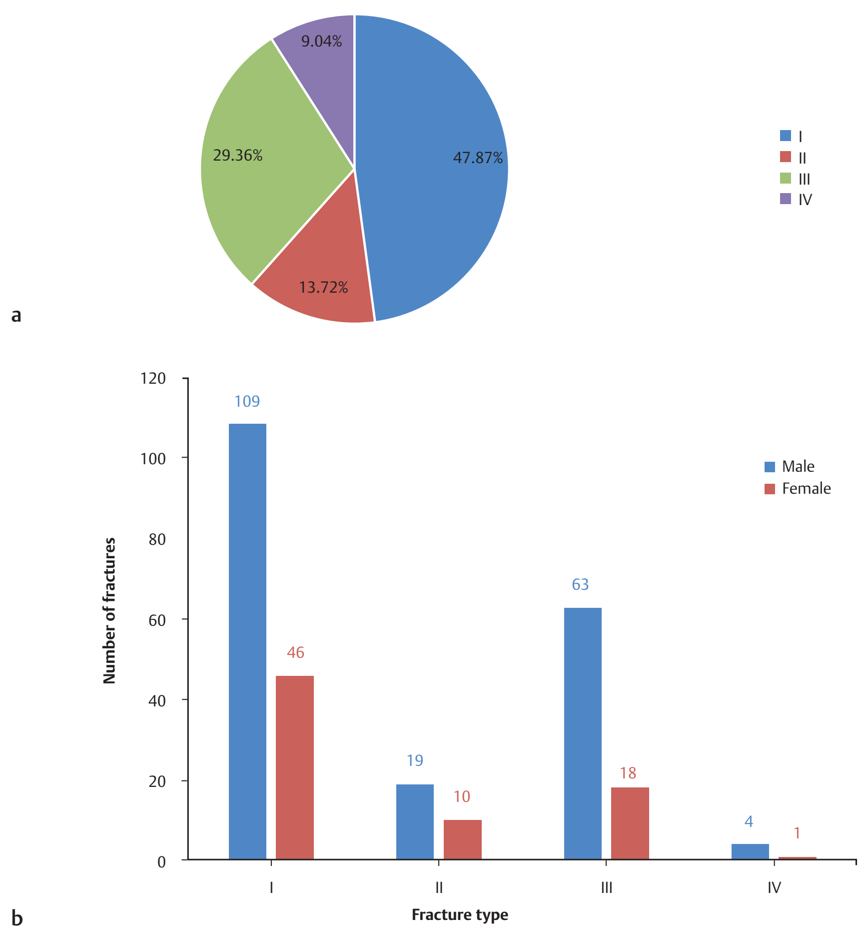


Fig. 3.36 (**a**) Fracture type distribution of 940 Monteggia fractures. (**b**) Sex and fracture type distribution of 940 Monteggia fractures.

Galeazzi Fractures

Overview

The Galeazzi fracture is an injury pattern involving a fracture of distal third of the radial shaft with associated subluxation or dislocation of the DRUJ (▶ Fig. 3.37).

Galeazzi fractures usually occur from a fall on the outstretched hand, causing an axial load on the hyperpronated forearm. This type of injury can also result from a direct blow on the wrist joint or dorsal rim of the distal third of the radial shaft, or from a manufacturing injury. In a fracture of the radial shaft with marked displacement, the radius will be shortened and angulated in relation to the ulna, with associated dorsal displacement of the ulnar head. Physical examination reveals tenderness to palpation over the DRUJ. Radiographic examination often shows dorsal angulation of the radial fracture with dorsal displacement of ulnar head. The injury of the DRUJ may occur as a purely ligamentous injury, or may be associated with an avulsion fracture of the ulnar styloid process.

Galeazzi fractures are easily misdiagnosed, and closed reduction and cast application can lead to unsatisfactory results. Open reduction and stable internal fixation of the radial fracture can usually reduce the DRUJ to a normal anatomic position. If the DRUJ is reducible but unstable, then stabilization of the DRUJ in supination should be attempted by placing a K-wire from the ulna into the radius, just proximal to the articular surface, for 6 weeks after surgery.

Clinical Epidemiologic Features of Galeazzi Fractures

A total of 796 Galeazzi fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 0.18% of all fractures and 1.04% of fractures of the radius/ulna. Their epidemiologic features are as follows:

- More males than females
- The high-risk age group is 11–15 years, the most affected female age group is 6–10 years, while males between the ages of 11 and 15 have the highest risk

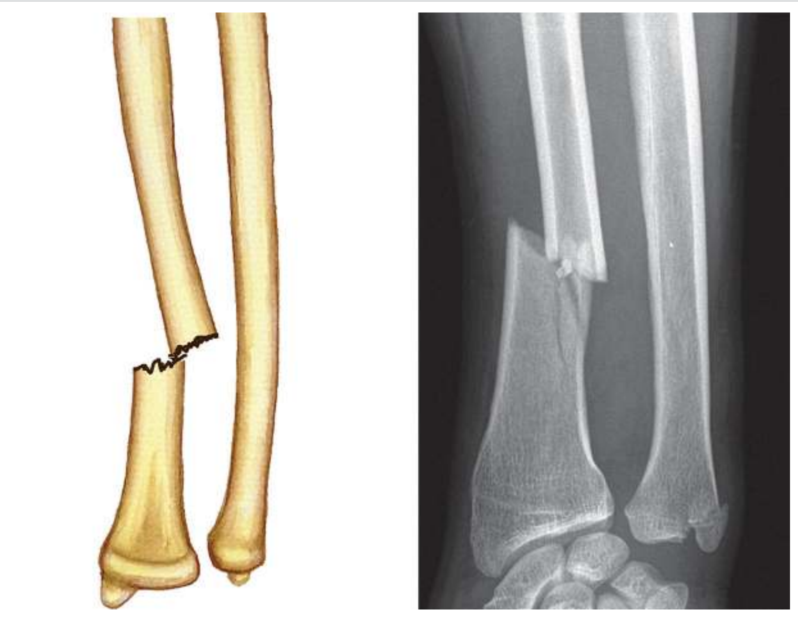


Fig. 3.37 Galeazzi fracture.

Galeazzi Fractures by Sex

See ▶ Table 3.26 and ▶ Fig. 3.38.

Table 3.26 Sex distribution of 796 Galeazzi fractures

Sex	Number of fractures	Percentage
Male	571	71.73
Female	225	28.27
Total	796	100.00

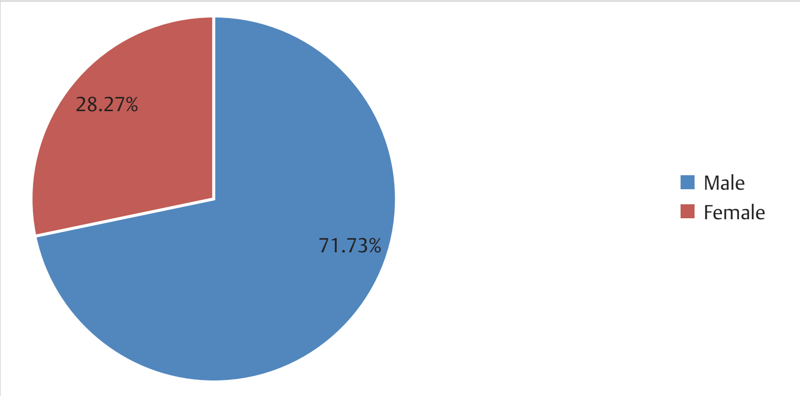


Fig. 3.38 Sex distribution of 796 Galeazzi fractures.

Galeazzi Fractures by Age Group

See ▶ Table 3.27 and ▶ Fig. 3.39.

Table 3.27 Age and sex distribution of 796 Galeazzi fractures

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	27	23	50	6.28
6–10	85	29	114	14.32
11–15	113	13	126	15.83
16–20	52	8	60	7.54
21–25	57	8	65	8.17
26–30	57	11	68	8.54
31–35	31	9	40	5.03
36–40	42	23	65	8.17
41–45	30	23	53	6.66
46–50	25	15	40	5.03
51–55	16	17	33	4.15
56–60	18	13	31	3.89
61–65	8	9	17	2.14
66–70	3	9	12	1.51
71–75	3	4	7	0.88
76–80	2	7	9	1.13
81–85	2	2	4	0.50
≥ 86	0	2	2	0.25
Total	571	225	796	100.00

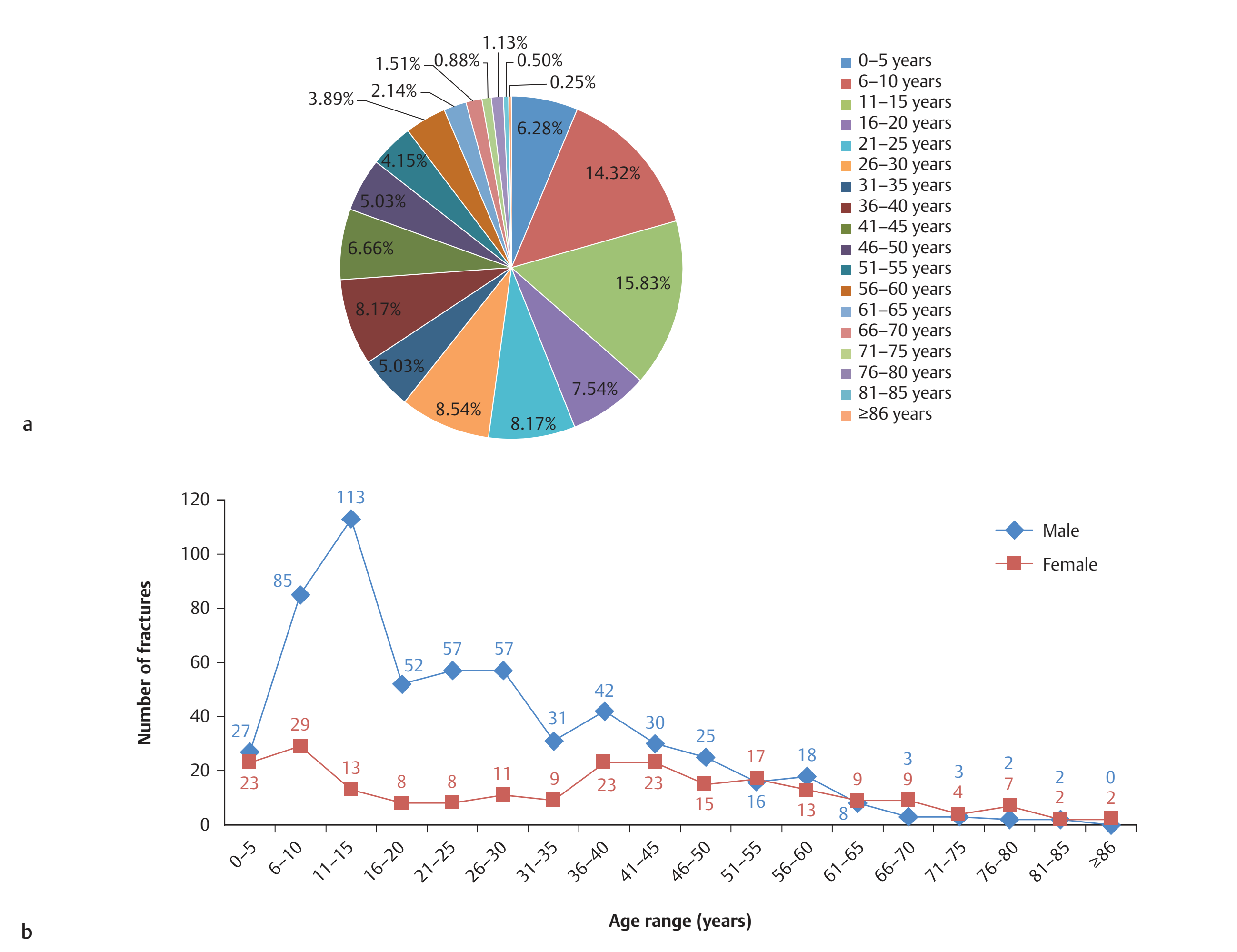


Fig. 3.39 (a) Age distribution of 796 Galeazzi fractures. (b) Age and sex distribution of 796 Galeazzi fractures.

Colles Fractures

Overview

Colles fracture describes a fracture through the distal metaphysis, about 2 to 3 cm proximal to the articular surface of the radius, with dorsal displacement of the distal fragment, and may be associated with an avulsion fracture of ulnar styloid process (▶ Fig. 3.40). Characteristic findings in a Colles fracture are a "dinner–fork" deformity from the lateral view and a "bayonet-shaped" deformity from the anterior view. Typical plain film findings include dorsal displacement of the distal radial fragment, dorsal tilt, radial shortening, ulnar angulation of the wrist, loss of radial inclination, and comminution at the fracture site. The wrist joint and DRUJ can be involved separately or in conjunction with each other.

The fracture is most commonly caused by falling forward on an outstretched hand with the wrist in extension. Treatment depends on the severity of the fracture; however, most Colles fractures can be managed by closed reduction and casting application and they rarely require surgical intervention.

Clinical Epidemiologic Features of Colles Fractures

A total of 14,790 Colles fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; they accounted for 3.43% of all fractures and 19.32% of fractures of the radius/ulna. Their epidemiologic features are as follows:

- More females than males
- The high-risk age group is 56–60 years, males between the ages of 11 and 15 years and females between the ages of 56 and 60 years have the highest risk

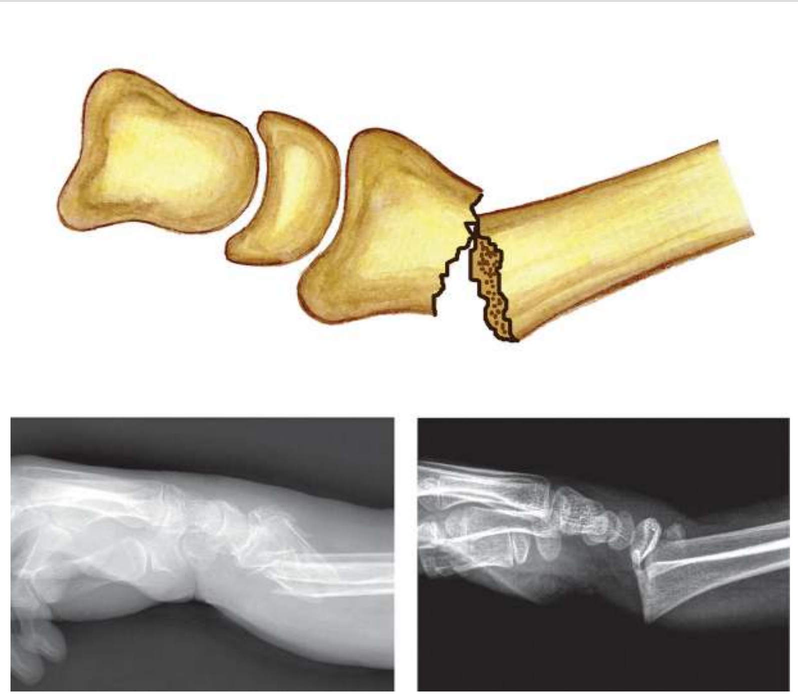


Fig. 3.40 Colles fracture.

Colles Fractures by Sex

See ▶ Table 3.28 and ▶ Fig. 3.41.

Table 3.28 Sex distribution of 14,790 Colles fractures

Sex	Number of fractures	Percentage
Male	6,842	46.26
Female	7,948	53.74
Total	14,790	100.00

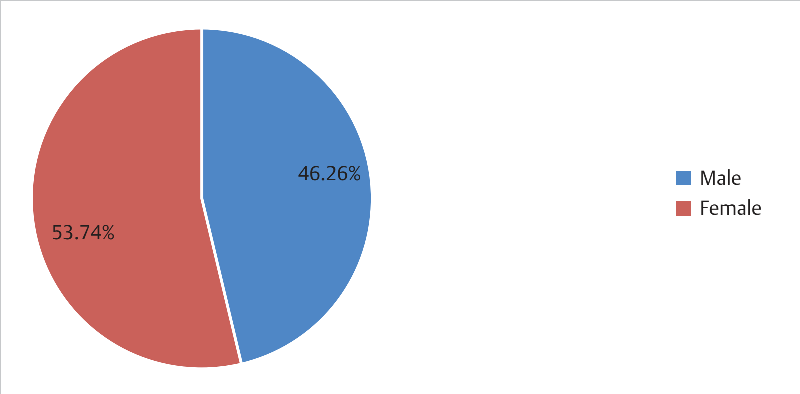


Fig. 3.41 Sex distribution of 14,790 Colles fractures.

Colles Fractures by Age Group

See ▶ Table 3.29 and ▶ Fig. 3.42.

Table 3.29 Age and sex distribution of 14,970 Colles fractures

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	280	130	410	2.77
6–10	954	272	1,226	8.29
11–15	1,327	199	1,526	10.32
16–20	654	124	778	5.26
21–25	429	158	587	3.97
26–30	308	165	473	3.20
31–35	306	207	513	3.47
36–40	362	274	636	4.30
41–45	389	359	748	5.06
46–50	413	618	1,031	6.97
51–55	376	927	1,303	8.81
56–60	329	1,335	1,664	11.25
61–65	227	830	1,057	7.15
66–70	182	736	918	6.21
71–75	112	658	770	5.21
76–80	107	531	638	4.31
81–85	56	278	334	2.26
≥ 86	31	147	178	1.20
Total	6,842	7,948	14,790	100.00

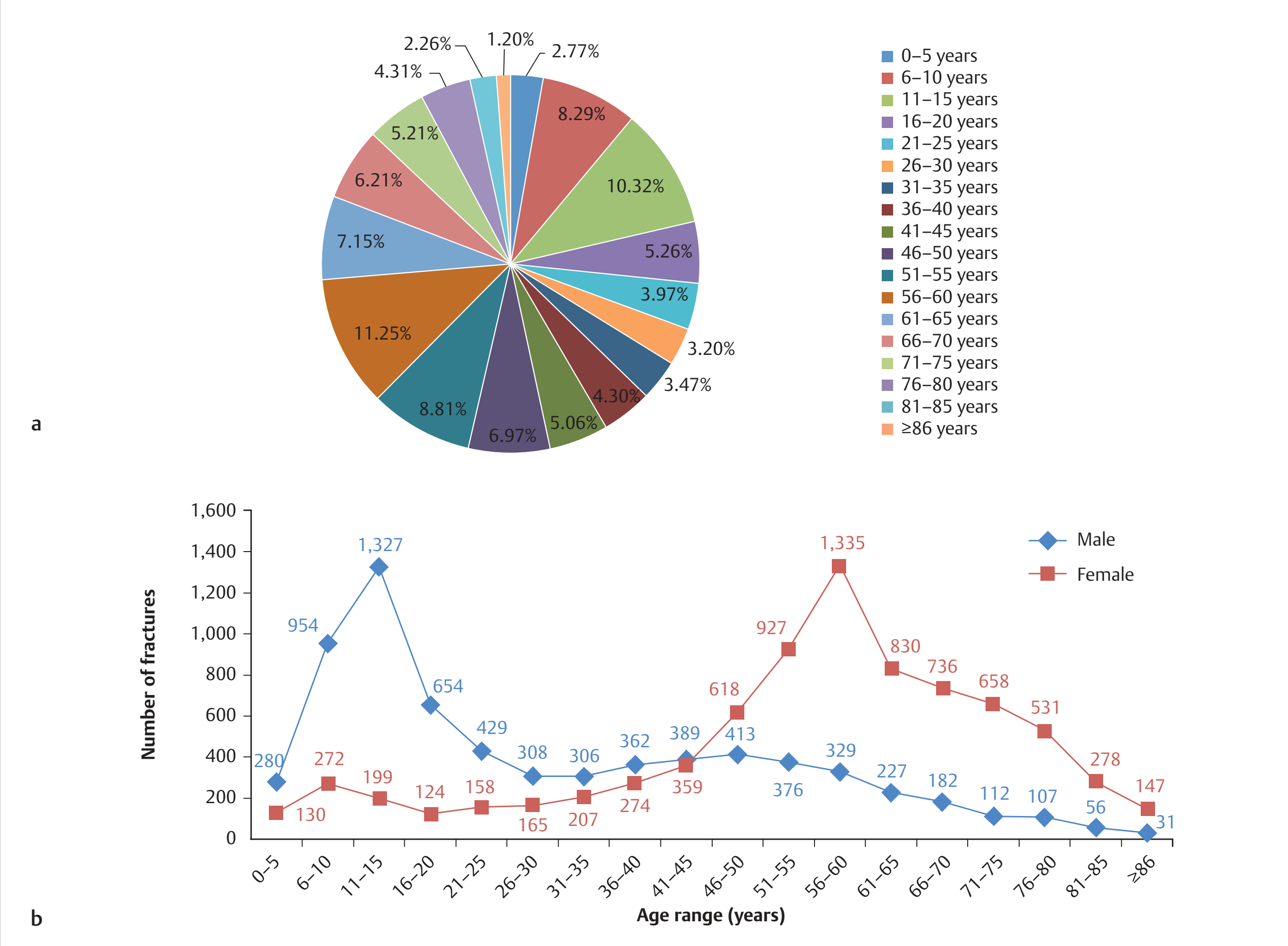


Fig. 3.42 (**a**) Age distribution of 14,790 Colles fractures. (**b**) Age and sex distribution of 14,790 Colles fractures.

Smith Fractures

Overview

A Smith fracture, also known as a reverse Colles fracture because it shares the same fracture location, is a fracture of the distal radius with associated volar displacement of the distal fragment. The injury usually occurs from falling on the back of the hand with the wrists in flexion, or from a direct blow to the dorsal wrist.

The classic finding in Smith fractures is a "garden spade" deformity resulting from volar angulation of the fracture. The subsequent compression on the carpal tunnel by the displaced fracture will cause carpal tunnel syndrome. Typical X-ray findings include volar displacement of the distal fragment, volar and radial angulation, communition of volar cortex at the fracture site, fragment rotation, and radial shortening.

According to Thomas, Smith fractures can be classified into three types as follows:

- *Type I:* extra-articular fracture of the distal radius with dorsal angulation and volar displacement (▶ Fig. 3.43a)
- *Type II:* intra-articular oblique fracture of the distal radius into the radiocarpal joint with volar displacement of the distal fragment with the carpal bones: equivalent to the volar type of Barton fractures (▶ Fig. 3.43b)
- *Type III:* oblique juxta-articular fracture of the distal radius with volar displacement of the distal fragment with the carpal bones (▶ Fig. 3.43c)

Treatment of Smith fractures depends on the severity of the fracture. A Smith fracture usually can be treated by closed reduction, splinting, or cast application. If the fracture is reducible but still unstable, the fracture should be stabilized by an external fixator. Significant angulation and displacement may require open reduction and internal fixation with a plate or K-wire.

Clinical Epidemiologic Features of Smith Fractures

A total of 3,237 Smith fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 4.23% of all fractures and 6.20% of fractures of the radius/ulna. Their epidemiologic features are as follows:

- More males than females
- The high-risk age group is 11–15 years, males belong to the aforementioned age group, while females between ages of 61 and 65 years have the highest risk
- The most common fracture type is Type I

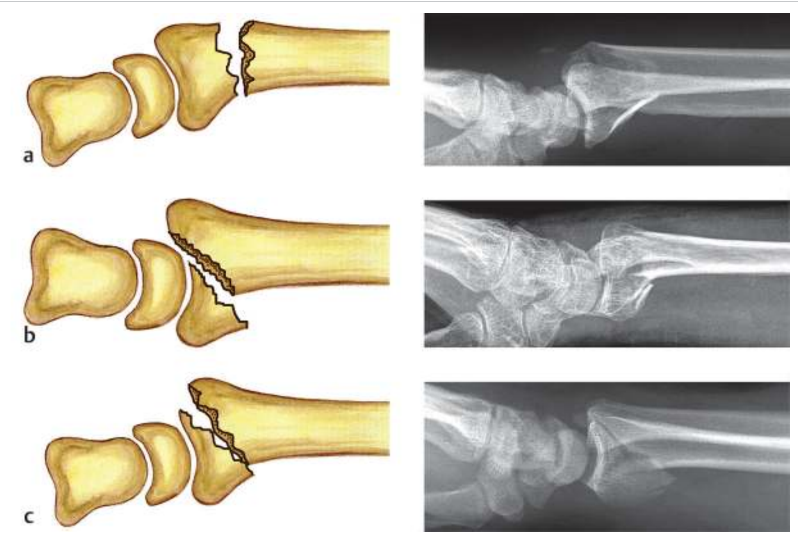


Fig. 3.43 Smith fracture: (**a**) Type I; (**b**) Type II; (**c**) Type III.

Smith Fractures by Sex

See ▶ Table 3.30 and ▶ Fig. 3.44.

Table 3.30 Sex distribution of 3,237 Smith fractures

Sex	Number of fractures	Percentage
Male	1,728	53.38
Female	1,509	46.62
Total	3,237	100.00

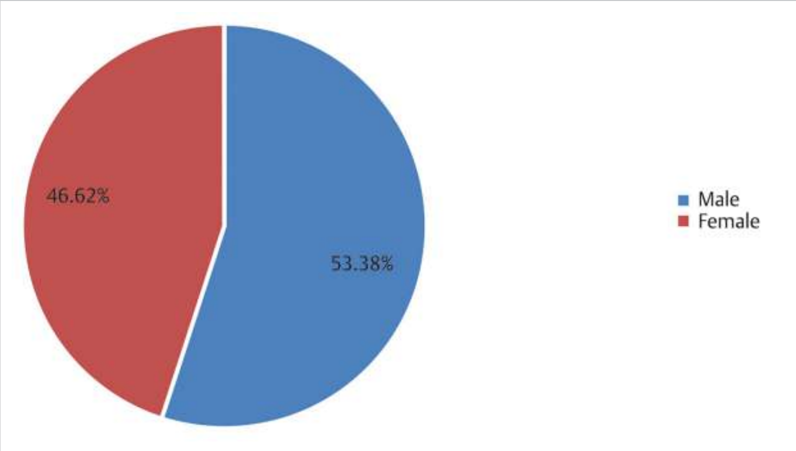


Fig. 3.44 Sex distribution of 3,237 Smith fractures.

Smith Fractures by Age Group

See ▶ Table 3.31 and ▶ Fig. 3.45.

Table 3.31 Age and sex distribution of 3,237 Smith fractures

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	55	29	84	2.59
6–10	205	99	304	9.39
11–15	487	113	600	18.54
16–20	157	29	186	5.75
21–25	95	37	132	4.08
26–30	80	47	127	3.92
31–35	72	50	122	3.77
36–40	80	63	143	4.42
41–45	107	64	171	5.28
46–50	117	117	234	7.23
51–55	79	155	234	7.23
56–60	55	158	213	6.58
61–65	52	162	214	6.61
66–70	34	125	159	4.91
71–75	28	125	153	4.73
76–80	15	72	87	2.69
81–85	4	41	45	1.39
≥ 86	6	23	29	0.90
Total	1,728	1,509	3,237	100.00

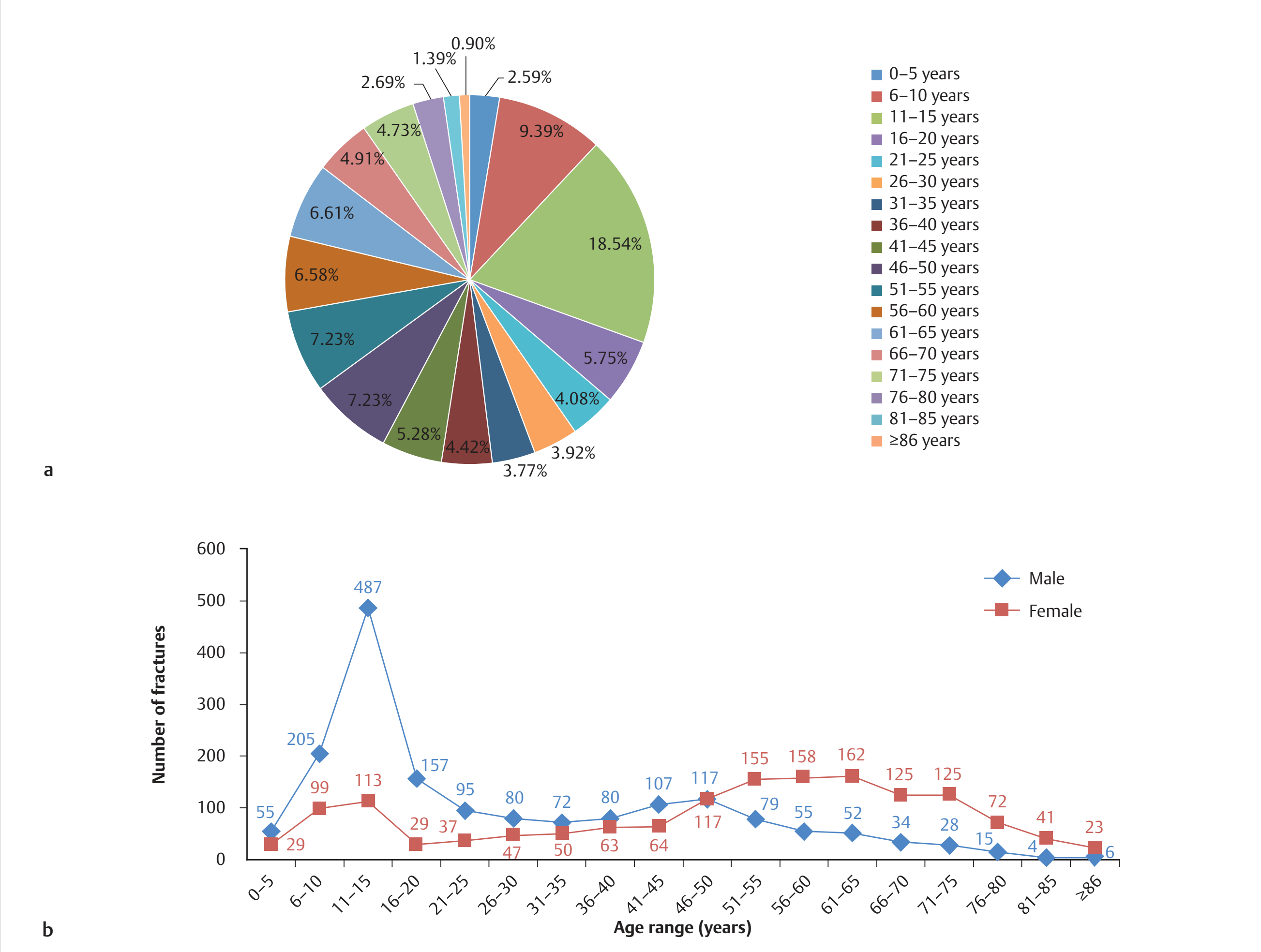


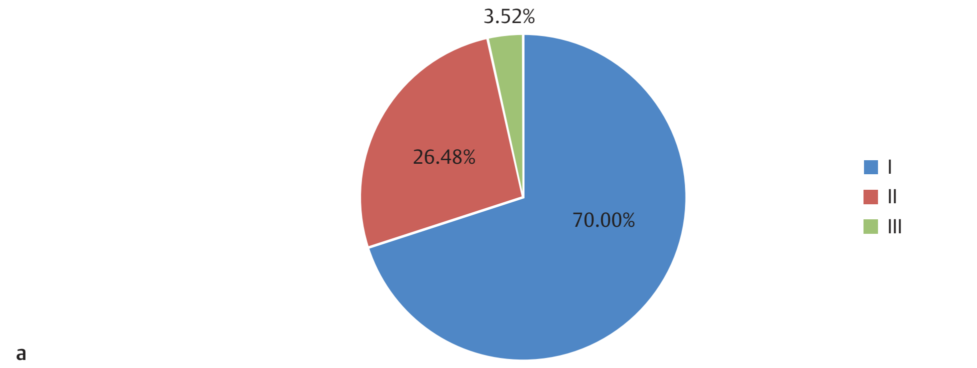
Fig. 3.45 (**a**) Age distribution of 3,237 Smith fractures. (**b**) Age and sex distribution of 3,237 Smith fractures.

Smith Fractures by Fracture Type

See ▶ Table 3.32 and ▶ Fig. 3.46.

Table 3.32 Sex and fracture type distribution of 3,237 Smith fractures

Fracture type	Male	Female	Number of fractures	Percentage	Percentage of radial/ ulnar fractures	Percentage of total
I	1,223	1,043	2,266	70.00	2.96	0.52
II	436	421	857	26.48	1.12	0.20
III	69	45	114	3.52	0.15	0.03
Total	1,728	1,509	3,237	100.00	4.23	0.75



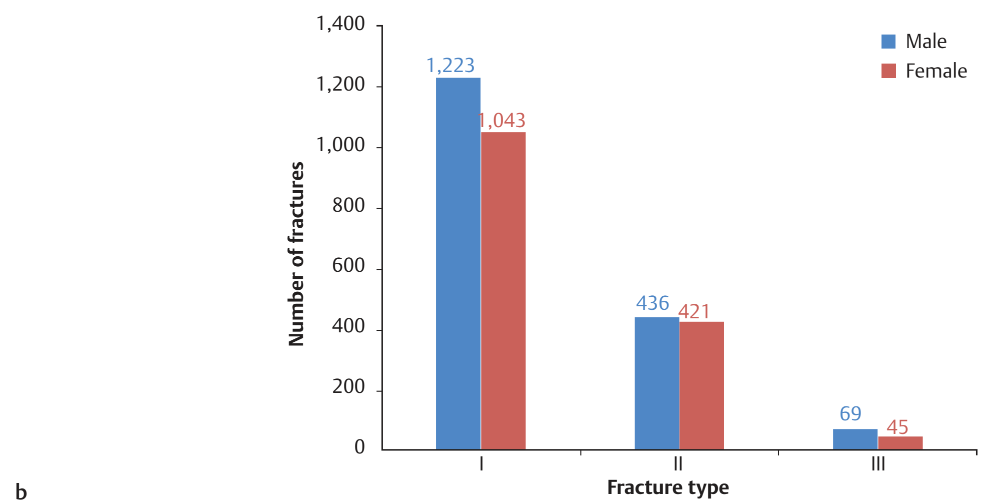


Fig. 3.46 (**a**) Fracture type distribution of 3,237 Smith fractures. (**b**) Sex and fracture type distribution of 3,237 Smith fractures.

Barton Fractures

Overview

A Barton fracture is an intra-articular fracture of the distal radius with dislocation of the radiocarpal joint. The fracture cleft extends proximally and obliquely in the coronal plane, and involves a single-wedged fragment of either the dorsal or palmar lip of the radius. As such, there are two types of Barton fractures, dorsal and palmar, the latter being the more common one. The palmar type of Barton fracture has a similar injury mechanism to the Smith fracture (▶ Fig. 3.47).

The dorsal type of Barton fracture usually results from a fall on an extended hand with wrists in forced pronation (▶ Fig. 3.48).

A Barton fracture, being exclusively an intra-articular fracture, does not have characteristic deformities such as those seen in Colles and Smith fractures. Typical X-ray findings reveal an intra-articular fracture of the dorsal or palmar rim of the distal radius, with displacement of the carpal bones. If the fragment is small, it may be associated with an avulsion fracture; if the fragment is large, it is usually subluxed toward the palmar direction, or dorsally along with the carpal bones. Subluxation or dislocation of the wrist joint can also result from severely damaged ligaments, even with a small-sized fragment.

Treatment for both types of injuries should first be attempted with a manipulative method, splinting, or a casting application. If the fracture is reducible but unstable, open reduction and internal fixation with a plate or K-wire may be indicated.

Clinical Epidemiologic Features of Barton Fractures

A total of 2,012 Barton fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 0.47% of all fractures and 2.63% of fractures of the radius/ulna and 3.85% of fractures of the distal radius/ulna. Their epidemiologic features are as follows:

- Slightly more males than females
- The high-risk age group is 56–60 years; males in the age groups of 16–20 and 36–40 years, and females in the age group of 56–60 years have the highest risk
- The palmar type is more common than the dorsal type of Barton fracture.

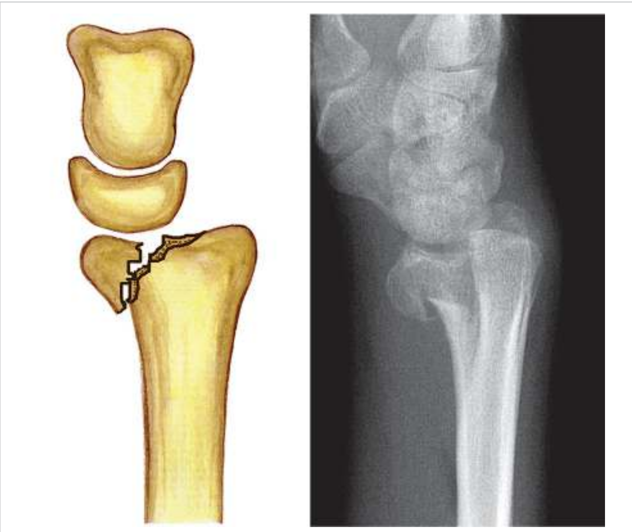


Fig. 3.47 Palmar-type Barton fracture.

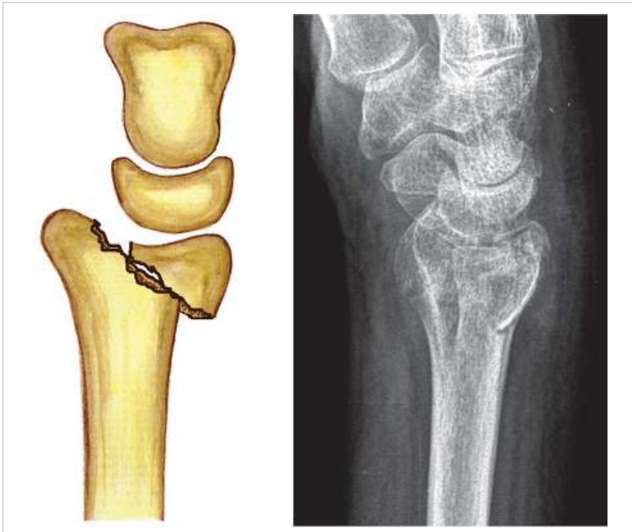


Fig. 3.48 Dorsal-type Barton fracture.

Barton Fractures by Sex

See ▶ Table 3.33 and ▶ Fig. 3.49.

Table 3.33 Sex distribution of 2,012 Barton fractures

Sex	Number of fractures	Percentage
Male	982	48.81
Female	1,030	51.19
Total	2,012	100.00

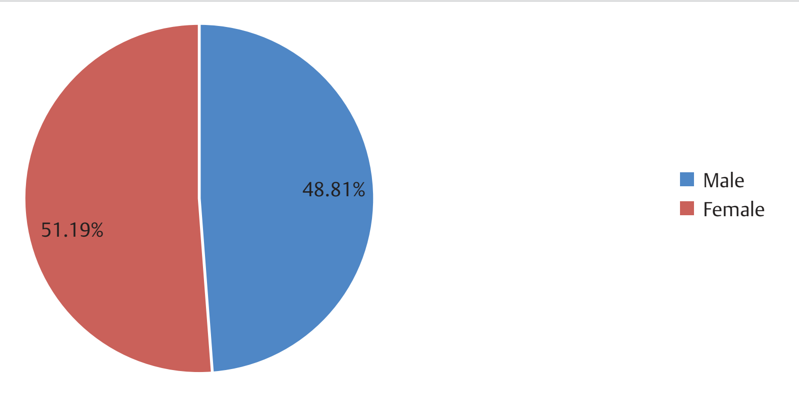


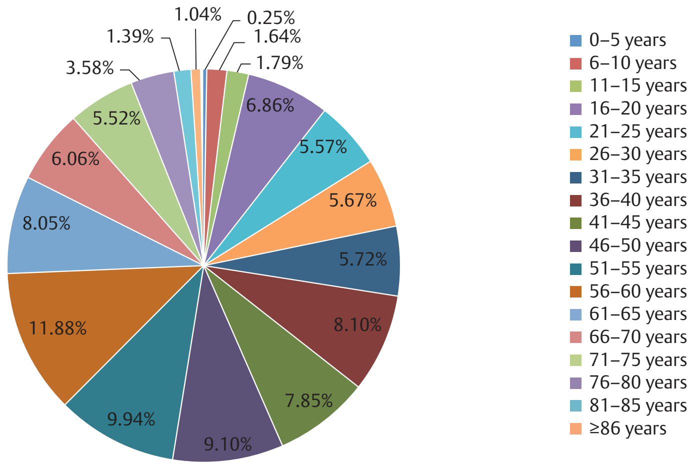
Fig. 3.49 Sex distribution of 2,012 Barton fractures.

Barton Fractures by Age Group

See ▶ Table 3.34 and ▶ Fig. 3.50.

Table 3.34 Age and sex distribution of 2,012 Barton fractures

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	3	2	5	0.25
6–10	23	10	33	1.64
11–15	31	5	36	1.79
16–20	117	21	138	6.86
21–25	88	24	112	5.57
26–30	87	27	114	5.67
31–35	78	37	115	5.72
36–40	119	44	163	8.10
41–45	105	53	158	7.85
46–50	91	92	183	9.10
51–55	60	140	200	9.94
56–60	67	172	239	11.88
61–65	49	113	162	8.05
66–70	18	104	122	6.06
71–75	20	91	111	5.52
76–80	17	55	72	3.58
81–85	4	24	28	1.39
≥ 86	5	16	21	1.04
Total	982	1,030	2,012	100.00



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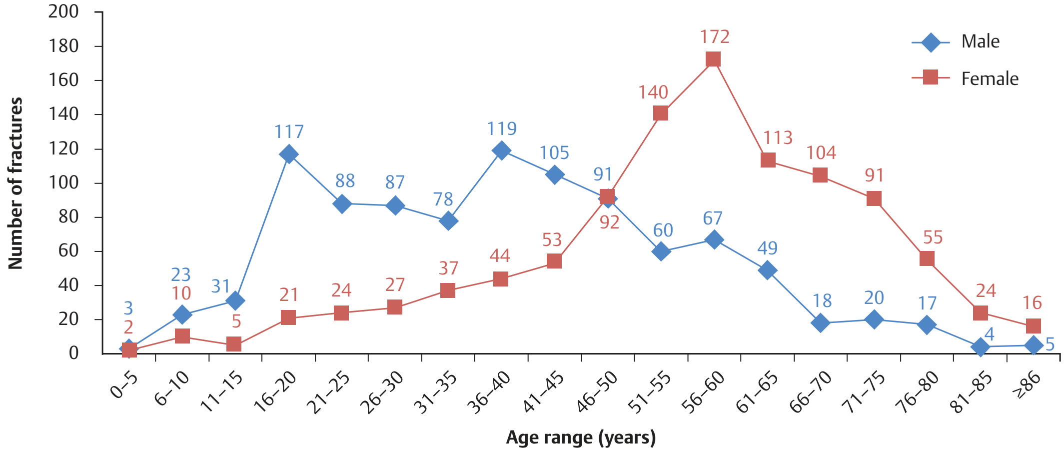

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Fig. 3.50 (**a**) Age distribution of 2,012 Barton fractures. (**b**) Age and sex distribution of 2,012 Barton fractures.

Barton Fractures by Fracture Type

See ▶ Table 3.35 and ▶ Fig. 3.51.

Table 3.35 Sex and fracture type distribution of 2,012 Barton fractures

Fracture type	Male	Female	Number of fractures	Percentage
Palmar-type Barton fracture	642	637	1,279	63.57
Dorsal-type Barton fracture	340	393	733	36.43
Total	982	1,030	2,012	100.00

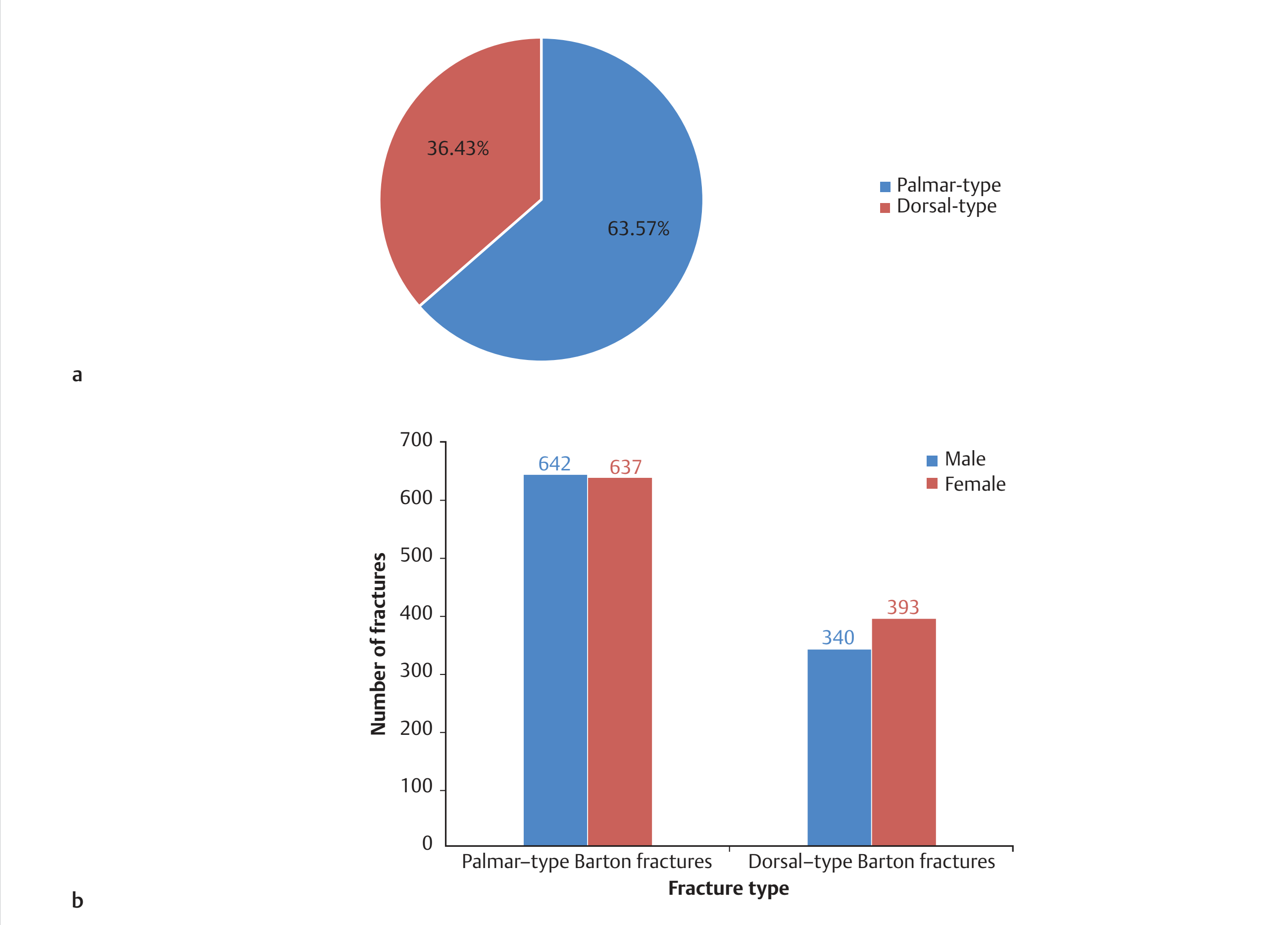

Fig. 3.51 (**a**) Fracture type distribution of 2,012 Barton fractures. (**b**) Sex and fracture type distribution of 2,012 Barton fractures.

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4 Fractures of the Femur

Yanbin Zhu, Yansen Li, and Enzeng Xing

Overview of Femoral Fractures

Anatomic Features

The femur is the longest and largest tubular bone in the human skeleton; the average length of an adult femur is 42.48 cm on the left side and 42.39 cm on the right side. The femur is cylindric in the upper third of its length, with the pectineal line running through the posteromedial surface of the femur, up to the base of the lesser trochanter. The pectineal line then continues with the intertrochanteric line, and down to the medial lip of the linea aspera. The gluteal tuberosity lies on the posterolateral aspect of the femur, up to the base of the greater trochanter and down to the lateral lip of the linea aspera. The middle part of the femur is slightly twisted and curved, with an anterior convexity that is 30 degrees rotated from the superolateral to inferomedial part of the femur. The lower third of the femur becomes flattened and widened anteroposteriorly. The linea aspera on the dorsal side of middle third has two lips that diverge and turn into the medial and lateral supracondylar ridge, respectively. The rough impression above the medial epicondyle gives origin to the medial head of the gastrocnemius, while the plantaris arises in the impression above and to the medial side of lateral epicondyle (▶ Fig. 4.1).

AO Classification and Coding System for Femoral Fractures

Based on the AO classification, the femoral fracture is coded as number "3." According to "Heim's Square," the anatomic delineation of the proximal and distal shaft is by the numbers "31, 32, and 33," respectively (▶ Fig. 4.2; ▶ Fig. 4.3).

Epidemiologic Features of Femoral Fractures in the China National Fracture Study

A total of 193 patients with 196 femoral fractures were investigated in the China National Fracture Study (CNFS). The fractures accounted for 10.95% of all patients with fractures and 10.69% of all types of fractures. The population-weighted incidence rate of femoral fractures was 35 per 100,000 population in 2014.

The epidemiologic features of femoral fractures in the CNFS are as follows:

- More males than females
- More left-side injuries than right-side injuries
- The highest risk age group is 15–64 years
- The proximal femoral fracture is the most common femoral fracture
- Injuries occurred most commonly via slips, trips, or falls

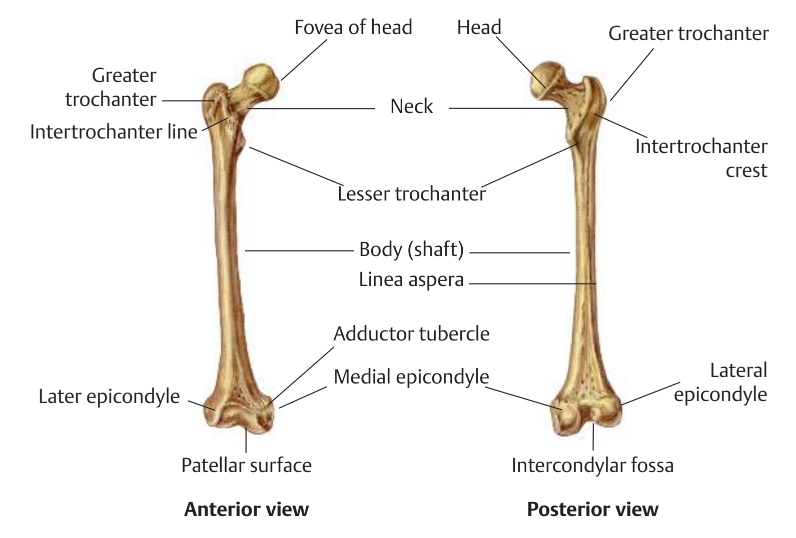

Fig. 4.1 Anterior and posterior views of the femur.

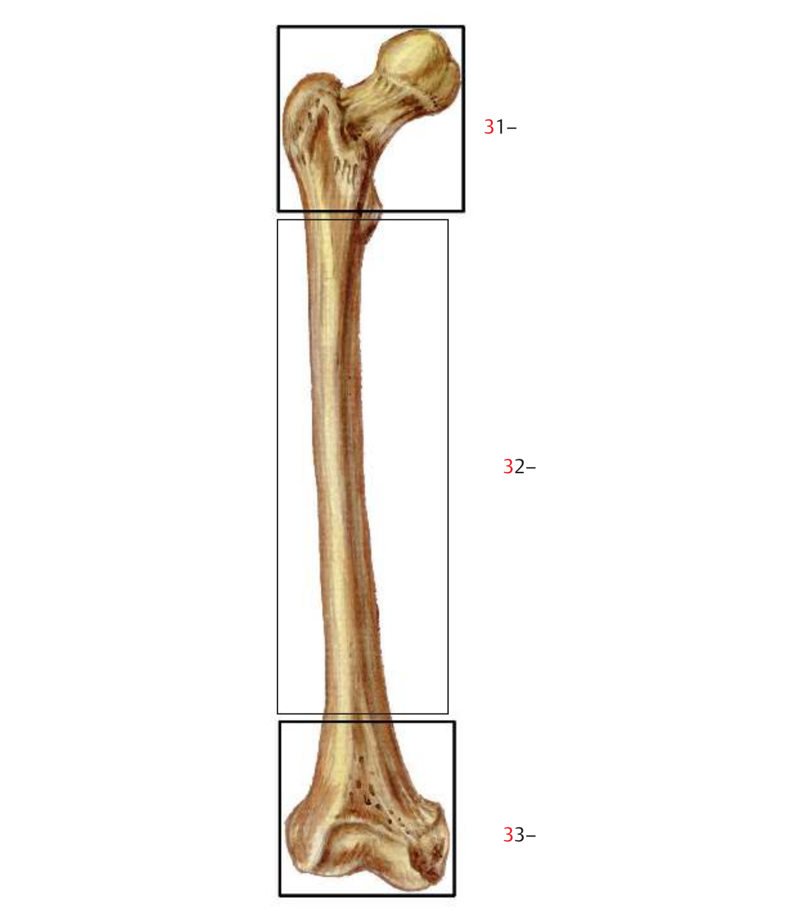

Fig. 4.2 AO codes for the femur.

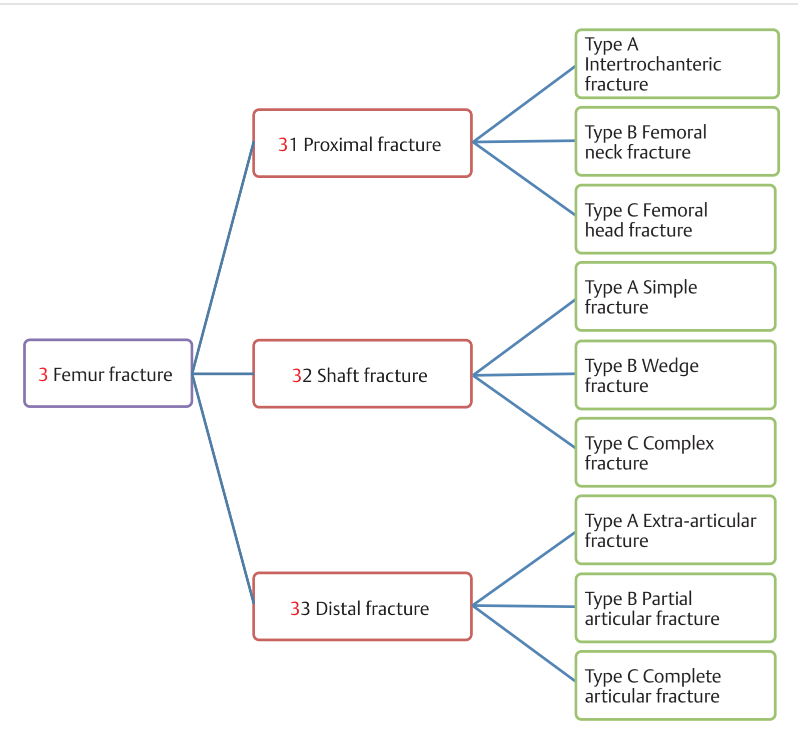

Fig. 4.3 Algorithm.

■ Femoral Fracture by Sex

See ▶ Table 4.1 and ▶ Fig. 4.4.

Table 4.1 Sex distribution of 193 patients with femoral fractures in the China National Fracture Study

Sex	Number of patients	Percentage
Male	122	63.21
Female	71	36.79
Total	193	100.00

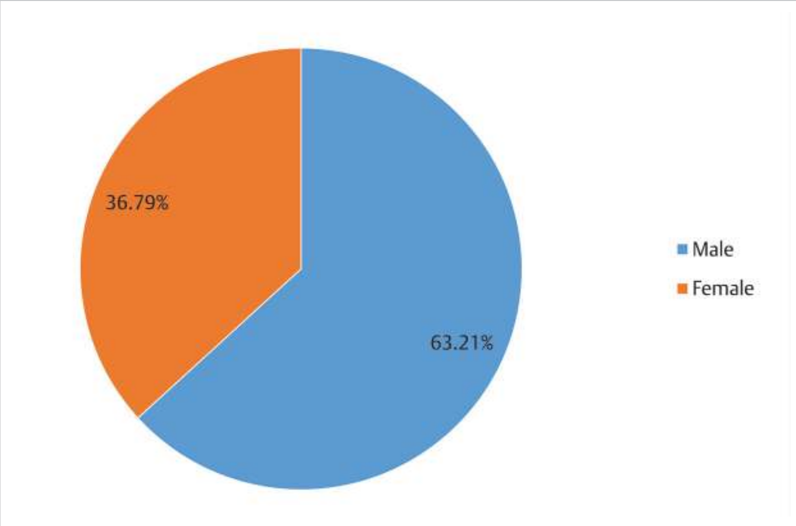

Fig. 4.4 Sex distribution of 193 patients with femoral fractures in the China National Fracture Study (CNFS).

■ Femoral Fracture by Injury Side

See ▶ Table 4.2 and ▶ Fig. 4.5.

Table 4.2 Injury side distribution of 193 patients with femoral fractures in the China National Fracture Study

Injured side	Number of patients	Percentage
Left	100	51.81
Right	90	46.63
Bilateral	3	1.55
Total	193	100.00

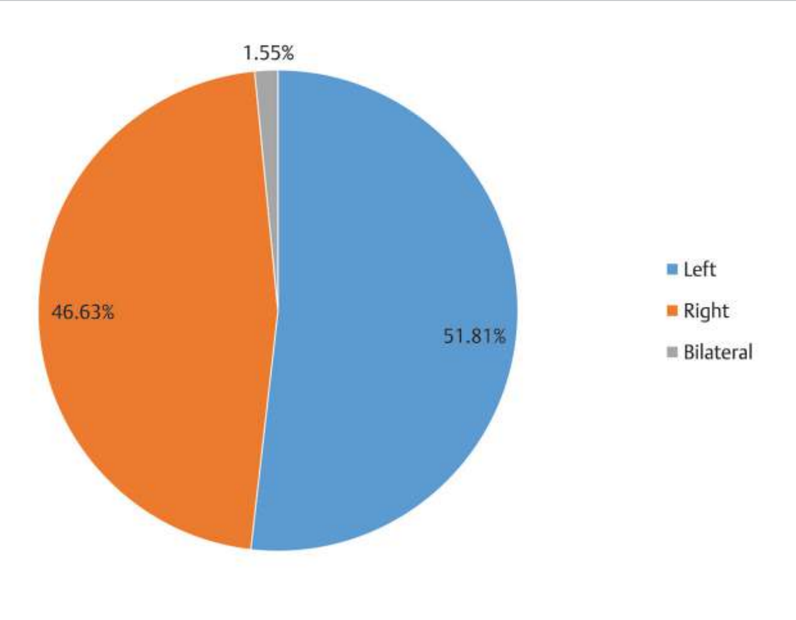

Fig. 4.5 Injury side distribution of 193 patients with femoral fractures in the China National Fracture Study (CNFS).

■ Femoral Fracture by Age Group and Sex

See ► Table 4.3 and ► Fig. 4.6.

Table 4.3 Age group and sex distribution of 193 patients with femoral fractures in the China National Fracture Study

Age group (years)	Male	Female	Total	Percentage
0–14	5	1	6	3.11
15–64	85	35	120	62.18
≥ 65	32	35	67	34.72
Total	122	71	193	100.00

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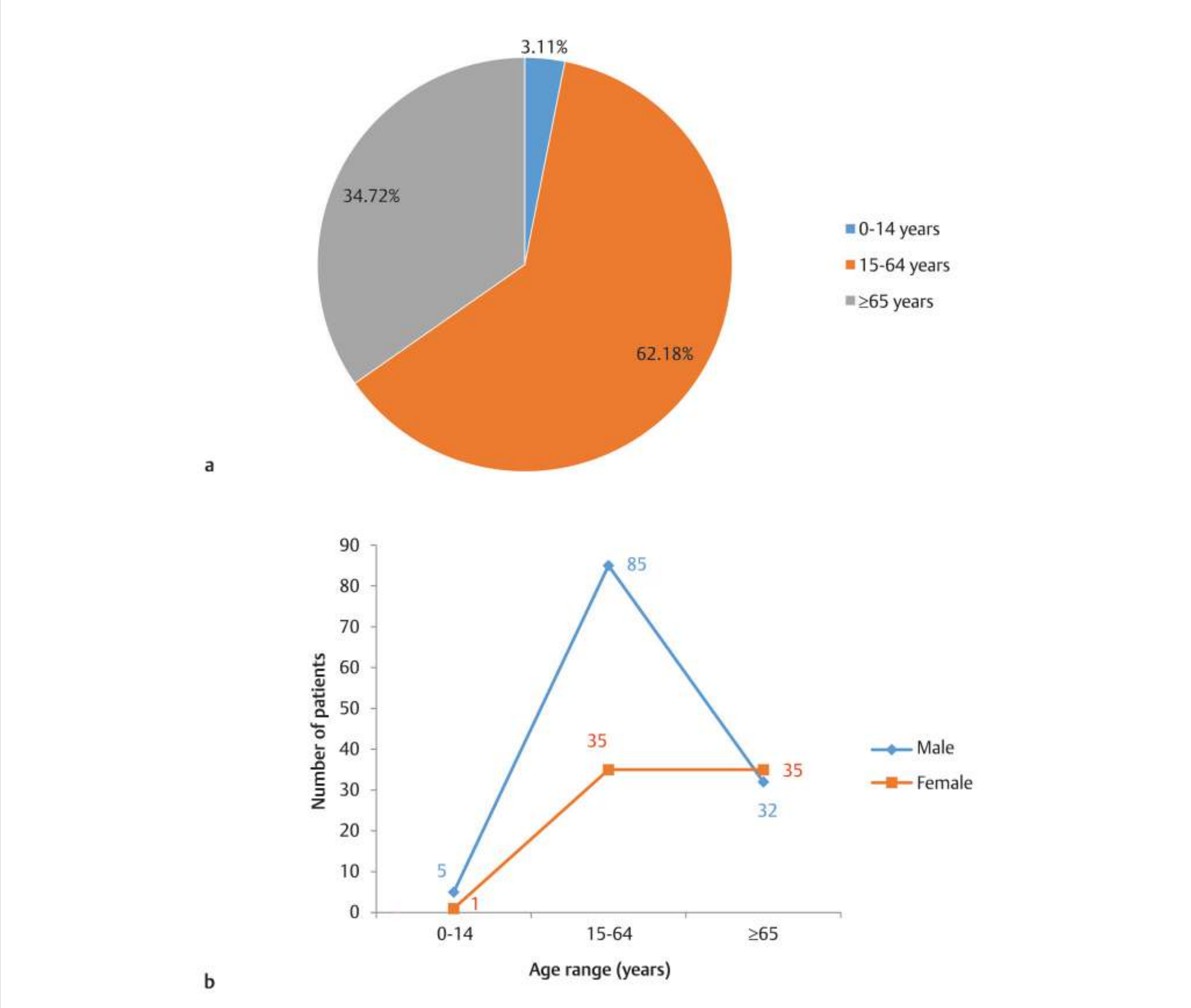


Fig. 4.6 (**a**) Age group distribution of 193 patients with femoral fractures in the China National Fracture Study (CNFS). (**b**) Age group and sex distribution of 193 patients with femoral fractures in the CNFS.

■ Femoral Fracture by Location

See ▶ Table 4.4 and ▶ Fig. 4.7.

Table 4.4 Segment distribution of 193 patients with femoral fractures in the China National Fracture Study based on AO classification

Segment	Male	Female	Total	Percentage
31	61	47	108	55.10
32	48	19	67	34.18
33	15	6	21	10.71
Total	124	72	196	100.00

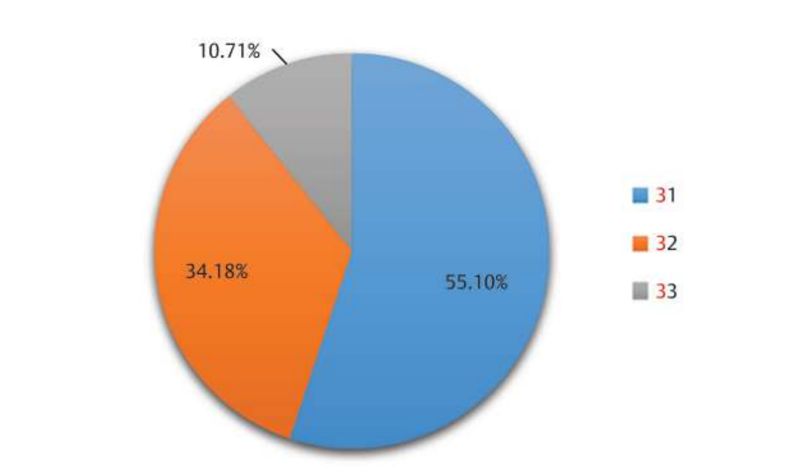


Fig. 4.7 Segment distribution of 193 patients with femoral fractures in the China National Fracture Study (CNFS) based on AO classification.

4

■ Femoral Fracture by Causal Mechanisms

See ► Table 4.5 and ► Fig. 4.8.

Table 4.5 Causal mechanisms distribution of 193 patients with femoral fractures in the China National Fracture Study

Causal mechanisms	Male	Female	Total	Percentage
Traffic accident	37	15	52	26.94
Slip, trip, or fall	69	52	121	62.69
Fall from heights	8	4	12	6.22
Crushing injury	5	0	5	2.59
Blunt force trauma	3	0	3	1.55
Total	122	71	193	100.00

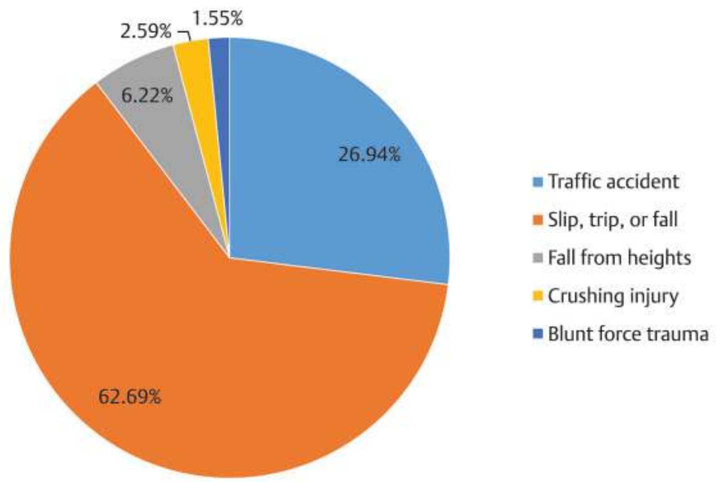


Fig. 4.8 Causal mechanisms distribution of 193 patients with femoral fractures in the China National Fracture Study (CNFS).

Clinical Epidemiologic Features of Femoral Fractures

A total of 42,377 patients with 42,978 femoral fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, accounting for 10.21% of all fractured patients and 9.95% of all types of fractures, respectively. Among these 42,377 patients, 3,243 are children with 3,282 fractures, and 39,134 adults with 39,696 fractures.

Epidemiologic features of femoral fractures are as follows:

- More males than females
- More left-side injuries than right-side injuries
- The highest-risk age group is 76–80 years. The most affected male age group is 41–45 years, while females aged 76–80 years have the highest risk.
- The proximal femoral fracture is the most common femoral fracture in adults. The diaphyseal femoral fracture is the most common femoral fracture in children.

Femoral Fractures by Sex

See ▶ Table 4.6 and ▶ Fig. 4.9.

Table 4.6 Sex distribution of 42,377 patients with femoral fractures

Sex	Number of patients	Percentage
Male	23,234	54.83
Female	19,143	45.17
Total	42,377	100.00

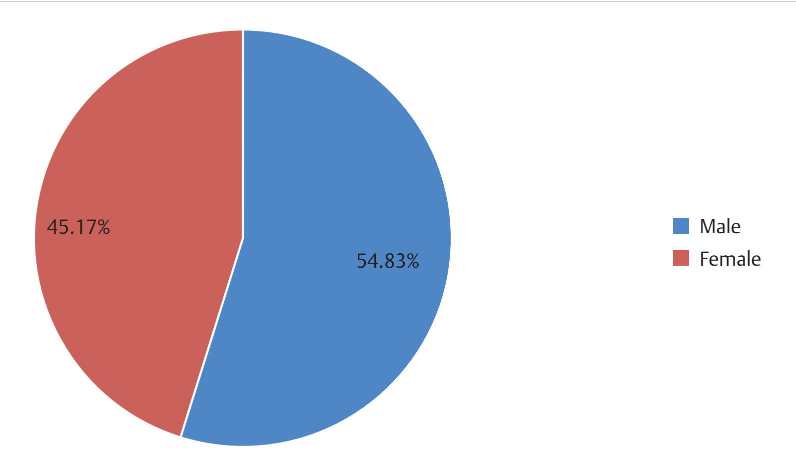


Fig. 4.9 Sex distribution of 42,377 patients with femoral fractures.

■ Femoral Fractures by Injury Side

See ▶ Table 4.7 and ▶ Fig. 4.10.

Table 4.7 Injury side distribution of 42,377 patients with femoral fractures

Injured side	Number of patients	Percentage
Left	21,931	51.75
Right	20,287	47.87
Bilateral	159	0.38
Total	42,377	100.00

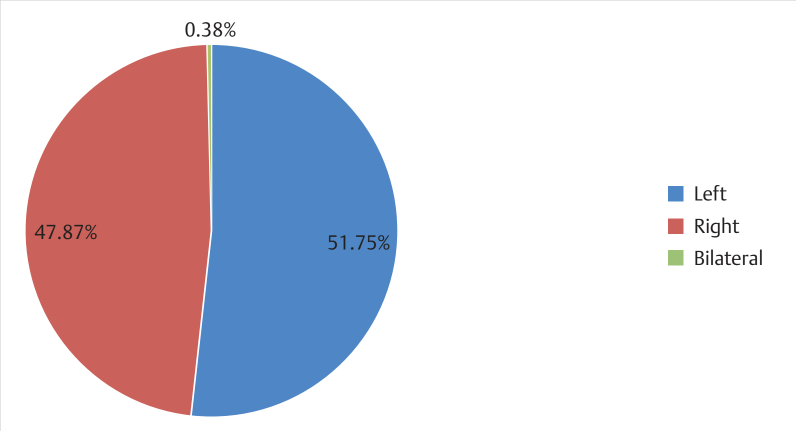


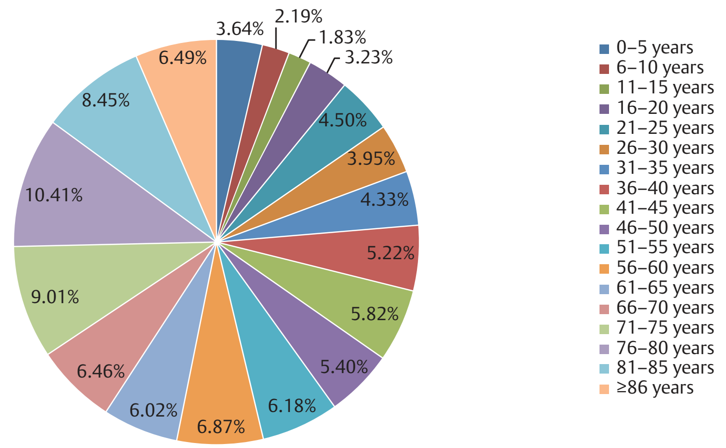
Fig. 4.10 Injury side distribution of 42,377 patients with femoral fractures.

■ Femoral Fractures by Age Group

See ▸ Table 4.8 and ▸ Fig. 4.11.

Table 4.8 Age and sex distribution of 42,377 patients with femoral fractures

Age group (years)	Male	Female	Number of patients	Percentage
0–5	958	585	1,543	3.64
6–10	583	343	926	2.19
11–15	552	222	774	1.83
16–20	1,105	264	1,369	3.23
21–25	1,503	403	1,906	4.50
26–30	1,354	322	1,676	3.95
31–35	1,431	404	1,835	4.33
36–40	1,718	493	2,211	5.22
41–45	1,889	578	2,467	5.82
46–50	1,617	670	2,287	5.40
51–55	1,567	1,051	2,618	6.18
56–60	1,525	1,386	2,911	6.87
61–65	1,176	1,377	2,553	6.02
66–70	1,085	1,654	2,739	6.46
71–75	1,437	2,382	3,819	9.01
76–80	1,572	2,840	4,412	10.41
81–85	1,252	2,330	3,582	8.45
≥ 86	910	1,839	2,749	6.49
Total	23,234	19,143	42,377	100.00



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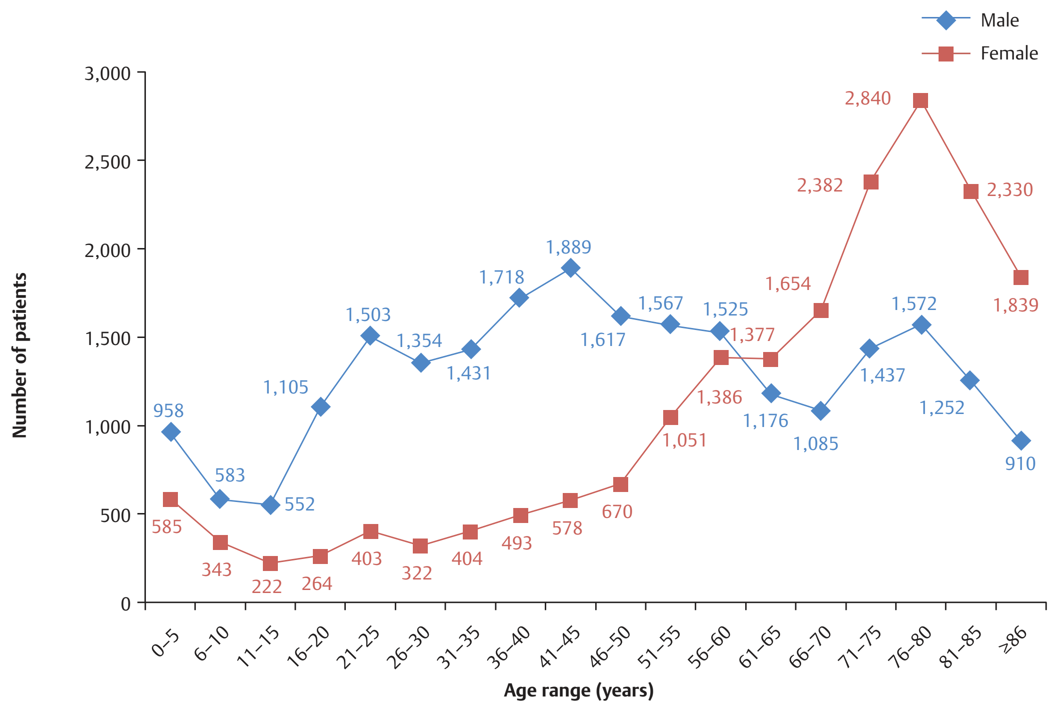


b

Fig. 4.11 (**a**) Age distribution of 42,377 patients with femoral fractures. (**b**) Age and sex distribution of 42,377 patients with femoral fractures.

■ Femoral Fractures by Fracture Segment

Segment Distribution of Femoral Fractures in Adults Based on AO Classification

See ▶ Table 4.9 and ▶ Fig. 4.12.

Table 4.9 Fracture segment distribution of 39,696 femoral fractures in adults based on AO classification

Segment	Number of fractures	Percentage
31 (Proximal)	28,027	70.60
32 (Diaphysis)	8,235	20.75
33 (Distal)	3,434	8.65
Total	39,696	100.00

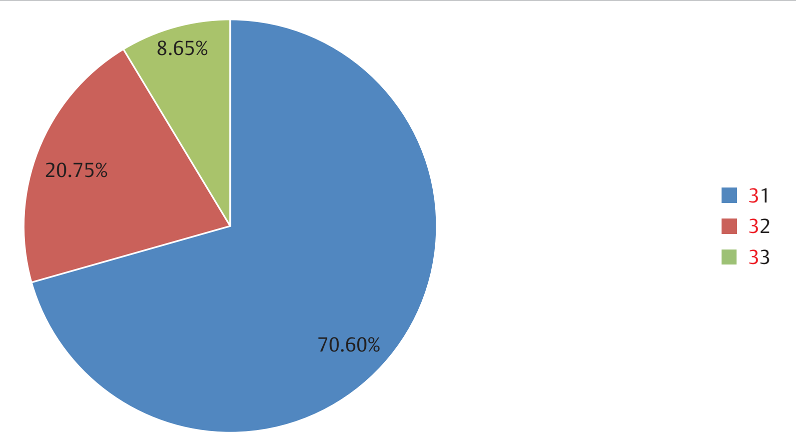


Fig. 4.12 Segment distribution of 39,696 femoral fractures in adults based on AO classification.

Segment Distribution of Femoral Fractures in Children

See ▶ Table 4.10 and ▶ Fig. 4.13.

Table 4.10 Segment distribution of 3,282 femoral fractures in children

Segment	Number of fractures	Percentage
Proximal	717	21.85
Diaphysis	2,183	66.51
Distal	382	11.64
Total	3,282	100.00

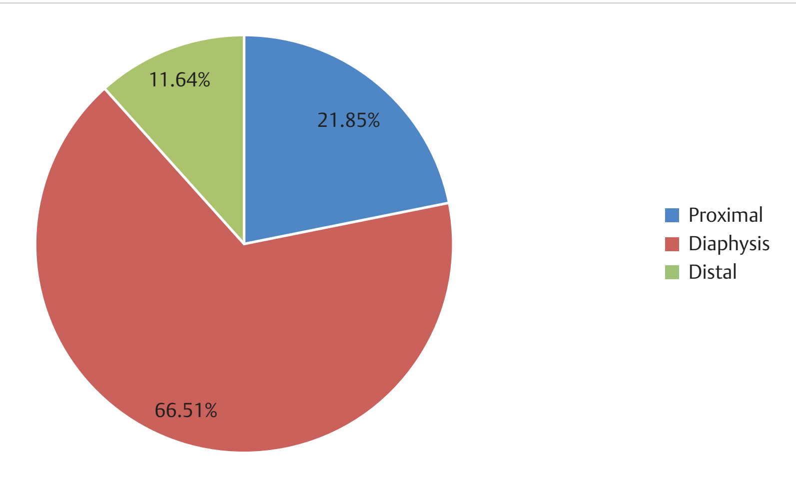


Fig. 4.13 Segment distribution of 3,282 femoral fractures in children.

Proximal Femoral Fractures (Segment 31)

Anatomic Features

The head of the femur is globular in shape and forms about two-thirds of a sphere (▶ Fig. 4.14). The neck projects forward to some extent, with an average anterior projection of 10 to 15 degrees. Flattened posteriorly, the neck is contracted in the middle, which is often the site of fractures. In adults, the neck forms an angle of approximately 120 to 130 degrees with the body. At the junction of the neck with the upper part of the body, there is a large eminence called the greater trochanter. A smaller eminence projecting from the lower and posterior part of the base of the neck is called the lesser trochanter. Running obliquely downward and medial from the tubercle is the intertrochanteric line, while the intertrochanteric crest courses obliquely downward and medially from the summit of the greater trochanter on the posterior surface of the neck.

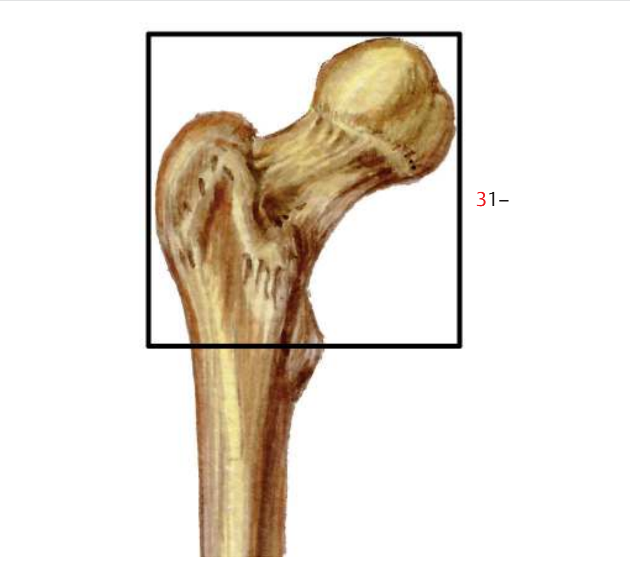


Fig. 4.14 The head of the femur.

AO Classification of the Proximal Femoral Fractures

Based on AO classification, the proximal femur is coded as number "31." It is further divided into three types: 31-A: Trochanteric fractures (extra-articular); 32-B: Femur neck fractures (articular); 33-C: Femur head fractures (intra-articular) (▶ Fig. 4.15).

Clinical Epidemiologic Features of the Proximal Femoral Fractures (Segment 31)

A total of 28,027 proximal femur fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All

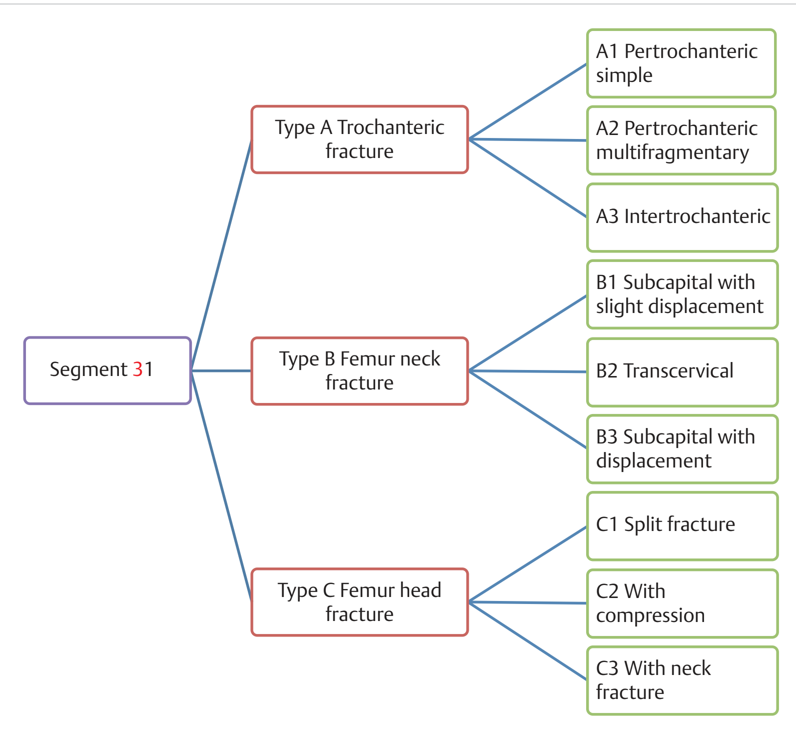


Fig. 4.15 Algorithm.

cases were reviewed and statistically studied; the fractures accounted for 70.60% of femur fractures in adults. Their epidemiologic features are as follows:

- More males than females
- The highest-risk age group for both sexes is 76–80 years
- The most common fracture type among segment 31 fractures is type 31-B. However, 31-A is more common in males while 31-B is more common in females
- The most common fracture group among segment 31 fractures is group 31-A2, the same fracture group in both males and females

Fractures of Segment 31 by Sex

See ▸ Table 4.11 and ▸ Fig. 4.16.

Table 4.11 Sex distribution of 28,027 fractures of segment 31

Sex	Number of fractures	Percentage
Male	13,154	46.93
Female	14,873	53.07
Total	28,027	100.00

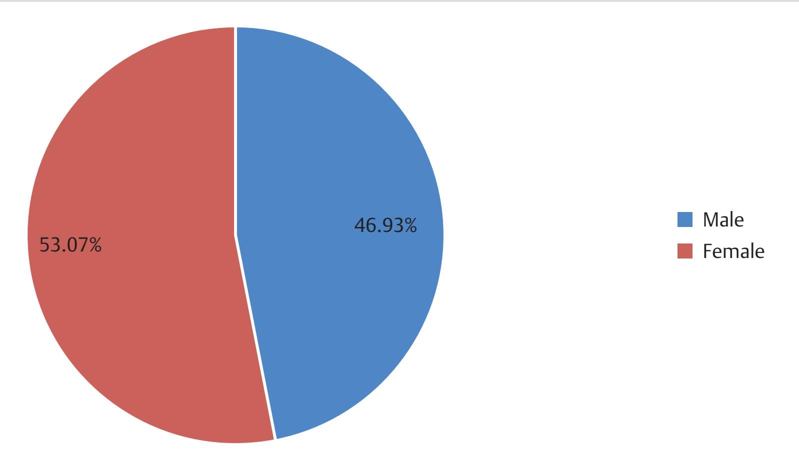


Fig. 4.16 Sex distribution of 28,027 fractures of segment 31.

■ Fractures of Segment 31 by Age Group

See ▶ Table 4.12 and ▶ Fig. 4.17.

Table 4.12 Age and sex distribution of 28,027 fractures of segment 31

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	306	100	406	1.45
21–25	453	171	624	2.23
26–30	465	153	618	2.21
31–35	655	217	872	3.11
36–40	814	258	1,072	3.82
41–45	888	343	1,231	4.39
46–50	893	433	1,326	4.73
51–55	981	785	1,766	6.30
56–60	1,026	1,069	2,095	7.47
61–65	901	1,156	2,057	7.34
66–70	927	1,433	2,360	8.42
71–75	1,311	2,180	3,491	12.46
76–80	1,472	2,626	4,098	14.62
81–85	1,193	2,200	3,393	12.11
≥ 86	869	1,749	2,618	9.34
Total	13,154	14,873	28,027	100.00

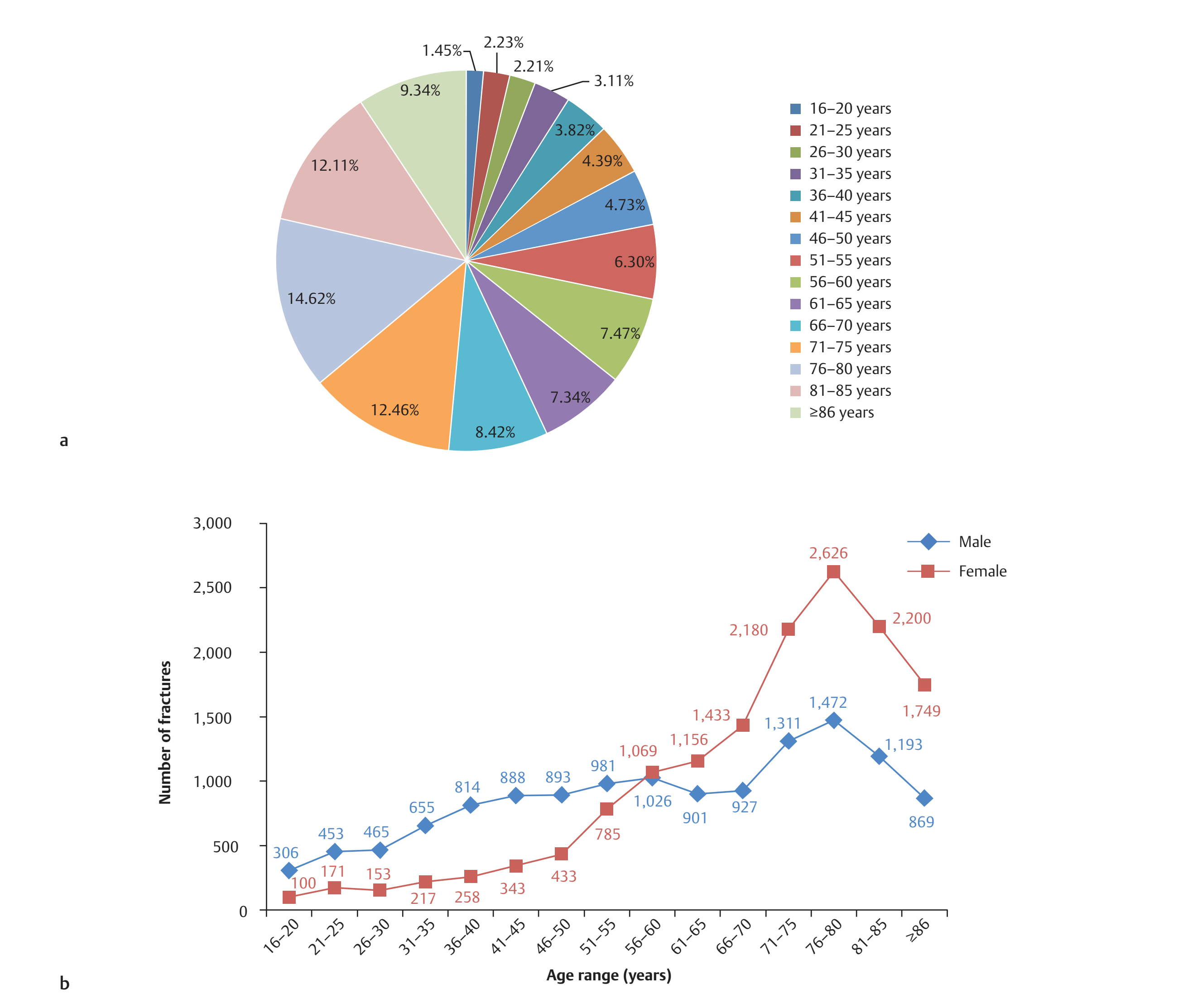


Fig. 4.17 (**a**) Age distribution of 28,027 fractures of segment 31. (**b**) Age and sex distribution of 28,027 fractures of segment 31.

■ Fractures of Segment 31 by Fracture Type

See ▶ Table 4.13 and ▶ Fig. 4.18.

Table 4.13 Sex and fracture type distribution of 28,027 fractures of segment 31

Fracture type	Male	Female	Number of fractures	Percentage
31-A	6,480	6,263	12,743	45.47
31-B	5,635	7,881	13,516	48.22
31-C	1,039	729	1,768	6.31
Total	13,154	14,873	28,027	100.00

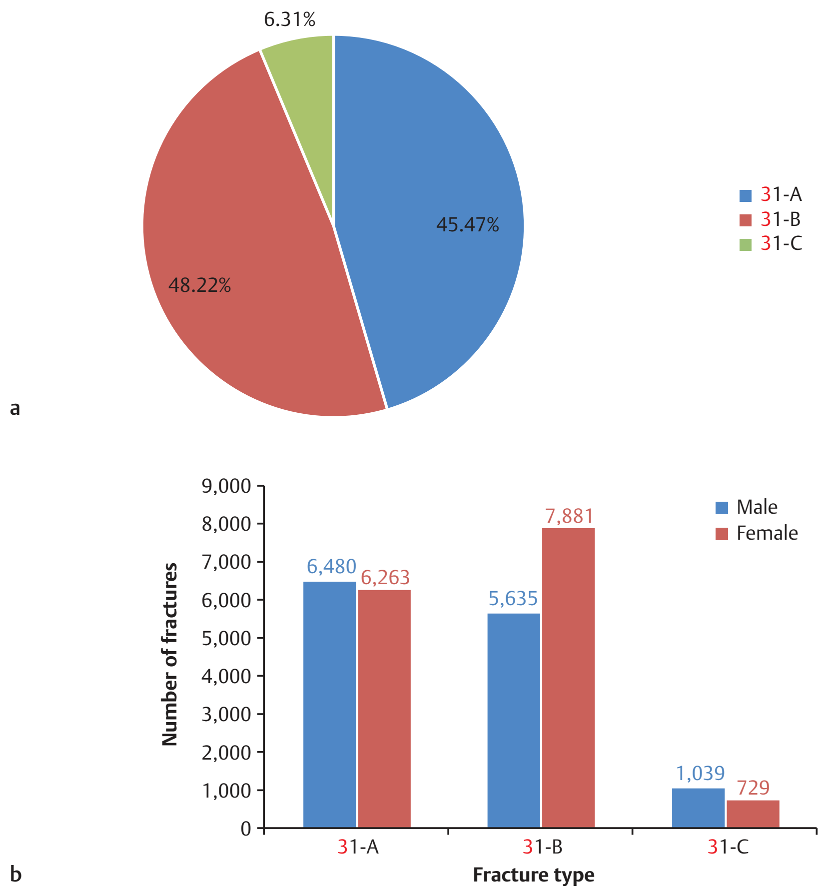


Fig. 4.18 (**a**) Fracture type distribution of 28,027 fractures of segment 31. (**b**) Sex and fracture type distribution of 28,027 fractures of segment 31.

■ Fractures of Segment 31 by Fracture Group

See ▶ Table 4.14 and ▶ Fig. 4.19.

Table 4.14 Sex and fracture group distribution of 28,027 fractures of segment 31

Fracture group	Male	Female	Number of fractures	Percentage of segment 31 fractures	Percentage of femoral fractures
31-A1	1,719	1,609	3,328	11.87	8.38
31-A2	3,542	3,866	7,408	26.43	18.66
31-A3	1,219	788	2,007	7.16	5.06
31-B1	1,234	1,711	2,945	10.51	7.42
31-B2	3,070	3,800	6,870	24.51	17.31
31-B3	1,331	2,370	3,701	13.21	9.32
31-C1	493	309	802	2.86	2.02
31-C2	348	269	617	2.20	1.55
31-C3	198	151	349	1.25	0.88
Total	13,154	14,873	28,027	100.00	70.60

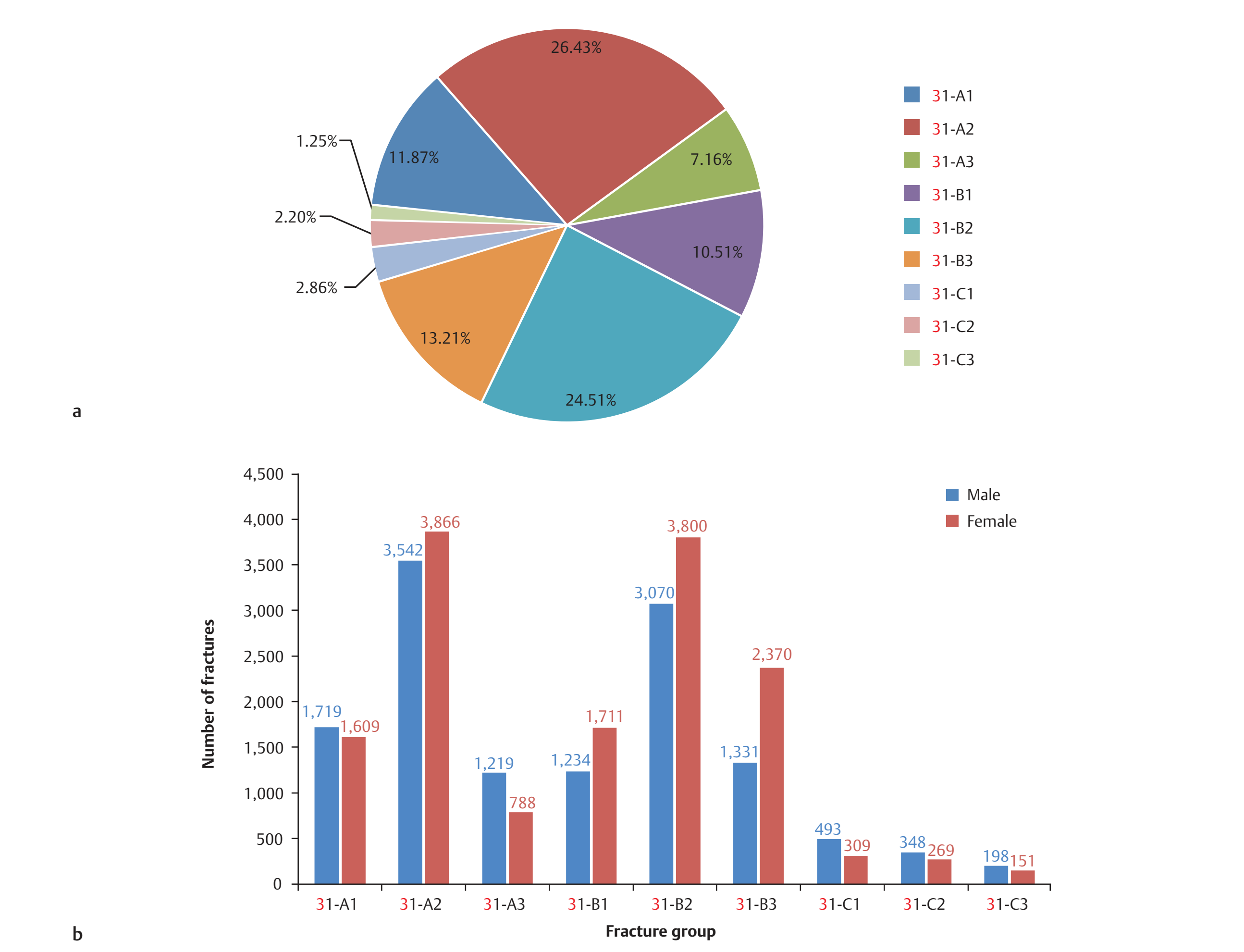
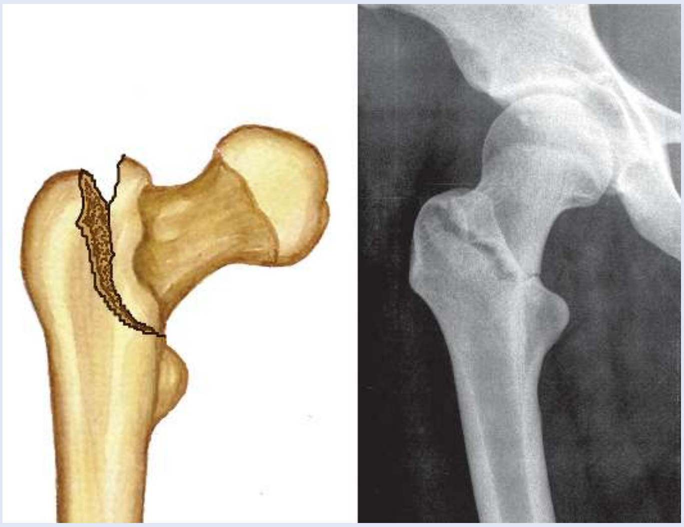


Fig. 4.19 (a) Fracture group distribution of 28,027 fractures of segment 31. (b) Sex and fracture group distribution of 28,027 fractures of segment 31.

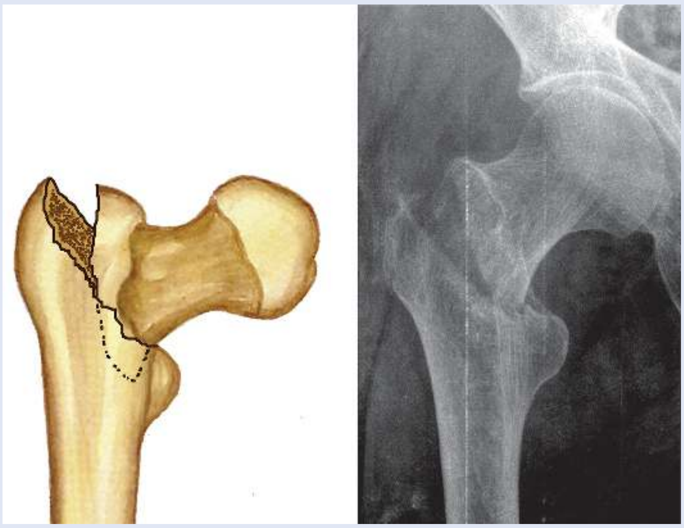
31-A Femur, proximal, extra-articular, trochanteric fractures

31-A1 Pertrochanteric simple
3,328 fractures
M: 1,719 (51.65%)
F: 1,609 (48.35%)
0.89% of total adult fractures
8.38% of adult femoral fractures
11.87% of segment 31
26.12% of type 31-A

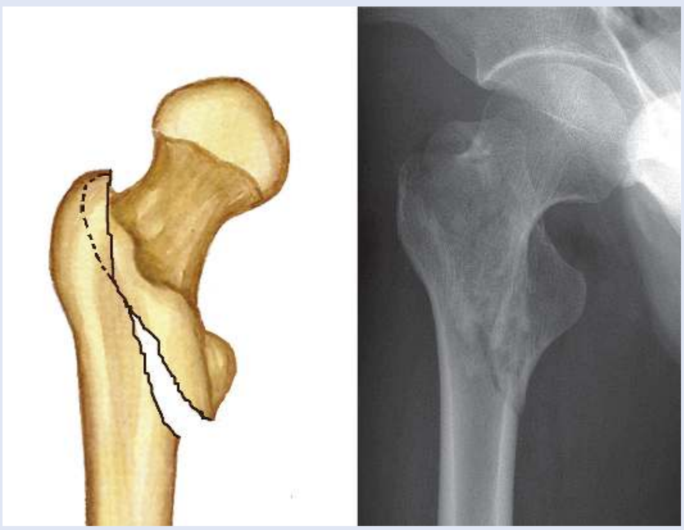
31-A1.1 Along the intertrochanteric line



31-A1.2 Through the greater trochanter



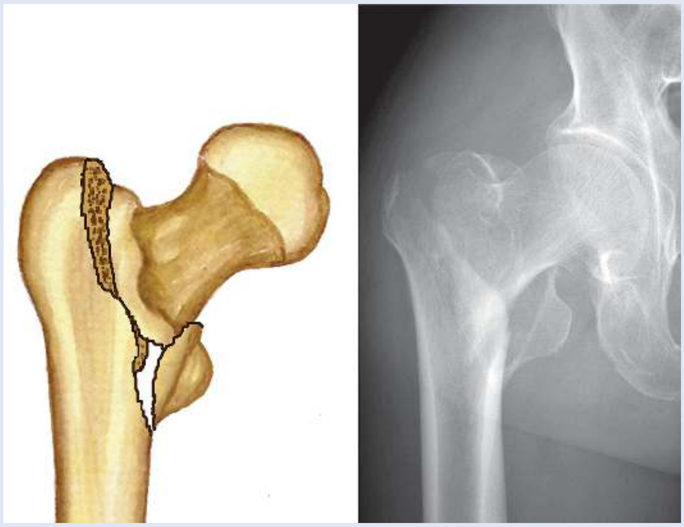
31-A1.3 Below the lesser trochanter



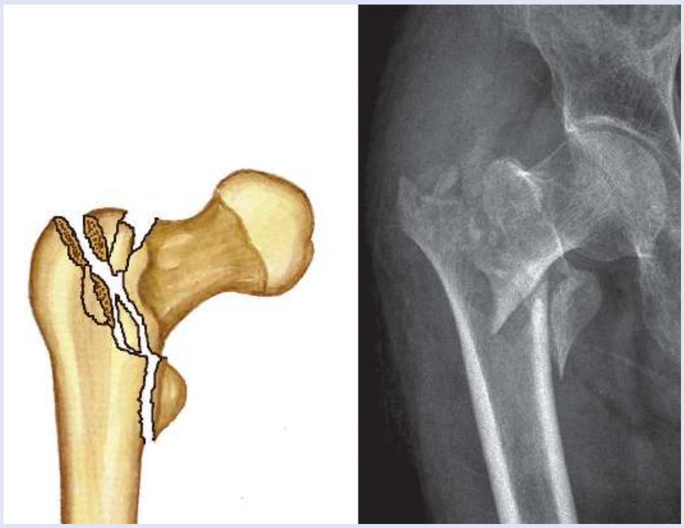
31-A Femur, proximal, extra-articular, trochanteric fractures

31-A2 Pertrochanteric multifragmentary
7,408 fractures
M: 3,542 (47.81%)
F: 3,866 (52.19%)
1.98% of total adult fractures
18.66% of adult femoral fractures
26.43% of segment 31
58.13% of type 31-A

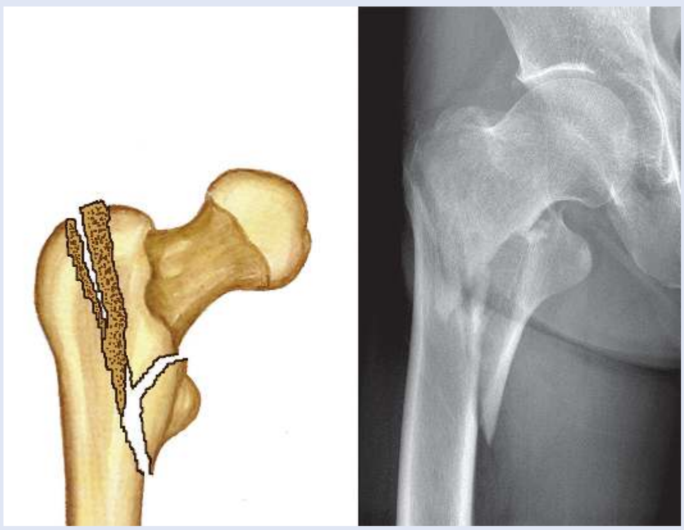
31-A2.1 With one intermediate fragment



31-A2.2 With several intermediate fragments



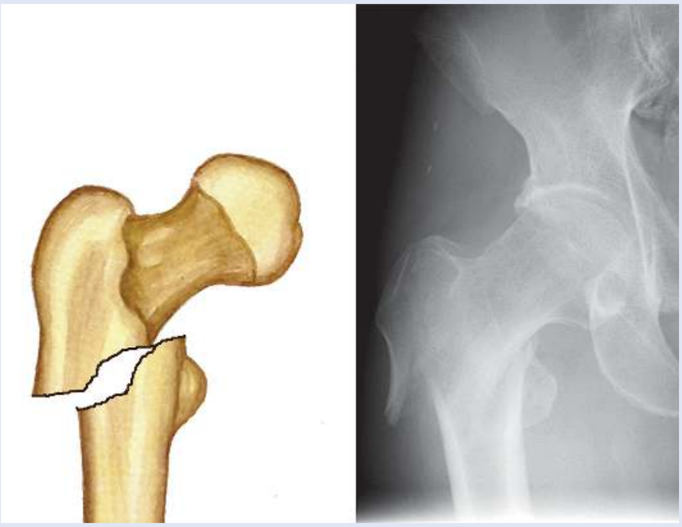
31-A2.3 Extending more than 1 cm below the lesser trochanter



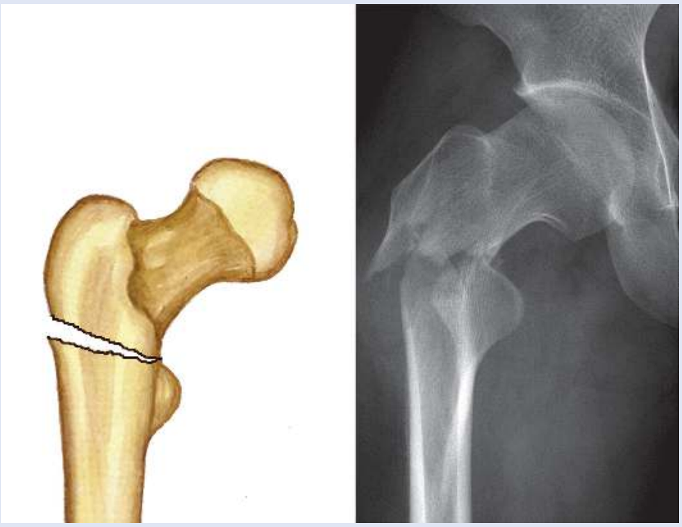
31-A Femur, proximal, extra-articular, trochanteric fractures

31-A3 Intertrochanteric
2,007 fractures
M: 1,219 (60.74%)
F: 788 (39.26%)
0.54% of total adult fractures
5.06% of adult femoral fractures
7.16% of segment 31
15.75% of type 31-A

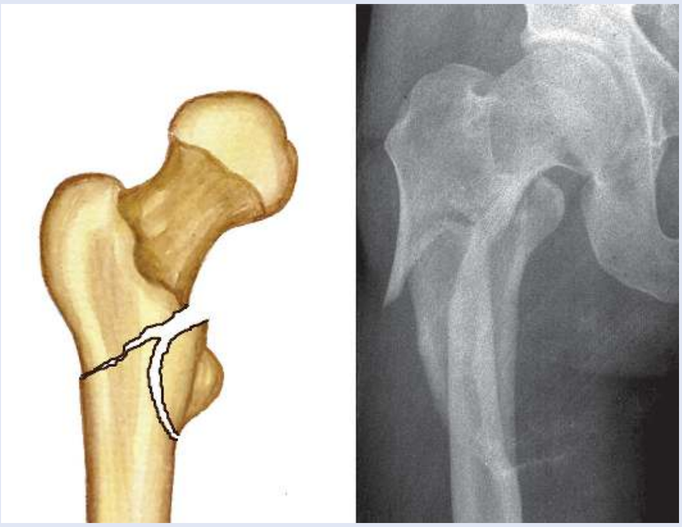
31-A3.1 Simple oblique



31-A3.2 Simple transverse



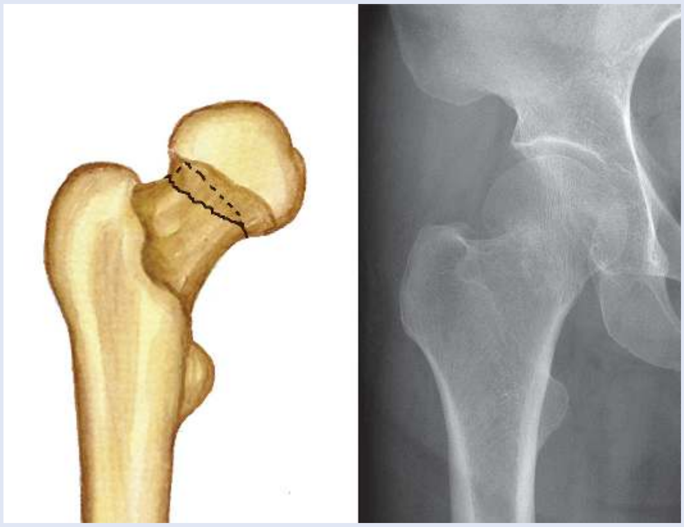
31-A3.3 Multifragmentary, fracture line extending into the diaphysis



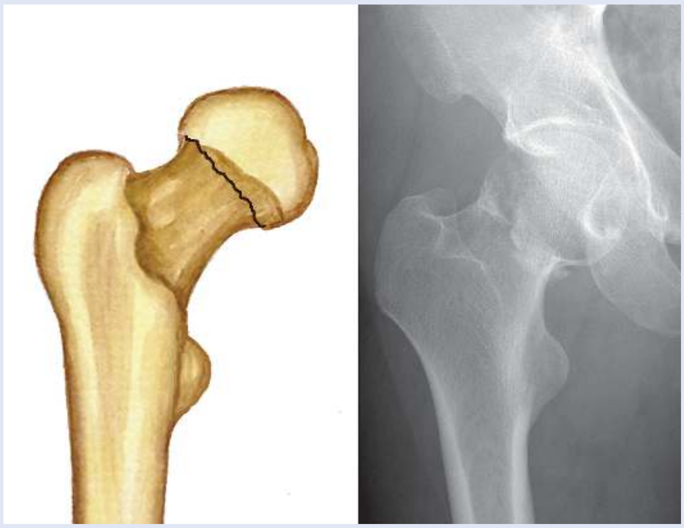
31-B Femur, proximal, intra-articular, neck fractures

31-B1 Subcapital, with slight or no displacement
2,945 fractures
M: 1,234 (41.90%)
F: 1,711 (58.10%)
0.79% of total adult fractures
7.42% of adult femoral fractures
10.51% of segment 31
21.79% of type 31-B

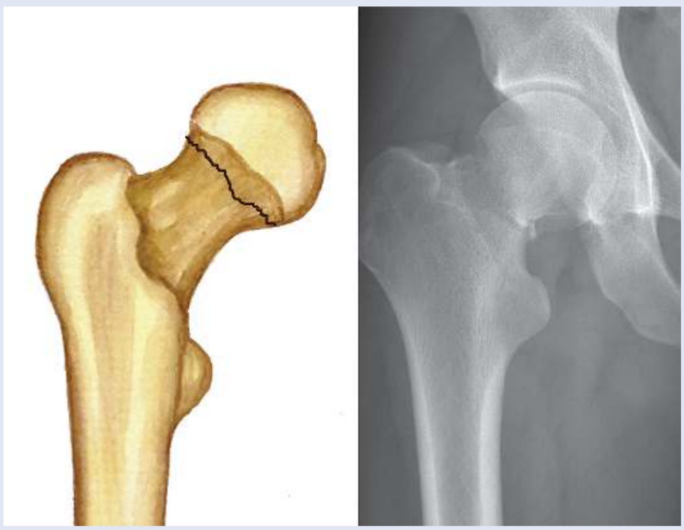
31-B1.1 Impacted with valgus displacement ≥ 15 degrees

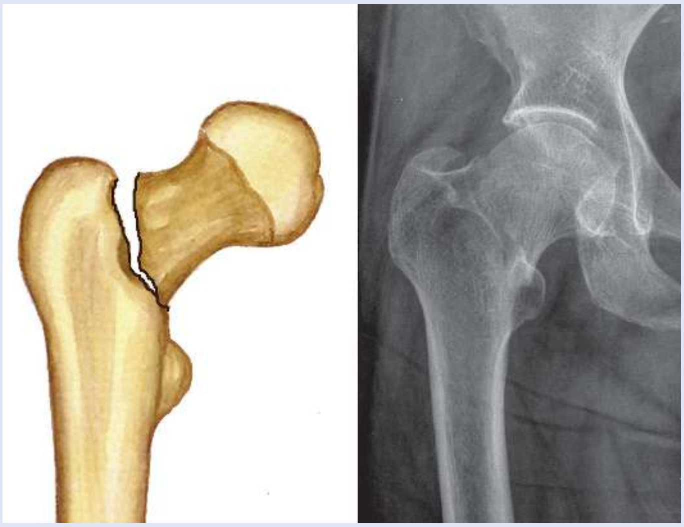
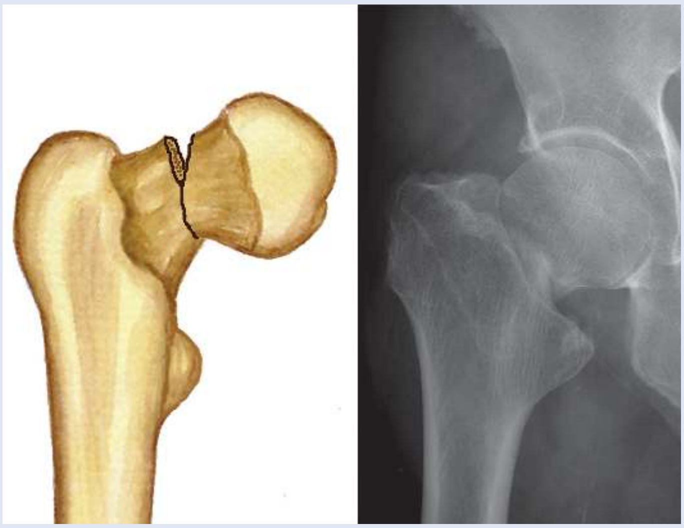
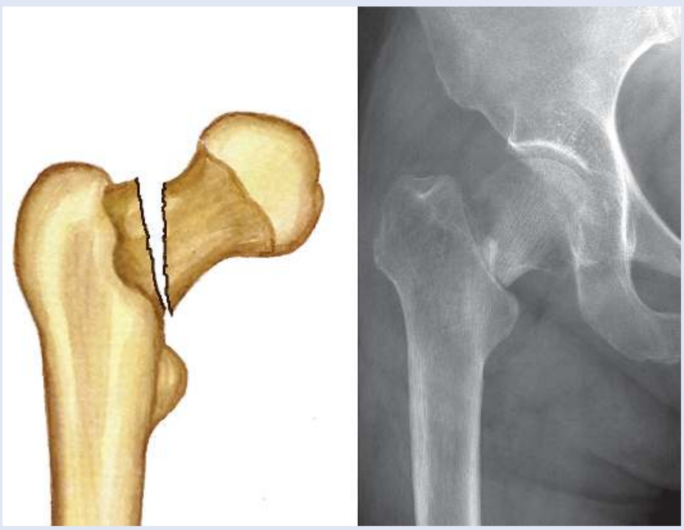


31-B1.2 Impacted with valgus displacement ≤ 15 degrees



31-B1.3 Nonimpacted

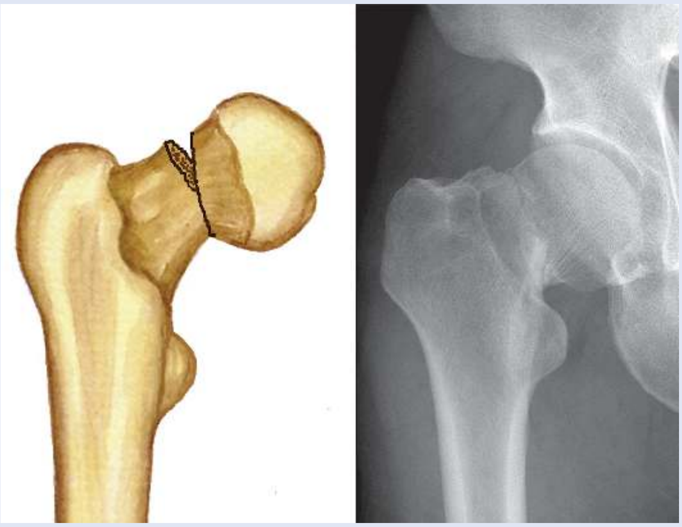


31-B Femur, proximal, intra-articular, neck fractures	
31-B2 Transcervical, with minimal displacement 6,870 fractures M: 3,070 (44.69%) F: 3,800 (55.31%) 1.83% of total adult fractures 17.31% of adult femoral fractures 24.51% of segment 31 50.83% of type 31-B	**31-B2.1** Basicervical  **31-B2.2** Midcervical adduction  **31-B2.3** Cervical shear 

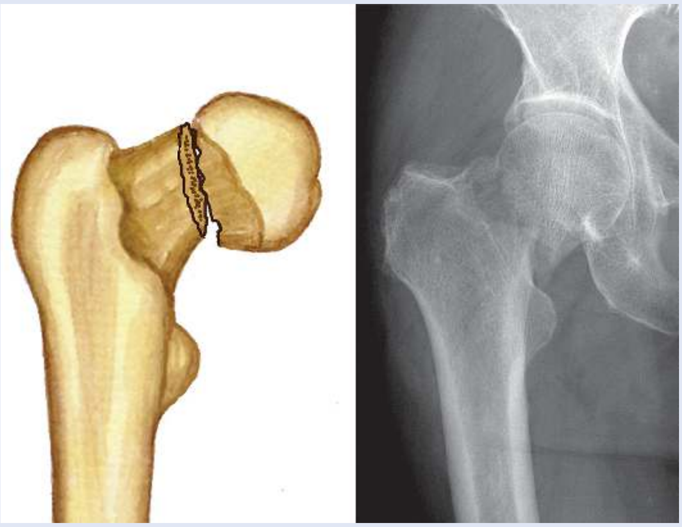
31-B Femur, proximal, intra-articular, neck fractures

31-B3 Subcapital, displaced without impaction
3,701 fractures
M: 1,331 (35.96%)
F: 2,370 (64.04%)
0.99% of total adult fractures
9.32% of adult femoral fractures
13.21% of segment 31
27.38% of type 31-B

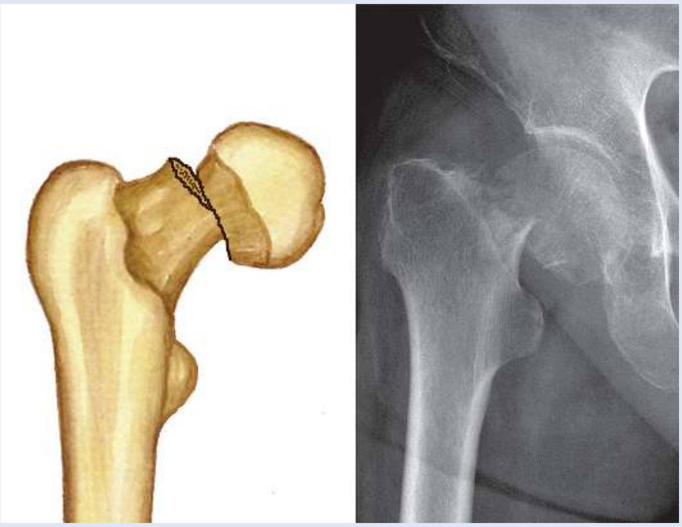
31-B3.1 Moderate displacement in varus and external rotation



31-B3.2 Moderate displacement in vertical translation and external rotation



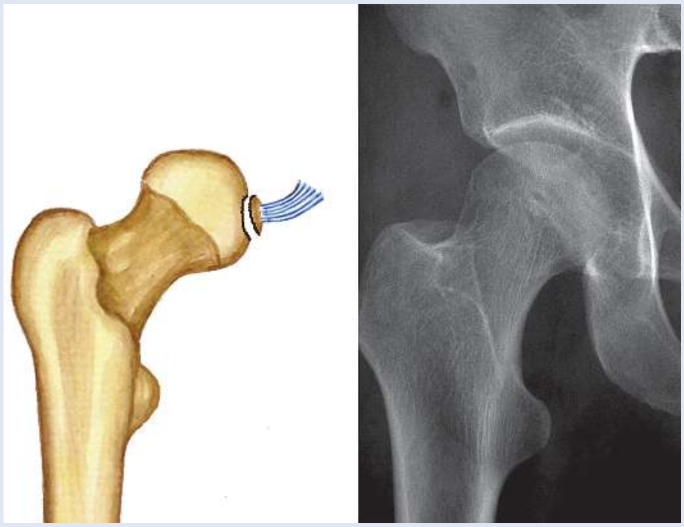
31-B3.3 Marked displacement in varus or vertical translation



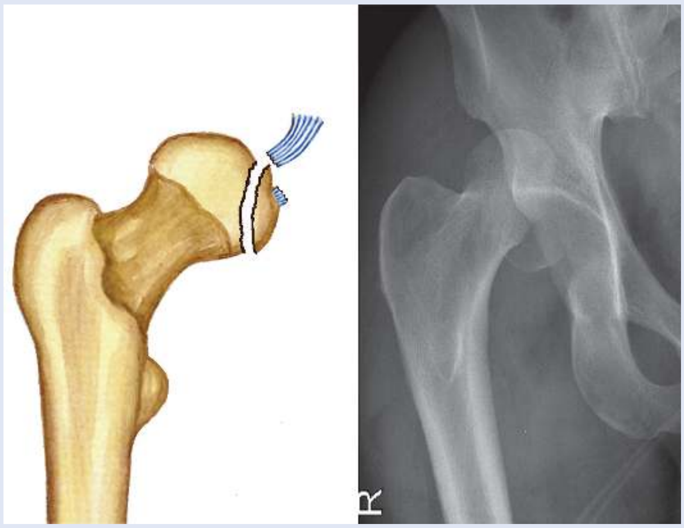
31-C Femur, proximal, intra-articular, head fractures

31-C1 Split
802 fractures
M: 493 (61.47%)
F: 309 (38.53%)
0.21% of total adult fractures
2.02% of adult femoral fractures
2.86% of segment 31
45.36% of type 31-C

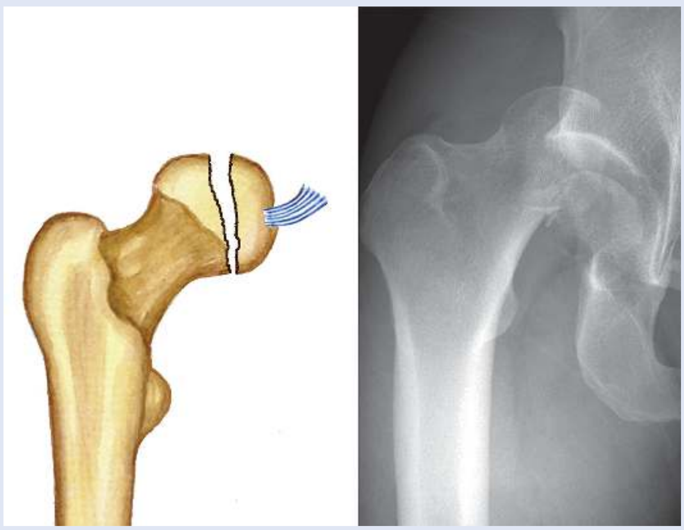
31-C1.1 Avulsion of the round ligament



31-C1.2 Fracture with rupture of the round ligament



31-C1.3 With a large fragment

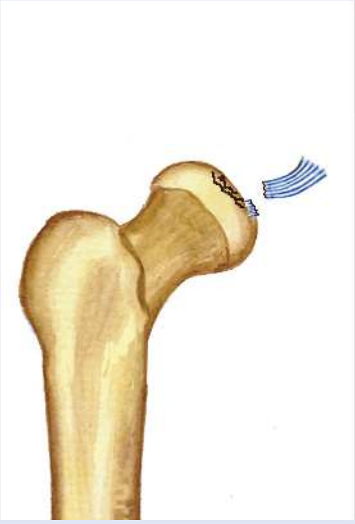


31-C Femur, proximal, intra-articular, head fractures

31-C2 Compressed
617 fractures
M: 348 (56.40%)
F: 269 (43.60%)
0.16% of total adult fractures
1.55% of adult femoral fractures
2.20% of segment 31
34.90% of type 31-C

31-C2.1 Posterior and superior


31-C2.2 Anterior and superior



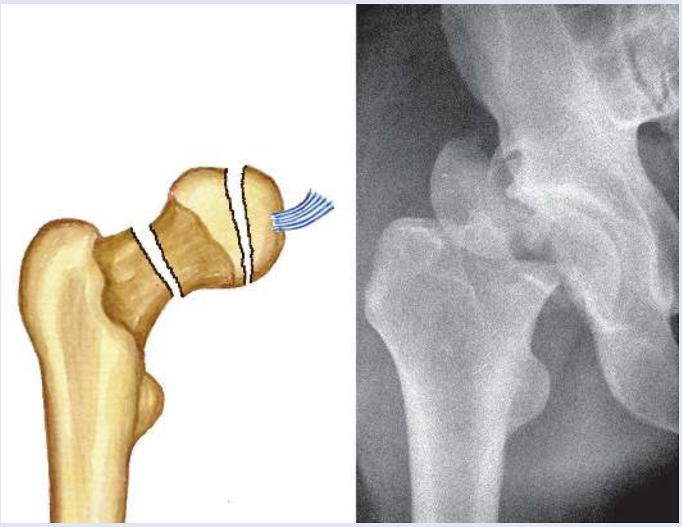

31-C2.3 Split and compressed


4

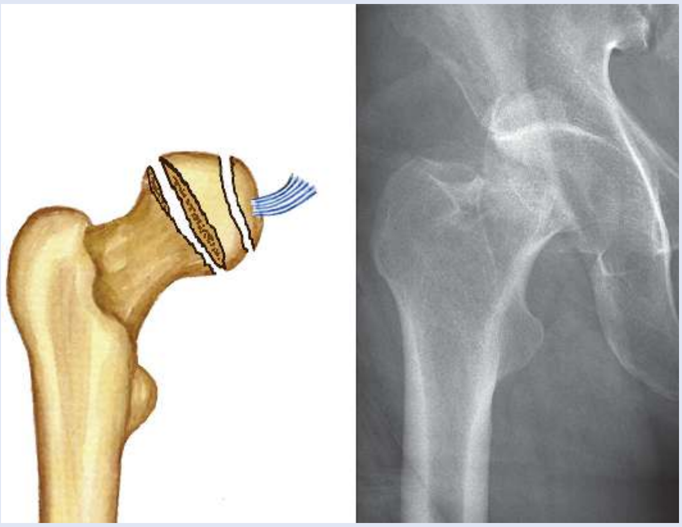
31-C Femur, proximal, intra-articular, head fractures

31-C3 With neck fracture
349 fractures
M: 198 (56.73%)
F: 151 (43.27%)
0.09% of total adult fractures
0.88% of adult femoral fractures
1.25% of segment 31
19.74% of type 31-C

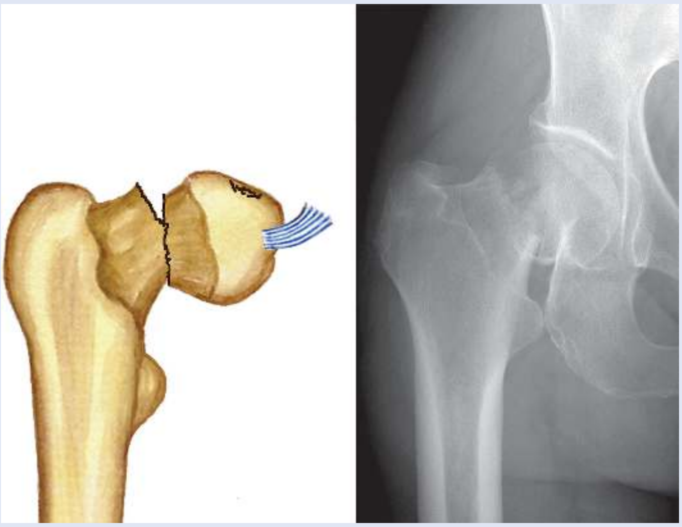
31-C3.1 Head split and neck fractured in transcervical region



31-C3.2 Head split and neck fractured in subcapital region



31-C3.3 Head compressed and neck fractured



Injury Mechanism

Intertrochanteric fracture can be caused by a direct force applied perpendicularly to the trochanteric area, or an indirect varus force transmitted to the intertrochanteric area through the hip. The forceful contraction of the gluteus medius and gluteus minimus muscles, or having the lower limb in hyperadduction, may lead to an avulsion fracture of the greater trochanter, while the pull of the iliopsoas muscle may result in avulsion of the lesser trochanter. Intertrochanteric fractures often occur in the elderly, mostly caused by falls. Since elderly patients often have osteoporotic bones, the resulting fractures are frequently complex fractures.

Femoral neck fractures can be caused by two types of force. Fractures may result from violent rotation of the hip as a result of falling onto the lateral aspect of the hip. This type of injury can also be caused by an indirect force transmitted to the neck through the greater trochanter, as seen in falls onto one's side from a height or a standing position. With decreased muscle tone in the hip area and increased bone fragility resulting from osteoporosis, elderly patients can sustain femoral neck fractures from minimal forces like a fall from a bed, sudden movements, or twisting of the leg. In young people, fractures of the femoral neck occur more frequently from high-energy trauma like car accidents or falls from a significant height. Avascular necrosis of the femoral head often occurs as a result of vascular disruption after fracture of the femoral neck.

Femoral head fractures usually result from a major force to a flexed knee and hip; the resulting force transmits to the hip joint through the axis of the femur and often leads to a posterior dislocation of the hip joint. When the fracture occurs with the hip flexed, abducted, and externally rotated, an anterior dislocation of hip joint usually follows.

Diagnosis

Intertrochanteric Fracture

If there is minimal or no displacement, patients may present with pain on palpation and percussive pain along the axis of the femur. If there is marked displacement, a typical presentation may include pain, deformity, abnormal range of movement, bony crepitus, and shortening of the involved limb. Imaging examinations must include standard anteroposterior (AP) and lateral views of the fracture site. A comparison AP view of the pelvis with the uninjured side is helpful in detecting fracture displacement, if the displacement is minimal. Computed tomography (CT) scanning might be indicated. For subtrochanteric fractures, radiographs should be taken to include the whole length of the diaphysis to rule out diaphyseal fractures of the femur.

Femoral Neck Fracture

Femoral neck fractures are intracapsular; therefore, patients may not present with much swelling. Physical examination reveals local pain to palpation and percussive pain along the axis of the femur. A standard hip radiographic series, including AP and lateral views of the affected hip, or a comparison AP view of the pelvis with the unaffected side, should be considered if neck fracture is suspected. Measurement of the Pauwel angle will be helpful in assessing the degree of fracture stability. If indicated, a CT scan of the hip joint should be carried out, which should include views of the acetabulum, the neck of femur, the head of femur, and the greater and lesser trochanter. A thin-slice CT scan and 2D- or 3D-CT reconstruction may also be required. CT is exquisitely useful for imaging abnormalities of the bone itself, such as in the disruption of the cortical bone and trabecula, and especially in detecting incomplete fractures without trabecula displacement. CT is the most useful test for evaluating bony injury, assessing the type of fracture and the degree of the displacement, and detecting the number and the location of the fragments.

The Garden classification is the most commonly used standard to assess the severity of femoral neck fracture in clinical setting. The Garden type I femoral neck fractures are defined as incomplete fractures of the neck of the femur as seen on the AP radiograph of the injured hip. In a prospective study, Zhang et al confirmed that incomplete femoral neck fractures identified on X-ray films are actually complete fractures on CT.

Femoral Head Fractures

The clinical presentation of femoral head fractures is atypical if the fractures are not displaced. Patients with femoral neck fractures usually present with different levels of pain to palpation over the hip joint, and percussive pain along the axis of femur. If the fractures are displaced, physical examination reveals bony crepitus, or a limited range of movement of the hip joint. Imaging examinations should include AP and lateral views of the hip joint and an AP view of the pelvis. A CT scan should be considered if X-ray films are equivocal. CT scans are not only useful in diagnosing but can also provide guidance on treatment. Plain radiographic findings on pediatric slipped capital femoral epiphysis and traumatic femoral head epiphysiolysis include a widening of the epiphyseal line, widening and irregularity of the growth plate, separation and displacement of the epiphyseal line from the metaphyses, and inferomedial displacement of the epiphysis. CT and magnetic resonance imaging (MRI) should be considered under such circumstances. Femoral head fractures in adults are more commonly fractures of the apex of the femoral head, and the resulting fragments often lie within the capsule. Radiographic images reveal the femoral head defect or irregularity. If there is fracture displacement, the fracture of the superior rim of the acetabulum usually accompanies the fracture. If the X-ray film cannot point to a clear diagnosis of a femoral head fracture, MRI is required to further to assess the nature of the fracture, or the location and the course of the fracture line. When fractures involve subchondral bones, MRI can clearly reveal the extent of the fracture.

Treatment

Intertrochanteric Fractures

Intramedullary nails, like the Gamma nail and proximal femoral nail (PFN), are usually used for internal fixation of proximal femoral fractures. Intramedullary nails have the biomechanic properties of internal fixators, and offer the advantage of small incisions and short operation times. Gamma nail fixation requires the affected limb to be slightly adducted, and traction for anatomic reduction. Radiographic measurement of femoral canal diameters and the shape of the femoral diaphysis must be done before the surgery. PFNs should not be used in patients with marked anterior bowing of the femur. Other internal fixators often used for fixation of proximal femoral fractures include dynamic hip screw (DHS), dynamic condylar screw (DCS), and DHS trochanter stabilizing plates, which provide double fixation by performing compression and a sliding motion leading to dynamic compression at the fracture site.

Femoral Neck Fractures

Subcapital fractures of the femoral neck have a high incidence of avascular necrosis of the femoral head. In young patients with good preservation of bone stock, one should consider artificial femoral head replacement or biological fixation of a total hip prosthesis. For elderly patients with osteoporotic bones, a self-centering bipolar head or total hip replacement is recommended. Transcervical femoral neck fractures can be fixed by screws, usually by three cancellous screws, which offer the advantages of providing significant compression to the fracture site, avoiding rotation, and causing minimal bone damage. The Anchor nail, developed by a group of talented orthopaedic surgeons at our hospital, combines the beauty of the Trifin nail and compression screw, which has the advantages of providing compression and anti-rotation at the fracture site with a simple procedure. A good clinical outcome has been observed after its application in treating femoral neck fractures in our hospital. Basicervical fractures can be treated surgically or conservatively, depending on the patient's medical condition. If complex basicervical fractures occur in patients with osteoporotic bones or with multifragmentary fractures of the cortical bone, then management should involve DHS and angle plates. A screw can be added to the DHS proximally to restore the rotational stability of the bone and provide support and fixation.

Anatomical reduction is difficult to achieve in some femoral neck fractures with routine manipulative maneuvers, and they require open surgical intervention. This kind of irreducible femoral neck fractures is frequently complicated by avascular necrosis of the femoral head and nonunion of the fracture. Three-dimensional interreaction reduction was invented by Zhang et al to deal with those problems. Zhang et al designed a quantitative score system used in treatment of adult femoral neck fractures with high factors for nonunion (age > 50 years, females, displacement fracture, high energy injury, and American Society of Anesthesiologists (ASA) grade above III), which includes patient's age, fracture type, bone mineral density, activities of daily living, and medical comorbidities. This quantitative score system helps in surgical decision-making regarding the treatment choice for adult patients with femoral neck fractures. In order to prevent nonunion and femoral head necrosis of femoral neck fracture, adult fresh femoral neck fractures with high factors for nonunion require early intervention, which consists of free iliac bone graft transplanting with bilateral cortical bone and internal fixation.

Femoral Head Fractures

If the fracture occurs in a nonweight-bearing part of the femur, with small free-floating fragments sitting within the joint capsule, then the floating fragments should be taken out to avoid further damage to the joint. If the fracture occurs in a weight-bearing section of the femur, small lag screws or absorbable screws can be inserted from the nonweight-bearing section to fix the fracture, with the head of the nail just beneath subchondral bone. As more than two-thirds of femoral head fractures involve a split head with an associated neck fracture or acetabular fracture, a total hip replacement is usually the treatment of choice.

Diaphyseal Femoral Fractures (Segment 32)

Anatomic Features

Femoral shaft fractures occur in the region extending from the lesser trochanter to the flare of femoral condyles (▶ Fig. 4.20). The body of the femur, almost cylindrical in form, is a little broader superiorly than in the center, and somewhat flattened and widened anteroposteriorly, especially at the lower end. It is slightly curved with a smooth convexity anteriorly, and strengthened posteriorly by a prominent longitudinal ridge, the linea aspera, which continues into the gluteal tuberosity superolaterally. The diameter of the femoral shaft and the thickness of the cortical layer of the shaft are associated with the weight bearing and the tension applied to the femur. As a result, the cortical layer of the shaft attenuates toward the proximal and distal ends of the femur.

AO Classification of Diaphyseal Femoral Fractures

Based on AO classification, the diaphysis of the femur is coded as number "32." It is further divided into three types depending on fracture patterns: 32-A: Simple fracture; 32-B: Wedge fracture; and 32-C: Complex fracture (▶ Fig. 4.21).

Fig. 4.20 The femoral shaft.

Clinical Epidemiologic Features of Diaphyseal Femoral Fractures (Segment 32)

A total of 8,235 diaphyseal femoral fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, accounting for 20.75% of femoral fractures in adults. Their epidemiologic features are as following:

- More males than females
- The highest-risk age group for both sexes is 21–25 years
- The most common fracture type among segment 32 fractures is type 32-A, the same fracture type in males and females
- The most common fracture group among segment 32 fractures is group 32-A3. However, 32-A3 is more common in males, while 32-A1 and 32-A3 are more common in females.

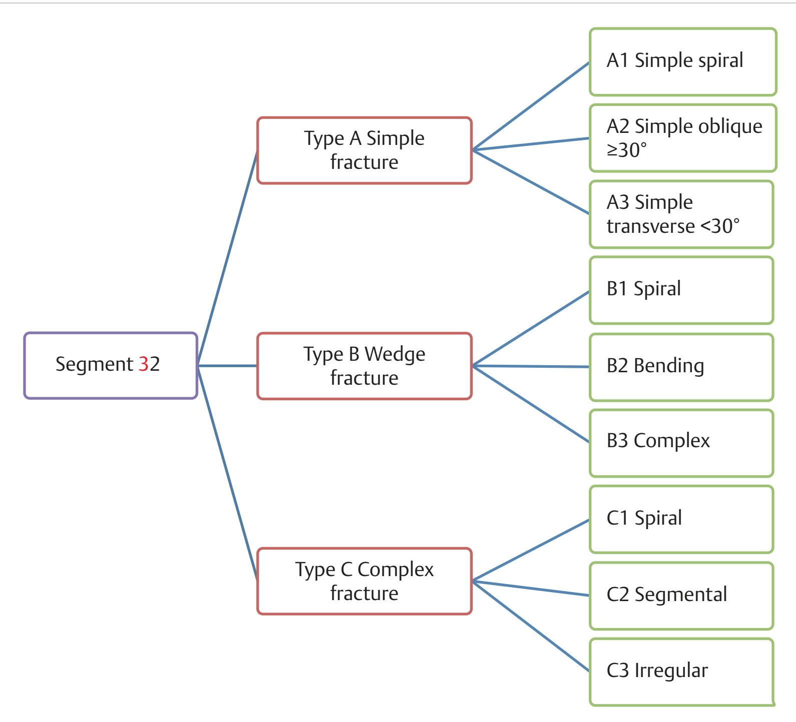


Fig. 4.21 Algorithm.

Fractures of Segment 32 by Sex

See ▶ Table 4.15 and ▶ Fig. 4.22.

Table 4.15 Sex distribution of 8,235 fractures of segment 32

Sex	Number of fractures	Percentage
Male	6,275	76.20
Female	1,960	23.80
Total	8,235	100.00

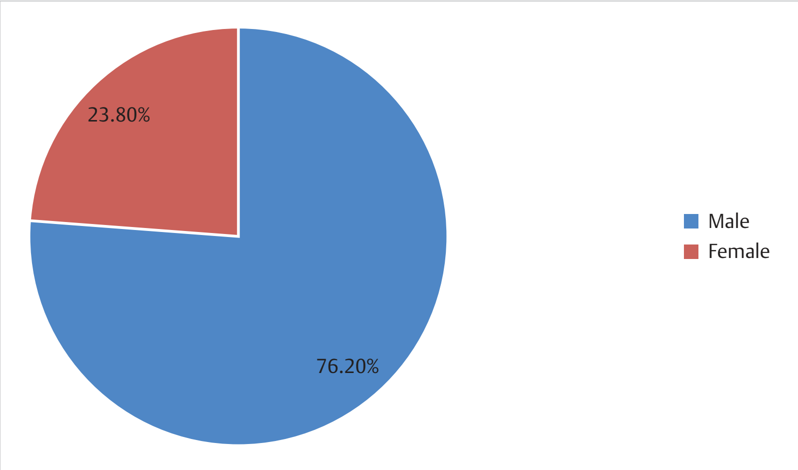


Fig. 4.22 Sex distribution of 8,235 fractures of segment 32.

■ Fractures of Segment 32 by Age Group

See ▶ Table 4.16 and ▶ Fig. 4.23.

Table 4.16 Age and sex distribution of 8,235 fractures of segment 32

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	635	122	757	9.19
21–25	892	193	1,085	13.18
26–30	758	138	896	10.88
31–35	640	145	785	9.53
36–40	689	157	846	10.27
41–45	778	157	935	11.35
46–50	546	154	700	8.50
51–55	413	131	544	6.61
56–60	361	187	548	6.65
61–65	200	95	295	3.58
66–70	115	101	216	2.62
71–75	89	121	210	2.55
76–80	79	119	198	2.40
81–85	47	89	136	1.65
≥ 86	33	51	84	1.02
Total	6,275	1,960	8,235	100.00

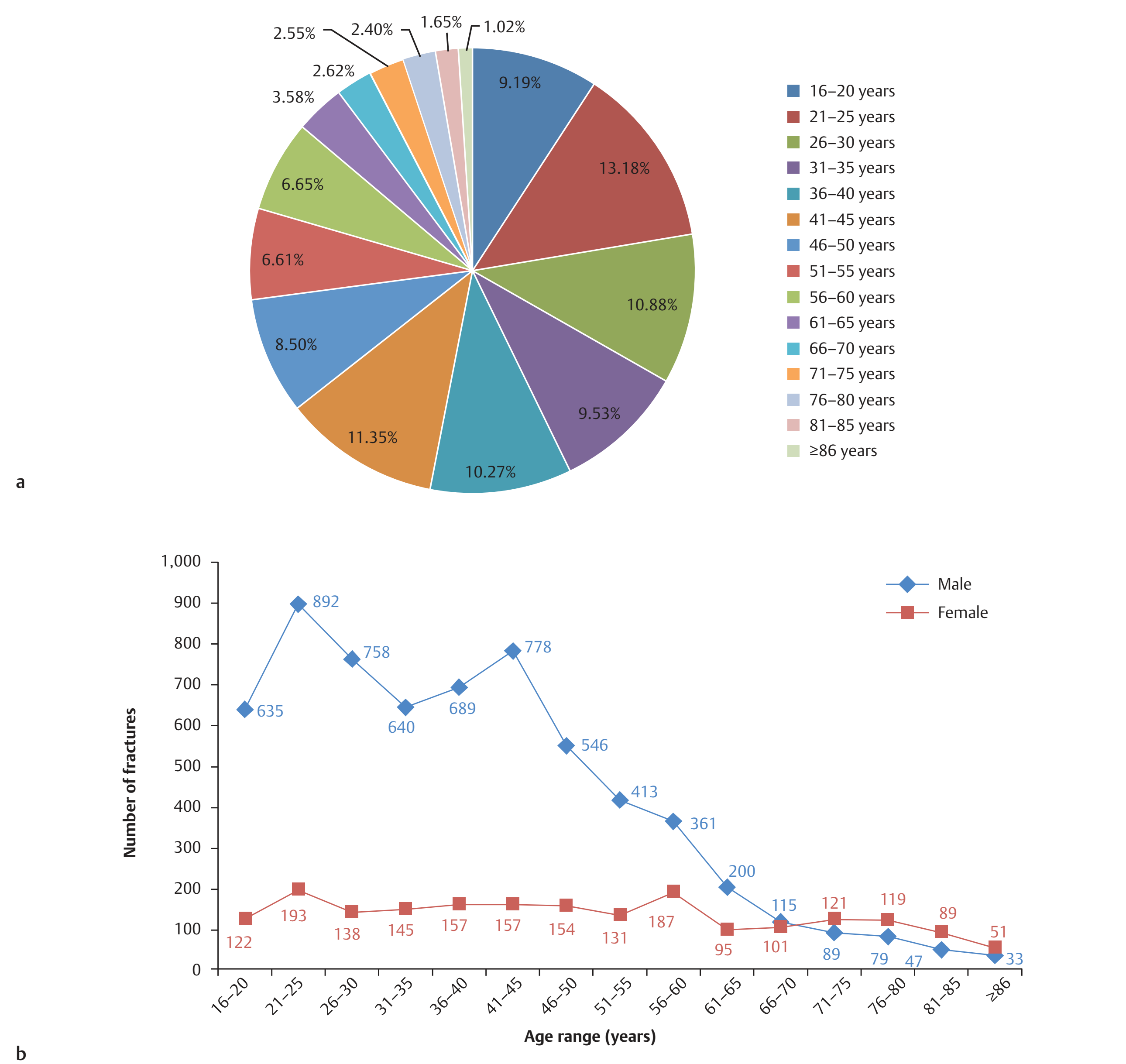


Fig. 4.23 (a) Age distribution of 8,235 fractures of segment 32. (b) Age and sex distribution of 8,235 fractures of segment 32.

■ Fractures of Segment 32 by Fracture Type

See ▶ Table 4.17 and ▶ Fig. 4.24.

Table 4.17 Sex and fracture type distribution of 8,235 fractures of segment 32

Fracture type	Male	Female	Number of fractures	Percentage
32-A	3,027	1,093	4,120	50.03
32-B	2,303	611	2,914	35.39
32-C	945	256	1,201	14.58
Total	6,275	1,960	8,235	100.00

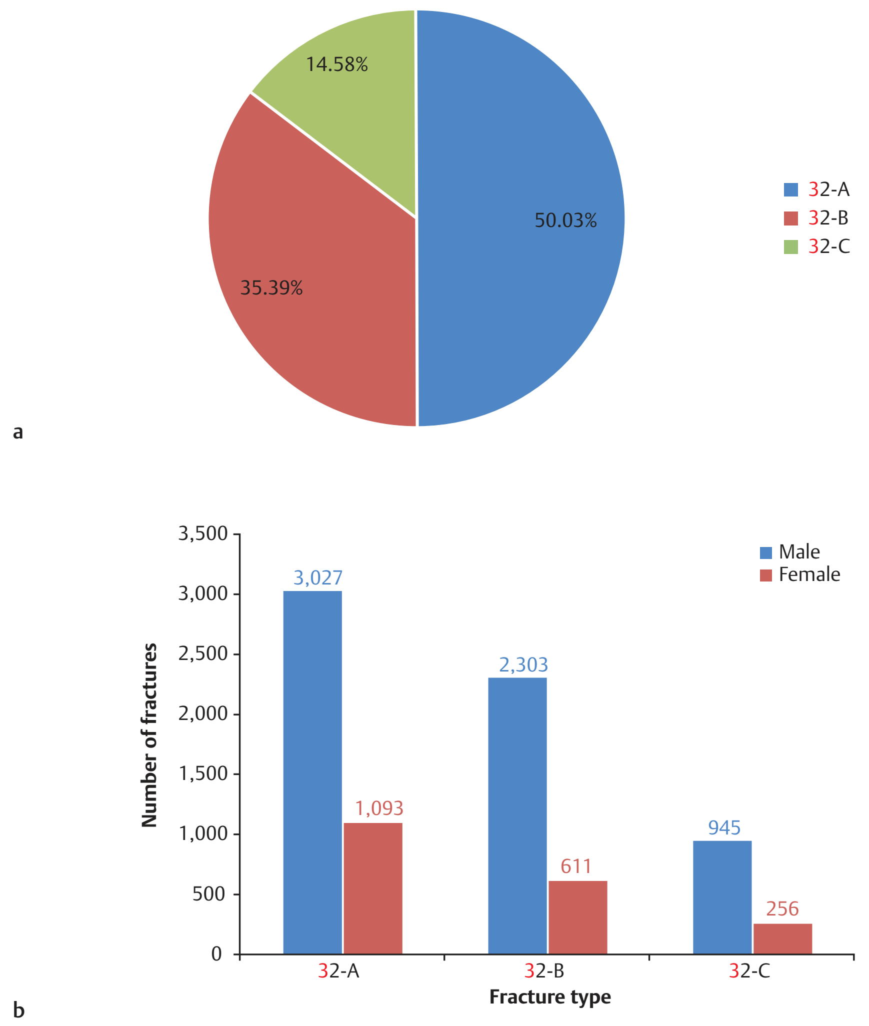


Fig. 4.24 (a) Fracture type distribution of 8,235 fractures of segment 32. (b) Sex and fracture type distribution of 8,235 fractures of segment 32.

■ Fractures of Segment 32 by Fracture Group

See ▶ Table 4.18 and ▶ Fig. 4.25.

Table 4.18 Sex and fracture group distribution of 8,235 fractures of segment 32

Fracture group	Male	Female	Number of fractures	Percentage of segment 32 fractures	Percentage of femoral fractures
32-A1	704	388	1,092	13.26	2.75
32-A2	896	317	1,213	14.73	3.06
32-A3	1,427	388	1,815	22.04	4.57
32-B1	596	219	815	9.90	2.05
32-B2	1,098	280	1,378	16.73	3.47
32-B3	609	112	721	8.76	1.82
32-C1	260	74	334	4.06	0.84
32-C2	221	70	291	3.53	0.73
32-C3	464	112	576	6.99	1.45
Total	6,275	1,960	8,235	100.00	20.75

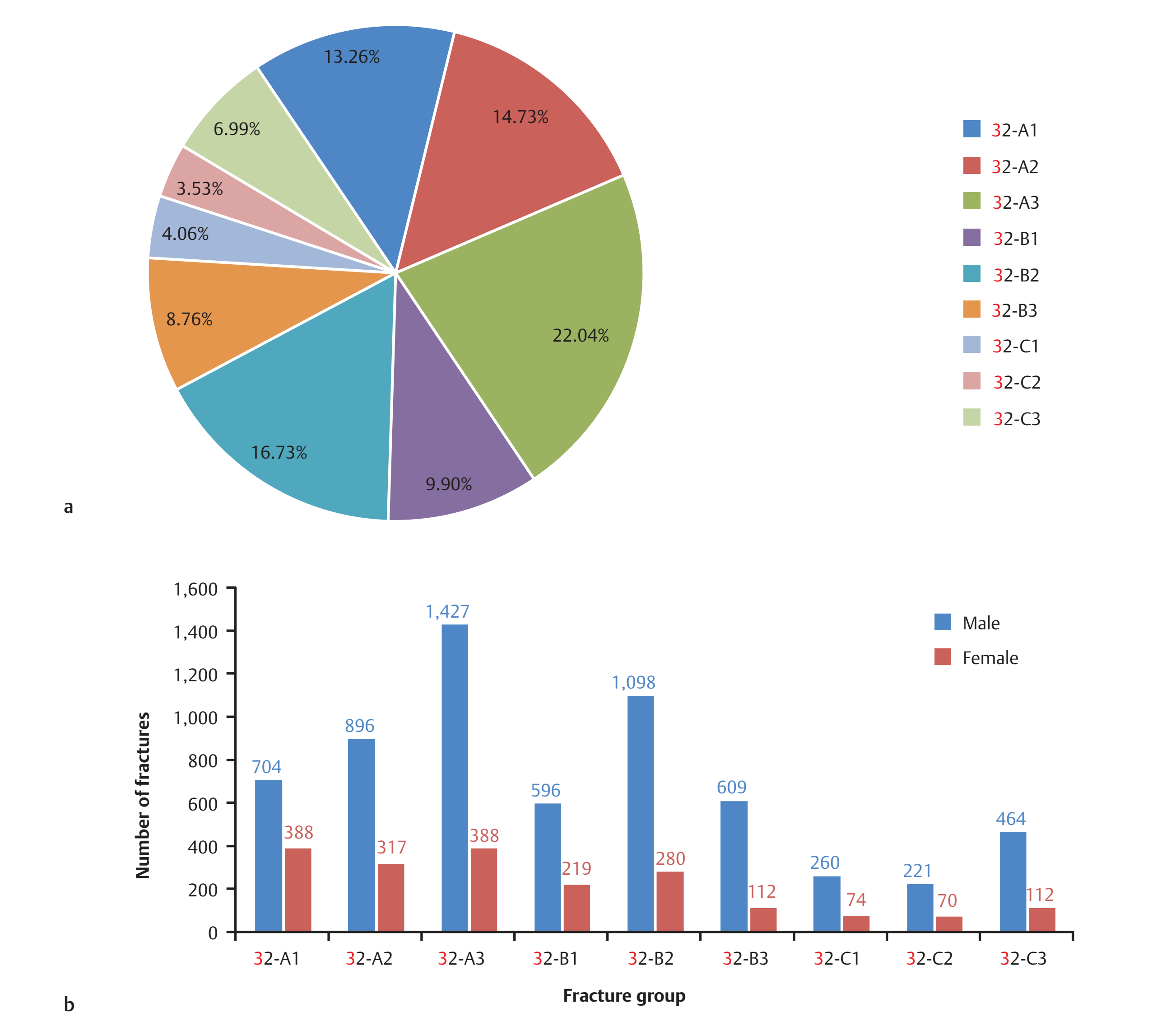
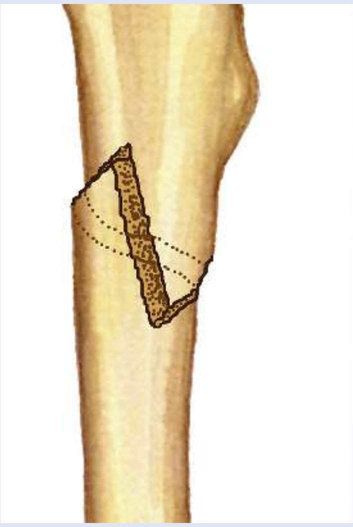


Fig. 4.25 (**a**) Fracture group distribution of 8,235 fractures of segment 32. (**b**) Sex and fracture group distribution of 8,235 fractures of segment 32.

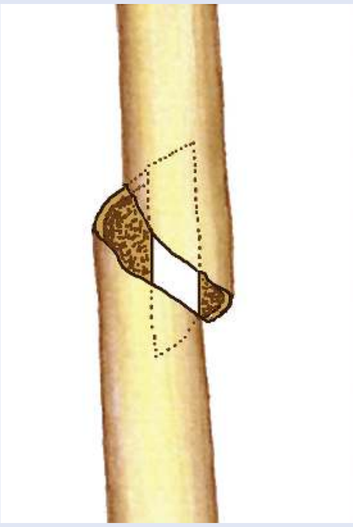
32-A Femur, diaphysis, simple fractures

32-A1 Spiral
1,092 fractures
M: 704 (64.47%)
F: 388 (35.53%)
0.29% of total adult fractures
2.75% of adult femoral fractures
13.26% of segment 32
26.50% of type 32-A

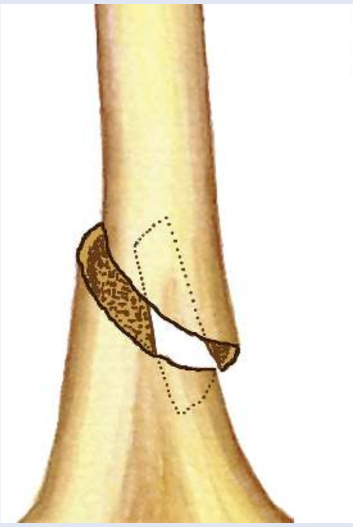
32-A1.1 Subtrochanteric section



32-A1.2 Middle section



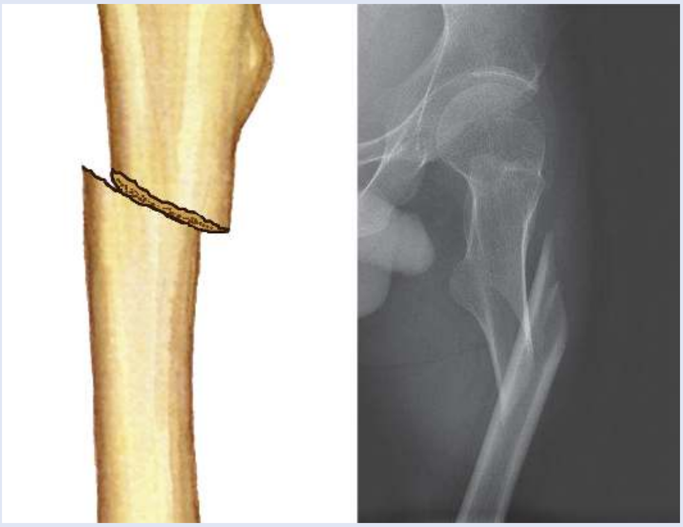
32-A1.3 Distal section



32-A Femur, diaphysis, simple fractures

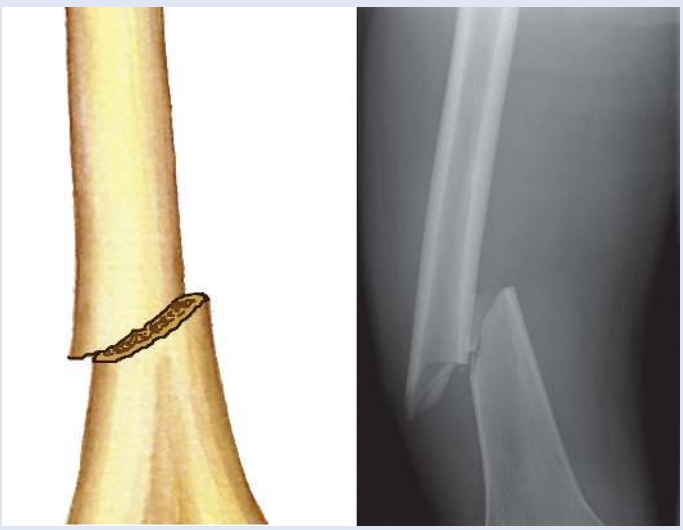
32-A2 Oblique (≥ 30 degrees)
1,213 fractures
M: 896 (73.87%)
F: 317 (26.13%)
0.32% of total adult fractures
3.06% of adult femoral fractures
14.73% of segment 32
29.44% of type 32-A

32-A2.1 Subtrochanteric section



32-A2.2 Middle section

32-A2.3 Distal section



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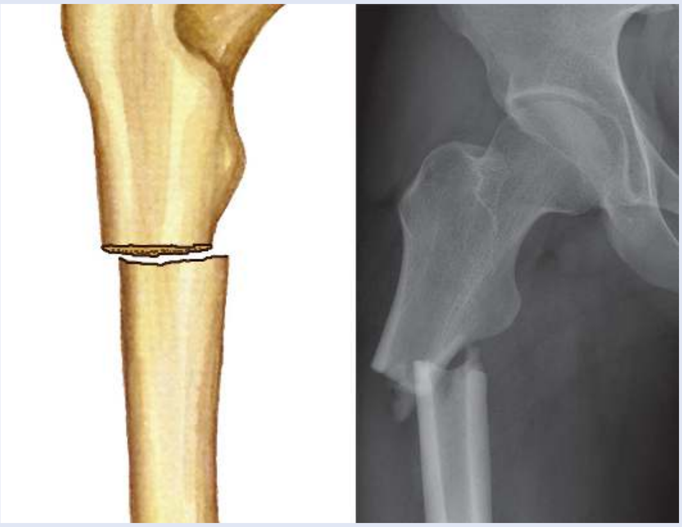
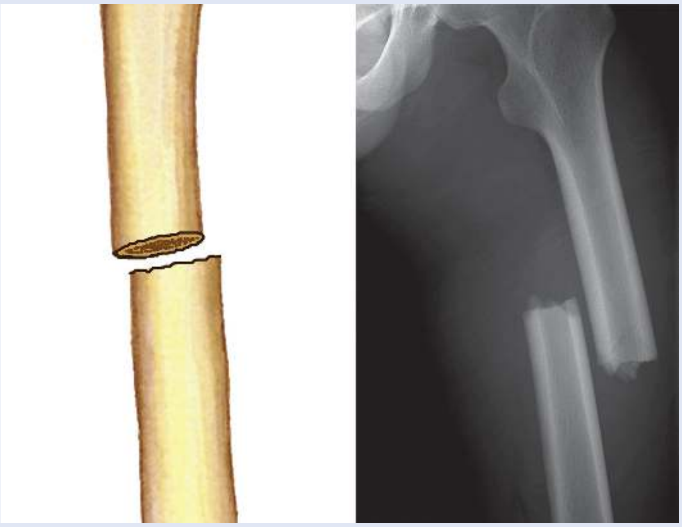
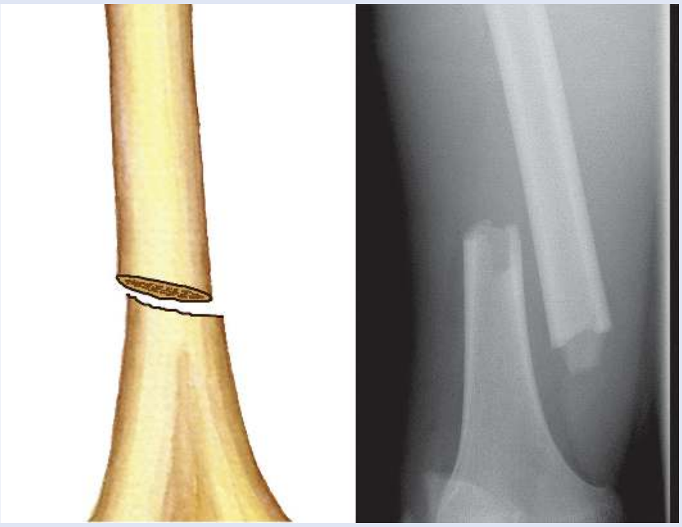
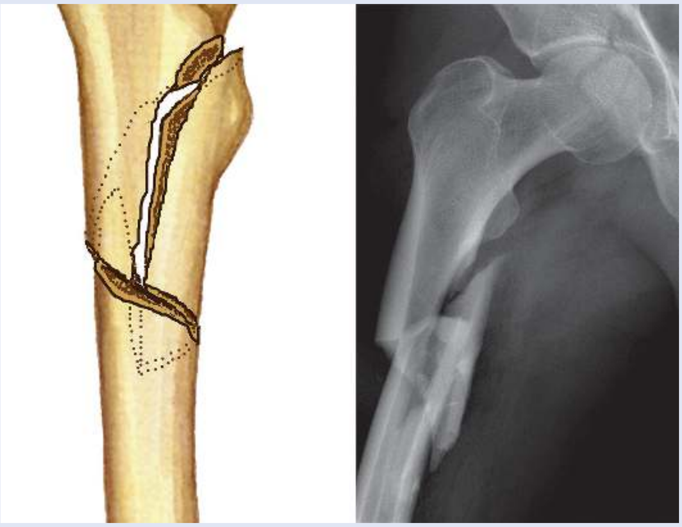
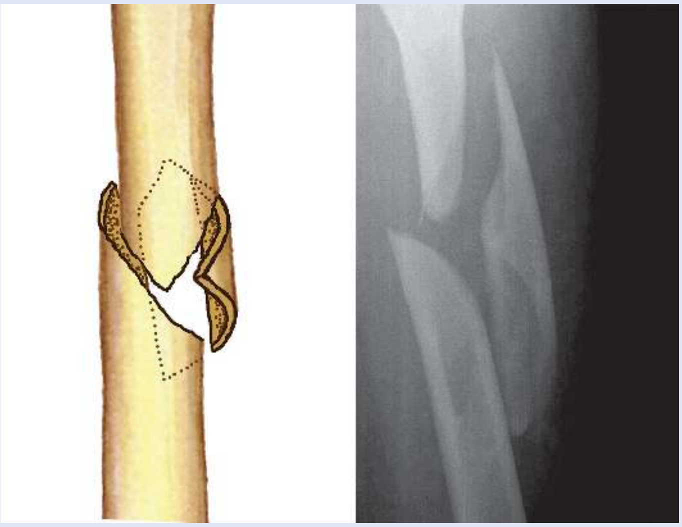
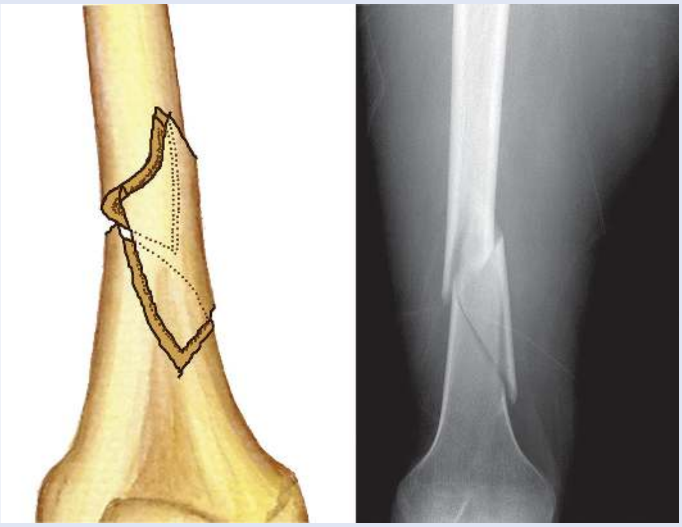
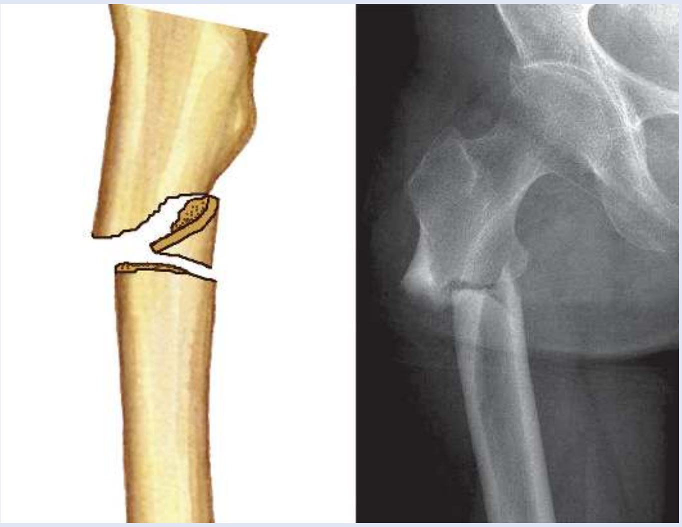
32-A Femur, diaphysis, simple fractures	
32-A3 Transverse (<30 degrees) 1,815 fractures M: 1,427 (78.62%) F: 388 (21.38%) 0.48% of total adult fractures 4.57% of adult femoral fractures 22.04% of segment 32 44.05% of type 32-A	**32-A3.1** Subtrochanteric section  **32-A3.2** Middle section  **32-A3.3** Distal section 

32-B Femur, diaphysis, wedge fractures	
32-B1 Spiral wedge 815 fractures M: 596 (73.13%) F: 219 (26.87%) 0.22% of total adult fractures 2.05% of adult femoral fractures 9.90% of segment 32 27.97% of type 32-B	**32-B1.1** Subtrochanteric section  **32-B1.2** Middle section  **32-B1.3** Distal section 

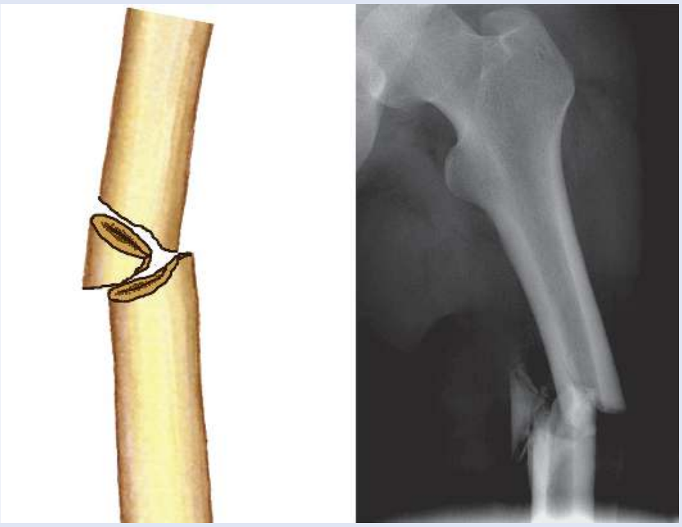
32-B Femur, diaphysis, wedge fractures

32-B2 Bending wedge
1,378 fractures
M: 1,098 (79.68%)
F: 280 (20.32%)
0.37% of total adult fractures
3.47% of adult femoral fractures
16.73% of segment 32
47.29% of type 32-B

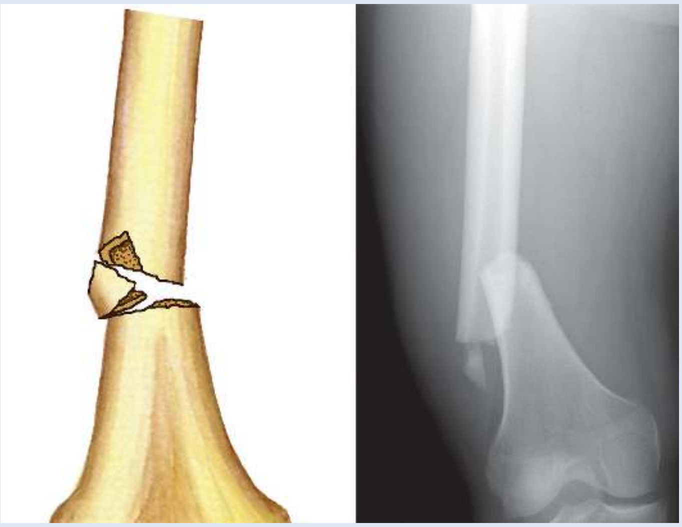
32-B2.1 Subtrochanteric section



32-B2.2 Middle section



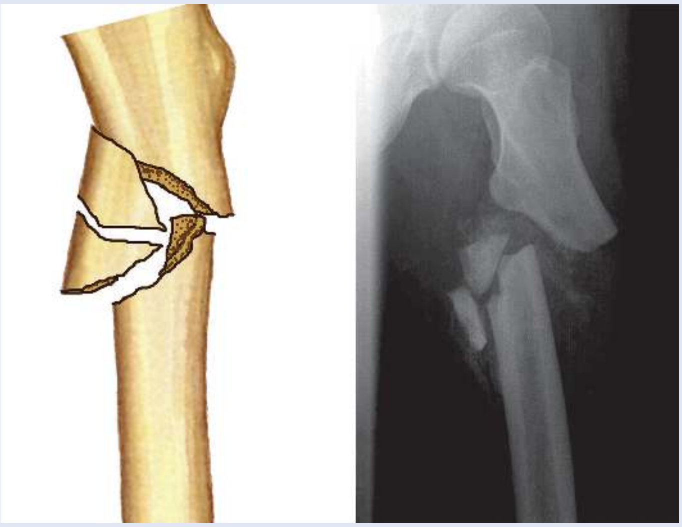
32-B2.3 Distal section



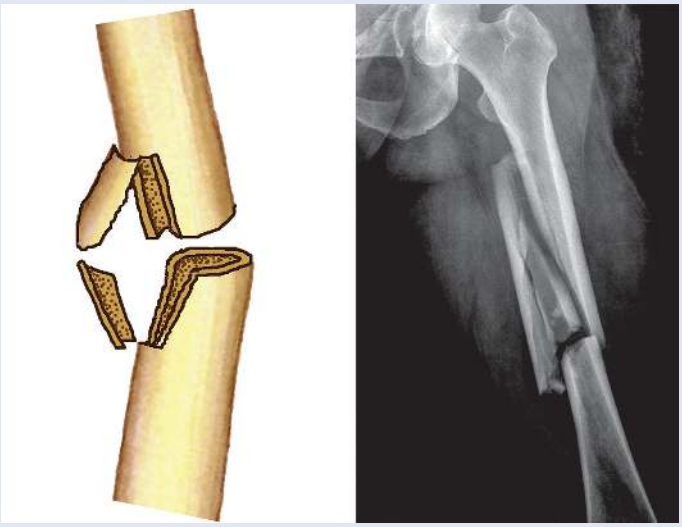
32-B Femur, diaphysis, wedge fractures

32-B3 Complex
721 fractures
M: 609 (84.47%)
F: 112 (15.53%)
0.19% of total adult fractures
1.82% of adult femoral fractures
8.76% of segment 32
24.74% of type 32-B

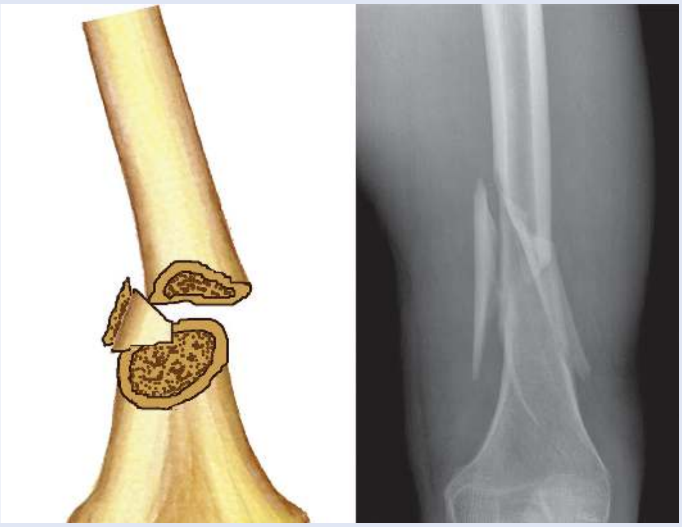
32-B3.1 Subtrochanteric section



32-B3.2 Middle section



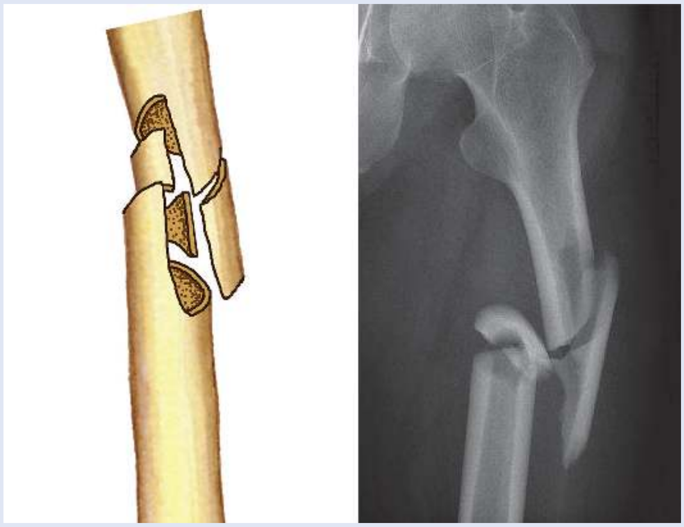
32-B3.3 Distal section



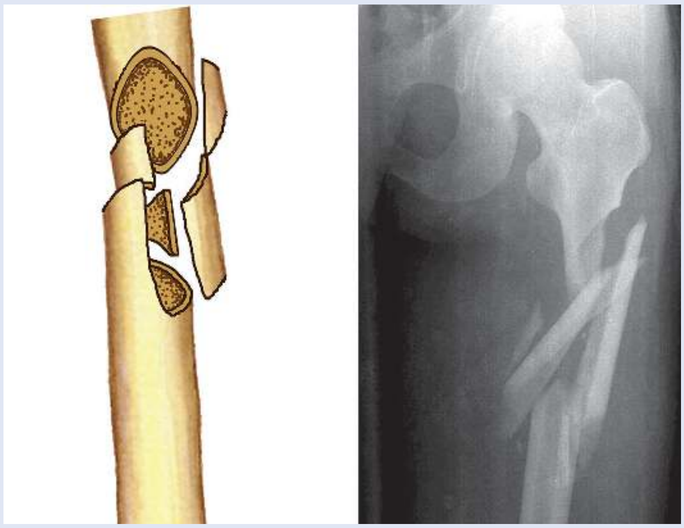
32-C Femur, diaphysis, complex fractures

32-C1 Spiral
334 fractures
M: 260 (77.84%)
F: 74 (22.16%)
0.09% of total adult fractures
0.84% of adult femoral fractures
4.06% of segment 32
27.81% of type 32-B

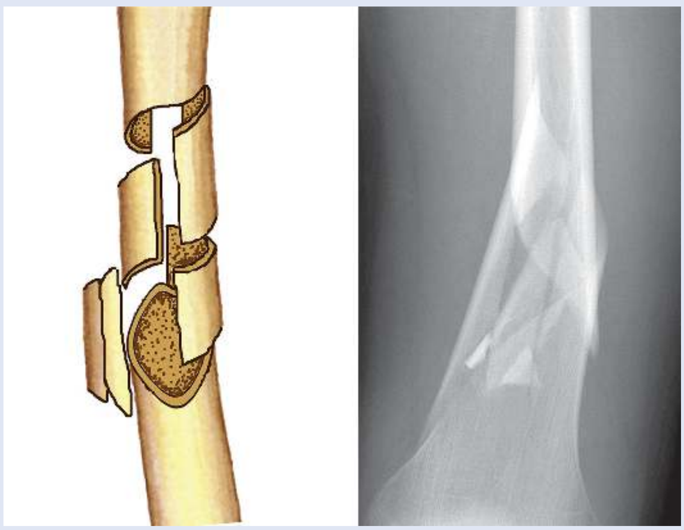
32-C1.1 With two intermediate fragments

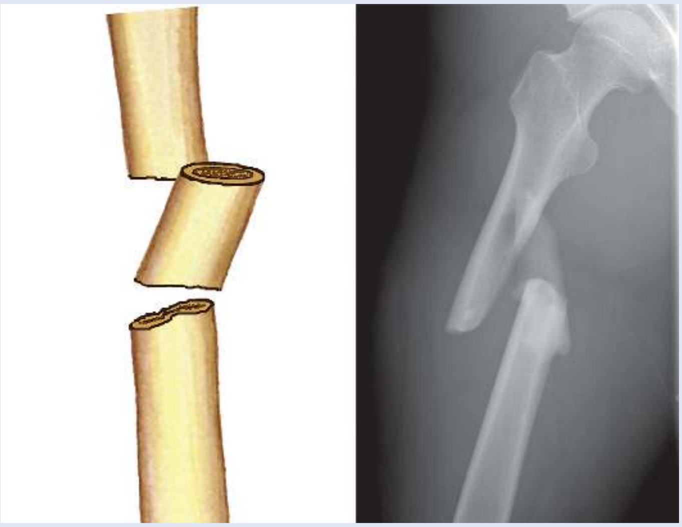
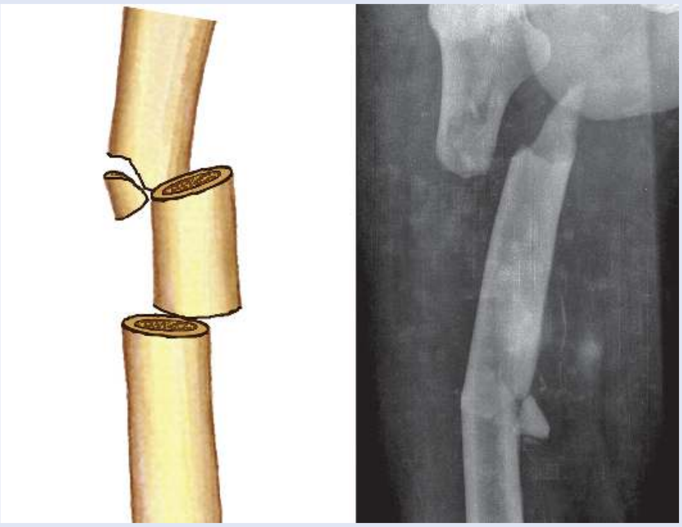
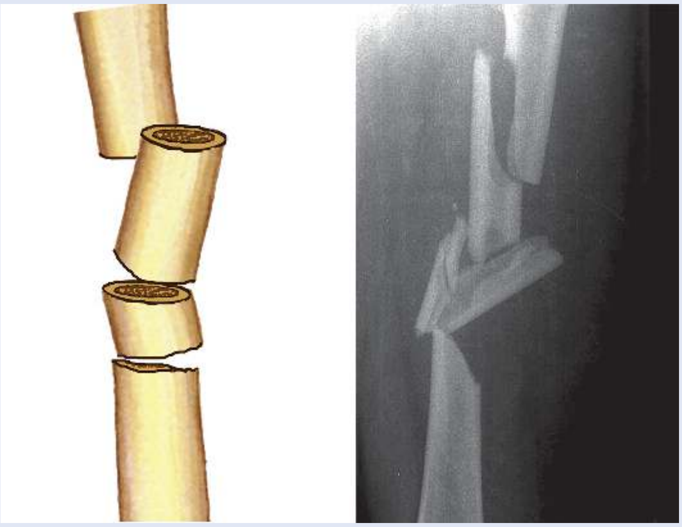


32-C1.2 With three intermediate fragments



32-C1.3 With more than three intermediate fragments

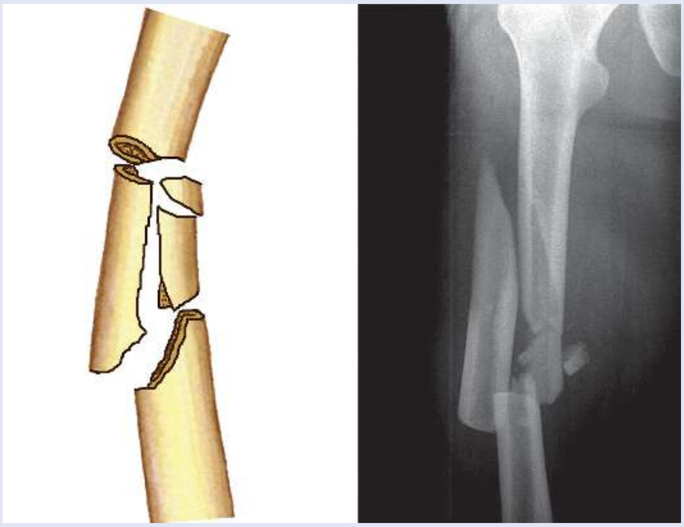


32-C Femur, diaphysis, complex fractures	
32-C2 Segmental 291 fractures M: 221 (75.95%) F: 70 (24.05%) 0.08% of total adult fractures 0.73% of adult femoral fractures 3.53% of segment 32 24.23% of type 32-C	**32-C2.1** With one intermediate segmental fragment  **32-C2.2** With one intermediate segmental fragment with an additional wedge fragment  **32-C2.3** With two or more intermediate segmental fragments 

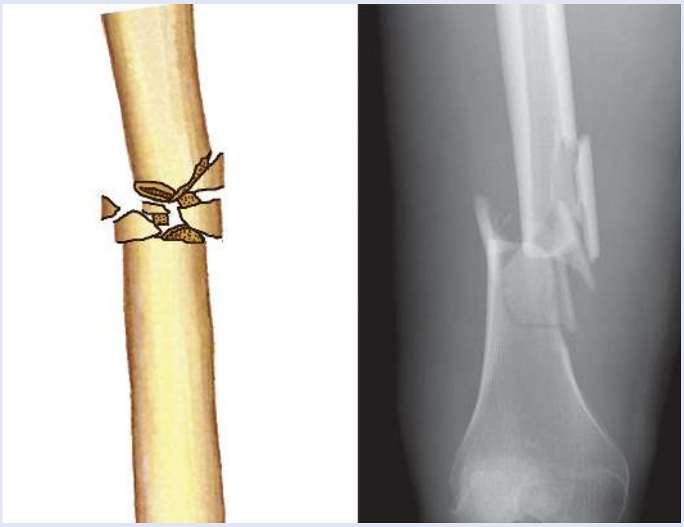
32-C Femur, diaphysis, complex fractures

32-C3 Irregular
576 fractures
M: 464 (80.56%)
F: 112 (19.44%)
0.15% of total adult fractures
1.45% of adult femoral fractures
6.99% of segment 32
47.96% of type 32-C

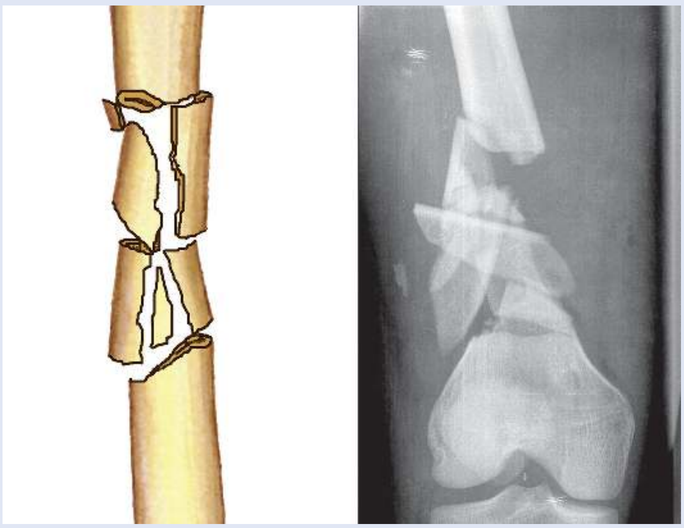
32-C3.1 With two or three intermediate fragments



32-C3.2 With limited shattering (< 5 cm)



32-C3.3 With extensive shattering (≥ 5 cm)



Injury Mechanism

Diaphyseal femoral fractures most often result from violent direct trauma, as seen in crush injuries or direct blows. A portion of fractures can be caused by indirect force, which involves leverage, twisting, or a fall from significant height. The direct trauma frequently leads to transverse or complex fractures, while oblique or spiral fractures may be the result of indirect force.

If fractures occur at the upper third of the femoral shaft, then the distal segment of the fracture displaces superoposteriorly while the proximal segment is pulled into flexion, abduction, and external rotation by the activity of a group of muscles including the gluteus medius and minor, iliopsoas muscle, and short external rotators. Displacement of fractures of the middle third of the shaft has not been observed with much regularity. When fractures occur at the distal third of the femoral shaft, the proximal segment is usually pulled in adduction and displaces anteriorly and the distal segment displaces posteriorly due to traction from the gastrocnemius and the capsule, which may damage the popliteal artery, vein, and sciatic nerve.

Diagnosis

Patients with femoral shaft fractures usually present with pain, swelling, limb shortening, limited range of movement, and deformity of the affected limb. Radiographic examination should include an AP pelvic view, as well as AP and lateral views of the knee that show the entire femur, because fractures often involve both the hip and knee joints. The lateral view should include an extension view of the intertrochanteric fracture site, to specifically detect the involvement of the anterior and posterior aspects of the sinus pyriformis. The diameter of the femoral canal, the shape of the shaft, the femoral neck angle, and the presence of prior deformity of the femur should be given special attention for proper choice of internal fixators.

Treatment

Early fixation of femoral shaft fractures can lead to satisfactory clinical outcomes, with better results in knee function and fewer complications. As such, these fractures in adults should be treated with surgical intervention. With the advancement of the interlocking intramedullary nail, it has become the preferred treatment of choice for fixation of femoral shaft fractures. The interlocking intramedullary nails provide fixation not only to fractures of the shaft, but also to fractures extending into the proximal and distal ends of the femur, especially to complex fractures of the femur. AO compression plates can be applied to treat transverse and short-oblique fractures of the upper middle third of the diaphysis. An angle plate with a wing is recommended for diaphyseal fractures of the distal third of the femur, especially when the intramedullary nail fails to provide stable fixation, and should be placed onto the femur laterally or anterolaterally. DHS and DCS plates are applied to both proximal and distal diaphyseal fractures. For various open fractures and closed femoral fractures in children, external fixators can be used to allow early mobilization and prompt recovery.

Distal Femoral Fractures (Segment 33)

Anatomic Features

The distal end of the femur extends laterally to form the medial and lateral condyles of the femur, with their AP diameter greater than their transverse diameter. The lateral condyle is the more prominent and is broader both in its AP and transverse diameters, but the medial condyle is longer and narrower. The location of the lateral condyle and its anterior projection protect the patella against lateral dislocation (▶ Fig. 4.26).

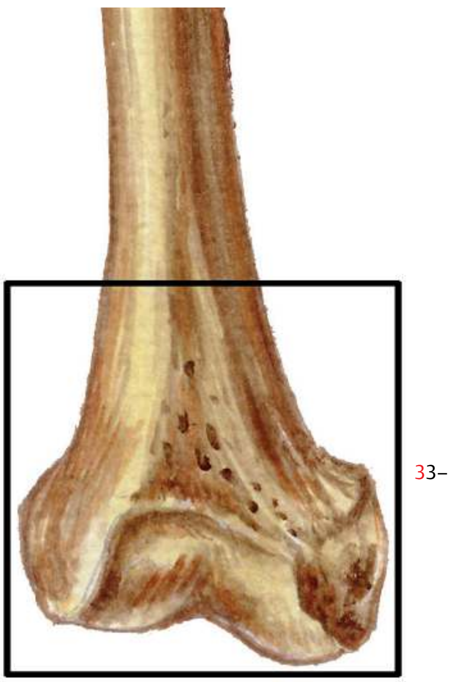


Fig. 4.26 Distal end of the femur.

AO Classification of Distal Femoral Fractures

Based on AO classification, distal femoral fractures are coded as number "33." It is further divided into three types depending on fracture patterns: 33-A: Extra-articular fracture; 33-B: Partial articular fracture; and 33-C: Complete articular fracture (▶ Fig. 4.27).

Clinical Epidemiologic Features of the Distal Femoral Fractures (Segment 33)

A total of 3,434 distal femoral fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, accounting for 8.65% of femur fractures in adults. Their epidemiologic features are as follows:

- More males than females
- The high-risk age group is 41–45 years, the same high-risk age group for males, while females aged 51–55 years have the highest risk
- The most common fracture type among segment 33 fractures is type 33-A, the same fracture type in both males and females
- The most common fracture group among segment 33 fractures is group 33-A1, the same fracture group in both males and females

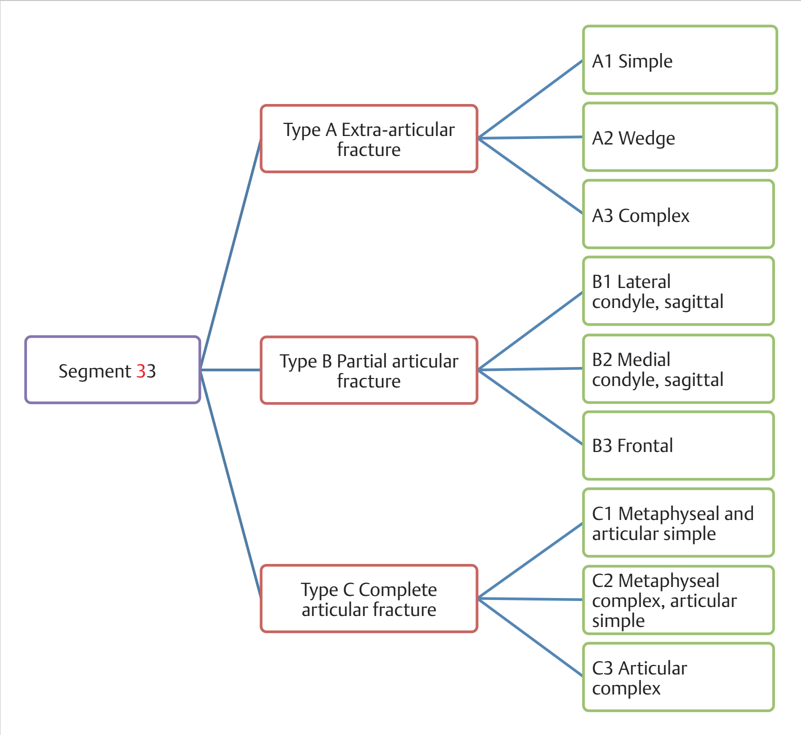


Fig. 4.27 Algorithm.

■ Fractures of Segment 33 by Sex

See ▶ Table 4.19 and ▶ Fig. 4.28.

Table 4.19 Sex distribution of 3,434 fractures of segment 33

Sex	Number of fractures	Percentage
Male	2,123	61.82
Female	1,311	38.18
Total	3,434	100.00

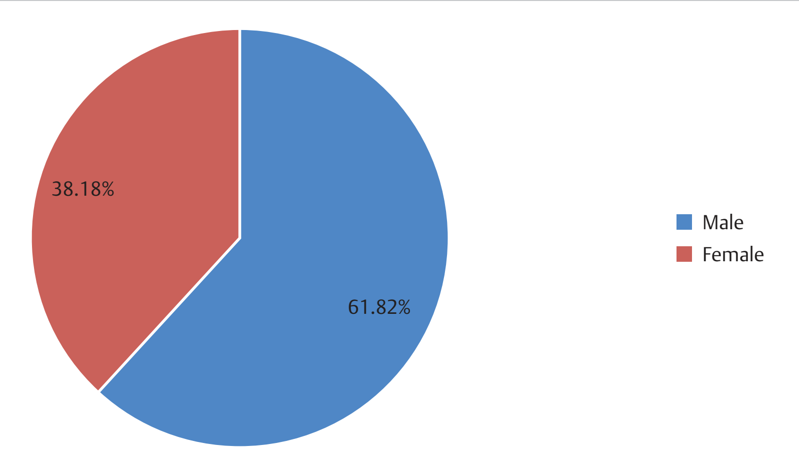


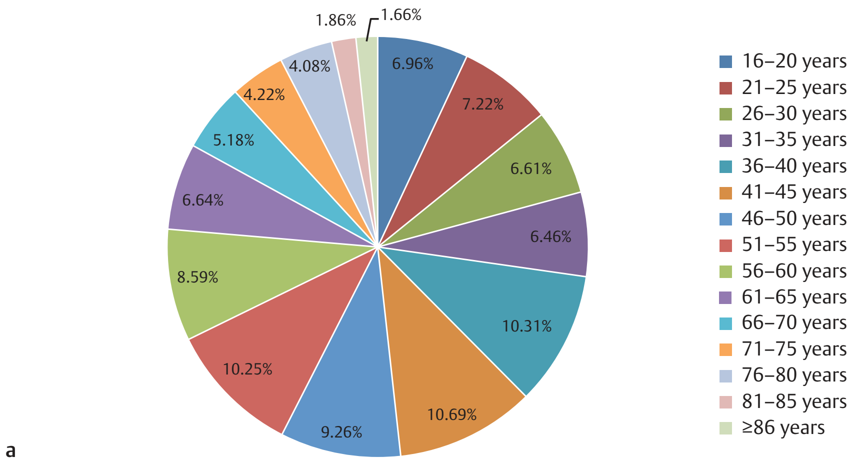
Fig. 4.28 Sex distribution of 3,434 fractures of segment 33.

■ Fractures of Segment 33 by Age Group

See ▶ Table 4.20 and ▶ Fig. 4.29.

Table 4.20 Age and sex distribution of 3,434 fractures of segment 33

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	192	47	239	6.96
21–25	199	49	248	7.22
26–30	189	38	227	6.61
31–35	174	48	222	6.46
36–40	268	86	354	10.31
41–45	271	96	367	10.69
46–50	222	96	318	9.26
51–55	206	146	352	10.25
56–60	157	138	295	8.59
61–65	91	137	228	6.64
66–70	49	129	178	5.18
71–75	46	99	145	4.22
76–80	30	110	140	4.08
81–85	16	48	64	1.86
≥ 86	13	44	57	1.66
Total	2,123	1,311	3,434	100.00



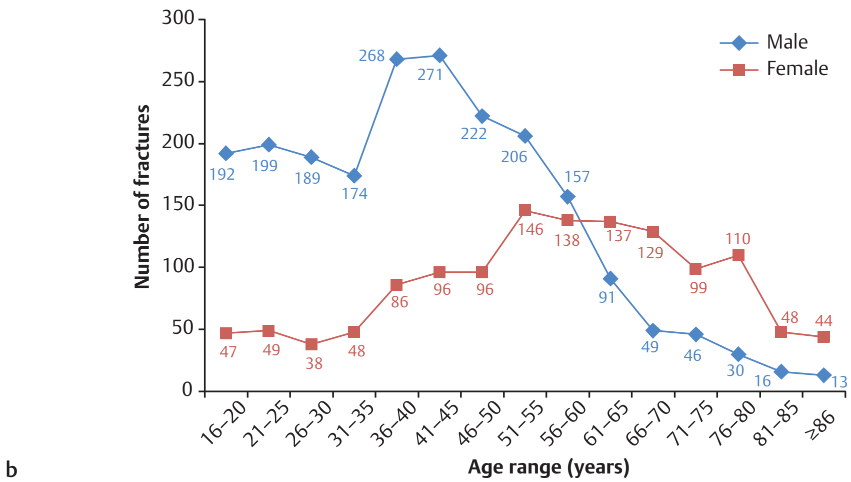


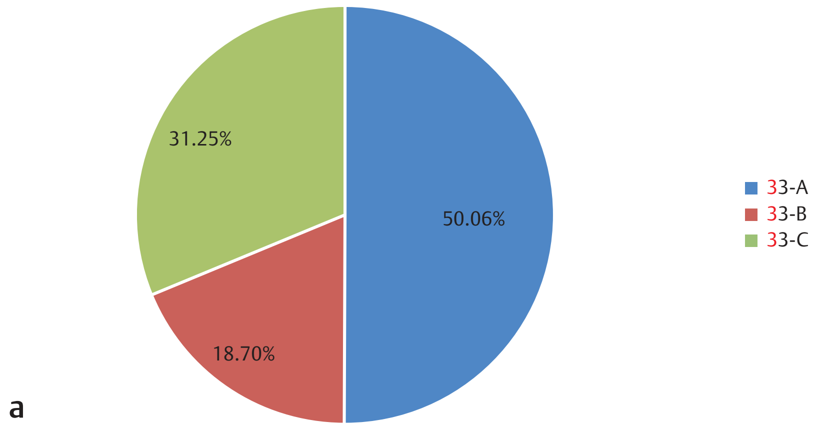
Fig. 4.29 (**a**) Age distributions of 3,434 fractures of segment 33. (**b**) Age and sex distributions of 3,434 fractures of segment 33.

■ Fractures of Segment 33 by Fracture Type

See ▶ Table 4.21 and ▶ Fig. 4.30.

Table 4.21 Sex and fracture type distribution of 3,434 fractures of segment 33

Fracture type	Male	Female	Number of fractures	Percentage
33-A	967	752	1,719	50.06
33-B	406	236	642	18.70
33-C	750	323	1,073	31.25
Total	2,123	1,311	3,434	100.00



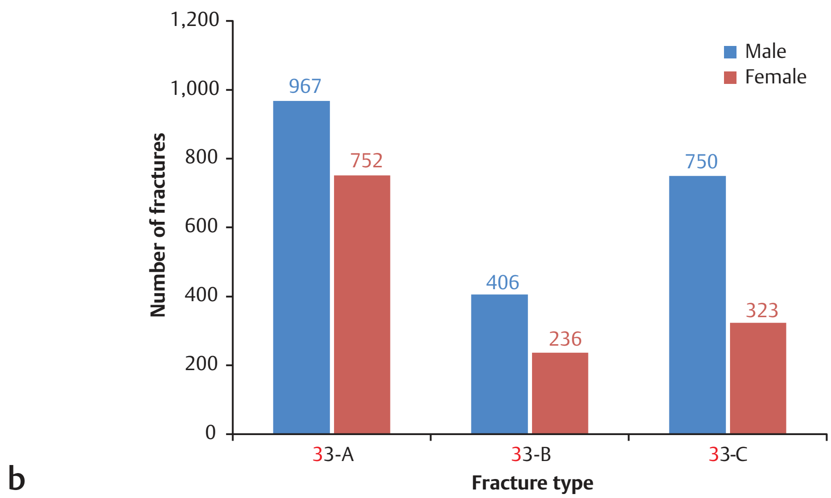


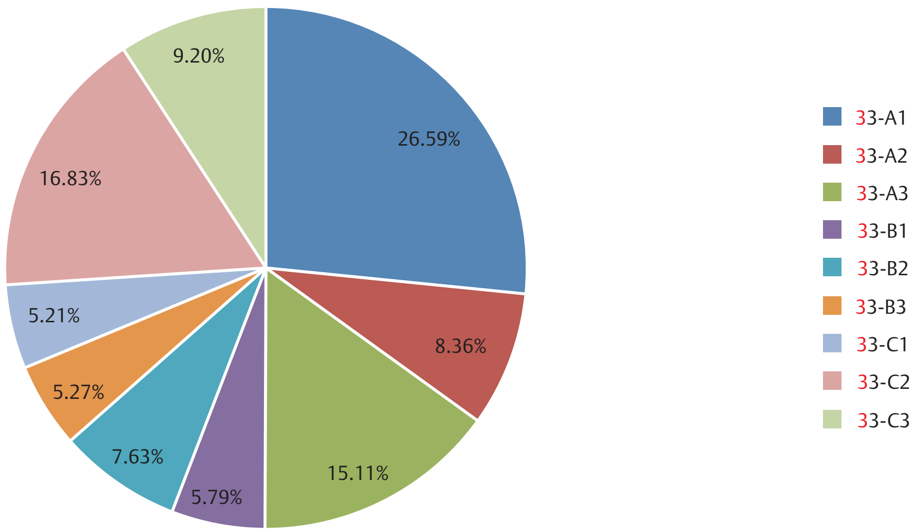
Fig. 4.30 (**a**) Fracture type distribution of 3,434 fractures of segment 33. (**b**) Sex and fracture type distribution of 3,434 fractures of segment 33.

■ Fractures of Segment 33 by Fracture Group

See ▶ Table 4.22 and ▶ Fig. 4.31.

Table 4.22 Sex and fracture group distribution of 3,434 fractures of segment 33

Fracture group	Male	Female	Number of fractures	Percentage of segment 33 fractures	Percentage of femoral fractures
33-A1	506	407	913	26.59	2.30
33-A2	152	135	287	8.36	0.72
33-A3	309	210	519	15.11	1.31
33-B1	131	68	199	5.79	0.50
33-B2	172	90	262	7.63	0.66
33-B3	103	78	181	5.27	0.46
33-C1	103	76	179	5.21	0.45
33-C2	410	168	578	16.83	1.46
33-C3	237	79	316	9.20	0.80
Total	2,123	1,311	3,434	100.00	8.65



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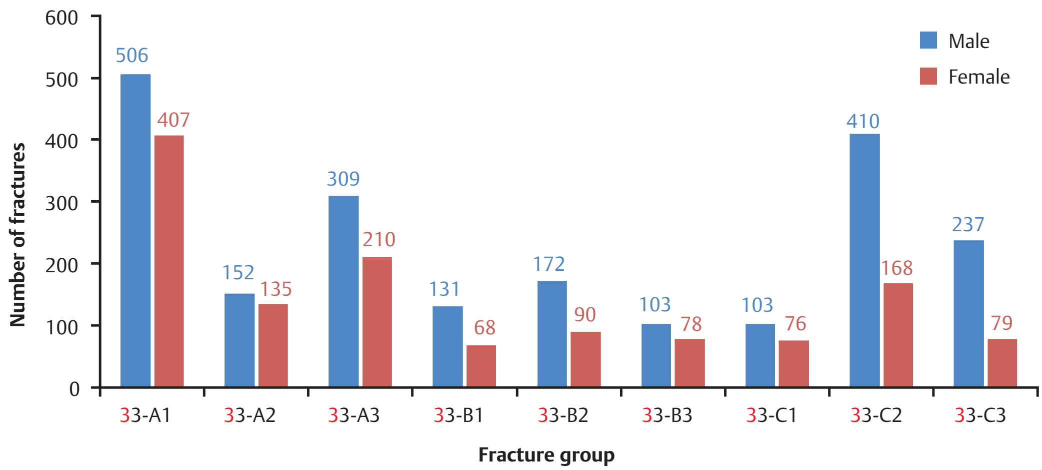


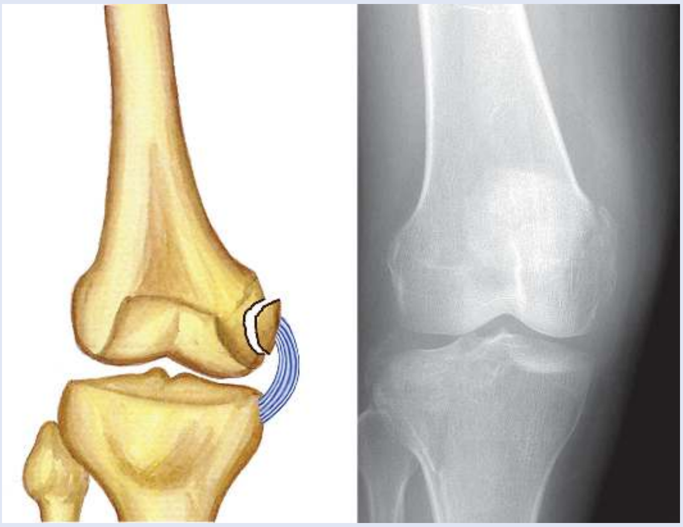
b

Fig. 4.31 (**a**) Fracture group distribution of 3,434 fractures of segment 33. (**b**) Sex and fracture group distribution of 3,434 fractures of segment 33.

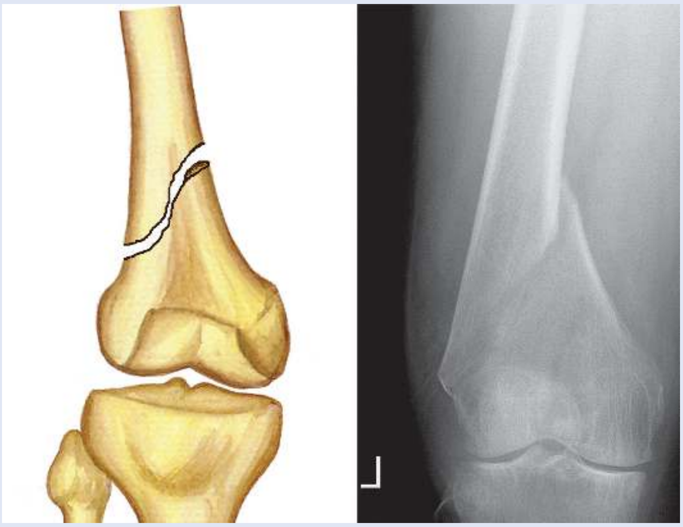
33-A Femur, distal, extra-articular fractures

33-A1 Simple
913 fractures
M: 506 (55.42%)
F: 407 (44.58%)
0.24% of total adult fractures
2.30% of adult femoral fractures
26.59% of segment 33
53.11% of type 33-A

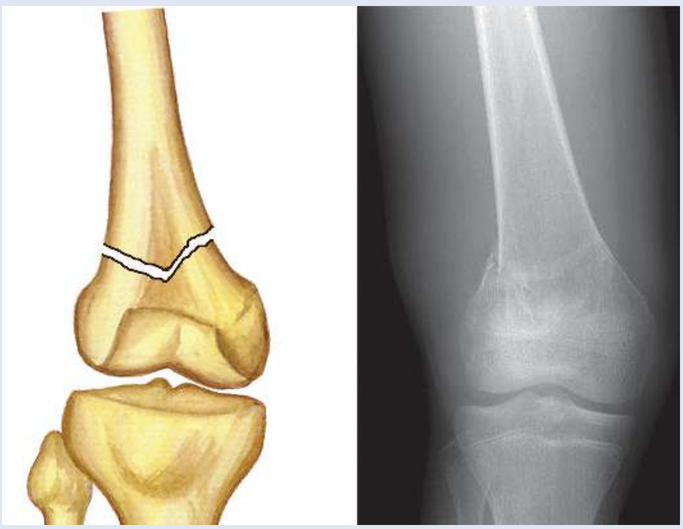
33-A1.1 Apophyseal avulsion



33-A1.2 Oblique or spiral



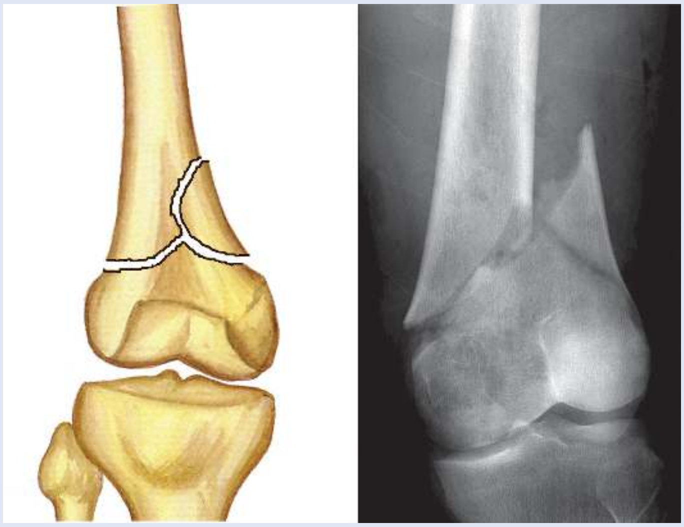
33-A1.3 Transverse



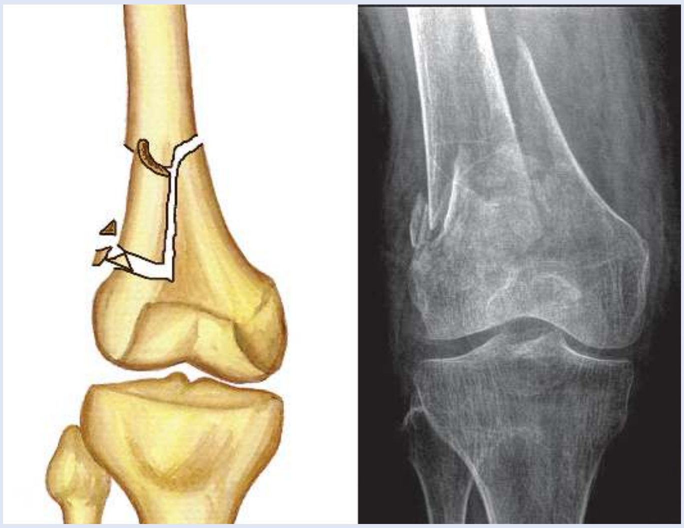
33-A Femur, distal, extra-articular fractures

33-A2 Wedge
287 fractures
M: 152 (52.96%)
F: 135 (47.04%)
0.08% of total adult fractures
0.72% of adult femoral fractures
8.36% of segment 33
16.70% of type 33-A

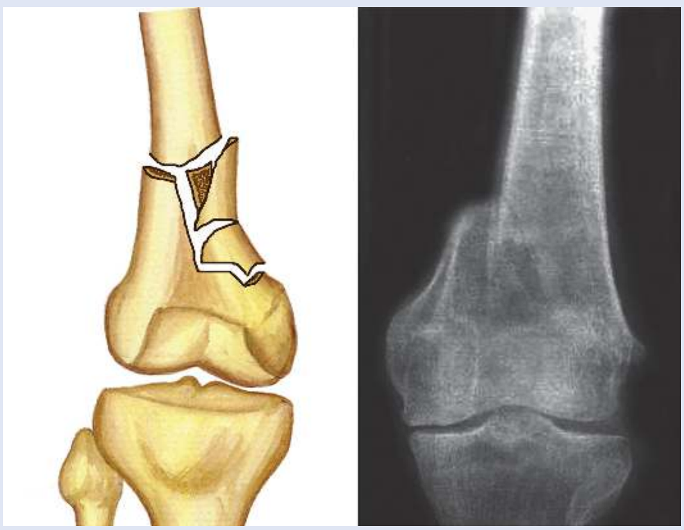
33-A2.1 Intact



33-A2.2 Lateral fragmented



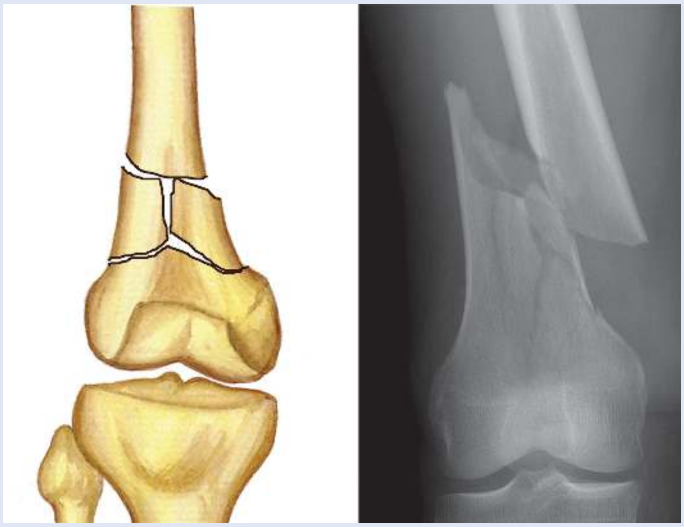
33-A2.3 Medial fragmented



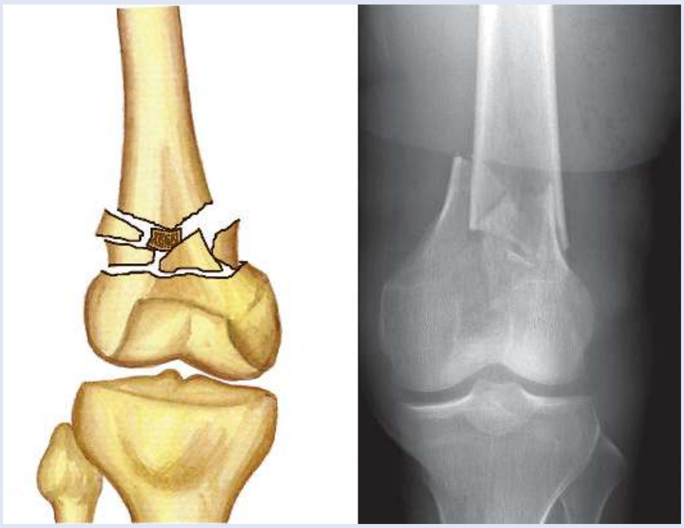
33-A Femur, distal, extra-articular fractures

33-A3 Complex
519 fractures
M: 309 (59.54%)
F: 210 (40.46%)
0.14% of total adult fractures
1.31% of adult femoral fractures
15.11% of segment 33
30.19% of type 33-A

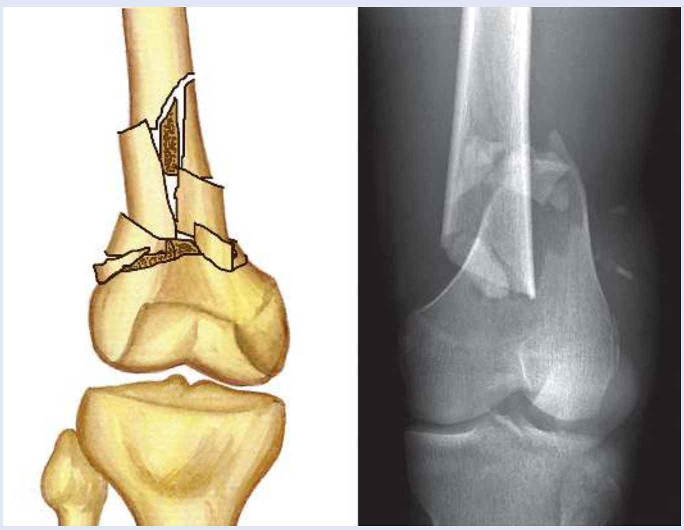
33-A3.1 With an intermediate split fragment



33-A3.2 Irregular, limited to the metaphysis



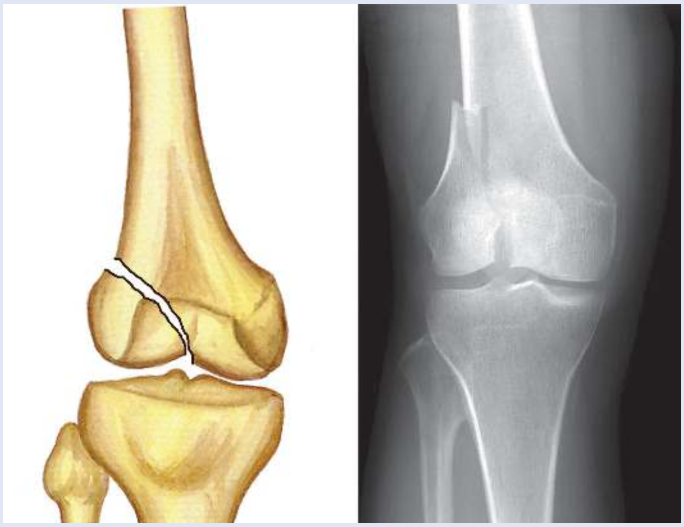
33-A3.3 Irregular, extending into the diaphysis



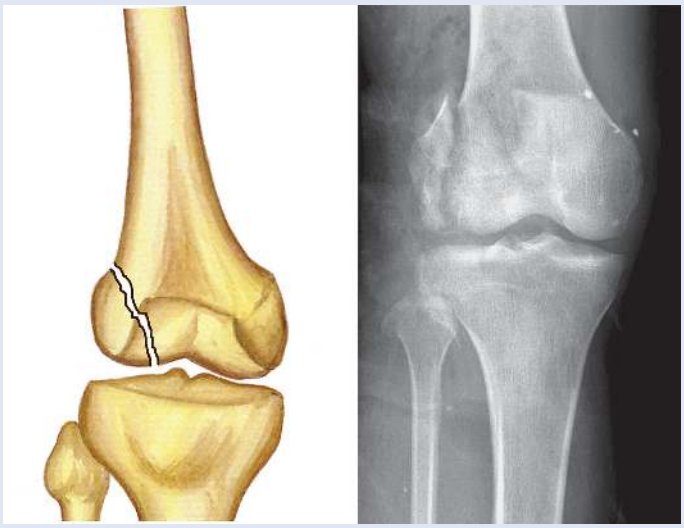
33-B Femur, distal, partial-articular fractures

33-B1 Lateral condyle, sagittal
199 fractures
M: 131 (65.83%)
F: 68 (34.17%)
0.05% of total adult fractures
0.50% of adult femoral fractures
5.79% of segment 33
31.00% of type 33-B

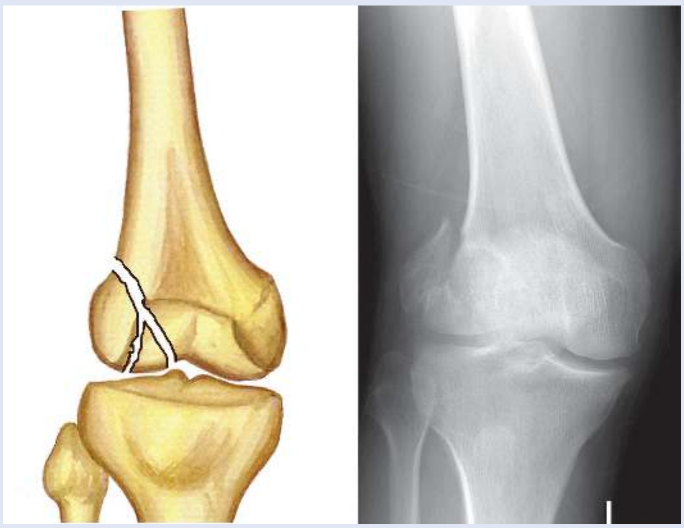
33-B1.1 Simple, through the notch



33-B1.2 Simple, through the load-bearing surface



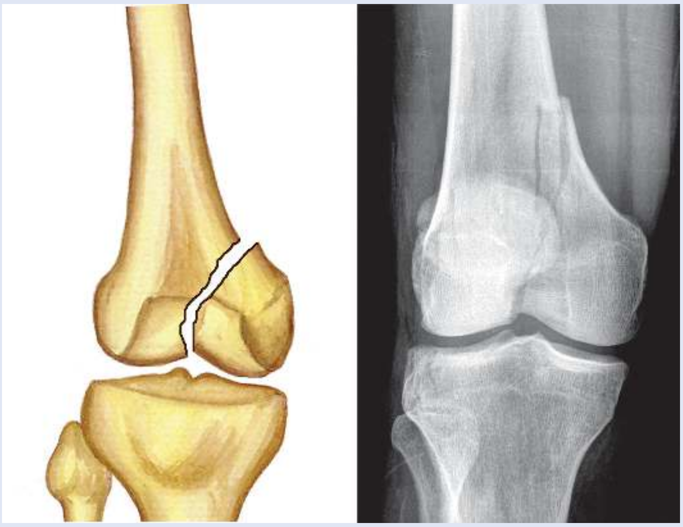
33-B1.3 Complex, through the load-bearing surface



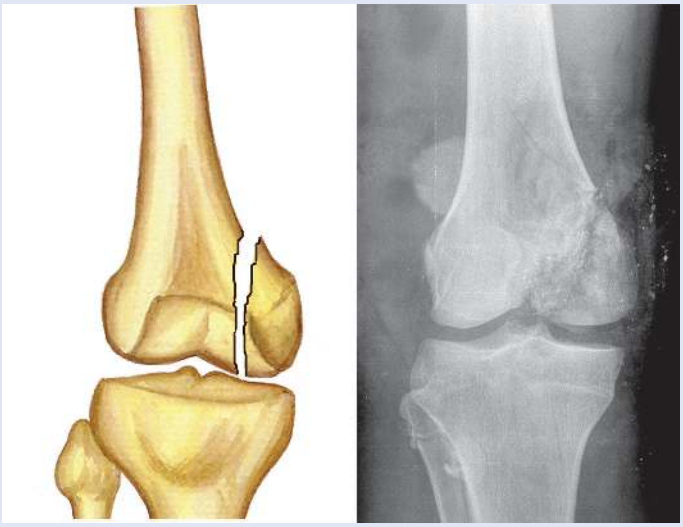
33-B Femur, distal, partial-articular fractures

33-B2 Medial condyle, sagittal
262 fractures
M: 172 (65.65%)
F: 90 (34.35%)
0.07% of total adult fractures
0.66% of adult femoral fractures
7.63% of segment 33
40.81% of type 33-B

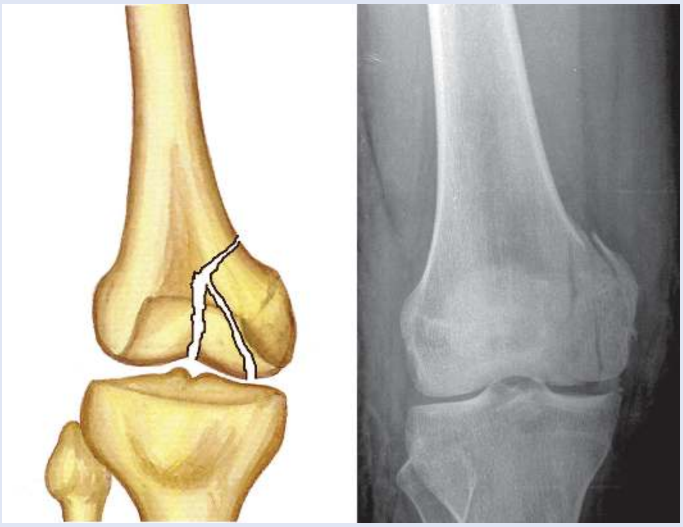
33-B2.1 Simple, through the notch



33-B2.2 Simple, through the load-bearing surface



33-B2.3 Complex, through the load-bearing surface



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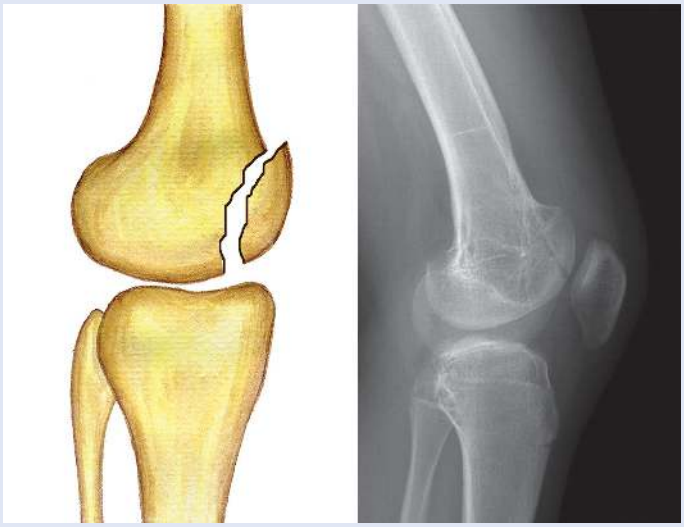
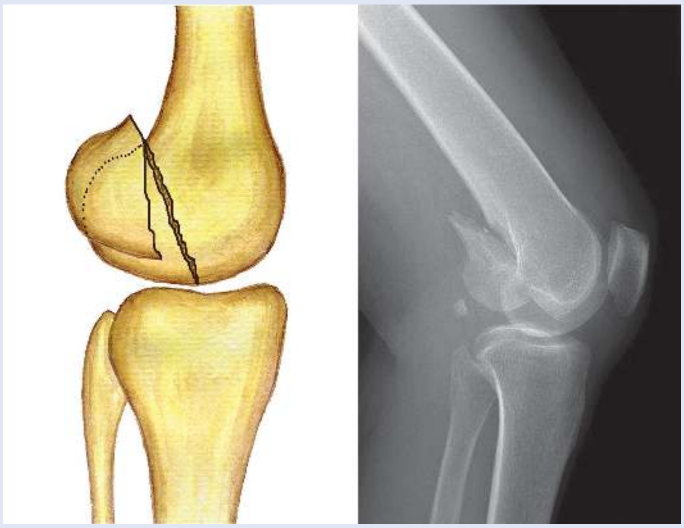
33-B Femur, distal, partial-articular fractures

33-B3 Frontal
181 fractures
M: 103 (56.91%)
F: 78 (43.09%)
0.05% of total adult fractures
0.46% of adult femoral fractures
5.27% of segment 33
28.19% of type 33-B

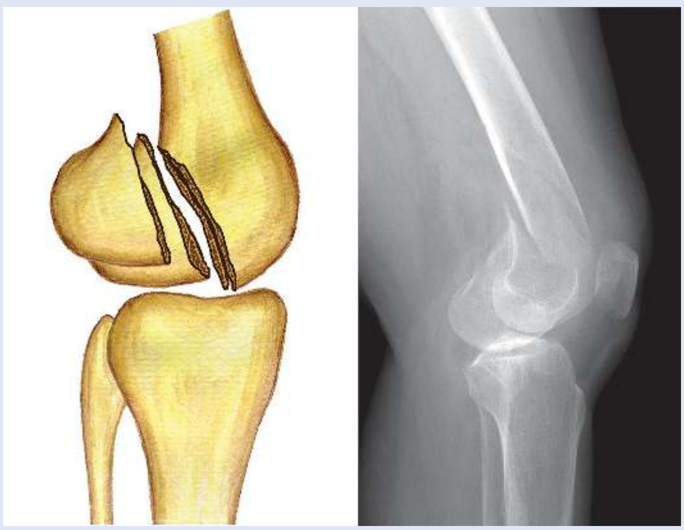
33-B3.1 Anterior and lateral flake fracture



33-B3.2 Unicondylar posterior



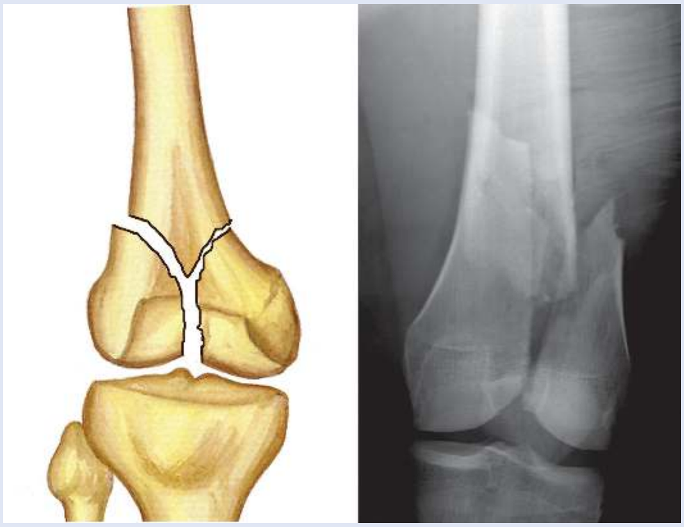
33-B3.3 Bicondylar posterior



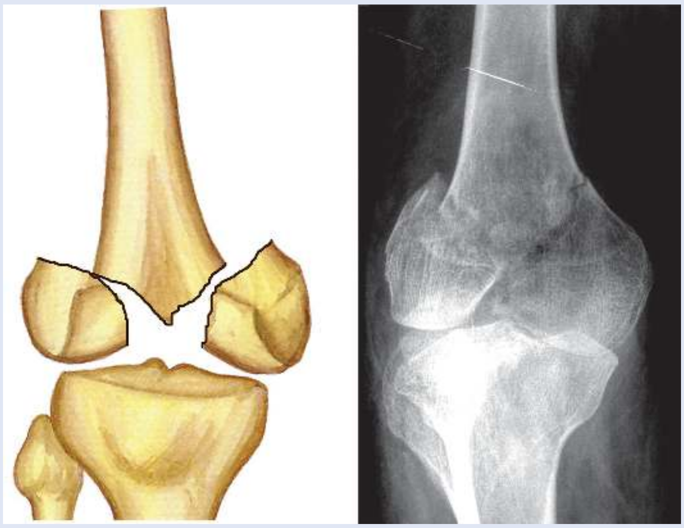
33-C Femur, distal, complete-articular fractures

33-C1 Metaphyseal simple, articular simple
179 fractures
M: 103 (57.54%)
F: 76 (42.46%)
0.05% of total adult fractures
0.45% of adult femoral fractures
5.21% of segment 33
16.68% of type 33-C

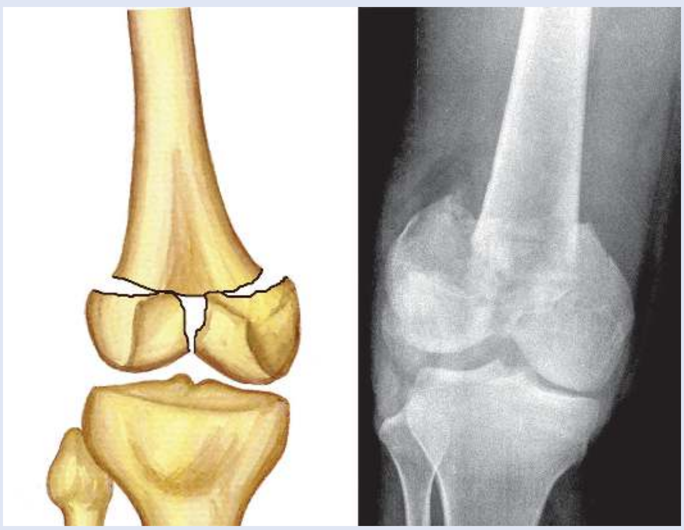
33-C1.1 T- or Y-shaped fracture with slight displacement



33-C1.2 Y-shaped fracture with marked displacement



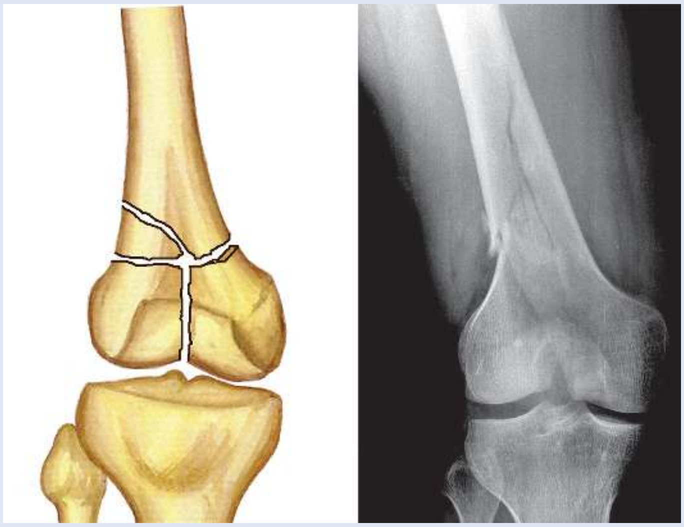
33-C1.3 T-shaped fracture



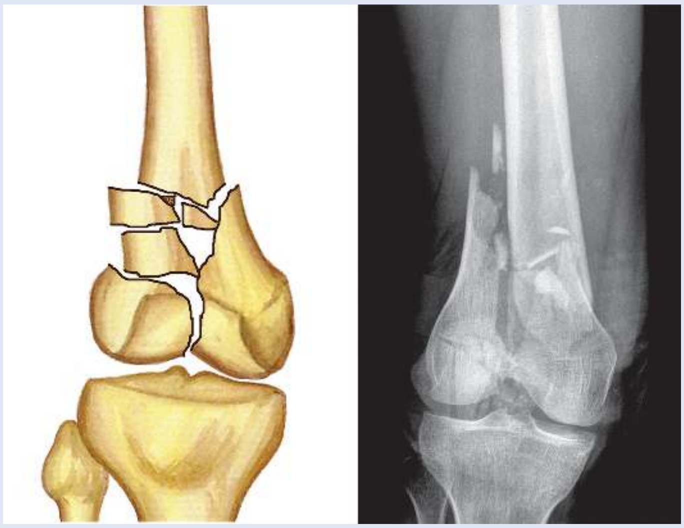
33-C Femur, distal, complete-articular fractures

33-C2 Metaphyseal multifragmentary, articular simple
578 fractures
M: 410 (70.93%)
F: 168 (29.07%)
0.15% of total adult fractures
1.46% of adult femoral fractures
16.83% of segment 33
53.87% of type 33-C

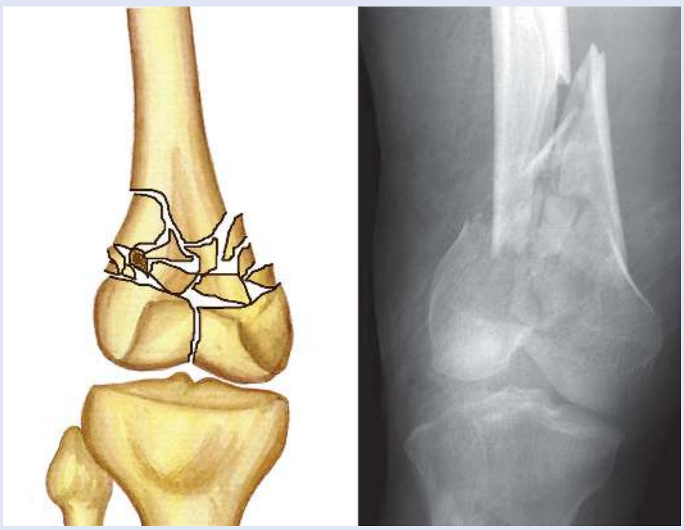
33-C2.1 With an intact wedge fragment



33-C2.2 With a fragmented wedge



33-C2.3 Metaphyseal complex



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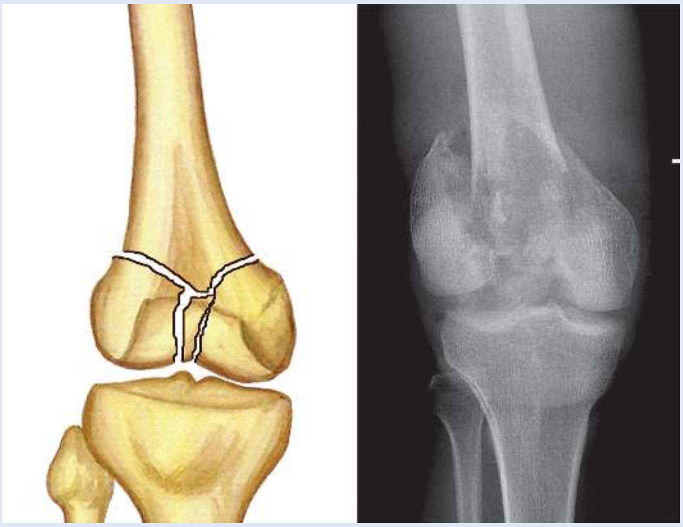
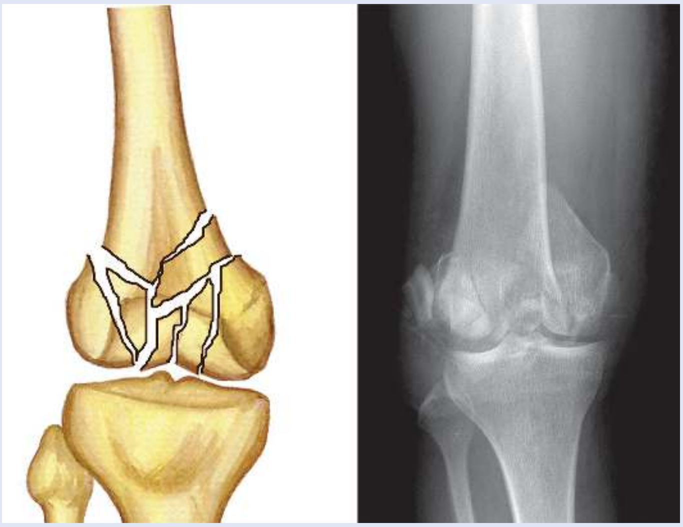
33-C Femur, distal, complete-articular fractures

33-C3 Articular multifragmentary
316 fractures
M: 237 (7500%)
F: 79 (25.00%)
0.08% of total adult fractures
0.80% of adult femoral fractures
9.20% of segment 33
29.45% of type 33-C

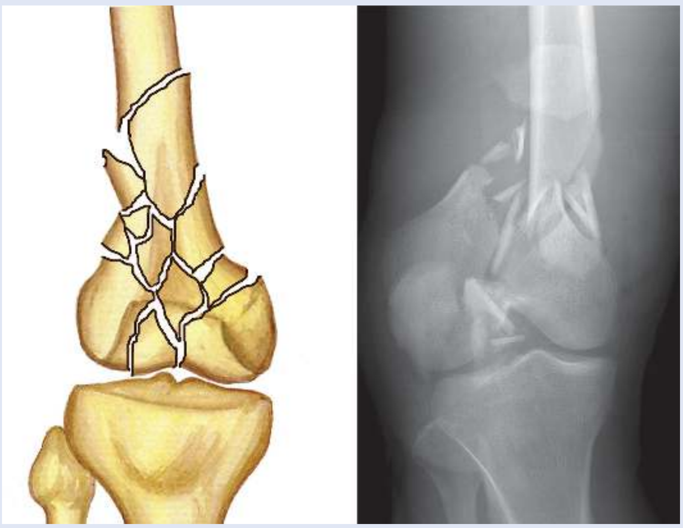
33-C3.1 Metaphyseal simple, articular multifragmentary



33-C3.2 Metaphyseal multifragmentary, articular multifragmentary



33-C3.3 Metaphysio-diaphyseal multifragmentary



4

Injury Mechanism

Supracondylar Femoral Fractures

These types of fractures are usually found 2 to 4 cm superior to the insertion of the gastrocnemius and are caused by a direct blow to the femoral supracondyle or by indirect force, as seen in a fall from a significant height with the knee joint in flexion. Supracondylar fractures are generally transverse or oblique, and occasionally complex or associated with condylar fractures. When supracondylar fractures occur, the resulting posterior displacement of the distal fragment may injure the popliteal artery.

Femoral Condyle Fractures

Direct violent force on the femoral condyle frequently results in complex fractures, while V-, Y-, or T-shaped fractures can result from axial compression on the knee.

Diagnosis

The patient with a distal femoral fracture typically presents with pain, swelling, bony crepitus, decreased range of motion, and deformity of the affected limb. Hematoma of the knee joint may follow after intercondylar or condylar fractures. Radiographic examination for a fracture around the knee should include the standard AP, lateral, and oblique views. The 45 degrees oblique views are useful in detecting fracture displacement if femoral condylar fracture is suspected. If distal femoral fractures occur in children, comparison views of the opposite extremity may be helpful in attempting to differentiate a fracture from a normal site. Femoral intercondylar fractures are severe intra-articular fractures, with a T- or Y-shaped fracture line, frequently accompanied by supracondylar fractures. A CT scan is useful in delineating the fracture, and detecting the severity of the fracture and the direction of the fracture displacement. If popliteal hematomas appear with weakened or absent pulsation in the dorsal artery of the foot following the supracondylar fracture, then an angiogram should be considered to investigate popliteal artery injury.

Treatment

Appropriate internal fixators should be chosen for fixation of distal femoral fractures depending on the fracture patterns. The 95 degrees condylar blade plate and DCS are classic internal fixators used to treat extra-articular complex and articular simple fractures. Femoral comminuted condylar fractures involving the frontal plane should be treated primarily with condylar buttress plates. The screw inserted into the condylar buttress plate provides enhanced fixation. Determination of the number of the screws is based on the individual circumstance. After the articular reduction under direct visualization, lag screws can be used to treat intra-articular fractures of the distal femur to provide compression between the fracture fragments. Retrograde intramedullary nails, locking compress plate (LCP), or less invasive stabilization system (LISS) can be used for fixation of extra-articular and simple intra-articular fractures. Open fractures can be treated with external fixators.

Other Classifications of Femoral Fractures

Evans' Classification for Trochanteric Fractures of the Femur

Evans presented his classification for trochanteric fractures of the femur based on the stability of the fracture. He proposed that the stability of proximal femoral fractures is dependent on posteromedial cortical continuity. In stable fracture patterns, the posteromedial cortex remains intact or has minimal fragmentation, while large posteromedial cortical fragments can be seen in unstable fracture patterns. If restoration of the posteromedial cortical continuity can be done surgically, then the unstable fracture can be reduced and stabilized. In addition, Evans described a fracture pattern called reversed obliquity fracture, which is inherently unstable. Evans' classification has the qualities of utility and ease of use, with emphasis on the difference between stable and unstable fractures.

A total of 12,743 trochanteric fractures of the femur were treated in 83 hospitals of china over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied. Epidemiologic features of the trochanteric femur fractures are as follows:

- More males than females
- The most common fracture type based on Evans' classification is Type I, the same fracture type in both males and females

See ▶ Table 4.23 and ▶ Fig. 4.32.

Table 4.23 Sex and fracture type distribution of 12,743 trochanteric fractures of the femur by Evans' classification

Fracture type	Male	Female	Number of fractures	Percentage
I	1,719	1,609	3,328	26.12
II	1,126	1,342	2,468	19.37
III	1,442	1,588	3,030	23.78
IV	974	936	1,910	14.99
V	1,219	788	2,007	15.75
Total	6,480	6,263	12,743	100.00

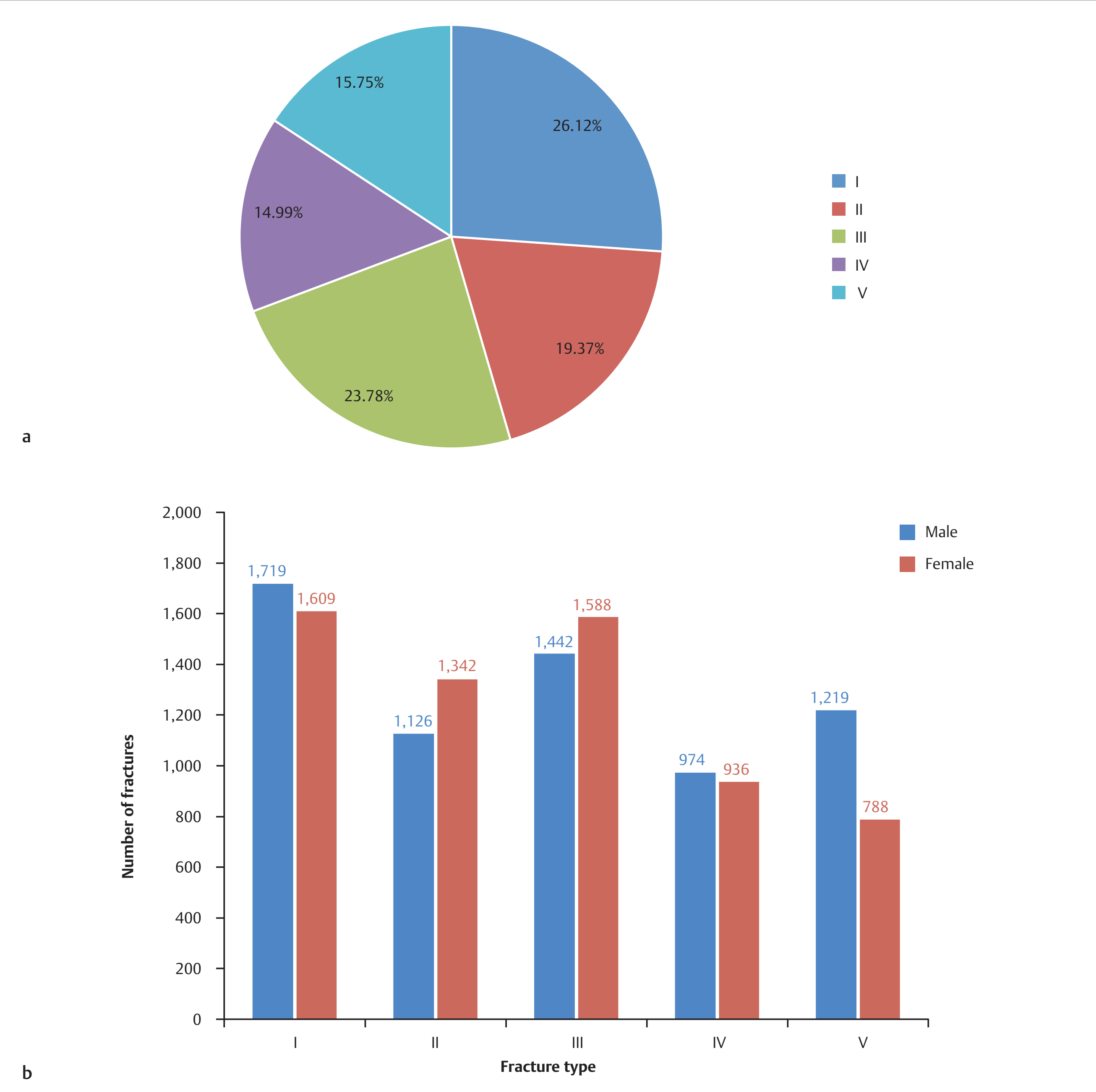
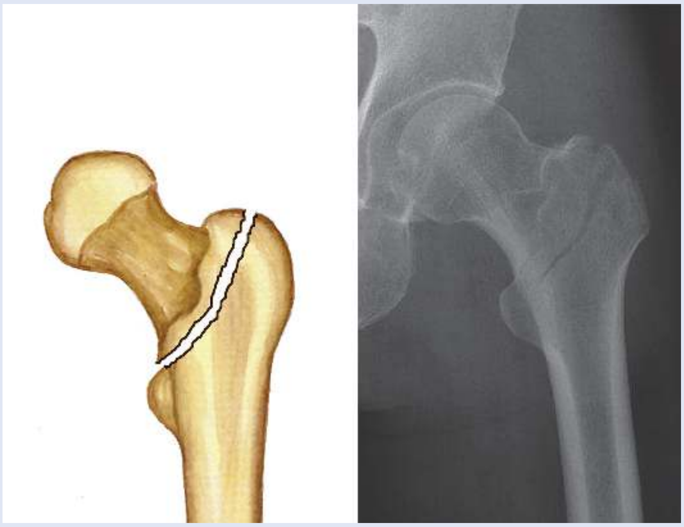
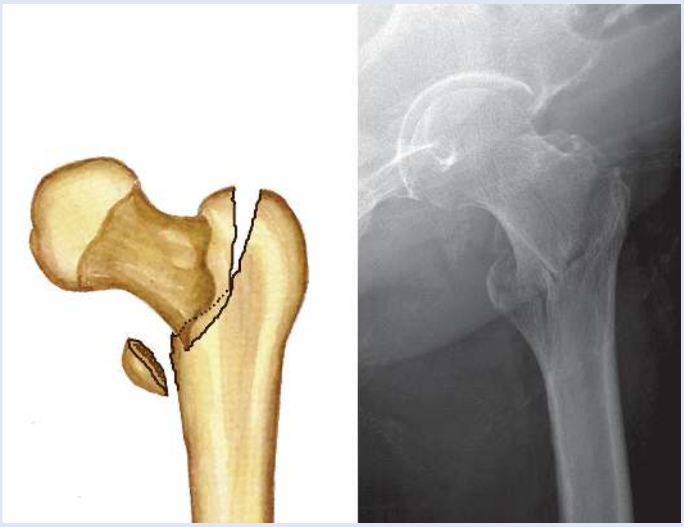
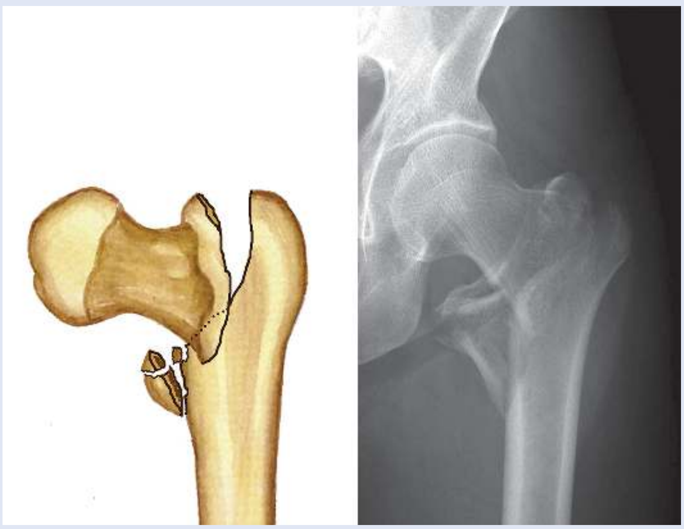
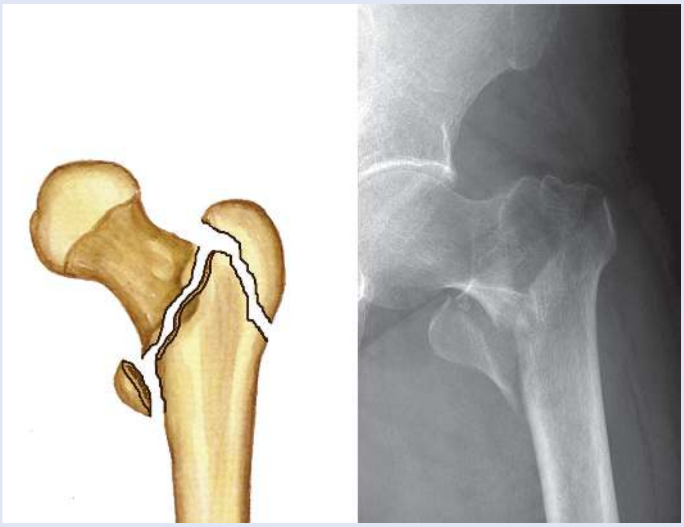
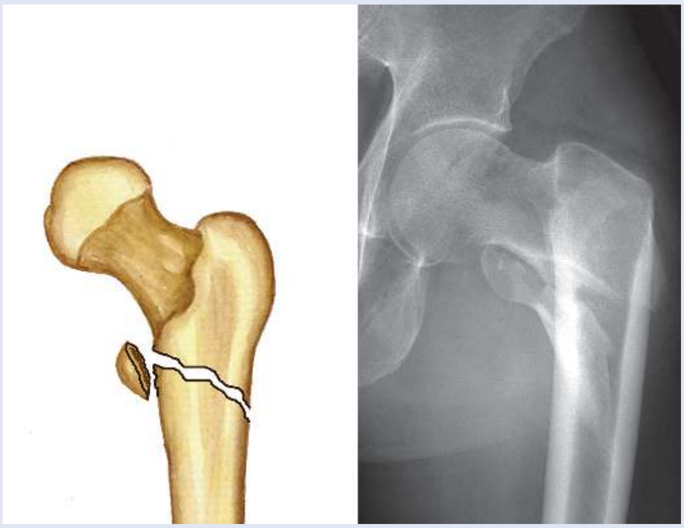


Fig. 4.32 (**a**) Fracture type distribution of 12,743 trochanteric fractures by Evans' classification. (**b**) Sex and fracture type distribution of 12,743 trochanteric fractures by Evans' classification.

Evans' classification of trochanteric femoral fractures	
Type I 3,328 fractures M: 1,719 (51.65%) F: 1,609 (48.35%) 26.12% of adult trochanteric fractures	Evans Type I: Nondisplaced 2-fragment fracture, stable fracture 
Type II 2,468 fractures M: 1,126 (45.62%) F: 1,342 (54.38%) 19.37% of adult trochanteric fractures	Evans Type II: Lesser trochanter fracture with slight displacement, stable fracture 
Type III 3,030 fractures M: 1,442 (47.59%) F: 1,588 (52.41%) 23.78% of adult trochanteric fractures	Evans Type III: Lesser trochanter multifragmentary without posterolateral support 

Evans' classification of trochanteric femoral fractures	
Type IV 1,910 fractures M: 974 (50.99%) F: 936 (49.01%) 14.99% of adult trochanteric fractures	Evans Type IV: Type III + greater trochanter fracture, unstable fracture 
Type V 2,007 fractures M: 1,219 (60.74%) F: 788 (39.26%) 15.75% of adult trochanteric fractures	Evans Type V: Reversed obliquity fracture with fracture line running upward and inward, extends above the lesser trochanter, unstable fracture 

The Garden Classification of Femoral Neck Fractures

Garden proposed a classification method for femoral neck fractures based on the degree of fracture displacement:

- *Type I*: incomplete or impacted fracture of the neck
- *Type II*: complete fracture without displacement
- *Type III*: complete fracture with marked displacement, and often accompanied by shortening and external rotation of the limb

See ▶ Table 4.24 and ▶ Fig. 4.33.

- *Type IV*: complete fracture with full displacement. The proximal fragment is not in contact with the distal part. Multifragmentation may occur.

A total of 13,516 femoral neck fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied. Epidemiologic features of the femoral neck fractures are as follows:

- More females than males
- The most common fracture type based on the Garden classification is Type III, the same fracture type in both males and females

Table 4.24 Sex and fracture type distribution of 13,516 femoral neck fractures by Garden classification

Fracture type	Male	Female	Number of fractures	Percentage
I	121	82	203	1.50
II	1,576	2,009	3,585	26.52
III	3,457	5,000	8,457	62.57
IV	481	790	1,271	9.40
Total	5,635	7,881	13,516	100.00

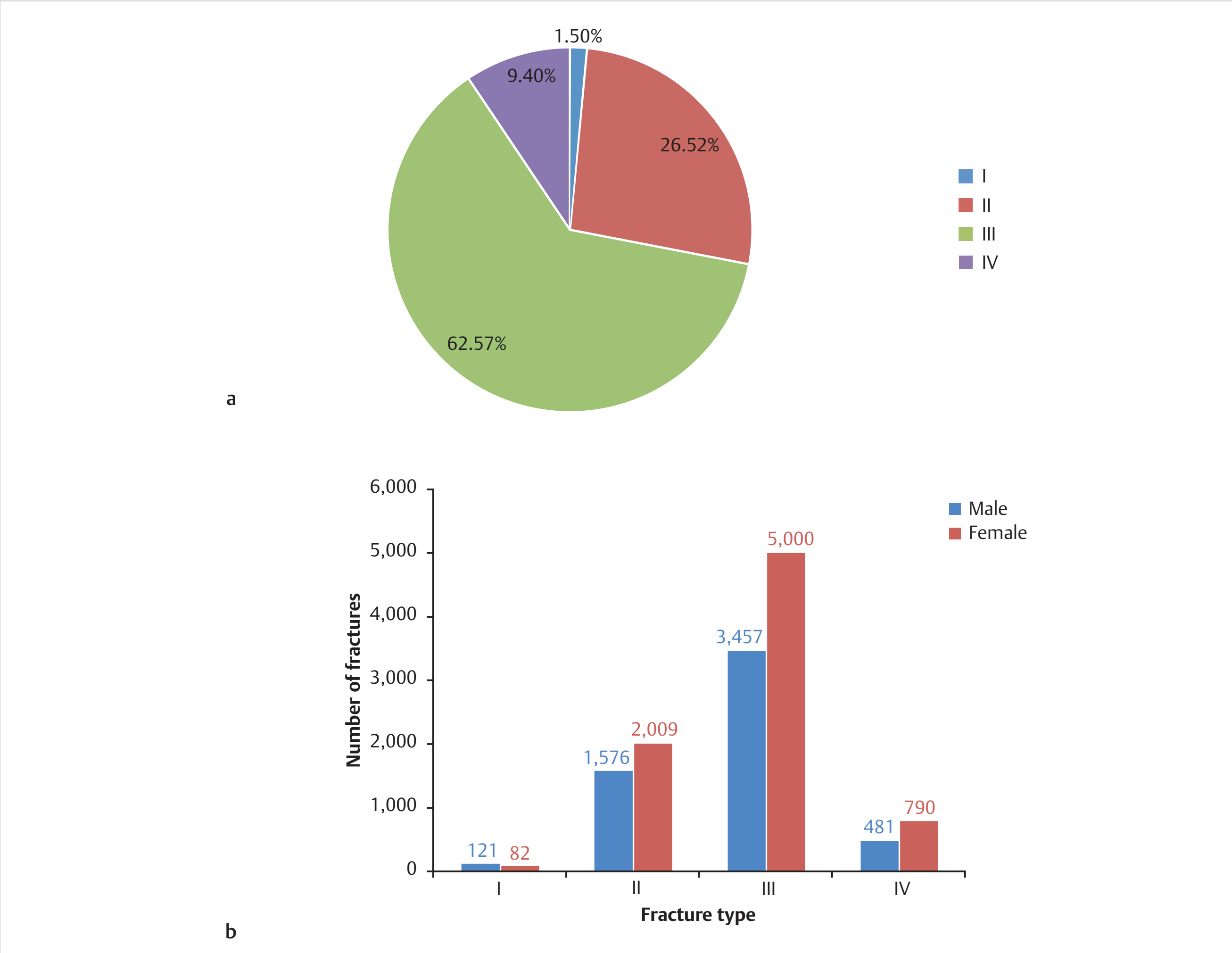
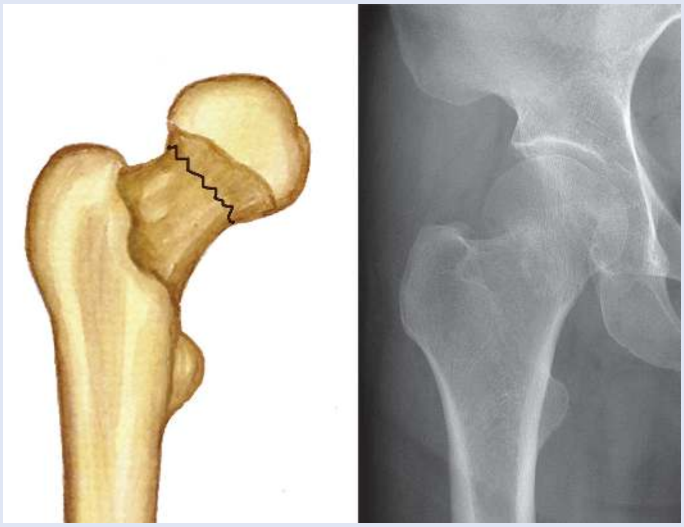
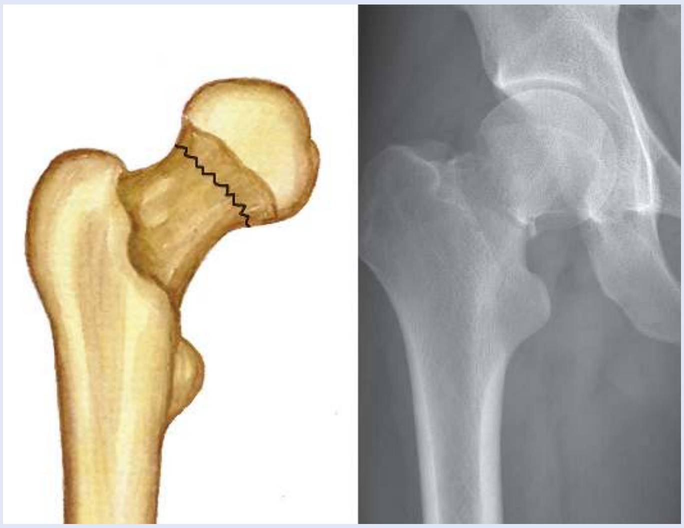
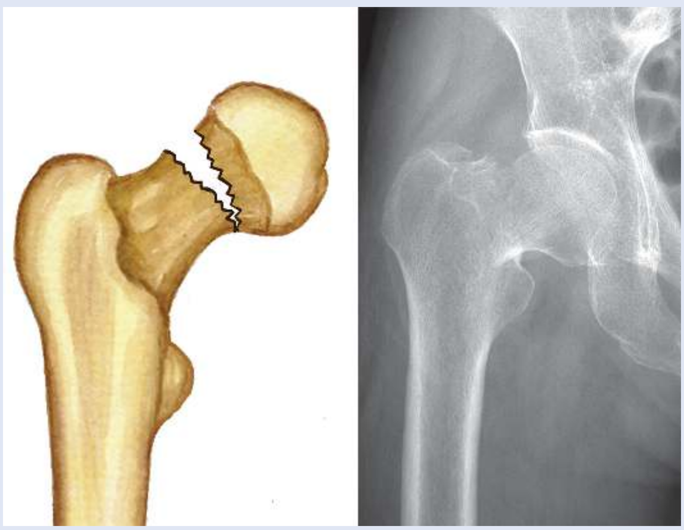
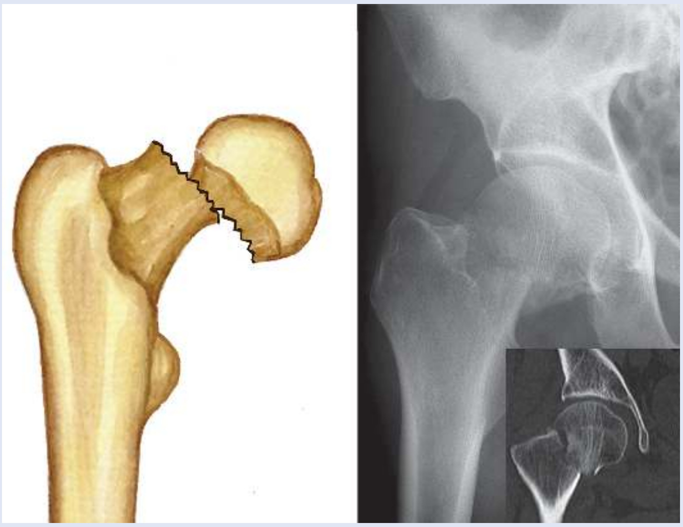


Fig. 4.33 (a) Fracture type distribution of 13,516 femoral neck fractures by Garden classification. (b) Sex and fracture type distribution of 13,516 femoral neck fractures by Garden classification.

Garden classification of femoral neck fractures	
Type I 203 fractures M: 121 (59.61%) F: 82 (40.39%) 1.50% of adult femoral neck fractures	Garden Type I: Incomplete fracture 
Type II 3,585 fractures M: 1,576 (43.96%) F: 2,009 (56.04%) 26.52% of adult femoral neck fractures	Garden Type II: Complete fracture without displacement 
Type III 8,457 fractures M: 3,457 (40.88%) F: 5,000 (59.12%) 62.57% of adult femoral neck fractures	Garden Type III: Complete fracture with displacement 

Garden classification of femoral neck fractures	
Type IV 1,271 fractures M: 481 (37.84%) F: 790 (62.16%) 9.40% of adult femoral neck fractures	Garden Type IV: Complete fracture, multifragmentary 

■ The Pipkin Classification of Femoral Head Fractures

Pipkin proposed a classification system for femoral head fractures in association with posterior dislocation of the hip that is very useful in guiding treatment and predicting prognosis. He divided femoral head fractures into four types:

- *Type I*: fracture of the femoral head inferior to the fovea centralis. Since the fracture is not within the weight-bearing area of the head, small, comminuted fragments can be excised without compromising outcome. If the fragment is large, absorbable screws can be used for fixation after the reduction.
- *Type II*: fracture of the femoral head superior to the fovea centralis. This fracture pattern involves the weight-bearing area of the head and requires anatomic reduction followed by absorbable screws for fixation. Each screw should be inserted perpendicular to the fracture line, with the head of the nail beneath the subchondral bone.
- *Type III*: similar to a Type I or II injury but associated with fracture of the femoral neck. This injury is the most disruptive to the vascular supply of the femoral head, with high incidence of avascular necrosis and nonunion of the femoral head. For patients older than 65 years, total hip replacement should be recommended. In younger patients, anatomic reduction should be considered first.
- *Type IV*: similar to a Type I or II injury but associated with fracture of the acetabular rim. Reconstruction plates can be used for fixation of the acetabular fracture after anatomic reduction of the femoral head.

A total of 1,768 femoral head fractures were treated at 83 hospitals over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied. Epidemiologic features of the femoral head fractures are as follows:

- More males than females
- The most common fracture type based on Pipkin classification is Type II, the same fracture type in both males and females

See ▶ Table 4.25 and ▶ Fig. 4.34.

Table 4.25 Sex and fracture type distribution of 1,768 femoral head fractures by Pipkin classification

Fracture type	Male	Female	Number of fractures	Percentage
I	257	198	455	25.74
II	539	367	906	51.24
III	198	151	349	19.74
IV	45	13	58	3.28
Total	1,039	729	1,768	100.00

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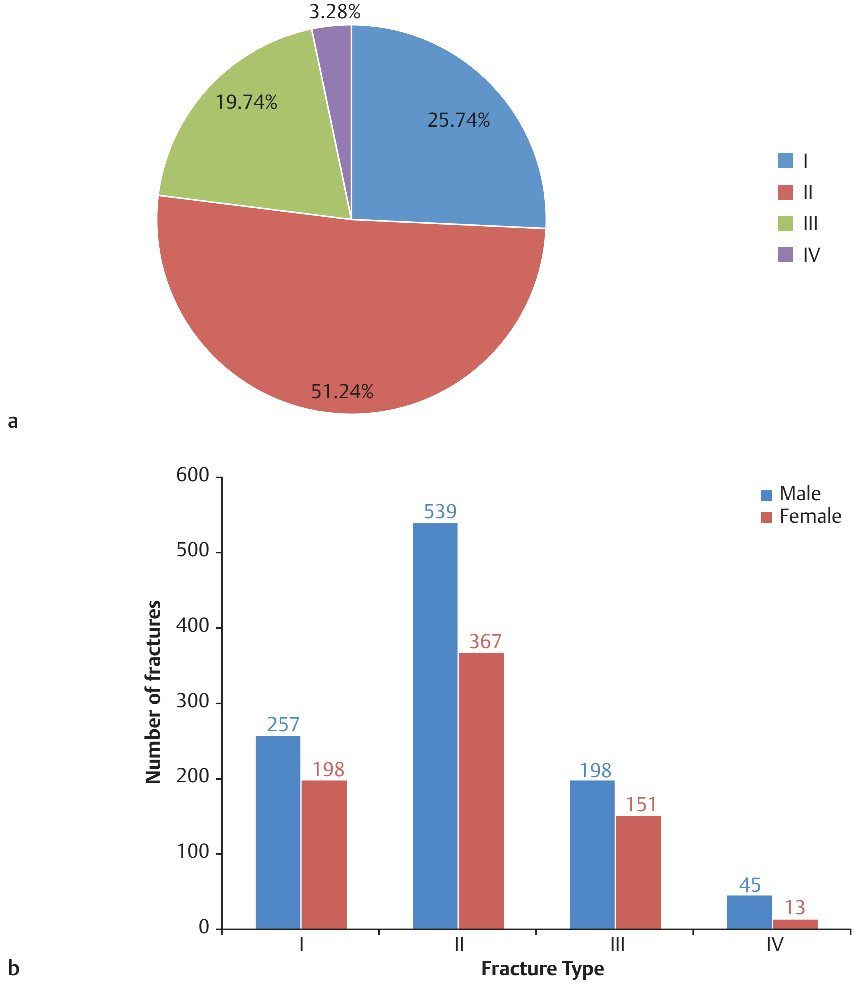
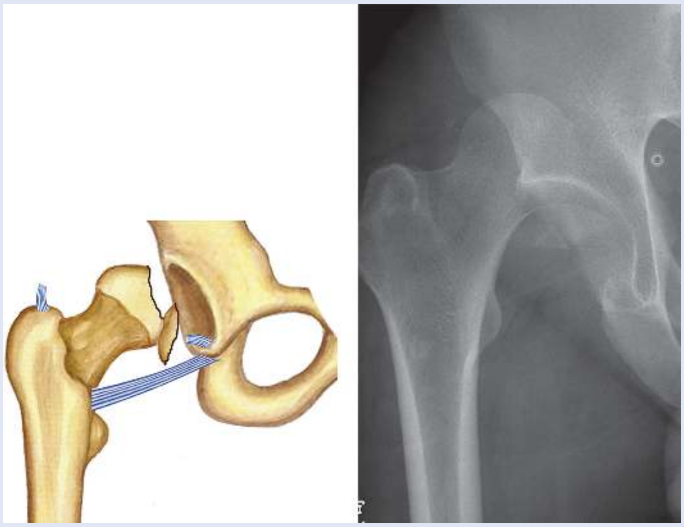
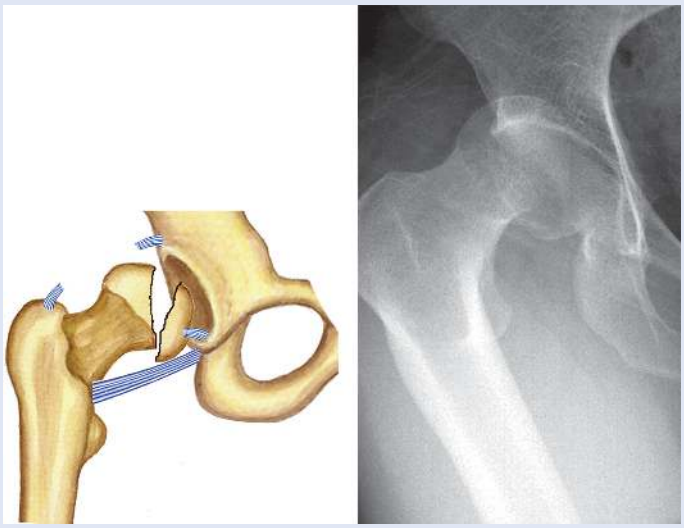
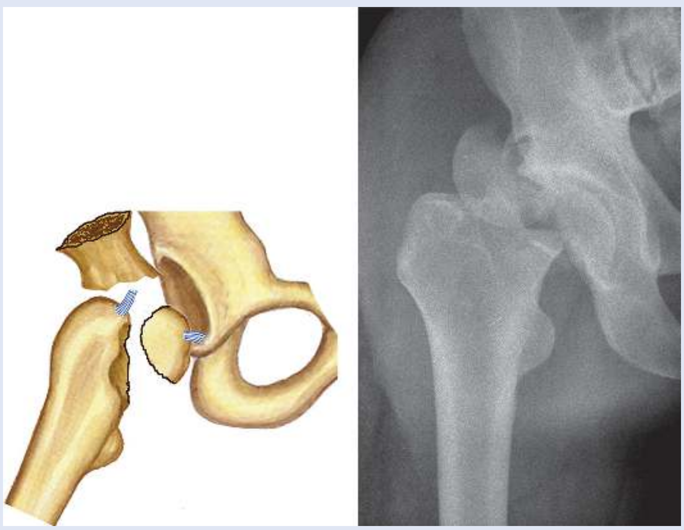


Fig. 4.34 (**a**) Fracture type distribution of 1,768 femoral head fractures by Pipkin classification. (**b**) Sex and fracture type distribution of 1,768 femoral head fractures by Pipkin classification.

Pipkin classification of femoral head fractures	
Type I 455 fractures M: 257 (56.48%) F: 198 (43.52%) 25.74% of adult femoral head fractures	Pipkin Type I: Fracture inferior to the fovea centralis 
Type II 906 fractures M: 539 (59.49%) F: 367 (40.51%) 51.24% of adult femoral head fractures	Pipkin Type II: Fracture superior to the fovea centralis 
Type III 349 fractures M: 198 (56.73%) F: 151 (43.27%) 19.74% of adult femoral head fractures	Pipkin Type III: Type I or II associated with fracture of femoral neck 

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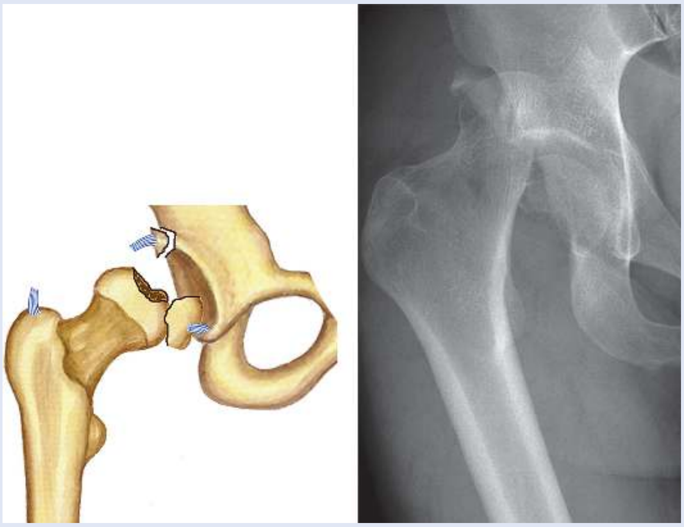
Pipkin classification of femoral head fractures	
Type IV 58 fractures M: 45 (77.59%) F: 13 (22.41%) 3.28% of adult femoral head fractures	Pipkin Type IV: Type I or II associated with fracture of acetabular rim 

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5 Fractures of the Tibia and Fibula

Juan Wang, Guang Yang, and Xiao Chen

Overview of Tibial/Fibular Fractures

Anatomic Features

The tibia is a large weight-bearing bone, located on the anterior and medial side of the leg. The proximal end of the tibia extends laterally to form the medial and lateral tibial plateaus that articulate with the femoral condyles. Both plateaus slope posteriorly approximately by 10 degrees. The medial plateau possesses higher mechanical strength and is better suited to withstand compression than the lateral plateau. The body of the tibia has three borders and three surfaces. It is sinuous and prominent in its upper two-thirds, but smooth and recessed below. The anterior border begins above at the tuberosity and ends below at the anterior margin of the medial malleolus. Tibial fractures are most often found at the junction of the middle and lower thirds of the bone, where tibial dimensions change. The fibula is situated on the lateral side of the tibia, to which it provides a small amount of support. The fibular head and distal third of the fibula are just beneath the skin's surface, with the remaining parts attached by muscles and ligaments. The medial malleolus of the tibia and the distal end of the fibula, along with the talar articulations, form the ankle mortise. The continuity of the fibula is very important in maintaining the stability of the ankle mortise (▶ Fig. 5.1).

AO Classification and Coding System of Tibial/Fibular Fractures

Based on AO classification, the tibia and fibula can be considered as one unit, with the coding number "4." According to the "Heim's Square" method, the anatomic assignment of the proximal, shaft, and distal portions are the numbers 41, 42, and 43, respectively. Malleolar fractures are the exception to the rule of dividing each long bone into three bony segments based on their anatomic characteristics: they are segment 44 of the tibial bone (▶ Fig. 5.2).

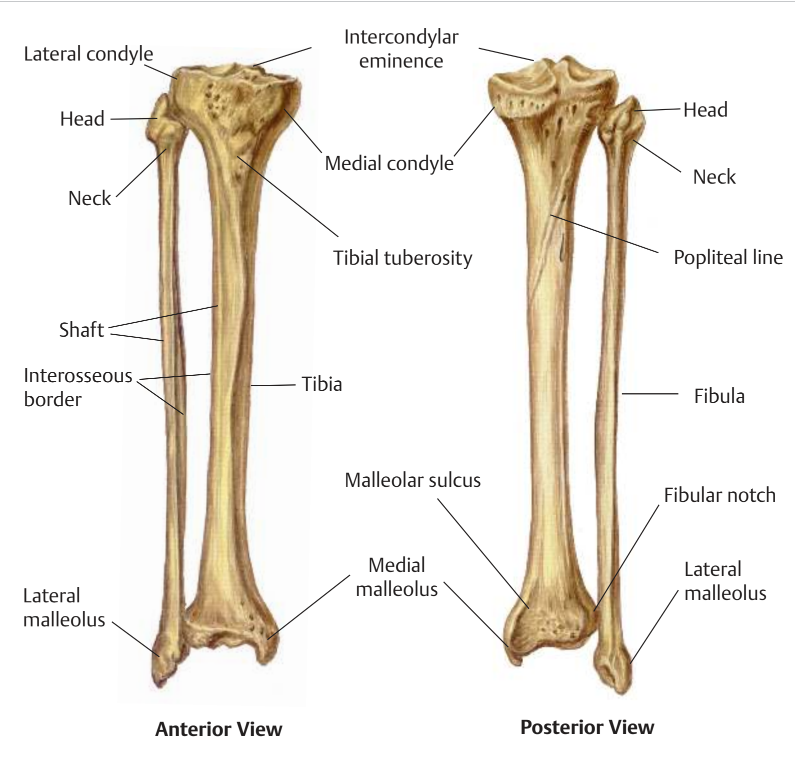

Fig. 5.1 Anterior and posterior views of the tibia and fibula.

5

Epidemiologic Features of Fractures of the Tibia and Fibula in the China National Fracture Study

A total of 417 patients with 423 fractures of the tibia/fibula were investigated in the China National Fracture Study (CNFS). The fractures accounted for 23.65% of all patients with fractures and 23.08% of all types of fractures. The population-weighted incidence rate of humeral fractures was 76 per 100,000 population.

The epidemiologic features of tibial/fibular fractures in the CNFS are as follows:

- More males than females
- More right-side injuries than left-side injuries
- The highest risk age group is 15–64 years
- Ankle fracture is the most common tibial/fibular fracture
- Injuries occurred most commonly via slips, trips, or falls

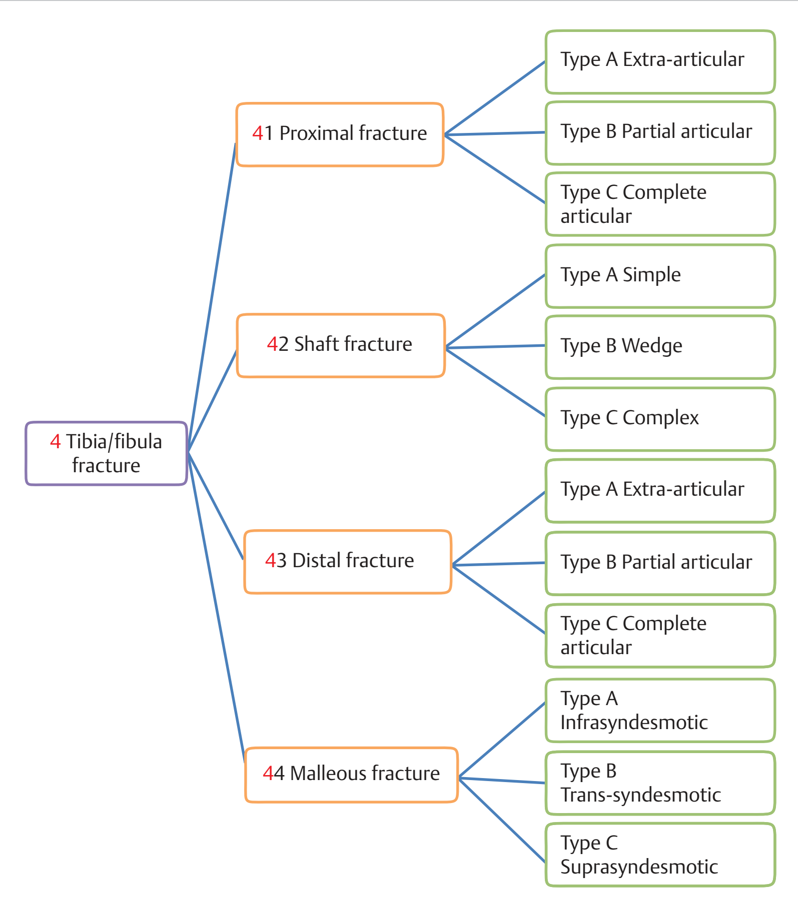

Fig. 5.2 Algorithm.

■ Tibial/Fibular Fracture by Sex

See ▶ Table 5.1 and ▶ Fig. 5.3.

Table 5.1 Sex distribution of 417 patients with tibial/fibular fractures in the China National Fracture Study

Sex	Number of patients	Percentage
Male	246	58.99
Female	171	41.01
Total	417	100.00

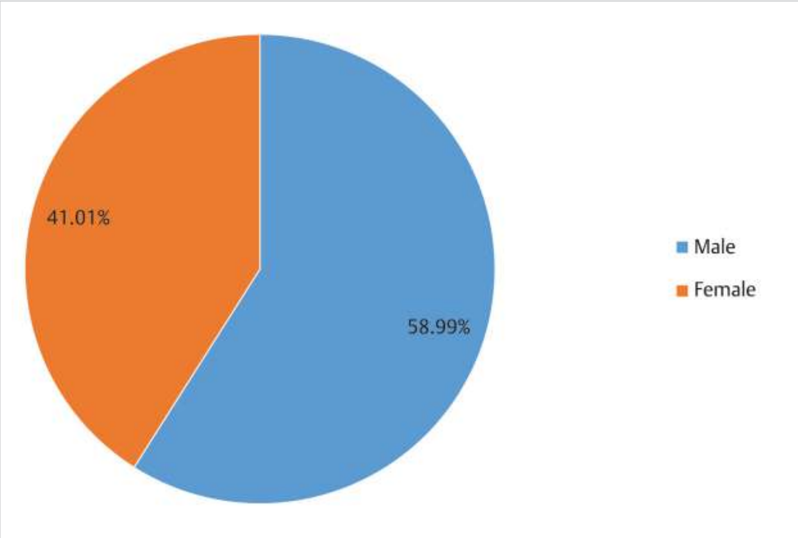

Fig. 5.3 Sex distribution of 417 patients with tibial/fibular fractures in the China National Fracture Study (CNFS).

■ Tibial/Fibular Fracture by Injury Side

See ▶ Table 5.2 and ▶ Fig. 5.4.

Table 5.2 Injury side distribution of 417 patients with tibial/fibular fractures in the China National Fracture Study

Injured side	Number of patients	Percentage
Left	191	45.8
Right	220	52.76
Bilateral	6	1.44
Total	417	100.00

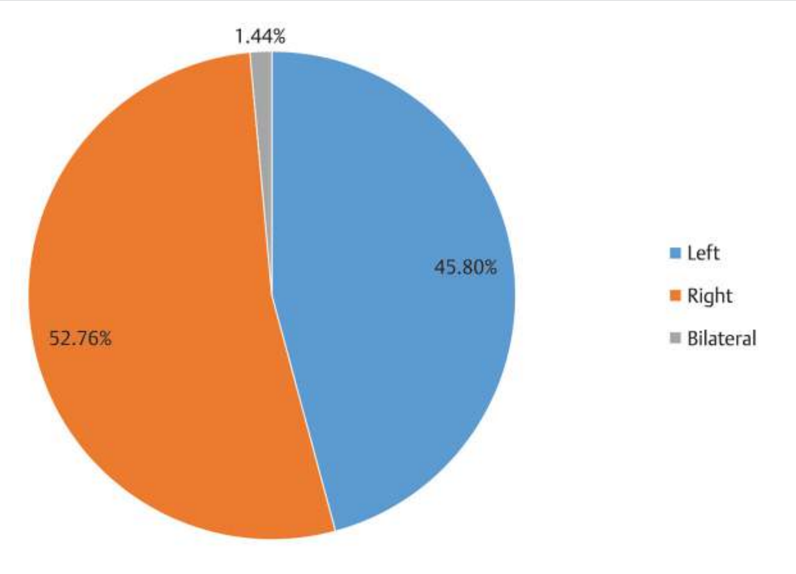

Fig. 5.4 Injury side distribution of 417 patients with tibial/fibular fractures in the China National Fracture Study (CNFS).

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■ Tibial/Fibular Fracture by Age Group and Sex

See ▶ Table 5.3 and ▶ Fig. 5.5.

Table 5.3 Age group and sex distribution of 417 patients with tibial/fibular fractures in the China National Fracture Study

Age group (years)	Male	Female	Total	Percentage
0–14	11	7	18	4.32
15–64	198	127	325	77.94
≥ 65	37	37	74	17.75
Total	246	171	417	100.00

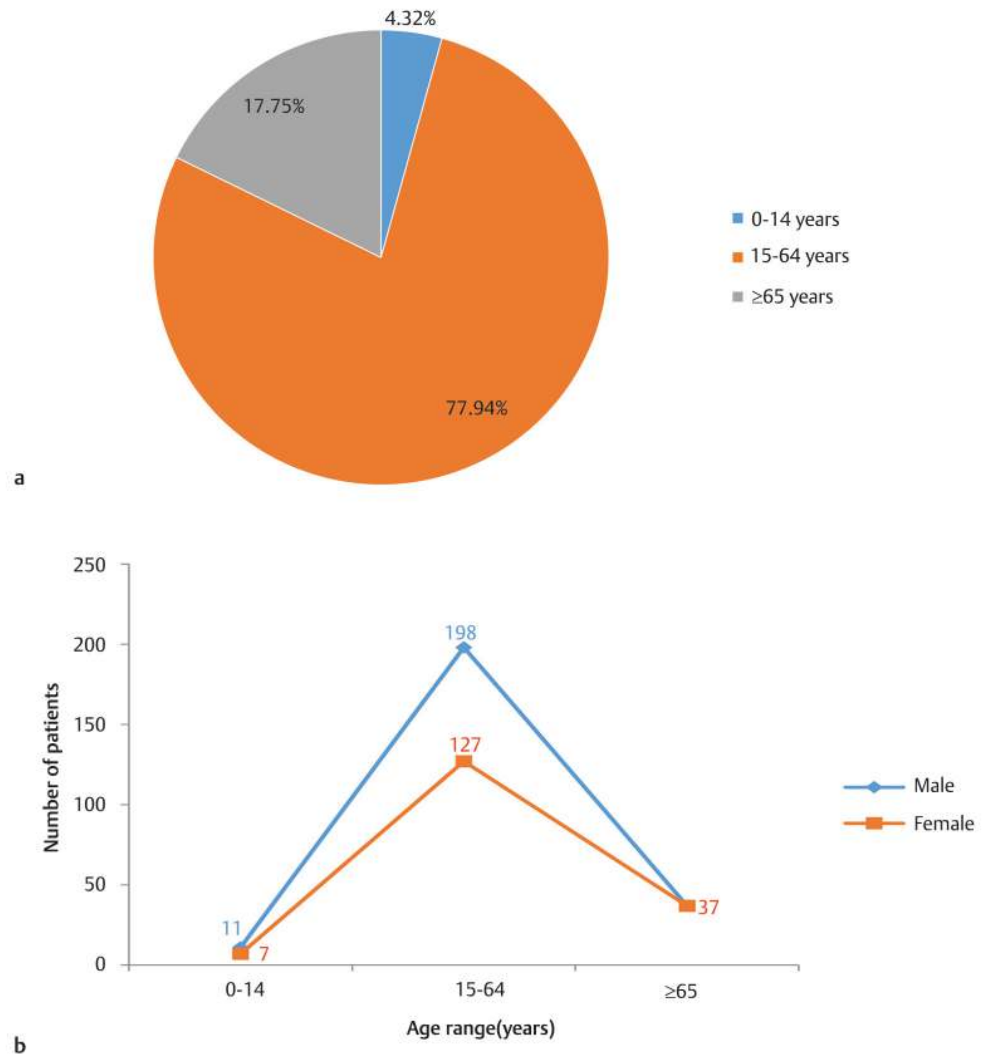

Fig. 5.5 (**a**) Age group distribution of 417 patients with tibial/fibular fractures in the China National Fracture Study (CNFS). (**b**) Age group and sex distribution of 417 patients with tibial/fibular fractures in the CNFS.

■ Tibial/Fibular Fracture by Location

See ▶ Table 5.4 and ▶ Fig. 5.6.

Table 5.4 Segment distribution of 417 patients with tibial/fibular fractures in the China National Fracture Study based on AO classification

Segment	Male	Female	Total	Percentage
41	44	20	64	15.13
42	66	29	95	22.46
43	43	28	71	16.78
44	99	94	193	45.63
Total	252	171	423	100.00

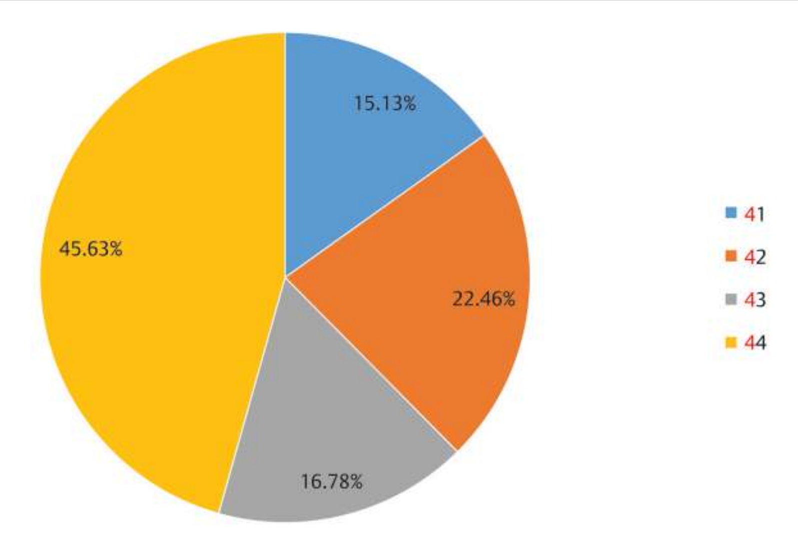

Fig. 5.6 Segment distribution of 417 patients with tibial/fibular fractures in the China National Fracture Study (CNFS) based on AO classification.

■ Tibial/Fibular Fracture by Causal Mechanisms

See ▶ Table 5.5 and ▶ Fig. 5.7.

Table 5.5 Causal mechanisms distribution of 417 patients with tibial/fibular fractures in the China National Fracture Study

Causal mechanisms	Male	Female	Total	Percentage
Traffic accident	72	33	105	25.18
Slip, trip, or fall	132	117	249	59.71
Fall from heights	23	12	35	8.39
Crushing injury	18	7	25	6.00
Sharp trauma	0	1	1	0.24
Blunt force trauma	1	1	2	0.48
Total	246	171	417	100.00

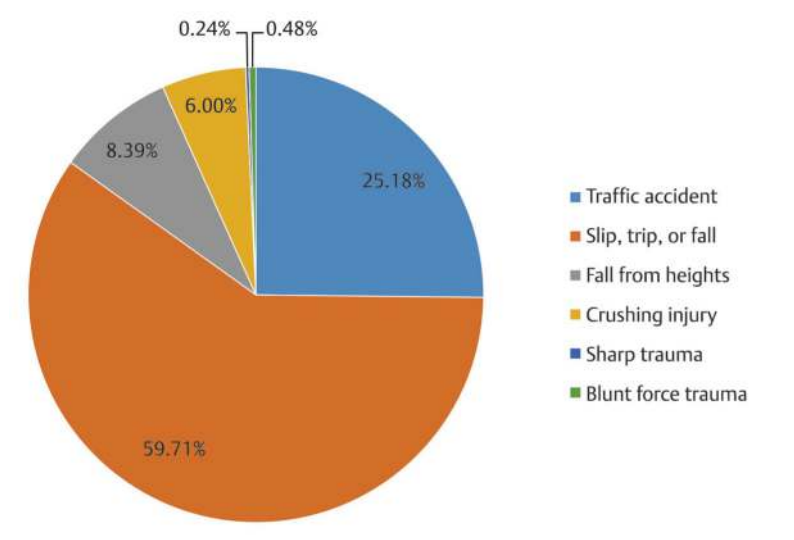

Fig. 5.7 Causal mechanisms distribution of 417 patients with tibial/fibular fractures in the China National Fracture Study (CNFS).

Clinical Epidemiologic Features of Tibial/Fibular Fractures

A total of 66,758 patients with 68,878 fractures of the tibia/fibula were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 16.09% of all patients with fractures and 15.95% of all types of fractures, respectively. Among these 66,758 patients, 8,144 were children with 8,264 fractures, and 58,614 were adults with 60,614 fractures.

Epidemiologic features of tibial/fibular fractures are as follows:

- More males than females
- More left-side than right-side injuries
- The high-risk age group is 41–45 years. The most affected male age group is 41–45 years, while females aged 56–60 years have the highest risk.
- The malleolar injury is the most common tibial/fibular fracture.

Tibial/Fibular Fractures by Sex

See ▶ Table 5.6 and ▶ Fig. 5.8.

Table 5.6 Sex distribution of 66,758 patients with tibial/fibular fractures

Sex	Number of patients	Percentage
Male	44,438	66.57
Female	22,320	33.43
Total	66,758	100.00

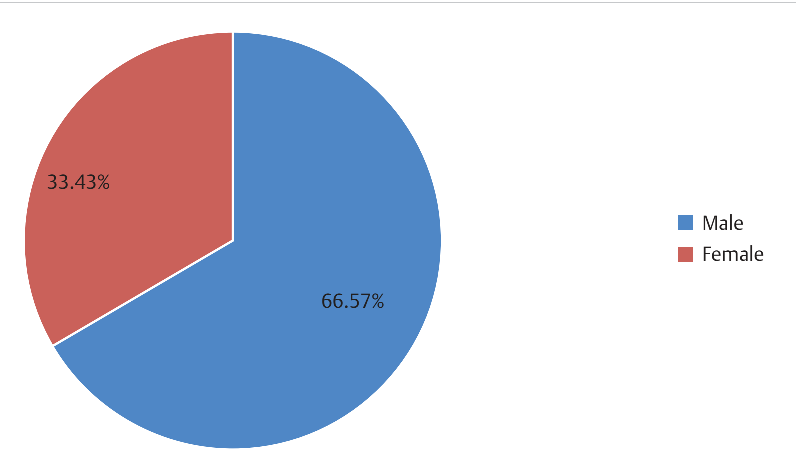

Fig. 5.8 Sex distribution of 66,758 patients with tibial/fibular fractures.

■ Tibial/Fibular Fractures by Injury Side

See ▶ Table 5.7 and ▶ Fig. 5.9.

Table 5.7 Injury side distribution of 66,758 patients with tibial/fibular fractures

Injury side	Number of patients	Percentage
Left	33,308	49.89
Right	32,700	48.98
Bilateral	750	1.12
Total	66,758	100.00

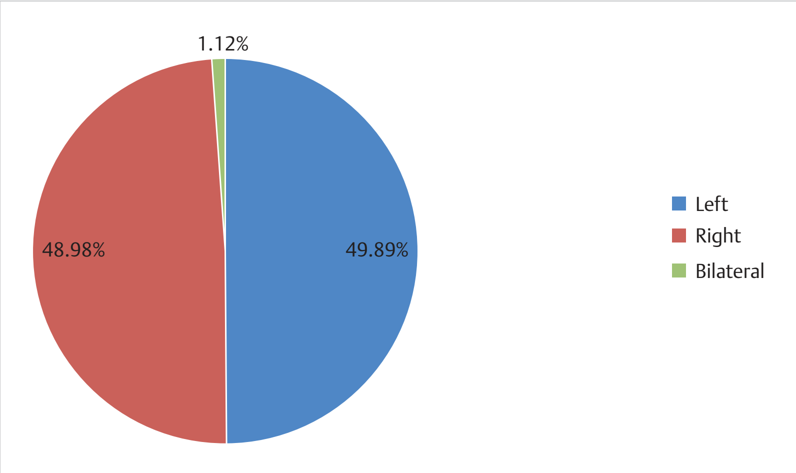

Fig. 5.9 Injury side distribution of 66,758 patients with tibial/fibular fractures.

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■ Tibial/Fibular Fractures by Age Group

See ▶ Table 5.8 and ▶ Fig. 5.10.

Table 5.8 Age and sex distribution of 66,758 patients with tibial/fibular fractures

Age group (years)	Male	Female	Number of patients	Percentage
0–5	1,652	837	2,489	3.73
6–10	1,643	836	2,479	3.71
11–15	2,315	861	3,176	4.76
16–20	3,355	1,009	4,364	6.54
21–25	4,283	1,405	5,688	8.52
26–30	3,828	1,273	5,101	7.64
31–35	3,950	1,348	5,298	7.94
36–40	4,958	1,888	6,846	10.25
41–45	5,095	2,083	7,178	10.75
46–50	4,178	2,198	6,376	9.55
51–55	3,150	2,162	5,312	7.96
56–60	2,578	2,298	4,876	7.30
61–65	1,452	1,437	2,889	4.33
66–70	777	1,003	1,780	2.67
71–75	566	762	1,328	1.99
76–80	364	566	930	1.39
81–85	221	228	449	0.67
≥ 86	73	126	199	0.30
Total	44,438	22,320	66,758	100.00

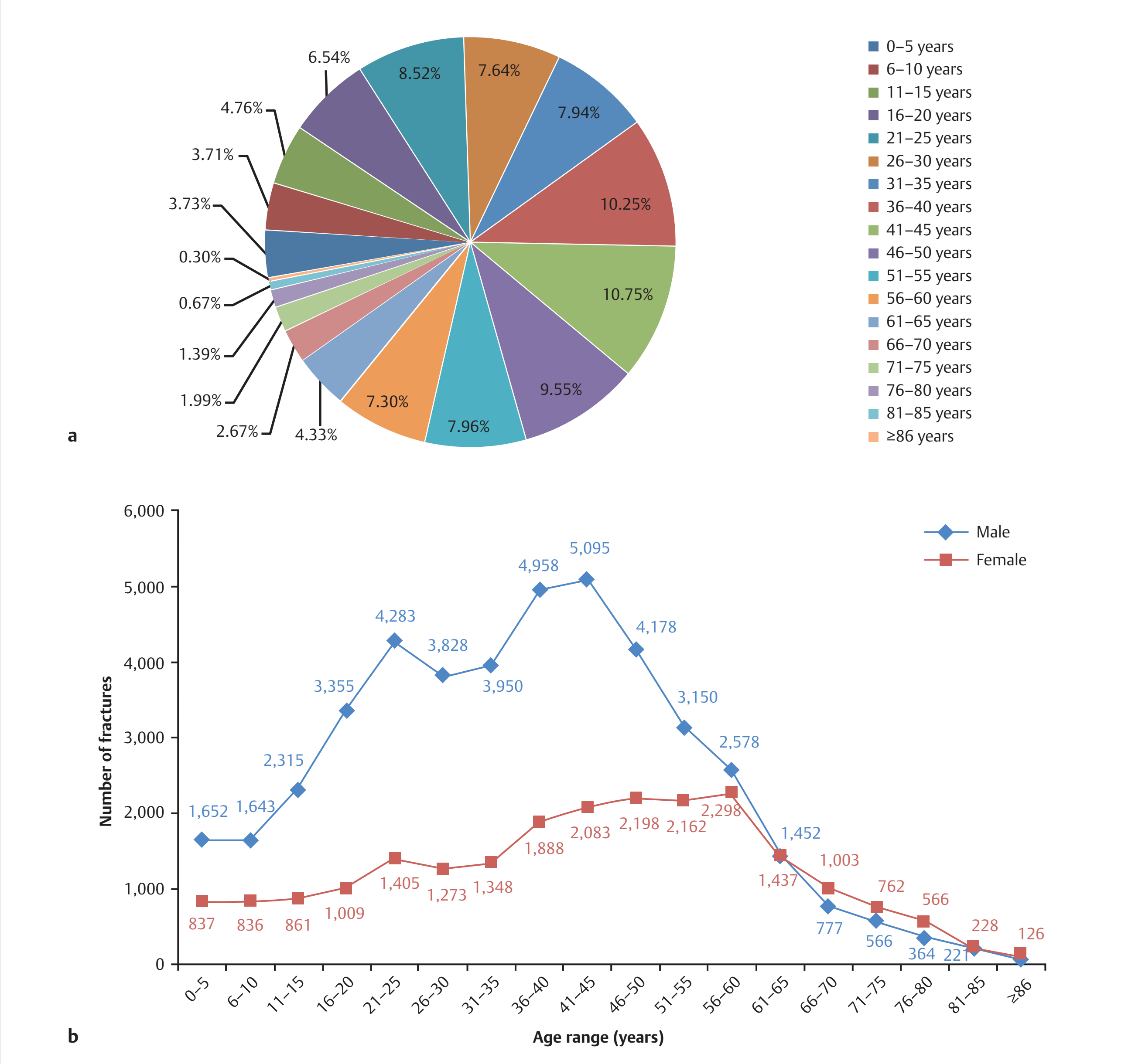


Fig. 5.10 (**a**) Age distribution of 66,758 patients with tibial/fibular fractures. (**b**) Age and sex distribution of 66,758 patients with tibial/fibular fractures.

5

■ Tibial/Fibular Fractures by Segment

Segment Distribution of Tibial/Fibular Fractures in Adults by AO Classification

See ▶ Table 5.9 and ▶ Fig. 5.11.

Table 5.9 Segment distribution of 60,614 tibial/fibular fractures in adults based on AO classification

Segment	Number of fractures	Percentage
41	10,944	18.06
42	15,000	24.75
43	6,391	10.54
44	28,279	46.65
Total	60,614	100.00

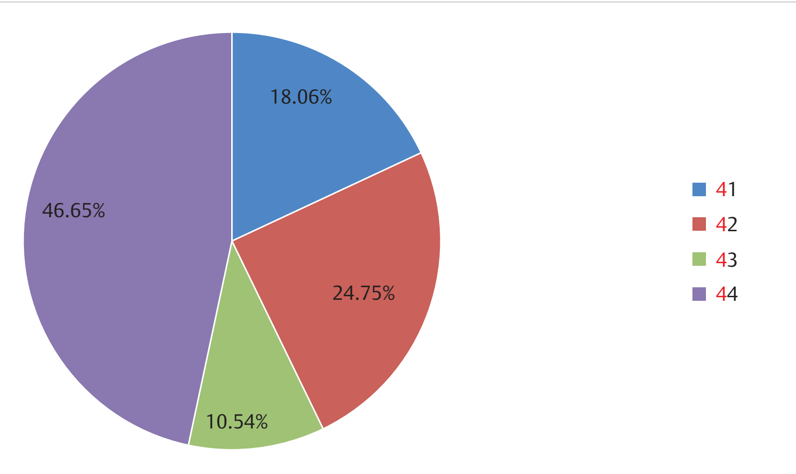


Fig. 5.11 Segment distribution of 60,614 tibial/fibular fractures based on AO classification.

Segment Distribution of Tibial/Fibular Fractures in Children

See ▶ Table 5.10 and ▶ Fig. 5.12.

Table 5.10 Segment distribution of 8,264 tibial/fibular fractures in children

Segment	Number of fractures	Percentage
Proximal	737	8.92
Diaphysis	4,079	49.36
Distal	1,469	17.78
Malleolus	1,979	23.95
Total	8,264	100.00

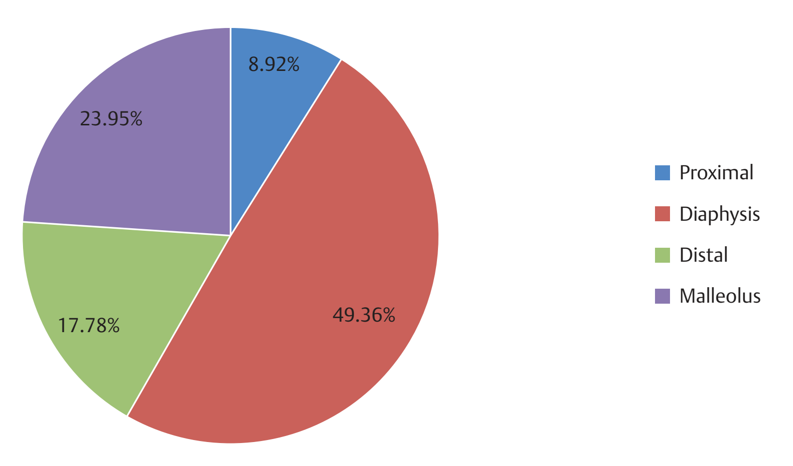


Fig. 5.12 Segment distribution of 8,264 tibial/fibular fractures in children.

5

Proximal Tibial Fractures (Segment 41)

■ Anatomic Features

The upper end of the tibia is large, and expands laterally into two ridges, the medial and lateral condyles. The medial and lateral tibial plateaus are the articular surfaces of the medial and lateral tibial condyles. These plateaus articulate with the medial and lateral femoral condyles, respectively. The tibial plateau is not perpendicular to the longitudinal axis of the tibial shaft, but slopes posteriorly at ~10 degrees. The bone comprising the tibial plateau is cancellous, as opposed to the thicker cortical bone of the tibial shaft. As a result, knee fractures often occur at the tibial plateau. The lateral plateau is smaller and higher than the medial plateau; thus, it decentralizes the shear load, which makes the lateral plateau more prone to fractures than the medial plateau. The outer portion of each plateau is covered by a semilunar fibrocartilaginous meniscus.

The two tibial plateaus are separated by the intercondyloid eminence, with its prominent medial and lateral tubercles, so-called tibial spines, where the anterior and posterior cruciate ligaments attach. The region of the tibial spines is extra-articular; therefore, there is no coverage by articular cartilage (▶ Fig. 5.13).

Between the lateral and medial condyles, on the proximal anterior surface of the tibia, lies a very large triangular prominence known as the tibial tuberosity. On the anterior side of the knee, running between the apex of the patella and tibial tuberosity is the patellar ligament. The tibial attachment of the patellar ligament is 2.5 to 3 cm distal to the joint line on the anterior tibial crest. Between the patellar ligament and the tibia lies the deep infrapatellar bursa. A small prominence, located on the anterior aspect of the lateral condyle of the tibia, is known as the Gerdy tubercle, where the iliotibial band inserts. The fibula acts as a splint, or crutch, for the tibia but does not bear nearly as much weight of the body as the tibia. The head of fibula is the site for the insertion of the lateral collateral ligament and the tendon of the biceps femoris muscle.

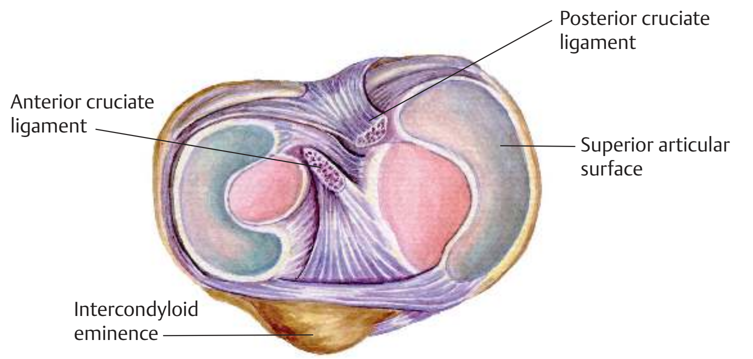


Fig. 5.13 Superior view of tibia.

AO Classification of Proximal Tibial Fractures

Based on AO classification, the proximal tibia is coded as number "41" (▶ Fig. 5.14). Proximal tibial fractures can be divided into three types depending on articular involvement: 41-A: extra-articular fracture; 41-B: partial-articular fracture; and 41-C: complete-articular fracture (▶ Fig. 5.15).

Clinical Epidemiologic Features of Proximal Tibial Fractures (Segment 41)

A total of 10,944 adult fractures of the proximal tibia/fibula were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 18.06% of all tibial/fibular fractures in adults. The epidemiologic features are as follows:

- More males than females
- The high-risk age group is 41–45 years. The most affected male age group is 41–45 years, while females between 56 and 60 years have the highest risk.
- The most common fracture type among segment 41 fractures is type 41-A, the same fracture type for both males and females.
- The most common fracture group among segment 41 fractures is group 41-A1, the same fracture group for both males and females.

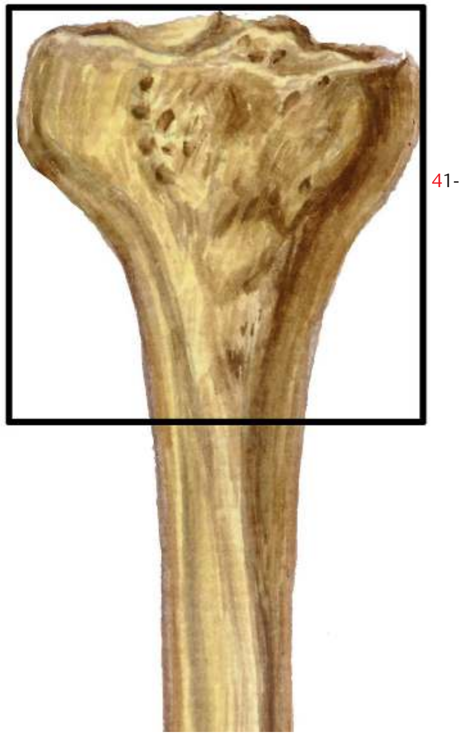


Fig. 5.14 AO code of proximal tibia.

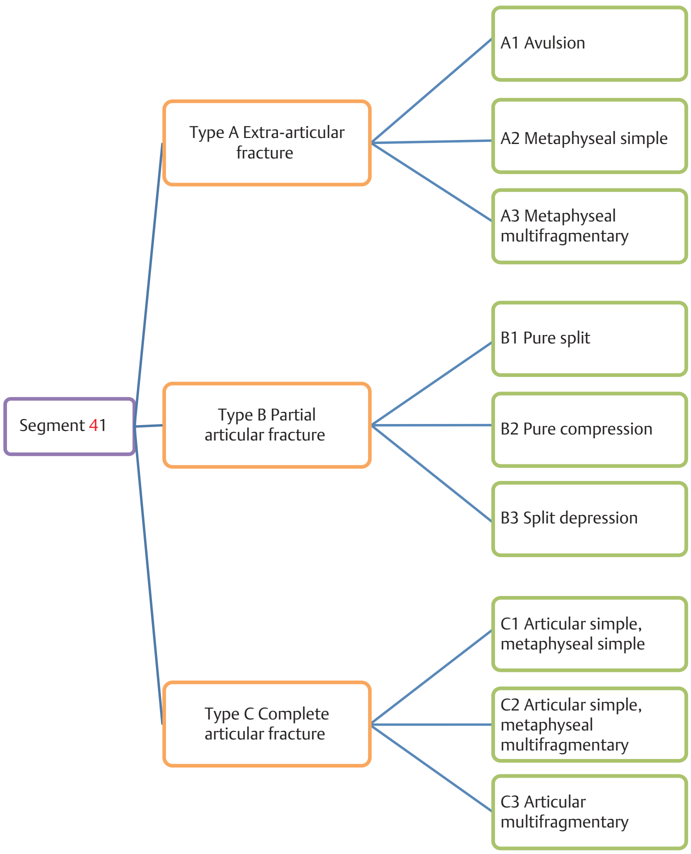


Fig. 5.15 Algorithm.

■ Fractures of Segment 41 by Sex

See ▶ Table 5.11 and ▶ Fig. 5.16.

Table 5.11 Sex distribution of 10,944 fractures of segment 41

Sex	Number of fractures	Percentage
Male	7,355	67.21
Female	3,589	32.79
Total	10,944	100.00

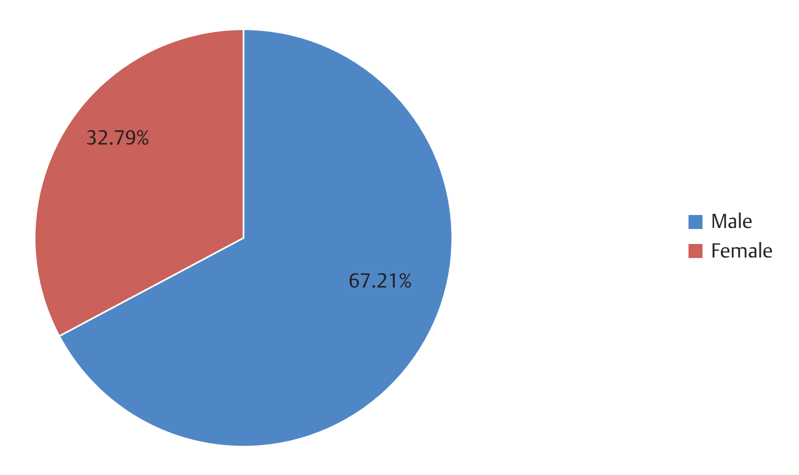


Fig. 5.16 Sex distribution of 10,944 fractures of segment 41.

■ Fractures of Segment 41 by Age Group

See ▶ Table 5.12 and ▶ Fig. 5.17.

Table 5.12 Age and sex distribution of 10,944 fractures of segment 41

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	482	137	619	5.66
21–25	578	179	757	6.92
26–30	556	177	733	6.70
31–35	701	240	941	8.60
36–40	999	282	1,281	11.71
41–45	1,072	354	1,426	13.03
46–50	964	389	1,353	12.36
51–55	708	447	1,155	10.55
56–60	568	470	1,038	9.48
61–65	311	328	639	5.84
66–70	154	219	373	3.41
71–75	134	166	300	2.74
76–80	78	130	208	1.90
81–85	42	44	86	0.79
≥ 86	8	27	35	0.32
Total	7,355	3,589	10,944	100.00

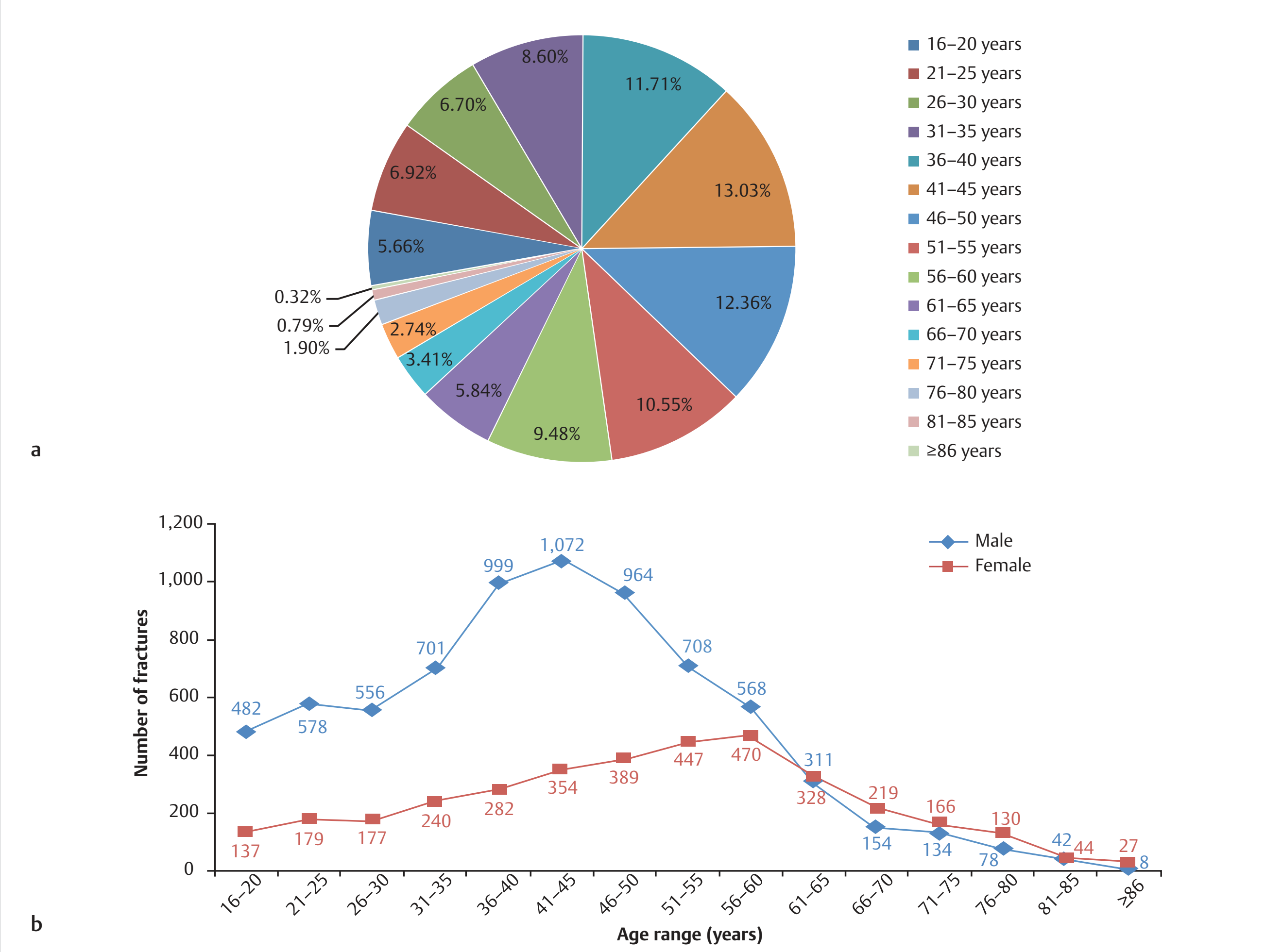


Fig. 5.17 (**a**) Age distribution of 10,944 fractures of segment 41. (**b**) Age and sex distribution of 10,944 fractures of segment 41.

■ Fractures of Segment 41 by Fracture Type

See ▶ Table 5.13, ▶ Table 5.14, ▶ Fig. 5.18, and ▶ Fig. 5.19.

Table 5.13 Sex and fracture type distribution of 10,944 fractures of segment 41

Fracture type	Male	Female	Number of fractures	Percentage
41-A	3,080	1,637	4,717	43.10
41-B	2,529	1,469	3,998	36.53
41-C	1,746	483	2,229	20.37
Total	7,355	3,589	10,944	100.00

Table 5.14 Sex and fracture group distribution of 10,944 fractures of segment 41

Fracture group	Male	Female	Number of fractures	Percentage of segment 41	Percentage of tibia/ fibula
41-A1	2,069	1,354	3,423	31.28	5.65
41-A2	460	178	638	5.83	1.05
41-A3	551	105	656	5.99	1.08
41-B1	1,002	433	1,435	13.11	2.37
41-B2	731	626	1,357	12.40	2.24
41-B3	796	410	1,206	11.02	1.99
41-C1	440	155	595	5.44	0.98
41-C2	609	138	747	6.83	1.23
41-C3	697	190	887	8.10	1.46
Total	7,355	3,589	10,944	100.00	18.06

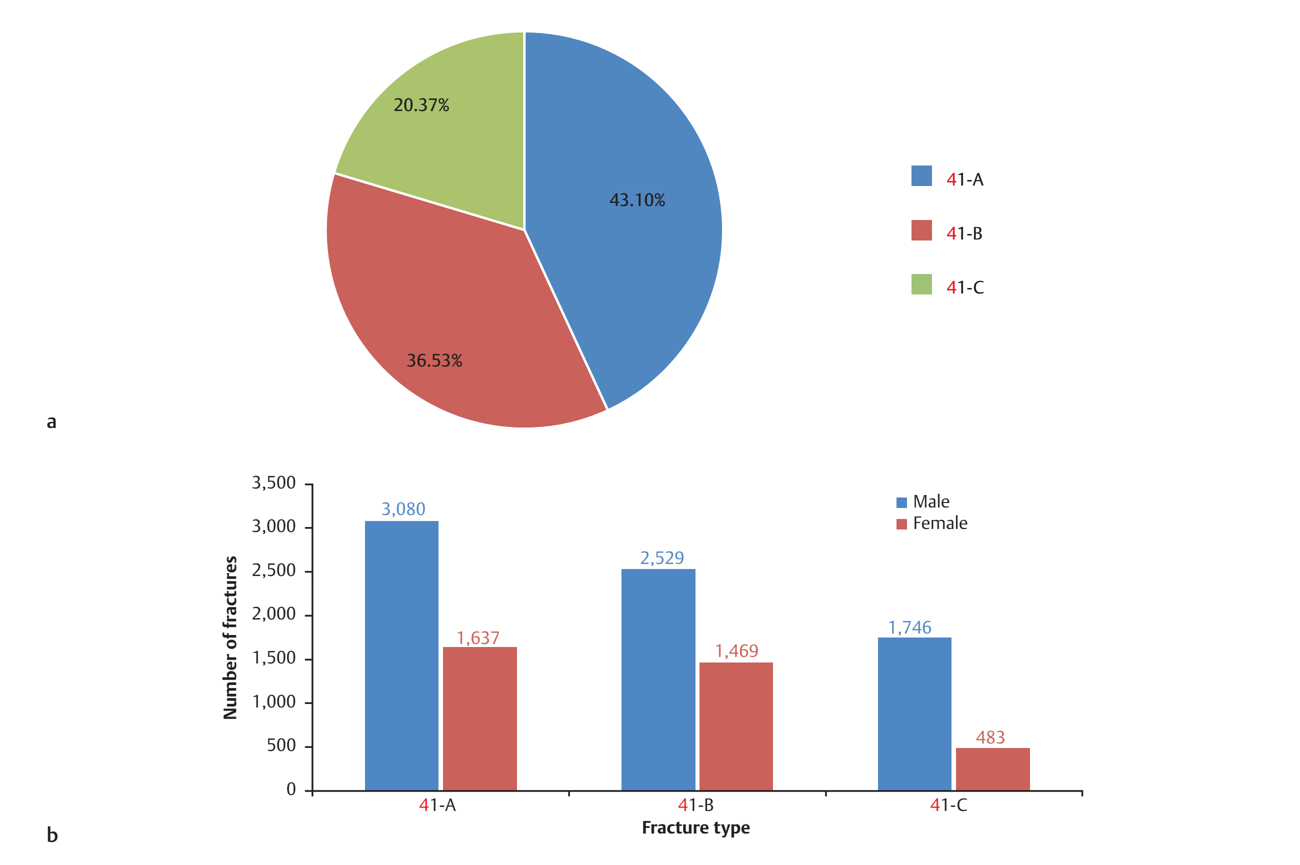


Fig. 5.18 (**a**) Fracture type distribution of 10,944 fractures of segment 41. (**b**) Sex and fracture type distribution of 10,944 fractures of segment 41.

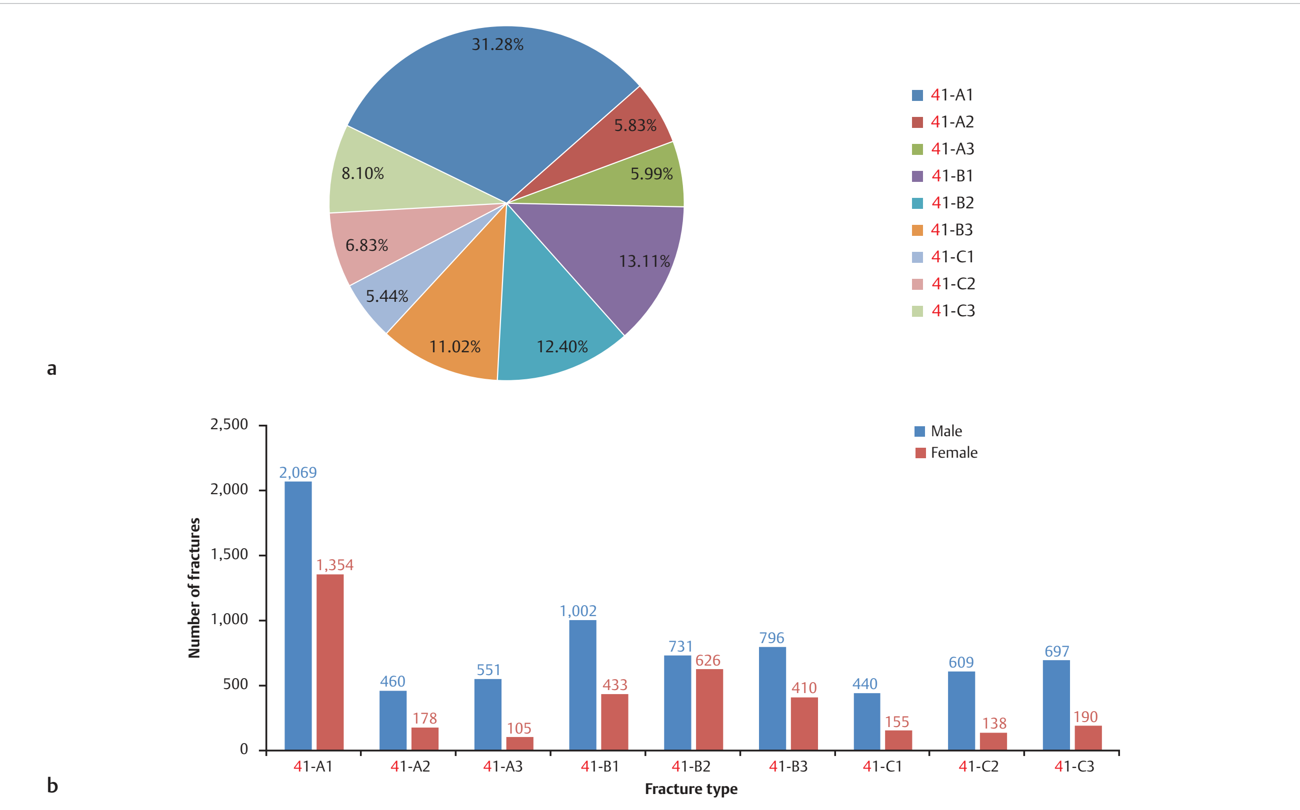
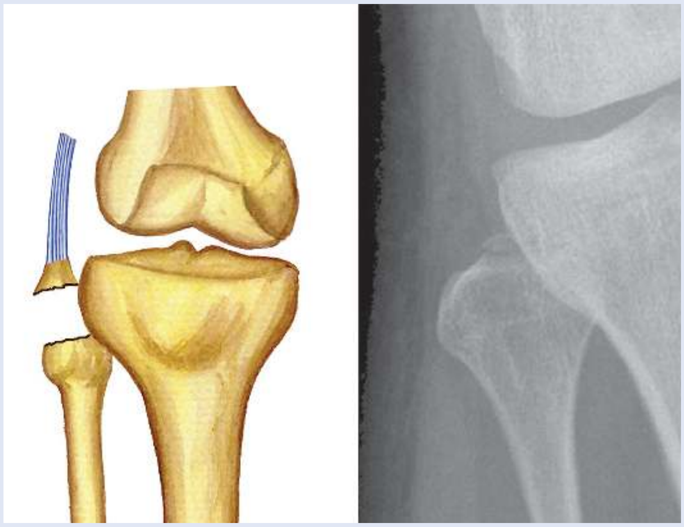


Fig. 5.19 (**a**) Fracture group distribution of 10,944 fractures of segment 41. (**b**) Sex and fracture group distribution of 10,944 fractures of segment 41.

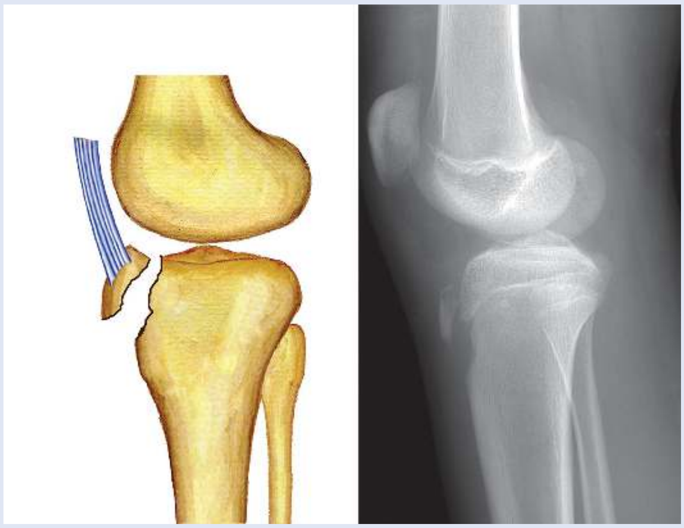
41-A Tibia/fibula, proximal, extra-articular fractures

41-A1 Avulsion
3,423 fractures
M: 2,069 (60.44%)
F: 1,354 (39.56%)
0.91% of total adult fractures
5.65% of adult tibial/fibular fractures
31.28% of segment 41
72.57% of type 41-A

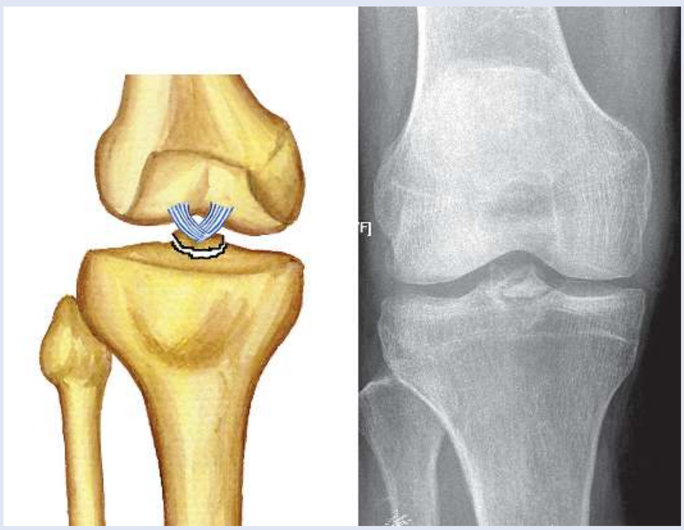
41-A1.1 Of the fibular head



41-A1.2 Of the tibial tuberosity



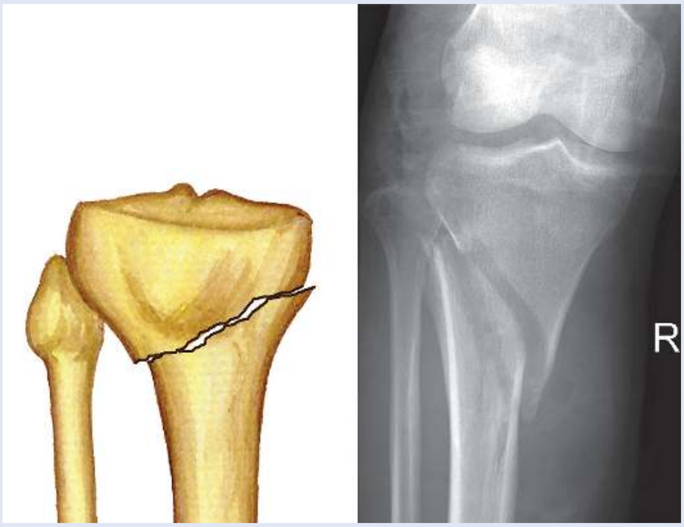
41-A1.3 Of the cruciate insertion



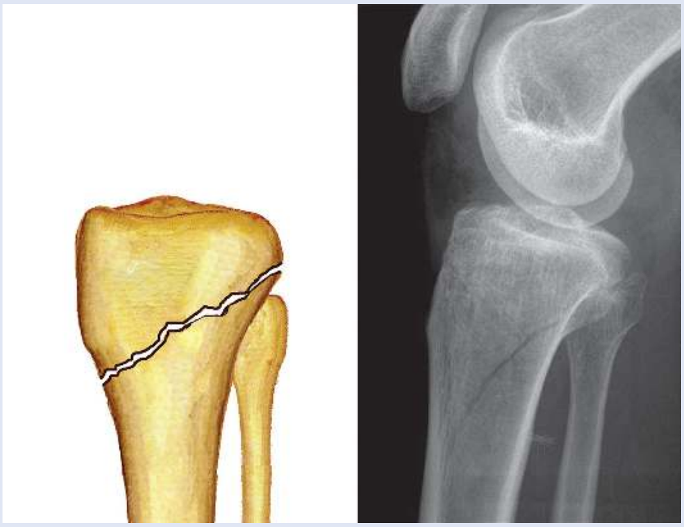
41-A Tibia/fibula, proximal, extra-articular fractures

41-A2 Metaphyseal simple
638 fractures
M: 460 (72.10%)
F: 178 (27.90%)
0.17% of total adult fractures
1.05% of adult tibial/fibular fractures
5.83% of segment 41
13.53% of type 41-A

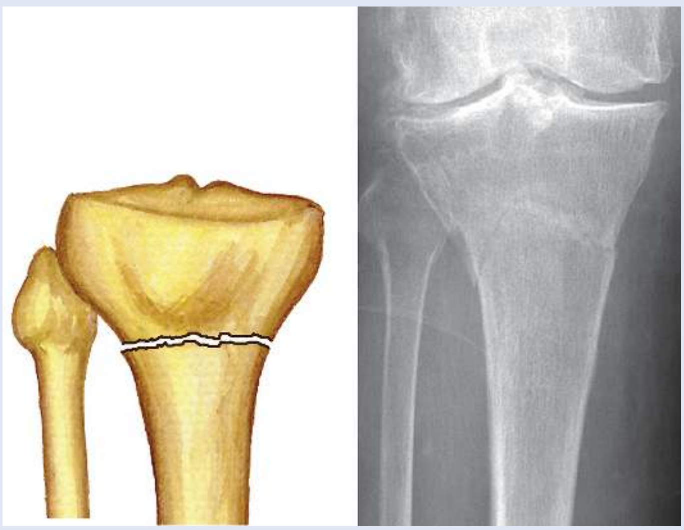
41-A2.1 Oblique in the sagittal plane



41-A2.2 Oblique in the frontal plane



41-A2.3 Transverse



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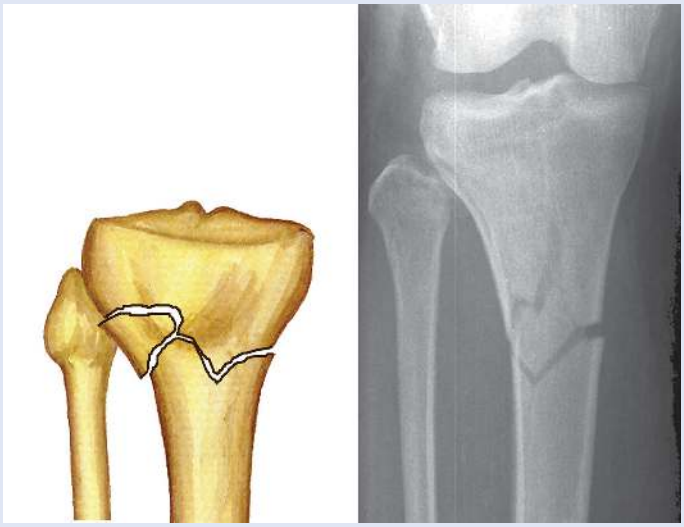
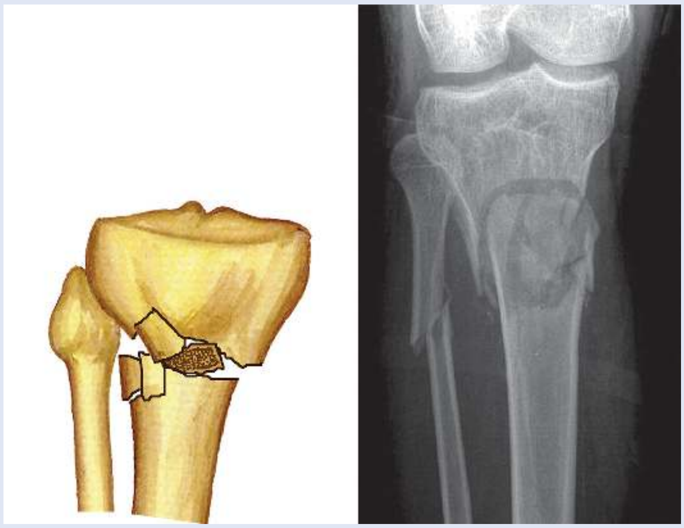
41-A Tibia/fibula, proximal, extra-articular fractures

41-A3 Metaphyseal multifragmentary
656 fractures
M: 551 (83.99%)
F: 105 (16.01%)
0.18% of total adult fractures
1.08% of adult tibial/fibular fractures
5.99% of segment 41
13.91% of type 41-A

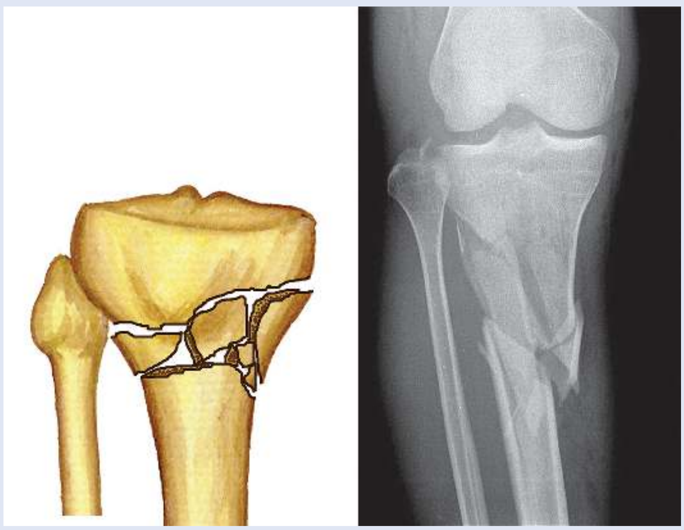
41-A3.1 Intact wedge



41-A3.2 Fragmented wedge



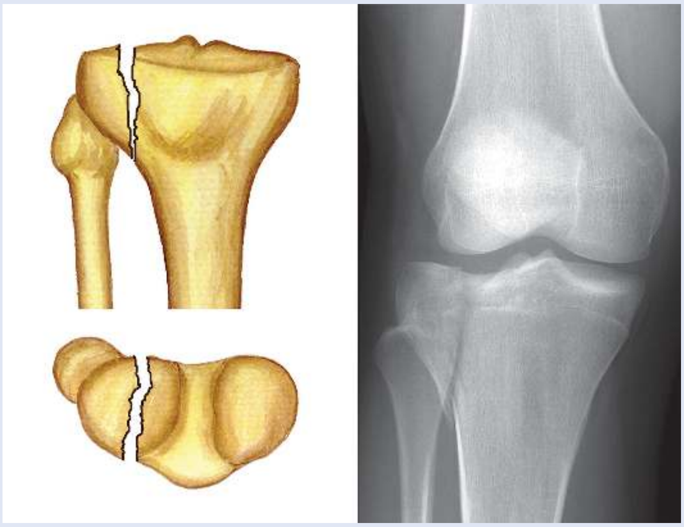
41-A3.3 Multifragmentary



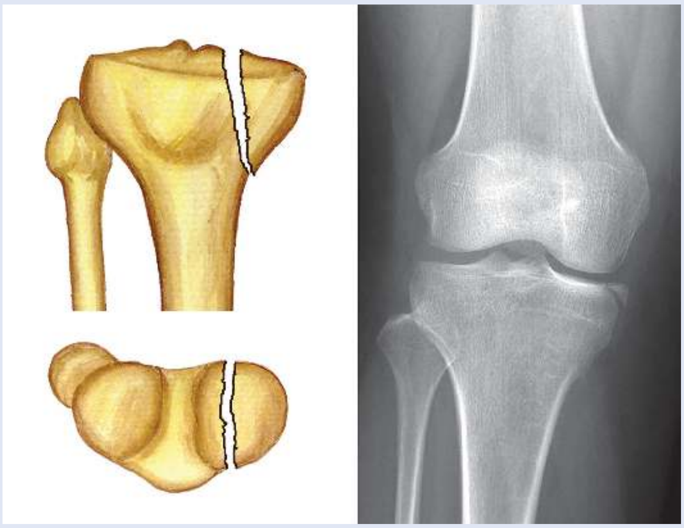
41-B Tibia/fibula, proximal, partial articular fractures

41-B1 Split fracture involving the articular surface of one tibial plateau
1,435 fractures
M: 1,002 (69.83%)
F: 433 (30.17%)
0.38% of total adult fractures
2.37% of adult tibial/fibular fractures
13.11% of segment 41
35.89% of type 41-B

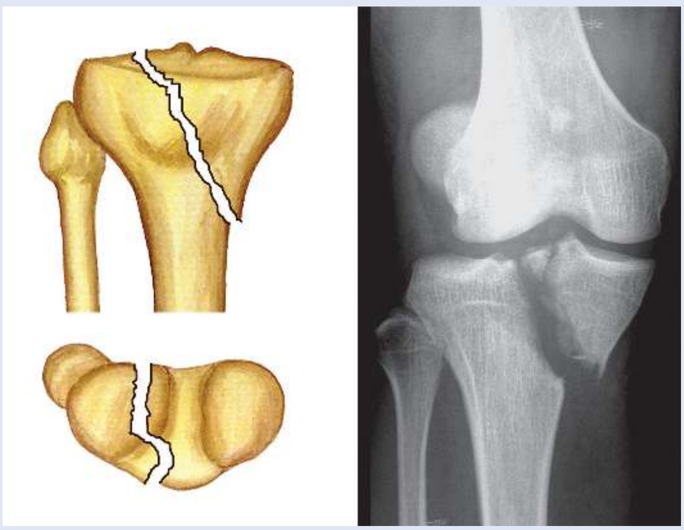
41-B1.1 Of the lateral surface

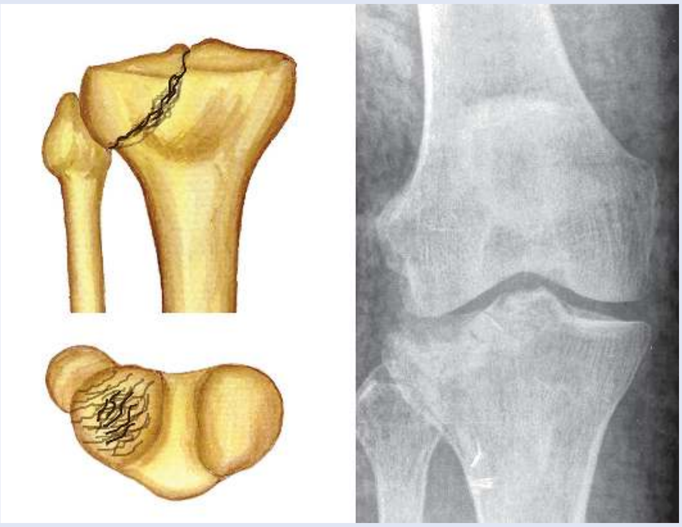
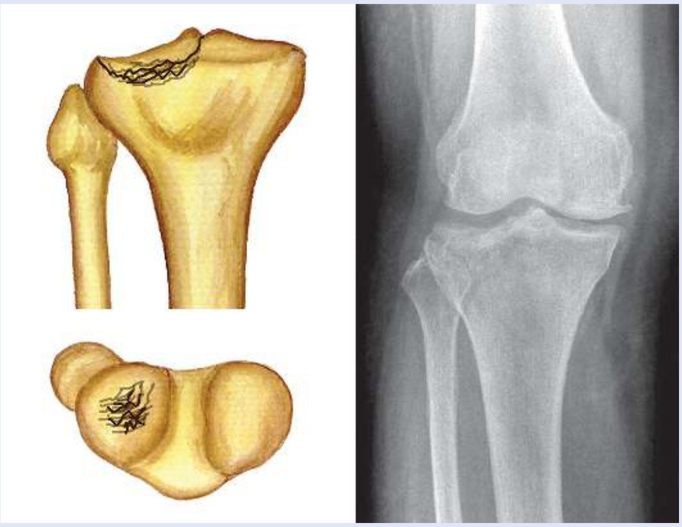
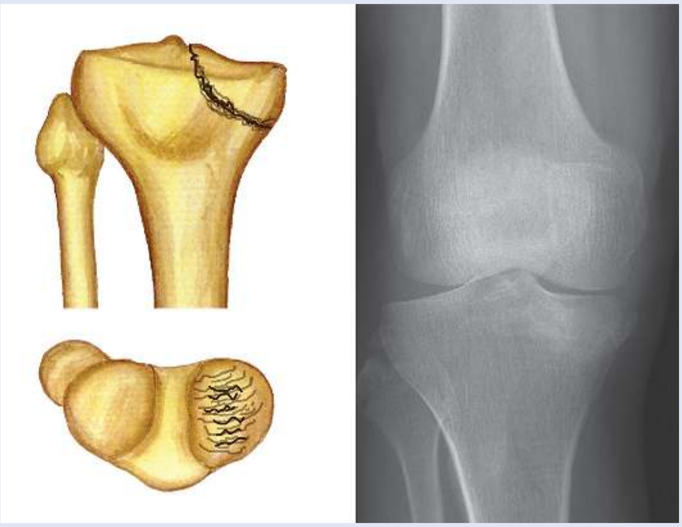


41-B1.2 Of the medial surface



41-B1.3 Oblique, involving the tibial spine and one of the plateaus

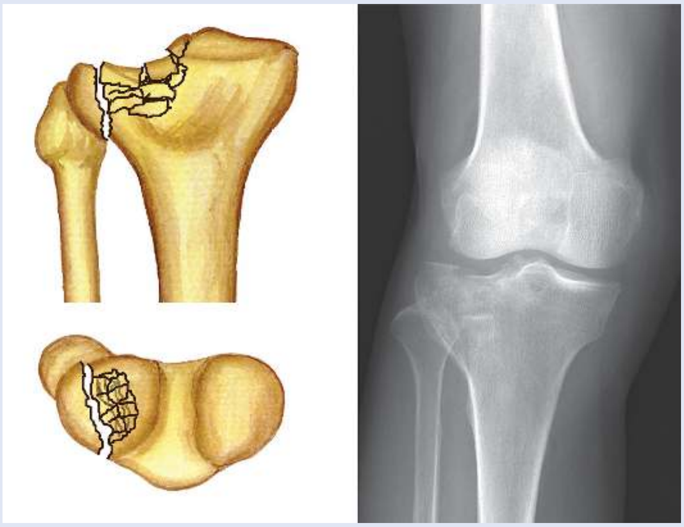


41-B Tibia/fibula, proximal, partial articular fractures	
41-B2 Depression fractures involving one tibial plateau 1,357 fractures M: 731 (53.87%) F: 626 (46.13%) 0.36% of total adult fractures 2.24% of adult tibial/fibular fractures 12.40% of segment 41 33.94% of type 41-B	**41-B2.1** Lateral total  **41-B2.2** Lateral limited  **41-B2.3** Medial 

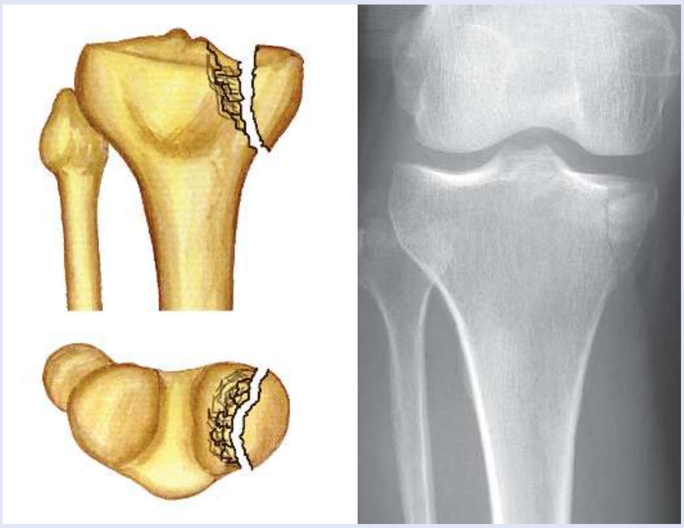
41-B Tibia/fibula, proximal, partial articular fractures

41-B3 Split-depression, involving one tibial plateau
1,206 fractures
M: 796 (66.00%)
F: 410 (34.00%)
0.32% of total adult fractures
1.99% of adult tibial/fibular fractures
11.02% of segment 41
30.17% of type 41-B

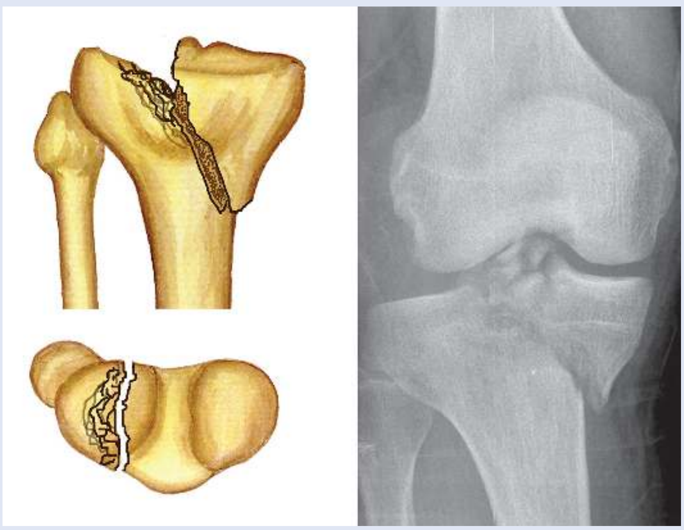
41-B3.1 Lateral



41-B3.2 Medial



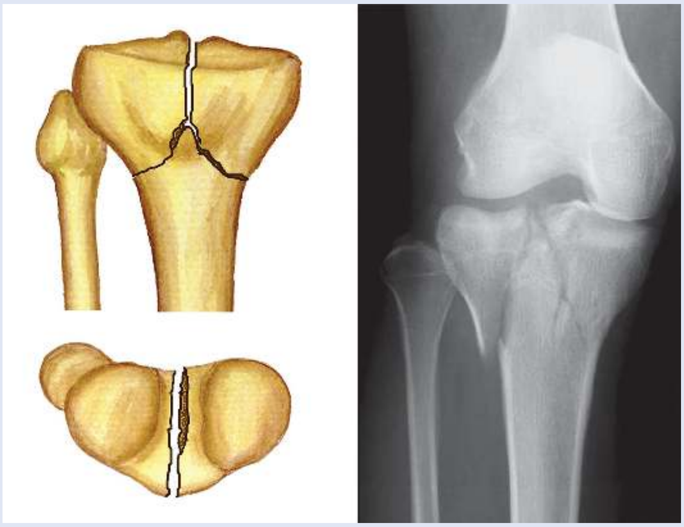
41-B3.3 Oblique, involving the tibial spines and one of the plateaus



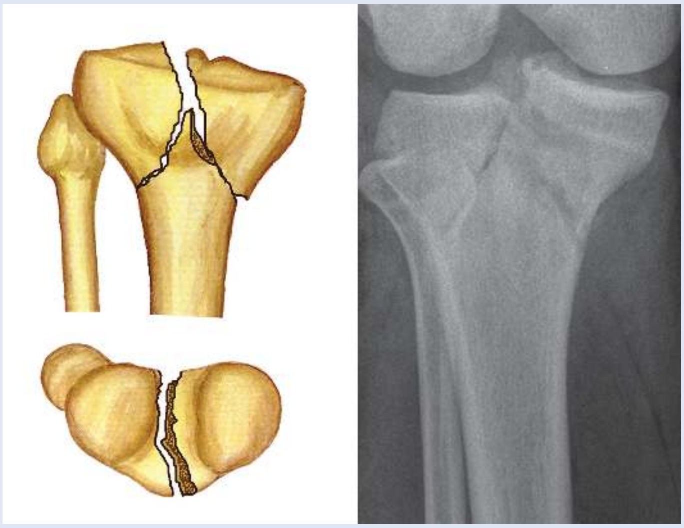
41-C Tibia/fibula, proximal, complete-articular fractures

41-C1 Articular simple, metaphyseal simple
595 fractures
M: 440 (73.95%)
F: 155 (26.05%)
0.16% of total adult fractures
0.98% of adult tibial/fibular fractures
5.44% of segment 41
26.69% of type 41-C

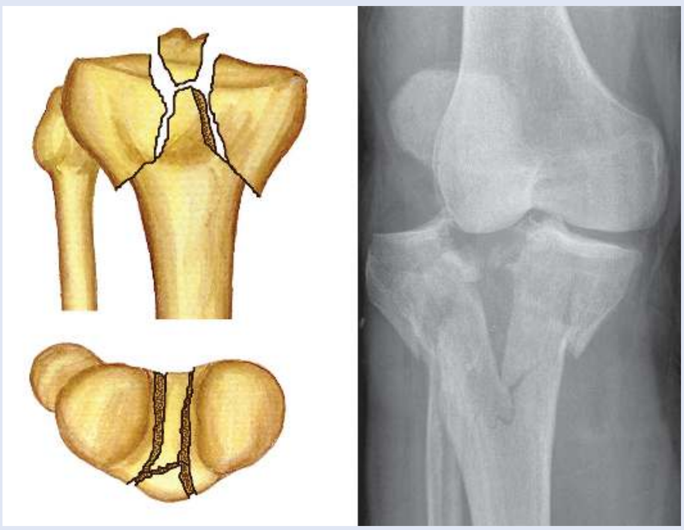
41-C1.1 With minimal or no displacement



41-C1.2 One plateau displaced



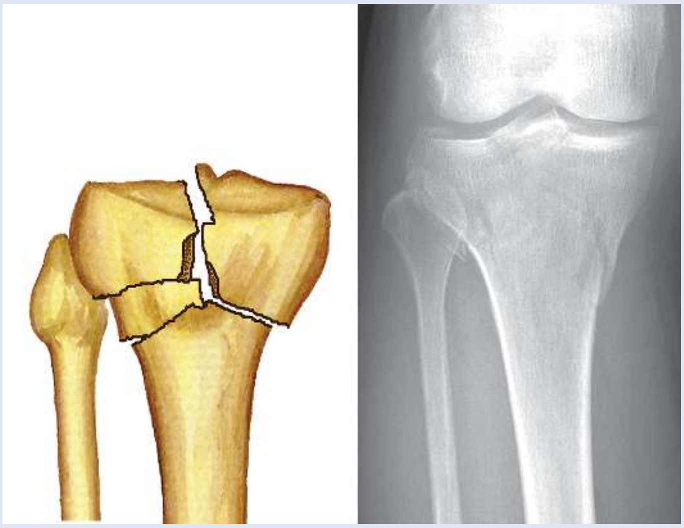
41-C1.3 Both plateaus displaced



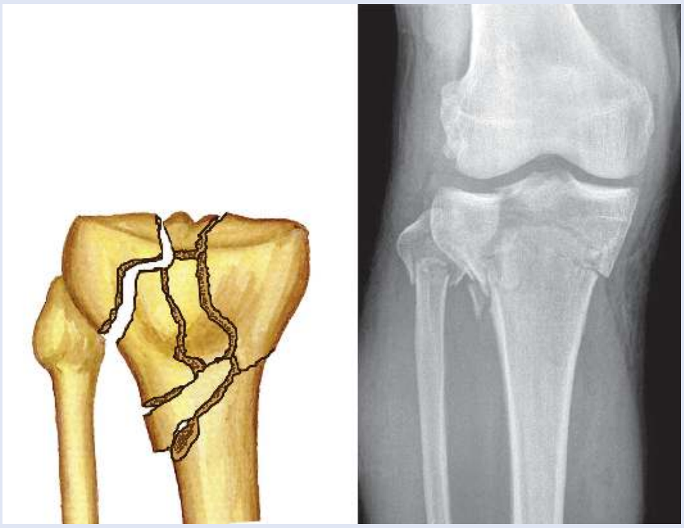
41-C Tibia/fibula, proximal, complete-articular fractures

41-C2 Articular simple, metaphyseal multifragmentary
747 fractures
M: 609 (81.53%)
F: 138 (18.47%)
0.20% of total adult fractures
1.23% of adult tibial/fibular fractures
6.83% of segment 41
33.51% of type 41-C

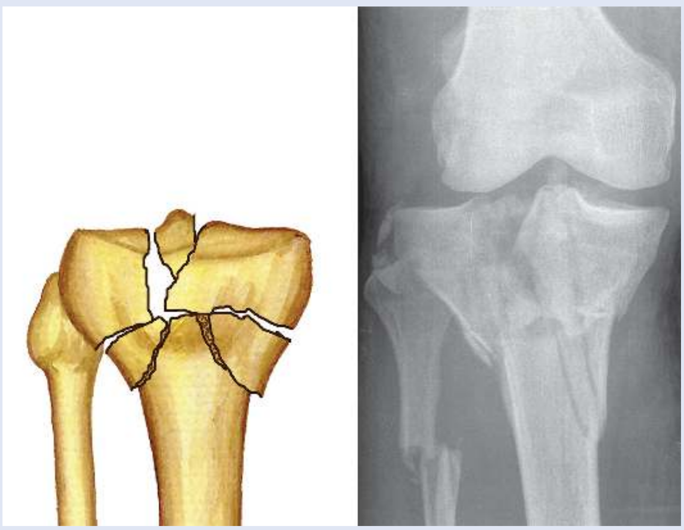
41-C2.1 With intact wedge



41-C2.2 Fragmented wedge



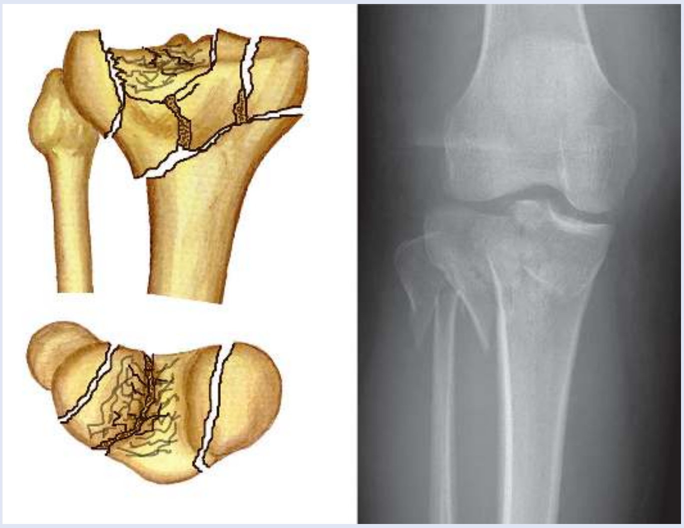
41-C2.3 Complex



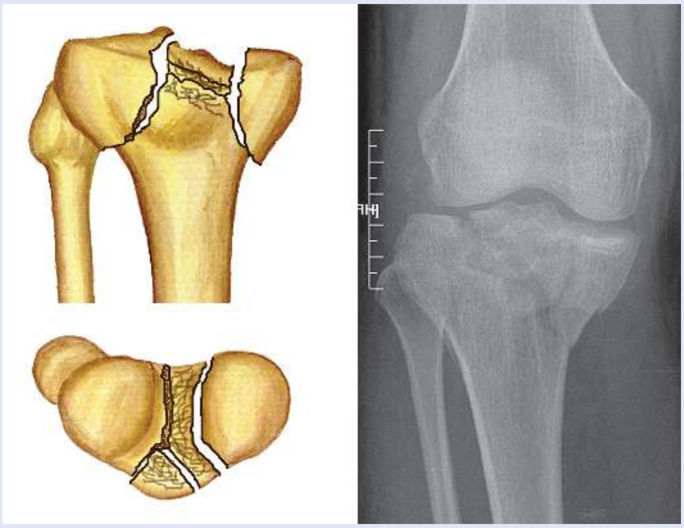
41-C Tibia/fibula, proximal, complete-articular fractures

41-C3 Articular multifragmentary
887 fractures
M: 697 (78.58%)
F: 190 (21.42%)
0.24% of total adult fractures
1.46% of adult tibial/fibular fractures
8.10% of segment 41
39.79% of type 41-C

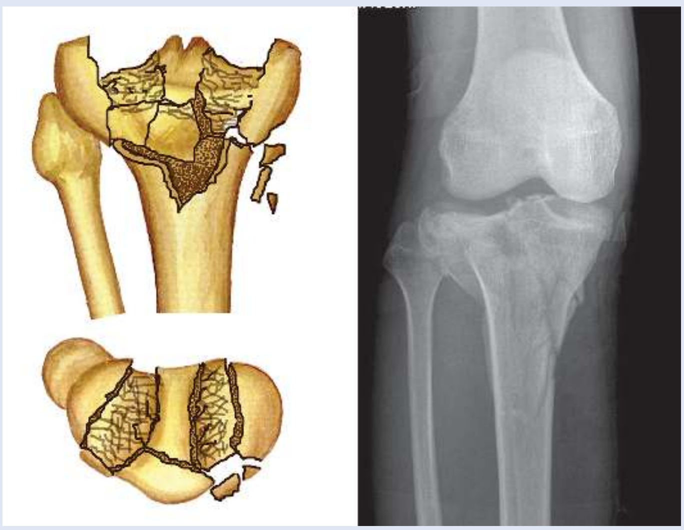
41-C3.1 Lateral



41-C3.2 Medial



41-C3.3 Lateral + medial



5

Injury Mechanism

The most common mechanism of injury involves axial loading and/or valgus or varus force, such as from a fall or automobile accident. The severity of the fracture is associated with the magnitude and duration of the force. The axial compression load resulting from a fall from a significant height can cause depression, splitting, or even comminuted fractures of the tibial plateau. Depression or avulsion of the lateral plateau is the most common trauma that results from valgus/varus or hyperflexion/hyperextension forces, which also can cause avulsion of the tibial attachment of the anterior/posterior cruciate ligaments.

Diagnosis

Patients with proximal tibial/fibular fractures may present with a knee effusion, pain, and stiffness, with a partial or limited range of motion. In severe fractures, a varus or valgus deformity of the affected limb may be present. If the injury resulted from high-energy trauma, a hypertonic blister, or compartment syndrome, rupture of ligaments, and disruption of the neurovascular supply may accompany the fractures. The neurovascular status of the extremity and the surrounding soft tissue must be carefully evaluated.

Most tibial plateau fractures are easy to identify on the standard anteroposterior (AP) and lateral projections of the knee. Traction views may be helpful in comminuted fractures that result from high-energy trauma, to identify the shape and location of the fracture fragments; 40 degrees internal and external oblique films can be used in assessing fractures involved with both tibial plateau surfaces. An AP projection with a 15 degrees backward inclination may be helpful in assessing the depression of the tibial plateau (▶ Fig. 5.20).

Three-dimensional computer tomography (CT) reconstruction and magnetic resonance imaging (MRI) can be used to further characterize fractures of the tibial plateau, and assess the depression of the tibia and the degree of fragment splitting to plan for surgical intervention. MRI is excellent for illustrating ligamentous and meniscal injuries.

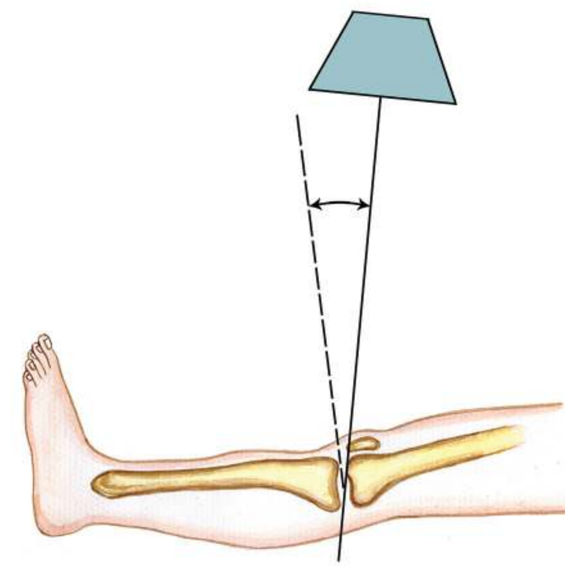


Fig. 5.20 An anteroposterior (AP) projection with a 15 degrees backward inclination may be helpful in assessing the depression of the tibial plateau.

Treatment

Intra-articular fractures of the proximal tibia/fibula are always associated with unstable fragments. If the fracture involves the articular surface, surgical intervention must be considered, using the principles of anatomic reduction, large-volume bone grafting, rigid fixation, and early postoperative nonweight-bearing active mobilization, which can minimize joint adhesion and joint stiffness. Depending on the fracture-healing stage, partial weight-bearing mobilization and exercise can be initiated under the supervision of an experienced therapist. Conservative methods such as casting or traction are inadequate in the treatment of such types of fractures, and should be applied cautiously even to treat fractures with minimal or no displacement.

Avulsion fractures of the fibular head are frequently associated with injuries of the lateral collateral ligament, and can be treated by casting, utilization of a joint, spanning external fixator, or internal fixation depending on the amount of fracture displacement and severity of ligamentous damage. The available internal fixators include a mini hook plate and Kirschner wire (K-wire), combined with a tension band wire. Tibial tuberosity fractures can be treated with lag screws, tension band wires, tension band wires combined with K-wires, or a mini hook plate, depending on the size of the fragments and amount of displacement. A few factors influence the treatment choice of either conservative or surgical intervention for fractures of the tibial spine, including the patient's age, size of the fragment, and amount of displacement. Surgical treatment usually can be done by arthroscopic reduction and fixation by screws or K-wires.

Fig. 5.21 The fibula functions as a splint or crutch to support the tibia.

Fig. 5.22 AO codes of the tibial diaphysis.

Tibial Diaphyseal Fractures (Segment 42)

Anatomic Features

The tibia is triangular in cross section, with proximal and distal flares. It has three surfaces, medial, lateral, and posterior, separated by three borders, anterior, medial, and lateral. This leg bone is thinnest in cross section at the junction of the middle and lower third, where fractures often occur. The anterior border, which begins at the tuberosity and ends below the anterior margin of the medial malleolus, is subcutaneous throughout its length. The tibial shaft bone is rigid, and can easily break through the skin to cause an open fracture if an injury occurs. As such, fractures of the tibia more commonly result in an open fracture than those of any other long bone. The intramedullary canal of the tibia is relatively straight longitudinally, and expands both proximally and distally. At the upper posterior surface of the tibia lies a prominent ridge, the soleal line, which extends obliquely from the superolateral to inferomedial. Although not able to withstand the weight of the body, the fibula functions as a splint or crutch to support the tibia (▶ Fig. 5.21).

AO Classification of Tibial Diaphyseal Fractures

Based on AO classification, the tibial diaphysis is coded as number "42" (▶ Fig. 5.22). Tibial diaphyseal fractures can be divided into three types based on individual fracture patterns: 42-A: simple fracture; 42-B: wedge fracture; and 42-C: complex fracture (▶ Fig. 5.23).

Clinical Epidemiologic Features of Tibial Diaphyseal Fractures (Segment 42)

A total of 15,000 adult tibial diaphyseal fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 24.75% of all tibial/fibular fractures in adults. Their epidemiologic features are as follows:

- More males than females
- The highest-risk age group is 41–45 years. The most affected age group of both males and females is 41–45 years.
- The most common fracture type among segment 42 fractures is type 42-A, the same fracture type for both males and females.
- The most common fracture group among segment 42 fractures is group 42-A1; group 42-B2 in males and group 42-A1 in females.

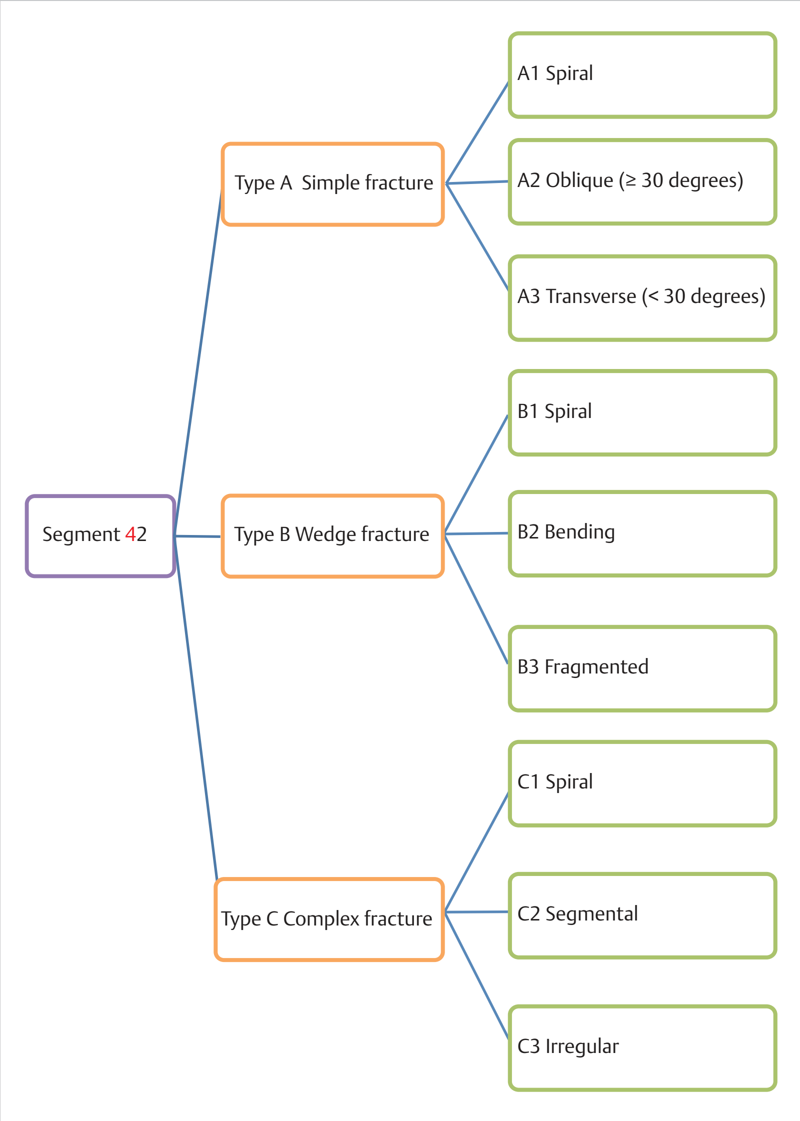


Fig. 5.23 Algorithm.

■ Fractures of Segment 42 by Sex

See ► Table 5.15 and ► Fig. 5.24.

Table 5.15 Sex distribution of 15,000 fractures of segment 42

Sex	Number of fractures	Percentage
Male	11,717	78.11
Female	3,283	21.89
Total	15,000	100.00

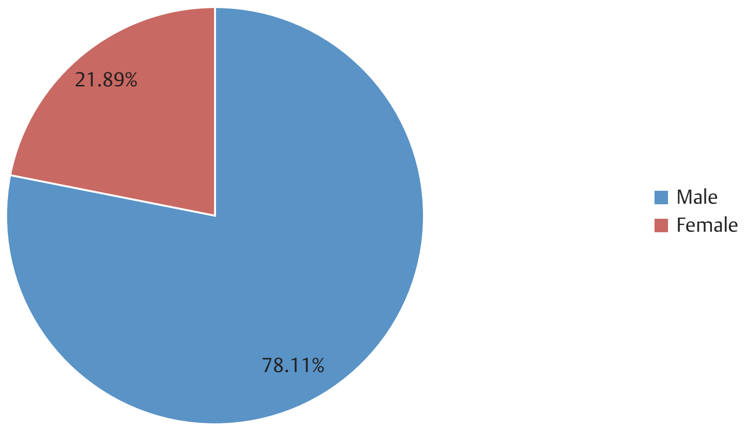


Fig. 5.24 Sex distribution of 15,000 fractures of segment 42.

■ Fractures of Segment 42 by Age Group

See ▶ Table 5.16 and ▶ Fig. 5.25.

Table 5.16 Sex and age distribution of 15,000 fractures of segment 42

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	948	195	1,143	7.62
21–25	1,365	299	1,664	11.09
26–30	1,211	235	1,446	9.64
31–35	1,246	271	1,517	10.11
36–40	1,574	411	1,985	13.23
41–45	1,686	485	2,171	14.47
46–50	1,249	392	1,641	10.94
51–55	975	272	1,247	8.31
56–60	719	241	960	6.40
61–65	338	168	506	3.37
66–70	167	108	275	1.83
71–75	110	71	181	1.21
76–80	68	74	142	0.95
81–85	41	36	77	0.51
≥ 86	20	25	45	0.30
Total	11,717	3,283	15,000	100.00

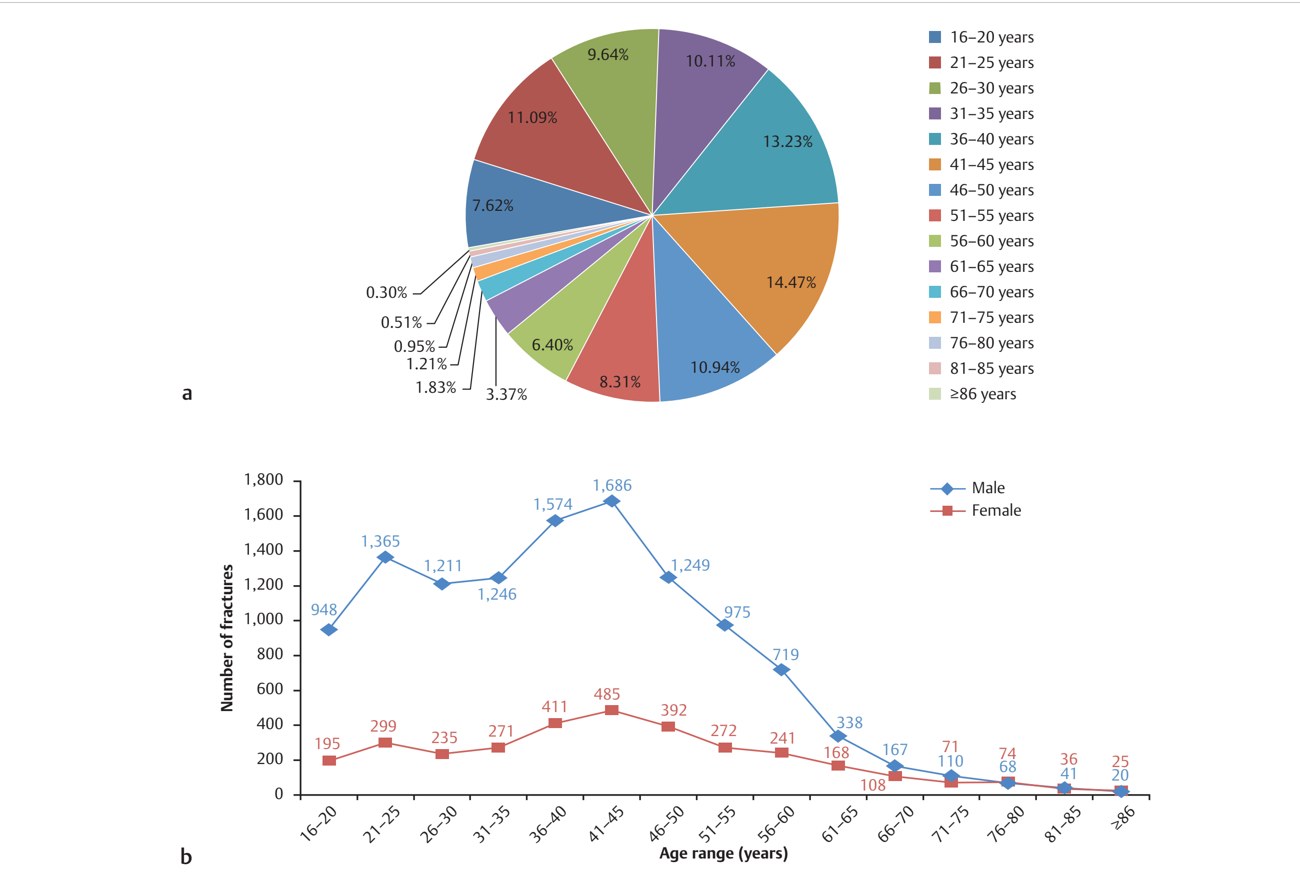


Fig. 5.25 (a) Age distribution of 15,000 fractures of segment 42. (b) Age and sex distribution of 15,000 fractures of segment 42.

■ Fractures of Segment 42 by Fracture Type

See ▶ Table 5.17, ▶ Table 5.18, ▶ Fig. 5.26, and ▶ Fig. 5.27.

Table 5.17 Sex and fracture type distribution of 15,000 fractures of segment 42

Fracture type	Male	Female	Number of fractures	Percentage
42-A	5,176	1,744	6,920	46.13
42-B	4,209	1,114	5,323	35.49
42-C	2,332	425	2,757	18.38
Total	11,717	3,283	15,000	100.00

Table 5.18 Sex and fracture group distribution of 15,000 fractures of segment 42

Fracture group	Male	Female	Number of fractures	Percentage of segment 42 fractures	Percentage of tibial/ fibular fractures
42-A1	1,881	889	2,770	18.47	4.57
42-A2	1,506	460	1,966	13.11	3.24
42-A3	1,789	395	2,184	14.56	3.60
42-B1	780	305	1,085	7.23	1.79
42-B2	2,072	542	2,614	17.43	4.31
42-B3	1,357	267	1,624	10.83	2.68
42-C1	404	89	493	3.29	0.81
42-C2	709	166	875	5.83	1.44
42-C3	1,219	170	1,389	9.26	2.29
Total	11,717	3,283	15,000	100.00	24.75

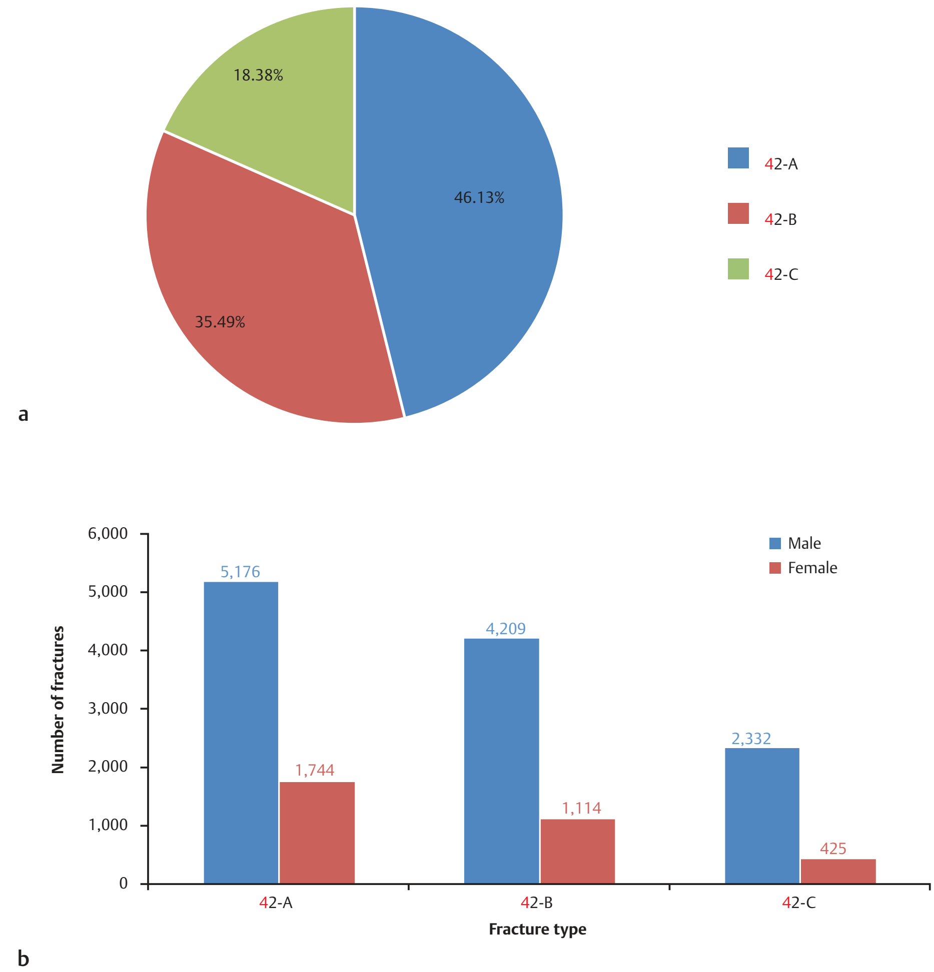


Fig. 5.26 (**a**) Fracture type distribution of 15,000 fractures of segment 42. (**b**) Sex and fracture type distribution of 15,000 fractures of segment 42.

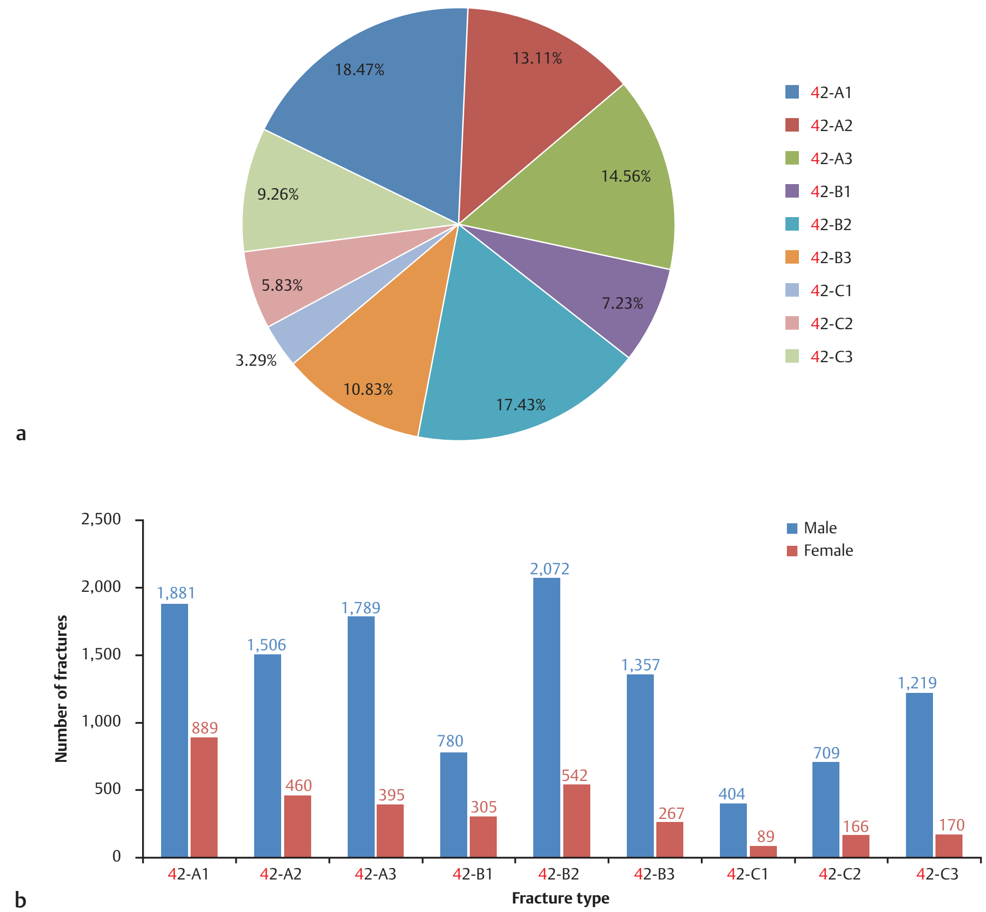
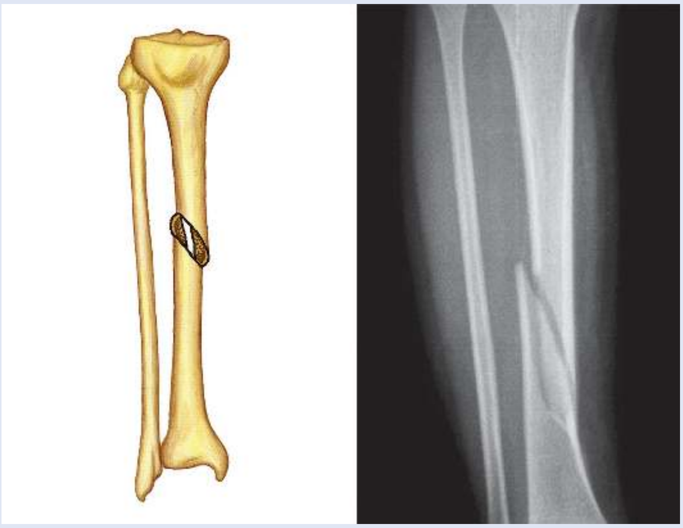


Fig. 5.27 (**a**) Fracture group distribution of 15,000 fractures of segment 42. (**b**) Sex and fracture group distribution of 15,000 fractures of segment 42.

42-A Tibia/fibula, diaphysis, simple fractures

42-A1 Spiral
2,770 fractures
M: 1,881 (67.91%)
F: 889 (32.09%)
0.74% of total adult fractures
4.57% of adult tibial/fibular fractures
18.47% of segment 42
40.03% of type 42-A

42-A1.1 Fibula intact



42-A1.2 Tibia and fibula fractures at different level

42-A1.3 Tibia and fibula fractures at the same level

42-A Tibia/fibula, diaphysis, simple fractures

42-A2 Oblique (≥ 30 degrees)
1,966 fractures
M: 1,506 (76.60%)
F: 460 (23.40%)
0.53% of total adult fractures
3.24% of adult tibial/fibular fractures
13.11% of segment 42
28.41% of type 42-A

42-A2.1 Fibula intact

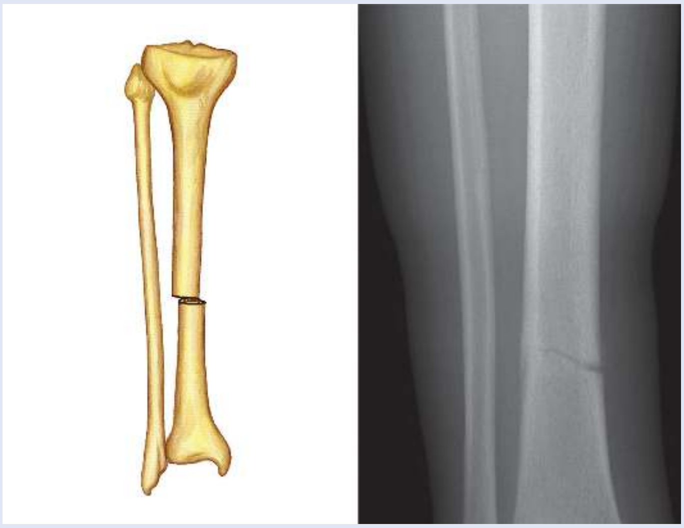
42-A2.2 Tibial and fibular fractures at different levels

42-A2.3 Tibial and fibular fractures at the same level

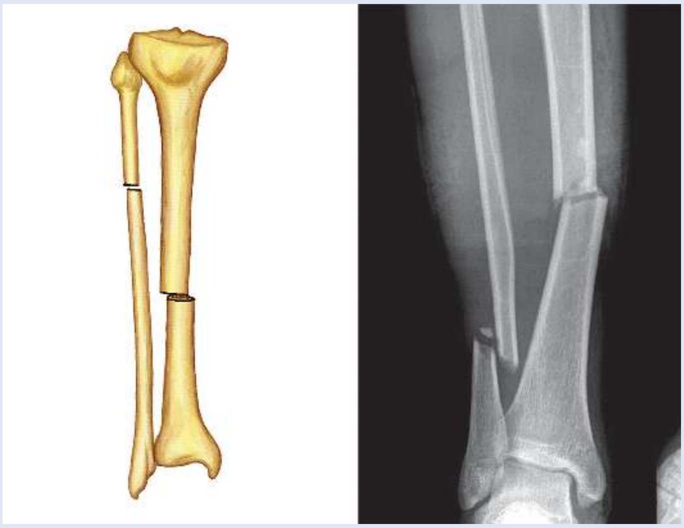
42-A Tibia/fibula, diaphysis, simple fractures

42-A3 Transverse (<30 degrees)
2,814 fractures
M: 1,789 (81.91%)
F: 395 (18.09%)
0.58% of total adult fractures
3.60% of adult tibial/fibular fractures
14.56% of segment 42
31.56% of type 42-A

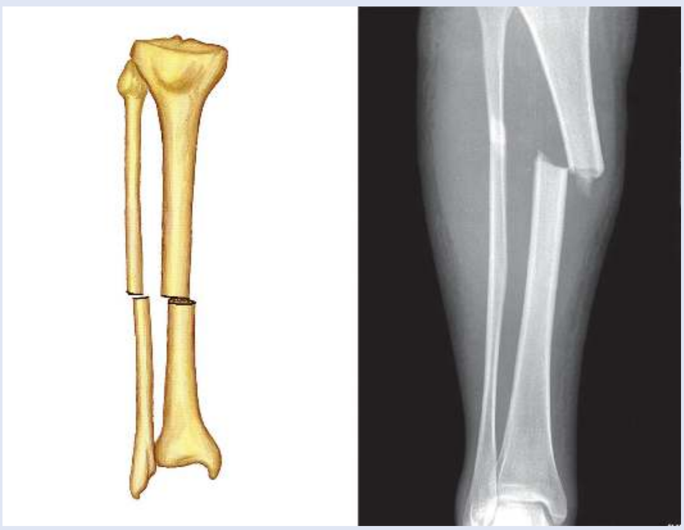
42-A3.1 Fibula intact



42-A3.2 Tibial and fibular fractures at different levels



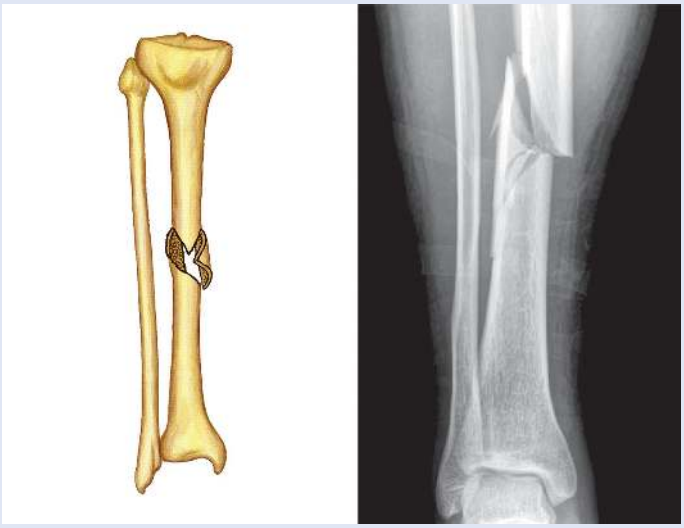
42-A3.3 Tibial and fibular fractures at the same level



42-B Tibia/fibula, diaphysis, wedge fractures

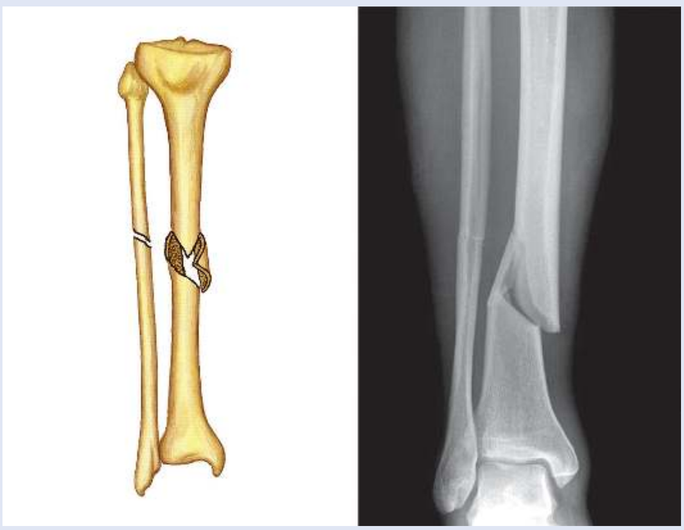
42-B1 Spiral
1,085 fractures
M: 780 (71.89%)
F: 305 (28.11%)
0.29% of total adult fractures
1.79% of adult tibial/fibular fractures
7.23% of segment 42
20.38% of type 42-B

42-B1.1 Fibula intact



42-B1.2 Tibial and fibular fractures at different levels

42-B1.3 Tibial and fibular fractures at the same level

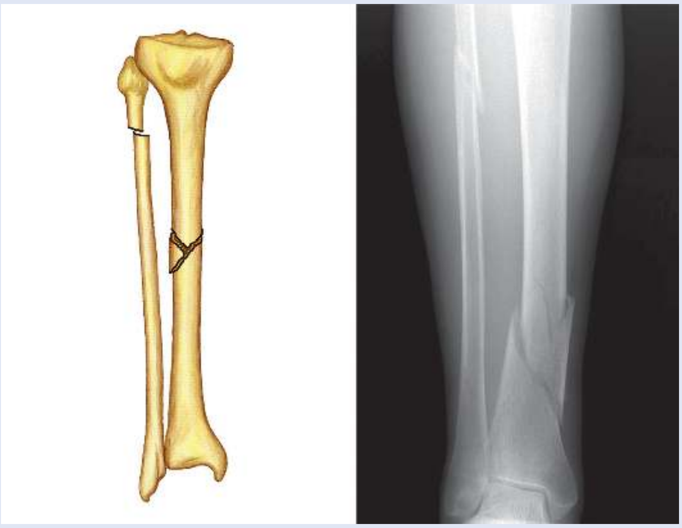


42-B Tibia/fibula, diaphysis, wedge fractures

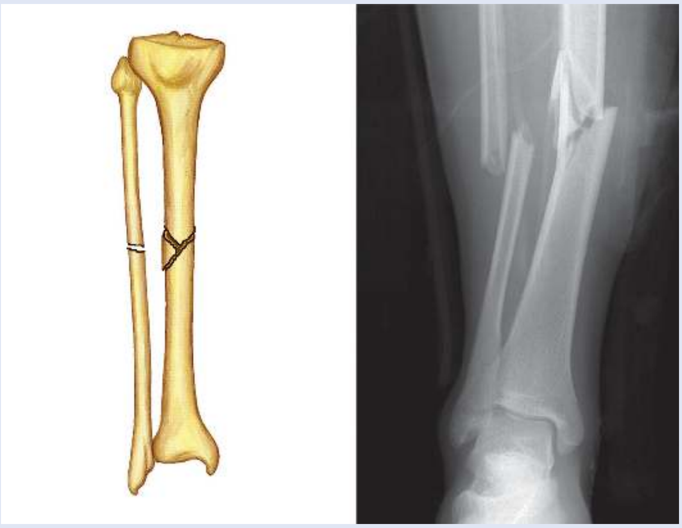
42-B2 Bending
2,614 fractures
M: 2,072 (79.27%)
F: 542 (20.73%)
0.70% of total adult fractures
4.31% of adult tibial/fibular fractures
17.43% of segment 42
49.11% of type 42-B

42-B2.1 Fibula intact

42-B2.2 Tibial and fibular fractures at different levels



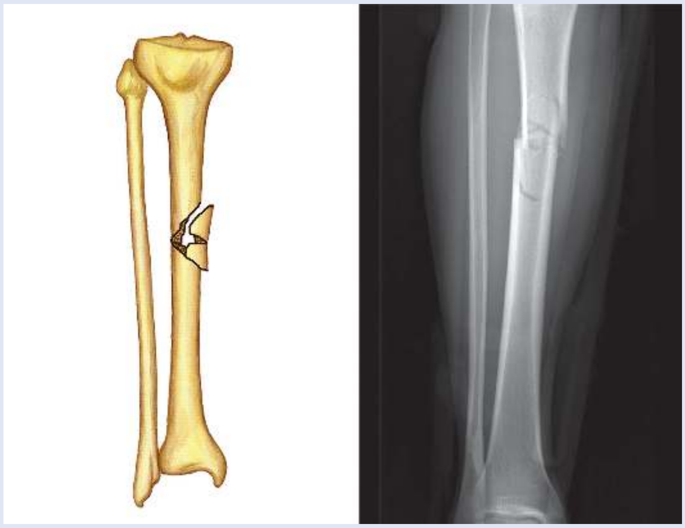
42-B2.3 Tibial and fibular fractures at the same level



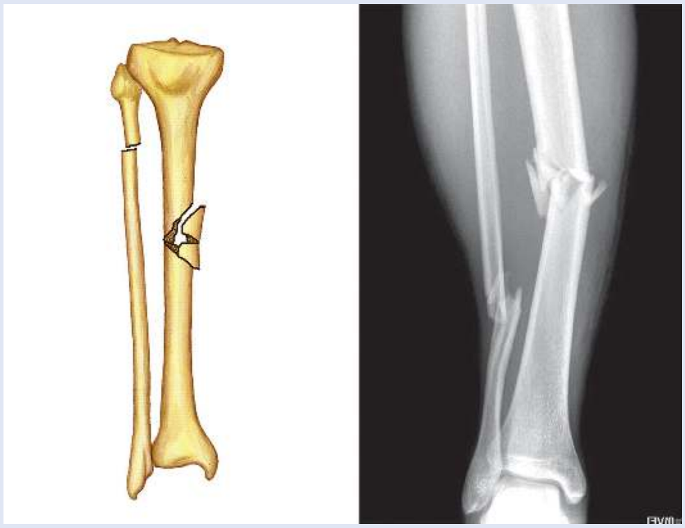
42-B Tibia/fibula, diaphysis, wedge fractures

42-B3 Fragmented
1,624 fractures
M: 1,357 (83.56%)
F: 267 (16.44%)
0.43% of total adult fractures
2.68% of adult tibial/fibular fractures
10.83% of segment 42
30.51% of type 42-B

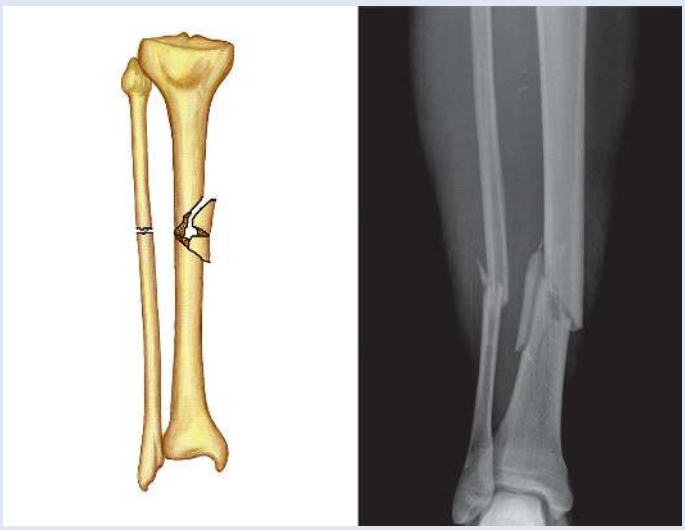
42-B3.1 Fibula intact



42-B3.2 Tibial and fibular fractures at different levels



42-B3.3 Tibial and fibular fractures at the same level



42-C Tibia/fibula, diaphysis, complex fractures

42-C1 Spiral
493 fractures
M: 404 (81.95%)
F: 89 (18.05%)
0.13% of total adult fractures
0.81% of adult tibial/fibular fractures
3.29% of segment 42
17.88% of type 42-C

42-C1.1 With two intermediate fragments

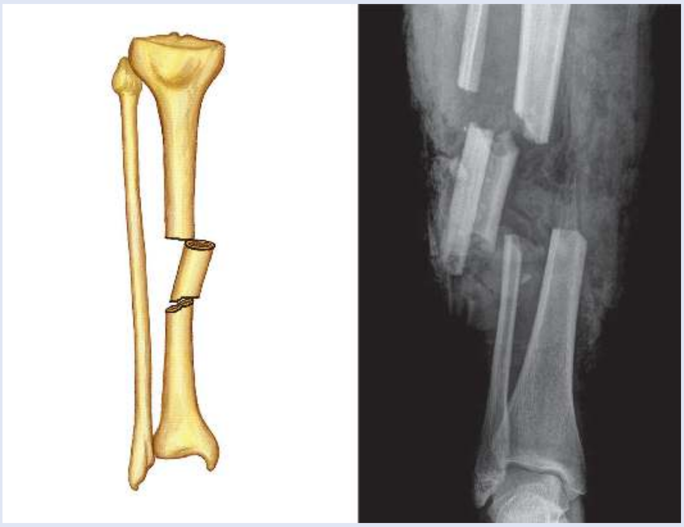
42-C1.2 With three intermediate fragments

42-C1.3 With more than three intermediate fragments

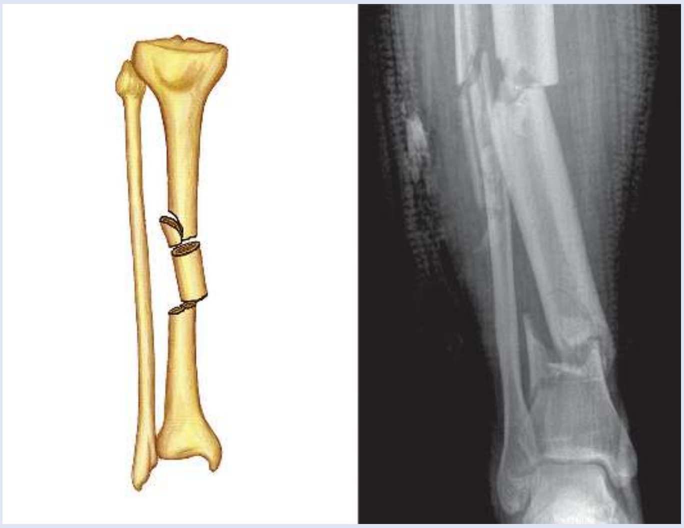
42-C Tibia/fibula, diaphysis, complex fractures

42-C2 Segmental
875 fractures
M: 709 (81.03%)
F: 166 (18.97%)
0.23% of total adult fractures
1.44% of adult tibial/fibular fractures
5.83% of segment 42
31.74% of type 42-C

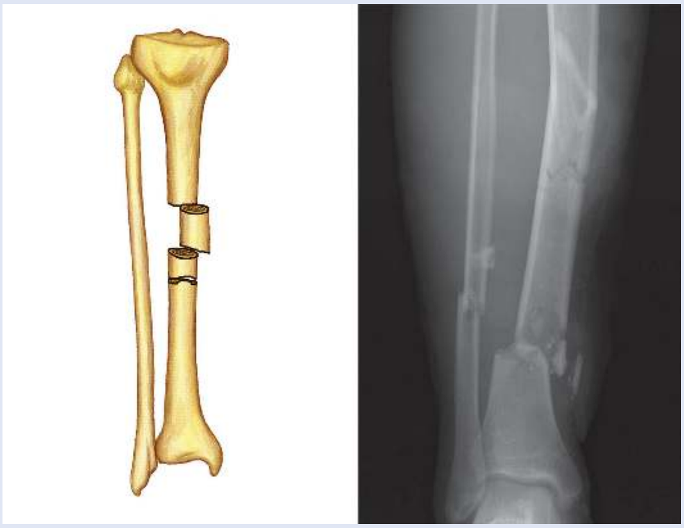
42-C2.1 With one intermediate fragment



42-C2.2 With one intermediate fragment and an additional wedge fragment



42-C2.3 With two intermediate fragments



42-C Tibia/fibula, diaphysis, complex fractures

42-C3 Irregular
1,389 fractures
M: 1,219 (87.76%)
F: 170 (12.24%)
0.37% of total adult fractures
2.29% of adult tibial/fibular fractures
9.26% of segment 42
50.38% of type 42-C

42-C3.1 With two or three intermediate fragments

42-C3.2 With limited shattering (< 4 cm)

42-C3.3 With extensive shattering (≥ 4 cm)

Injury Mechanism

The mechanism of a diaphyseal tibial fracture can be direct or indirect. Direct mechanisms of injury lead to high-energy fractures resulting from, for example, violent blows, motor vehicle crashes, being crushed by heavy objects, etc. High-energy insults produce transverse, short oblique, or comminuted displaced diaphyseal fractures with a high incidence of compound and soft-tissue injuries. Indirect mechanisms lead to low-energy injuries, which produce spiral, nondisplaced, and minimally comminuted fractures with minimal soft-tissue damage.

Diagnosis

A thorough physical examination should be conducted to assess soft-tissue damage, deformity of the affected limb, and stability of the fracture. Special attention should be given to assessment of neurovascular status and the presence of compartment syndrome. Standard AP and lateral views of the injured leg are invaluable in identifying the location and type of fracture. The ipsilateral knee and ankle are also often radiographically imaged because concomitant injury to one or both of these joints is common. Injury is especially likely when the deformity or point tenderness of the tibia and fibula are is at the same level, or if a fracture of the proximal fibula is suspected. Fractures of the distal third of the tibia are often associated with posterior malleolar fractures. If there is obvious point tenderness over the posterior malleolus but X-ray films are normal, CT or MRI should be considered to detect the evidence of fractures.

Treatment

The goals in treatment of diaphyseal tibial fractures are to correct angulation and deformity, and to restore normal alignment, length, and joint congruity. Closed fractures with minimal displacement or stable reduction may be treated nonoperatively with a long leg cast. Operative fixation is required when fractures are unstable. A few fixation methods are widely used, including intramedullary nailing, plating (locking compression plate or U-grooved locking compression plate), and external fixation, the choice of which is based on the fracture type and the severity of the soft-tissue damage. When plating tibial shaft fractures, an anterolateral surgical incision should be used. The standard site for tibial plating is the lateral surface of the bone, due to the fact that skin lesions occur most frequently on the anteromedial side, because that the medial surface is covered only with a layer of skin. Severe open tibial fractures should be treated primarily by external fixation, and converted to internal fixation only when the swelling of the soft tissue is diminished and the patient becomes stable. If there is a skin defect, a skin graft, or a free skin flap, a vascular pedicle flap can be used to cover the wound and reconstruct the defect. Since increased nonunion and healing times have been associated with tibial fractures, bone grafting, in addition to surgical reduction and internal fixation, is frequently used to augment the bone-healing process.

Distal Tibial Fractures (Segment 43)

Anatomical Features

The lower end of the tibia expands and becomes quadrilateral-shaped. It has five surfaces: anterior, posterior, inferior, lateral, and medial. The anterior surface is smooth and covered by tendons of the extensor muscles; its lower margin presents a rough transverse depression for the attachment of the articular capsule of the ankle joint. The medial surface is convex and rough, and continues downward into a triangular process called the medial malleolus. On the posterior surface there are two grooves for passage of the flexor hallucis longus tendon. The lateral surface has a triangular rough depression, the lower part of which is called the fibular notch, where the tibia articulates with the fibula. The anterior and posterior margins of the fibular notch give attachment to the anterior and posterior tibiofibular ligaments, respectively. The inferior surface is four-sided, slightly concave, and smooth, for articulation with the talus. Its posterior margin, called the posterior malleolus, is slightly elevated to prevent posterior dislocation of the talus.

AO Classification of Distal Tibial Fractures

Based on AO classification, the distal tibia is coded as number "43" (▶ Fig. 5.28). Distal tibial fractures can be divided into three types depending on articular involvement: 43-A: extra-articular fracture, 43-B: partial articular fracture, and 43-C: complete articular fracture (▶ Fig. 5.29).

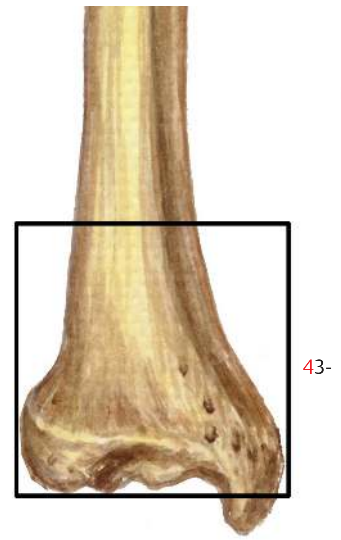


Fig. 5.28 AO code of the distal tibia.

Clinical Epidemiologic Features of Distal Tibial Fractures (Segment 43)

A total of 6,391 distal tibial fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 10.54% of all tibial/fibular fractures in adults. Their epidemiologic features are as follows:

- More males than females
- The highest-risk age group is 41–45 years. The most affected male age group is 41–45 years, while females in the age group 51–60 years have the highest risk.
- The most common fracture type among segment 43 fractures is type 43-A, the same fracture type for both males and females.
- The most common fracture group among segment 43 fractures is group 43-A2, the same fracture group for both males and females.

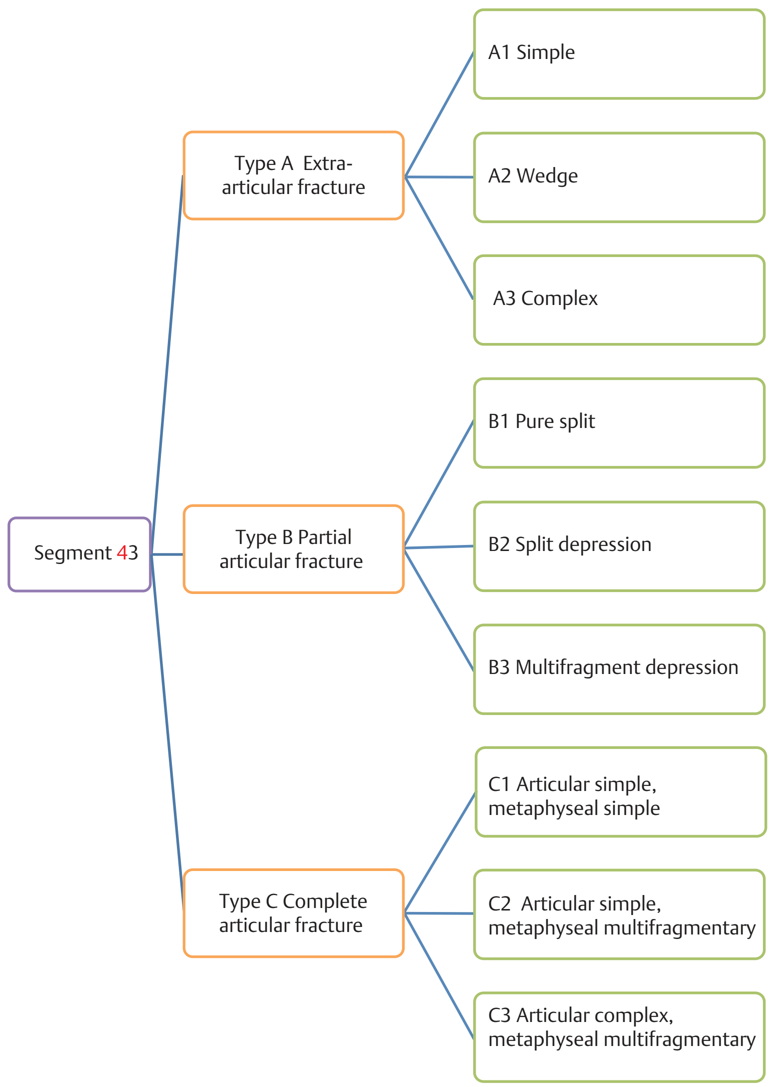


Fig. 5.29 Algorithm.

■ Fractures of Segment 43 by Sex

See ▶ Table 5.19 and ▶ Fig. 5.30.

Table 5.19 Sex distribution of 6,391 fractures of segment 43

Sex	Number of fractures	Percentage
Male	4,445	69.55
Female	1,946	30.45
Total	6,391	100.00

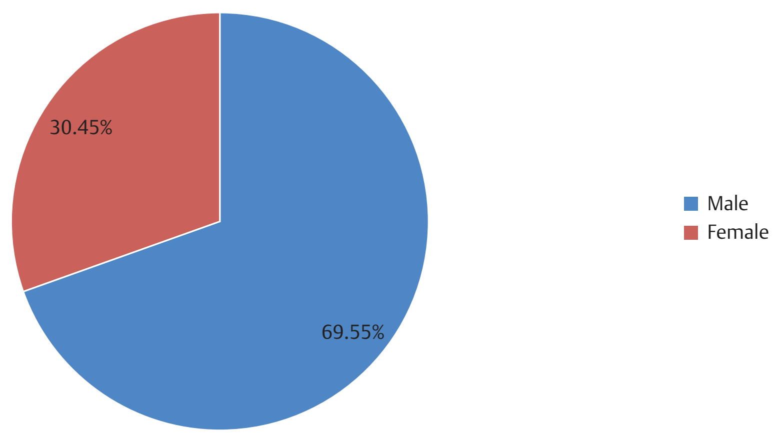


Fig. 5.30 Sex distribution of 6,391 fractures of segment 43.

■ Fractures of Segment 43 by Age Group

See ▶ Table 5.20 and ▶ Fig. 5.31.

Table 5.20 Age and sex distribution of 6,391 fractures of segment 43

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	265	47	312	4.88
21–25	320	104	424	6.63
26–30	403	120	523	8.18
31–35	491	127	618	9.67
36–40	631	200	831	13.00
41–45	713	213	926	14.49
46–50	527	213	740	11.58
51–55	384	213	597	9.34
56–60	296	226	522	8.17
61–65	190	138	328	5.13
66–70	83	122	205	3.21
71–75	64	81	145	2.27
76–80	39	60	99	1.55
81–85	27	49	76	1.19
≥ 86	12	33	45	0.70
Total	4,445	1,946	6,391	100.00

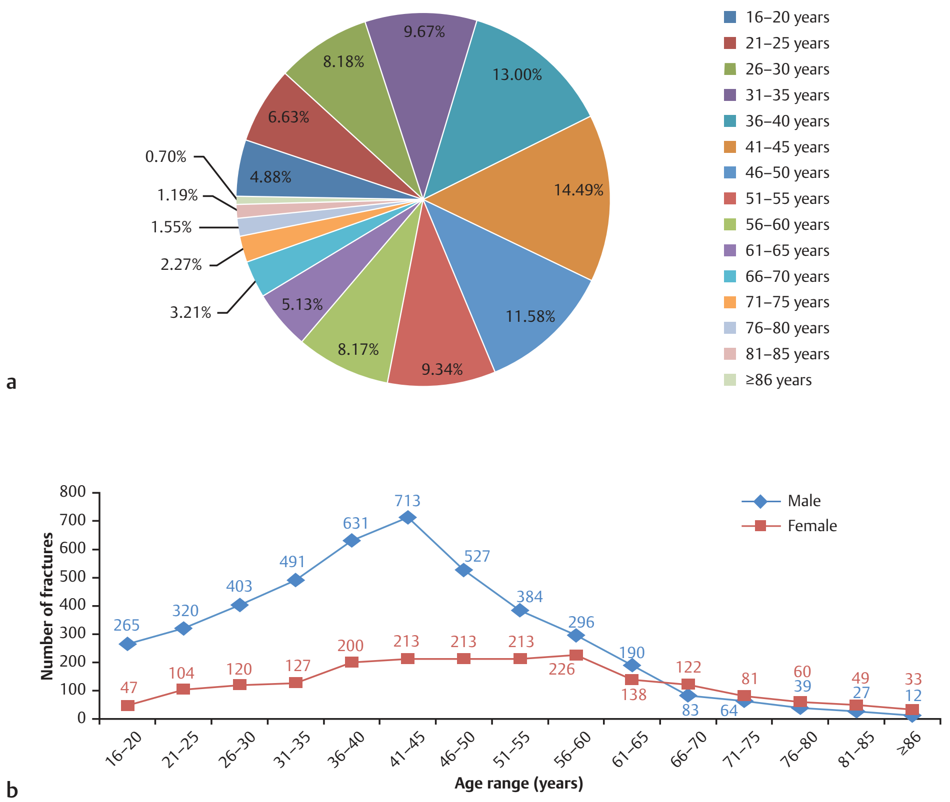


Fig. 5.31 (a) Age distribution of 6,391 fractures of segment 43. (b) Age and sex distribution of 6,391 fractures of segment 43.

■ Fractures of Segment 43 by Fracture Type

See ▶ Table 5.21, ▶ Table 5.22, ▶ Fig. 5.32, and ▶ Fig. 5.33.

Table 5.21 Sex and fracture type distribution of 6,391 fractures of segment 43

Fracture type	Male	Female	Number of fractures	Percentage
43-A	1,731	796	2,527	39.54
43-B	1,264	732	1,996	31.23
43-C	1,450	418	1,868	29.23
Total	4,445	1,946	6,391	100.00

Table 5.22 Sex and fracture group distribution of 6,391 fractures of segment 43

Fracture group	Male	Female	Number of fractures	Percentage of segment 43 fractures	Percentage of adult tibial/fibular fractures
43-A1	511	289	800	12.52	1.32
43-A2	541	259	800	12.52	1.32
43-A3	679	248	927	14.50	1.53
43-B1	827	519	1,346	21.06	2.22
43-B2	252	134	386	6.04	0.64
43-B3	185	79	264	4.13	0.44
43-C1	256	108	364	5.70	0.60
43-C2	521	150	671	10.50	1.11
43-C3	673	160	833	13.03	1.37
Total	4,445	1,946	6,391	100.00	10.54

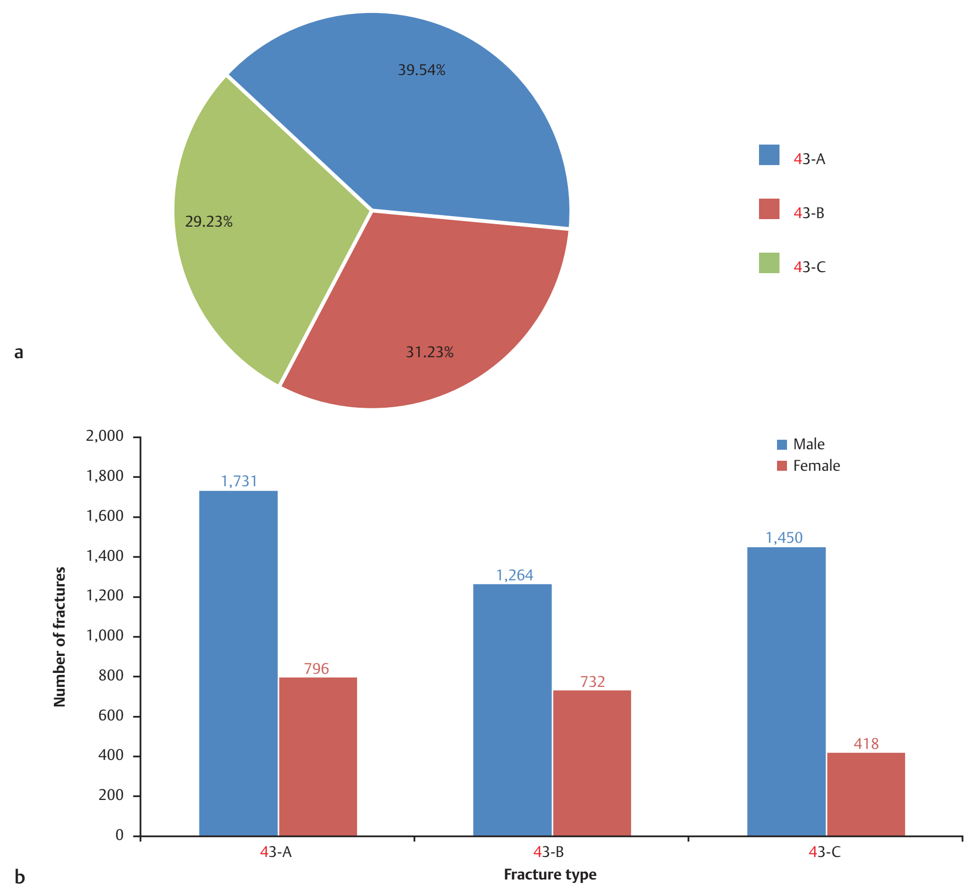


Fig. 5.32 (a) Fracture type distribution of 6,391 fractures of segment 43. (b) Sex and fracture type distribution of 6,391 fractures of segment 43.

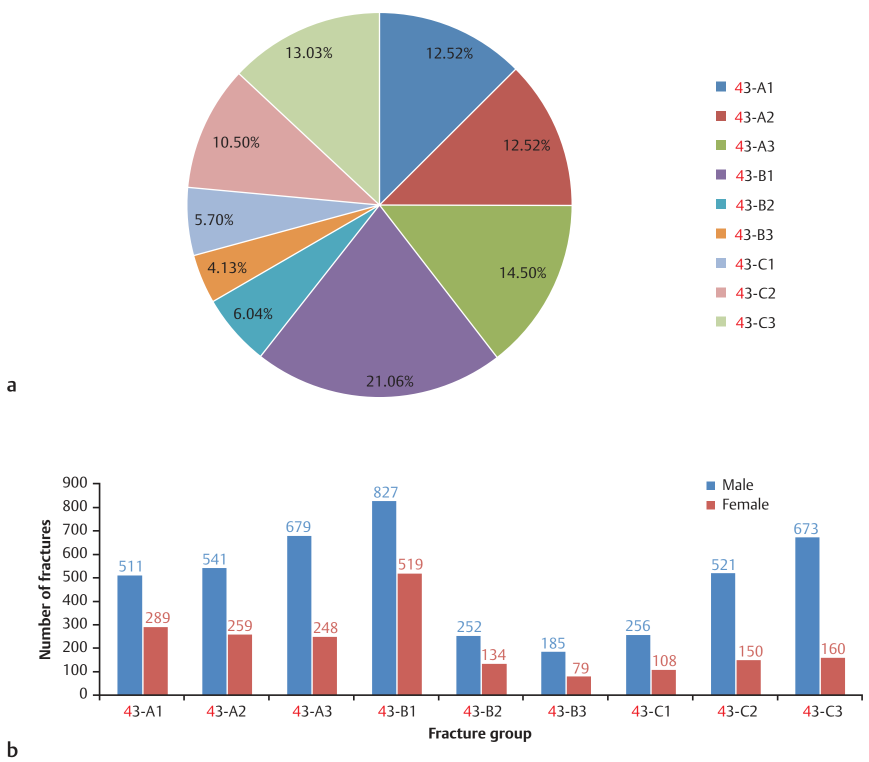
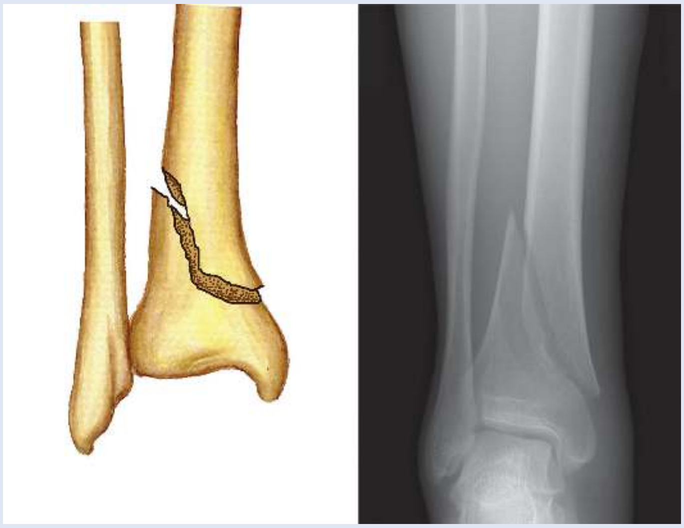


Fig. 5.33 (a) Fracture group distribution of 6,391 fractures of segment 43. (b) Sex and fracture group distribution of 6,391 fractures of segment 43.

43-A Tibia/fibula, extra-articular fractures

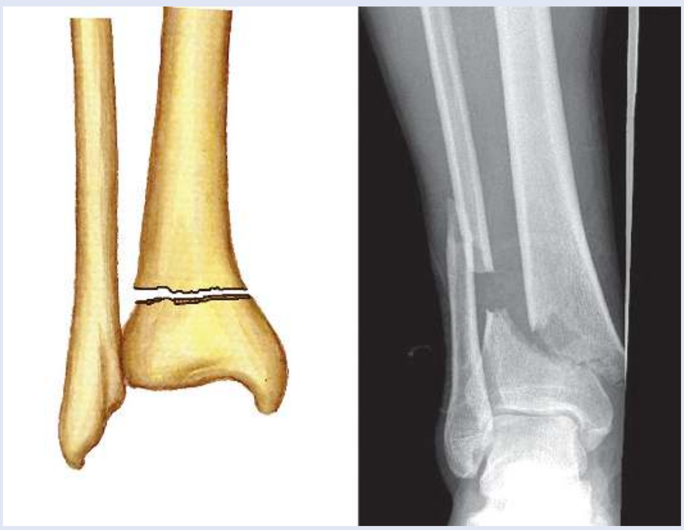
43-A1 Simple
800 fractures
M: 511 (63.88%)
F: 289 (36.13%)
0.21% of total adult fractures
1.32% of adult tibial/fibular fractures
12.52% of segment 43
31.66% of type 43-A

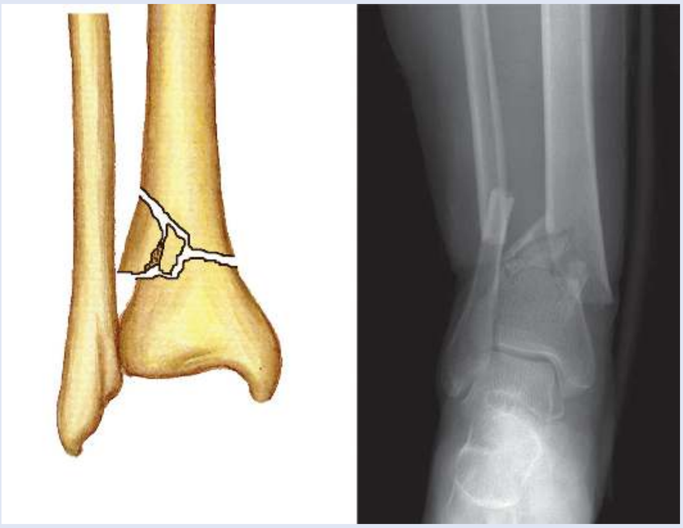
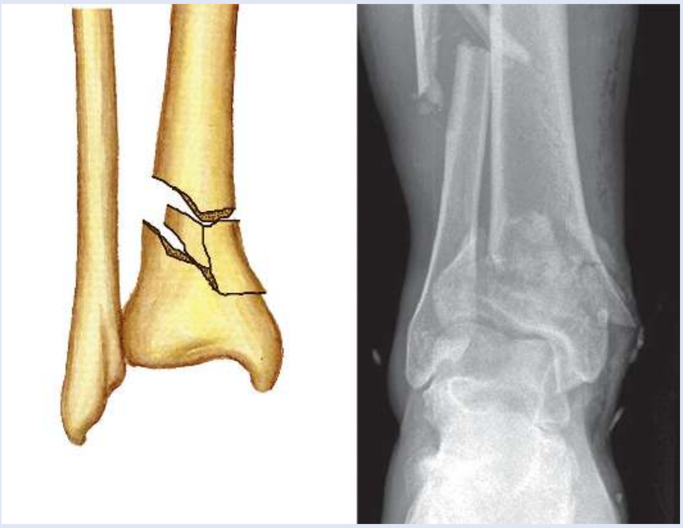
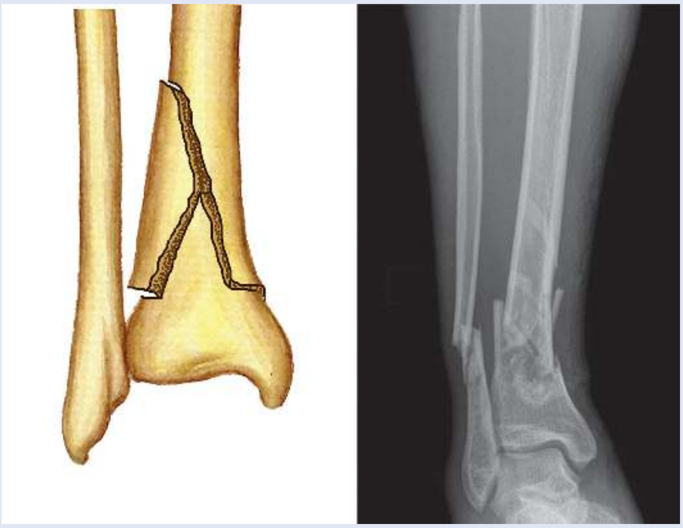
43-A1.1 Spiral

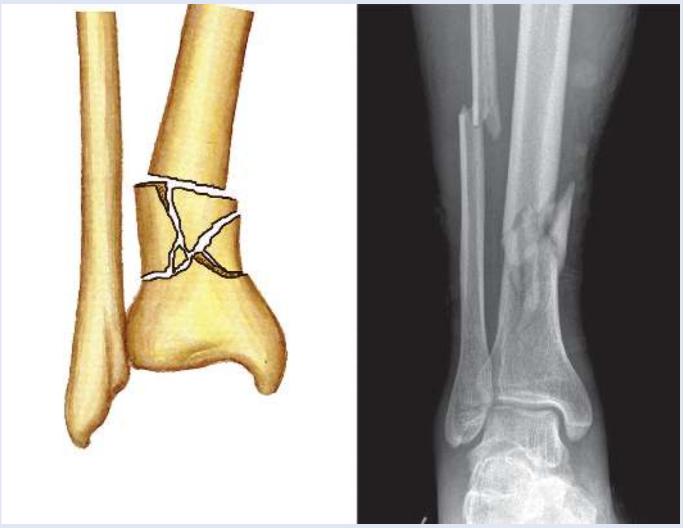
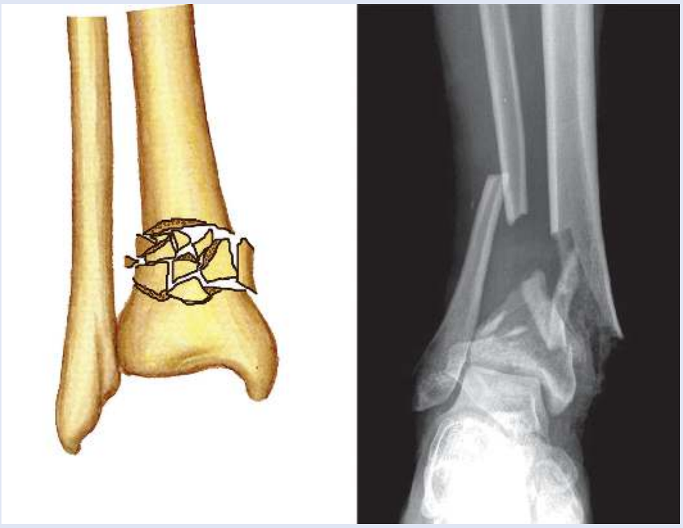
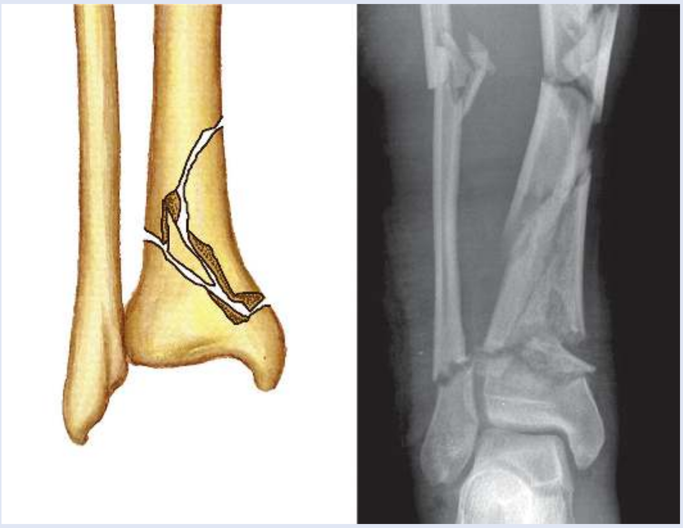


43-A1.2 Oblique

43-A1.3 Transverse



43-A Tibia/fibula, extra-articular fractures	
43-A2 Wedge 800 fractures M: 541 (67.32%) F: 259 (32.37%) 0.21% of total adult fractures 1.32% of adult tibial/fibular fractures 12.52% of segment 43 31.66% of type 43-A	**43-A2.1** Posterolateral wedge  **43-A2.2** Anteromedial wedge  **43-A2.3** Fracture line extending into the diaphysis 

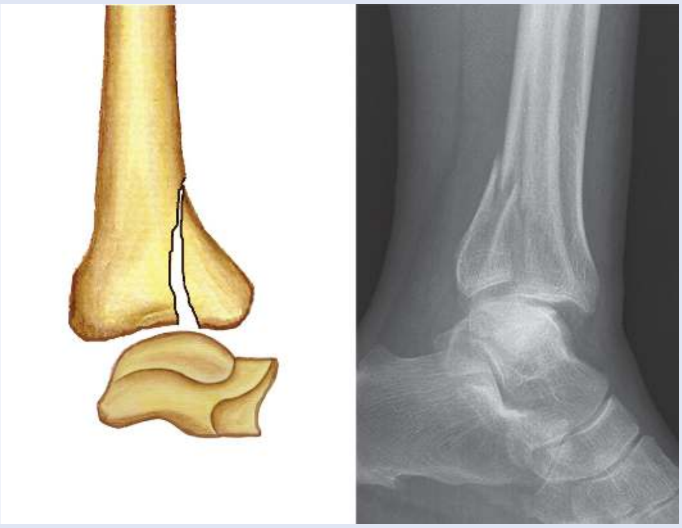
43-A Tibia/fibula, extra-articular fractures	
43-A3 Complex 927 fractures M: 679 (73.25%) F: 248 (26.75%) 0.25% of total adult fractures 1.53% of adult tibial/fibular fractures 14.50% of segment 43 36.68% of type 43-A	**43-A3.1** With three intermediate fragments  **43-A3.2** With more than three intermediate fragments  **43-A3.3** Fracture line extending into the diaphysis 

5

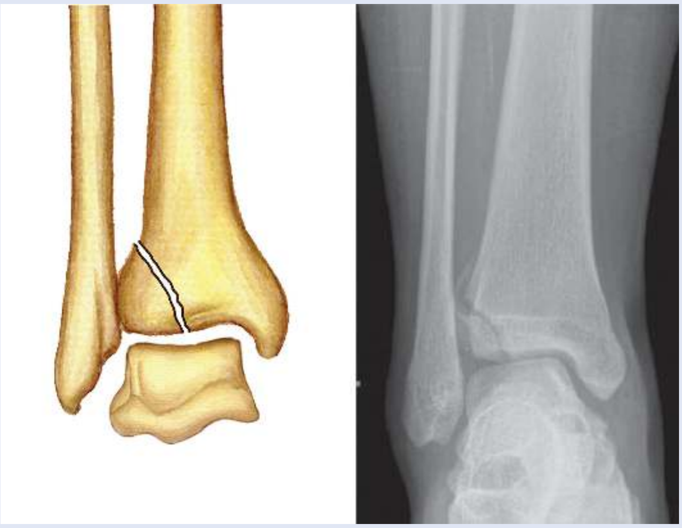
43-B Tibia/fibula, partial-articular fractures

43-B1 Pure split
1,346 fractures
M: 827 (61.44%)
F: 159 (38.56%)
0.36% of total adult fractures
2.22% of adult tibial/fibular fractures
21.06% of segment 43
67.43% of type 43-B

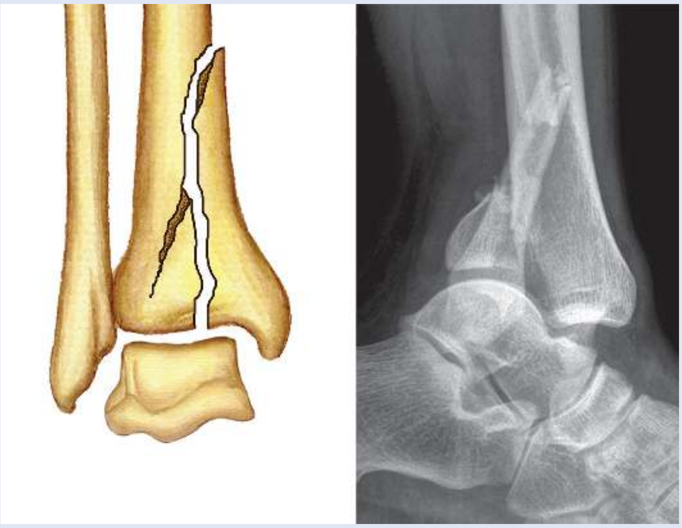
43-B1.1 Frontal



43-B1.2 Sagittal



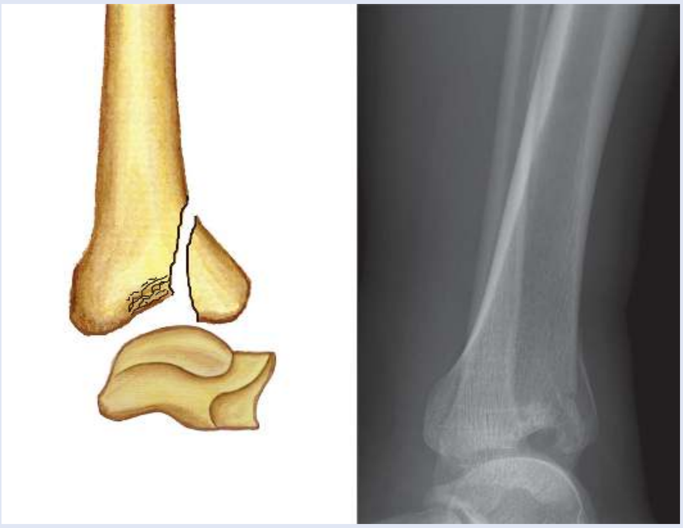
43-B1.3 Metaphyseal multifragmentary



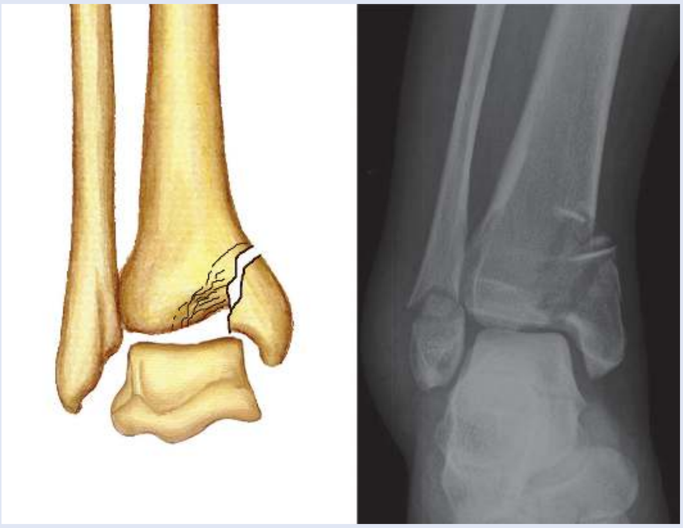
43-B Tibia/fibula, partial-articular fractures

43-B2 Split depression
386 fractures
M: 252 (65.28%)
F: 134 (34.72%)
0.10% of total adult fractures
0.64% of adult tibial/fibular fractures
6.04% of segment 43
19.34% of type 43-B

43-B2.1 Frontal



43-B2.2 Sagittal

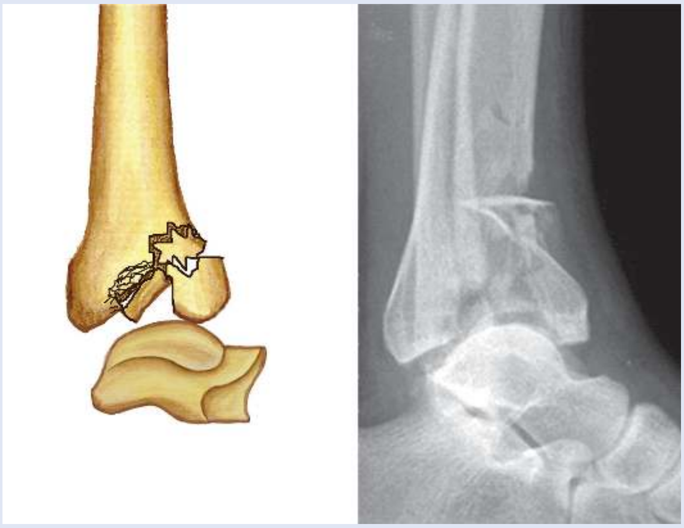


43-B2.3 With central fragment

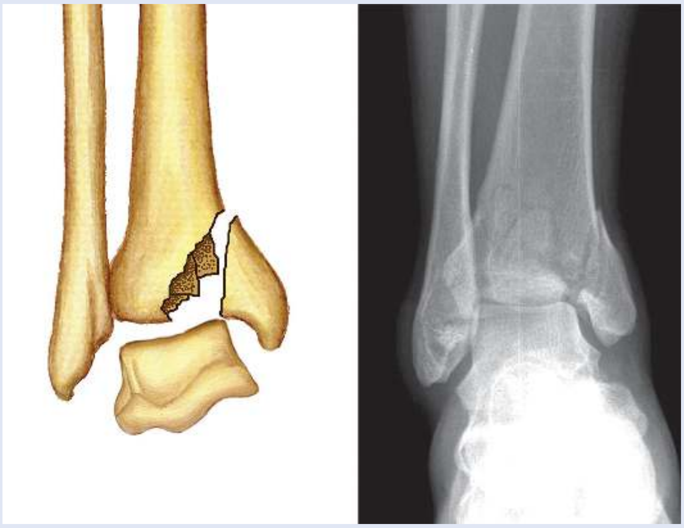
43-B Tibia/fibula, partial-articular fractures

43-B3 Multifragmentary depression
264 fractures
M: 185 (70.08%)
F: 79 (29.92%)
0.07% of total adult fractures
0.44% of adult tibial/fibular fractures
4.13% of segment 43
13.23% of type 43-B

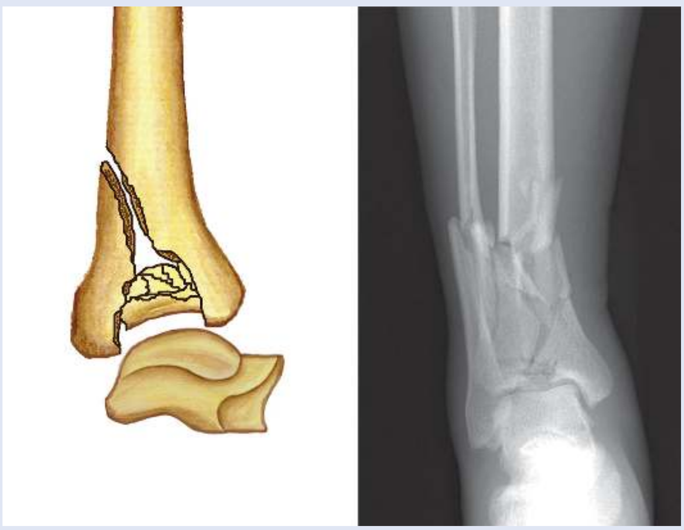
43-B3.1 Frontal



43-B3.2 Sagittal



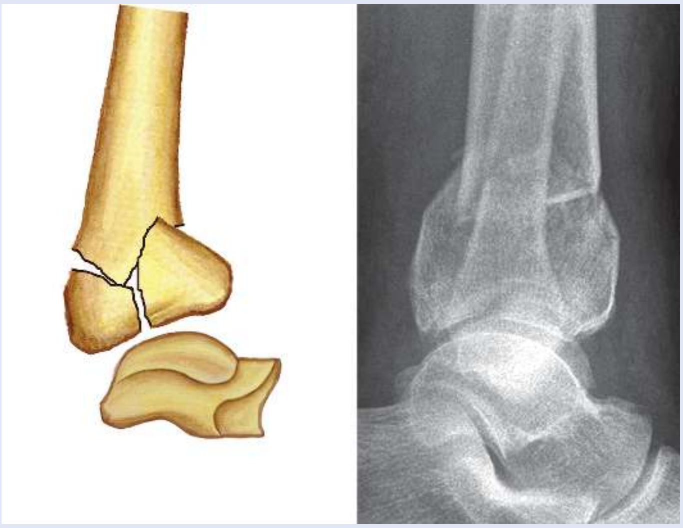
43-B3.3 Metaphyseal multifragmentary



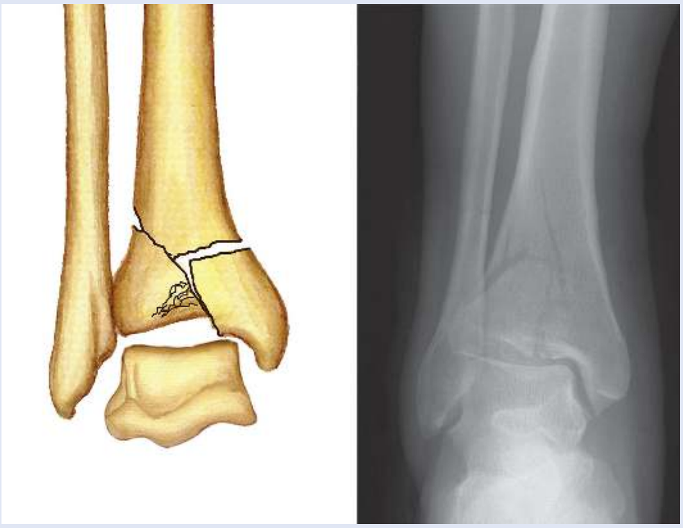
43-C Tibia/fibula, complete articular fractures

43-C1 Articular simple, metaphyseal simple
364 fractures
M: 256 (70.33%)
F: 108 (29.67%)
0.10% of total adult fractures
0.60% of adult tibial/fibular fractures
5.70% of segment 43
19.49% of type 43-C

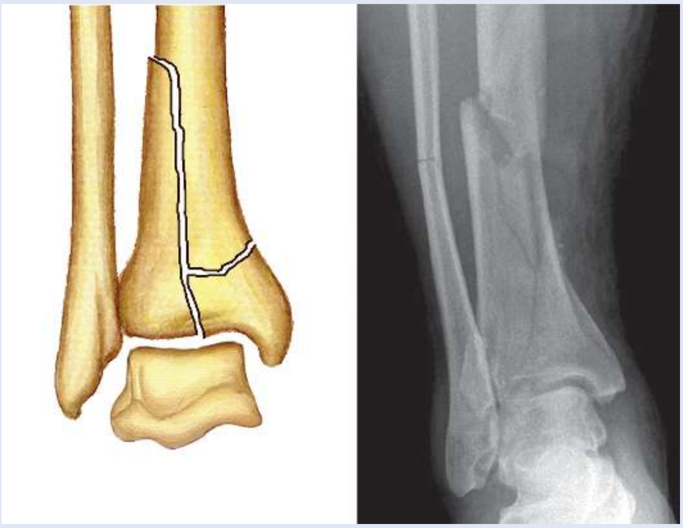
43-C1.1 Without depression



43-C1.2 With depression



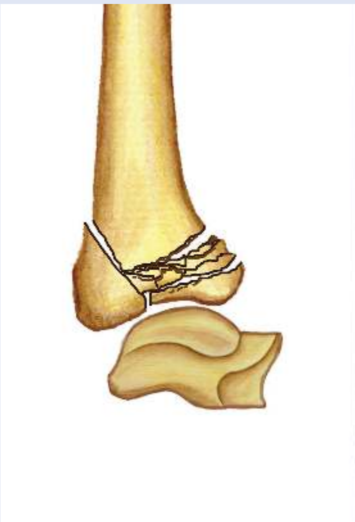
43-C1.3 Fracture line extending into the diaphysis



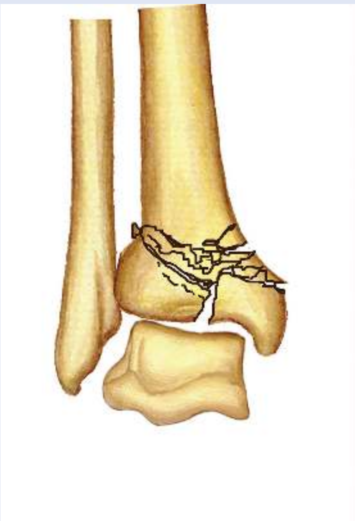
43-C Tibia/fibula, complete articular fractures

43-C2 Articular simple, metaphyseal multifragmentary
671 fractures
M: 521 (77.65%)
F: 150 (22.35%)
0.18% of total adult fractures
1.11% of adult tibial/fibular fractures
10.50% of segment 43
35.92% of type 43-C

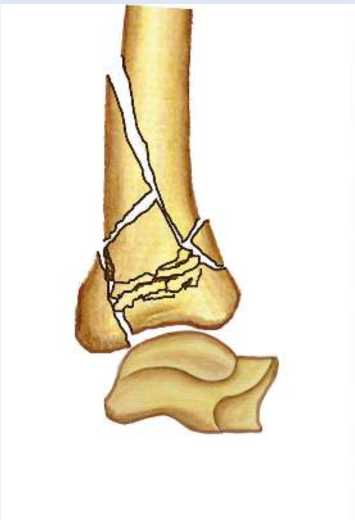
43-C2.1 With asymmetric impaction



43-C2.2 Without asymmetric impaction



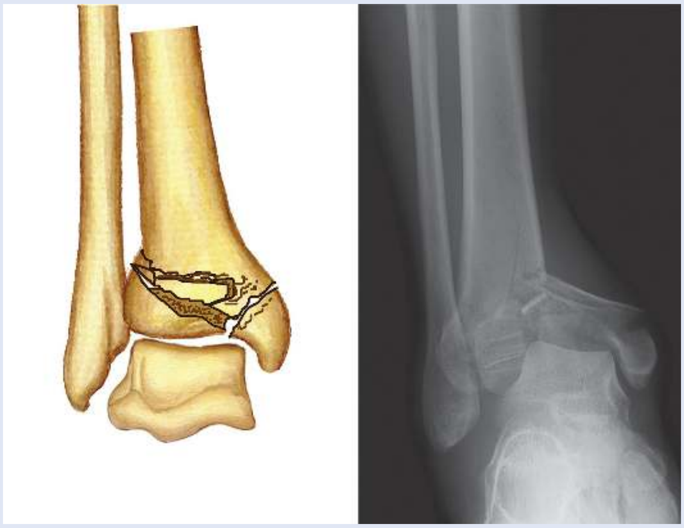
43-C2.3 Fracture line extending into the diaphysis



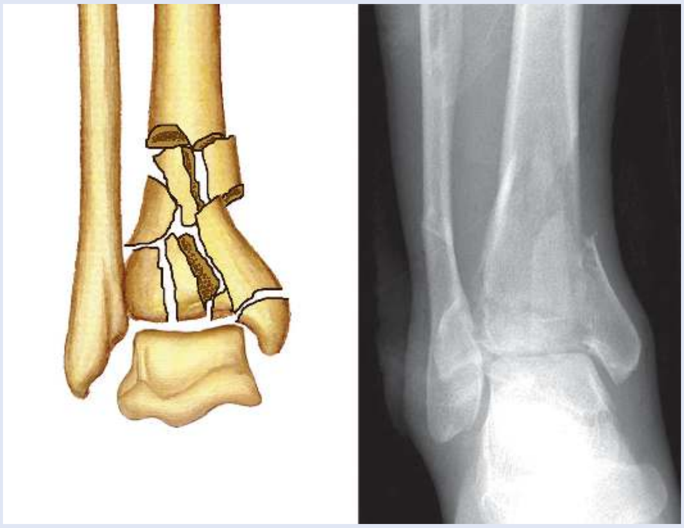
43-C Tibia/fibula, complete articular fractures

43-C3 Metaphyseal multifragmentary
833 fractures
M: 673 (80.79%)
F: 160 (19.21%)
0.22% of total adult fractures
1.37% of adult tibial/fibular fractures
13.03% of segment 43
44.59% of type 43-C

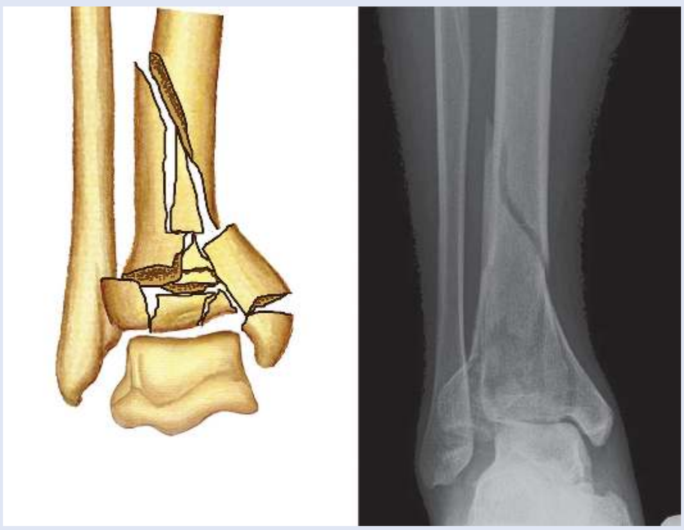
43-C3.1 Epiphyseal



43-C3.2 Epiphyseal + metaphyseal



43-C3.3 Epiphyseal, metaphyseal, and diaphyseal



Injury Mechanism

Mechanisms of injury for tibial/fibular fractures can be divided into two categories: low-energy injuries such as ground-level falls and athletic injuries involving twisting motions (accompanied by rotational force) that can produce spiral fractures; and high-energy injuries such as falls from a significant height and motor vehicle injuries. In either case, the resulting axial load forces transmitted through the talus to the distal tibia can cause depression of the articular surface and/or a split fracture of the distal tibia.

Diagnosis

Distal tibial fractures present with localized pain and swelling during the early stages of symptoms. The swelling may spread down to the ankle joint at a later time. Swelling, tenderness, and ecchymosis over the area of the Achilles tendon often suggest fracture of the posterior malleolus. The anteromedial surface of the tibia is subcutaneous, and the state of the skin and subcutaneous tissue is of enormous importance in influencing the wound-healing process. A careful assessment of skin, soft tissue, and neurovascular status should be performed early.

Radiographic examination should include a standard AP, lateral, and mortise views (taken with the foot/ankle at 15 degrees of internal rotation) of the ankle joint. If necessary, additional X-ray films can be taken when the foot/ankle is held in external rotation at 45 degrees to visualize the anteromedial and posterolateral surface of the tibia. CT can further help to evaluate the degree of articular comminution and extent of articular depression.

Treatment

Several factors influence the treatment of distal tibial fractures, including age, general medical condition, severity of soft-tissue injury, and fracture pattern. Closed fractures with minimal displacement or stable reduction can be managed successfully by nonsurgical treatment. Surgical intervention is indicated when fractures are unstable. Operative fixation methods include: screws, plating, a locking compression plate, and circular ring external fixation. The principle of open reduction and internal fixation is: (1) restoration of the length of the fibula; (2) reconstruction of the articular surface of the distal tibia; (3) bone grafting to ensure adequate bone tissue for the metaphyseal defect; and (4) plating of the medial surface of the tibia. A closed fracture with poor soft-tissue status should be treated with talus traction first, and one should proceed to surgical intervention when the soft-tissue status improves.

Malleolar Injury (Segment 44)

Anatomical Features

The lateral malleolus is the distal expansion of the fibula, whereas the medial malleolus is that of the tibia. Together they form a mortise, a rectangular recess into which the talus fits. The medial malleolus is a broader prominence, situated at a higher level and somewhat farther forward than the lateral malleolus. The tibia and fibula are connected to each other by the attachment of the interosseous ligament. Stability of the ankle mortise relies on the configuration of the osseus structures, the ligament, and the joint capsule. The interosseous membrane of the leg extends between the interosseous crests of the tibia and fibula. It also separates the muscles on the front from those on the back of the leg, and gives attachments to several muscles. The oblique fibers, for the most part, run downward and lateralward; a few fibers, however, pass in the opposite direction. They are continuous below with the interosseous ligament of the tibiofibular syndesmosis.

The distal tibiofibular syndesmosis is between the convex medial surface of the distal end of the fibula and the rough concave fibular notch of the tibia. It is composed of the anterior and posterior tibiofibular ligaments, the interosseous membrane with its corresponding ligament, and the transverse tibiofibular ligament. The anterior tibiofibular ligament is a flat, triangular band of fibers, which extends obliquely downward and lateralward between the adjacent margins of the tibia and fibula, on the front aspect of the syndesmosis. The posterior tibiofibular ligament rests on the posterior surface of the syndesmosis. The transverse tibiofibular ligament lies deep to the posterior tibiofibular ligament. Because there are variations in the slope of the lateral malleolar surface of the talus, dorsiflexion of the foot, combined with slight external rotation of the fibula, can result in a small separation of the tibia and fibula. Normally the medial open space (between the talus and medial malleolus) should be less than 3 mm, and when it is greater than 3 mm, a lateral shift of the talus is present.

The ligaments of the ankle joint are grouped into two categories, the lateral collateral ligaments and the medial collateral ligaments. The lateral collateral ligaments include the anterior talofibular ligament, calcaneofibular ligament, and posterior talofibular ligament. The posterior talofibular ligament is the strongest fibrous ligament among the three. The medial collateral ligaments, so-called deltoid ligaments, are composed of superficial and deep components. The superficial components run from the medial malleolus to the navicular bone, the edge of the calcaneus, and the sustentaculum of tali. The deep layers merge into the joint capsule.

AO Classification of Malleolar Injury

Based on AO classification, the malleolus is coded as number "44" (▶ Fig. 5.34). Malleolar injury can be divided into three types

Fig. 5.34 AO code of the malleolus.

defined by the level of the lateral malleolar lesion, in relation to the ligamentous complex of the syndesmosis: 44-A: infrasyndesmotic malleolar lesion; 44-B: trans-syndesmotic fibular fracture; and 44-C: suprasyndesmotic lesion (▶ Fig. 5.35).

Clinical Epidemiologic Features of Malleolar Injury (Segment 44)

A total of 28,279 malleolar injuries were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 46.65% of all tibial/fibular fractures in adults. Their epidemiologic features are as follows:

- More males than females
- The highest-risk age group is 21–25 years. The most affected male age group is 21–25 years, while females aged 56–60 years have the highest risk.
- The most common fracture type among segment 44 fractures is 44-A, the same fracture type for both males and females.
- The most common fracture group among segment 44 fractures is 44-A1, group 44-A2 in males and group 44-A1 in females.

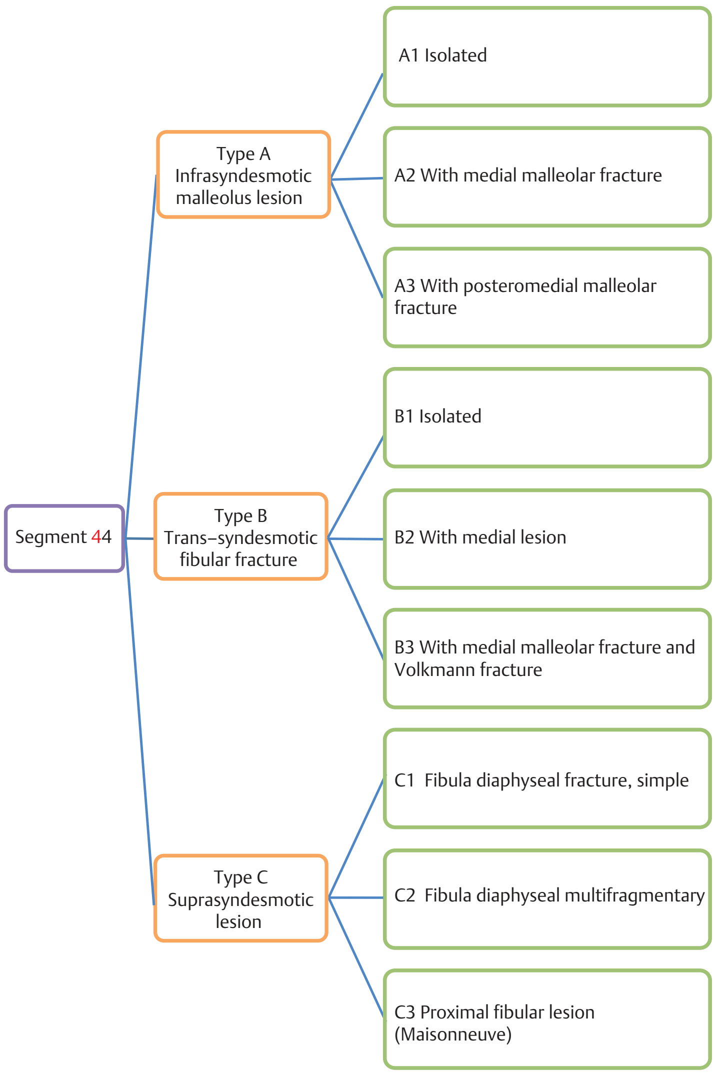


Fig. 5.35 Algorithm.

■ Fractures of Segment 44 by Sex

See ▶ Table 5.23 and ▶ Fig. 5.36.

Table 5.23 Sex distribution of 28,279 fractures of segment 44

Sex	Number of fractures	Percentage
Male	16,860	59.62
Female	11,419	40.38
Total	28,279	100.00

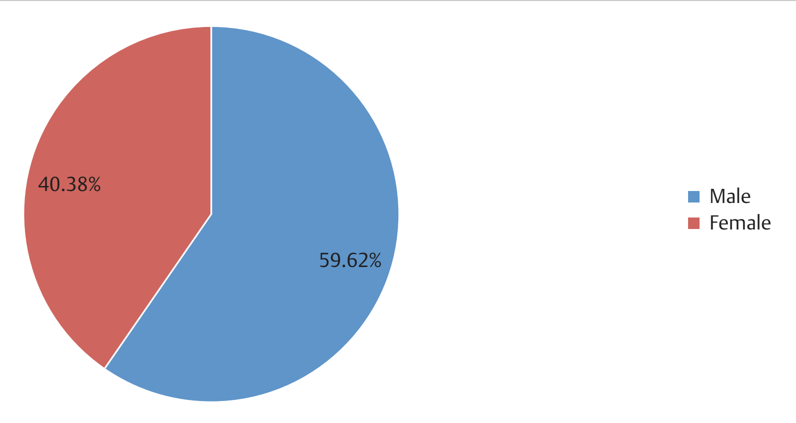


Fig. 5.36 Sex distribution of 28,279 fractures of segment 44.

■ Fractures of Segment 44 by Age Group

See ▸ Table 5.24 and ▸ Fig. 5.37.

Table 5.24 Sex and age distribution of 28,279 fractures of segment 44

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	1,748	649	2,397	8.48
21–25	2,171	858	3,029	10.71
26–30	1,814	763	2,577	9.11
31–35	1,686	740	2,426	8.58
36–40	1,974	1,049	3,023	10.69
41–45	1,826	1,094	2,920	10.33
46–50	1,620	1,249	2,869	10.15
51–55	1,221	1,278	2,499	8.84
56–60	1,109	1,404	2,513	8.89
61–65	664	835	1,499	5.30
66–70	408	580	988	3.49
71–75	277	461	738	2.61
76–80	192	313	505	1.79
81–85	116	103	219	0.77
≥ 86	34	43	77	0.27
Total	16,860	11,419	28,279	100.00

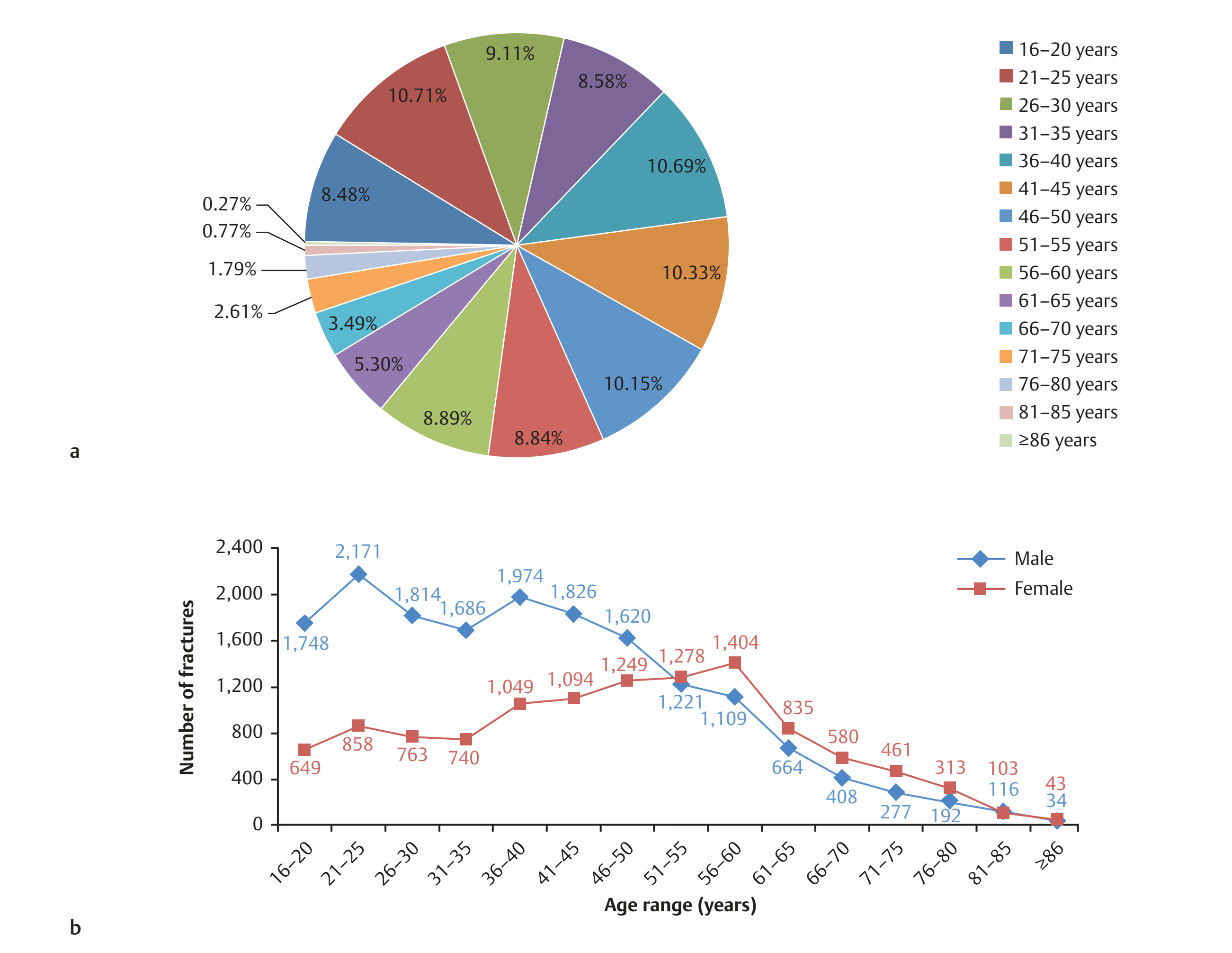


Fig. 5.37 (a) Age distribution of 28,279 fractures of segment 44. (b) Age and sex distribution of 28,279 fractures of segment 44.

■ Fractures of Segment 44 by Fracture Type

See ▶ Table 5.25, ▶ Table 5.26, ▶ Fig. 5.38, and ▶ Fig. 5.39.

Table 5.25 Sex and fracture type distribution of 28,279 fractures of segment 44

Fracture type	Male	Female	Number of fractures	Percentage
44-A	6,431	4,821	11,252	39.79
44-B	6,046	5,084	11,130	39.36
44-C	4,383	1,514	5,897	20.85
Total	16,860	11,419	28,279	100.00

Table 5.26 Sex and fracture group distribution of 28,279 fractures of segment 44

Fracture group	Male	Female	Number of fractures	Percentage of segment 44 fractures	Percentage of adult tibial/fibular fractures
44-A1	3,898	3,652	7,550	26.70	12.46
44-A2	2,289	1,054	3,343	11.82	5.52
44-A3	244	115	359	1.27	0.59
44-B1	3,063	2,494	5,557	19.65	9.17
44-B2	2,072	1,709	3,781	13.37	6.24
44-B3	911	881	1,792	6.34	2.96
44-C1	2,299	806	3,105	10.98	5.12
44-C2	1,408	430	1,838	6.50	3.03
44-C3	676	278	954	3.37	1.57
Total	16,860	11,419	28,279	100.00	46.65

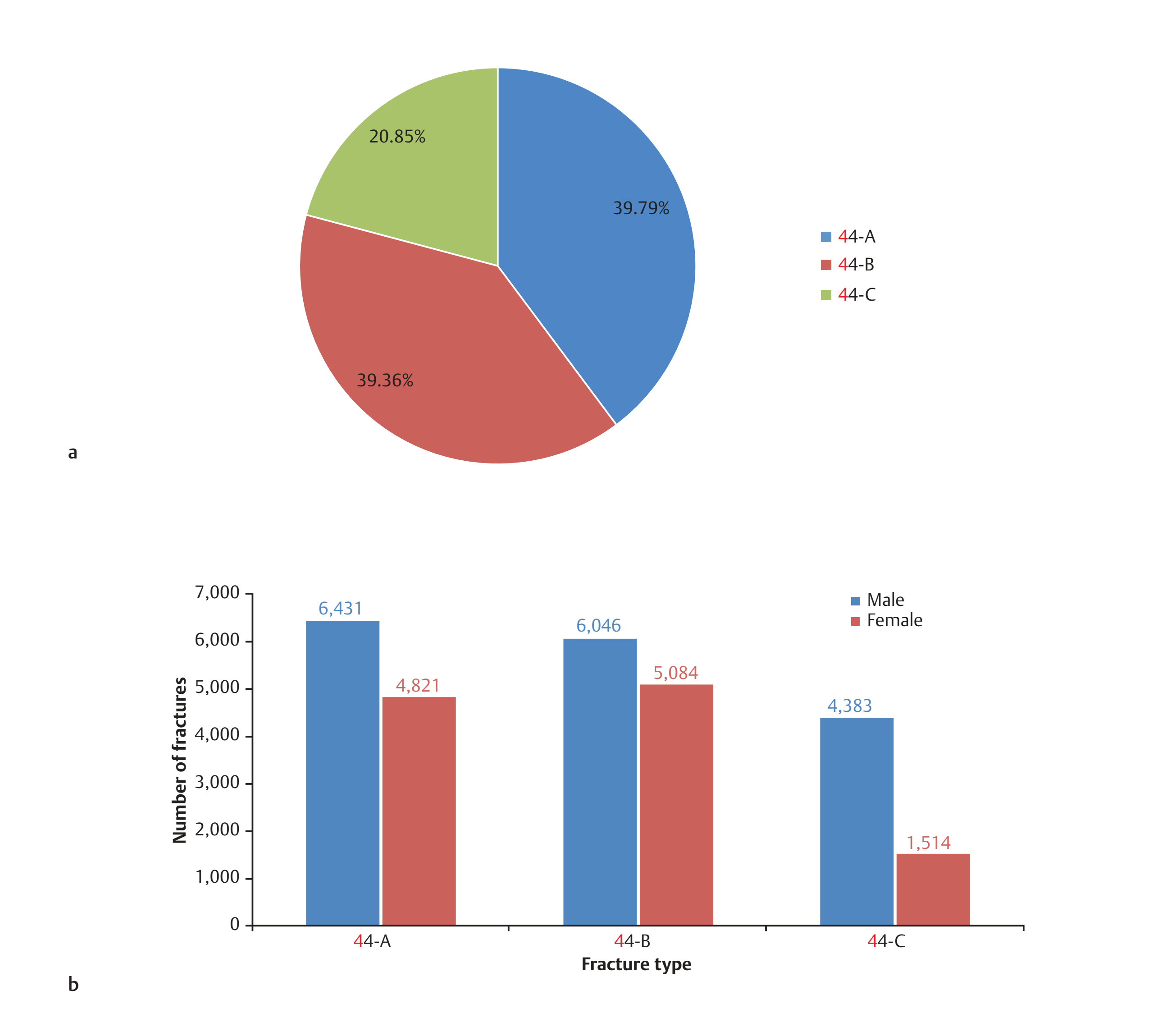
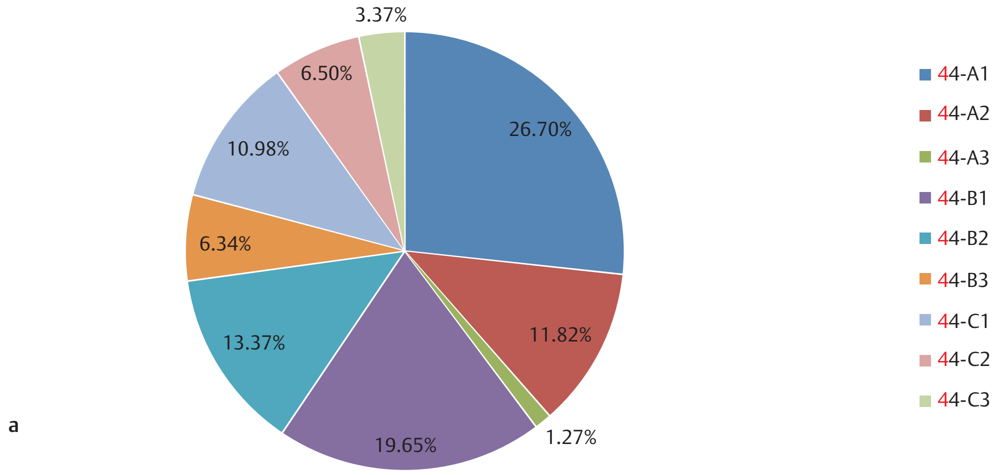


Fig. 5.38 (**a**) Fracture type distribution of 28,279 fractures of segment 44. (**b**) Sex and fracture type distribution of 28,279 fractures of segment 44.



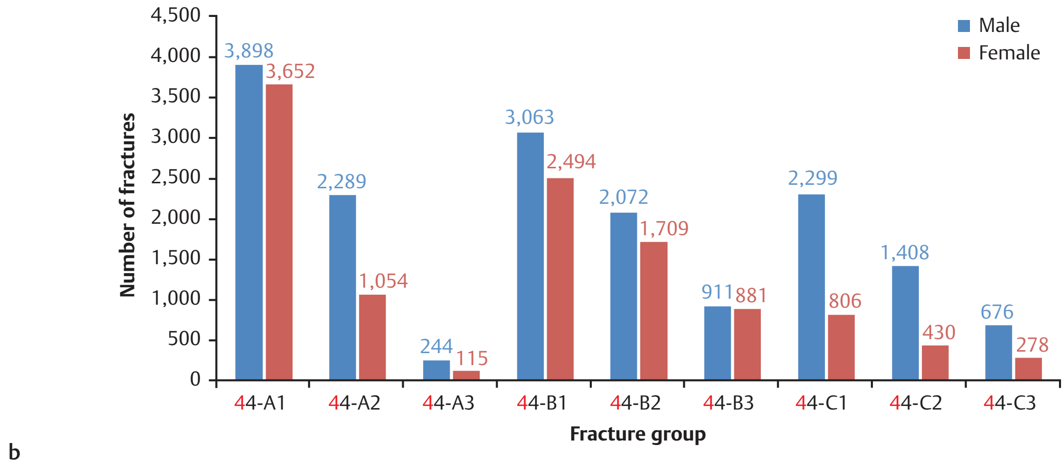
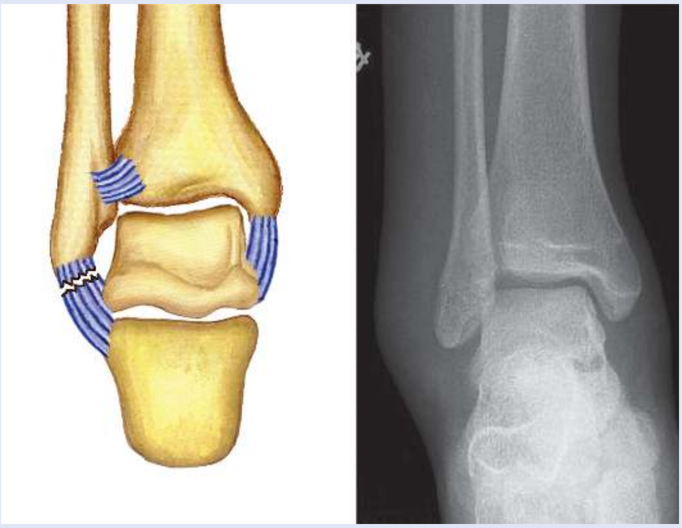
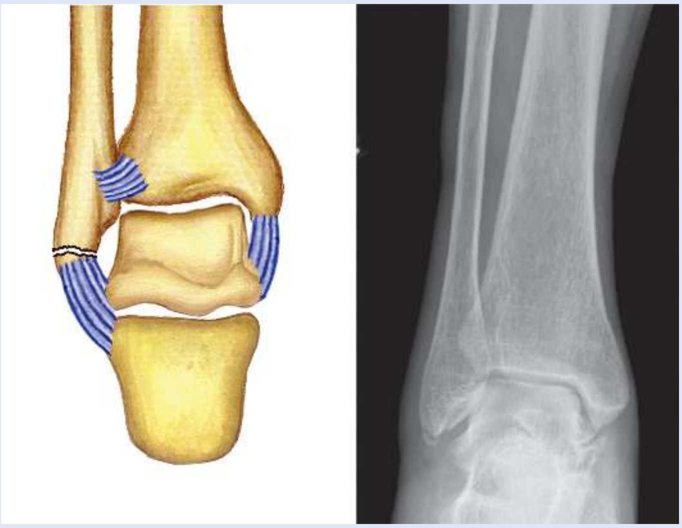
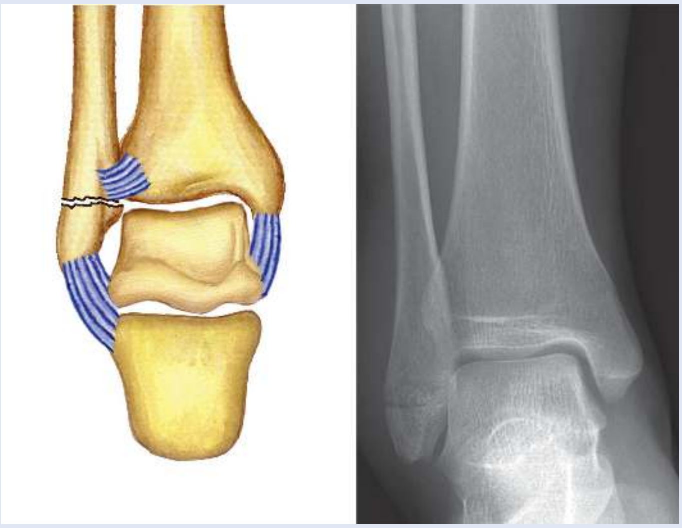


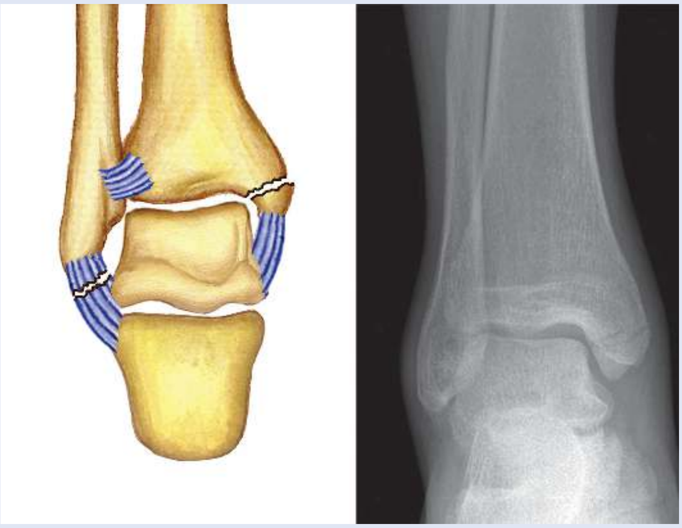
Fig. 5.39 (**a**) Fracture group distribution of 28,279 fractures of segment 44. (**b**) Sex and fracture group distribution of 28,279 fractures of segment 44.

44-A Tibia/fibula, malleolar segment, infrasyndesmotic lesion	
44-A1 Isolated 7,550 fractures M: 3,898 (51.63%) F: 3,652 (48.37%) 2.02% of total adult fractures 12.46% of adult tibial/fibular fractures 26.70% of segment 44 67.10% of type 44-A	**44-A1.1** Rupture of the lateral collateral ligament  **44-A1.2** Avulsion of the tip of the lateral malleolus  **44-A1.3** Transverse fracture, lateral malleolus 

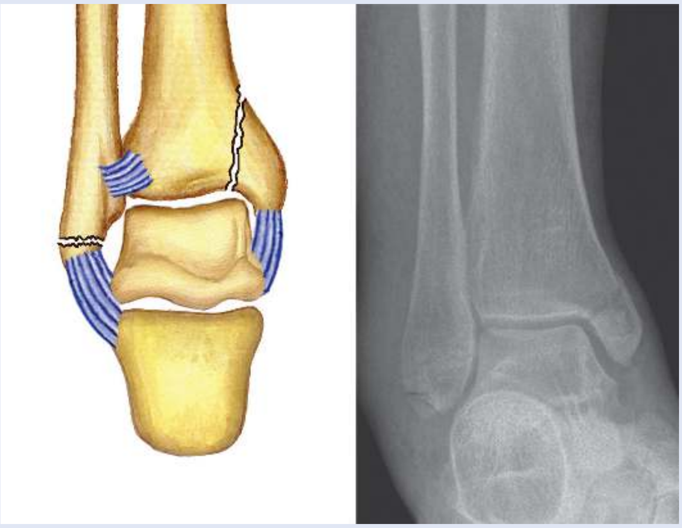
44-A Tibia/fibula, malleolar segment, infrasyndesmotic lesion

44-A2 With fracture of the medial malleolus
3,343 fractures
M: 2,289 (68.47%)
F: 1054 (31.53%)
0.89% of total adult fractures
5.52% of adult tibial/fibular fractures
11.82% of segment 44
29.71% of type 44-A

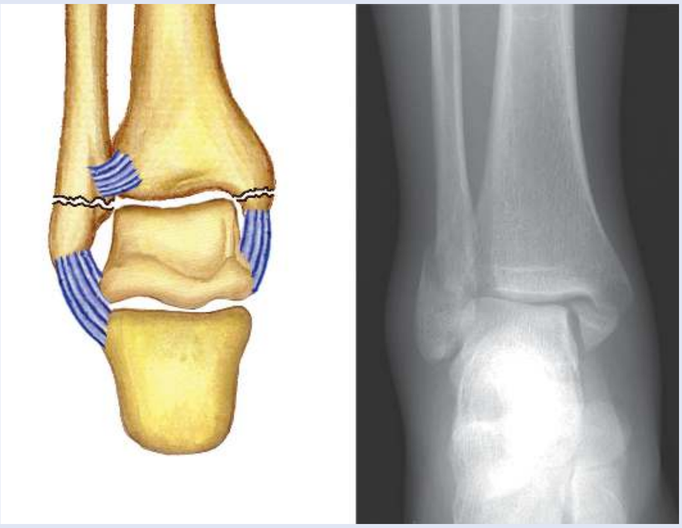
44-A2.1 Rupture of the lateral collateral ligament



44-A2.2 Avulsion of the tip of the lateral malleolus



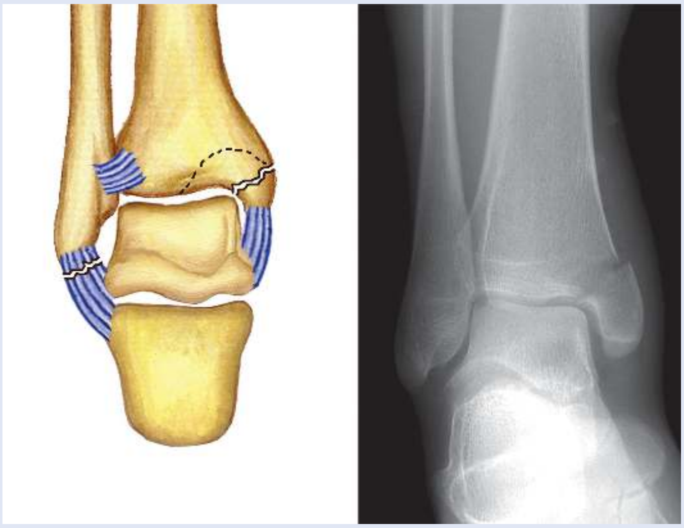
44-A2.3 Transverse fracture, lateral malleolus



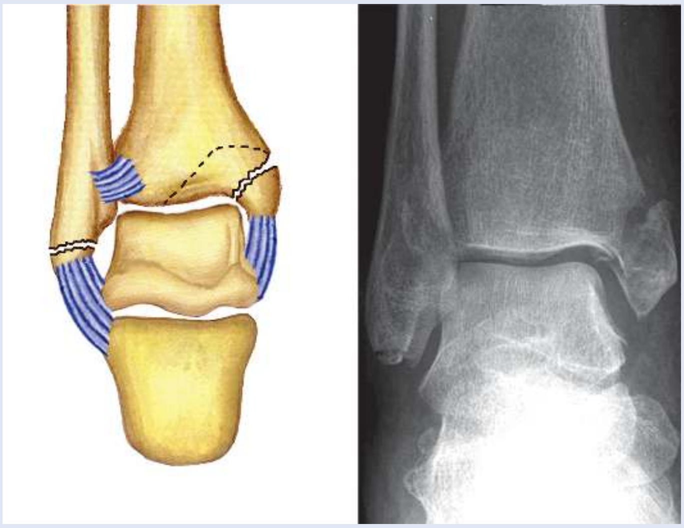
44-A Tibia/fibula, malleolar segment, infrasyndesmotic lesion

44-A3 With posteromedial fracture
359 fractures
M: 244 (67.97%)
F: 115 (32.03%)
0.10% of total adult fractures
0.59% of adult tibial/fibular fractures
1.27% of segment 44
3.19% of type 44-A

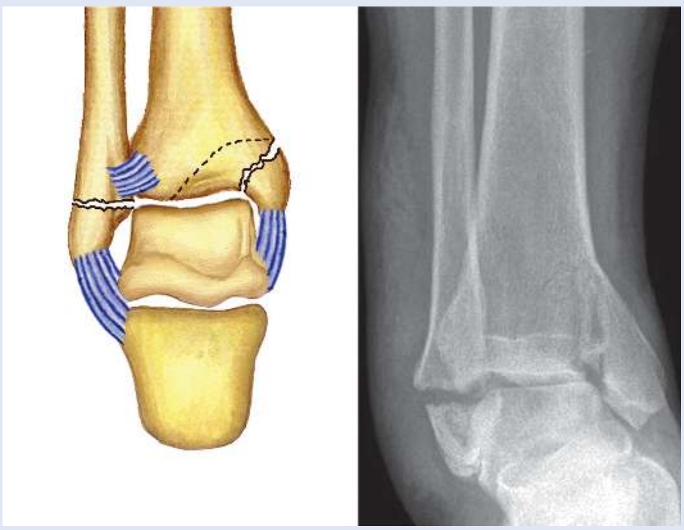
44-A3.1 Rupture of the lateral collateral ligament

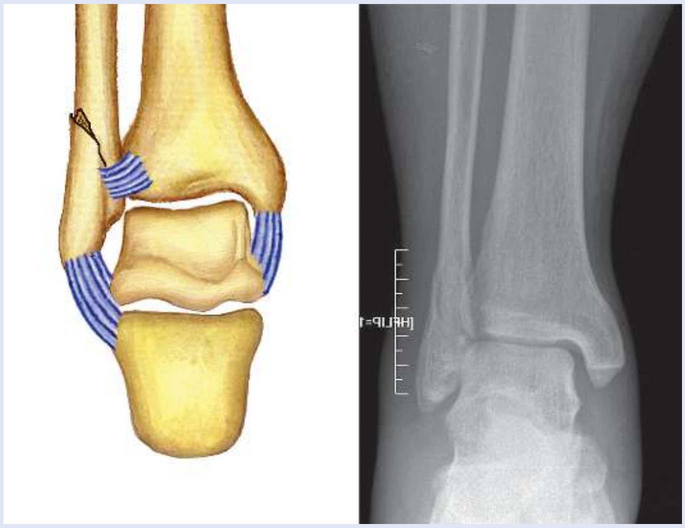
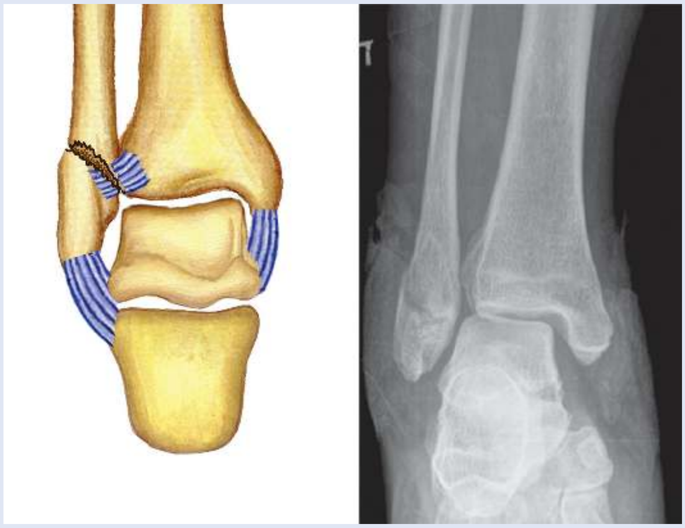
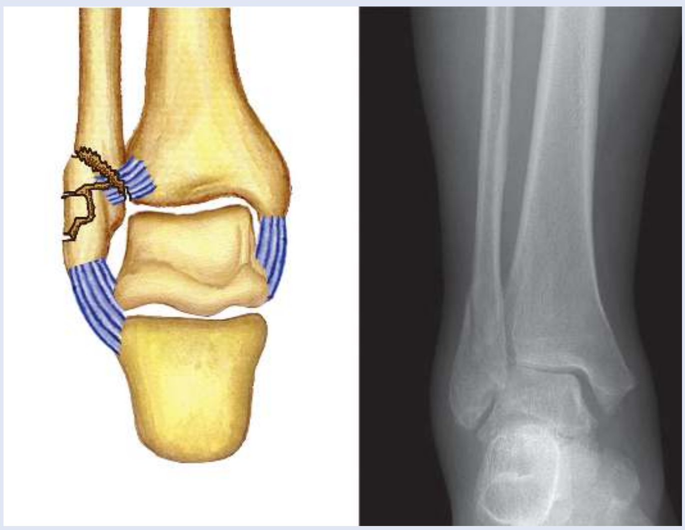


44-A3.2 Avulsion of the tip of the lateral malleolus



44-A3.3 Transverse fracture, lateral malleolus

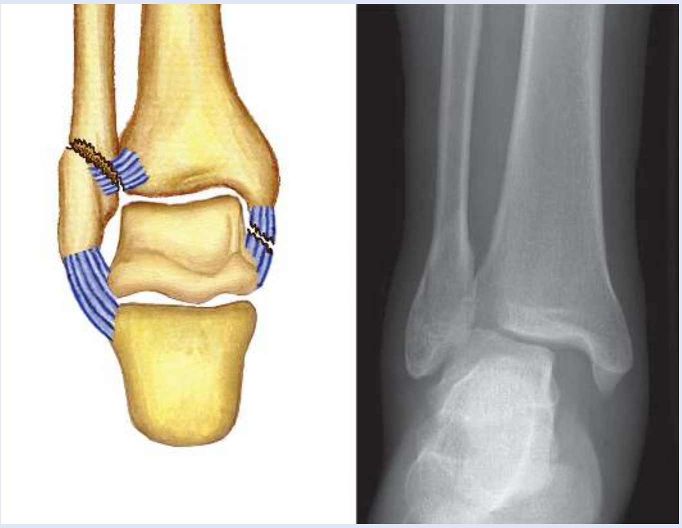


44-B Tibia/fibula, malleolar segment, trans-syndesmotic fibular fractures	
44-B1 Isolated 5,557 fractures M: 3,063 (55.12%) F: 2,494 (44.88%) 1.48% of total adult fractures 9.17% of adult tibial/fibular fractures 19.65% of segment 44 49.93% of type 44-B	**44-B1.1** Fibular simple  **44-B1.2** Fibular simple, with rupture of the anterior syndesmosis  **44-B1.3** Fibular multifragmentary 

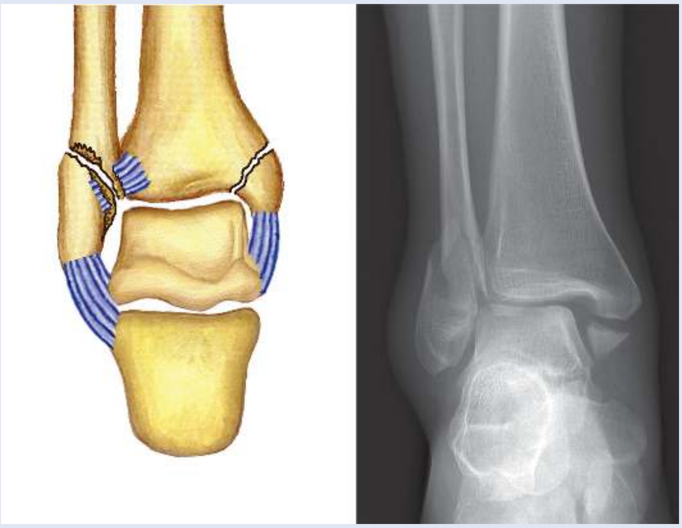
44-B Tibia/fibula, malleolar segment, trans-syndesmotic fibular fractures

44-B2 With medial lesion
3,781 fractures
M: 2,072 (54.80%)
F: 1,709 (45.20%)
1.01% of total adult fractures
6.24% of adult tibial/fibular fractures
13.37% of segment 44
33.97% of type 44-B

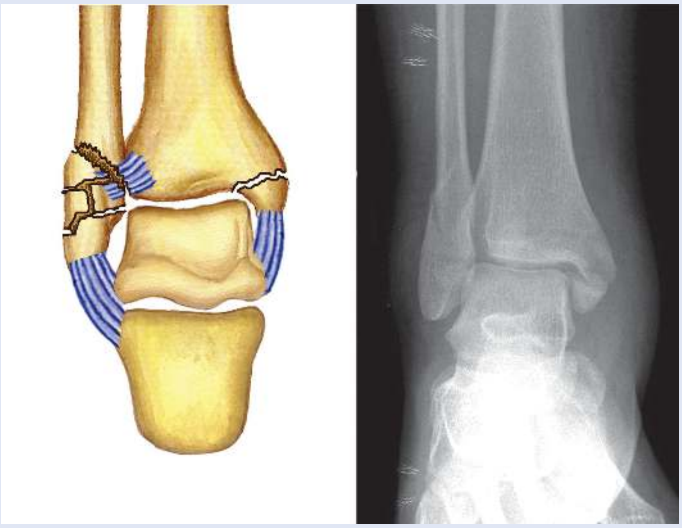
44-B2.1 Fibular simple, with rupture of anterior syndesmosis + medial collateral ligament



44-B2.2 Fibular simple, with rupture of anterior syndesmosis + fracture of medial malleolus



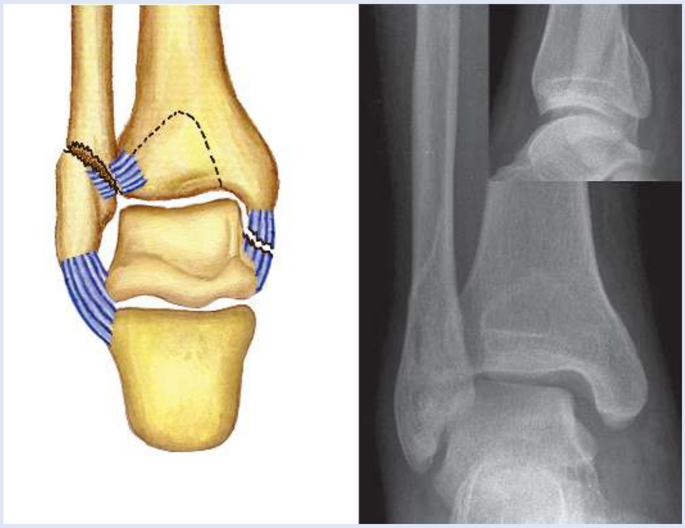
44-B2.3 Fibular multifragmentary, with medial lesion



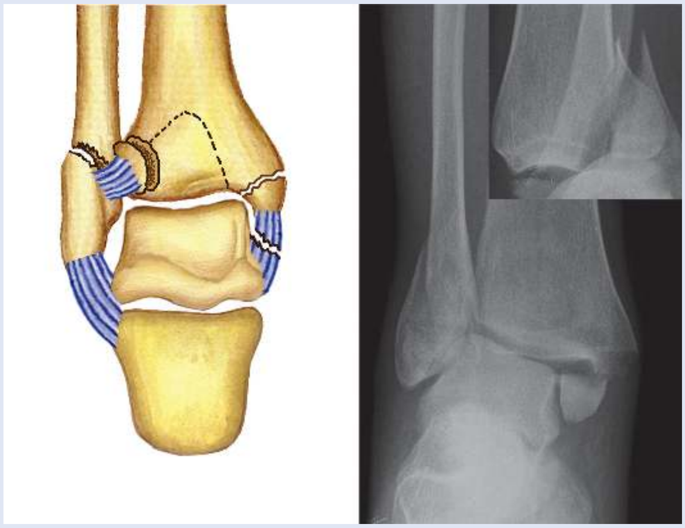
44-B Tibia/fibula, malleolar segment, trans-syndesmotic fibular fractures

44-B3 With medial lesion and a Volkmann fracture
1,792 fractures
M: 911 (50.84%)
F: 881 (49.16%)
0.48% of total adult fractures
2.96% of adult tibial/fibular fractures
6.34% of segment 44
16.10% of type 44-B

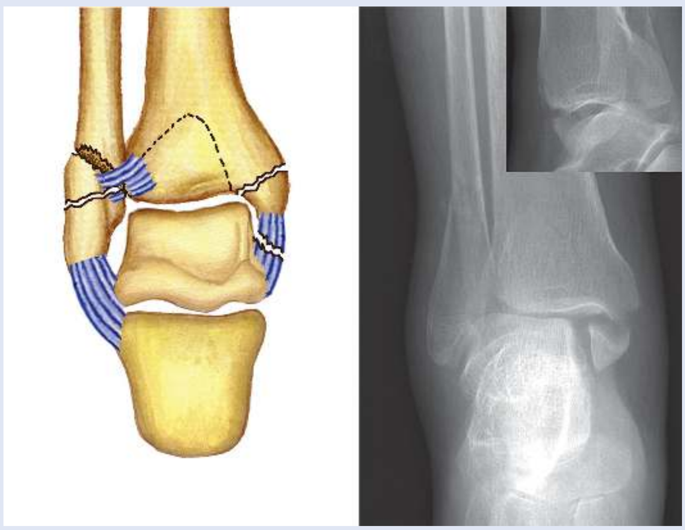
44-B3.1 Fibular simple, with rupture of medial collateral ligament + a Volkmann fracture



44-B3.2 Fibular simple, with fracture of medial malleolus + a Volkmann fracture



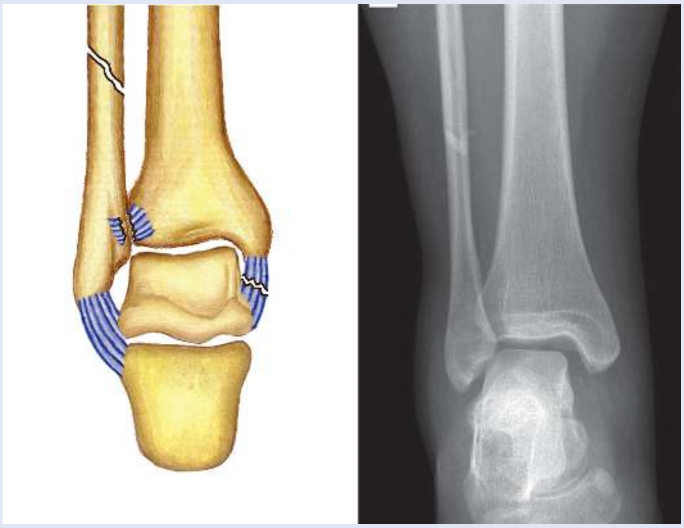
44-B3.3 Fibular multifragmentary, with fracture of medial malleolus + a Volkmann fracture



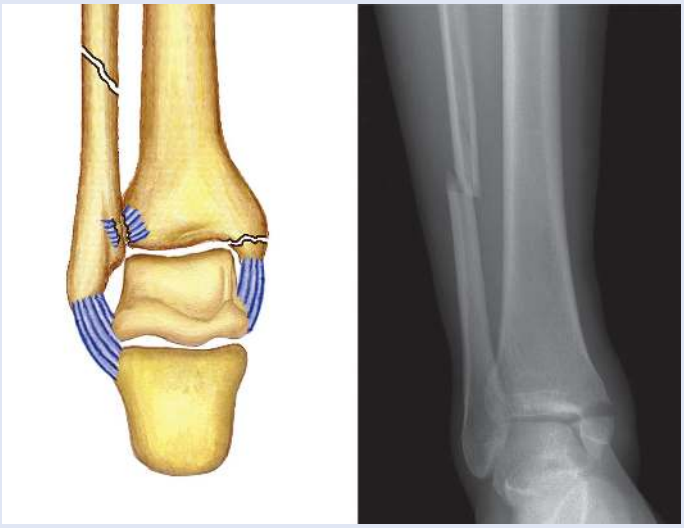
44-C Tibia/fibula, malleolar segment, suprasyndesmotic lesion

44-C1 Fibular diaphyseal simple
3,105 fractures
M: 2,299 (74.04%)
F: 806 (25.96%)
0.83% of total adult fractures
5.12% of adult tibial/fibular fractures
10.98% of segment 44
52.65% of type 44-C

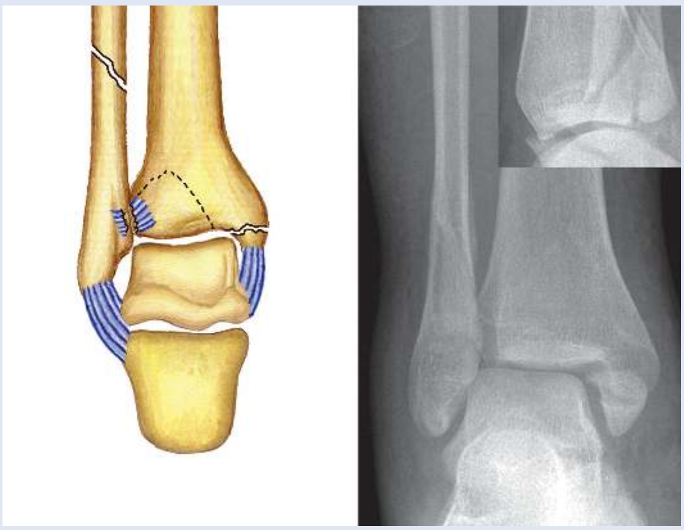
44-C1.1 With rupture of medial collateral ligament



44-C1.2 With fracture of medial malleolus



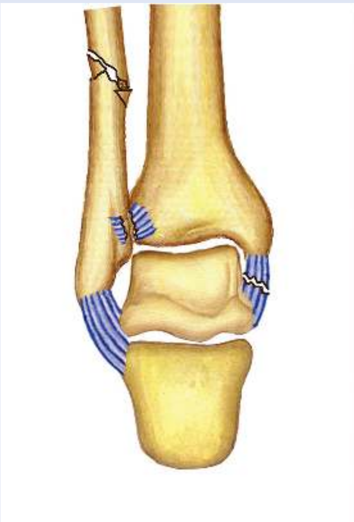
44-C1.3 With fracture of medial malleolus + a Volkman fracture



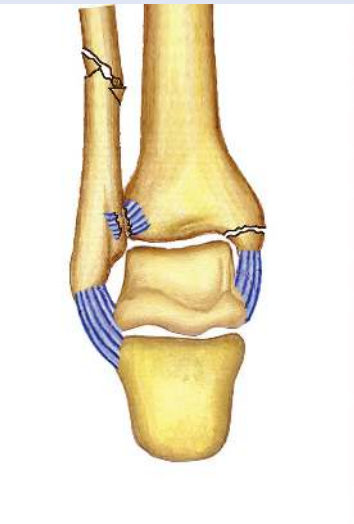
44-C Tibia/fibula, malleolar segment, suprasyndesmotic lesion

44-C2 Fibular diaphyseal multifragmentary
1,838 fractures
M: 1,408 (76.61%)
F: 430 (23.39%)
0.49% of total adult fractures
3.03% of adult tibial/fibular fractures
6.50% of segment 44
31.17% of type 44-C

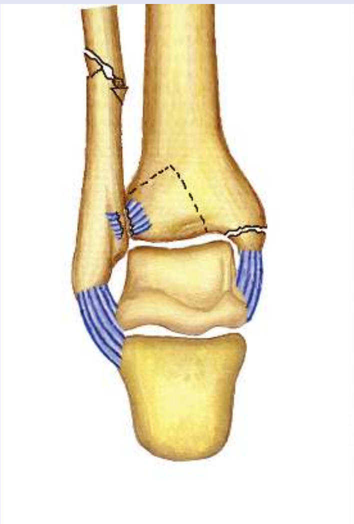
44-C2.1 With rupture of medial collateral ligament




44-C2.2 With fracture of medial malleolus



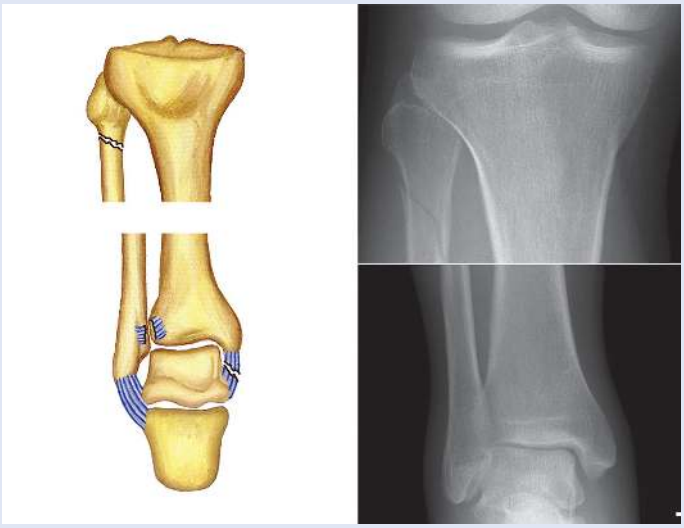

44-C2.3 With fracture of medial malleolus + a Volkman fracture



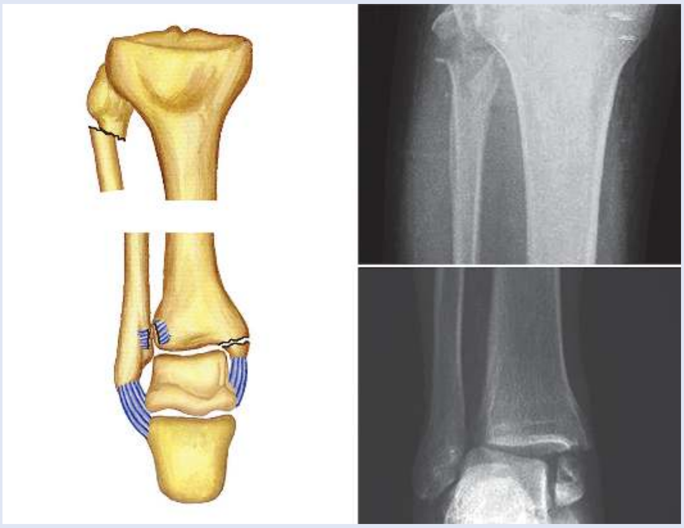

44-C Tibia/fibula, malleolar segment, suprasyndesmotic lesion

44-C3 Proximal fibular fracture (Maisonneuve)
954 fractures
M: 676 (70.86%)
F: 278 (29.14%)
0.25% of total adult fractures
1.57% of adult tibial/fibular fractures
3.37% of segment 44
16.18% of type 44-C

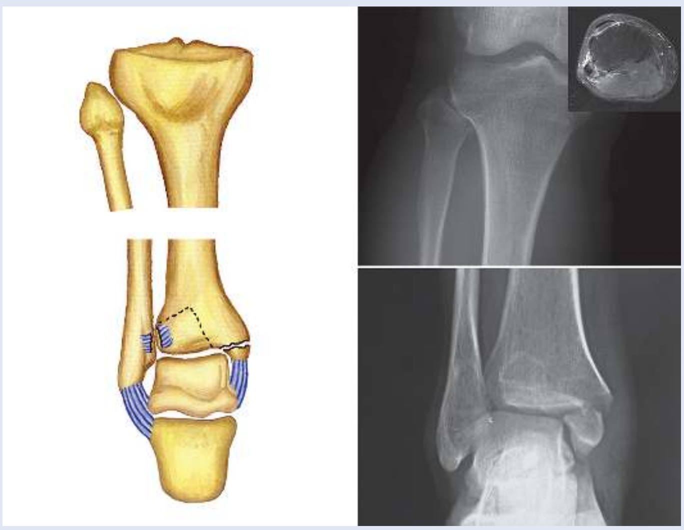
44-C3.1 Without shortening, without Volkmann fracture



44-C3.2 With shortening, without Volkmann fracture



44-C3.3 With dislocation of proximal fibula, + fracture of medial malleolus + a Volkmann fracture



Injury Mechanism

Ankle fractures are usually caused by an indirect mechanism, such as eversion, inversion, dorsiflexion, or plantar flexion. Injury to the ankle occurs when the foot is fixed on the ground in supination or pronation and an exorotation or adduction force is applied. The fracture type varies depending on the magnitude and direction of the force, and the position of the ankle at the time of injury.

Diagnosis

Ankle fractures usually present with swelling, pain, and deformity if the ankle joint is dislocated. With a partial or limited range of motion, patients experience the pain is getting worse with activity. According to individual injury mechanisms, a careful evaluation of relevant ligament and osseous structures should be performed. Special attention should be paid to the ankle's range of motion, specifically for eversion/inversion and dorsiflexion/plantar flexion. If ligamentous injury is suspected, a comparison with the unaffected limb is helpful. Physicians should be aware of the possible association of fractures or dislocations of the proximal fibula, and the need to avoid a hasty underdiagnosis.

Radiographic evaluation of ankle injuries should include standard AP, lateral, and mortise views (taken with a 15 degrees internal rotation of the foot). An additional oblique view can be obtained if necessary. A special X-ray, called a "stress test," can be performed after the acute stage has passed; it is very useful in determining the status of the ligamentous injury and the stability of the mortise joint. CT scan can be considered to further assess complex fractures or if plain films are inconclusive. MRI is indicated if ligamentous injury is suspected. Physicians should be aware of the possible associated fracture displacement of the diaphyseal or proximal fibula, for which an X-ray can be taken over the entire length of the tibia/fibula. An additional AP view of the proximal tibia/fibula can be helpful for diagnosis if a view of the entire length of the tibia/fibula cannot be obtained.

Treatment

The main principles of treatment in malleolar injury are anatomical reduction of the malleolus and restoration of ankle joint mortise. Malleolus fractures can be divided into stable and unstable fractures. Stable fractures are those where the lateral malleolus has an isolated fracture and the talus lies within the center of the ankle mortise without dislocation. Unstable fractures are fractures that do not fit into the "stable" category. Stable fractures of the ankle can usually be managed by nonsurgical treatment, such as a U-shaped or tubular casting. Minimally invasive plating or screw fixation can also be applied to facilitate early mobilization. Unstable fractures of the ankle should be treated by surgical intervention. Plating or screw fixation can be applied for rigid fixation and ligament repair, based upon the fracture patterns and severity of the ligamentous injury.

Commonly Used Classifications for Fractures of the Tibia/Fibula

Tibial Plateau Fractures

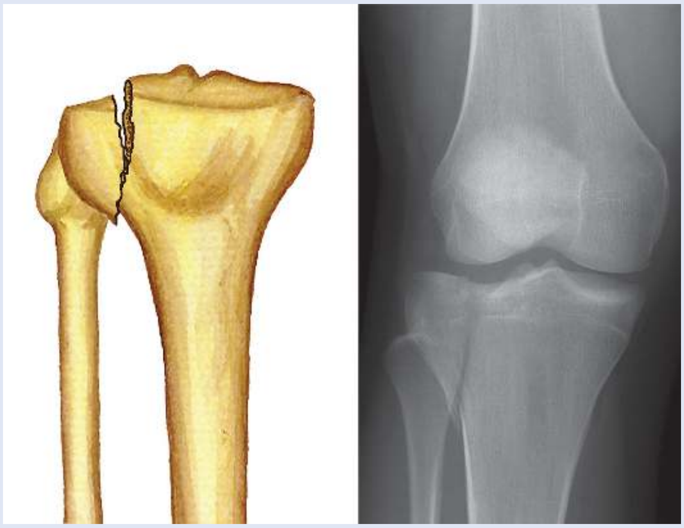
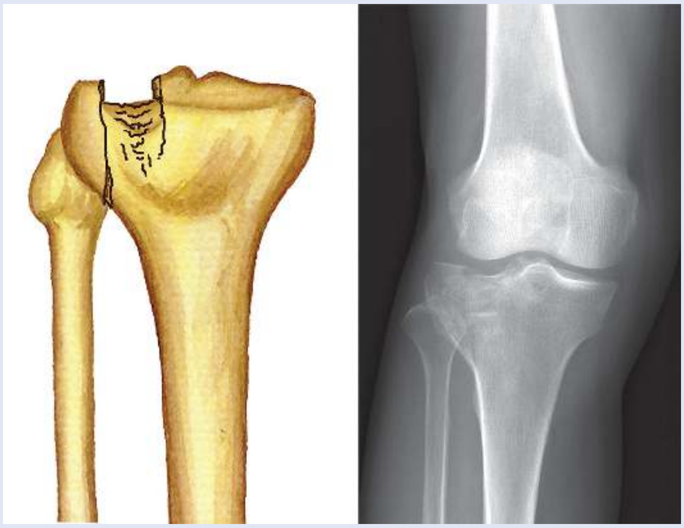
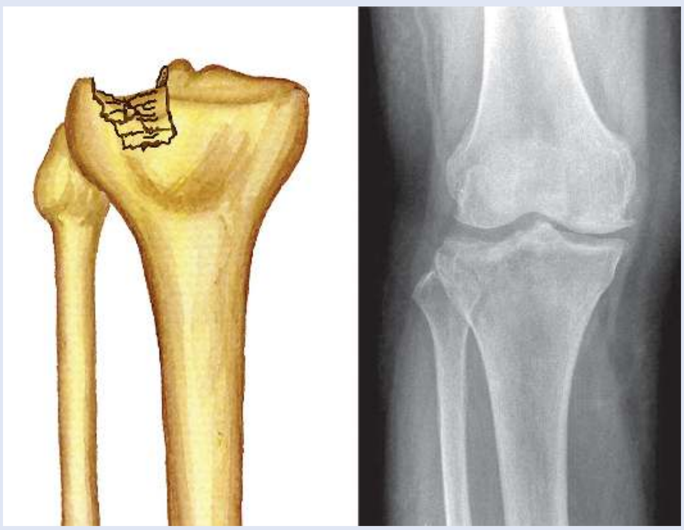
Overview

The Schatzker classification system is the most commonly used classification for tibial plateau fractures, and is based on the location and extent of the fracture and associated depression of the bone:

- *Type I*: split fracture of the lateral tibial plateau without articular depression
- *Type II*: split fracture of the lateral tibial plateau with articular depression
- *Type III*: isolated depression of the lateral plateau
- *Type IV*: fracture of the medial plateau with associated intercondylar eminence avulsion
- *Type V*: split bicondylar fracture
- *Type VI*: split bicondylar fracture with diaphyseal and metaphyseal dissociation

Patients who have tibial plateau fractures may experience swelling, pain, partial or limited active or passive range of motion, and varus or valgus deformity in severe cases. Fractures resulting from high-energy trauma are often associated with tension blisters, compartment syndrome, ligament rupture, and neurovascular injury. Radiographic evaluation should include standard AP and lateral views of the knee joint. Complex fractures resulting from high-energy injuries can be viewed with application of knee traction to better visualize the pattern and location of the fracture fragments; 40 degrees internal and external oblique views can clearly show lateral and medial plateaus. An AP projection with an inclination of 15 degrees backward may be helpful in assessing the depression of the tibial plateau. 3D CT reconstruction and MRI can be used to further characterize fractures of the tibial plateau and assess the degree of articular comminution, as well as the extent of the depression. MRI is excellent for illustrating injuries of the anterior/posterior cruciate ligament, collateral ligament, and meniscus.

Most tibial plateau fractures are unstable fractures and require surgical intervention that strictly follows the principles of anatomic reduction, adequate bone grafting, and rigid fixation. Early nonweight-bearing mobilization exercises should be initiated to avoid joint stiffness and adhesion. Limited weight-bearing exercises, based upon the stage of the fracture-healing process, can be conducted under the supervision of an experienced therapist.

Tibial Plateau Fracture Types	
Type I Split fracture of the lateral tibial plateau, without articular depression 881 fractures M: 607 (68.90%) F: 274 (31.10%) 14.15% of adult tibial plateau 1.45% of adult tibial/fibular fractures 0.24% of total adult fractures	Schatzker Type I 
Type II Split fracture of the lateral tibial plateau, with articular depression 909 fractures M: 570 (62.71%) F: 339 (37.29%) 14.60% of adult tibial plateau 1.50% of adult tibial/fibular fractures 0.24% of total adult fractures	Schatzker Type II 
Type III Isolated depression of the lateral plateau 960 fractures M: 497 (51.77%) F: 463 (48.23%) 15.42% of adult tibial plateau 1.58% of adult tibial/fibular fractures 0.26% of total adult fractures	Schatzker Type III 

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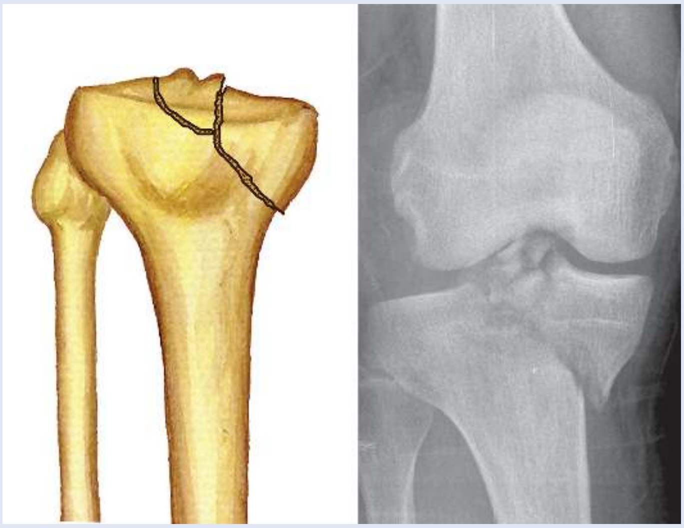
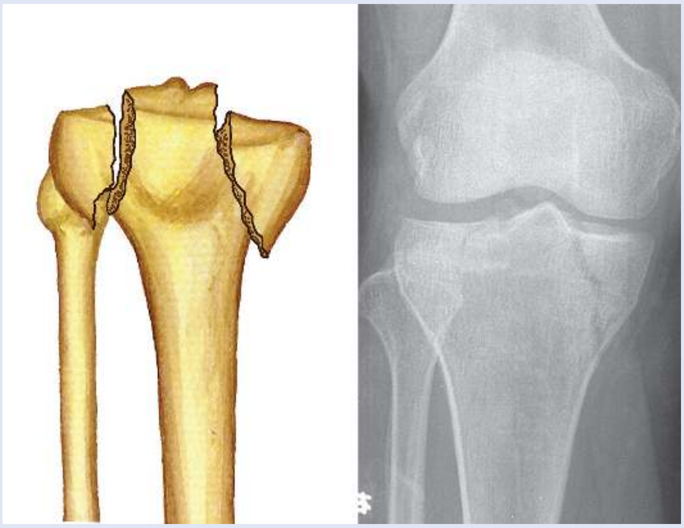
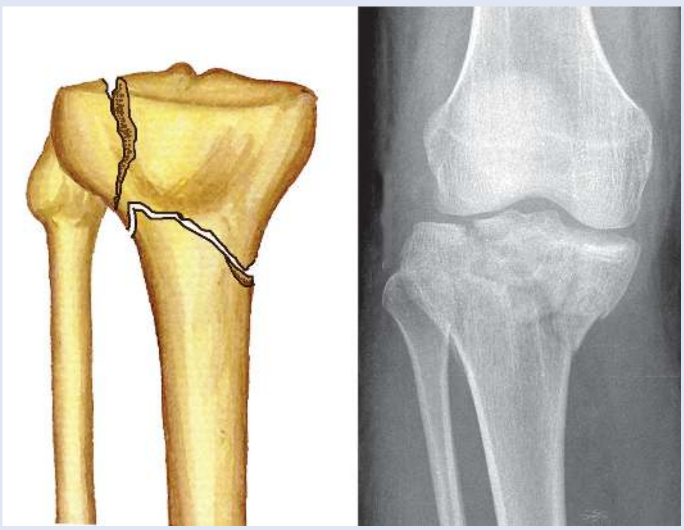
Tibial Plateau Fracture Types	
Type IV Fracture of the medial plateau, with associated intercondylar eminence avulsion 1,278 fractures M: 870 (68.08%) F: 408 (31.92%) 20.52% of adult tibial plateau 2.11% of adult tibial/fibular fractures 0.34% of total adult fractures	Schatzker Type IV 
Type V Split bicondylar fracture 511 fractures M: 377 (73.78%) F: 134 (26.22%) 8.21% of adult tibial plateau 0.84% of adult tibial/fibular fractures 0.14% of total adult fractures	Schatzker Type V 
Type VI Split bicondylar fracture, with diaphyseal, metaphyseal dissociation 1,688 fractures M: 1,354 (80.21%) F: 334 (19.79%) 27.11% of adult tibial plateau 2.78% of adult tibial/fibular fractures 0.45% of total adult fractures	Schatzker Type VI 

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■ Clinical Epidemiologic Features of Tibial Plateau Fractures

A total of 6,227 tibial plateau fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 10.27% of all tibial/fibular fractures in adults and 1.66% of all types of fractures in adults. Their epidemiologic features are as follows:

- More males than females
- The highest-risk age group is 41–45 years; the most affected male age group is 41–45 years, while females aged 56–60 years have the highest risk.
- The most common fracture type according to Schatzker classification is type VI; type VI is most common for males, while type III is most common for females.

Tibial Plateau Fractures by Sex

See ▶ Table 5.27 and ▶ Fig. 5.40.

Table 5.27 Sex distribution of 6,227 tibial plateau fractures

Sex	Number of fractures	Percentage
Male	4,275	68.65
Female	1,952	31.35
Total	6,227	100.00

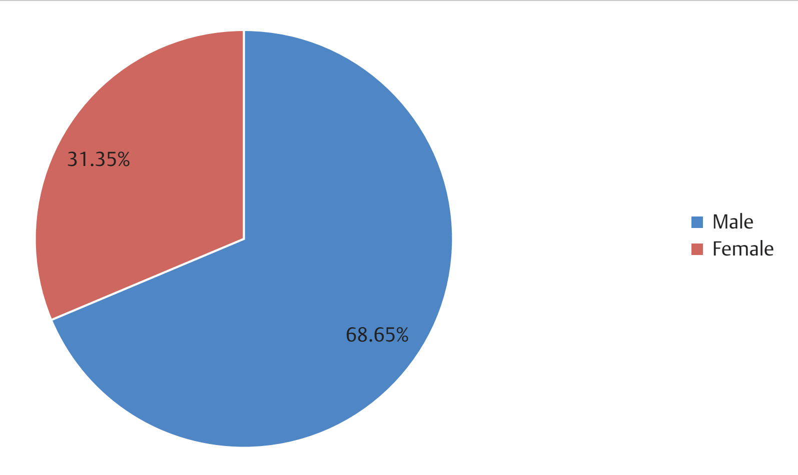


Fig. 5.40 Sex distribution of 6,227 tibial plateau fractures.

Tibial Plateau Fractures by Age Group

See ▶ Table 5.28 and ▶ Fig. 5.41.

Table 5.28 Sex and age distribution of 6,227 tibial plateau fractures

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	169	55	224	3.60
21–25	266	67	333	5.35
26–30	296	86	382	6.13
31–35	423	125	548	8.80
36–40	624	171	795	12.77
41–45	694	206	900	14.45
46–50	607	232	839	13.47
51–55	459	247	706	11.34
56–60	338	276	614	9.86
61–65	185	181	366	5.88
66–70	90	117	207	3.32
71–75	65	67	132	2.12
76–80	36	75	111	1.78
81–85	19	30	49	0.79
≥ 86	4	17	21	0.34
Total	4,275	1,952	6,227	100.00

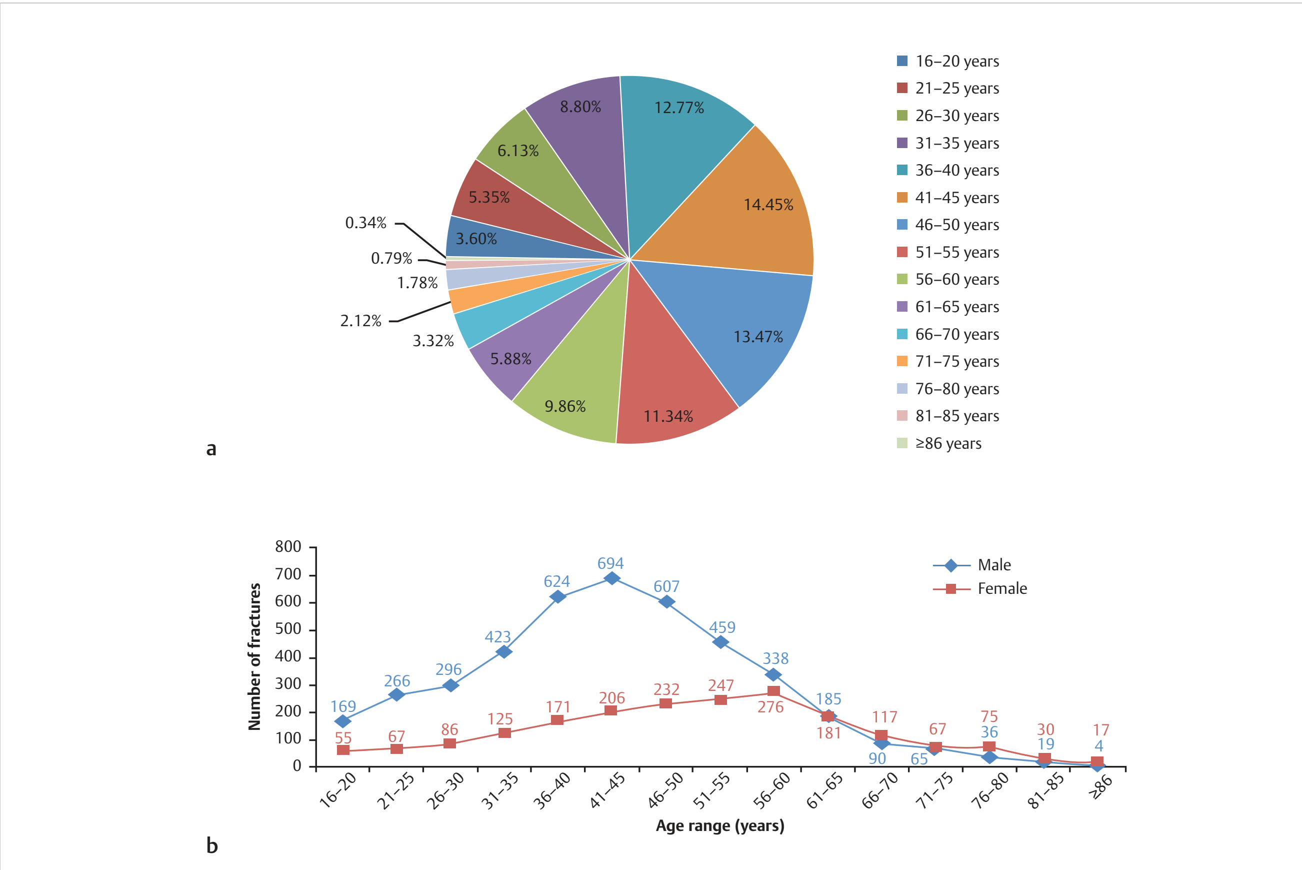


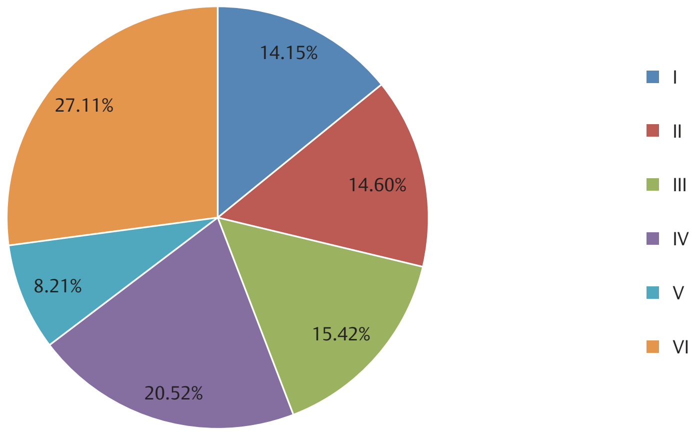
Fig. 5.41 (**a**) Age distribution of 6,227 tibial plateau fractures. (**b**) Age and sex distribution of 6,227 tibial plateau fractures.

Tibial Plateau Fractures by Fracture Type Based on Schatzker Classification

See ▶ Table 5.29 and ▶ Fig. 5.42.

Table 5.29 Sex and fracture type distribution of 6,227 tibial plateau fractures by Schatzker classification

Fracture type (Schatzker)	Male	Female	Number of fractures	Percentage
I	607	274	881	14.15
II	570	339	909	14.60
III	497	463	960	15.42
IV	870	408	1,278	20.52
V	377	134	511	8.21
VI	1,354	334	1,688	27.11
Total	4,275	1,952	6,227	100.00



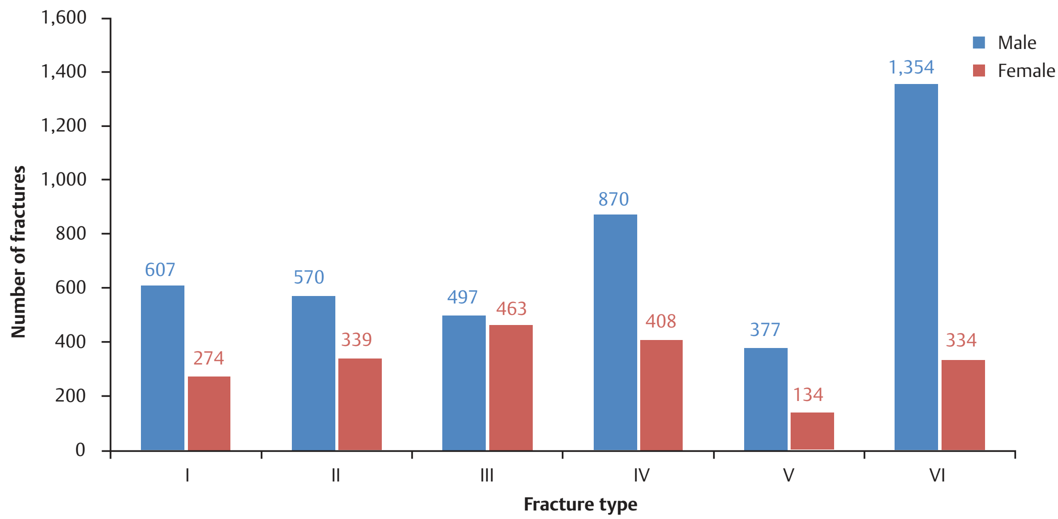


Fig. 5.42 (**a**) Fracture type distribution of 6,227 tibial plateau fractures by Schatzker classification. (**b**) Sex and fracture type distribution of 6,227 tibial plateau fractures by Schatzker classification.

Pilon Fractures

Overview

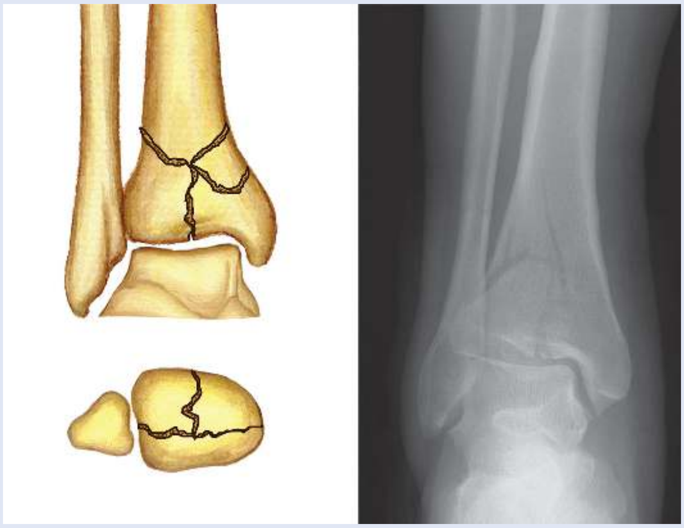
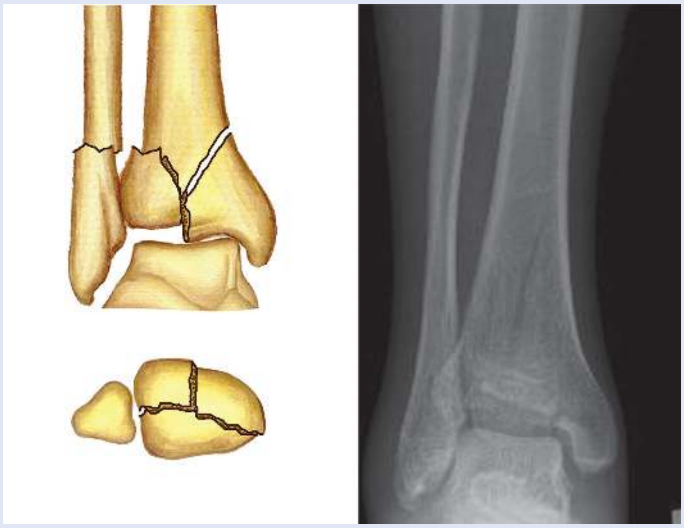
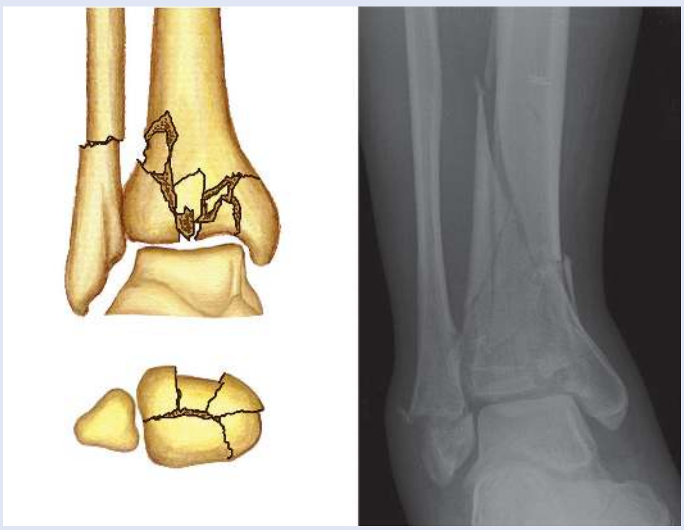
Pilon fracture is a comminuted fracture of the distal tibia. Destot first described this type of compression injury in 1911, while Ruedi and Allgower divided it into three types:

- Type I: articular split fracture without significant displacement; it can be managed with conservative treatment
- Type II: articular fracture displacement with articular incongruity but minimal comminution
- Type III: severe articular comminution and articular impaction fracture

Radiographic evaluations should include AP, lateral, and mortise views of the ankle joint, with the foot in 15 degrees of internal rotation. Additional views with the foot/ankle held in external rotation at 45 degrees can be obtained, if indicated, to visualize the anteromedial and posterolateral surface of the tibia. CT can be of great help in evaluating the degree of articular comminution and extent of articular depression. Stable Pilon fractures with minimal displacement are generally managed nonsurgically, while unstable Pilon fractures usually require surgical intervention. Operative approaches include: screw fixation, plating, use of a locking compression plate, circular ring external fixation, etc. Open reduction and internal fixation can be performed utilizing the following principles:

- Restoration of the fibular length
- Reconstruction of the articular surface of the distal tibia
- Restoration of the mortise structure
- Plating of the medial surface of the tibia
- Adequate bone grafting to cover the metaphyseal defect

Closed fractures with poor soft-tissue status should be treated first with talar traction, then one should proceed to surgical intervention after the soft-tissue status has improved.

Pilon fractures by Ruedi and Allgower classification	
Type I: Articular split fracture without significant displacement 1,532 fractures M: 896 (58.49%) F: 636 (41.51%) 39.65% of adult Pilon 2.53% of adult tibial/fibular fractures 0.41% of total adult fractures	Pilon Type I 
Type II: Articular fracture displacement with articular incongruity but minimal comminution 1,238 fractures M: 924 (74.64%) F: 314 (25.36%) 32.04% of adult Pilon 2.04% of adult tibial/fibular fractures 0.33% of total adult fractures	Pilon Type II 
Type III: Severe articular comminution and articular impaction fracture 1,094 fractures M: 894 (81.72%) F: 200 (18.28%) 28.31% of adult Pilon 1.80% of adult tibial/fibular fractures 0.29% of total adult fractures	Pilon Type III 

■ Epidemiologic Features of Pilon Fractures

A total of 3,864 Pilon fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 6.37% of all tibial/fibular fractures in adult, and 1.03% of all type of fractures in adults. Their epidemiologic features are as follows:

- More males than females
- The highest-risk age group is 41–45 years; the most affected male age group is 41–45 years, while females aged 41–45 years have the highest risk.
- The most common fracture type according to Ruedi and Allgower classification is type I; type II is most common for males, while type I is most common for females.

Pilon Fractures by Sex

See ▶ Table 5.30 and ▶ Fig. 5.43.

Table 5.30 Sex distribution of 3,864 Pilon fractures

Sex	Number of fractures	Percentage
Male	2,714	70.24
Female	1,150	29.76
Total	3,864	100.00

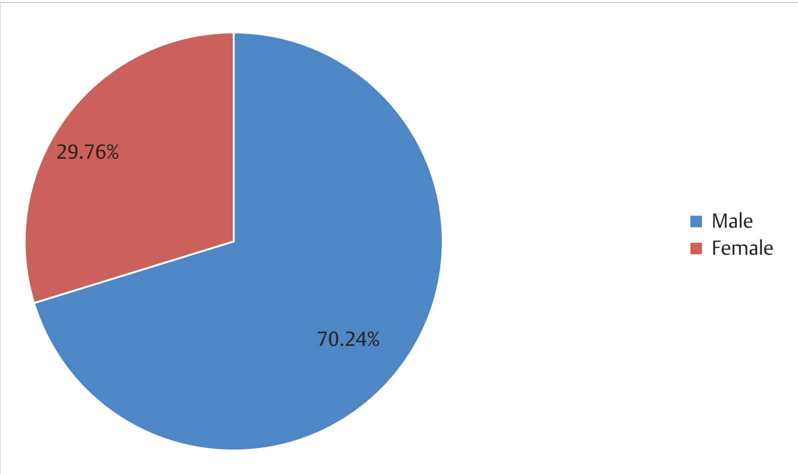


Fig. 5.43 Sex distribution of 3,864 Pilon fractures.

Pilon Fractures by Age Group

See ▶ Table 5.31 and ▶ Fig. 5.44.

Table 5.31 Age and sex distribution of 3,864 Pilon fractures

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	146	29	175	4.53
21–25	201	72	273	7.07
26–30	275	86	361	9.34
31–35	346	76	422	10.92
36–40	407	127	534	13.82
41–45	460	136	596	15.42
46–50	297	136	433	11.21
51–55	213	135	348	9.01
56–60	156	128	284	7.35
61–65	107	61	168	4.35
66–70	42	61	103	2.67
71–75	30	33	63	1.63
76–80	15	28	43	1.11
81–85	15	23	38	0.98
≥ 86	4	19	23	0.60
Total	2,714	1,150	3,864	100.00

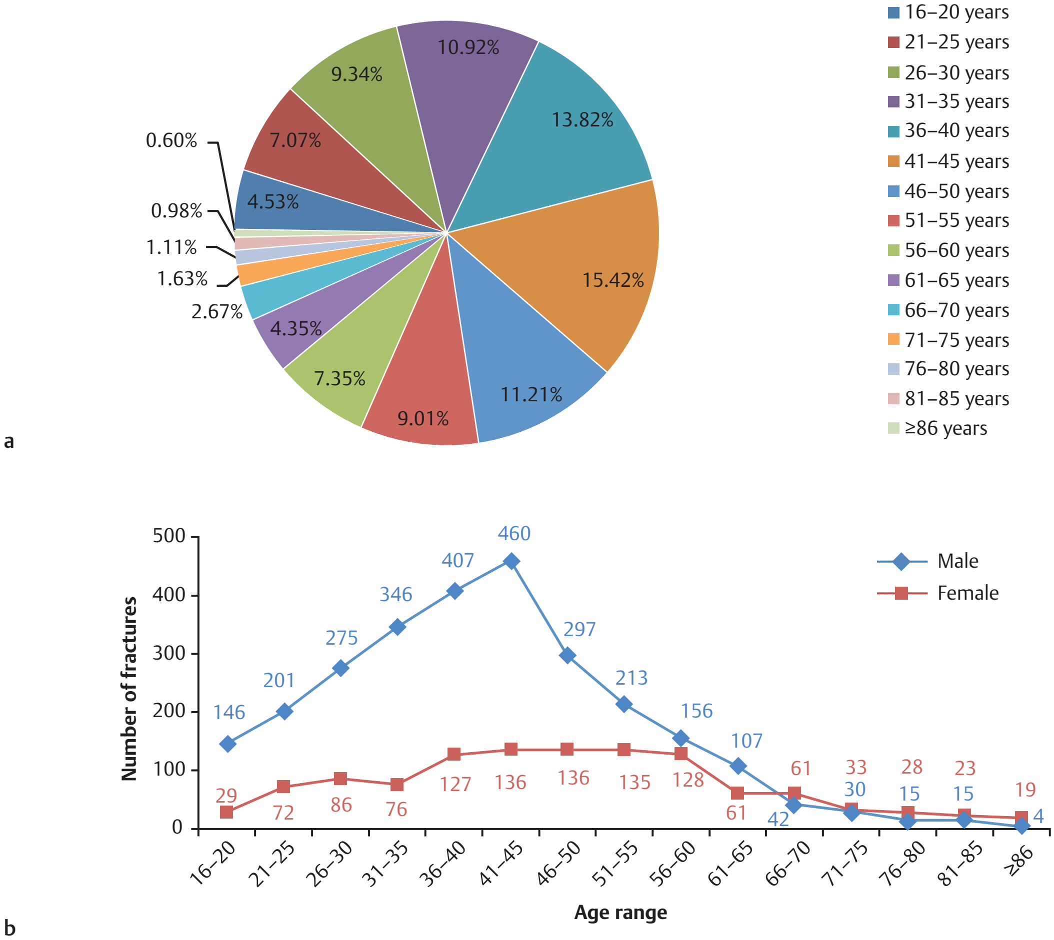


Fig. 5.44 (**a**) Age distribution of 3,864 Pilon fractures. (**b**) Age and sex distribution of 3,864 Pilon fractures.

Fracture Type Distribution of Pilon Fractures by Ruedi and Allgower Classification

See ▶ Table 5.32 and ▶ Fig. 5.45.

Table 5.32 Sex and fracture type distribution of 3,864 Pilon fractures by Ruedi and Allgower classification

Fracture type (Ruedi and Allgower)	Male	Female	Number of fractures	Percentage
I	896	636	1,532	39.65
II	924	314	1,238	32.04
III	894	200	1,094	28.31
Total	2,714	1,150	3,864	100.00

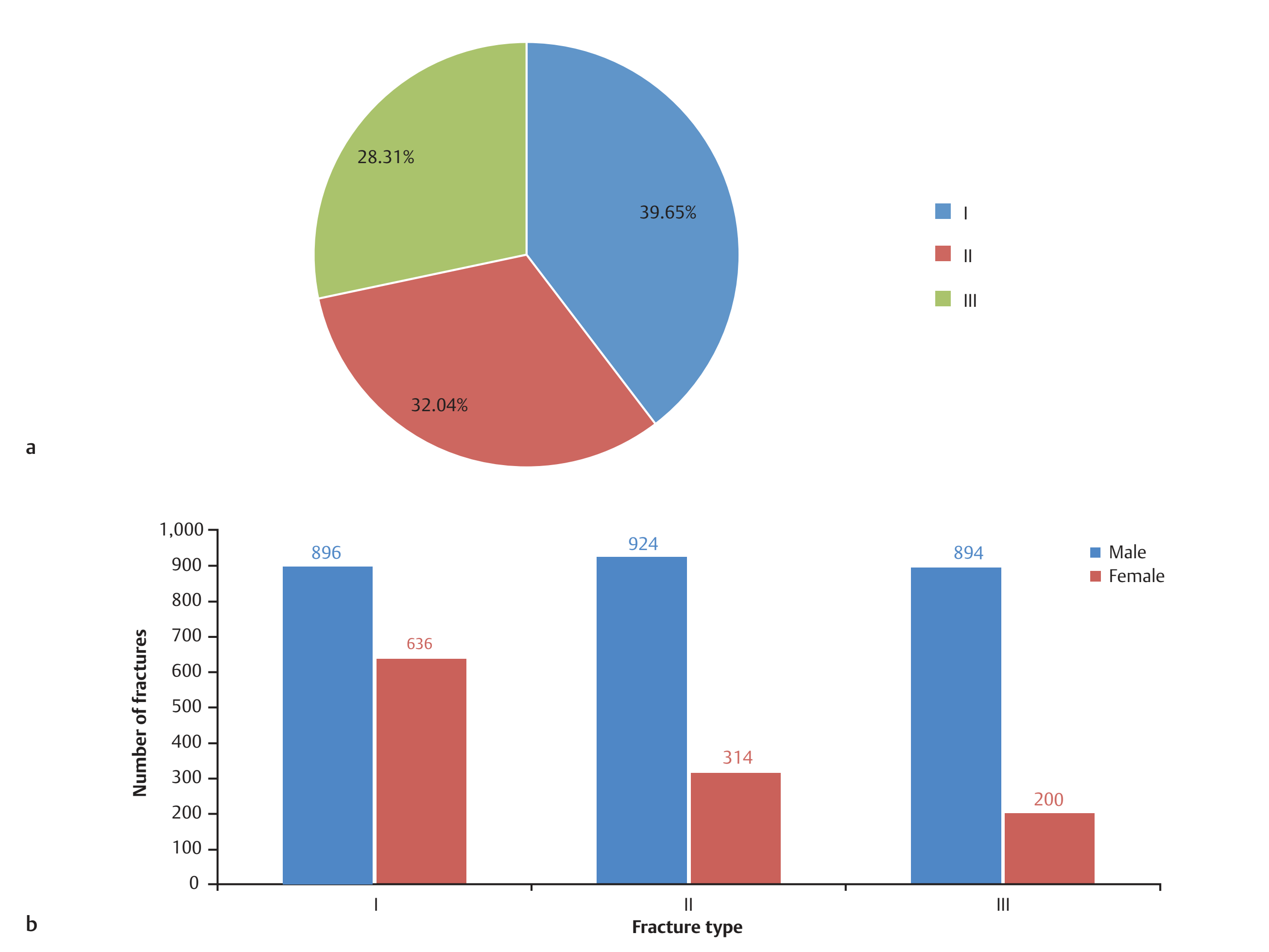


Fig. 5.45 (**a**) Fracture type distribution of 3,864 Pilon fractures by Ruedi and Allgower classification. (**b**) Sex and fracture type distribution of 3,864 Pilon fractures by Ruedi and Allgower classification.

Suggested Readings

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6 Fractures of the Spine

Wei Chen, Di Zhang, and Jiayuan Sun

Overview of Spinal Fractures

Anatomic Features

The spinal column consists of individual bony vertebrae and intervertebral disks that connect each vertebra in the front of the spine. A healthy spine provides strength, is flexible, and allows movement in several planes. Body movement and weight-bearing changes can produce an alteration in the geometry of the spine. The vertebral column is made of 26 separate vertebrae, and can be divided into five sections: cervical, thoracic, lumbar, sacral, and coccygeal. Because the sacrum and coccyx are fused with five sacral vertebrae and four coccygeal vertebrae, respectively, some believe the vertebral column is actually made up of 33 vertebral bones. Each vertebra is composed of a body anteriorly and a neural arch posteriorly. The arch has two supporting pedicles and two arched laminae; it encloses an opening, the vertebral foramen, which helps to form the vertebral canal in which the spinal cord is housed. Seven processes arise from the vertebral arch: the central spinous process, two transverse processes, two superior facets, and two inferior facets. Three quarters of the length of the vertebral column is from the vertebral bodies and one quarter is from the thickness of the intervertebral disks.

Two important concepts have emerged during the study of the spine's anatomic features. They are the two-column concept and three-column concept. In 1968, Kelly and Whitesides proposed a two-column concept that aided the assessment of angular deformation (▶ Fig. 6.1). The two columns, namely the anterior and posterior columns, are defined as involving the vertebral bodies and neural arches, respectively, and are delineated by the posterior longitudinal ligament. The anterior column is composed of the anterior longitudinal ligament, posterior longitudinal ligament, and vertebral body. The posterior column, otherwise known as the hollow column, is composed of the vertebral canal and the posterior ligamentous complex. Kelly and Whitesides highlighted the importance of the posterior ligamentous complex in the assessment of spinal stability. However, the two-column concept is limited in assessing posterior nerve root injury in spinal fractures, and has been gradually replaced by the three-column concept.

The three-column concept was introduced by Denis in 1983, and is more consistent with clinical observations regarding spinal stability than the two-column concept (▶ Fig. 6.2). It divides the spine into three columns: the anterior, middle, and posterior columns. Using this scheme, the anterior column is composed

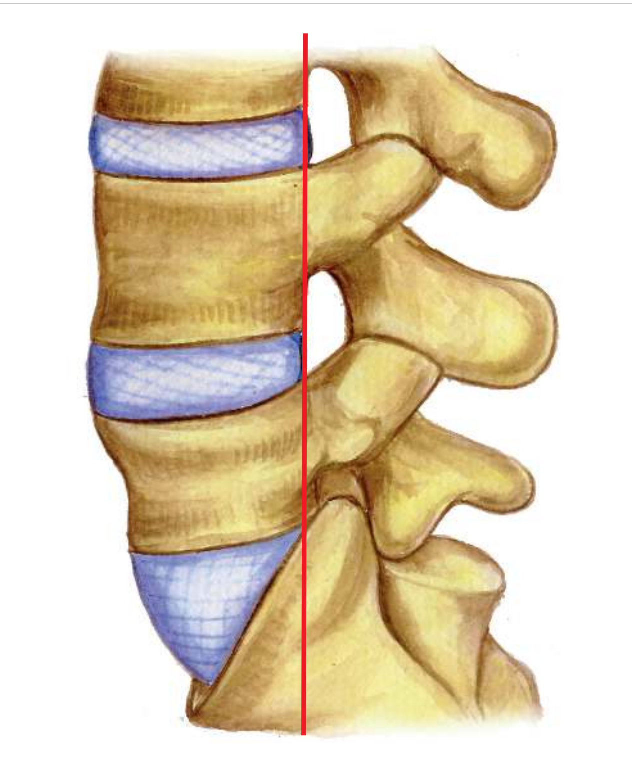

Fig. 6.1 Delineation illustration of two-column spine concept.

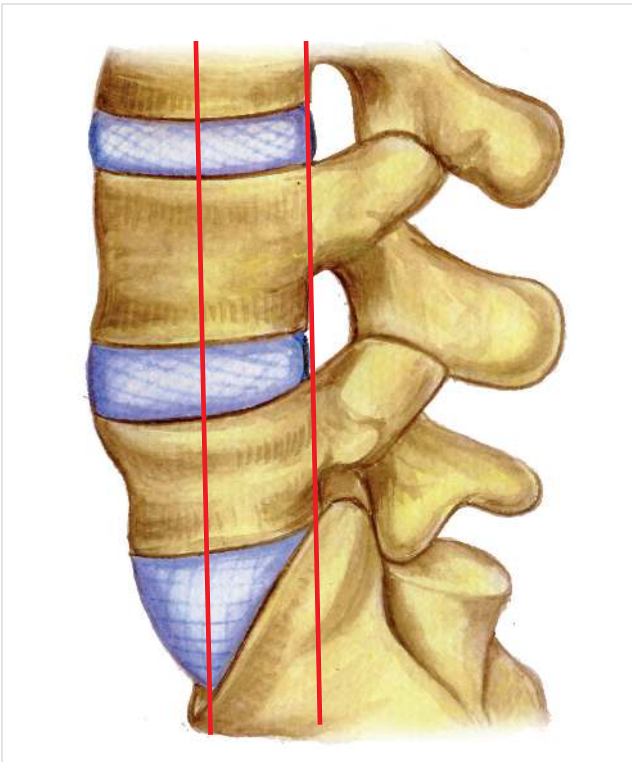

Fig. 6.2 Delineation illustration of three-column spine concept.

of the anterior half of the vertebral body, the intervertebral disk, and the anterior longitudinal ligament; the middle column includes the posterior part of vertebral body and the disk, and the posterior longitudinal ligament; and the posterior column includes the pedicles, the facet joints, and the supraspinous ligaments. In 1984, McAfee proposed that the demarcation lies between the anterior and middle columns at the junction of the anterior two-thirds and posterior one-third of the vertebral body, instead of the midpoint of the vertebral body as proposed by Denis. With McAfee's scheme, fractures involving the middle column are unstable fractures. This concept is able to provide a better and more accurate assessment of spinal stability and neurological injury.

AO Classification and Coding System for Spinal Fractures

Based on AO classification, the spinal column is coded as number "5." Cervical, thoracic, lumbar, and sacral fractures are assigned as numbers "51," "52," "53," and "54," respectively. Pelvic fractures always involve sacrococcygeal fractures; therefore, we put sacral and coccygeal fractures into the pelvic section during our statistical analysis.

Because the atlas (51.01) and axis (51.02) have different anatomic features and unique functions from the other cervical vertebrae, they require different methods of assessment regarding the stability and neurological injury resulting from fractures. As such, AO classification describes vertebral column fractures into four sections: atlas, axis, lower cervical, and thoracolumbar fractures. The atlas and axis constitute the upper cervical spine.

For AO classification of spinal fractures, number "5" is assigned for the spine; "51" for cervical spine, 51.01–51.07 for vertebrae C1–C7, respectively (▶ Fig. 6.3); "52" for thoracic spine, 52.01–52.12 for vertebrae T1–T12, respectively; and "53" for lumbar spine, 53.01–53.05 for L1–L5, respectively (▶ Fig. 6.4).

Epidemiologic Features of Spinal Fractures in the China National Fracture Study

A total of 168 patients with 168 spinal fractures were investigated in the China National Fracture Study (CNFS). The fractures accounted for 9.53% of all patients with fractures and 9.17% of all types of fractures. The population-weighted incidence rate of spinal fractures was 29 per 100,000 population.

The epidemiologic features of spinal fractures in the CNFS are as follows:

- More males than females
- The highest risk age group is 15–64 years
- The thoracic and lumbar vertebral fracture is the most common spinal fractures
- Injuries occurred most commonly via falls

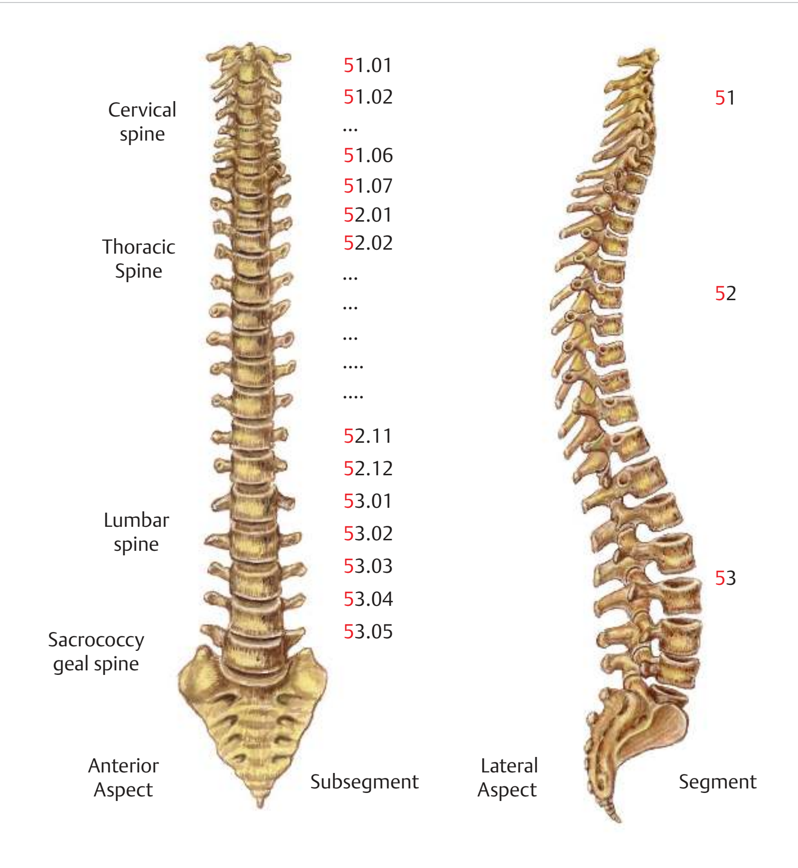

Fig. 6.3 AO codes for the spine.

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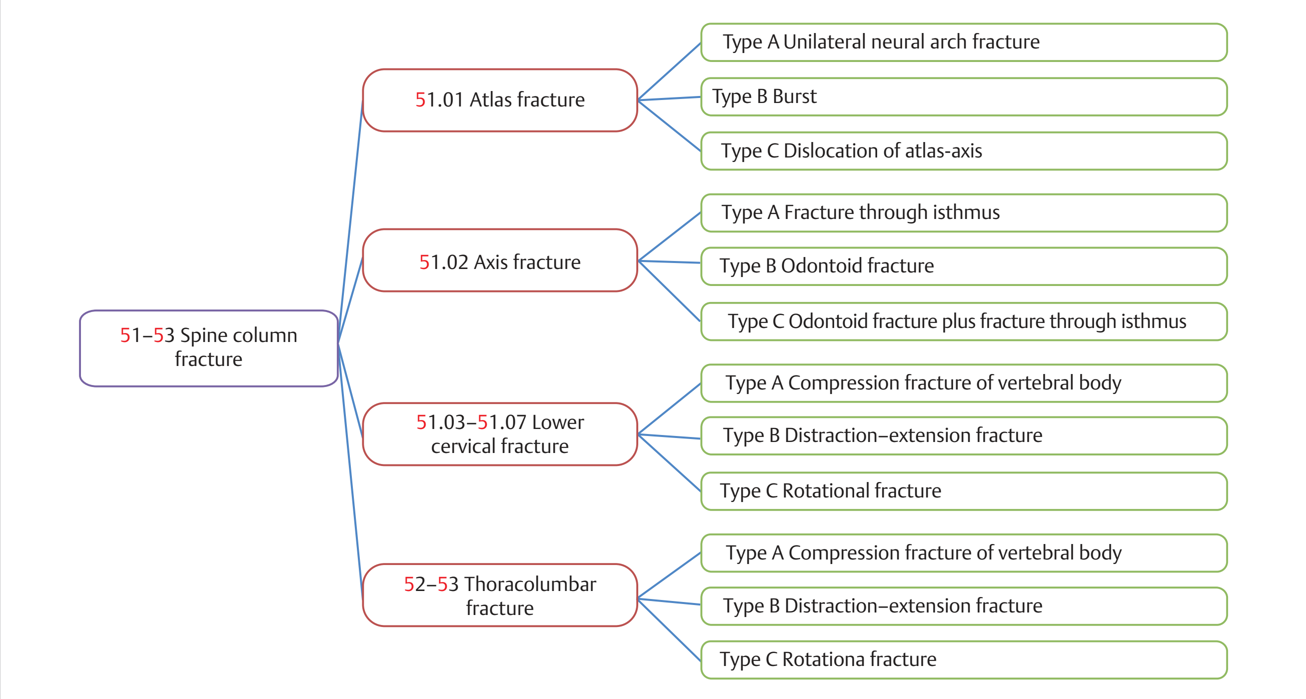

Fig. 6.4 Algorithm.

■ Spinal Fractures by Sex in CNFS

See ► Table 6.1 and ► Fig. 6.5.

Table 6.1 Sex distribution of 168 patients with spinal fractures in the China National Fracture Study

Sex	Number of patients	Percentage
Male	92	54.76
Female	76	45.24
Total	168	100.00

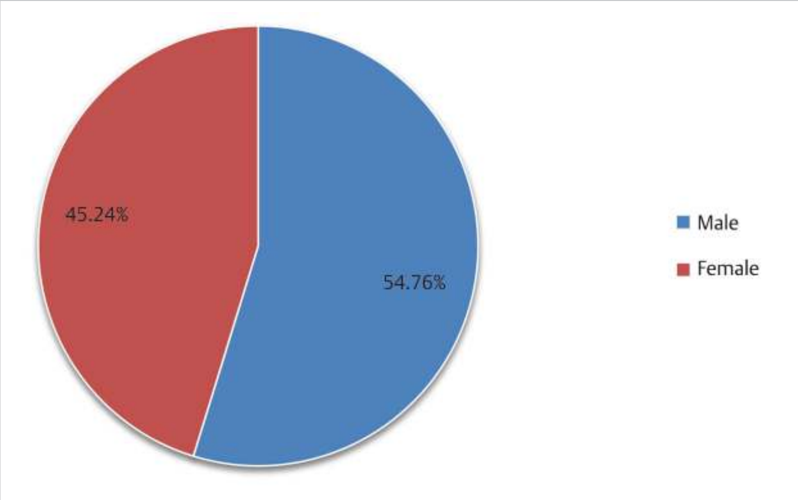

Fig. 6.5 Sex distribution of 168 patients with spinal fractures in the China National Fracture Study (CNFS).

■ Spinal Fractures by Age and Sex in CNFS

See ▶ Table 6.2 and ▶ Fig. 6.6.

Table 6.2 Age distribution of 168 patients with spinal fractures in the China National Fracture Study

Age group (years)	Male	Female	Total	Percentage
0–14	2	1	3	1.79
15–64	65	50	115	68.45
≥65	25	25	50	29.76
Total	92	76	168	100.00

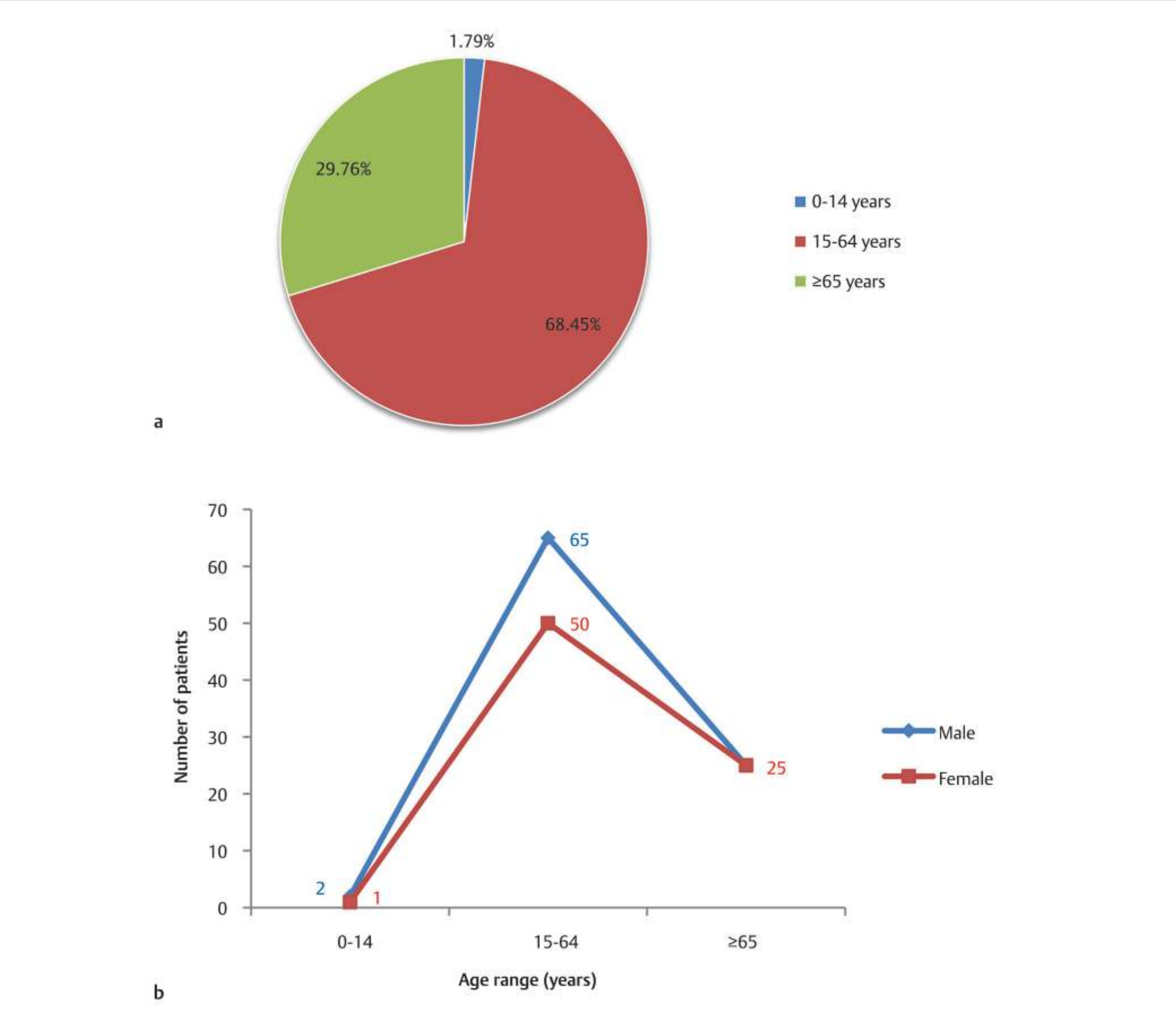

Fig. 6.6 (**a**) Age distribution of 168 patients with spinal fractures in the China National Fracture Study (CNFS); (**b**) age and sex distribution of 168 patients with spinal fractures in the CNFS.

■ Spinal Fractures by Location in CNFS

See ▶ Table 6.3 and ▶ Fig. 6.7.

Table 6.3 Segment distribution of 168 patients with spinal fractures in the China National Fracture Study

Segment	Male	Female	Total	Percentage
51	7	0	7	4.17
52 and 53	85	76	161	95.83
Total	92	76	168	100.00

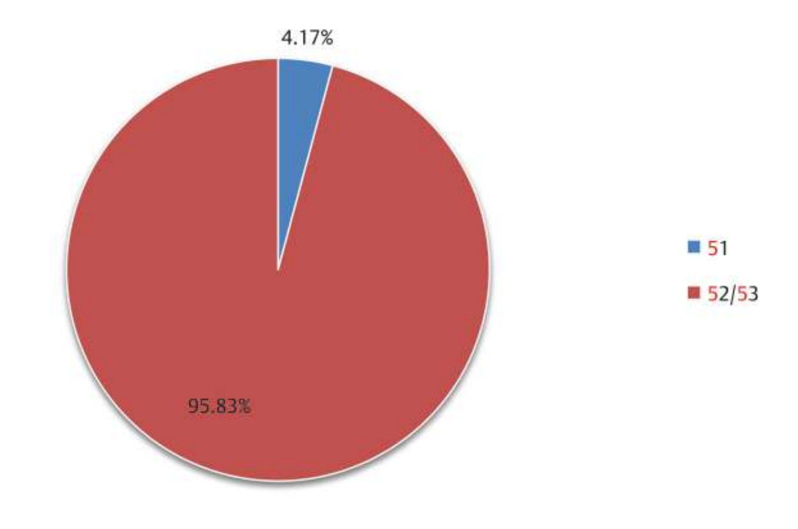

Fig. 6.7 Segment distribution of 168 patients with spinal fractures in the China National Fracture Study (CNFS).

■ Spinal Fractures by Causal Mechanisms in CNFS

See ▶ Table 6.4 and ▶ Fig. 6.8.

Table 6.4 Causal mechanisms of 168 patients with spinal fractures in the China National Fracture Study

Causal mechanisms	Male	Female	Total	Percentage
Traffic accident	23	19	42	25.00
Slip, trip, or fall	35	49	84	50.00
Fall from heights	21	5	26	15.48
Crushing injury	9	3	12	7.14
Sharp trauma	1	0	1	0.60
Blunt force trauma	3	0	3	1.79
Total	92	76	168	100.00

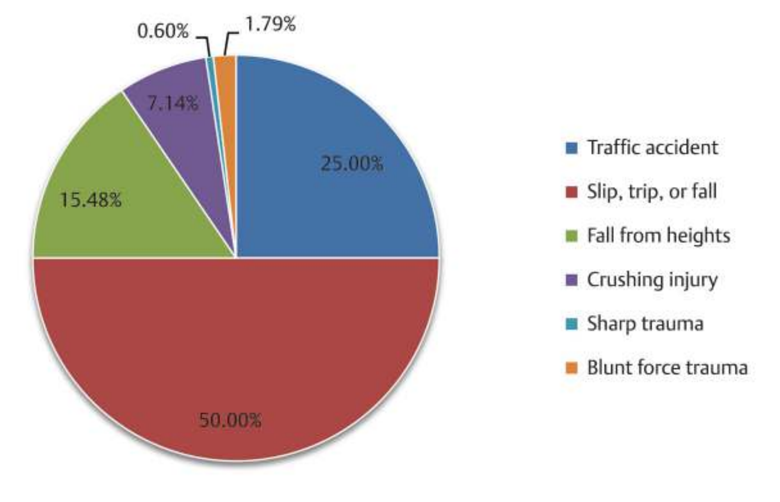

Fig. 6.8 Causal mechanisms of 168 patients with spinal fractures in the China National Fracture Study (CNFS).

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Clinical Epidemiologic Features of Fractures of the Spinal Column

A total of 49,679 patients with 55,097 spinal column fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, accounting for 11.97% of all patients with fractures and 12.76% of all types of fractures, respectively. Among these 49,679 patients, there were 517 children and 49,162 adults. Epidemiologic features of fractures of the spinal column are as follows:

- More males than females
- The high-risk age group is 56–60 years. The most affected male age group is 41–45 years, while females aged 56–60 years have the highest risk.
- Thoracolumbar fractures occur more frequently than cervical or sacrococcygeal fractures.

Spinal Column Fractures by Sex

See ▶ Table 6.5 and ▶ Fig. 6.9.

Table 6.5 Sex distribution of 49,679 patients with spinal column fractures

Sex	Number of patients	Percentage
Male	25,280	50.89
Female	24,399	49.11
Total	49,679	100.00

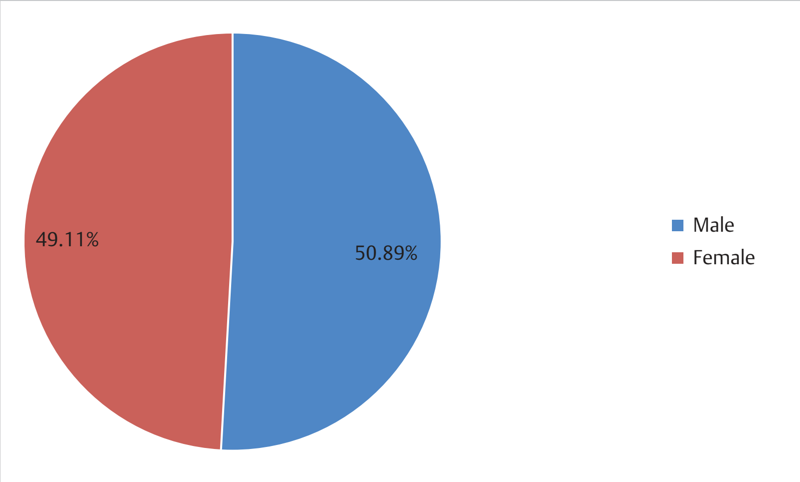

Fig. 6.9 Sex distribution of 49,679 patients with spinal column fractures.

Spinal Column Fractures by Age Group

See ▶ Table 6.6 and ▶ Fig. 6.10.

Table 6.6 Age and sex distribution of 49,679 patients with spinal column fractures

Age group (years)	Male	Female	Number of patients	Percentage
0–5	58	38	96	0.19
6–10	75	62	137	0.28
11–15	172	112	284	0.57
16–20	750	307	1,057	2.13
21–25	1,337	440	1,777	3.58
26–30	1,483	557	2,040	4.11
31–35	1,622	664	2,286	4.60
36–40	2,468	1,045	3,513	7.07
41–45	2,847	1,323	4,170	8.39
46–50	2,723	1,649	4,372	8.80
51–55	2,356	2,010	4,366	8.79
56–60	2,530	3,099	5,629	11.33
61–65	1,757	2,883	4,640	9.34
66–70	1,399	2,867	4,266	8.59
71–75	1,392	2,995	4,387	8.83
76–80	1,176	2,493	3,669	7.39
81–85	727	1,286	2,013	4.05
≥ 86	408	569	977	1.97
Total	25,280	24,399	49,679	100.00

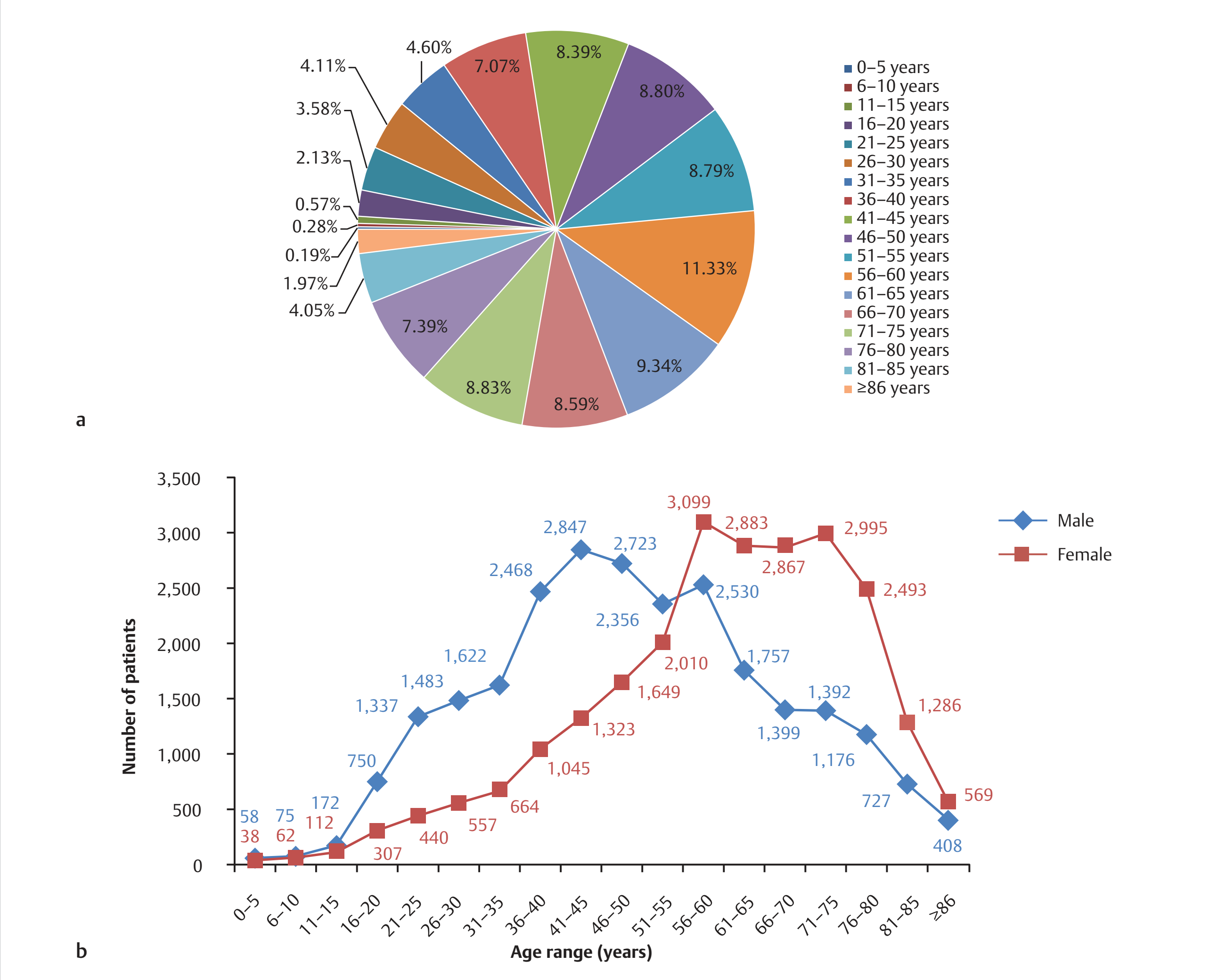

Fig. 6.10 (**a**) Age distribution of 49,679 patients with spinal column fractures and (**b**) age and sex distribution of 49,679 patients with spinal column fractures.

Spinal Column Fractures by Segment

See ▶ Table 6.7.

Table 6.7 Sex and fracture subsegment distribution of 55,097 spinal column fractures

Subsegment	Male	Female	Number of fractures	Percentage
51.01	189	118	307	0.56
51.02	694	417	1,111	2.02
51.03	200	74	274	0.50
51.04	314	114	428	0.78
51.05	619	223	842	1.53
51.06	433	191	624	1.13
51.07	128	44	172	0.31
52.01	593	748	1,341	2.43
52.02	112	201	313	0.57
52.03	62	63	125	0.23
52.04	92	99	191	0.35
52.05	107	111	218	0.40
52.06	164	198	362	0.66
52.07	233	280	513	0.93
52.08	243	316	559	1.01
52.09	232	289	521	0.95
52.01	282	388	670	1.22
52.11	1,337	1,660	2,997	5.44
52.12	4,657	5,535	10,192	18.50
53.01	9,399	8,970	18,369	33.34
53.02	3,918	3,547	7,465	13.55
53.03	1,863	1,788	3,651	6.63
53.04	1,320	1,259	2,579	4.68
53.05	603	670	1,273	2.31
Total	27,794	27,303	55,097	100.00

Cervical Fractures (Segment 51)

Anatomic Features

The first two vertebral bodies in the cervical spine are called the atlas and the axis. They are very special with respect to their unique anatomic features and functions; therefore, assessment of injuries to the atlas and axis is very different from those of other vertebrae. AO classification has special descriptions for fractures of the atlas and axis (▶ Fig. 6.11).

The atlas, a ring-shaped bone, is remarkable for having no "body." It consists of anterior and posterior arches, and two lateral masses, from which two transverse processes project laterally and downward. Its superior articular facets articulate with the occipital condyles of the skull, and it forms the atlantoaxial joint with the dens of the axis. The two transverse processes of the atlas serve as an attachment site for muscles and ligaments, which assist in rotating the head. The foramen transversarium pierces the transverse processes of the atlas, and gives passage to the vertebral artery and vein. The anterior and posterior arches are thin, especially at their junction with the lateral mass, which is particularly susceptible to injury and, if damaged, may lead to fracture and dislocation.

The dens of the axis was originally part of the atlas, but became separated from the atlas during development; therefore, malformations commonly occur, such as absence of the dens of axis, hypoplasia or agenesis of the dens, occipital–atlas fusion, and atlas–axis fusion. These malformations may result in poor stability of the craniocervical region and compression of the spinal cord.

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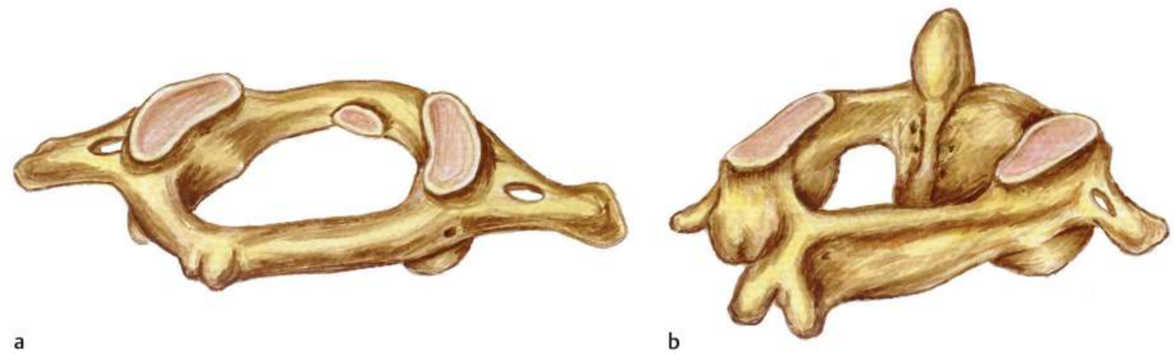

Fig. 6.11 Oblique posterior–superior views of atlas (a) and axis (b).

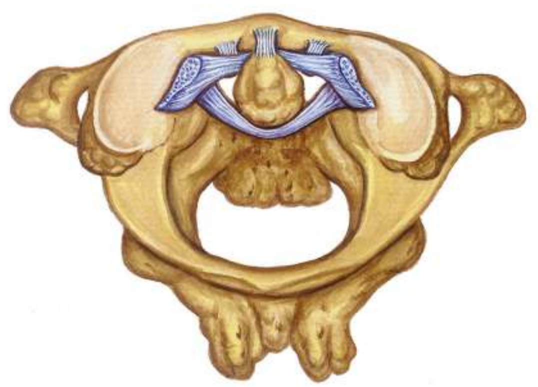

Fig. 6.12 Superior view of atlantoaxial ligaments.

The root of the dens is very thin, making it especially prone to injury. The resultant fracture and dislocation of the root would lead to a high risk of paraplegia or even death (▶ Fig. 6.11).

There are important ligaments between the atlas and axis, connecting two or more bones, condrites, or other soft tissues. The atlantoaxial ligament complex provides stability to the atlantoaxial joint through its great range of motion, and prevents hyperflexion or hyperextension of the joint (▶ Fig. 6.12). The upper cervical ligament is important in stabilizing the upper cervical spine and preventing neurological injury. Loss of stability of the ligament can result in subluxation of C1–C2, and lead to lethal neurological injuries.

Each vertebra in the lower cervical spine (C3–C7) consists of a vertebral body, a vertebral arch, which is formed by a pair of pedicles, and a pair of laminae (▶ Fig. 6.13). Each vertebra also has seven processes, four articular, two transverse, and one spinous. By comparison, cervical vertebrae are smaller than thoracolumbar vertebrae. The lateral aspect of each vertebral body has a superior projection (uncinate process) that forms Luschka's joints (uncovertebral joints) with a projection downward from the inferior surface of the vertebral body above. The transverse process is short and broad, with a wide groove for the existing spinal nerve on its upper surface. It gives attachment to a number of muscles. The bony protuberances at the end of the transverse processes are called the anterior and posterior tubercles, accordingly. The articular facets are inclined approximately 45 degrees from the horizontal plane. A characteristic feature of vertebrae C2 to C6 is a projection known as the bifid spinous process, whereas C7 has a prominent nonbifid spinous process that can be felt at the base of the neck.

AO Classification of Cervical Spinal Fractures

Based on AO classification, 51.01 (atlas) fractures can be divided into three types: A, unilateral neural arch fractures; B, burst fractures; and C, dislocation of the atlas–axis. And 51.02 (axis) fractures can also be grouped into three types: A, fractures through the isthmus, including neural arch (ring) fractures or Hangman's fractures; B, dens fractures; and C, fractures through the isthmus plus a dens fracture. The AO classification for segment 51.03–51.07 (lower cervical spine) has three categories: A, compression fractures of the vertebral body; B, distraction injuries of the anterior and posterior elements; and C, rotational injuries with translation affecting the anterior and posterior elements (▶ Fig. 6.14).

Clinical Epidemiologic Features of Fractures of the Upper Cervical Spine (Segment 51.01–51.02)

A total of 1,341 adult fractures of the upper cervical column were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All were reviewed and statistically studied, accounting for 2.46% of all spinal column fractures in adults. Their epidemiologic features are as follows:

- More males than females
- The highest-risk age group is 41–50 years
- The most common type of fracture among segment 51.01 (atlas) fractures is type A
- The most common type of fracture among segment 51.02 (axis) fractures is type B

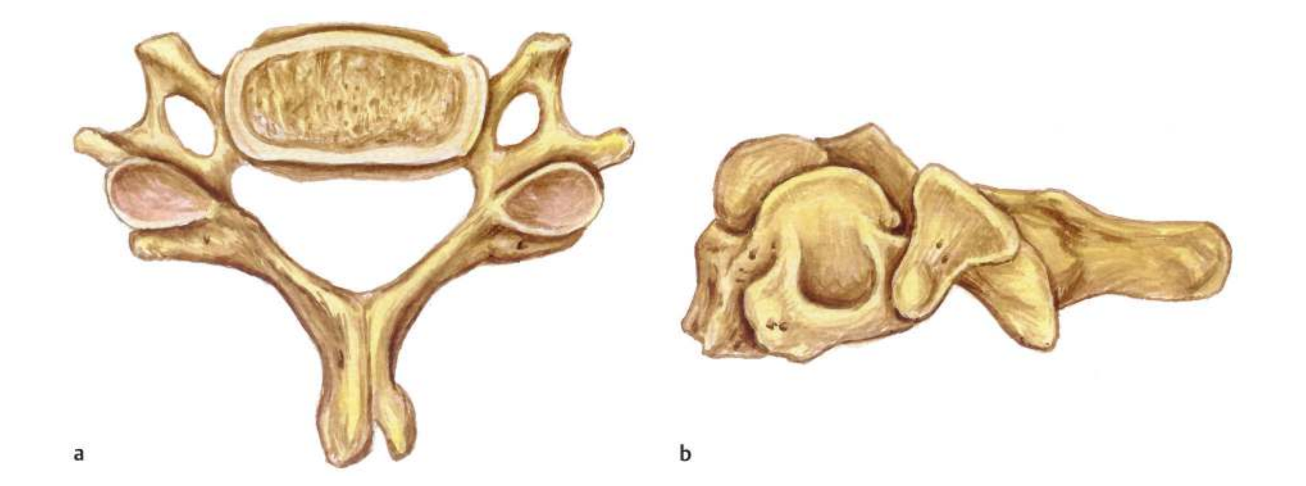

Fig. 6.13 Superior (**a**) and oblique lateral (**b**) views of anatomical features of the lower cervical spine.

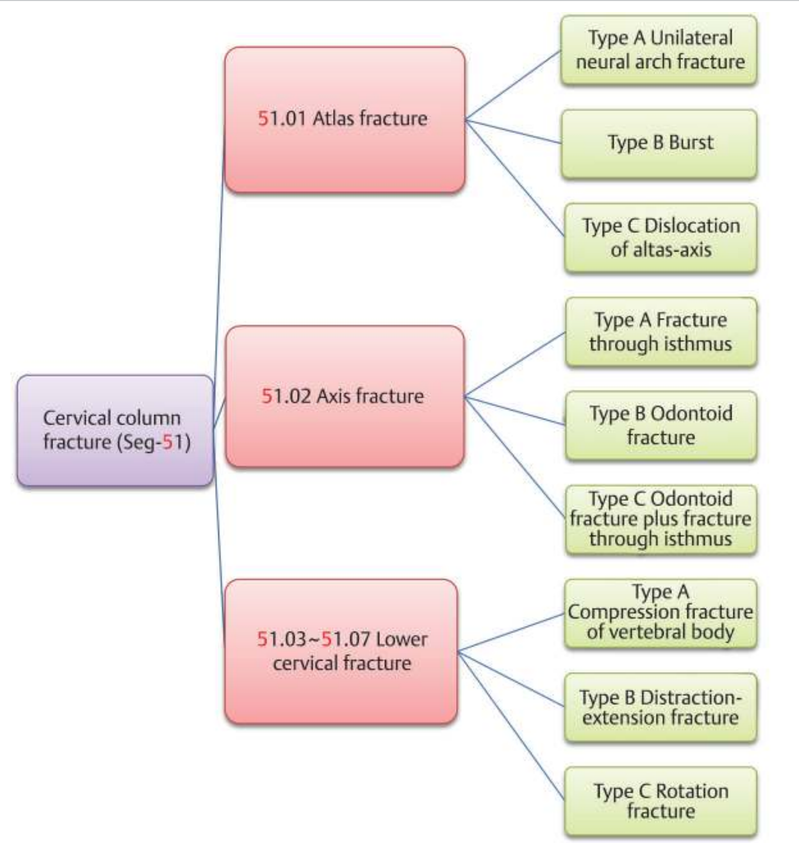

Fig. 6.14 Algorithm.

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■ Fractures of Segment 51.01–51.02 by Sex

See ▶ Table 6.8 and ▶ Fig. 6.15.

Table 6.8 Sex distribution of 1,341 upper cervical spine fractures in adults

Sex	Number of fractures	Percentage
Male	831	61.97
Female	510	38.03
Total	1,341	100.00

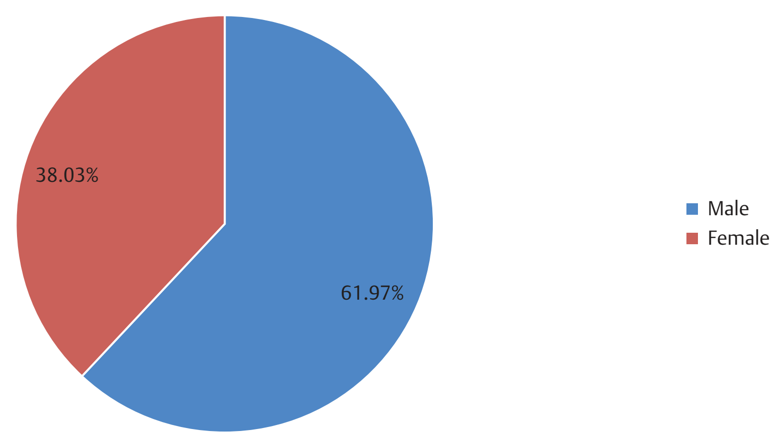


Fig. 6.15 Sex distribution of 1,341 upper cervical spine fractures in adults.

■ Fractures of Segment 51.01–51.02 by Age Group

See ▶ Table 6.9 and ▶ Fig. 6.16.

Table 6.9 Age and sex distribution of 1,341 upper cervical spine fractures in adults

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	34	16	50	3.73
21–25	59	19	78	5.82
26–30	63	47	110	8.20
31–35	57	41	98	7.31
36–40	100	50	150	11.19
41–45	123	62	185	13.80
46–50	95	72	167	12.45
51–55	90	37	127	9.47
56–60	73	41	114	8.50
61–65	45	48	93	6.94
66–70	36	26	62	4.62
71–75	26	24	50	3.73
76–80	16	20	36	2.68
81–85	9	6	15	1.12
≥ 86	5	1	6	0.45
Total	831	510	1,341	100.00

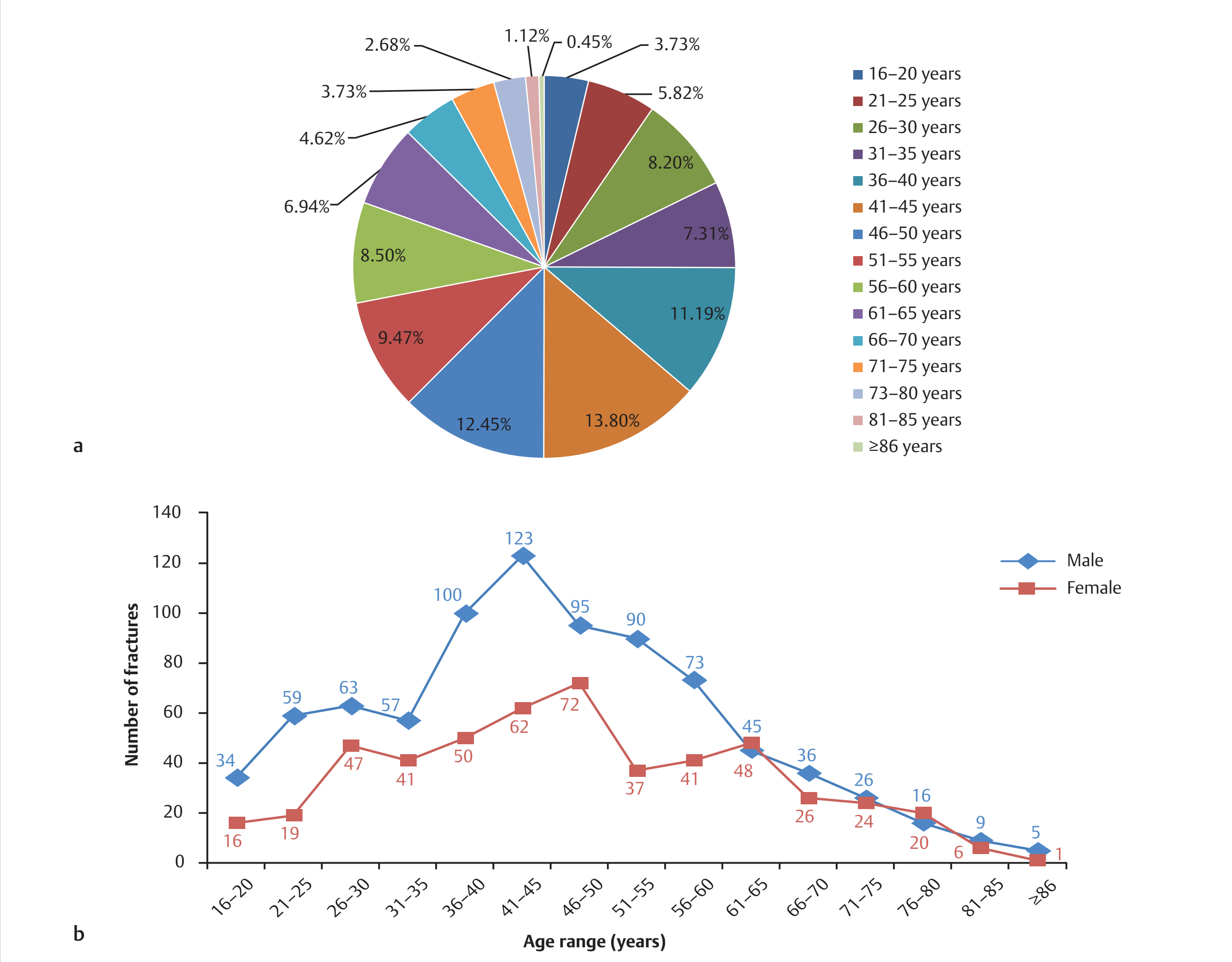


Fig. 6.16 (**a**) Age distribution of 1,341 upper cervical spine fractures in adults and (**b**) age and sex distribution of 1,341 upper cervical spine fractures in adults.

■ Fractures of Segment 51.01–51.02 by Fracture Type

Segment 51.01 (Atlas) Fractures by Fracture Type

See ▶ Table 6.10 and ▶ Fig. 6.17.

Table 6.10 Sex and fracture type distribution of 280 fractures of segment 51.01 in adults

Fracture type	Male	Female	Number of fractures	Percentage of 51.01 fractures	Percentage of spine fractures
51.01-A	87	53	140	50.00	0.26
51.01-B	28	20	48	17.14	0.09
51.01-C	57	35	92	32.86	0.17
Total	172	108	280	100.00	0.51

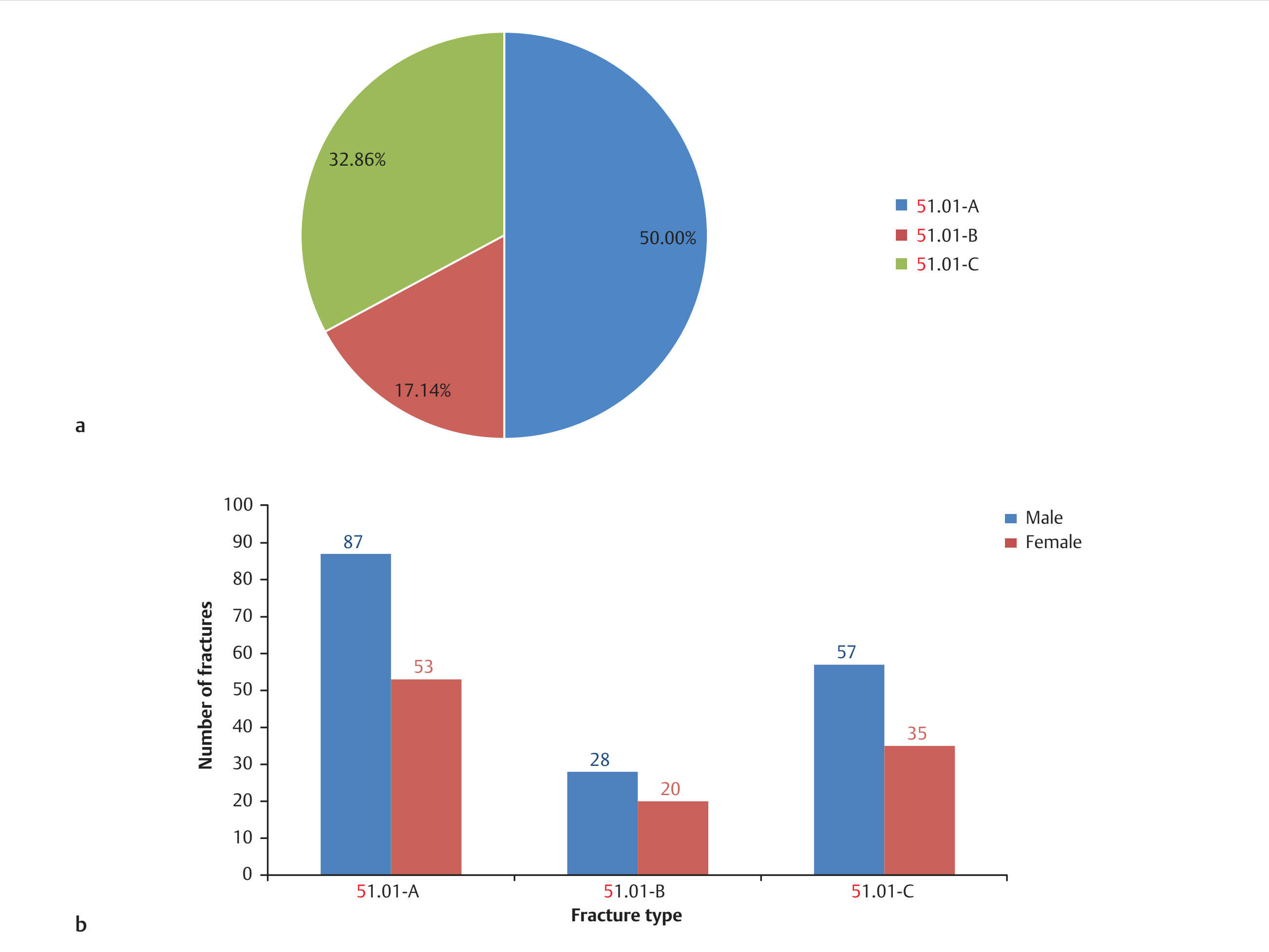


Fig. 6.17 (**a**) Fracture type distribution of 280 fractures of segment 51.01 in adults and (**b**) sex and fracture type distribution of 280 fractures of segment 51.01 in adults.

Segment 51.02 (Axis) Fractures by Fracture Type

See ► Table 6.11 and ► Fig. 6.18.

Table 6.11 Sex and fracture type distribution of 1,061 fractures of segment 51.02 in adults

Fracture type	Male	Female	Number of fractures	Percentage of 51.02 fractures	Percentage of spine fractures
51.02-A	137	63	200	18.85	0.37
51.02-B	466	300	766	72.20	1.40
51.02-C	56	39	95	8.95	0.17
Total	659	402	1,061	100.00	1.95

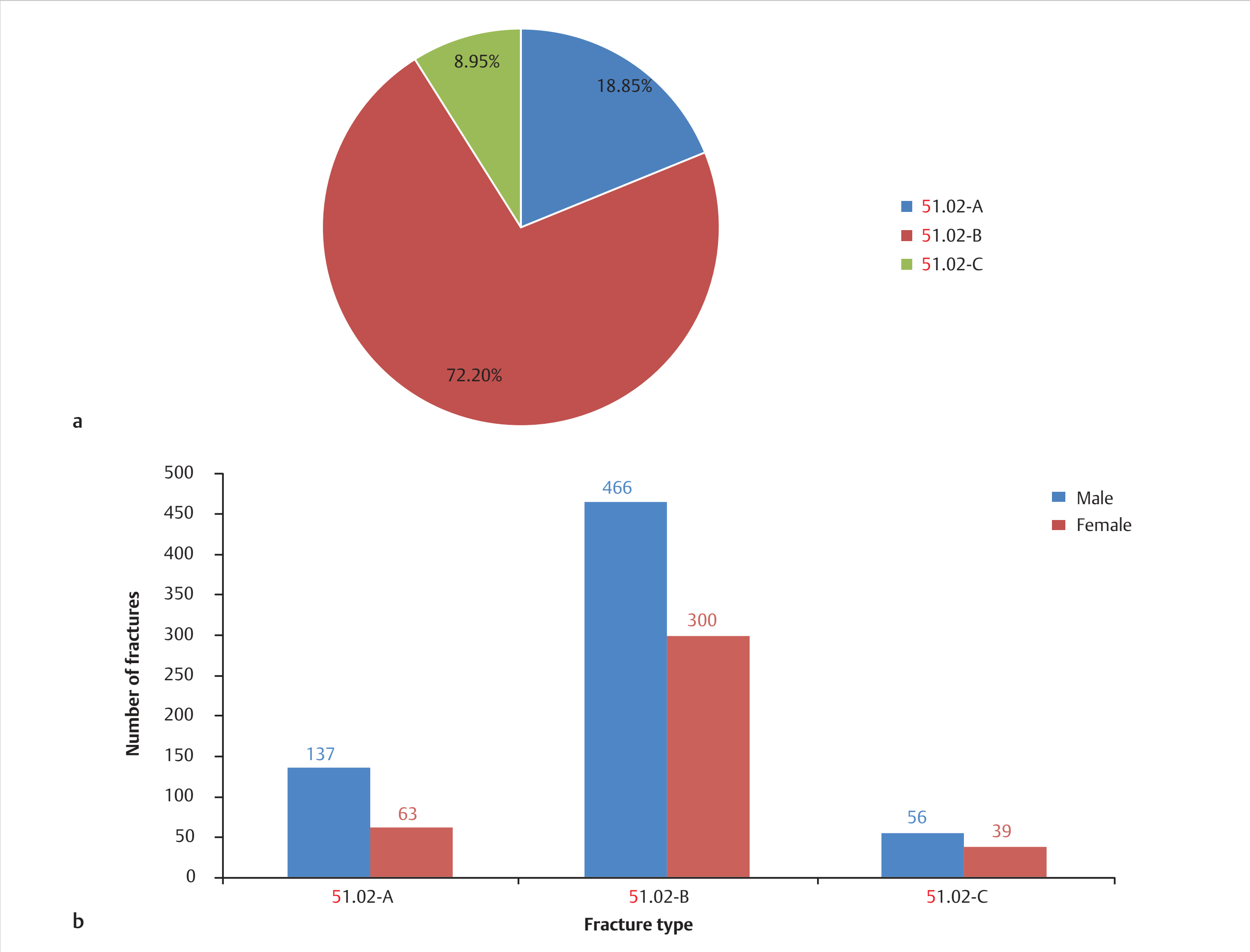


Fig. 6.18 (a) Fracture type distribution of 1,061 fractures of segment 51.02 in adults and (b) sex and fracture type distribution of 1,061 fractures of segment 51.02 in adults.

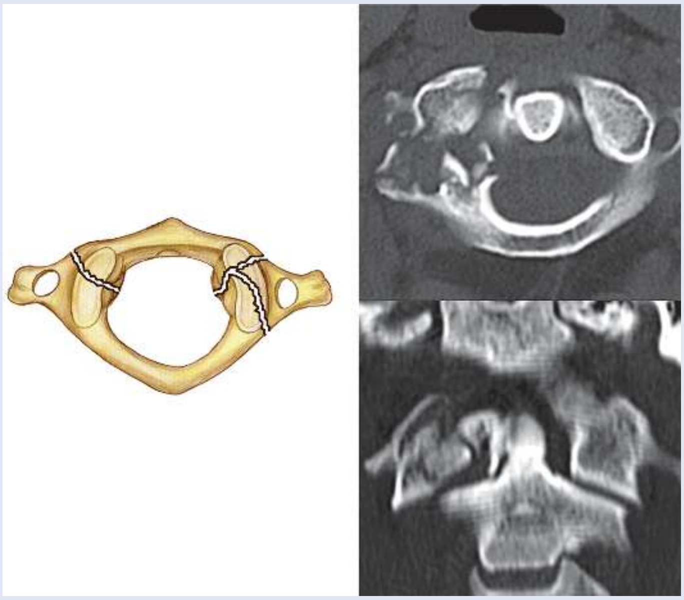
Segment 51.01 (atlas) fractures

51.01-A Unilateral neural arch fracture
140 fractures
M: 87 (62.14%)
F: 53 (37.86%)
0.04% of total adult fractures
0.26% of adult spinal column fractures
3.86% of adult cervical column fractures

51.01-A Unilateral neural arch fracture

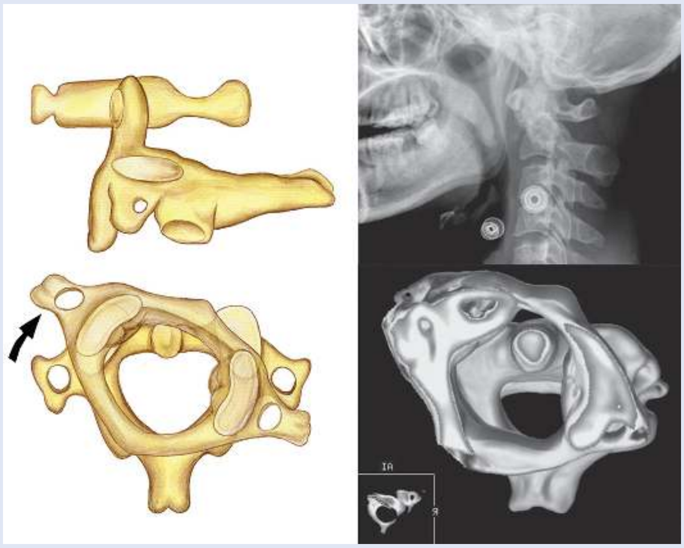
51.01-B Burst fracture
48 fractures
M: 28 (58.33%)
F: 20 (41.67%)
0.01% of total adult fractures
0.09% of adult spinal column fractures
1.32% of adult cervical column fractures

51.01-B Burst fracture



51.01-C Dislocation of atlas–axis
92 fractures
M: 57 (61.96%)
F: 35 (38.04%)
0.02% of total adult fractures
0.17% of adult spinal column fractures
2.54% of adult cervical column fractures

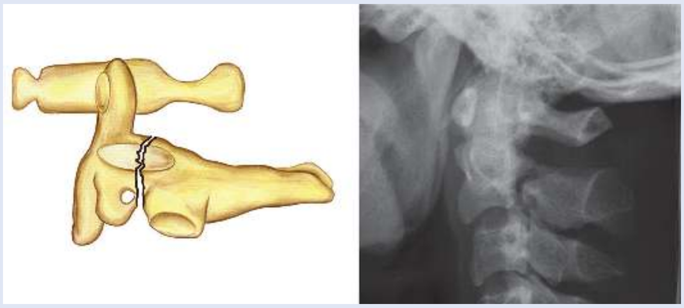
51.01-C Dislocation of the atlas–axis



Segment 51.02 (axis) fracture

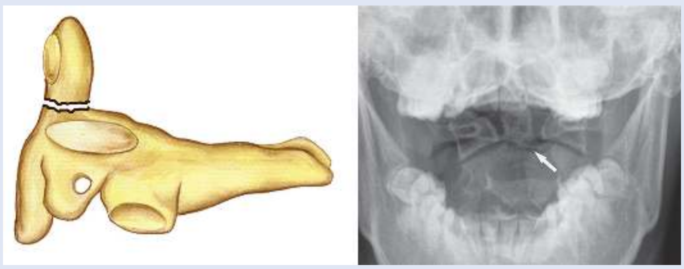
51.02-A Fractures through isthmus
200 fractures
M: 137 (68.50%)
F: 63 (31.50%)
0.05% of total adult fractures
0.37% of adult spinal column fractures
5.52% of adult cervical column fractures

51.02-A Fractures through isthmus



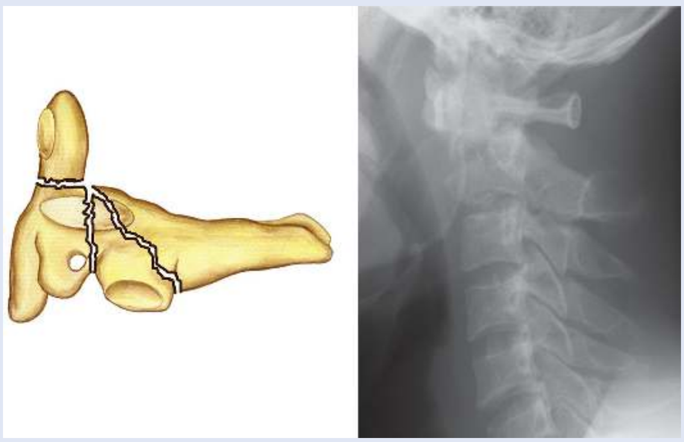
51.02-B Odontoid fracture
766 fractures
M: 466 (60.84%)
F: 300 (39.16%)
0.20% of total adult fractures
1.40% of adult spinal column fractures
21.14% of adult cervical column fractures

51.02-B Odontoid fracture



51.02-C Odontoid fracture plus fractures through isthmus
95 fractures
M: 56 (58.95%)
F: 39 (41.05%)
0.03% of total adult fractures
0.17% of adult spinal column fractures
2.62% of adult cervical column fractures

51.02-C Odontoid fracture plus fractures through isthmus



Clinical Epidemiologic Features of Fractures of the Lower Cervical Spine (Segment 51.03–51.07)

A total of 2,282 adult fractures of the lower cervical column were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All were reviewed and statistically studied, accounting for 4.18% of all spinal column fractures in adults, and 0.61% of all types of fractures in adults. Their epidemiologic features are as follows:

- More males than females
- The highest-risk age group is 46–50 years. The most affected male age group is 41–45 years, while females aged 51–55 years have the highest risk.
- The most common type of fracture among lower cervical spine fractures is type A—the same for both males and females.

Fractures of Segment 51.03–51.07 by Sex

See ▶ Table 6.12 and ▶ Fig. 6.19.

Table 6.12 Sex distribution of 2,282 fractures of segment 51.03–51.07 in adults

Sex	Number of fractures	Percentage
Male	1,657	72.61
Female	625	27.39
Total	2,282	100.00

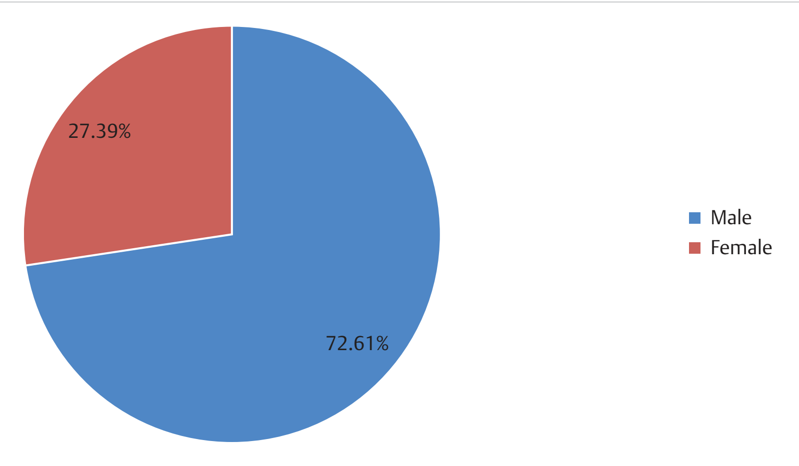


Fig. 6.19 Sex distribution of 2,282 fractures of segment 51.03–51.07 in adults.

6

■ Fractures of Segment 51.03–51.07 by Age Group

See ▶ Table 6.13 and ▶ Fig. 6.20.

Table 6.13 Age and sex distribution of 2,282 fractures of segment 51.03–51.07 in adults

Age group (years)	Male	Female	Number of fractures	Percentage of 51.01–51.07 fractures	Percentage of spinal fractures
16–20	46	11	57	2.50	0.10
21–25	107	26	133	5.83	0.24
26–30	137	30	167	7.32	0.31
31–35	123	35	158	6.92	0.29
36–40	193	56	249	10.91	0.46
41–45	199	76	275	12.05	0.50
46–50	197	81	278	12.18	0.51
51–55	173	87	260	11.39	0.48
56–60	183	66	249	10.91	0.46
61–65	113	62	175	7.67	0.32
66–70	70	41	111	4.86	0.20
71–75	60	26	86	3.77	0.16
76–80	37	17	54	2.37	0.10
81–85	14	7	21	0.92	0.04
≥ 86	5	4	9	0.39	0.02
Total	1,657	625	2,282	100.00	4.18

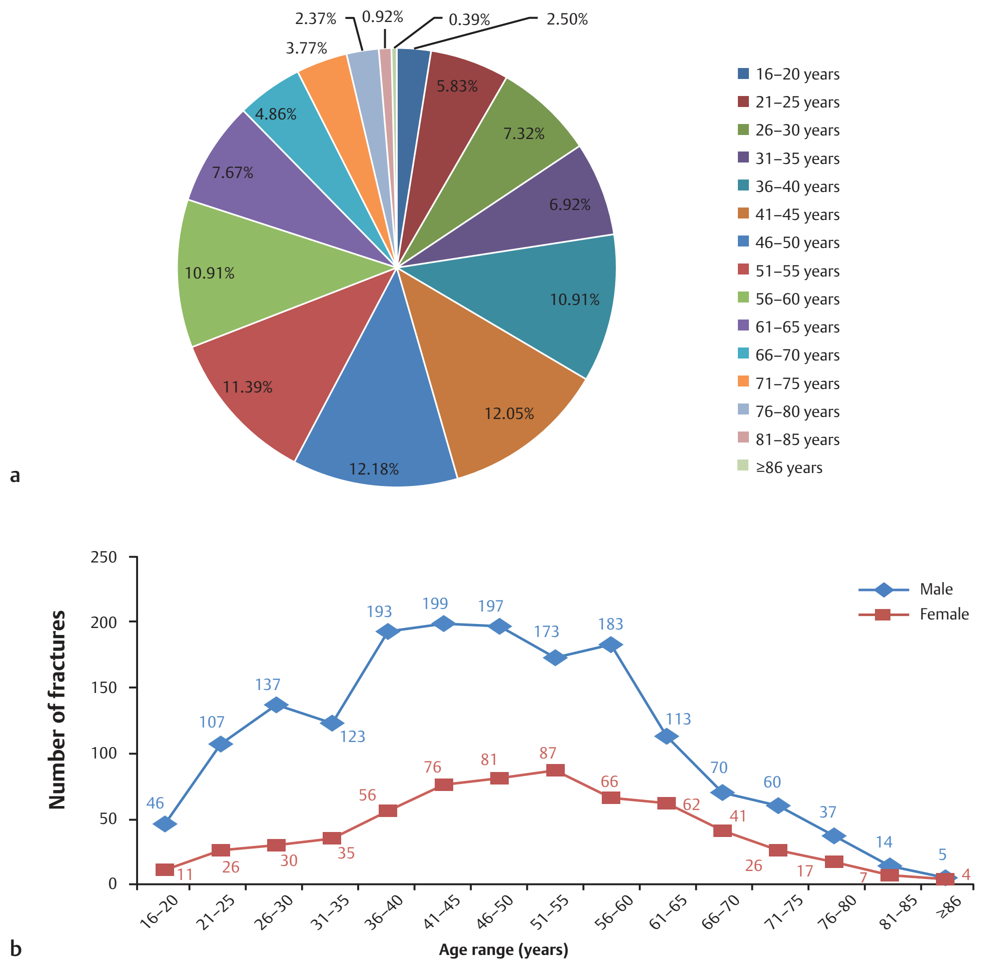


Fig. 6.20 (**a**) Age distribution of 2,282 fractures of segment 51.03–51.07 in adults and (**b**) age and sex distribution of 2,282 fractures of segment 51.03–51.07 in adults.

■ Fractures of Segment 51.03–51.07 by Fracture Type

See ► Table 6.14 and ► Fig. 6.21.

Table 6.14 Sex and fracture type distribution of 2,282 fractures of segment 51.03–51.07 in adults

Fracture type	Male	Female	Number of fractures	Percentage
51.03–51.07 A	996	439	1,435	62.88
51.03–51.07 B	537	152	689	30.19
51.03–51.07 C	124	34	158	6.92
Total	1,657	625	2,282	100.00

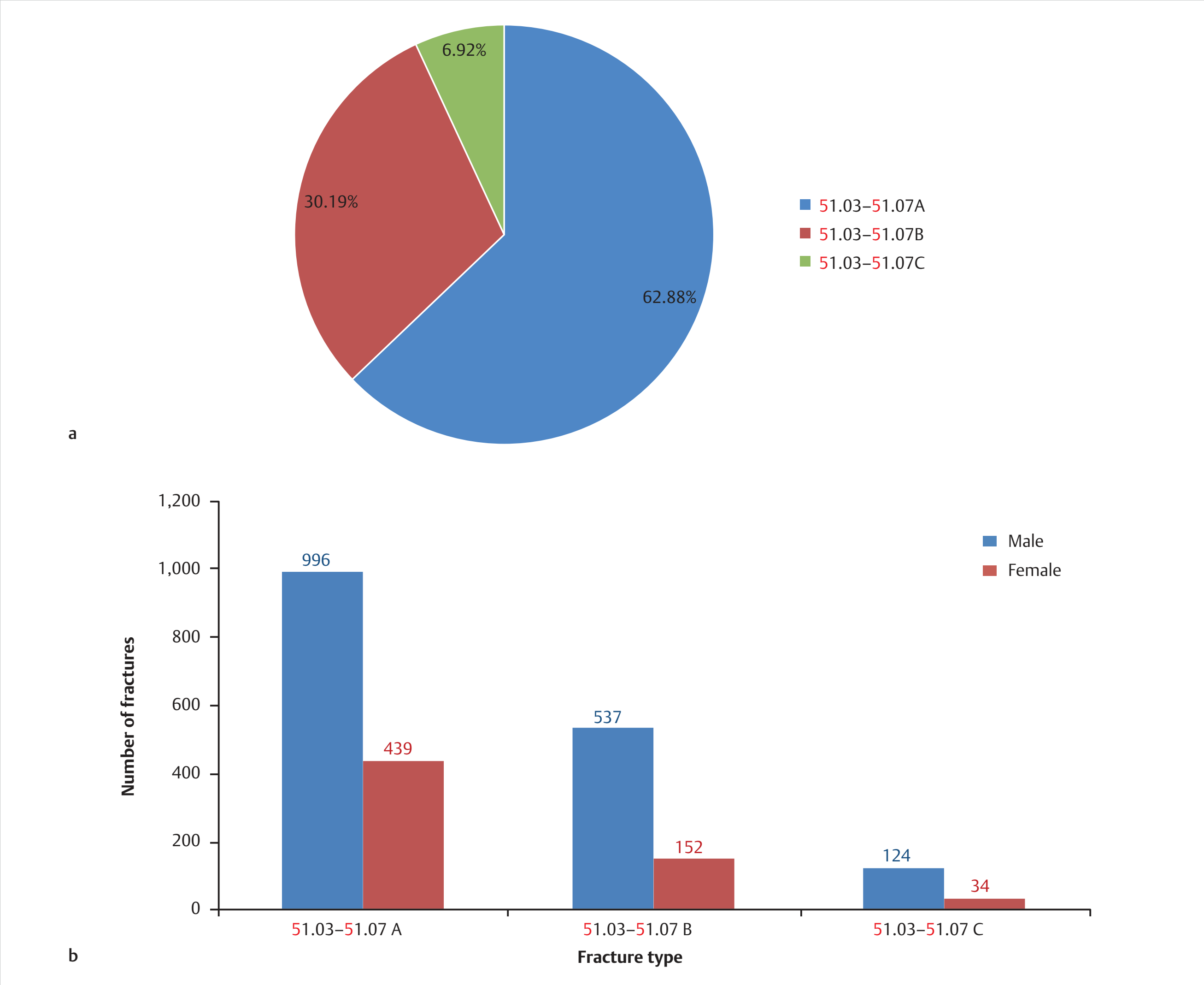
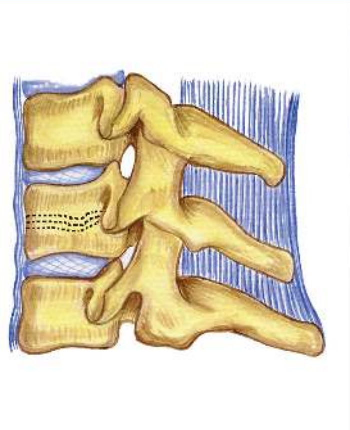


Fig. 6.21 (**a**) Fracture type distribution of 2,282 fractures of segment 51.03–51.07 in adults and (**b**) sex and fracture type distribution of 2,282 fractures of segment 51.03–51.07 in adults.

51.03–51.07 Lower cervical spine fracture

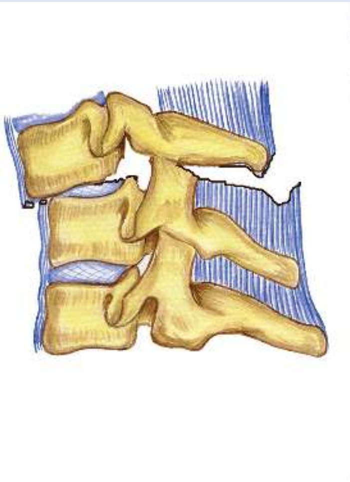
51.03–51.07-A Compression fracture of vertebral body
1,435 fractures
M: 996 (69.41%)
F: 439 (30.59%)
0.38% of total adult fractures
2.63% of adult spinal factures
39.61% of adult cervical fractures

51.03–51.07-A Compression fracture of vertebral body



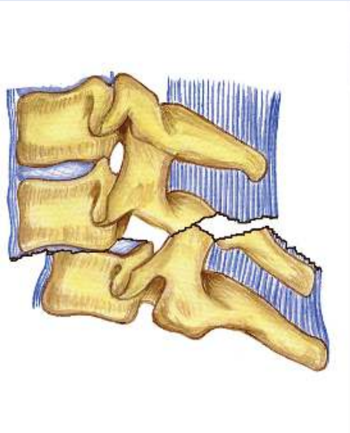

51.03–51.07-B Distraction injuries of the anterior and posterior elements
689 fractures
M: 537 (77.94%)
F: 152 (22.06%)
0.18% of total adult fractures
1.26% of adult spinal fractures
19.02% of adult cervical fractures

51.03–51.07-B Distraction injuries of the anterior and posterior elements




51.03–51.07-C Rotation injuries with translation affecting the anterior and posterior elements
158 fractures
M: 124 (78.48%)
F: 34 (21.52%)
0.04% of total adult fractures
0.29% of adult spinal fractures
4.36% of adult cervical fractures

51.03–51.07-C Rotation injuries with translation affecting the anterior and posterior elements




Injury Mechanism

The most common mechanism for cervical column fracture involves either direct or indirect force:

- *Direct force*: Less common; seen in traffic accidents, natural disasters (earthquake, tornado, etc.), or gunshot wounds, and are often associated with soft-tissue damage, which should be noted.
- *Indirect force*: Relatively common; extreme forces can be transmitted to the vertebrae through the head, feet, or buttocks (e.g., when a heavy object is placed on top of the head, or when an individual falls from a significant height and lands on the feet or buttocks), and may involve fracture-dislocation of cervical bodies. Indirect forces can be grouped into five categories, according to the direction of the force applied on the vertebrae:
  - *Vertical (axial) compressive forces*: An example of this mechanism is when a compressive downward force is transmitted to a lower level in the cervical spine, the body of the vertebra can shatter outward, or be compressed, along with a possible fracture or disruption of the neural arch.
  - *Flexion compressive forces*: This mechanism can be described as the force produced when a person falls from a height and lands on the ground with his or her spine in flexion, due to an innate protective reflex. The resulting force, along with vertical axial compression, causes wedge compression of the cervical body. In severe cases, facet dislocation may occur.
  - *Extension compressive forces*: This can be explained as the force produced when a person strains to look up by bending the head back, as in the athletic activities (e.g., gymnastics, diving, etc.). The effects of forceful posterior bending may result in injuries of the anterior longitudinal ligament, lamina, and facet joint.
  - *Lateral compressive forces*: This force is produced when a person falls from a height and lands on the ground unevenly, with the entire body leaning toward one side. The resulting force may cause unilateral compression of the cervical body and facet injury.
  - *Rotary compressive forces*: This mechanism usually accompanies the injuries previously mentioned and is relatively common. This force is produced when a person falls from a height and lands on the ground with his or her body in rotation.

Diagnosis

It may be difficult to diagnose upper cervical fractures with a regular anteroposterior view (AP) of the C-spine alone, which can be easily missed on X-ray images of the C-spine. A standard three-view C-spine trauma series, used for radiological screening of C-spine injuries, consists of anteroposterior, lateral, and open mouth odontoid views. An axial CT scan can be obtained for any questionable injury that cannot be visualized on plain radiographs. Based on individual injury mechanisms and clinical manifestations, if a patient presents with a suboccipital extradural hematoma radiographically, one should suspect the possibility of the upper cervical fractures.

Plain radiographic evaluation is useful in detecting ligamentous injury. The normal distance between the anterior arch of the atlas and the odontoid process is 3 to 5 mm. A distance greater than 5 mm may indicate rupture of the transverse atlantal ligament and instability of the atlantoaxial joint. Radiographs may reveal an anterior shift of C1 on C2. The commonly used radiographic evaluations for stability of the atlantoaxial joint include: (1) anteroposterior (AP) open mouth view with 15 degrees bending of the neck to the right and left, (2) lateral view of C-spine, and (3) cervical spine radiographs with the patient actively positioning his or her neck in extreme flexion and extension positions. If the cervical spine radiographs are inconclusive, then CT scan, 3D reformatting CT, or MRI can be used to delineate bony details of the cervical spine, demonstrate fractures, and the extent of the bone injury.

On an AP open-mouth radiograph, the medial aspect of the C1 lateral masses should be equidistant to the odontoid. The normal distance between the C1 lateral masses is ≤ 7 mm. A distance greater than 7 mm indicates a ruptured transverse ligament. If an atlantoaxial rotatory subluxation is suspected but not present on the open-mouth view, then the spinous process of C2 being out of alignment with the other cervical spinous process may likely indicate rotation of the atlas.

The vertebral body of C6 or C7 cannot be seen in some cases, for example, when the shoulders obscure this area in the lateral view. If this is the case, then traction on the upper extremities should be used to lower the shoulders. An improved visualization of the lower cervical spine can then be obtained. If the radiographs are still inconclusive, CT or MRI may be indicated for further investigation.

Treatment

The goal of treatment for upper cervical spine fractures is decompressing the injured spinal cord and nerve root, and providing stability to the spine. The fracture-dislocation of the cervical spine combined with a spinal cord injury requires open reduction, decompression, internal fixation, and interbody fusion with bone grafting. Generally speaking, ligamentous injury alone is usually treated nonsurgically, but with poor prognosis. However, some ligament injuries, such as an isolated unilateral alar ligament injury or a transverse ligament injury, should be treated with surgical intervention if conservative methods fail.

Nonsurgical treatments include: a semi-rigid collar, casting, skeletal traction, and Halo external fixation. The duration of the fixation is usually 2 to 4 months, depending on the reduction outcome with proper radiographic evidence.

Surgical treatment is indicated if conservative measures fail. The available internal fixation techniques include: odontoid screw fixation, C2–C3 anterior decompression of vertebral bodies and fusion, Gallie fusion, Brooks and Jenkins fusion for atlantoaxial arthrodesis, C1–C2 fusion with screw fixation, occipital cervical fusion, etc.

Usually, patients who sustain cervical spine injuries after treatment with nonsurgical methods (e.g., skeletal traction) do not require further surgical intervention if they have good spine stability and are without symptoms and signs of spinal cord or nerve root compression. The average healing time is 6 to 12 weeks with conservative treatment. If the clinical outcome is not satisfactory after the traction or external fixation is removed, surgical treatment should then be considered.

The primary indications for surgical intervention in cervical spine fracture include: fracture-dislocation of the cervical spine (malalignment of the spine), with neurological deficits (evidence of spinal cord and nerve root compression); progressive neurological deterioration (suggestive of persistent compression from bony or disk fragments); and an unstable fracture in the lower cervical spine. Neurological deficits due to spinal cord or nerve root compression usually require surgical intervention for decompression. Patients with multiple injuries should have emergency surgery involving open reduction and internal fixation as soon as their medical condition allows. For paralyzed patients, elective surgery is usually a better option than emergent surgery. An anterior or posterior approach can be applied depending on the fracture pattern. Available surgical methods include: anterior or posterior cervical decompression and fusion, posterior wiring fixation (including Bohlman's method, facet wiring, facet and spinous process wiring technique), lateral mass screw fixation, pedicle screw fixation, etc.

Further Classification of Cervical Spine Fractures

Anderson Classification of Odontoid Fractures

Anderson classified fractures of the odontoid process into three types:

- *Type I*: oblique avulsion fracture of the tip of the dens.
- *Type II*: fracture through the base of the odontoid process. Blood supply is often compromised in this type and associated with a high rate of nonunion fractures.
- *Type III*: fracture extends into the vertebral body of C2.

Most dens fractures can be identified on plain radiographs, except a Type II fracture, which is easily missed on radiographs because the convex shape of the superior facet obscures this region. CT scanning with thick cuts can also miss a Type II injury. Therefore, thin-section CT with sagittal reformation may be necessary to identify this type of odontoid fracture.

Hangman's Fracture

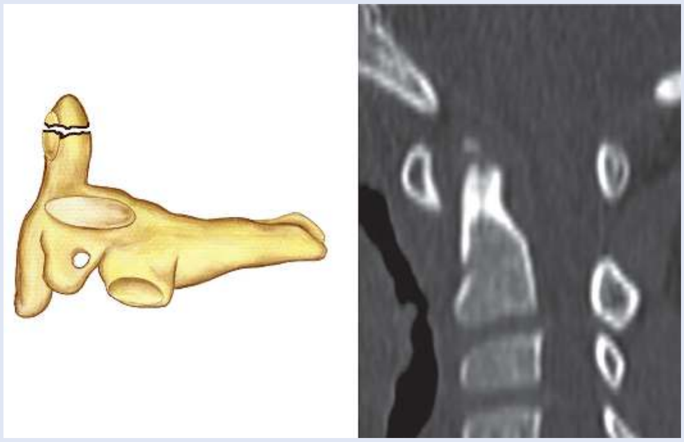
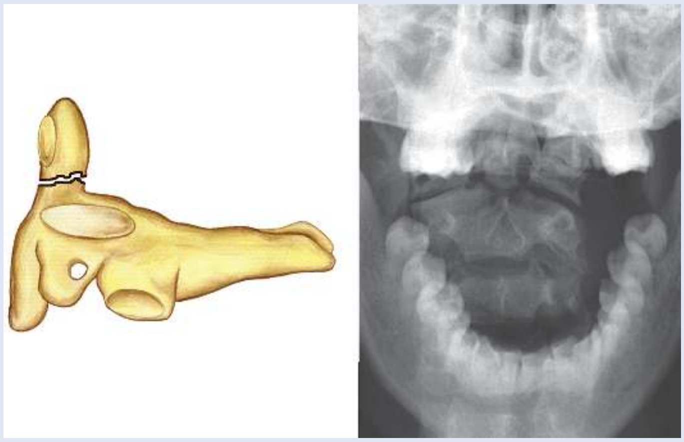
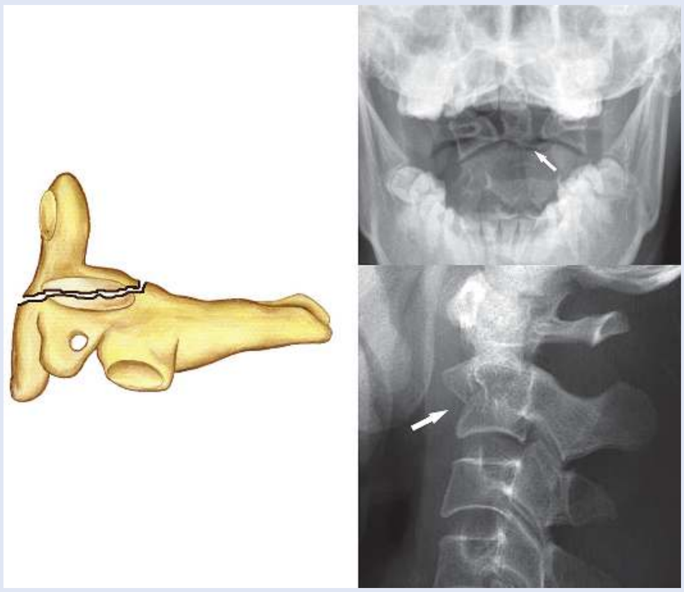
The Hangman's fracture consists of bilateral pedicle or pars fractures involving the vertebral body of C2. Associated with this fracture is anterior subluxation or dislocation of the C2 vertebral body. The mechanism of the injury is forcible hyperextension of the head, which would occur during judicial hanging; thus this type of fracture was given the term "Hangman's Fracture." With this type of injury, spondylolisthesis of the axis is usually seen on a lateral view of the cervical spine; therefore the Hangman's fracture is also called "traumatic spondylolisthesis of the axis."

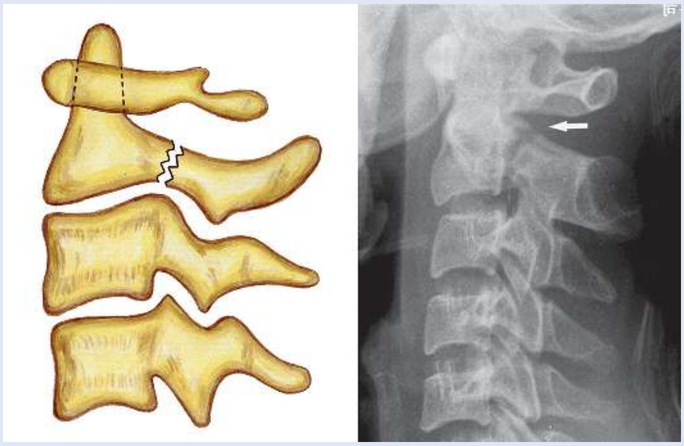
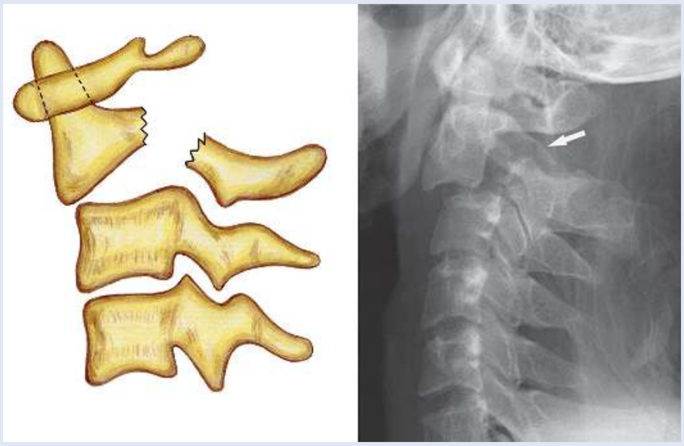
Levine–Edwards Classification of Hangman's Fracture

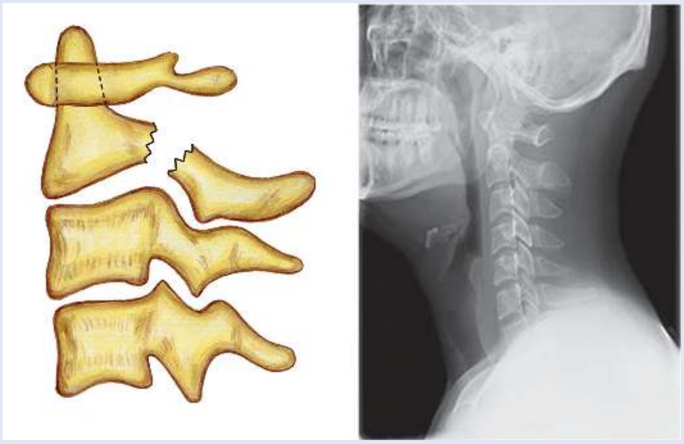
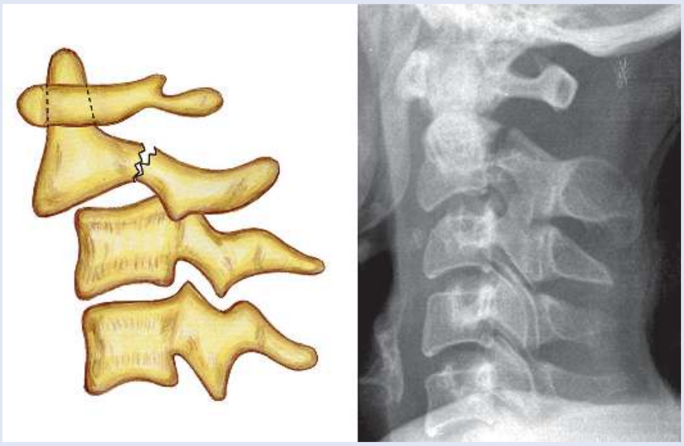
- *Type I*: minimally displaced with no angulation; translation < 3 mm; stable.
- *Type II*: significant angulation at C2–C3; Translation ≥ 3 mm; unstable; C2–C3 disk disrupted; subclassified into flexion, extension, and listhetic types.
- *Type IIA*: avulsion of entire C2–C3 intervertebral disk in flexion, anterior longitudinal ligament intact; severe angulation; no translation; unstable due to flexion-distraction injury.
- *Type III*: unilateral or bilateral anterior facet dislocation of C2 on C3, due to extension injury; severe angulation; unstable.

Allen-Ferguson Classification of Lower Cervical Spine Fractures

Allen described six types of lower cervical injuries: compressive flexion, vertical compression, distractive flexion, compressive extension, distractive extension, and lateral flexion. They are further classified into several subtypes according to their stage of progressive injury.

Anderson classification of odontoid fractures	
Type I Oblique avulsion fracture of tip of dens 132 fractures M: 73 (55.30%) F: 59 (44.70%) 0.04% of total adult fractures 0.24% of adult spinal fractures 15.33% of adult odontoid fractures	Anderson Type I 
Type II Fracture through the base of the odontoid process 488 fractures M: 300 (61.48%) F: 188 (38.52%) 0.13% of total adult fractures 0.89% of adult spinal fractures 56.68% of adult odontoid fractures	Anderson Type II 
Type III Fracture extends into the vertebral body of C2 241 fractures M: 149 (61.83%) F: 92 (38.17%) 0.06% of total adult fractures 0.44% of adult spinal fractures 27.99% of adult odontoid fractures	Anderson Type III 

Levine–Edwards classification of Hangman's fracture	
Type I Minimally displaced with no angulation; translation < 3 mm; stable 207 fractures M: 147 (71.01%) F: 60 (28.99%) 0.06% of total adult fractures 0.38% of adult spinal fractures 70.17% of adult Hangman's fracture	Hangman's Type I 
Type II Significant angulation at C2–C3; Translation ≥ 3 mm; **unstable; C2–C3 disk disrupted; subclassified into flexion,** **extension, and listhetic types** 44 fractures M: 29 (65.91%) F: 15 (34.09%) 0.01% of total adult fractures 0.08% of adult spinal fractures 14.92% of adult Hangman's fracture	Hangman's Type II 

Levine–Edwards classification of Hangman's fracture	
Type IIA Avulsion of entire C2–C3 intervertebral disk in flexion, **anterior longitudinal ligament intact; severe angulation;** **no translation; unstable due to flexion-distraction injury** 9 fractures M: 6 (66.67%) F: 3 (33.33%) 0.002% of total adult fractures 0.02% of adult spinal fractures 3.05% of adult Hangman's fracture	Hangman's Type IIA 
Type III Unilateral or bilateral anterior facet dislocation of C2 on C3, **due to extension injury, severe angulation, unstable** 35 fractures M: 28 (80.00%) F: 7 (20.00%) 0.01% of total adult fractures 0.06% of adult spinal fractures 11.86% of adult Hangman's fracture	Hangman's Type III 

6

Thoracolumbar Fractures (Segments 52 and 53)

■ Anatomic Features

The thoracic spine is made up of 12 vertebrae. Each thoracic vertebra increases slightly in size from the neck down and each connects to an individual rib via a costovertebral joint on either side of spine. The costovertebral joint has two components that articulate with the vertebral column: the head of the ribs and the costotransverse joint. The head of each rib articulates with the superior facet of the same vertebral body and the inferior facet of the superior vertebra. The spinal canal is round in shape and relatively small. The pedicle bone is short but thin. The thoracic facet joints are oriented in a nearly coronal plane, which facilitates greater rotational movement and are less likely to be displaced. The spinous processes are thin but long, and directed obliquely downward. These processes overlap from the fifth to the eighth vertebra. The transverse processes are thick and strong, directed obliquely backward and lateralward.

The lumbar vertebral body is large and wider from side to side than from front to back. The vertebral foramen within the arch is larger than in the thoracic vertebrae, but smaller than in the cervical vertebrae. The transverse processes are long and slender. The lumbar facet joints are oblique in the sagittal plane, and the superior facets are oriented medially with respect to the inferior facets of the superior vertebrae. The spinous processes are thick and broad, and project backward. There are wide intervals between each lumbar spinous process, which is helpful in the event of a lumbar puncture (▶ Fig. 6.22).

■ AO Classification of Thoracolumbar Spinal Fractures

Based on AO classification, the thoracic spine and lumbar spine are assigned the numbers “52” and “53,” respectively. Thoracolumbar spinal fractures are classified into three types: A: Compression; B: Flexion/distraction; and C: Rotation (▶ Fig. 6.23).

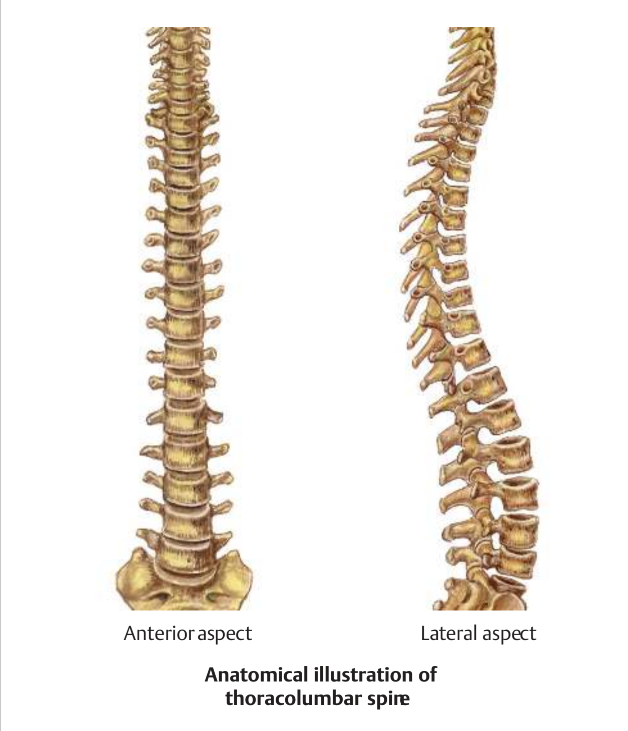


Fig. 6.22 The thoracolumbar spine.

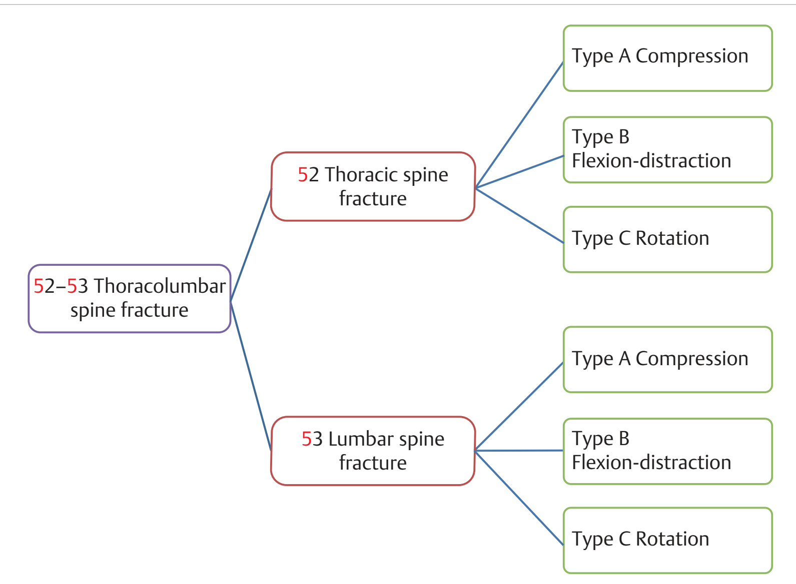


Fig. 6.23 Algorithm.

Clinical Epidemiologic Features of Fractures of the Thoracolumbar Spine (Segments 52 and 53)

A total of 50,910 adult thoracolumbar spinal fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 93.36% of all adult spinal fractures. Their epidemiologic features are as follows:

- More females than males
- The highest-risk age group is 56–60 years. The most affected male age group is 41–45 years, while females aged 71–75 have the highest risk.
- The most common type of fracture among thoracolumbar spinal fractures is type A, the same for both males and females.
- The most common fracture group is group A1, the same for both males and females.

Fractures of Segments 52 and 53 by Sex

See ▶ Table 6.15 and ▶ Fig. 6.24.

Table 6.15 Sex distribution of 50,910 fractures of segments 52 and 53 in adults

Sex	Number of fractures	Percentage
Male	24,978	49.06
Female	25,932	50.94
Total	50,910	100.00

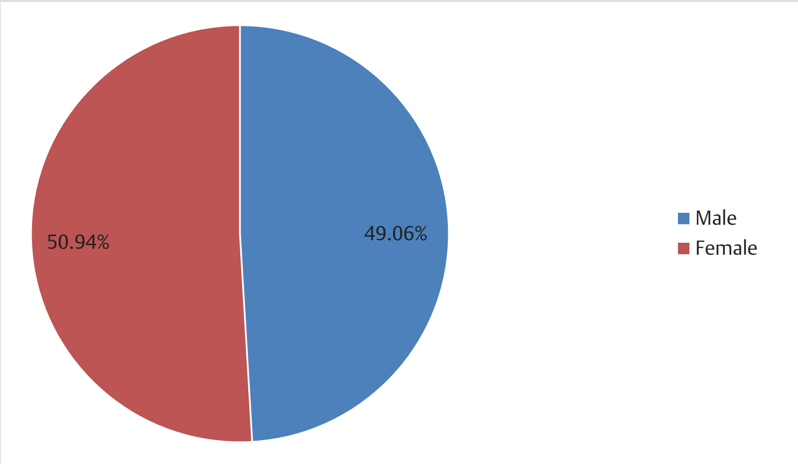


Fig. 6.24 Sex distribution of 50,910 adult fractures of segments 52 and 53 in adults.

■ Fractures of Segments 52 and 53 by Age Group

See ▶ Table 6.16 and ▶ Fig. 6.25.

Table 6.16 Age and sex distribution of 50,910 fractures of segments 52 and 53 in adults

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	749	321	1,070	2.10
21–25	1,312	433	1,745	3.43
26–30	1,413	510	1,923	3.78
31–35	1,539	616	2,155	4.23
36–40	2,378	1,004	3,382	6.64
41–45	2,769	1,261	4,030	7.92
46–50	2,705	1,612	4,317	8.48
51–55	2,316	2,027	4,343	8.53
56–60	2,583	3,306	5,889	11.57
61–65	1,796	3,143	4,939	9.70
66–70	1,440	3,153	4,593	9.02
71–75	1,471	3,429	4,900	9.62
76–80	1,273	2,913	4,186	8.22
81–85	786	1,518	2,304	4.53
≥ 86	448	686	1,134	2.23
Total	24,978	25,932	50,910	100.00

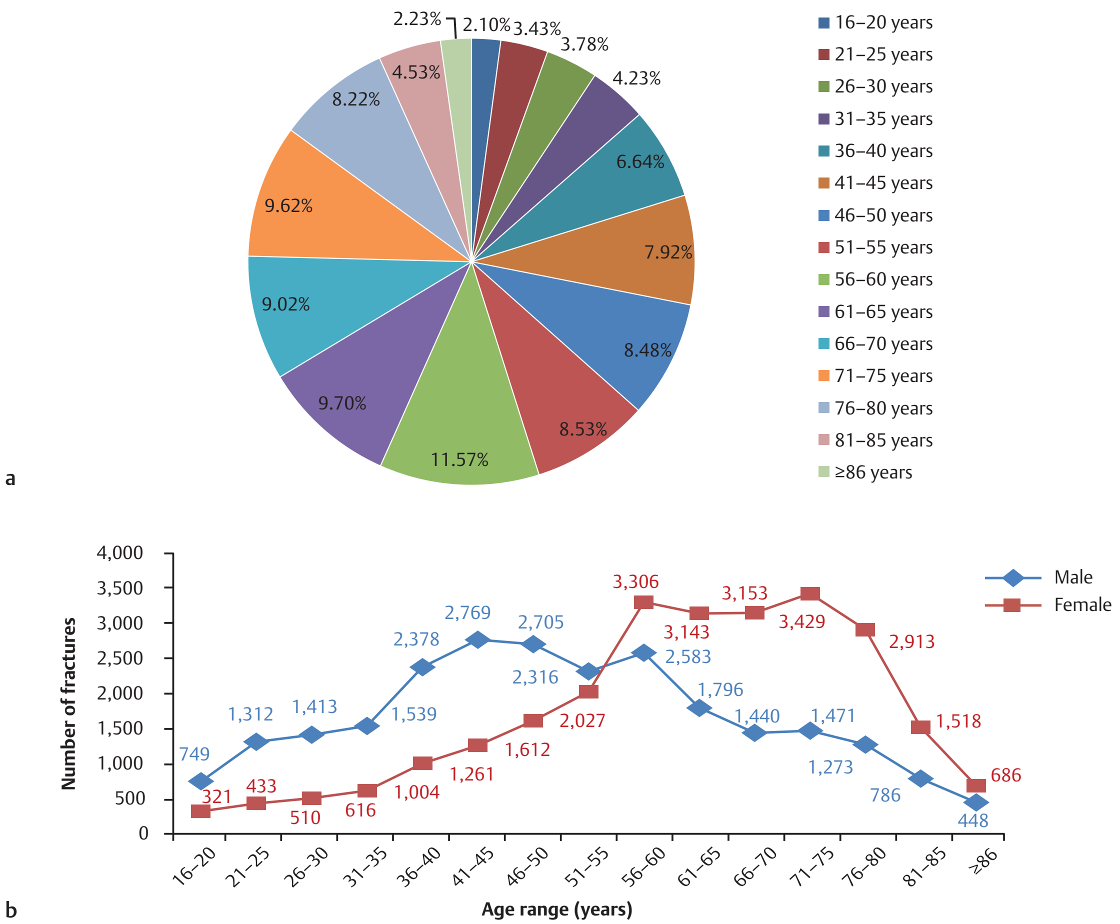


Fig. 6.25 (a) Age distribution of 50,910 fractures of segments 52 and 53 in adults and (b) age and sex distribution of 50,910 fractures of segments 52 and 53 in adults.

■ Fractures of Segments 52 and 53 by Fracture Type Based on AO Classification

See ▶ Table 6.17 and ▶ Fig. 6.26.

Table 6.17 Sex and fracture type distribution of 50,910 fractures of segments 52 and 53 in adults

Fracture type	Male	Female	Number of fractures	Percentage
52-53 A	22,668	23,883	46,551	91.44
52-53 B	1,663	1,651	3,314	6.51
52-53 C	647	398	1,045	2.05
Total	24,978	25,932	50,910	100.00

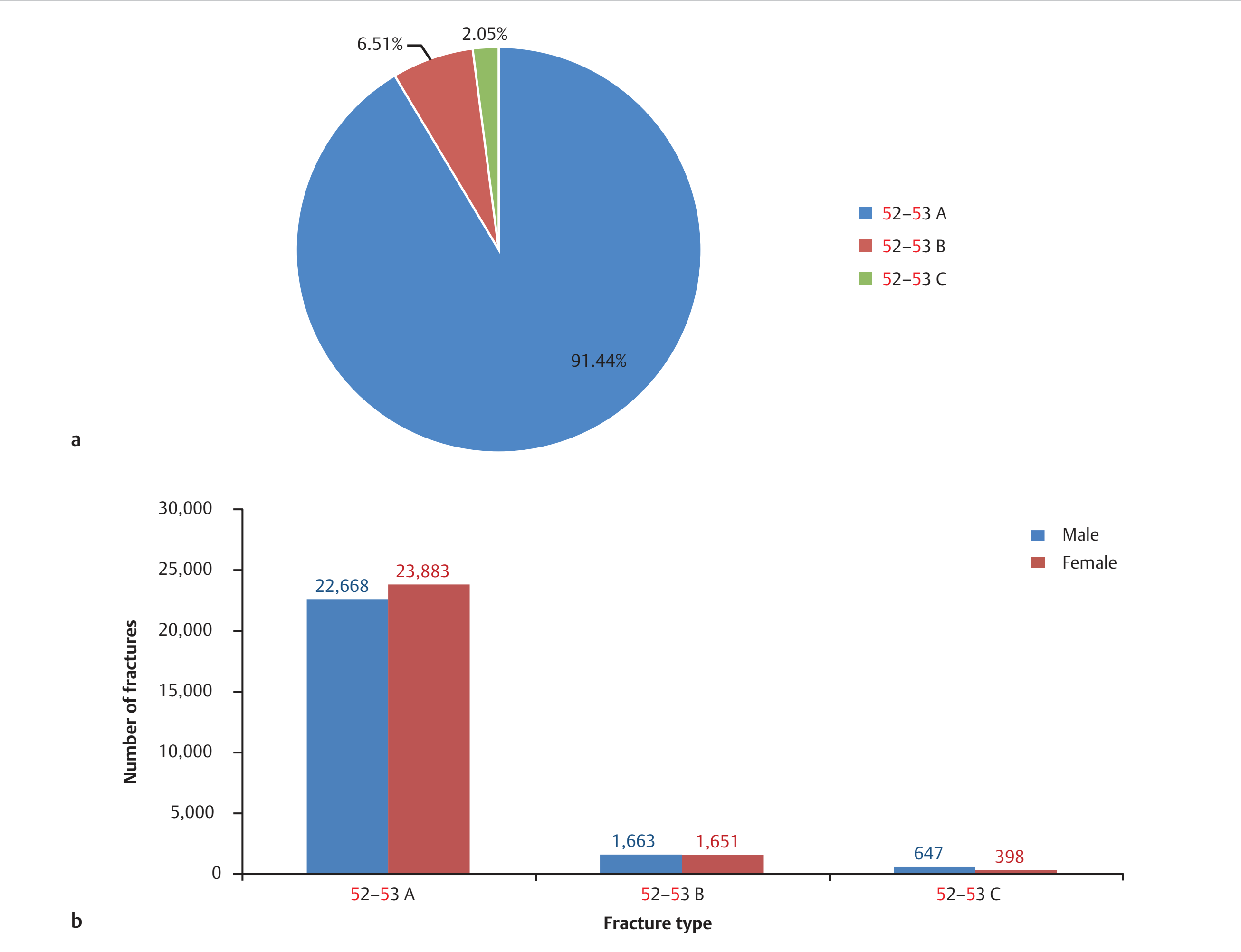


Fig. 6.26 (**a**) Fracture type distribution of 50,910 fractures of segments 52 and 53 in adults and (**b**) sex and fracture type distribution of 50,910 fractures of segments 52 and 53 in adults.

■ Fractures of Segments 52 and 53 by Fracture Group Based on AO Classification

See ▶ Table 6.18 and ▶ Fig. 6.27.

Table 6.18 Sex and fracture group distribution of 50,910 fractures of segments 52 and 53 in adults

Fracture group	Male	Female	Number of fractures	Percentage
52-53 A1	16,984	17,100	34,084	66.95
52-53 A2	1,988	1,776	3,764	7.39
52-53 A3	3,696	5,007	8,703	17.09
52-53 B1	900	996	1,896	3.72
52-53 B2	560	415	975	1.92
52-53 B3	203	240	443	0.87
52-53 C1	348	261	609	1.20
52-53 C2	222	102	324	0.64
52-53 C3	77	35	112	0.22
Total	24,978	25,932	50,910	100.00

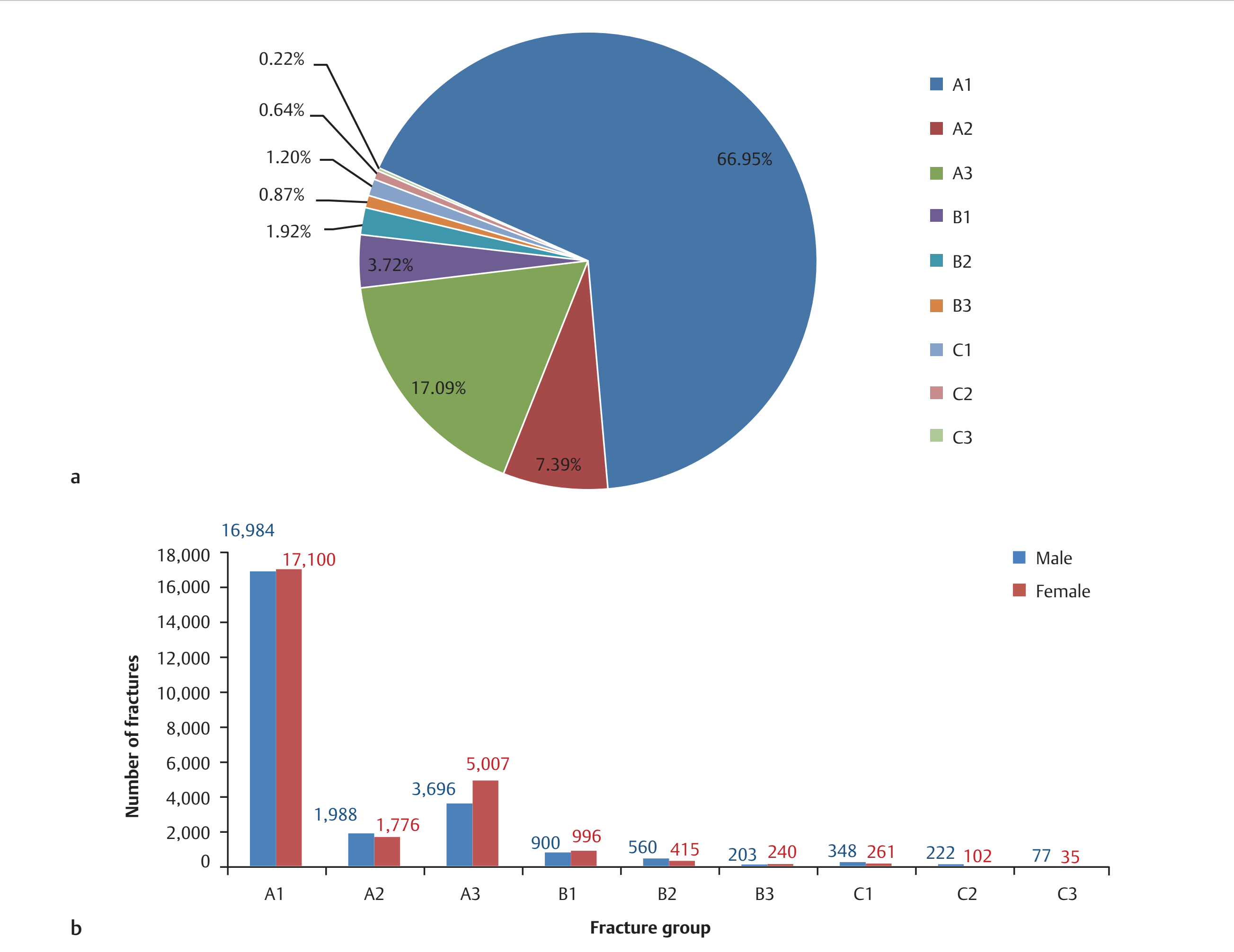
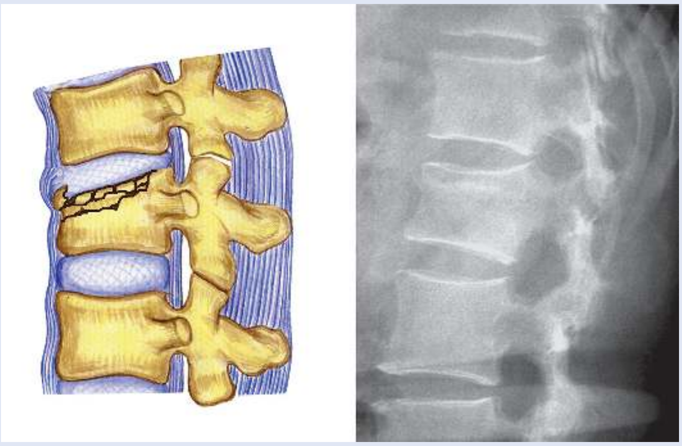


Fig. 6.27 (**a**) Fracture type distribution of 50,910 fractures of segments 52 and 53 in adults and (**b**) sex and fracture type distribution of 50,910 fractures of segments 52 and 53 in adults.

52–53-A Thoracolumbar spine, vertebral body compression

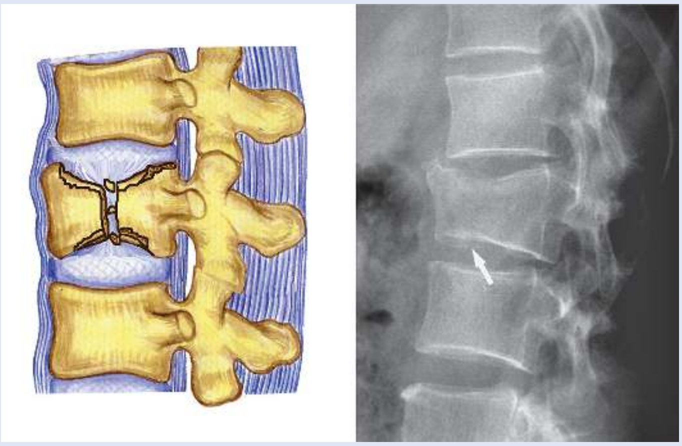
52-53-A1 Impaction fracture
34,084 fractures
M: 16,984 (49.83%)
F: 17,100 (50.17%)
9.10% of total adult fractures
62.50% of adult spinal fractures
66.95% of adult thoracolumbar spinal fractures

52-53-A1



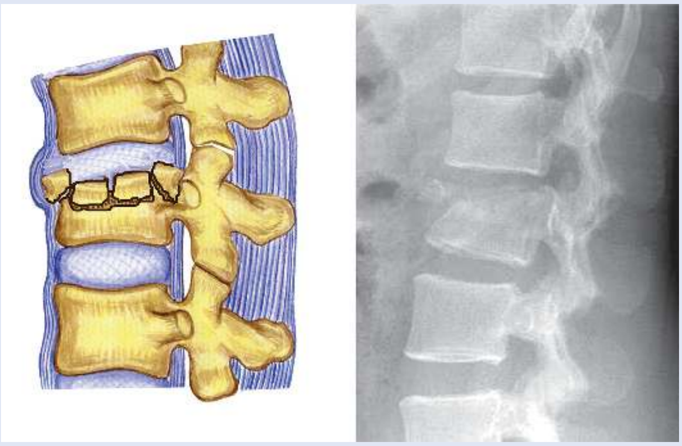
52-53-A2 Split fracture
3,764 fractures
M: 1,988 (52.82%)
F: 1,776 (47.18%)
1.01% of total adult fractures
6.90% of adult spinal fractures
7.39% of adult thoracolumbar spinal fractures

52-53-A2



52-53-A3 Burst fracture
8,703 fractures
M: 3,696 (42.47%)
F: 5,007 (57.53%)
2.32% of total adult fractures
15.96% of adult spinal fractures
17.09% of adult thoracolumbar spinal fractures

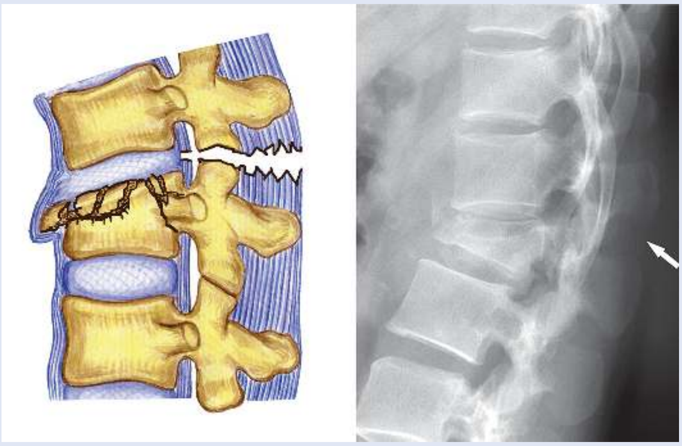
52-53-A3



52-53-B Thoracolumbar spine, anterior and posterior injuries with flexion-distraction

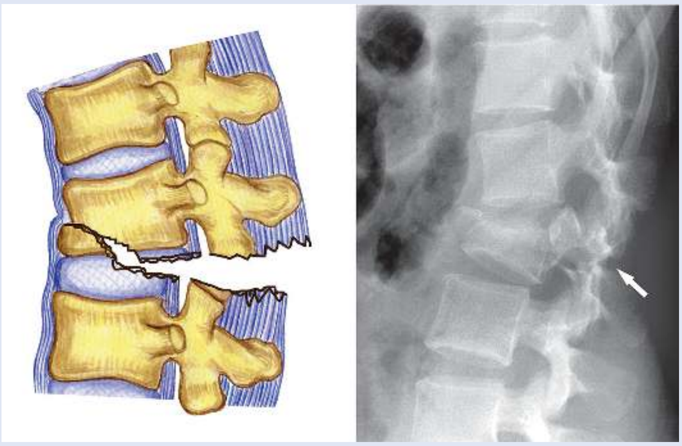
52-53-B1 Posterior disruption predominantly ligamentous
1,896 fractures
M: 900 (47.47%)
F: 996 (52.53%)
0.51% of total adult fractures
3.48% of adult spinal fractures
3.72% of adult thoracolumbar spinal fractures

52-53-B1



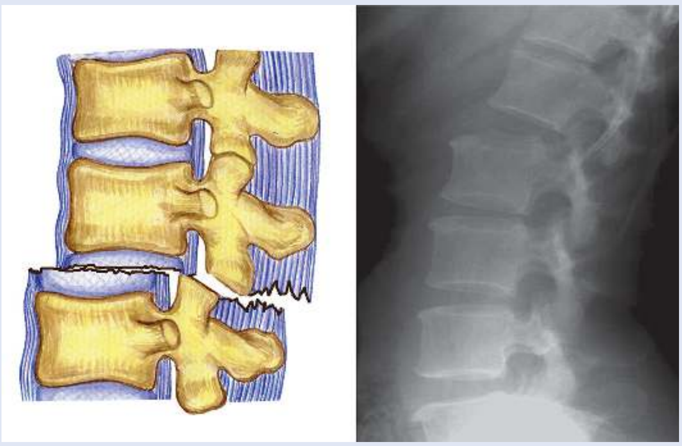
52-53-B2 Posterior disruption predominantly bony
975 fractures
M: 560 (57.44%)
F: 415 (42.56%)
0.26% of total adult fractures
1.79% of adult spinal fractures
1.92% of adult thoracolumbar spinal fractures

52-53-B2



52-53-B3 Anterior disruption through disk
443 fractures
M: 203 (45.82%)
F: 240 (54.18%)
0.12% of total adult fractures
0.81% of adult spinal fractures
0.87% of adult thoracolumbar spinal fractures

52-53-B3



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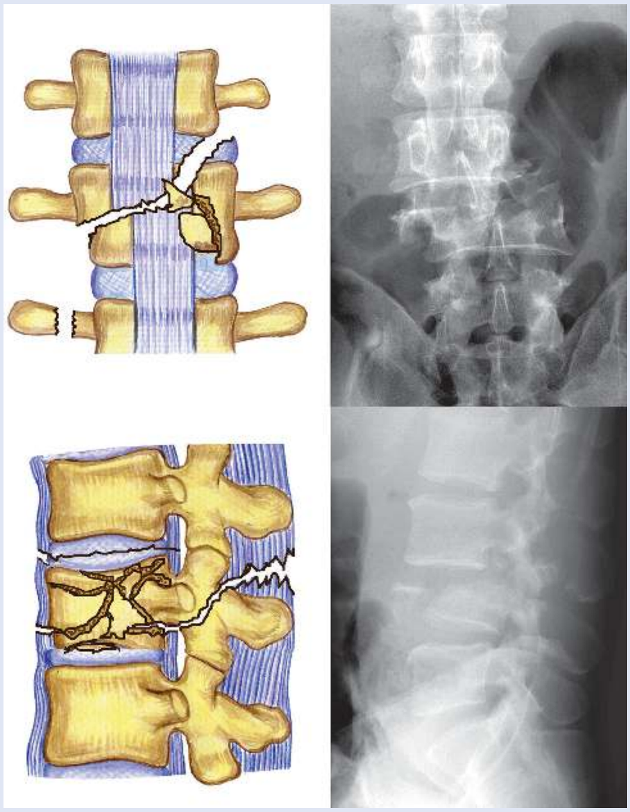
52-53-C Thoracolumbar spine, anterior and posterior element injury with rotation

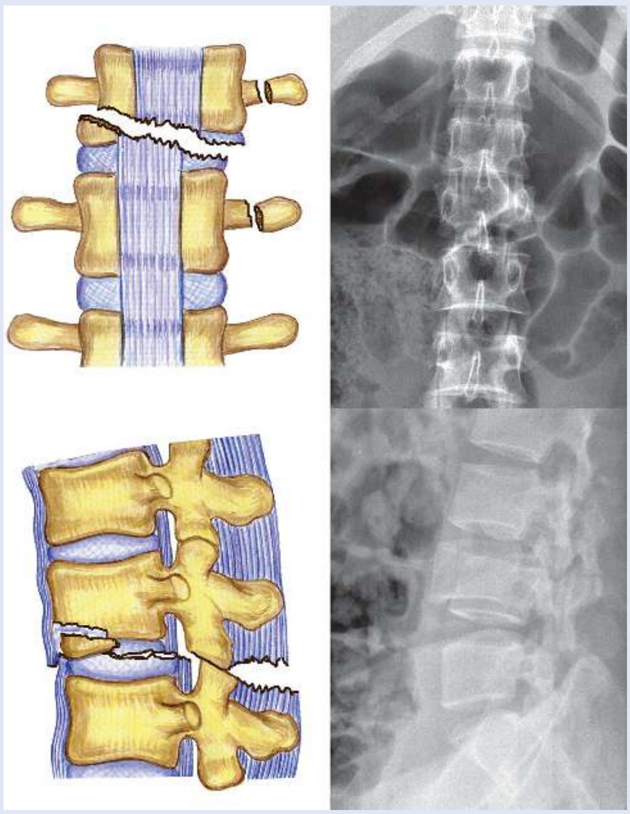
52-53-C1 Type A injury with rotation
609 fractures
M: 348 (57.14%)
F: 261 (42.86%)
0.16% of total adult fractures
1.12% of adult spinal fractures
1.20% of adult thoracolumbar spinal fractures

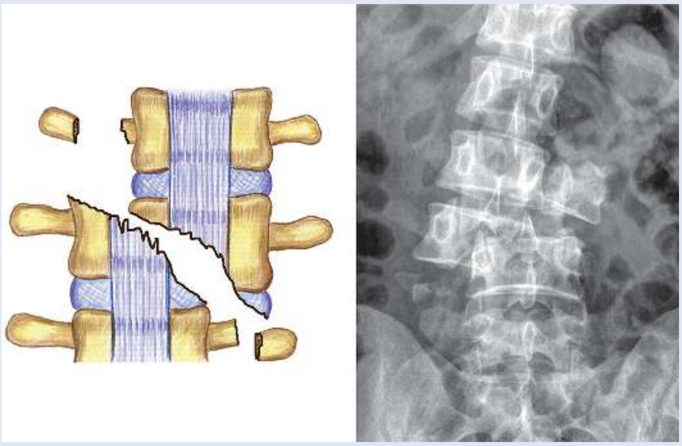
52-53-C1



52-53-C2 Type B injury with rotation
324 fractures
M: 222 (68.52%)
F: 102 (31.48%)
0.09% of total adult fractures
0.59% of adult spinal fractures
0.64% of adult thoracolumbar spinal fractures

52-53-C2



52-53-C Thoracolumbar spine, anterior and posterior element injury with rotation	
52-53-C3 Rotational shear injury 112 fractures M: 77 (68.75%) F: 35 (31.25%) 0.03% of total adult fractures 0.21% of adult spinal fractures 0.22% of adult thoracolumbar spinal fractures	52-53-C3 

Injury Mechanism

Fractures of the thoracolumbar spine involve a number of injury mechanisms, including:

1. Axial compression, which usually results in a burst fracture.
2. Flexion injury, which often results in a compression fracture, with compression of the anterior column and distraction of the posterior column.
3. Lateral compression, which results in a lateral compression fracture, but the posterior ligament remains intact.
4. Flexion rotation, which is always associated with varying degrees of spinal cord injury (also results in the disruption of posterior ligaments and capsule joints, and an oblique rupture of the vertebral body and disk).
5. Flexion-distraction, which results in axial rotation of the anterior column, and tension failures in both the anterior and posterior columns (since it most commonly occurs in lap-belt-restrained passengers, it is also called a seat-belt type injury).
6. Shear injury, which results in failure of all three columns, most commonly in posterior-anterior directions. Radiographs show all three types of fractures and dislocations, which can be anterior, posterior, or lateral.
7. Distractive extension, which results in compression of the posterior column, while the anterior column is pulled by the effect of extension-distraction.

Diagnosis

The diagnosis for thoracolumbar spinal fractures is dependent on the clinical presentation, imaging studies, and the assessment of spinal stability. Typical clinical presentations include pain, deformity, and impaired function. Anteroposterior (AP) and lateral radiographs of the thoracolumbar spine usually can detect the fracture and help in making the diagnosis. Conventional and computed axial tomography can be very important in assessing posterior element integrity and spinal canal encroachment. CT scans are very sensitive in detecting subtle fractures of posterior elements, especially a laminar fracture. MRI is useful in detecting the extent of damage to the spinal cord. MRI is most useful in patients when traumatic disk herniation, epidural hematoma, or spinal cord injury is suspected. Based on the three-column concept, post-traumatic spine stability is primarily dependent upon the integrity of the middle column. The middle column remains intact in simple wedge compression injuries, which are thus stable fractures, whereas the anterior and middle columns fail in burst fractures, making them unstable fractures.

6

Treatment

The principal treatments of thoracolumbar spinal fracture are shown in ▶ Fig. 6.28. The management of thoracolumbar spinal injury consists of conservative and surgical treatments. The indications for conservative treatment include: (1) stable fracture, with less than 50% of vertebral body height loss; (2) fracture of posterior elements without any signs of cord or multiple-root compromise, and the canal encroachment is less than 50% of the cross-sectional area of the canal; or (3) burst fracture with an intact posterior column.

In contrast, the following cases are more likely to require surgical intervention: (1) unstable fracture, even without evidence of neurological injury; (2) burst fracture, where a fragment of more than 50% of the canal's cross-sectional area encroaches upon the canal; (3) burst fracture, complicated by neurological signs; (4) fracture-dislocation or loss of joint congruity; (5) posterior decompression fails and requires a second surgery; (6) compression of the spinal cord, resulting from laminar fracture subsidence; (7) presentation of delayed neurological syndrome resulting from compression of the anterior cord by an old fracture; or (8) progression of kyphosis.

Surgical procedures should be performed when patients become medically stable. The operative methods include: (1) posterior fracture reduction and fusion, and pedicle screw fixation; (2) anterior vertebrectomy, graft fusion, and internal fixation; and (3) combined anterior–posterior decompression and graft fusion.

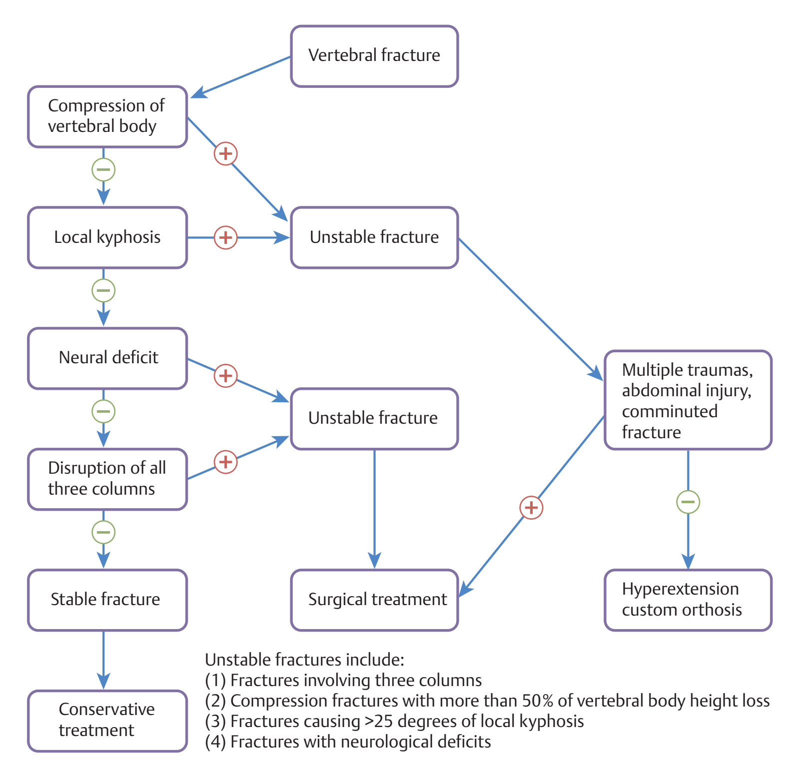


Fig. 6.28 Algorithm.

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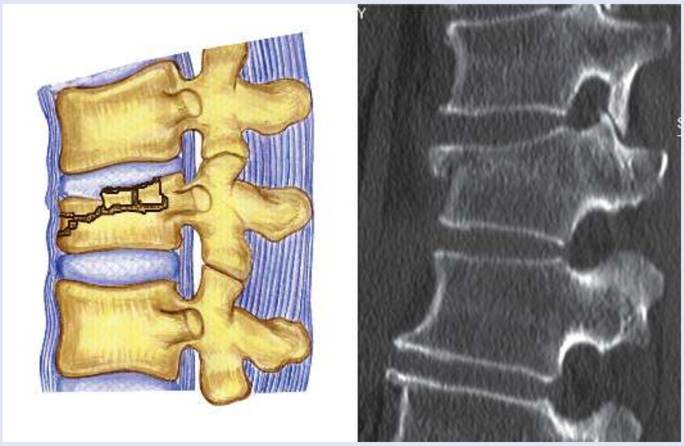
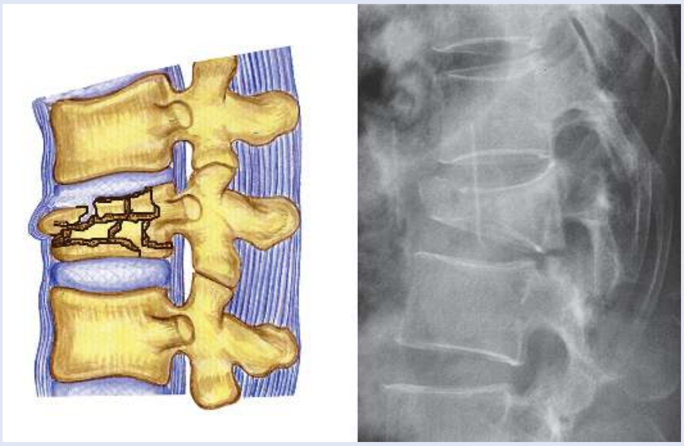
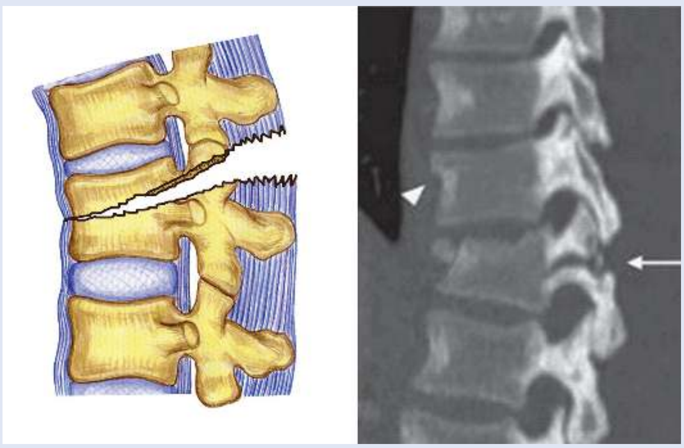
Table 6.19 The Denis classification of thoracolumbar spinal fractures

Fracture type	Subtype	Injury force	Column involved	Stability
Compression fracture	—	Axial load	Anterior column	Stable
Burst fracture	A: Fracture of both endplates	Axial load	Anterior and middle columns	Unstable
	B: Fracture of superior endplate	Axial load, extension, flexion	Anterior and middle columns	May be unstable
	C: Fracture of inferior endplate	Axial load, extension, flexion	Anterior and middle columns	May be unstable
	D: Burst rotation fracture	Axial load, rotation	All three columns	Unstable
	E: Burst lateral flexion fracture	Lateral compressive load	All three columns	May be unstable
Chance Fracture	–	Flexion-distraction	Middle and posterior columns	Unstable
Fracture-dislocation	Flexion-rotation	Hyperextension and flexion, rotation	All three columns	Unstable
	Shear injury	Hyperextension and dislocation	All three columns	Unstable

Denis Classification of Thoracolumbar Spinal Fractures

The Denis classification of spinal injuries is one of the most commonly used classifications in clinical practice. It classifies spinal injuries into four types and ten subtypes, as illustrated in ▶ Table 6.19. Of 50,910 thoracolumbar spinal fractures, only 49,487 are able to be classified based on the Denis classification. Certain compound fracture types cannot be grouped into any category in the Denis system. Details are shown below.

Denis classification of thoracolumbar spinal fractures	
Type I Axial compression 36,904 fractures M: 18,401 (49.86%) F: 18,503 (50.14%) 9.86% of total adult fractures 67.67% of adult spinal fractures 72.49% of adult thoracolumbar spinal fractures	Denis Type I Axial compression 
Type II Burst fracture 9,281 fractures M: 4,082 (43.98%) F: 5,199 (56.02%) 2.48% of total adult fractures 17.02% of adult spinal fractures 18.23% of adult thoracolumbar spinal fractures	Denis Type II Burst fracture 
Type III Chance fracture 2,158 fractures M: 1,100 (50.97%) F: 1,058 (49.03%) 0.58% of total adult fractures 3.96% of adult spinal fractures 4.24% of adult thoracolumbar spinal fractures	Denis Type III Chance fracture 

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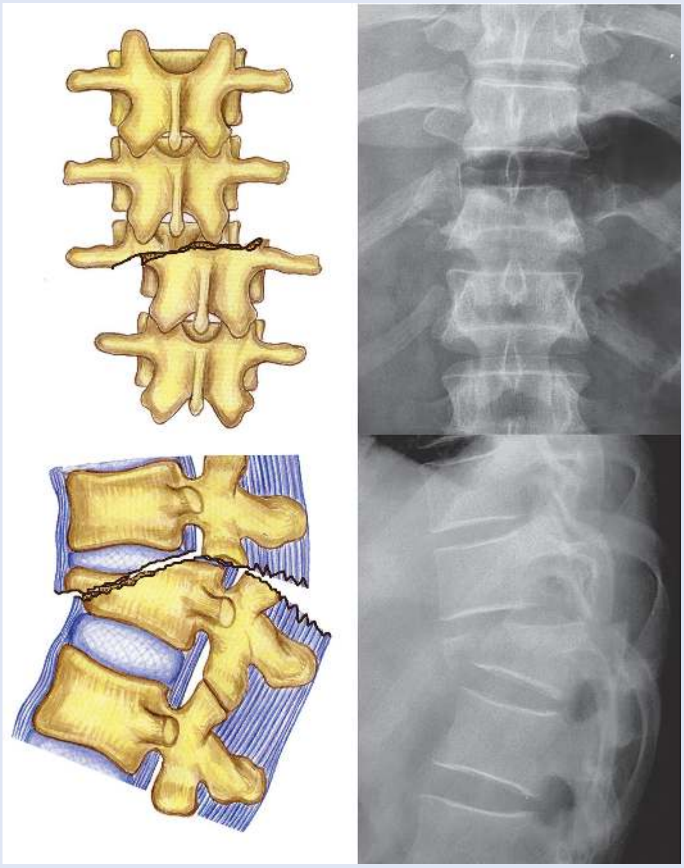
Denis classification of thoracolumbar spinal fractures	
Type IV Fracture-dislocation (lateral) 1,144 fractures M: 693 (60.58%) F: 451 (39.42%) 0.31% of total adult fractures 2.10% of adult spinal fractures 2.25% of adult thoracolumbar spinal fractures	Denis Type IV Fracture dislocation (lateral) 

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7 Fractures of the Pelvic Ring and Acetabulum

Zhiyong Hou, Haili Wang, and Shiji Qin

Overview of Pelvic Ring and Acetabular Fractures

Anatomical Features

The pelvis is composed of four bones: the two hip bones laterally and in front, and the sacrum and coccyx behind (▶ Fig. 7.1). The hip bone is a large, flattened, irregularly shaped bone that forms the sides and anterior wall of the pelvic cavity together with its counterparts on the opposite side. It consists of three parts, the ilium, ischium, and pubis, which are fused into one bony structure in adults. The hip bone is narrow in the middle and expands above and below, with a large oval shaped hole, the obturator foramen, on its inferior aspect. The acetabulum, a large cup-shaped articular cavity, is situated near the middle of the bone's outer surface. The external surface of the upper part of the hip bone is smooth and gives attachment to the gluteal muscles. The ilium is divided into two parts, the body and the ala. The ischium, the lower and back part of the hip bone, consists of three portions: a body and two rami. The pubis, which forms the anterior part of the hip bone, is divided into a body, and a superior and an inferior ramus. The pubic ramus is a very thin bone, making it an easy target for fractures. The sacrum is a triangular bone at the base of the spine and consists of five vertebrae which usually are completely fused into a single bone in adults. The sacral canal in the middle runs throughout the greater part of the bone; its walls are perforated by the anterior and posterior sacral foramina through which the sacral nerves passes. The coccyx, or tailbone, comprised of four fused vertebrae, articulates superiorly with the sacrum and extends downward as an individual piece (▶ Fig. 7.2; ▶ Fig. 7.3).

Based on fracture pattern, pelvic fractures can be divided into pelvic ring fractures and acetabular fractures. The pelvic ring is divided into an anterior and posterior ring by the acetabulum. The acetabulum is divided into the anterior column, the posterior column, anterior wall, posterior wall. In the erect posture, the pelvis is inclined forward so that the anterior superior iliac spines and the front of the top of the symphysis pubis are in the same coronal plane. When an individual is standing, his or her weight is transmitted from the upper body and trunk, through the spine, the sacrum, sacroiliac joint, and acetabulum, and continues down to the lower extremities. When an individual is in the sitting position, his or her weight is transmitted down the spine, the sacrum, and sacroiliac joint to the ischium (▶ Fig. 7.4).

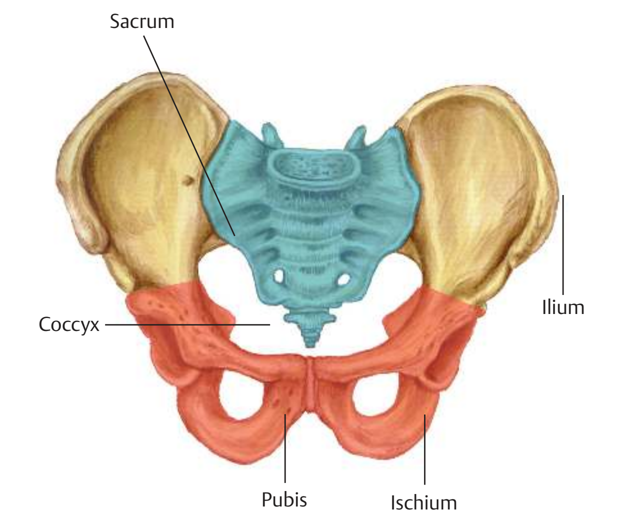

Fig. 7.1 Composition of the pelvis.

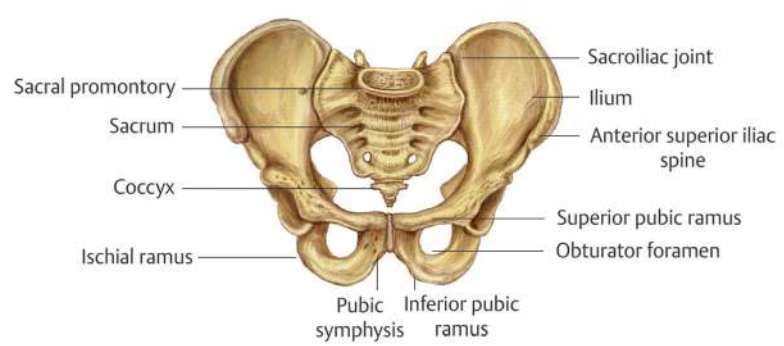

Fig. 7.2 Anterior view of the pelvis.

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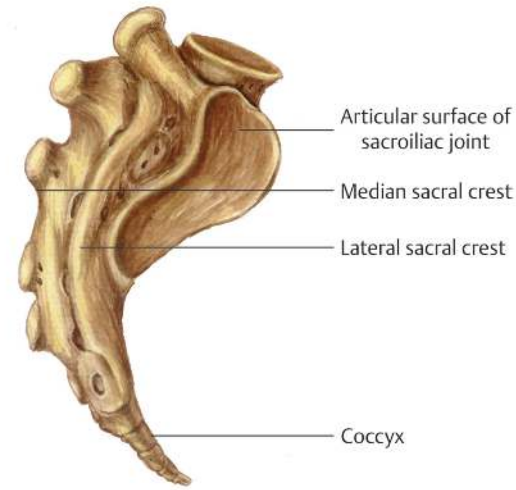

Fig. 7.3 Lateral view of the sacrum.

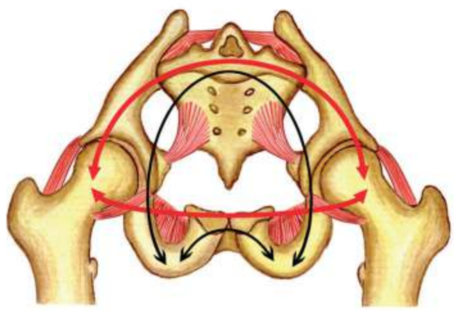

Fig. 7.4 Transmission of load through the pelvis.

AO Classification and Coding System for Fractures of the Pelvic Ring and Acetabulum

According to the AO fracture classification principle, the pelvis is considered one unit, with the location code of "6." The following sections will be divided into discussions of the pelvic ring and acetabulum. The numbers "61" and "62" are used to represent the pelvic ring and acetabulum respectively (▶ Fig. 7.5; ▶ Fig. 7.6).

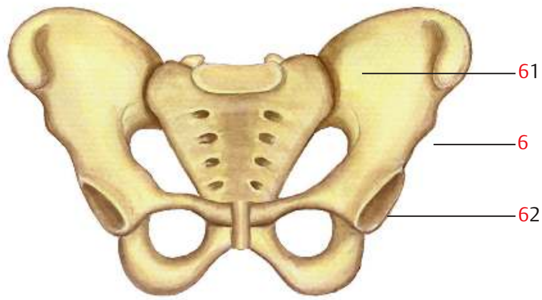

Fig. 7.5 AO codes of the pelvis.

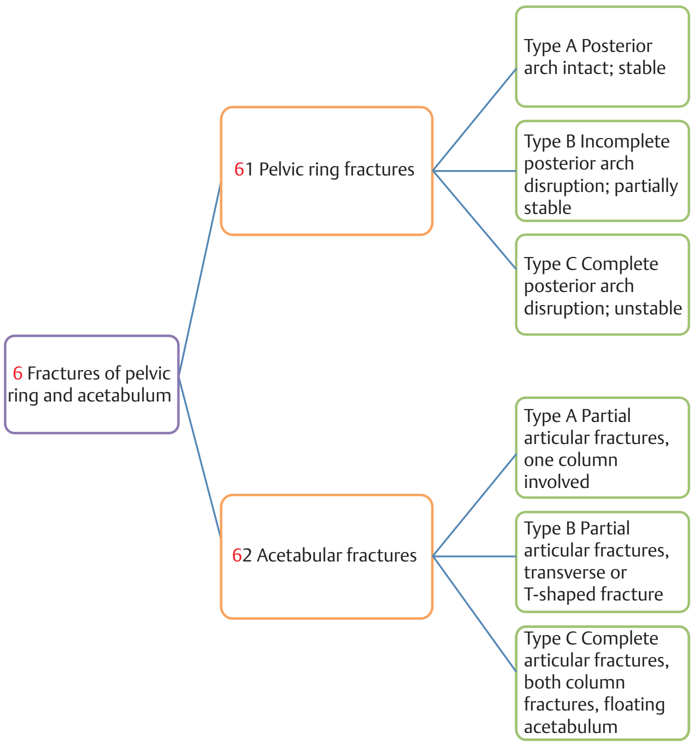

Fig. 7.6 Algorithm.

Epidemiologic Features of Pelvic and Acetabular Fractures in the China National Fracture Study

A total of 53 patients with 53 pelvic ring and acetabular fractures were investigated in the China National Fracture Study (CNFS). The fractures accounted for 3.01% of all patients with fractures and 2.89% of all types of fractures. The population-weighted incidence rate of pelvic ring and acetabular fractures was 9 per 100,000 population. The epidemiologic features of pelvic ring and acetabular fractures in the CNFS are as follows:

- More females than males
- The highest risk age group is 15–64 years
- The pelvic ring fracture is the most common pelvic ring and acetabular fractures
- Injuries occurred most commonly via falls and traffic accidents

Pelvic Ring and Acetabular Fracture by Sex in CNFS

See ▶ Table 7.1 and ▶ Fig. 7.7.

Table 7.1 Sex distribution of 53 patients with pelvic ring and acetabular fractures in the China National Fracture Study

Sex	Number of patients	Percentage
Male	23	43.40
Female	30	56.60
Total	53	100.00

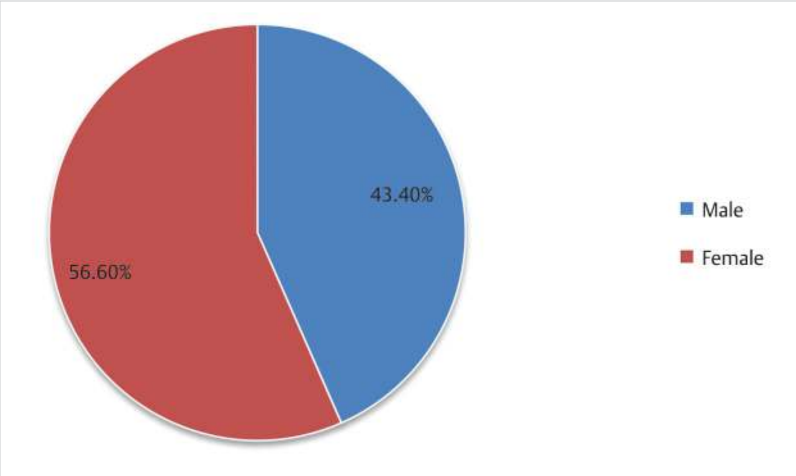

Fig. 7.7 Sex distribution of 53 patients with pelvic ring and acetabular fractures in the China National Fracture Study (CNFS).

■ Pelvic Ring and Acetabular Fracture by Age and Sex in CNFS

See ▶ Table 7.2 and ▶ Fig. 7.8.

Table 7.2 Age distribution of 53 patients with pelvic ring and acetabular fractures in the China National Fracture Study

Age group (years)	Male	Female	Total	Percentage
0–14	0	1	1	1.89
15–64	18	15	33	62.26
≥ 65	5	14	19	35.85
Total	23	30	53	100.00

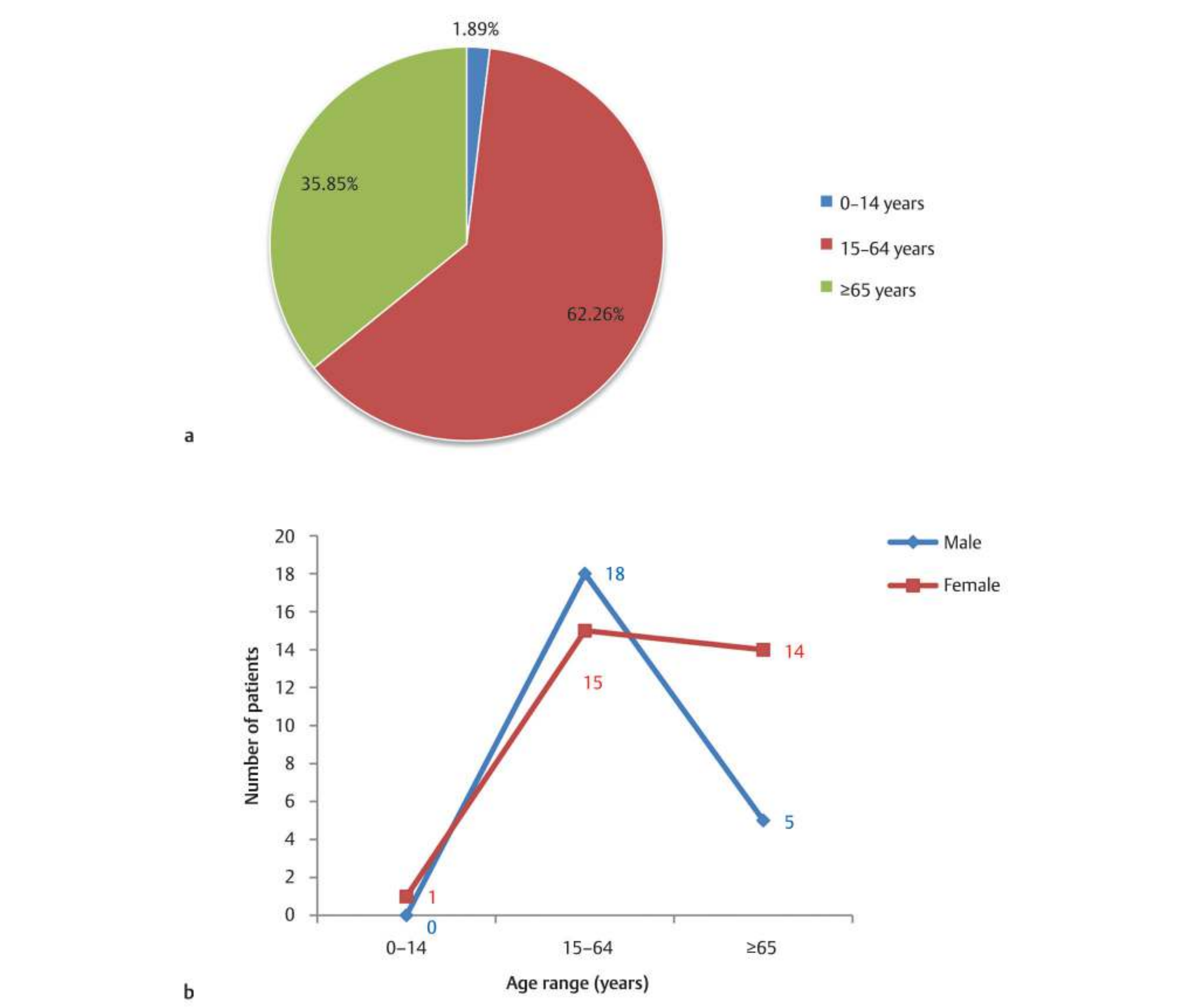

Fig. 7.8 (**a**) Age distribution of 53 patients with pelvic ring and acetabular fractures in the China National Fracture Study (CNFS). (**b**) Age and sex distribution of 53 patients with pelvic ring and acetabular fractures in the CNFS.

■ Pelvic Ring and Acetabular Fracture by Location in CNFS

See ▶ Table 7.3 and ▶ Fig. 7.9.

Table 7.3 Segment distribution of 53 patients with pelvic ring and acetabular fractures in the China National Fracture Study

Segment	Male	Female	Total	Percentage
61	18	26	44	83.02
62	5	4	9	16.98
Total	23	30	53	100.00

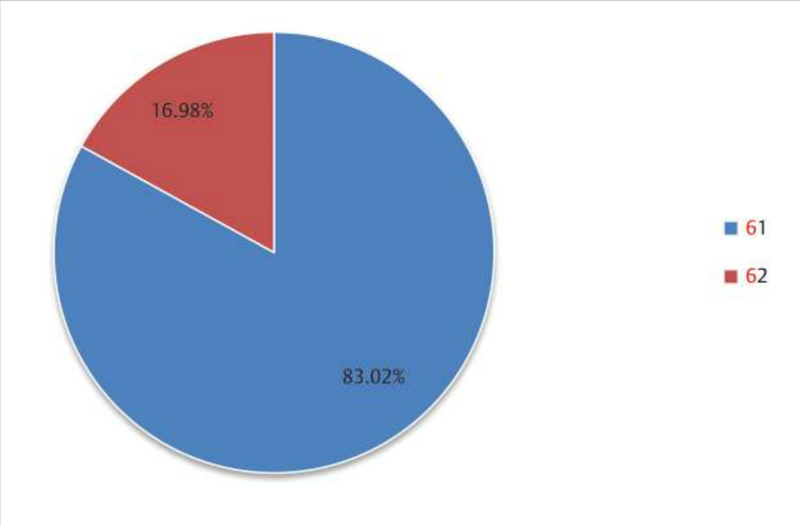

Fig. 7.9 Segment distribution of 53 patients with pelvic ring and acetabular fractures in the China National Fracture Study (CNFS).

Pelvic Ring and Acetabular Fracture by Causal Mechanisms in CNFS

See ▶ Table 7.4 and ▶ Fig. 7.10.

Table 7.4 Causal mechanisms distribution of 53 patients with pelvic ring and acetabular fractures in the China National Fracture Study

Causal mechanisms	Male	Female	Total	Percentage
Traffic accident	8	10	18	33.96
Slip, trip, or fall	10	20	30	56.60
Fall from heights	4	0	4	7.55
Crushing injury	1	0	1	1.89
Total	23	30	53	100.00

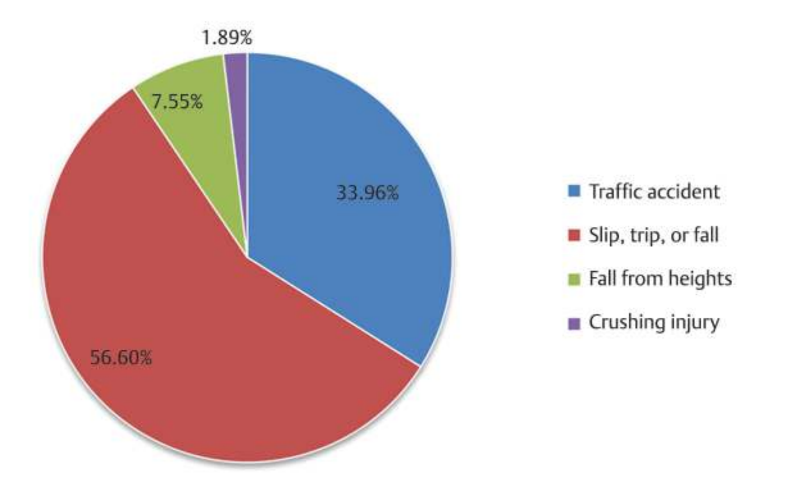

Fig. 7.10 Causal mechanisms distribution of 53 patients with pelvic ring and acetabular fractures in the China National Fracture Study (CNFS).

7

Clinical Epidemiological Features of Fractures of the Pelvic Ring and Acetabulum

A total of 14,420 patients with 14,555 fractures of the pelvic ring and/or acetabulum were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, comprising 3.48% of all fractured patients and 3.37% of all types of fractures. Of a total 14,420 patients, there were 685 children with 687 fractures, accounting for 1.25% of pediatric patients with fractures, and 1.20% of all types of fractures in children. The rest of the 13,735 adult patients had 13,868 fractures, representing 3.81% of adult patients with fractures, and 3.70% of all types of fractures in adults.

Epidemiological features of fractures of the pelvic ring and acetabulum are the following:

- More males than females
- The high-risk age groups are 36–40 and 41–45 years; while the high-risk age group for males is 41–45 years, the groups 36–40 and 41–45 years are at risk for females.
- Pelvic ring fractures occur more frequently than acetabular fractures.

■ Fractures of the Pelvic Ring and Acetabulum by Sex

See ▶ Table 7.5 and ▶ Fig. 7.11.

Table 7.5 Sex distribution of 14,420 patients with fractures of the pelvic ring and acetabulum

Sex	Number of patients	Percentage
Male	7,892	54.73
Female	6,528	45.27
Total	14,420	100.00

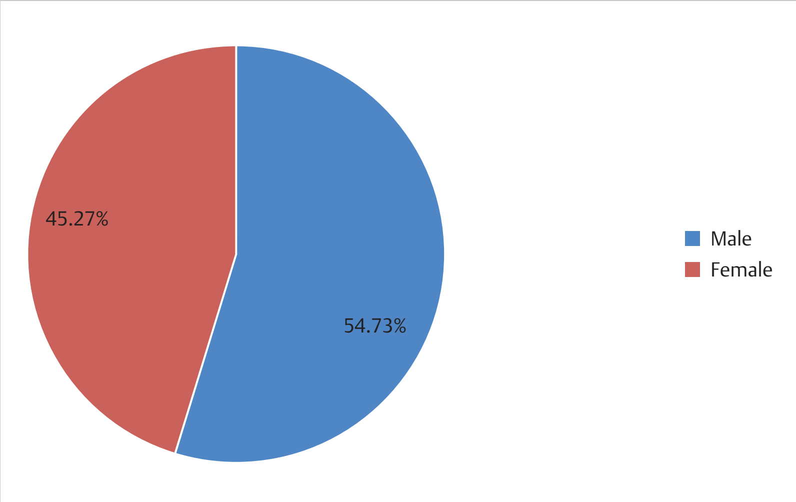

Fig. 7.11 Sex distribution of 14,420 patients with fractures of the pelvic ring and acetabulum.

7

■ Fractures of the Pelvic Ring and Acetabulum by Age Group

See ▶ Table 7.6 and ▶ Fig. 7.12.

Table 7.6 Age and sex distribution of 14,420 patients with fractures of the pelvic ring and acetabulum

Age group (years)	Male	Female	Number of patients	Percentage
0–5	60	86	146	1.01
6–10	98	109	207	1.44
11–15	201	131	332	2.30
16–20	407	237	644	4.47
21–25	720	549	1,269	8.80
26–30	728	569	1,297	8.99
31–35	723	518	1,241	8.61
36–40	941	738	1,679	11.64
41–45	983	738	1,721	11.93
46–50	857	581	1,438	9.97
51–55	648	491	1,139	7.90
56–60	565	438	1,003	6.96
61–65	292	302	594	4.12
66–70	236	268	504	3.50
71–75	174	269	443	3.07
76–80	134	234	368	2.55
81–85	82	169	251	1.74
≥ 86	43	101	144	1.00
Total	7,892	6,528	14,420	100.00

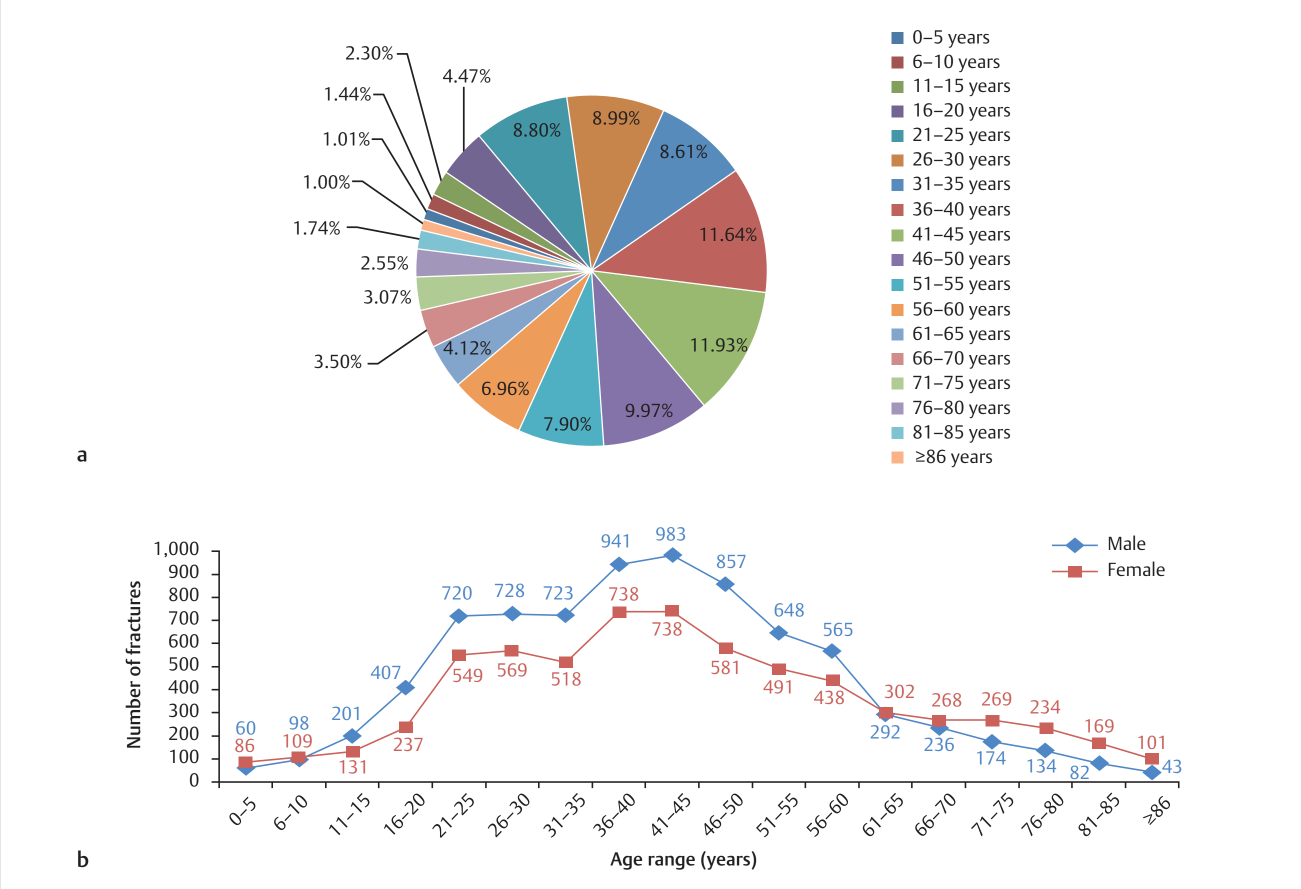

Fig. 7.12 (**a**) Age distribution of 14,420 patients with fractures of the pelvic ring and acetabulum. (**b**) Age and sex distribution of 14,420 patients with fractures of the pelvic ring and acetabulum.

Fractures of the Pelvic Ring and Acetabulum by Fracture Location Based on the AO Classification

Fractures of the Pelvic Ring and Acetabulum in Adults by Fracture Segment Based on the AO Classification

See ▶ Table 7.7 and ▶ Fig. 7.13.

Table 7.7 Segment distribution of 13,868 fractures of the pelvic ring and acetabulum in adults

Segment	Number of fractures	Percentage
61	10,694	77.11
62	3,174	22.89
Total	13,868	100.00

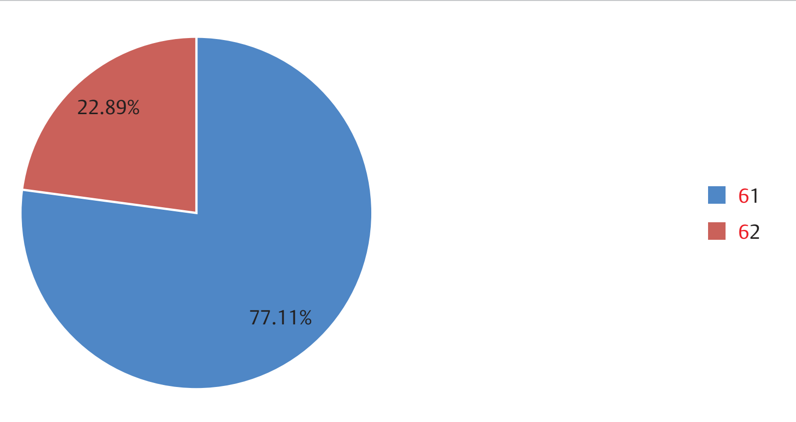

Fig. 7.13 Segment distribution of 13,868 fractures of the pelvic ring and acetabulum in adults.

Fractures of the Pelvic Ring and Acetabulum in Children by Fracture Location

See ▶ Table 7.8 and ▶ Fig. 7.14.

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Table 7.8 Fracture location distribution of 687 fractures of the pelvic ring and acetabulum in children

Fracture location	Number of fractures	Percentage
Pelvic ring	568	82.68
Acetabulum	119	17.32
Total	687	100.00

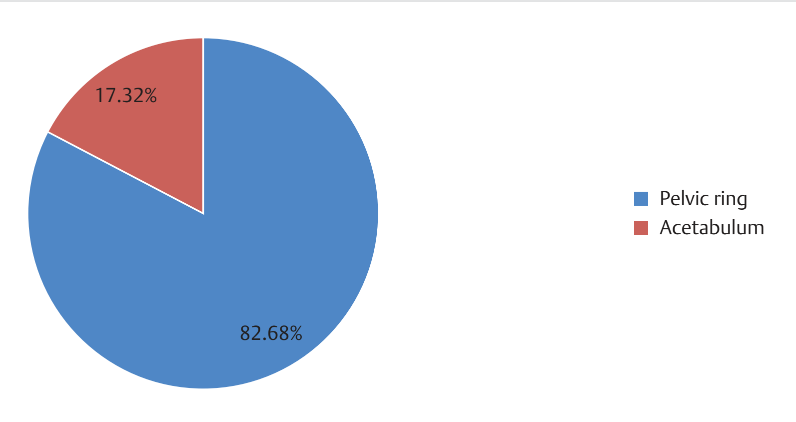

Fig. 7.14 Fracture location distribution of 687 fractures of pelvic ring and acetabulum in children.

Fractures of the Pelvic Ring and Acetabulum in Children by Sex

See ▶ Table 7.9, ▶ Table 7.10, ▶ Fig. 7.15, and ▶ Fig. 7.16.

Table 7.9 Sex distribution of 568 pediatric patients with pelvic ring fractures

Sex	Number of patients	Percentage
Male	296	52.11
Female	272	47.89
Total	568	100.00

Table 7.10 Sex distribution of 119 pediatric patients with acetabular fractures (2 children had pelvic ring fracture and acetabular fracture at the same time)

Sex	Number of patients	Percentage
Male	63	52.94
Female	56	47.06
Total	119	100.00

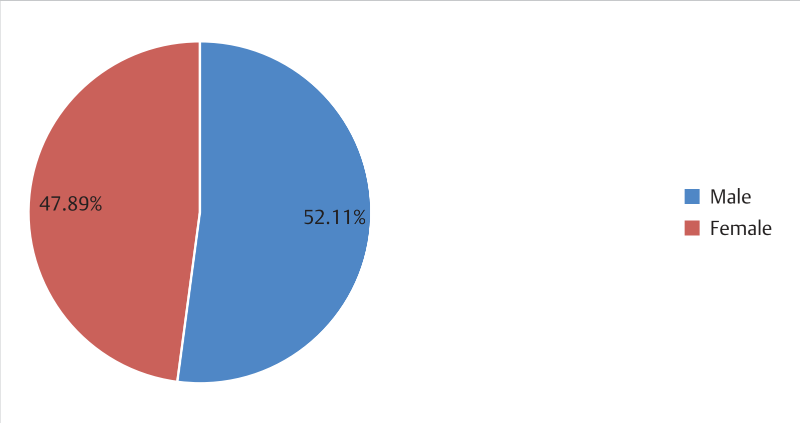

Fig. 7.15 Sex distribution of 568 pediatric patients with pelvic ring fractures.

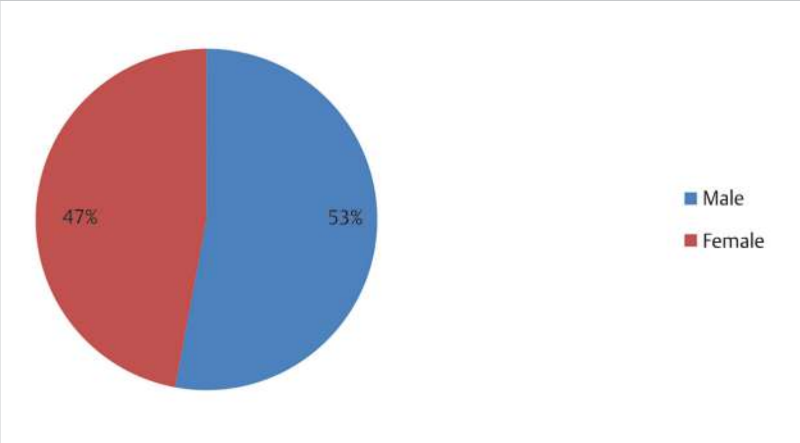

Fig. 7.16 Sex distribution of 119 pediatric patients with acetabular fractures.

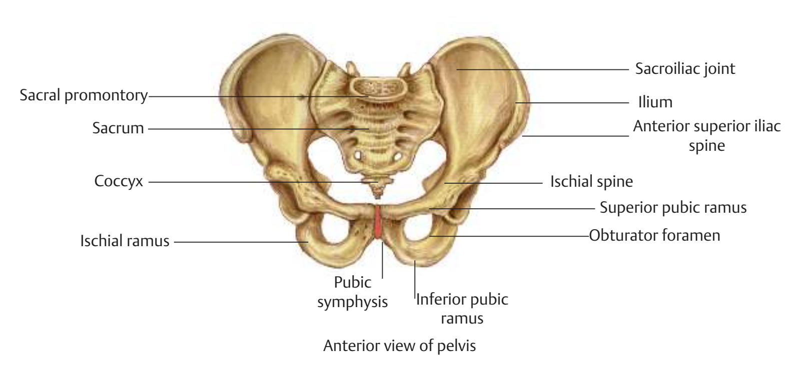

Fig. 7.17 Anterior view of the pelvis.

Pelvic Ring Fractures (Segment 61)

Anatomical Features

The pelvic ring is made up of paired innominate, pubic, ischial, and sacral bones. It is joined posteriorly by the sacroiliac joints and ligaments, and anteriorly by the pubic symphysis. The ischial bones, pubic rami, and pubic symphysis comprise the anterior ring. The sacroiliac joint is formed between the two auricular, or ear-shaped, articular surfaces of the ilium and sacrum, and connect to the posterior pelvic ring. The upper part of the sacroiliac articulation is formed by ligaments connecting the sacrum and ilium, while the lower part is separated by a space containing synovial fluid, thus comprising a synovial joint. The sacroiliac joint, together with posterior sacroiliac, sacrotuberous, and sacrospinous ligaments, as well as muscles and fascia of the pelvic floor, form the sacroiliac complex, a very important structure that maintains the stability of the pelvis. The sacrotuberous and sacrospinous ligaments enclose the greater sciatic notch and lesser sciatic notch, which form the greater sciatic foramen and the lesser sciatic foramen respectively, through which muscles, vessels, and nerves pass (▶ Fig. 7.17).

AO Classification of Pelvic Ring Fractures

Based on AO classification, the location code for the pelvic ring is number “61.” According to the mechanism of injury, fracture location, and the stability of the pelvis, segment 61 fractures can be further divided into: 61-A: Posterior arch intact, stable; 61-B: Incomplete posterior arch disruption, partially stable; and 61-C: Complete posterior arch disruption, unstable (▶ Fig. 7.18; ▶ Fig. 7.19).

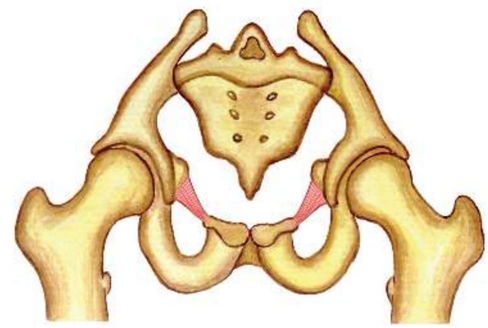

Fig. 7.18 AO codes for the pelvic ring.

Clinical Epidemiological Features of Pelvic Ring Fractures (Segment 61)

A total of 10,672 adult patients with 10,694 pelvic ring fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, comprising 2.96% of all adult patients with fractures and 2.86% of all types of fractures.

Epidemiological features of pelvic ring fractures are the following:

- Slightly more females than males.
- The high-risk age group is between ages 36–40 and 41–45 years; while the age group 41–45 years is the high-risk for males, age group 36–40 years is at risk for females.
- The most common fracture type of segment 61 fractures is type 61-A, the same fracture type for both males and females.
- The most common fracture group of segment 61 fractures is group 61-A2, the same group for males, and the most common fracture group for females is group 61-A3.

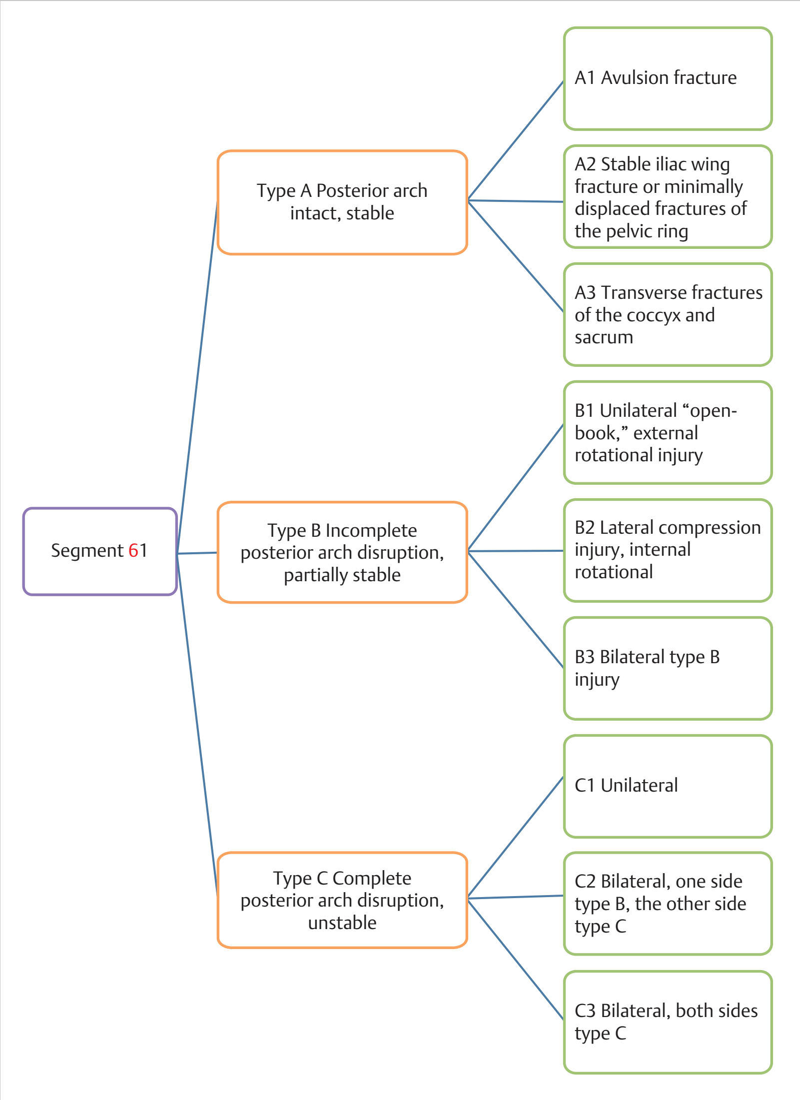

Fig. 7.19 Algorithm.

■ Fractures of Segment 61 by Sex

See ▶ Table 7.11 and ▶ Fig. 7.20.

Table 7.11 Sex distribution of 10,694 fractures of segment 61

Sex	Number of fractures	Percentage
Male	5,343	49.96
Female	5,351	50.04
Total	10,694	100.00

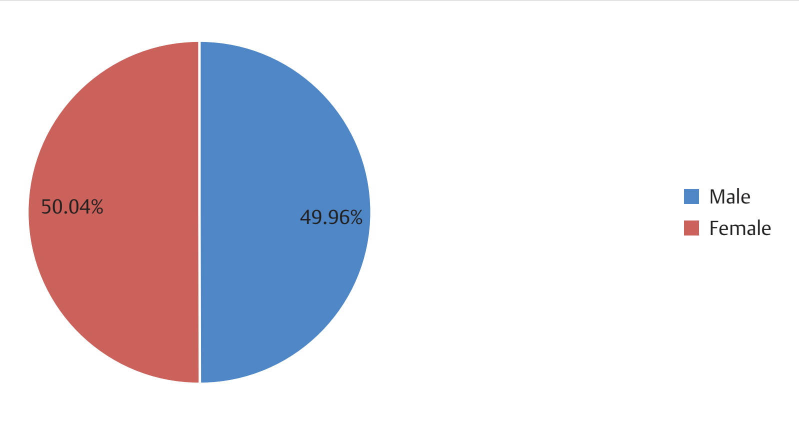

Fig. 7.20 Sex distribution of 10,694 fractures of segment 61.

■ Fractures of Segment 61 by Age Group

See ▶ Table 7.12 and ▶ Fig. 7.21.

Table 7.12 Age and sex distribution of 10,694 fractures of segment 61

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	320	209	529	4.95
21–25	538	479	1,017	9.51
26–30	551	521	1,072	10.02
31–35	488	478	966	9.03
36–40	654	652	1,306	12.21
41–45	700	630	1,330	12.44
46–50	604	480	1,084	10.14
51–55	426	396	822	7.69
56–60	383	361	744	6.96
61–65	196	246	442	4.13
66–70	160	227	387	3.62
71–75	127	236	363	3.39
76–80	101	196	297	2.78
81–85	58	151	209	1.95
≥ 86	37	89	126	1.18
Total	5,343	5,351	10,694	100.00

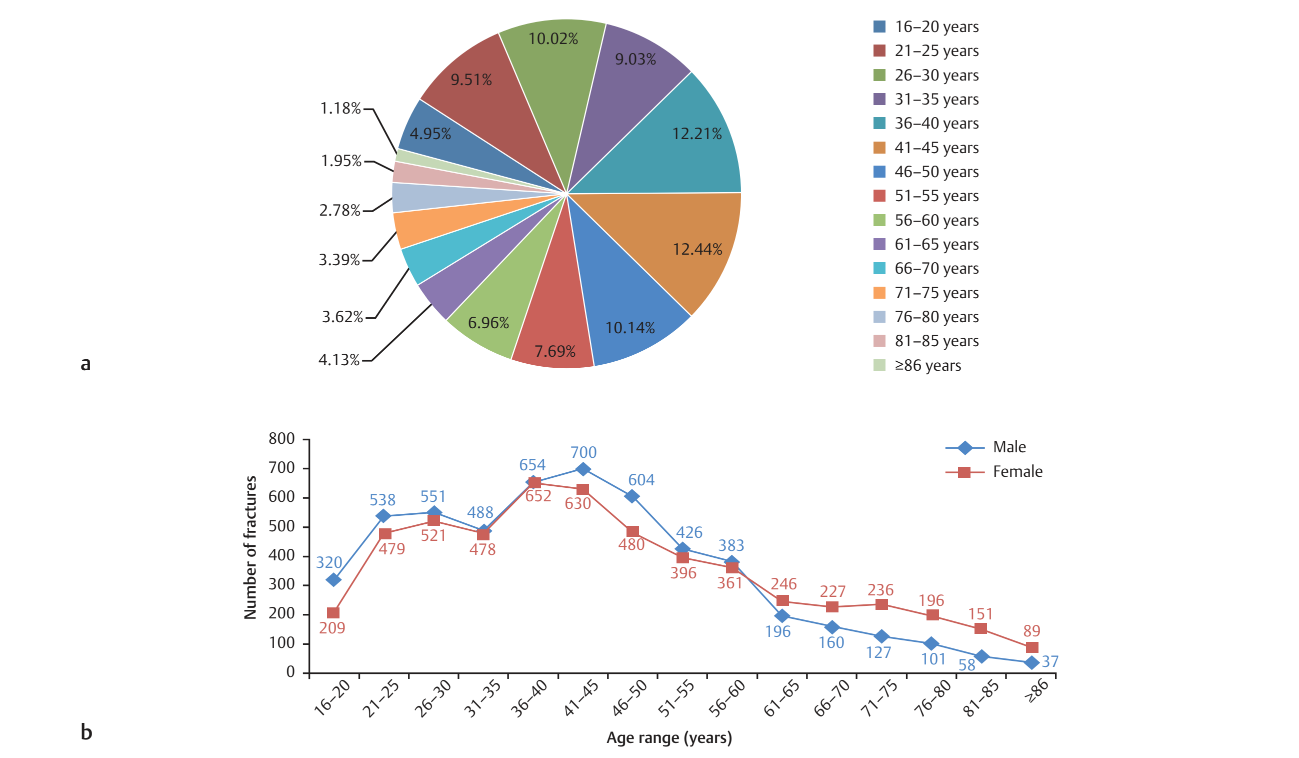

Fig. 7.21 (a) Age distribution of 10,694 fractures of segment 61. (b) Age and sex distribution of 10,694 fractures of segment 61.

■ Fractures of Segment 61 by Fracture Type

See ▶ Table 7.13, ▶ Table 7.14, ▶ Fig. 7.22, and ▶ Fig. 7.23.

Table 7.13 Sex and fracture type distribution of 10,694 fractures of segment 61

Fracture type	Male	Female	Number of fractures	Percentage
61-A	4,240	4,680	8,920	83.41
61-B	768	503	1,271	11.89
61-C	335	168	503	4.70
Total	5,343	5,351	10,694	100.00

Table 7.14 Sex and fracture group distribution of 10,694 fractures of segment 61

Fracture group	Male	Female	Number of fractures	Percentage in total segment 61 fractures	Percentage in total fractures of pelvic ring and acetabulum in adults
61-A1	342	170	512	4.79	3.69
61-A2	2,862	2,129	4,991	46.67	35.99
61-A3	1,036	2,381	3,417	31.95	24.64
61-B1	449	324	773	7.23	5.57
61-B2	276	143	419	3.92	3.02
61-B3	43	36	79	0.74	0.57
61-C1	238	126	364	3.40	2.62
61-C2	66	26	92	0.86	0.66
61-C3	31	16	47	0.44	0.34
Total	5,343	5,351	10,694	100.00	77.11

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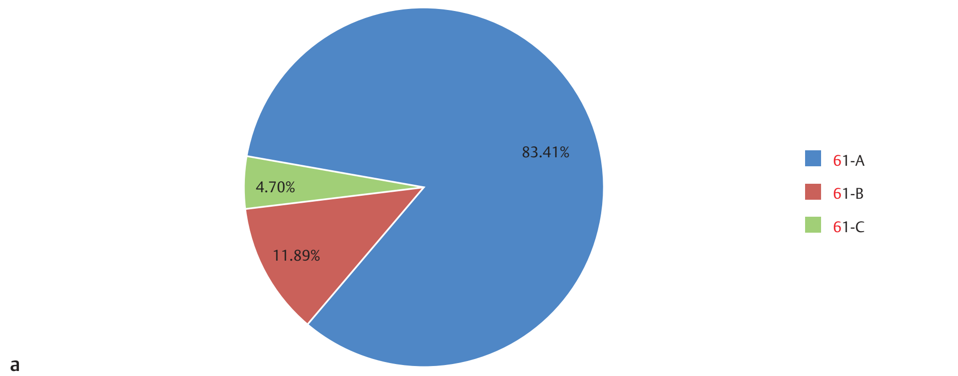


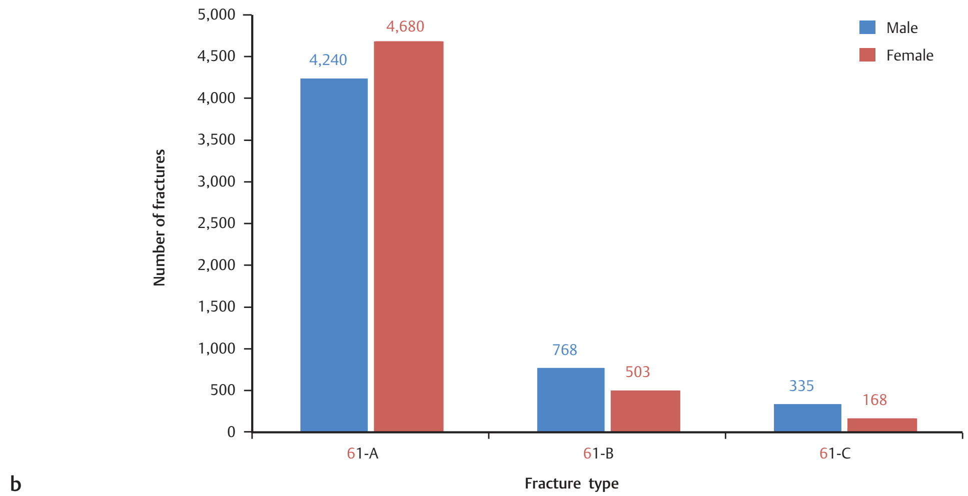
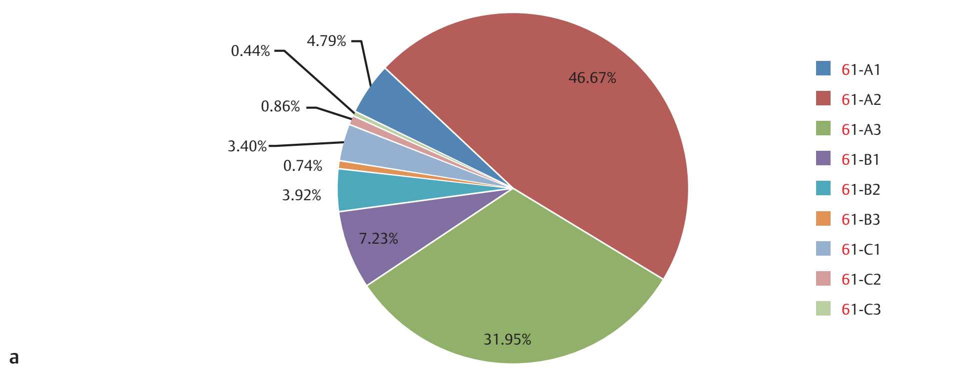


Fig. 7.22 (**a**) Fracture type distributions of 10,694 fractures of segment 61. (**b**) Sex and fracture type distribution of 10,694 fractures of segment 61.



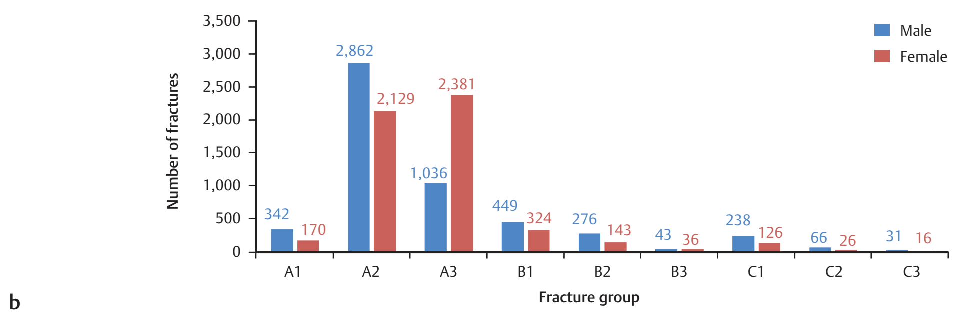


Fig. 7.23 (**a**) Fracture group distribution of 10,694 fractures of segment 61. (**b**) Sex and fracture group distribution of 10,694 fractures of segment 61.

61-A Pelvic ring, posterior arch intact, stable fractures

61-A1 Avulsion fracture
512 fractures
M: 342 (66.80%)
F: 170 (33.20%)
0.14% of total adult fractures
3.69% of adult pelvic ring and acetabulum
4.79% of segment 61
5.74% of type 61-A

61-A1.1 Fracture involving anterior superior iliac spine, anterior inferior iliac spine, or pubic spine

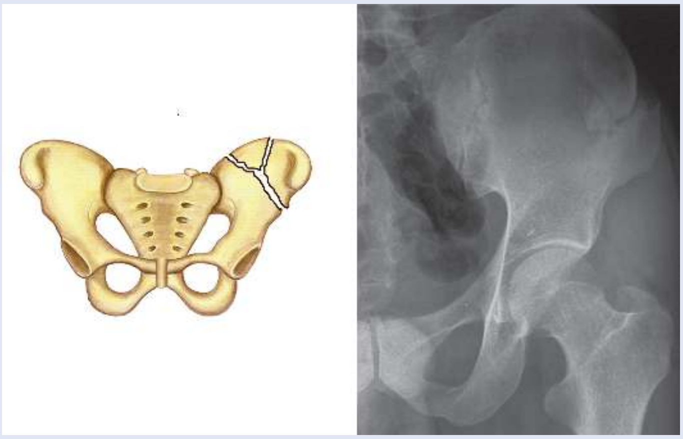
61-A1.2 Iliac crest

61-A1.3 Ischial tuberosity

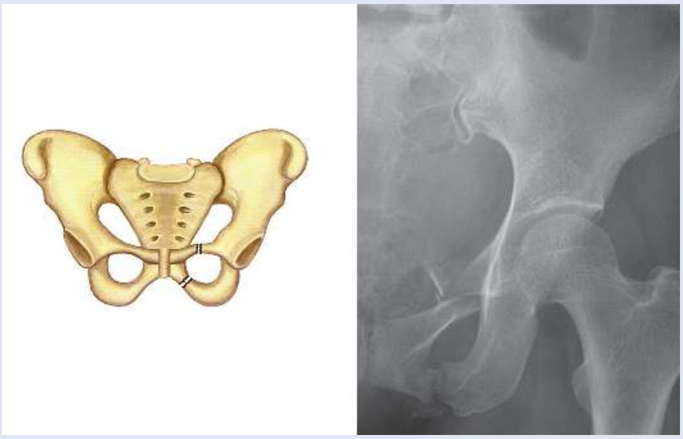
61-A Pelvic ring, posterior arch intact, stable fractures

61-A2 Stable iliac wing fracture or minimally displaced fractures of the pelvic ring (result of a direct blow to the ilium)
4,991 fractures
M: 2,862 (57.34%)
F: 2,129 (42.66%)
1.33% of total adult fractures
35.99% of adult pelvic ring and acetabulum
46.67% of segment 61
55.95% of type 61-A

61-A2.1 Iliac wing fracture, with one or more fragments



61-A2.2 Unilateral pubic rami fracture

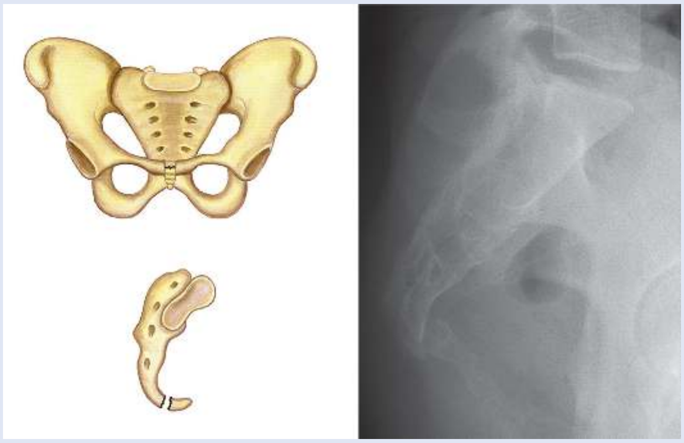


61-A2.3 Bilateral pubic rami fracture

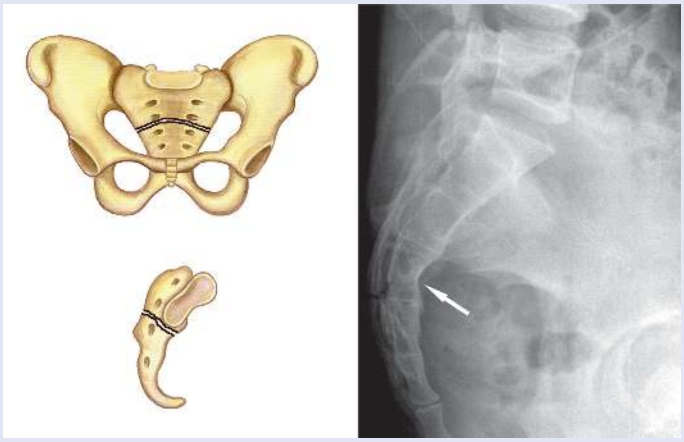
61-A Pelvic ring, posterior arch intact, stable fractures

61-A3 Transverse fractures of the coccyx and sacrum
3,417 fractures
M: 1,036 (30.32%)
F: 2,381 (69.68%)
0.91% of total adult fractures
24.64% of adult pelvic ring and acetabulum
31.95% of segment 61
38.31% of 61-A

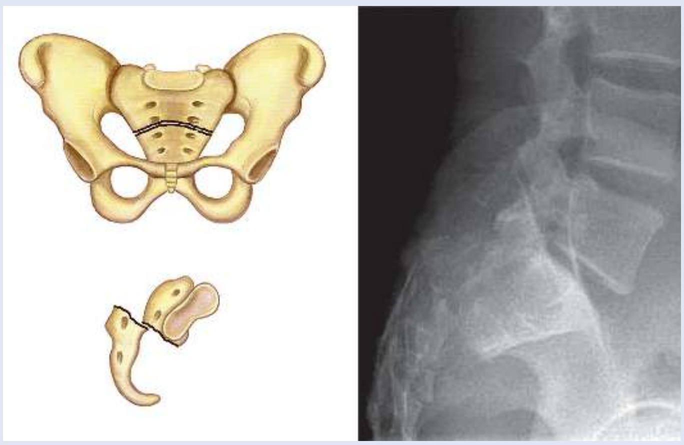
61-A3.1 Sacrococcygeal dislocation



61-A3.2 Nondisplaced sacral fracture



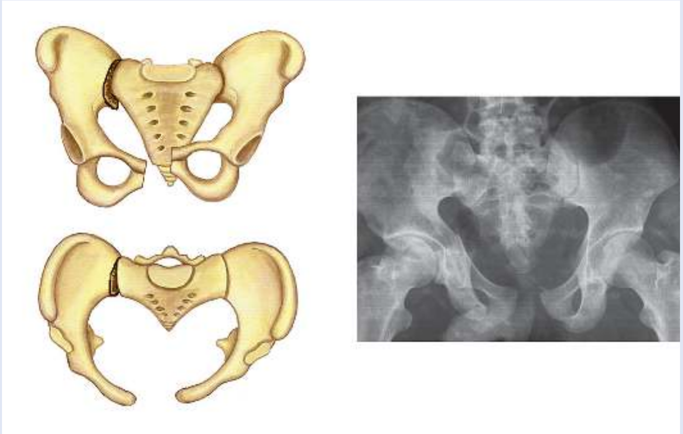
61-A3.3 Displaced sacral fracture



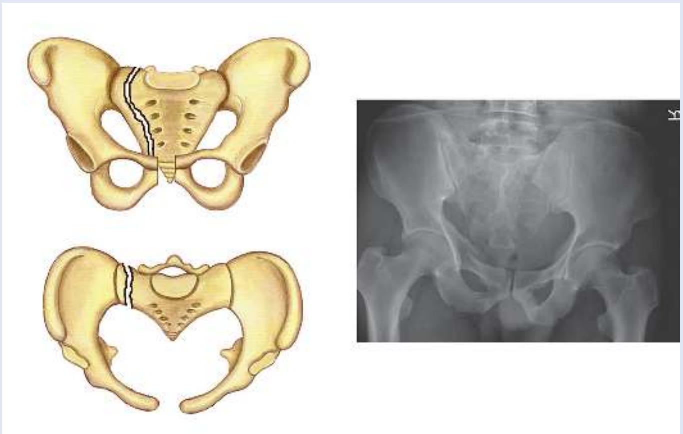
61-B Pelvic ring, incomplete posterior arch disruption, partial stable fractures

61-B1 Unilateral "open-book" injury (external rotational instability)
773 fractures
M: 449 (58.09%)
F: 324 (41.91%)
0.21% of total adult fractures
5.57% of adult pelvic ring and acetabulum
7.23% of segment 61
60.82% of type 61-B

61-B1.1 Anterior sacroiliac joint disruption + A injury*



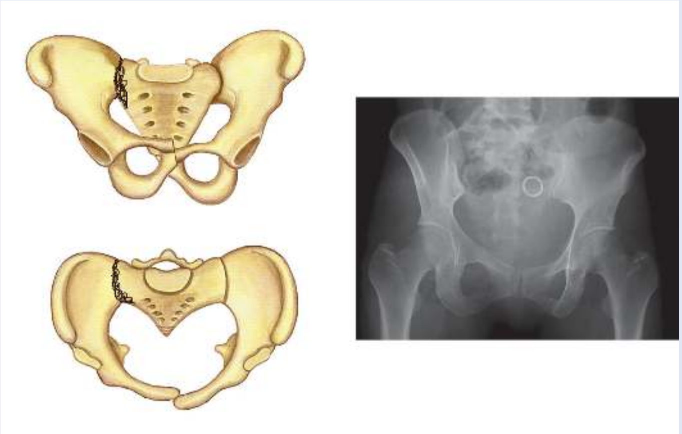
61-B1.2 Sacral fracture + A injury*



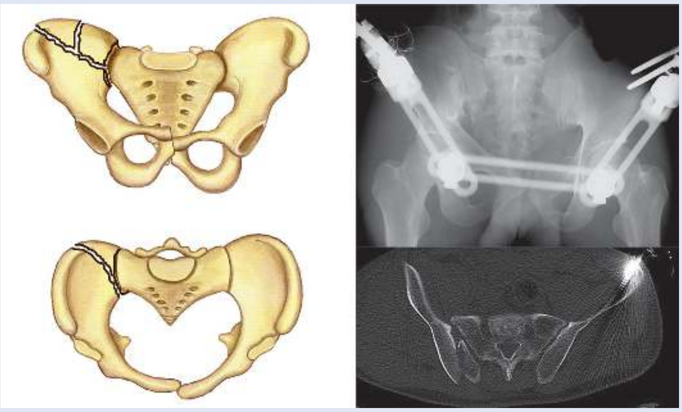
61-B Pelvic ring, incomplete posterior arch disruption, partial stable fractures

61-B2 Lateral compression injury (internal rotational instability)
419 fractures
M: 276 (65.87%)
F: 143 (34.13%)
0.11% of total adult fractures
3.02% of adult pelvic ring and acetabulum
3.92% of segment 61
32.97% of type 61-B

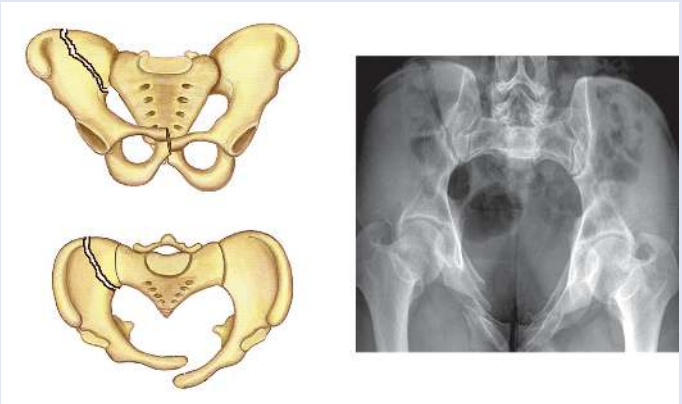
61-B2.1 Ipsilateral, anterior sacral buckle fracture + A injury*



61-B2.2 Contralateral, partial sacroiliac joint fracture/subluxation (bucket-handle) + A injury*



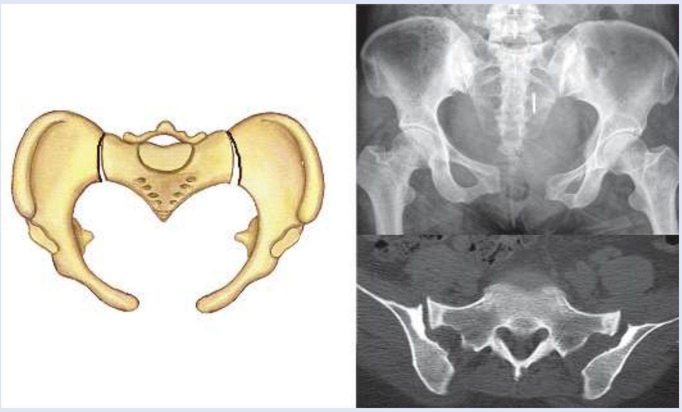
61-B2.3 Incomplete posterior iliac fracture + A injury*



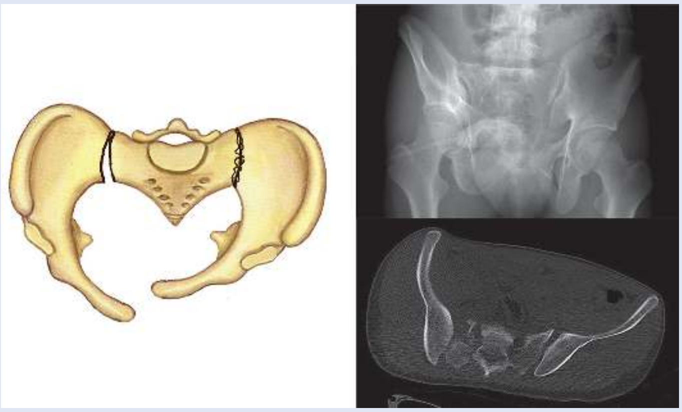
61-B Pelvic ring, incomplete posterior arch disruption, partial stable fractures

61-B3 Bilateral type B injury
79 fractures
M: 43 (54.43%)
F: 36 (45.57%)
0.02% of total adult fractures
0.57% of adult pelvic ring and acetabulum
0.74% of segment 61
6.22% of type 61-B

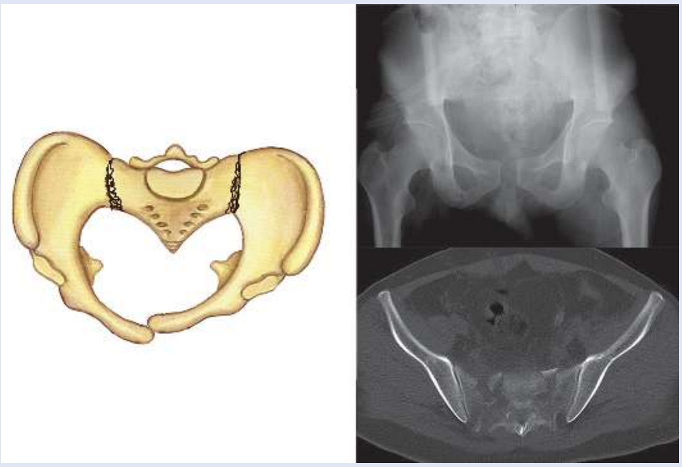
61-B3.1 Bilateral type B1 injury



61-B3.2 One side type B1 injury, the other side type B2 injury



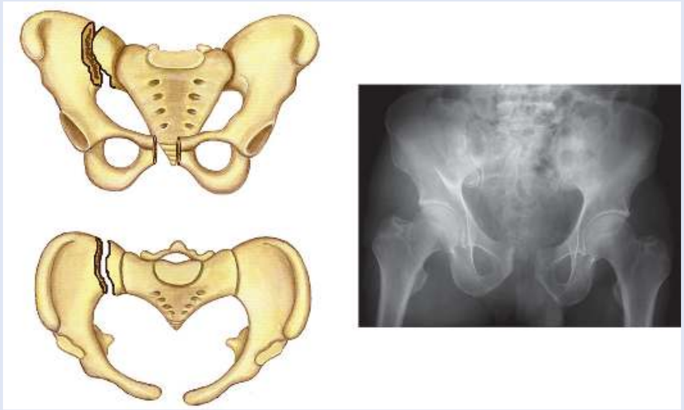
61-B3.3 Bilateral type 61-B2 injury



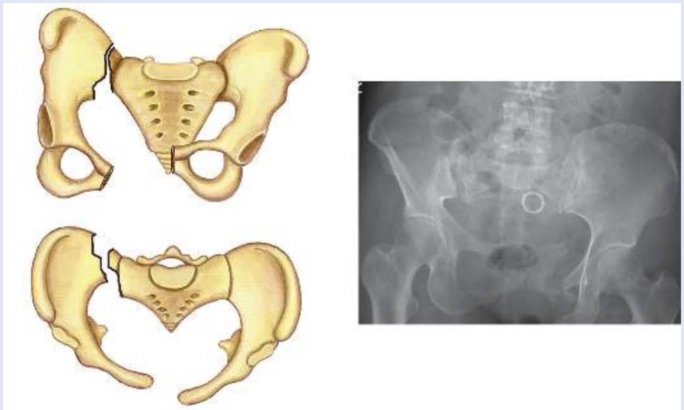
61-C Pelvic ring, complete posterior arch disruption, unstable fractures

61-C1 Unilateral
364 fractures
M: 238 (65.38%)
F: 126 (34.62%)
0.10% of total adult fractures
2.62% of adult pelvic ring and acetabulum
3.40% of segment 61
72.37% of type 61-C

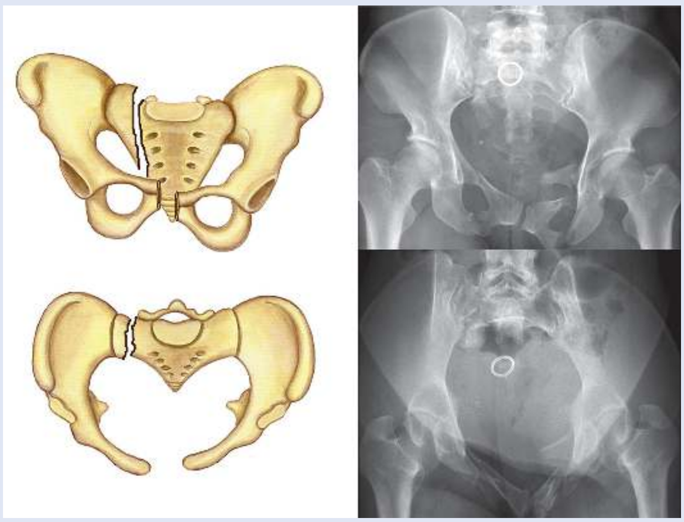
61-C1.1 Fracture of ilium + A injury*



61-C1.2 Sacroiliac dislocation or fracture dislocation + A injury*



61-C1.3 Fracture of sacrum (lateral, medial, or through the sacral foramina) + A injury*



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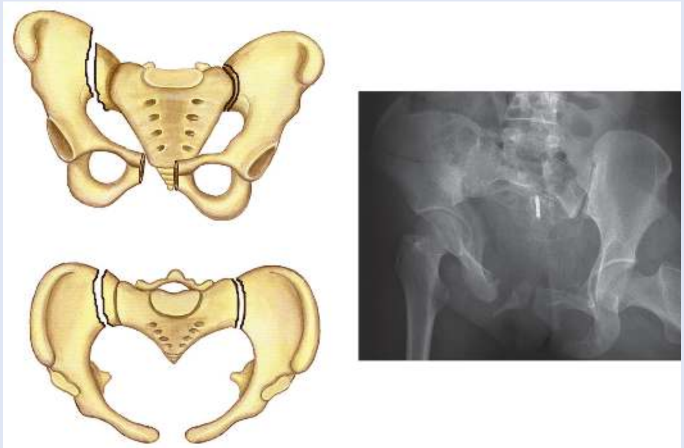
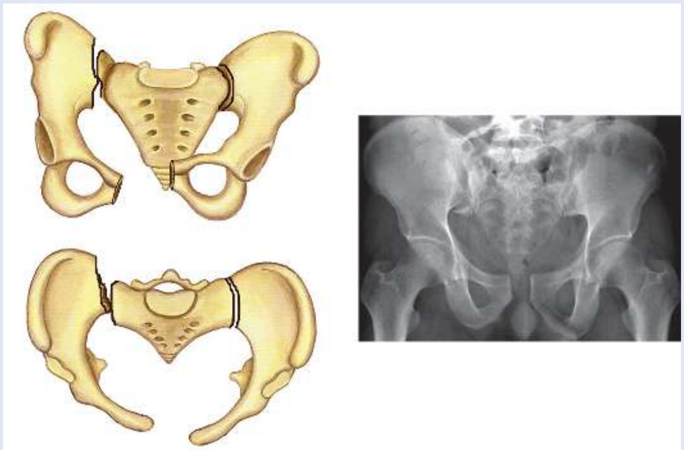
61-C Pelvic ring, complete posterior arch disruption, unstable fractures

61-C2 Bilateral, one side type 61-B, the other side type 61-C
92 fractures
M: 66 (71.74%)
F: 26 (28.26%)
0.02% of total adult fractures
0.66% of adult pelvic ring and acetabulum
0.86% of segment 61
18.29% of type 61-C

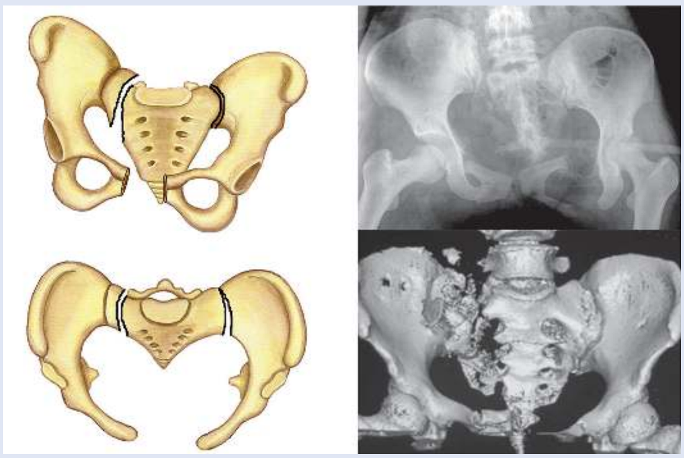
61-C2.1 Ipsilateral C1 lesion through the ilium, contralateral B1 or B2 injury + A injury*



61-C2.2 Ipsilateral C1 lesion through the sacroiliac joint (transiliac fracture dislocation, pure dislocation, transsacral fracture dislocation), contralateral B1 or B2 injury + A injury*



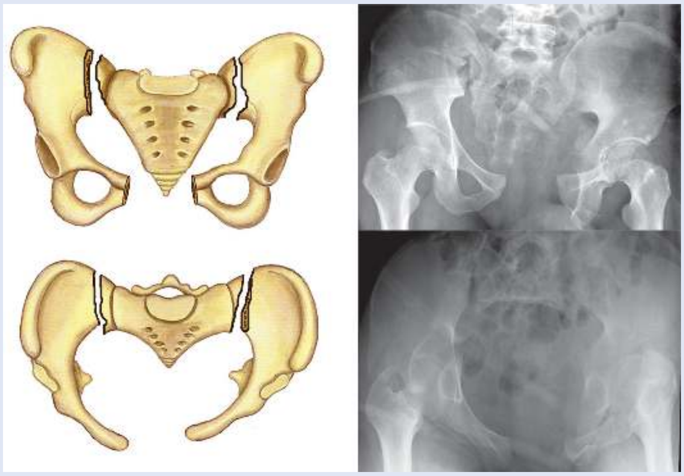
61-C2.3 Ipsilateral C1 lesion through the sacrum (lateral, medial, or through the sacral foramina) contralateral B1 or B2 injury + A injury*



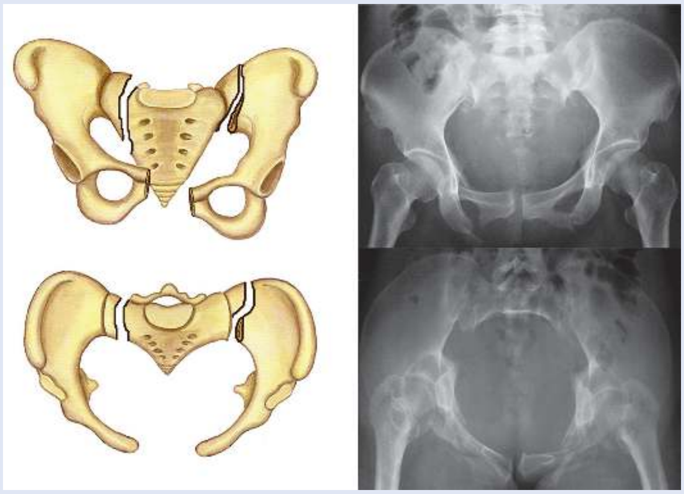
61-C Pelvic ring, complete posterior arch disruption, unstable fracture

61-C3 Bilateral, both type 61-C1
47 fractures
M: 31 (65.96%)
F: 16 (34.04%)
0.01% of total adult fractures
0.34% of adult pelvic ring and acetabulum
0.44% of segment 61
9.34% of type 61-C

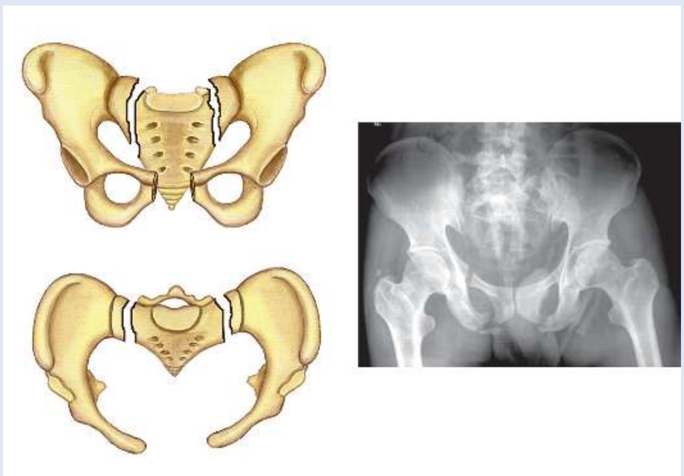
61-C3.1 Extrasacral on both sides (ilium, transiliac sacroiliac (SI) joint fracture/dislocation, transsacral SI joint fracture/dislocation, SI joint dislocation)



61-C3.2 One side C1 lesion through the sacrum (lateral, medial, or through the sacral foramina), the other side extra sacral lesion + A injury*



61-C3.3 Sacral lesion on both sides (lateral, medial, or through the sacral foramina) + A injury*



Note: * "A injury" includes: ipsilateral pubic or pubic rami fracture; contralateral pubic or pubic rami fracture; bilateral pubic or pubic rami fracture; isolated symphysis pubis separation ≥ 2.5 cm; isolated symphysis pubis separation < 2.5 cm; isolated symphysis separation, or locked; symphysis separation + ipsilateral pubic or ramus fracture; symphysis separation + contralateral pubic or ramus fracture; symphysis separation + bilateral pubic or rami fracture; without anterior lesion.

7

Injury Mechanism

Pelvic ring fractures involve direct or indirect mechanisms. The direct mechanism includes a direct blow, motor vehicle crash, crush injury, fall, etc. Based on the direction of the force, the injury mechanisms can be classified into the following types: anteroposterior (AP) compression, lateral compression, and vertical shear. Different forces can result in different types of pelvic ring fractures. Indirect forces usually result in avulsion fractures from the traction of muscles or tendons.

The force of AP compression usually produces an "open-book"-type injury, that is, a symphysis disruption, by acting on the posterior superior spine and symphysis pubis, or by forced external rotation through the hip joints unilateral or bilaterally. If more force is applied, the anterior ligaments of the sacroiliac joint and the sacrospinous ligament may also be injured, and the posterior dislocation of sacroiliac joint, which is the traditional dislocation of the sacroiliac joint, may occur. In rare conditions, enormous AP force can lead to "anterior" dislocation of sacroiliac joint, in which the ilium dislocates anterior to the sacrum and often combines with symphyseal diastasis and fractures of pubic rami and ilia. Different locations upon which the AP compression is applied may lead to different types of "open-book" injuries.

The force of lateral compression can be transmitted by a direct blow to the iliac crest, often causing an internal rotation of the hemipelvis, or the so-called bucket-handle fracture. Lateral compression may also cause an ipsilateral injury through the femoral head, occasionally causing contralateral injury. The injuries caused by internal rotation account for the majority of pelvic fractures.

Shearing forces in the vertical plane can cause marked displacement of bony structures of the pelvic ring, and gross disruption of soft-tissue structures.

Complex forces, resulting from a combination of these injury patterns, often cause associated acetabular fractures. The most common combined mechanism is lateral compression and vertical shearing. The combined injury of the acetabulum and posterior pelvic ring can be described by three patterns: (1) Acetabular fractures associated with ipsilateral posterior pelvic ring injuries. (2) Acetabular fractures associated with controlateral posterior pelvic ring injuries. (3) Acetabular fractures associated with bilateral posterior pelvic ring injuries.

Diagnosis

Pelvic ring injuries are generally high-energy fractures and frequently associated with multiple injuries. Evaluation of the patient should begin with an initial assessment to form a general impression of the degree or severity of the injury, such as to assess hemodynamic status, and the presence of other severe associated injuries. Physical examination should note the morphology of the pelvis and hip joint, as well as the function of the lower extremities. A careful examination of the painful area should be performed. The pelvic compression and separation test, Gaenslen's maneuver, and the Yeoman test can be used to assess an injury and point to appropriate imaging studies.

The radiographic evaluation includes the AP, inlet, outlet, and Judet views of the pelvis. An AP view of pelvis is usually sufficient to uncover most pelvic injuries. Abnormalities depicted on the AP view can direct the need for the next set of radiographs, which usually include inlet and outlet views of the pelvis in pelvic ring fractures, and Judet (oblique) radiographs of the pelvis in acetabular fractures. Inlet radiographs of the pelvis allow the evaluation of pelvic brim integrity, AP displacement of the hemipelvis, internal/external rotation of the hemipelvis, and sacral impaction. Outlet views of the pelvis allow for confirmation of vertical displacement of the hemipelvis. Judet views of the pelvis illustrate the anterior and posterior columns of the acetabulum, free of superimposition. Computed (CT) or magnetic resonance imaging (MRI) should be performed when plain diagnostic radiographs are inconclusive, with regard to pelvic fractures or the presence of concomitant visceral or neurovascular injuries are suspected.

Treatment

Patients with hemodynamic instability require emergency rehydration, and temporary stabilization of pelvic fractures, such as by pelvic ring pocket and external fixation, to decrease hemorrhage. Interventional radiology therapy can be applied if necessary. For instance, patients who sustain type B or C injuries often have concomitant severe bony and soft tissue injuries; for example, massive internal bleeding is commonly associated with complete sacroiliac joint disruption. To prevent recurrence of hemorrhage in such patients, temporary fracture stabilization should be performed.

For hemodynamically stable patients, surgical intervention should be performed 5 to 7 days after the injury. Either an external fixation device or open reduction fixation is used for isolated anterior arch fractures. The preferred treatment of choice for unstable pelvic fractures is anatomic reduction and rigid internal fixation. In addition, minimally invasive methods, such as percutaneous iliosacral screw fixation for fracture dislocations of the sacroiliac joint, are increasingly applied in the clinical setting. The sacral pedicel axial view projection is an optimal radiographic technique for percutaneous placement of iliosacral screws in clinical practice. AO classification of pelvis fractures provides a guide in selecting appropriate surgical plans: type A2 and B1 injuries, in which symphysis separation is less than 2.5 cm, can be managed nonsurgically; if symphysis disruption is greater than 2.5 cm, either an external fixation device or plate fixation can be applied; type B2 injuries, being relatively mild, require only reduction and maintenance in proper position; type B3 injuries with shortening of the limb > 1.5 cm should be considered for internal fixation. Operative reduction and internal fixation should be performed if the fracture fragments protrude into the perineal region.

Type C fractures should be treated with an anterior external fixation device combined with skeletal traction (8 to 12 weeks), or operative reduction and internal fixation. In addition to iliosacral screw fixation, posterior pelvic disruptions can be treated with the use of posterior tension band plate and the minimally invasive adjustable plate (MIAP). The MIAP conforms to the

7

irregular shape of posterior pelvic ring and can be used without prebending. This plate also has a role in reducing compressed or separated fractures/dislocations. Favorable clinical and radiological outcomes can be achieved in treating posterior pelvic disruptions with MIAP.

Acetabular Fractures (Segment 62)

■ Anatomical Features

The acetabulum is a hemispherical horseshoe-shaped articular cavity, with a diameter of 3.5 cm, which articulates with the head of femur. It is formed at the confluence of the ilium, ischium, and pubis, and is situated near the middle of the outer surface of the hip bone, between the anterior superior iliac spine and ischial tuberosity (▶ Fig. 7.24).

The hip joint is enclosed in a strong fibrous capsule and surrounding musculature, which provide a good amount of stability. At the lower brim of the acetabulum is the acetabular notch. The external surface of the acetabulum is partly articular, partly nonarticular; the articular segment forms a curved, crescent-moon shaped surface, the lunate surface; the nonarticular portion contributes to a circular depression, the acetabular fossa, situated at the bottom of the acetabulum, inside which the Haversian gland is located and enhances the depth of the hip joint.

The acetabulum is divided into anterior and posterior columns, and dome (▶ Fig. 7.25). The anterior column (iliopectineal) begins at the iliac wing and extends down the anterior portion of the acetabulum, through the superior pubic ramus to the symphysis pubis. It is composed of the iliac crest, the iliac

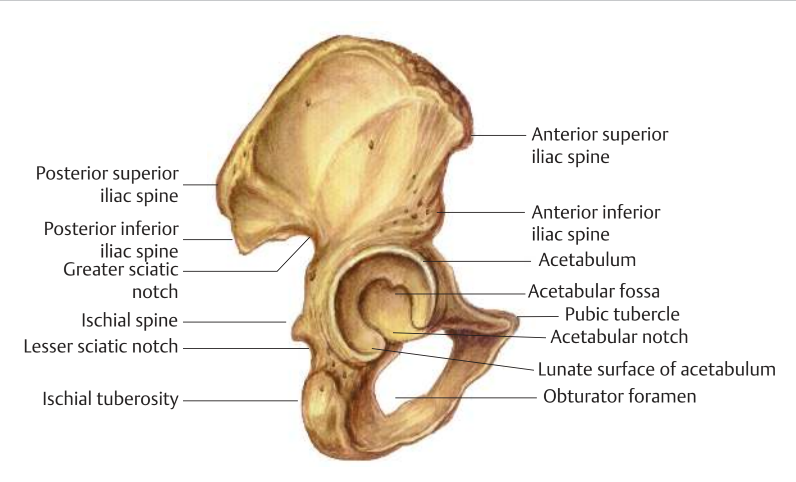


Fig. 7.24 The acetabulum.

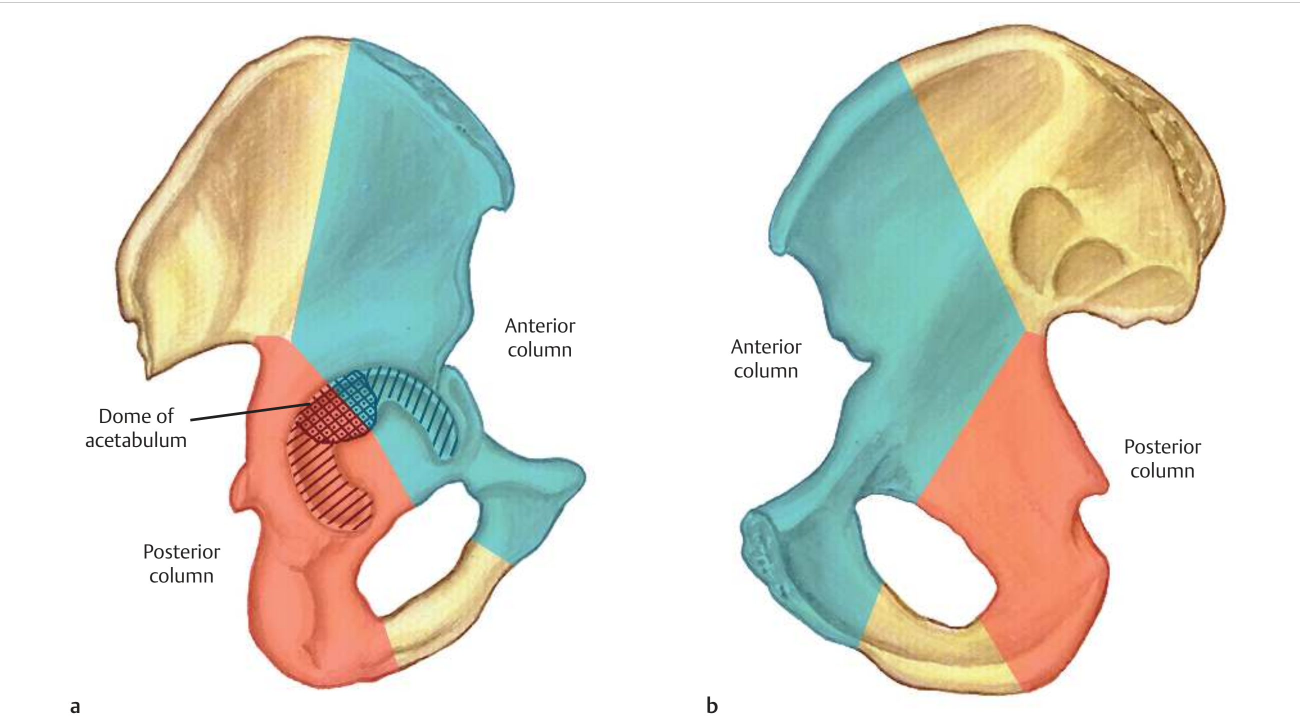


Fig. 7.25 (**a, b**) The acetabulum is divided into anterior and posterior columns, and dome.

spines, the anterior wall, the anterior one-half of the acetabulum, and the superior pubic ramus, and can be divided into major three parts: the iliac, acetabular, and pubic portions. The posterior column (ilioischial line) begins at the sciatic notch and extends down the posterior acetabulum into the ischium. It is composed of dense bone superior to the sciatic notch, posterior wall, and posterior one-half of the acetabulum and the ischium. The dome, or roof of the acetabulum, formed by the iliac bone, is the weight-bearing surface, making up 40% of the acetabulum.

AO Classification of Acetabular Fractures

Based on AO fracture classification, the location code for the acetabulum is number “62.” According to fracture patterns, acetabular fractures can be divided into three types: A-partial articular fracture, involving one column; B-partial articular fracture, transverse; and C-complete articular fracture, involving both columns (▶ Fig. 7.26).

Clinical Epidemiological Features of Acetabular Fractures (Segment 62)

A total of 3,131 adult patients with 3,174 pelvic ring fractures, including 43 patients with bilateral acetabular fracture, were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied. Acetabular fractures comprise 22.89% of adult fractures of the pelvic ring and acetabulum. Epidemiological features of pelvic ring fractures are the following:

- More males than females
- The high-risk age group is 41–45 years; while age group 36–40 years is the high-risk group for males, age group 41–45 years is the high-risk group for females.
- The most common fracture type of segment 62 fractures is type 62-A, the same fracture type for both males and females.
- The most common fracture group of segment 62 fractures is group 62-A1, the same group for males, while the most common fracture group for females is 62-A2.

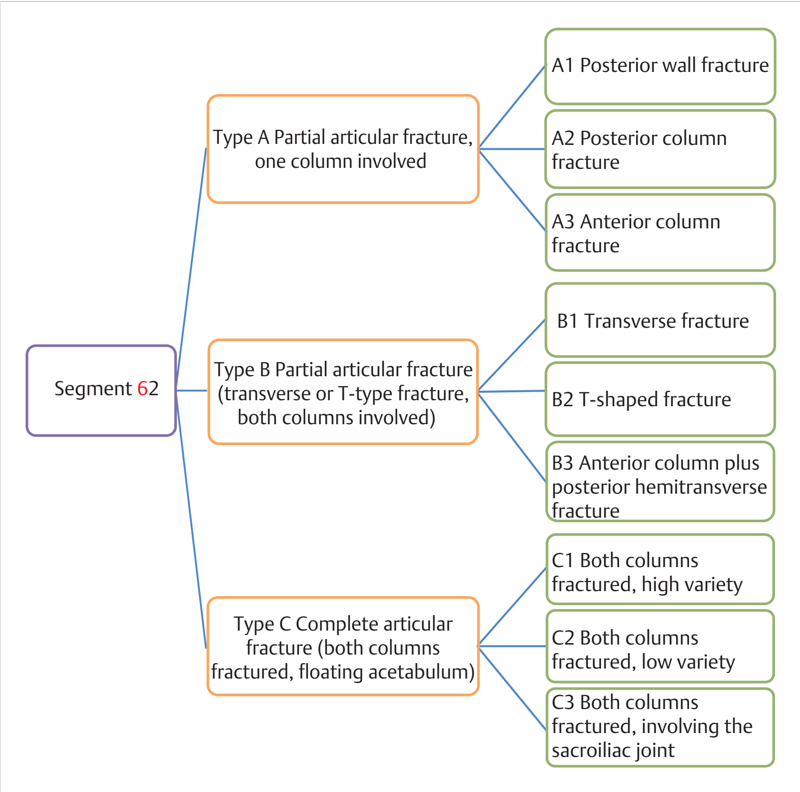


Fig. 7.26 Algorithm.

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■ Fractures of Segment 62 Fractures by Sex

See ▶ Table 7.15 and ▶ Fig. 7.27.

Table 7.15 Sex distribution of 3,174 fractures of segment 62

Sex	Number of fractures	Percentage
Male	2,286	72.02
Female	888	27.98
Total	3,174	100.00

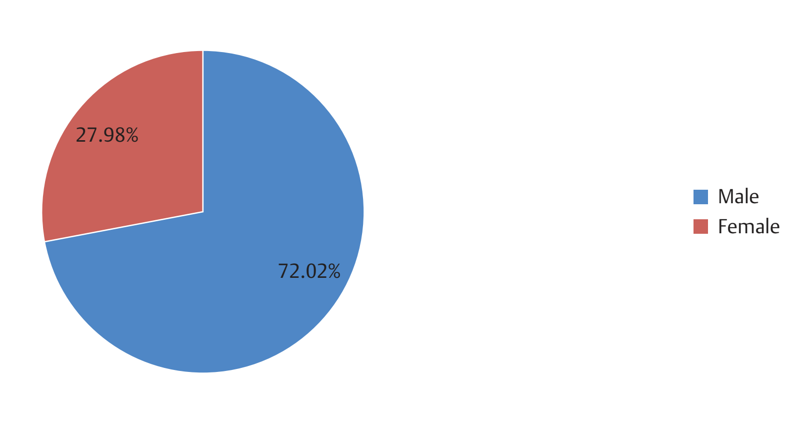

Fig. 7.27 Sex distribution of 3,174 fractures of segment 62.

■ Fractures of Segment 62 by Fracture Side

See ▶ Table 7.16 and ▶ Fig. 7.28.

Table 7.16 Fracture side distribution of 3,131 patients with fractures of segment 62

Fracture side	Number of patients	Percentage
Left	1,713	54.71
Right	1,375	43.92
Both	43	1.37
Total	3,131	100.00

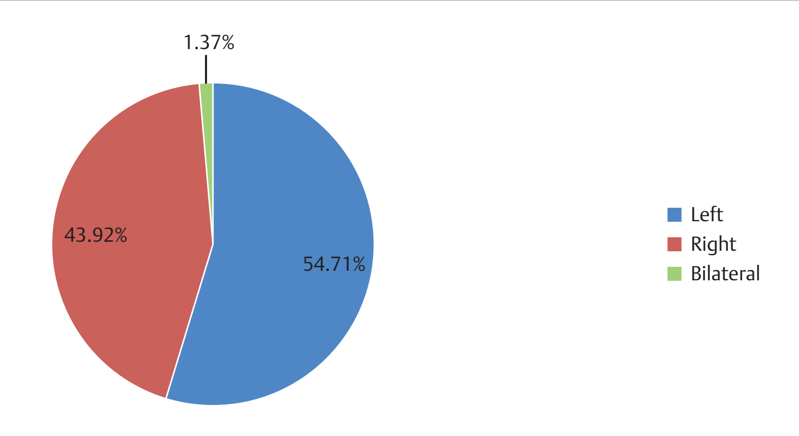

Fig. 7.28 Fracture side distribution of 3,131 patients with fractures of segment 62.

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■ Fractures of Segment 62 by Age Group

See ▶ Table 7.17 and ▶ Fig. 7.29.

Table 7.17 Age and sex distribution of 3,131 fractures of segment 62

Age group (years)	Male	Female	Total number of fractures	Percentage
16–20	89	28	117	3.74
21–25	187	72	259	8.27
26–30	187	50	237	7.57
31–35	239	44	283	9.04
36–40	296	91	387	12.36
41–45	289	118	407	13.00
46–50	262	103	365	11.66
51–55	227	95	322	10.28
56–60	188	78	266	8.50
61–65	98	58	156	4.98
66–70	77	41	118	3.77
71–75	49	33	82	2.62
76–80	33	38	71	2.27
81–85	24	19	43	1.37
≥ 86	6	12	18	0.57
Total	2,251	880	3,131	100.00

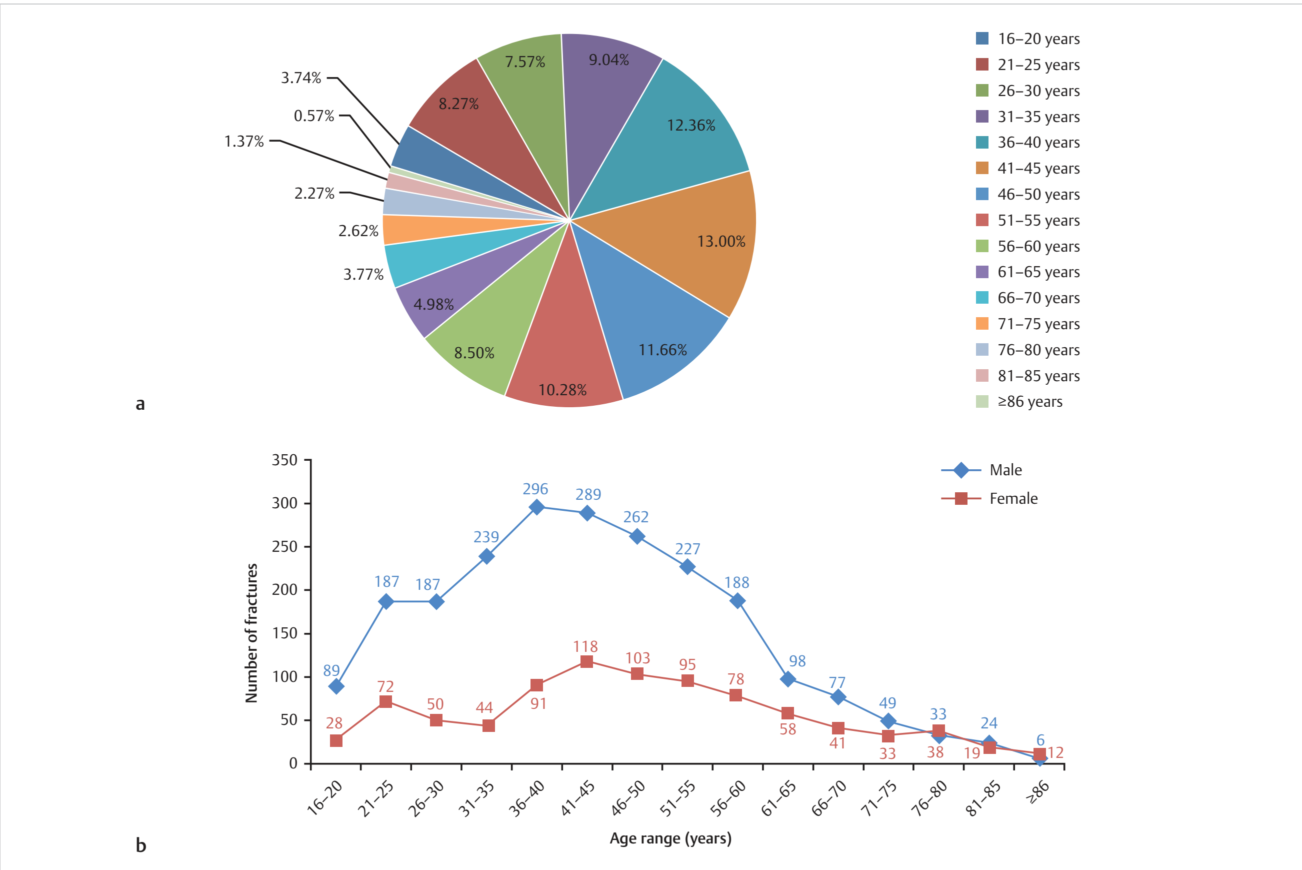


Fig. 7.29 (a) Age distribution of 3,131 fractures of segment 62. (b) Age and sex distribution of 3,131 fractures of segment 62.

■ Fractures of Segment 62 by Fracture Type

See ▶ Table 7.18, ▶ Table 7.19, ▶ Fig. 7.30, and ▶ Fig. 7.31.

Table 7.18 Sex and fracture type distribution of 3,174 fractures of segment 62

Fracture type	Male	Female	Number of fractures	Percentage
62-A	1,237	516	1,753	55.23
62-B	784	286	1,070	33.71
62-C	265	86	351	11.06
Total	2,286	888	3,174	100.00

Table 7.19 Sex and fracture group distribution of 3,174 fractures of segment 62

Fracture group	Male	Female	Number of fractures	Percentage in total segment 62 fractures	Percentage in total fractures of pelvic ring and acetabulum in adults
62-A1	557	165	722	22.75	5.21
62-A2	396	217	613	19.31	4.42
62-A3	284	134	418	13.17	3.01
62-B1	466	175	641	20.20	4.62
62-B2	185	81	266	8.38	1.92
62-B3	133	30	163	5.14	1.18
62-C1	91	29	120	3.78	0.87
62-C2	127	28	155	4.88	1.12
62-C3	47	29	76	2.39	0.55
Total	2,286	888	3,174	100.00	22.89

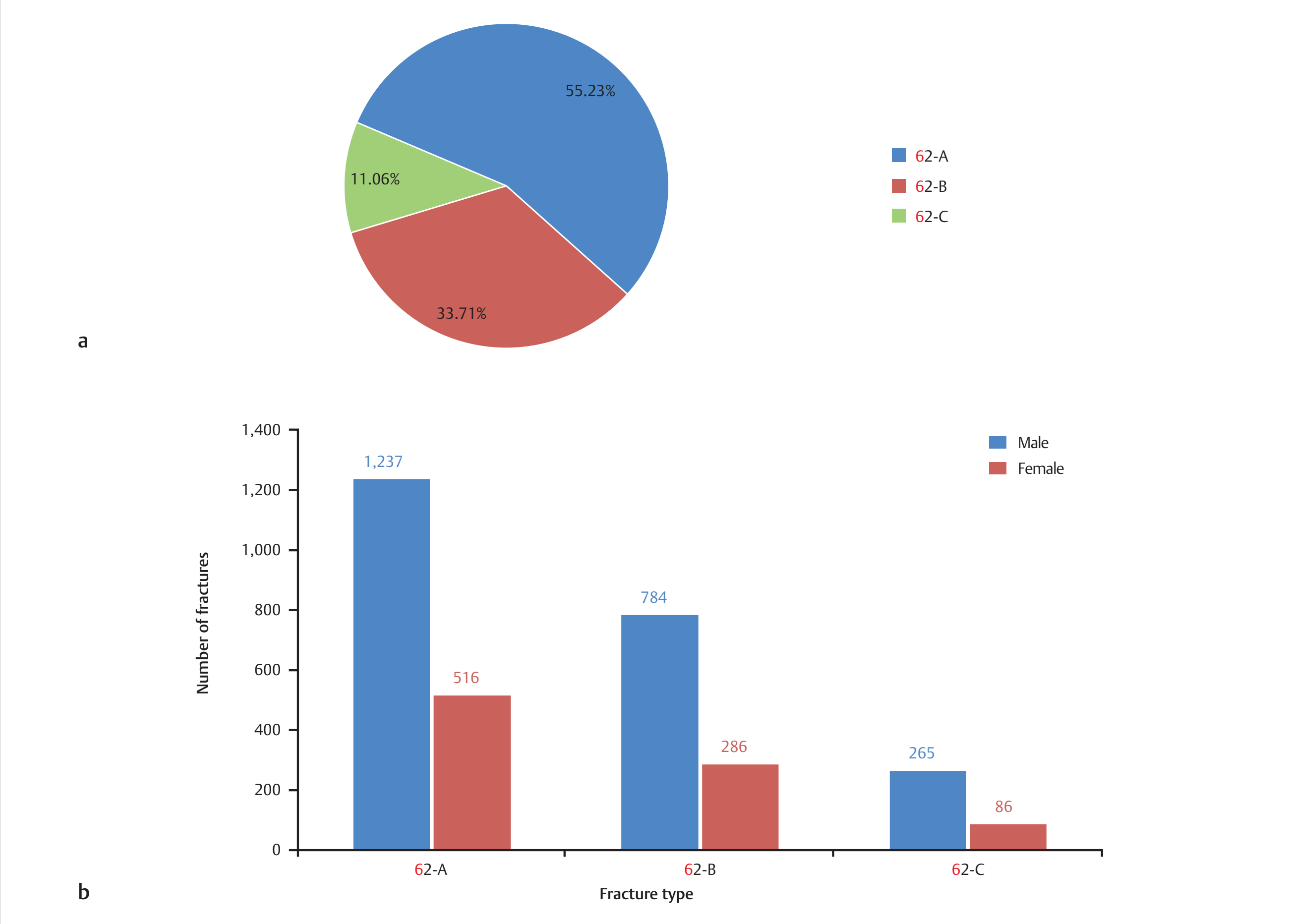


Fig. 7.30 (**a**) Fracture type distribution of 3,174 fractures of segment 62. (**b**) Sex and fracture type distribution of 3,174 fractures of segment 62.

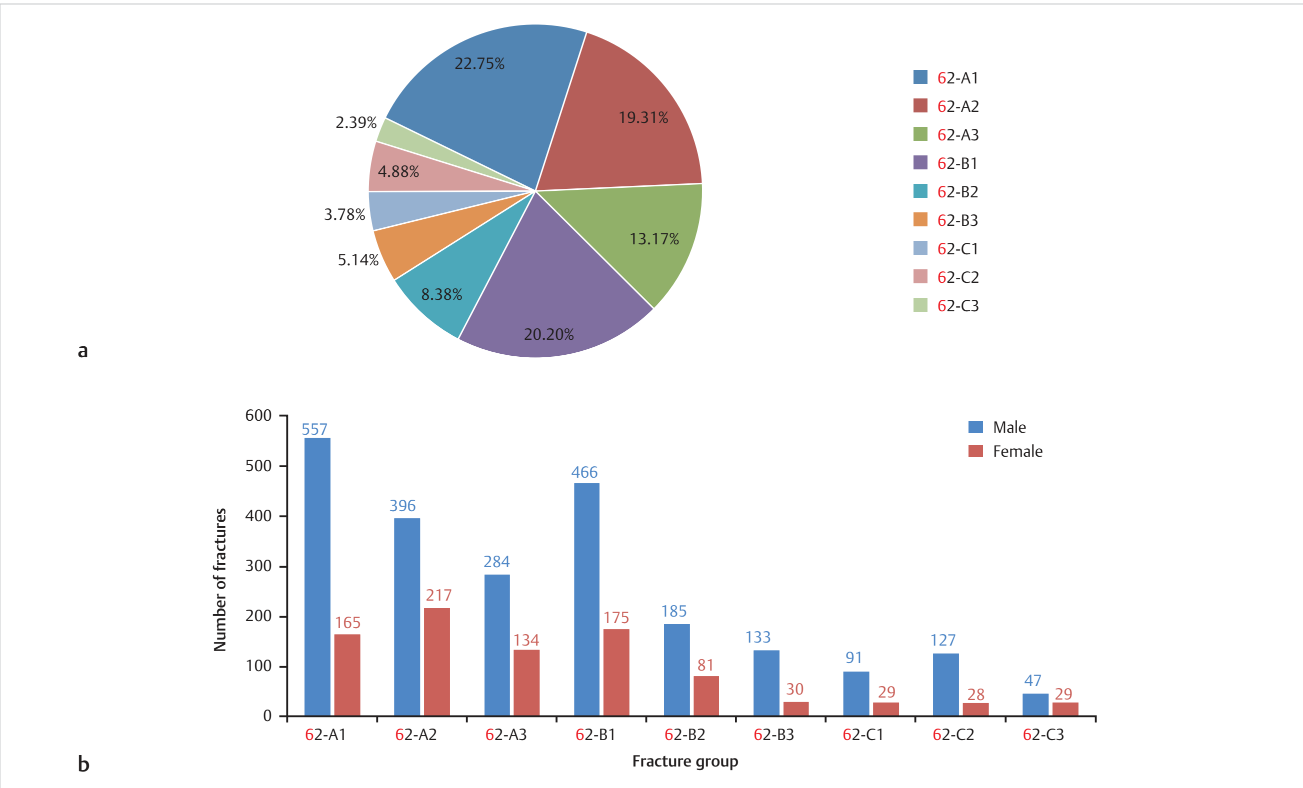
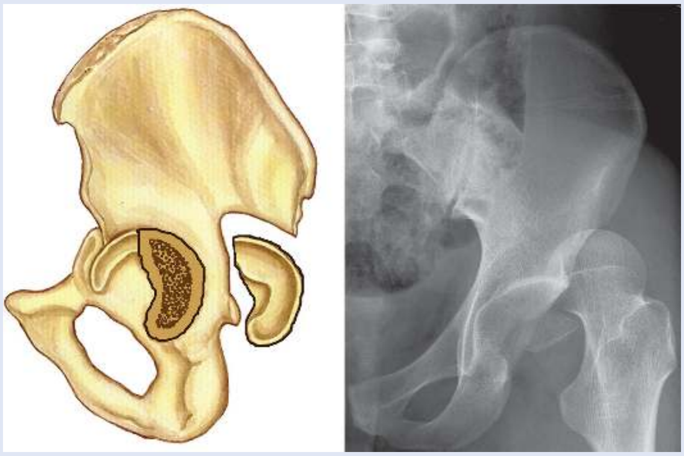


Fig. 7.31 (**a**) Fracture group distribution of 3,174 fractures of segment 62. (**b**) Sex and fracture group distribution of 3,174 fractures of segment 62.

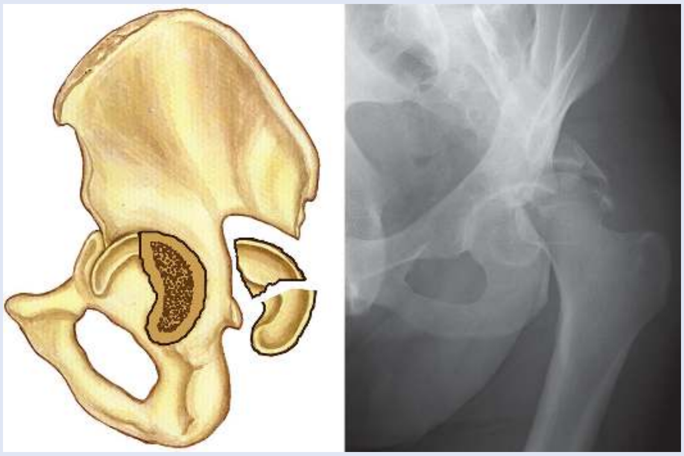
62-A Acetabular, partial articular fracture, one column involved

62-A1 Posterior wall fracture
722 fractures
M: 557 (77.15%)
F: 165 (22.85%)
0.19% of total adult fractures
5.21% of adult pelvis and acetabulum
22.75% of segment 62
41.19% of type 62-A

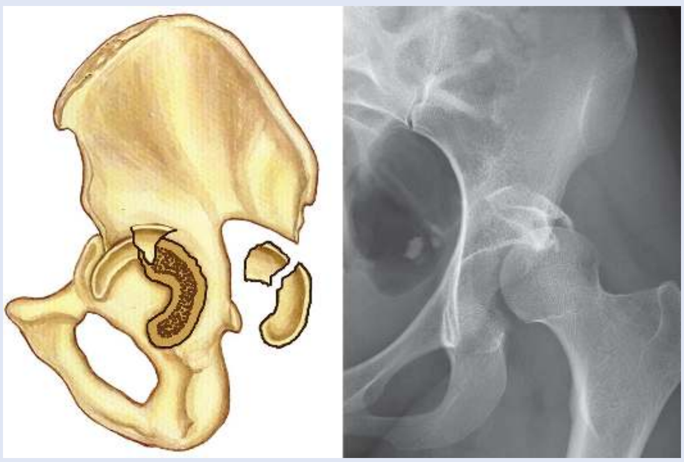
62-A1.1 Pure fracture dislocation, one fragment in the posterior, posterosuperior, or posteroinferior



62-A1.2 Pure fracture dislocation, multifragmentary in posterior, posterosuperior, or posteroinferior



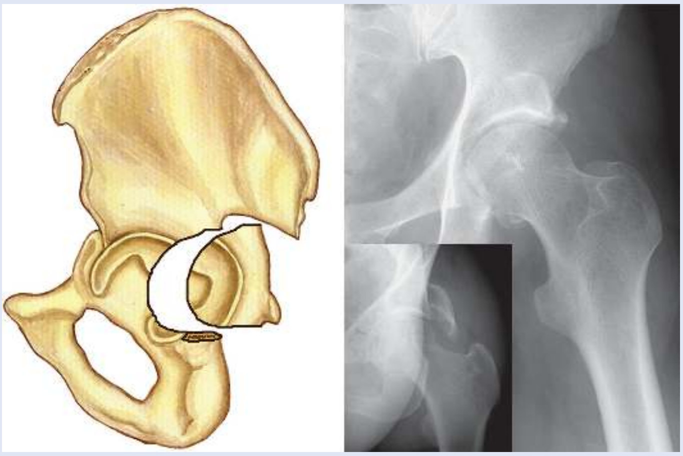
62-A1.3 Fracture-dislocation, with marginal impaction in posterior, posterosuperior, or posteroinferior



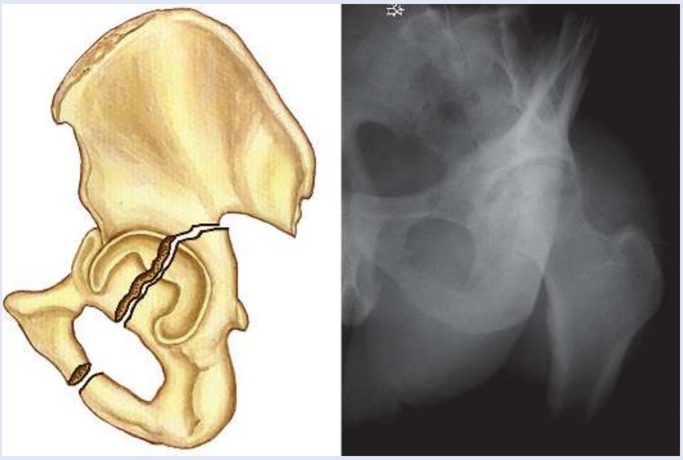
62-A Acetabular, partial articular fracture, one column involved

62-A2 Posterior column fracture
613 fractures
M: 396 (64.60%)
F: 217 (35.40%)
0.16% of total adult fractures
4.42% of adult pelvis and acetabulum
19.31% of segment 62
34.97% of type 62-A

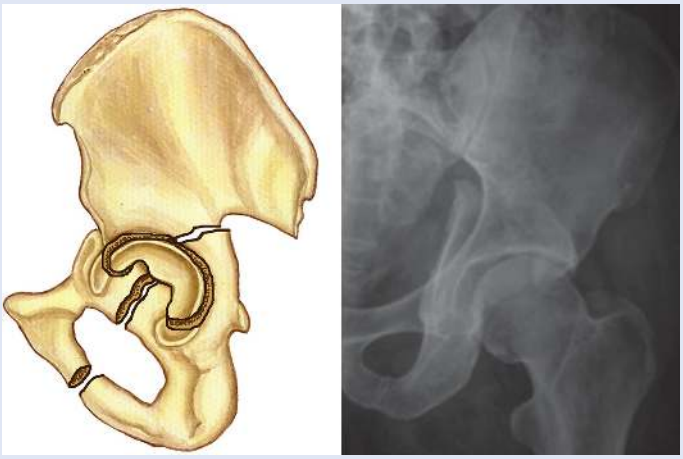
62-A2.1 Through the ischium



62-A2.2 Through the obturator foramen (preserving tear drop or involving tear drop)



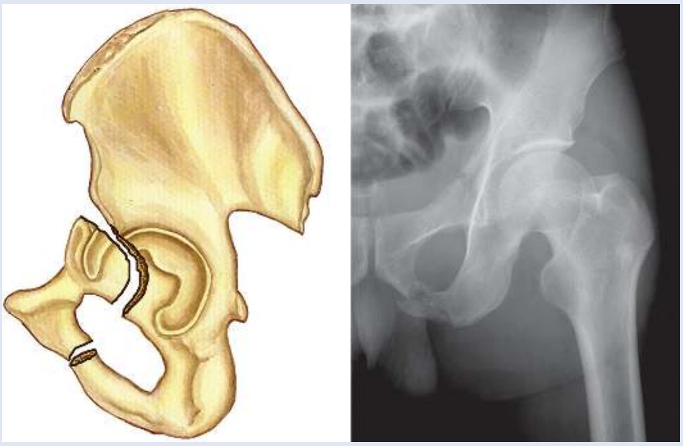
62-A2.3 Associated with posterior wall fracture in posterior, posterosuperior, or posteroinferior



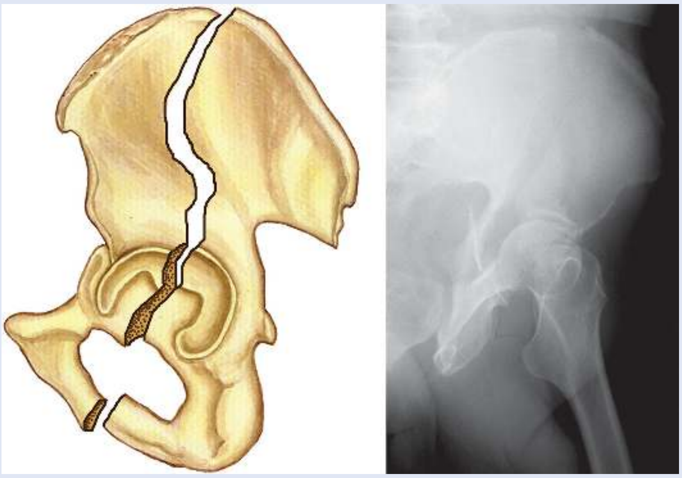
62-A Acetabular, partial articular fracture, one column involved

62-A3 Anterior column fracture
418 fractures
M: 284 (67.94%)
F: 134 (32.06%)
0.11% of total adult fractures
3.01% of adult pelvis and acetabulum
13.17% of segment 62
23.84% of type 62-A

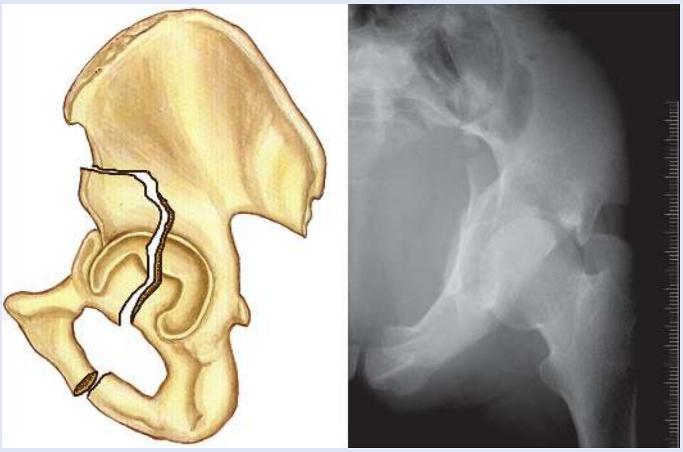
62-A3.1 Anterior wall fracture, with one or more fragments



62-A3.2 Anterior column fracture, high fracture to iliac crest, with one or more fragments



62-A3.3 Anterior column fracture, low fracture to anterior border, with one or more fragments



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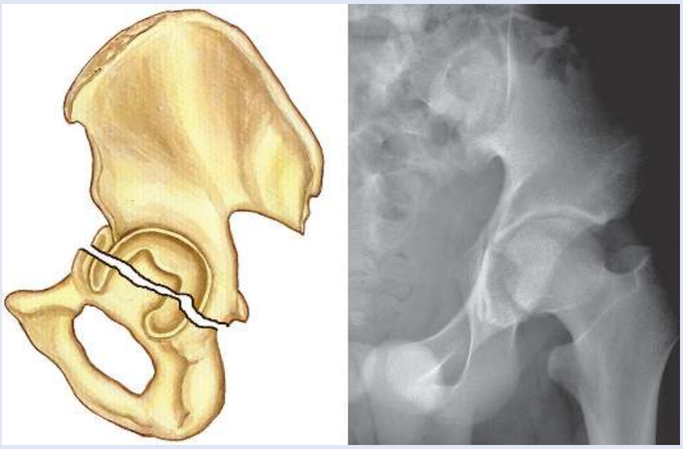
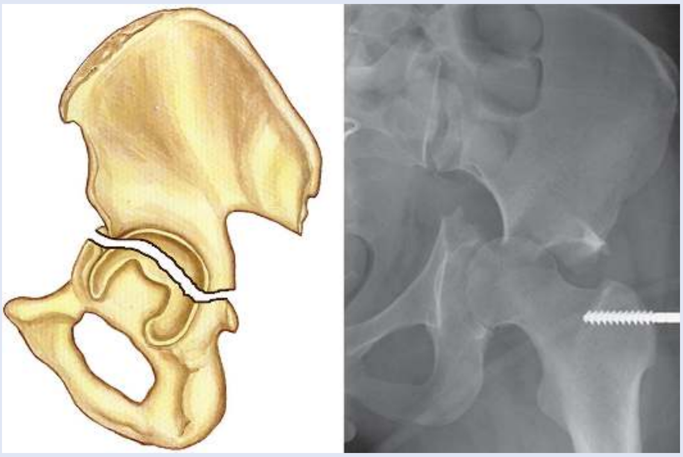
62-B Acetabular, partial articular fracture, transverse

62-B1 Transverse
641 fractures
M: 466 (72.70%)
F: 175 (27.30%)
0.17% of total adult fractures
4.62% of adult pelvis and acetabulum
20.20% of segment 62
59.91% of type 62-B

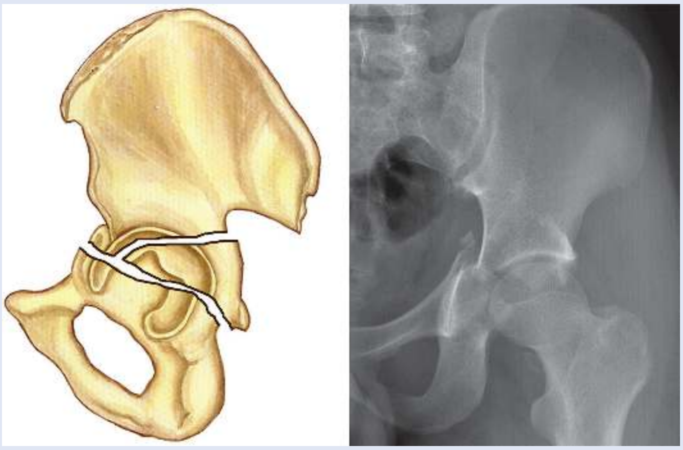
62-B1.1 Infratectal



62-B1.2 Juxtatectal



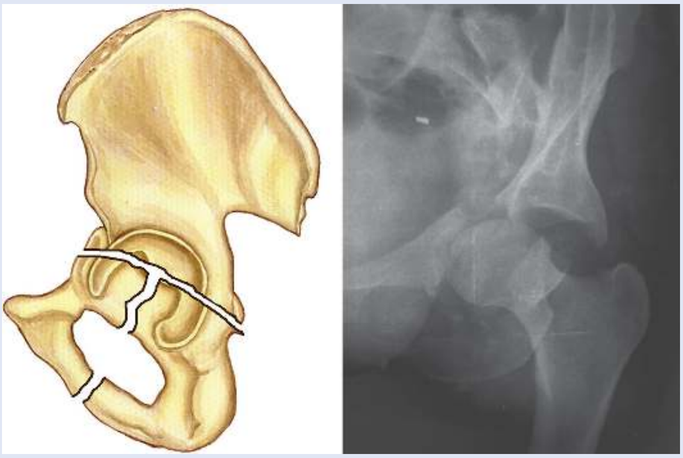
62-B1.3 Transtectal



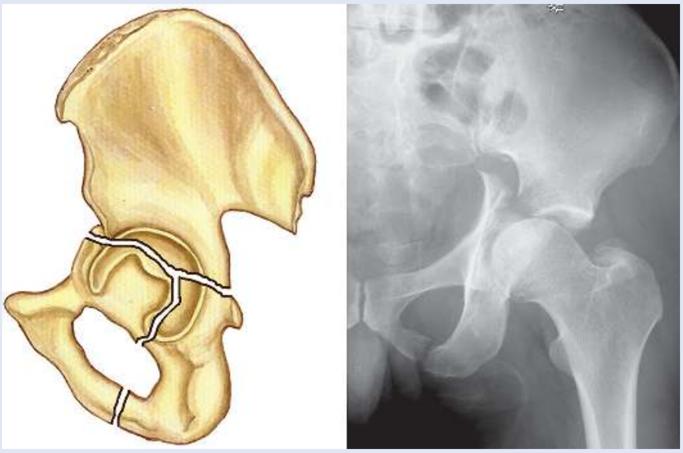
62-B Acetabular, partial articular fracture, transverse

62-B2 T-shaped
266 fractures
M: 185 (69.55%)
F: 81 (30.45%)
0.07% of total adult fractures
1.92% of adult pelvis and acetabulum
8.38% of segment 62
24.86% of type 62-B

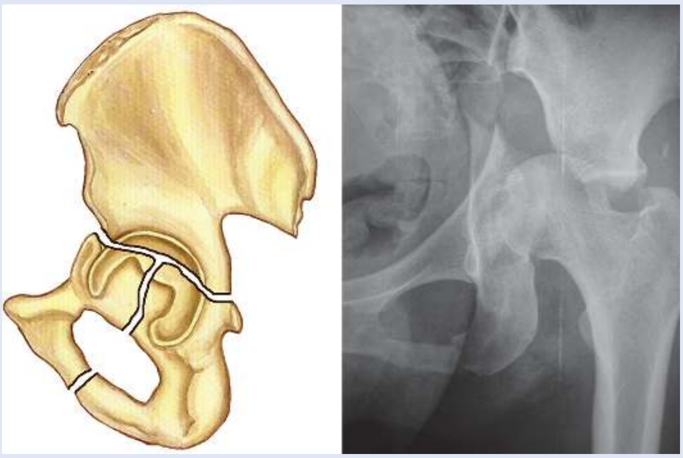
62-B2.1 Infratectal fracture (stem posterior, stem through obturator foramen, stem anterior)



62-B2.2 Juxtatectal fracture (stem posterior, stem through obturator foramen, stem anterior)



62-B2.3 Transtectal fracture (stem posterior, stem through obturator foramen, stem anterior)



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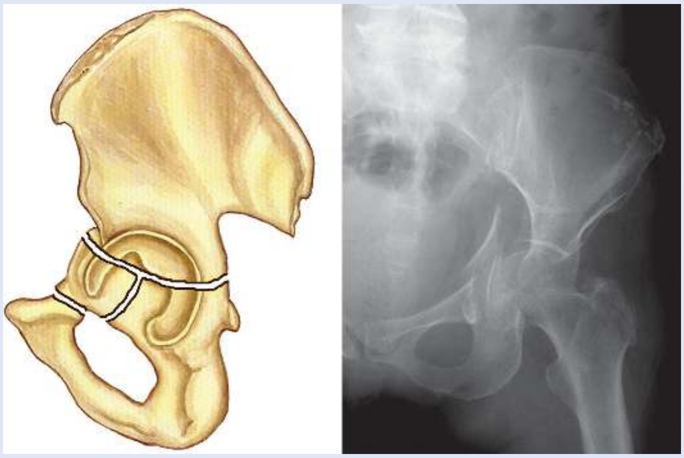
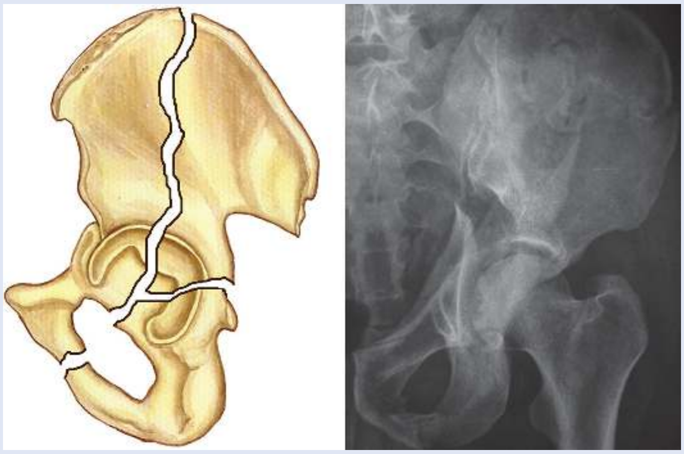
62-B Acetabular, partial articular fracture, transverse

62-B3 Anterior column, posterior hemitransverse
163 fractures
M: 133 (81.60%)
F: 30 (18.40%)
0.04% of total adult fractures
1.18% of adult pelvis and acetabulum
5.14% of segment 62
15.23% of type 62-A

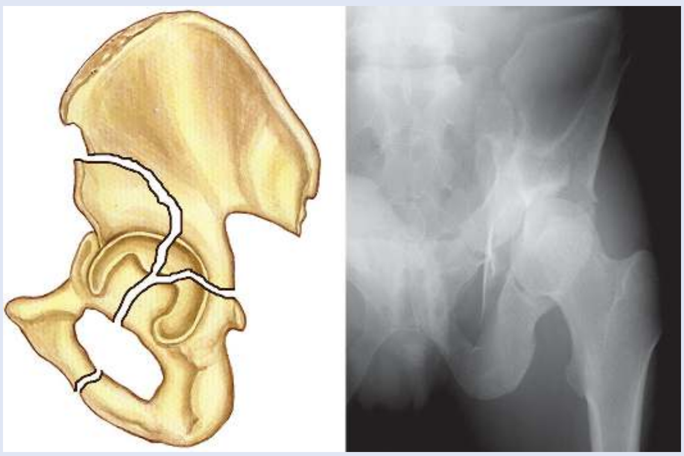
62-B3.1 Anterior wall



62-B3.2 Anterior column high



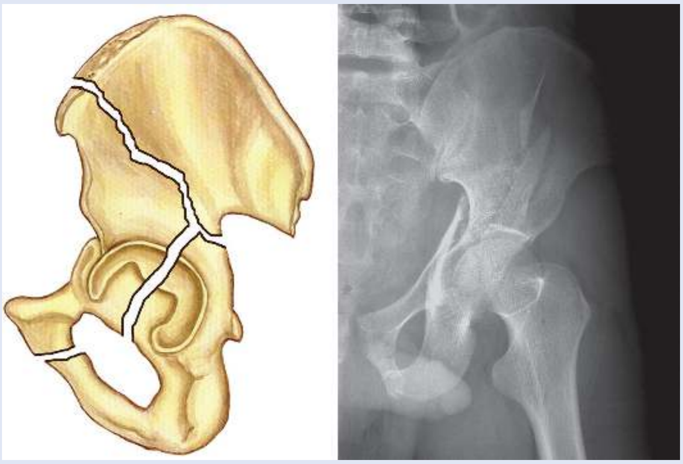
62-B3.3 Anterior column low



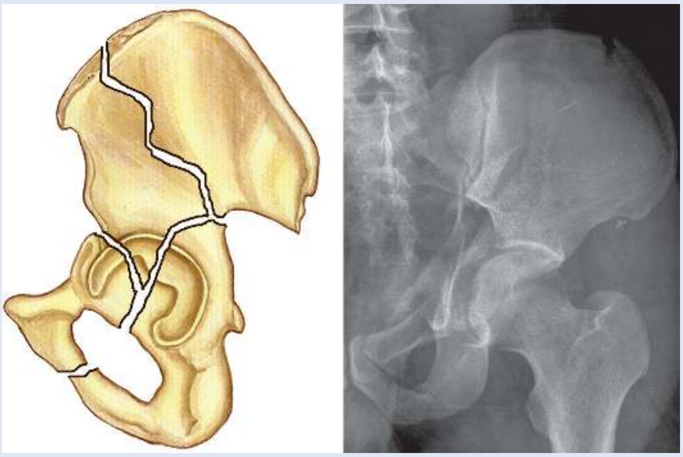
62-C Acetabular, complete articular fracture, both columns (floating acetabulum)

62-C1 High
120 fractures
M: 91 (75.83%)
F: 29 (24.17%)
0.03% of total adult fractures
0.87% of adult pelvis and acetabulum
3.78% of segment 62
34.19% of type 62-C

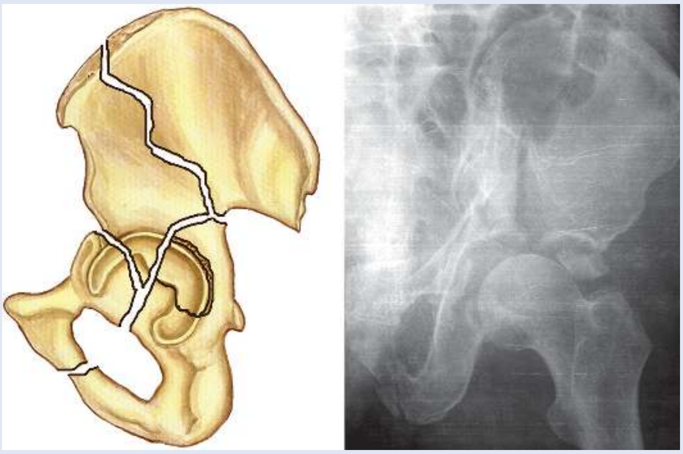
62-C1.1 Both columns simple



62-C1.2 Posterior column simple, anterior column multifragmentary



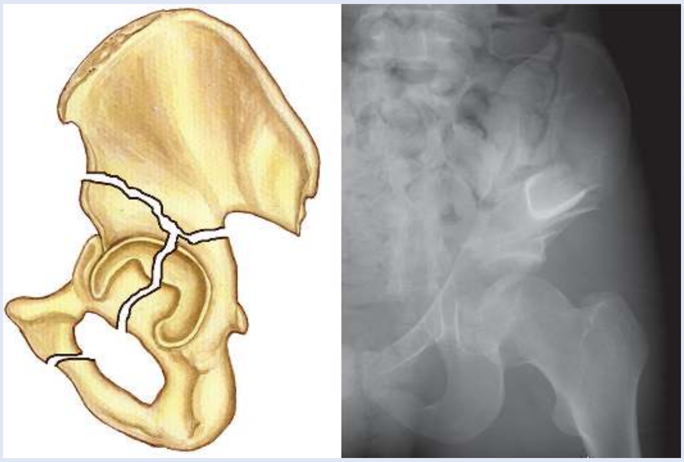
62-C1.3 Posterior column and posterior wall



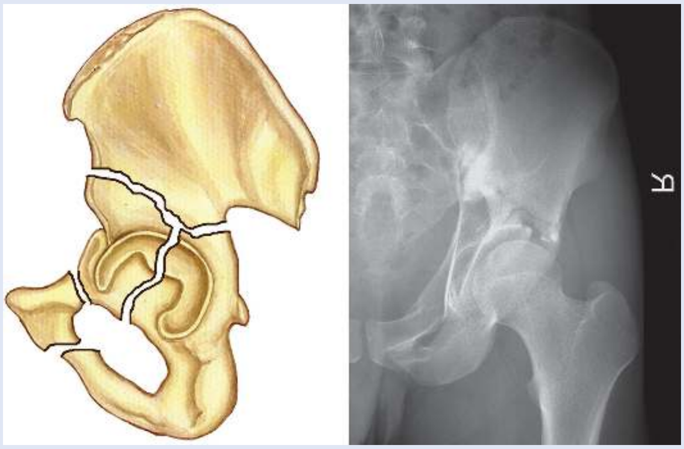
62-C Acetabular, complete articular fracture, both columns (floating acetabulum)

62-C2 Low
155 fractures
M: 127 (81.94%)
F: 28 (18.06%)
0.04% of total adult fractures
1.12% of adult pelvis and acetabulum
4.88% of segment 62
44.16% of type 62-C

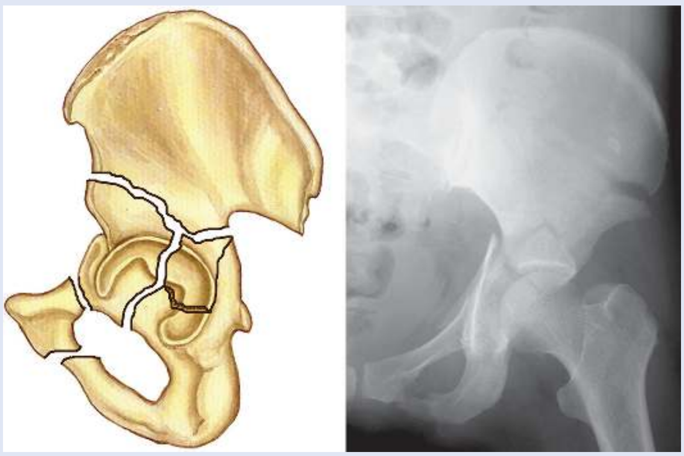
62-C2.1 Both columns simple



62-C2.2 Posterior column simple, anterior column multifragmentary



62-C2.3 Posterior column and posterior wall



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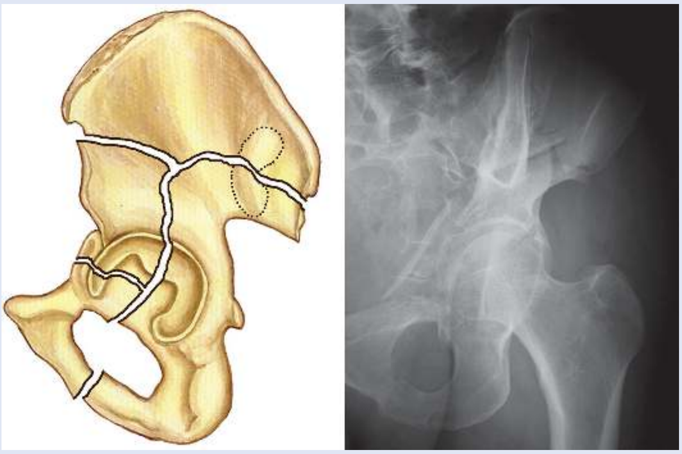
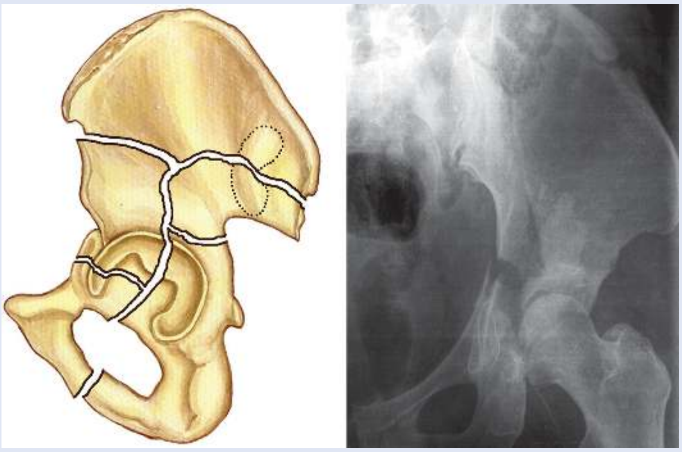
62-C Acetabular, complete articular fracture, both columns (floating acetabulum)

62-C3 Involving sacroiliac joint
76 fractures
M: 47 (61.84%)
F: 29 (38.16%)
0.02% of total adult fractures
0.55% of adult pelvis and acetabulum
2.39% of segment 62
21.65% of type 62-C

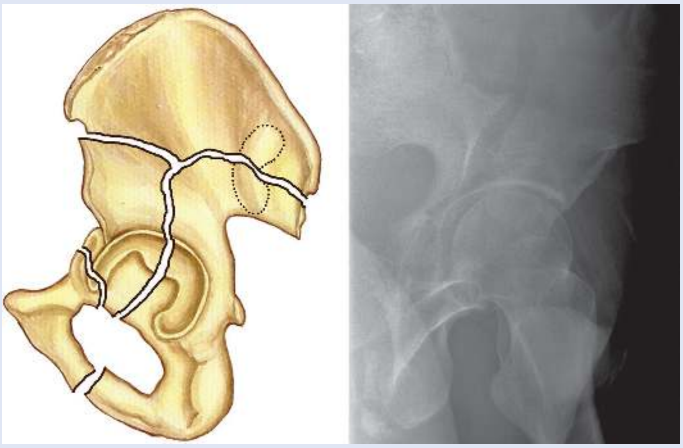
62-C3.1 Anterior wall (anterior column high/low, simple; high/low multifragmentary)



62-C3.2 Posterior column multifragmentary, anterior column high



62-C3.3 Posterior column multifragmentary, anterior column low



Injury Mechanism

Most acetabular fractures occur as a result of high-energy trauma such as motor-vehicle accidents or falls from a height. Occasionally, this injury can also be caused by epileptic seizures. Most injuries occur when force is exerted on the femur (greater tuberosity, neck, or head), passes through the femoral head, and is transferred to the acetabulum; axial compression injuries along the femur can also lead to acetabular fractures. The position of the femoral head at the time of injury, as well as the direction and magnitude of the force determine the pattern of acetabular injury. Flexion and internal rotation of the hip predispose to posterior column injuries, while extension and external rotation of the hip predispose to anterior column injuries.

Diagnosis

Acetabular fractures typically present as groin and hip pain exacerbated by passive hip motion. Range of motion is limited by pain, local tenderness to palpation is noted, and the heel percussion test is positive. Radiographic evaluation includes AP views of the pelvis that provide a general impression of the pelvic ring. Iliac oblique views illustrate the ilioischial line (posterior column) and anterior wall, while obturator oblique views illustrate the iliopectineal line (anterior column) of the pelvis and posterior wall. If the clinical presentation is highly suggestive of a fracture, and X-ray findings fail to demonstrate a subtle fracture, then a CT scan of the pelvis, including three-dimensional reformatted images, may be required to assist in conceptualizing the fracture pattern, and thereby help in the planning of orthopaedic surgery. For hemodynamically unstable patients with acetabular fractures, angiography can greatly assist in making the diagnosis (▶ Fig. 7.32), and embolotherapy can be performed at the same time.

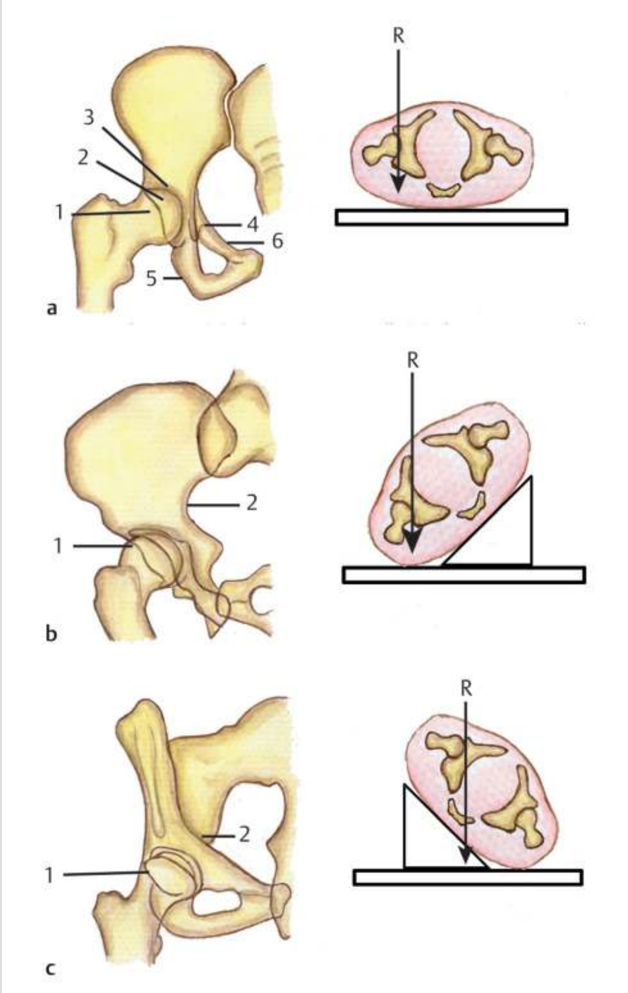


Fig. 7.32 Angiography for patients with acetabular fractures. (**a**) Anteroposterior (AP) view showing posterior wall (1), anterior wall (2), dome of acetabulum (3), tear drop (4), ilioischial line (posterior column) (5), and iliopubic line (anterior column) (6). (**b**) External (iliac) oblique view showing anterior wall (1) and posterior column (2). (**c**) Internal (obturator) oblique view showing posterior wall (1) and anterior column (2).

Treatment

Nonsurgical Treatment

Indications for nonsurgical treatment are:

- Fractures with no displacement or displacement ≤ 3 mm
- Displaced fractures but the weight-bearing area of the acetabulum remains intact
- Both columns with fracture displacement and secondary congruence
- Pure posterior wall fractures including ≤ 40% of the acetabulum, with a stable stress test

Surgical Treatment

The goal of surgical intervention for acetabular fractures is to reconstruct the articular surface, and to restore the congruity and stability of the hip joint. The surgical objective for severe comminuted acetabular fractures is to help ensure adequate bone stock for further arthroplasty. W-shaped acetabular angular plate can be used in the operation to fix the end of fracture, which can prevent the screw from penetrating into the joint effectively and reduce complications.

The indications for open reduction and internal fixation are:

- Articular displacement of more than 3 mm
- Incarcerated intra-articular fragments or impaction of the articular surface that lead to incongruity
- Posterior displacement of the femoral head, associated with a post wall fracture, which leads to instability of the hip joint
- Transverse fractures of the acetabulum associated with a posterior dislocation of the hip joint
- Posterior wall fractures associated with sciatic nerve injuries
- Associated with ipsilateral femoral neck fractures or diaphyseal femoral fractures

Timing of Operation

Ideally, closed fractures should be treated with surgical treatment usually between the third and seventh day after the time of injury. Beyond 3 weeks, an anatomic reduction becomes progressively more difficulty to obtain.

Reduction Criteria

Various acetabular components should be reconstructed. The surgeon should do concentric reduction with the femoral head as a reference, especially for the reduction of the weight-bearing dome of the acetabulum. Displacement < 3 mm is the criteria of anatomical reduction.

Other Classifications for Fractures of the Pelvic Ring and Acetabulum

Tile Classification of Pelvic Ring Fractures

The Tile classification for pelvic ring fractures was established in 1986 by Tile and colleagues, based on the stability of the posterior lesion, its direction, and the nature of the force involved. This classification was later modified and refined in 1988. The Tile classification has gained widespread recognition from AO/The Association for the Study of Internal Fixation (ASIF), Orthopaedic Trauma Association (OTA), and Société Internationale de Chirurgie Orthopédique et de Traumatologie (SICOT) et al. AO classification of pelvic ring fractures has been developed and refined over years of practice, based on the Tile system (▶ Fig. 7.33). The Tile classification of pelvic ring fractures is shown below.

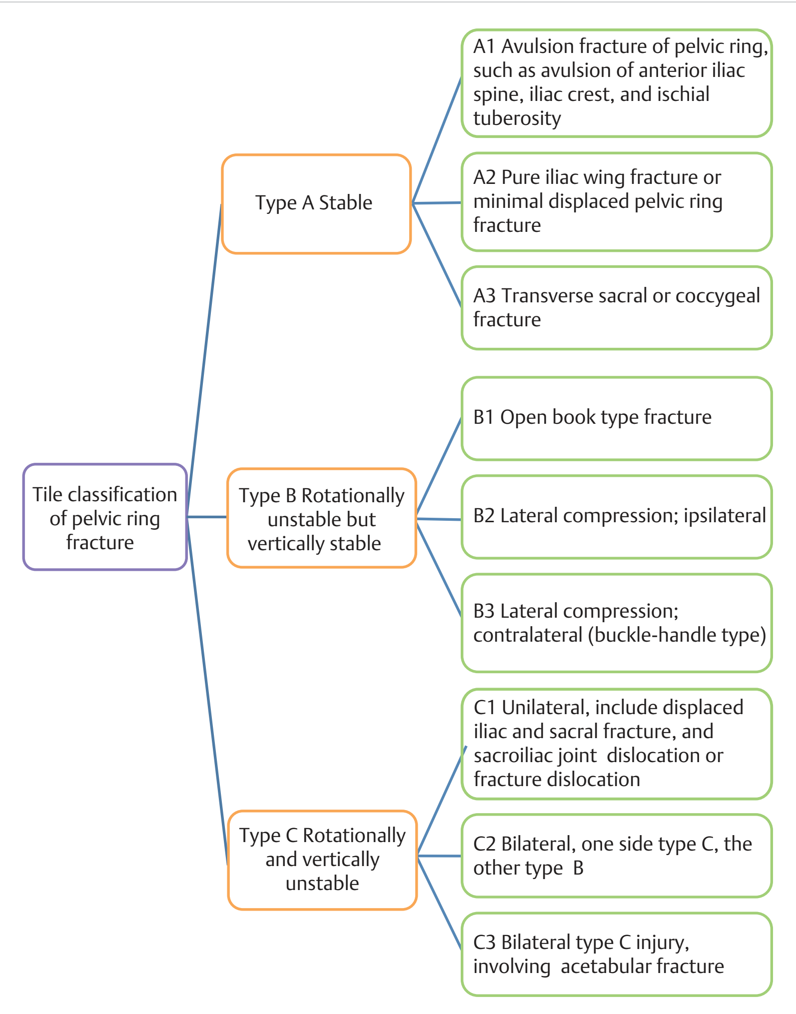


Fig. 7.33 Algorithm.

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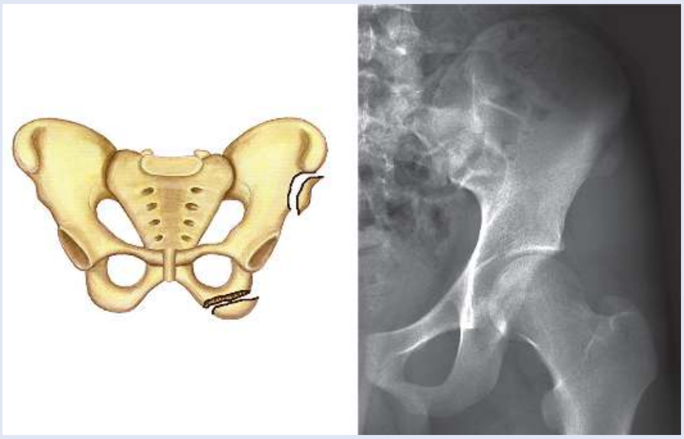
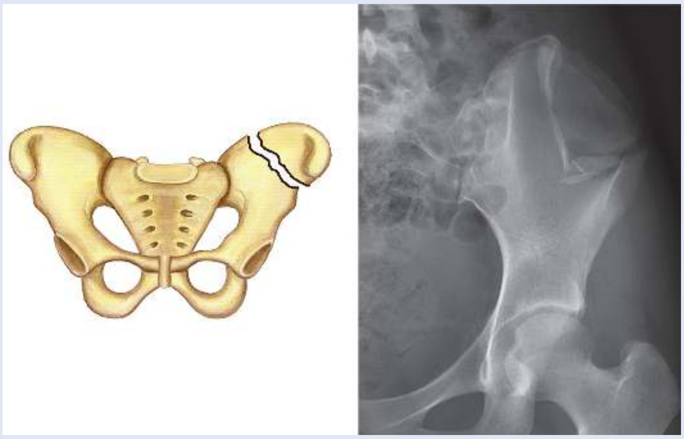
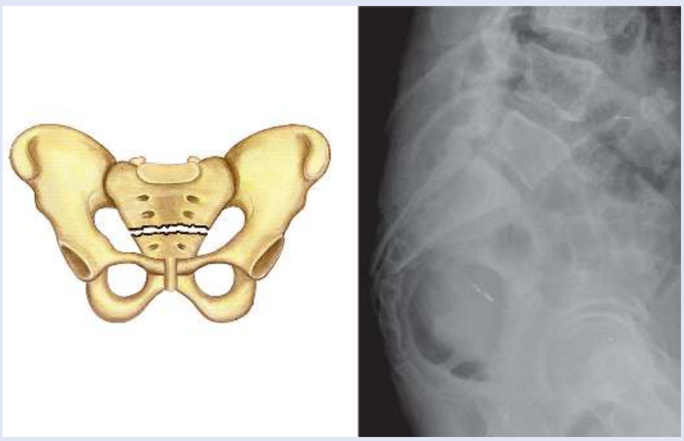
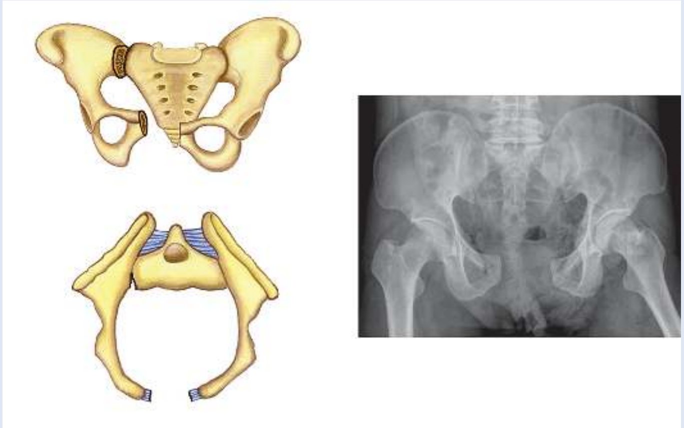
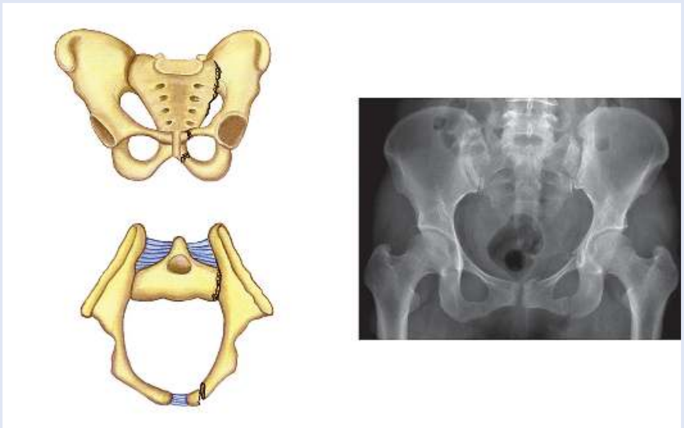
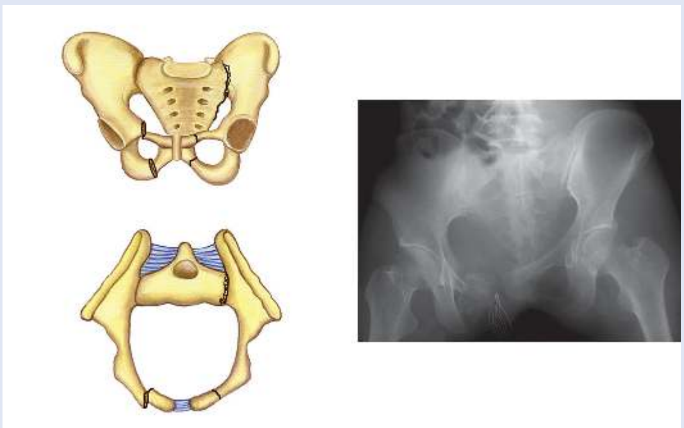
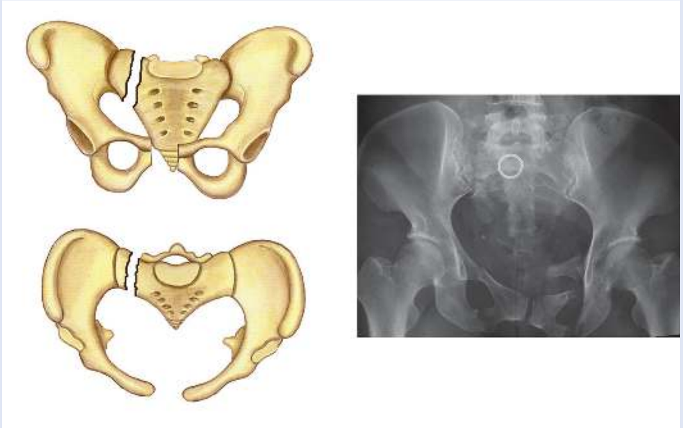
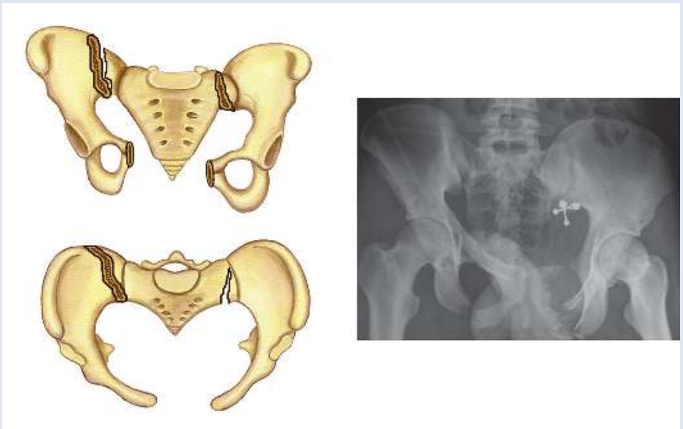
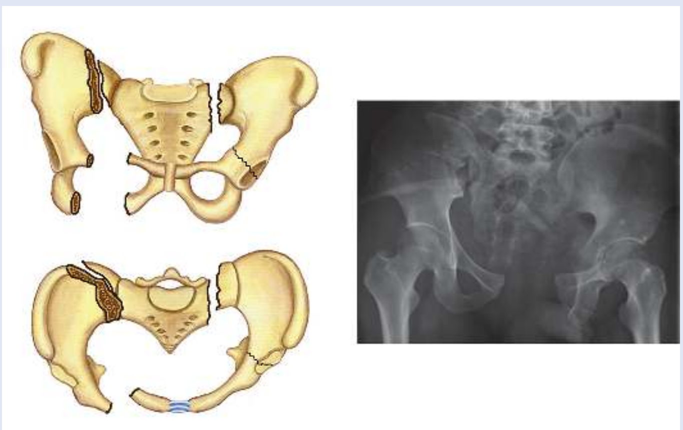
Tile Classification, Type A	
Tile Type A stable	**Tile A1** Avulsion fracture, without disruption of the pelvic ring 
	Tile A2 Pure iliac wing fracture with minimal displacement 
	Tile A3 Transverse sacral or coccygeal fracture 

Tile Classification, Type B	
Tile Type B Rotationally unstable, vertically stable	**Tile B1** "Open-book"-type injury 
	Tile B2 Lateral compression; ipsilateral 
	Tile B3 Lateral compression; contralateral (Buckle handle type) 

Tile Classification, Type C	
Tile Type C **Rotationally and vertically unstable**	**Tile C1** Unilateral injury 
	Tile C2 Bilateral injury, ipsilateral vertically unstable, contralateral rotationally unstable 
	Tile C3 Bilateral Type C injury, involving an acetabular fracture 

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Young–Burgess Classification of Pelvic Ring Fractures

Overview

In 1990, based on the Tile concept of pelvic ring fractures, Young and Burgess developed and established their own classification to describe pelvic ring fractures that classify all pelvic ring fractures as one of four major groups: lateral compression (LC), anteroposterior compression (APC), vertical shear (VS), or combined mechanism injury (CM). The APC injuries are those in which the disruptive force is in the sagittal plane, as seen in blows to the front of the pelvis, commonly occurring in a motor vehicle accident. The resultant force tends to disrupt the anterior pelvis, either by fracturing the pubic rami, ischial rami, or by producing a diastasis of the pubic symphysis; as further force is applied, a typical "open-book"-type injury will occur. The force from a lateral compression injury is from the side and is associated with horizontal pubic rami fractures or interlocking of the pubic symphysis. With increasing lateral force, a typical lateral compression pelvic fracture will occur. This classification is based on the mechanism of injury and the direction of the injury force that allows for an accurate and timely application of the appropriate treatment, which consequently, contributes to a more favorable outcome. According to the Young–Burgess classification, acetabular fractures (AFs) are separate injuries. AF and LC injuries are commonly seen in car accidents while APC and AF frequently occur in motorcycle accidents. Crush trauma usually results in APC type injuries while falls from a height usually result in VS and LC type injuries. LC and APC injuries have a high rate of concomitant visceral injuries. APC injuries have a high incidence of brain, abdominal visceral, and pelvic vascular injuries, and retroperitoneal hematomas, while concomitant arterial injuries are more frequently encountered during LC injury. LC and APC injuries have high mortality rates. Brain damage is commonly the cause of death in the LC injury, while acute respiratory distress syndrome (ARDS), sepsis, and shock are common causes of death for patients with APC injuries (▶ Fig. 7.34).

Management includes initial bed rest and early mobilization for LC injuries, and open reduction and internal fixation for APC injuries. Hemodynamically stable patients with VS/APC injuries can be treated nonsurgically initially, with possible delayed open reduction and internal fixation. Emergency external fixation should be performed first for hemodynamically unstable patients. Surgical exploration should proceed if there is major visceral or vascular damage, and internal fixation can be performed simultaneously.

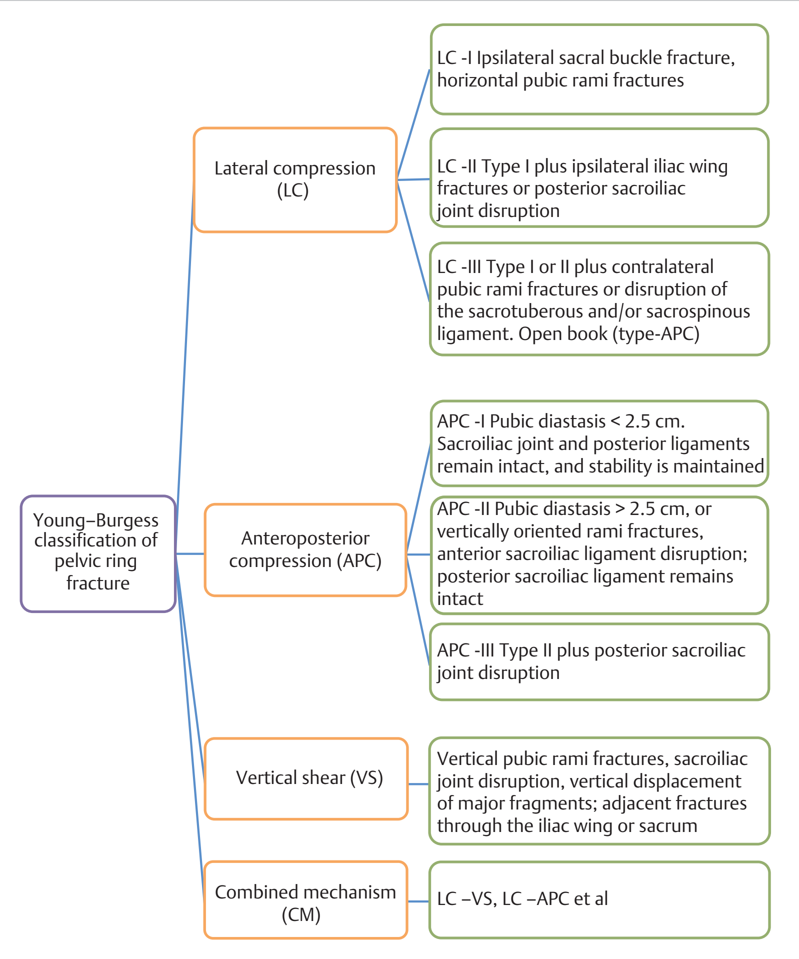


Fig. 7.34 Algorithm.

■ Epidemiological Features of Pelvic Ring Fractures Based on the Young–Burgess Classification

We retrospectively reviewed 1,956 pelvic ring fractures that fit into the description of the Young–Burgess classification system over a period of 2 years, from 2010 to 2011. These cases account for 17.37% of all pelvic ring fractures and 13.44% of all fractures of the pelvic ring and acetabulum, respectively.

Epidemiological features of pelvic ring fractures based on the Young–Burgess classification are the following:

- More males than females
- The high-risk age group is 41–45 years, the same age group for both males and females
- The most common fracture type of Young–Burgess fractures is Type APC, while the most common fracture group is Group-APC-II, the same type and group for both males and females

Pelvic Ring Fractures Based on the Young–Burgess Classification by Sex

See ▶ Table 7.20 and ▶ Fig. 7.35.

Table 7.20 Sex distribution of 1,956 Young–Burgess fractures

Sex	Number of fractures	Percentage
Male	1,205	61.61
Female	751	38.39
Total	1,956	100.00

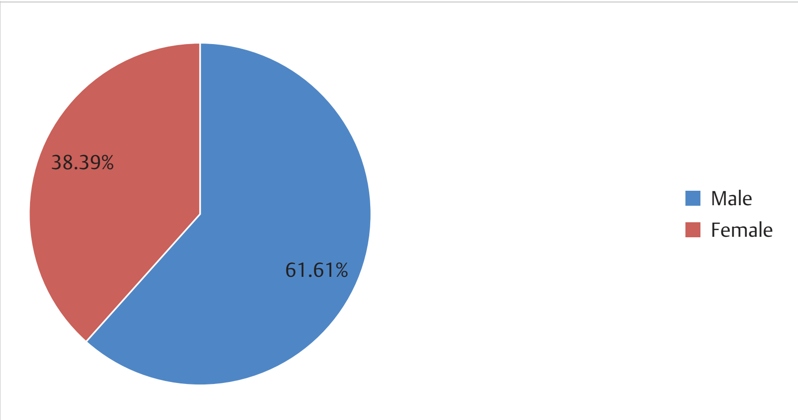


Fig. 7.35 Sex distribution of 1,956 Young–Burgess fractures.

Pelvic Ring Fractures Based on the Young–Burgess Classification by Age Group

See ▶ Table 7.21 and ▶ Fig. 7.36.

Table 7.21 Age and sex distribution of 361 Young–Burgess fractures

Age group (years)	Male	Female	Number of fractures	Percentage	Percentage of pelvic ring fractures
0–5	11	7	18	0.92	0.16
6–10	18	19	37	1.89	0.33
11–15	40	24	64	3.27	0.57
16–20	81	40	121	6.19	1.07
21–25	117	90	207	10.58	1.84
26–30	118	66	184	9.41	1.63
31–35	94	54	148	7.57	1.31
36–40	133	87	220	11.25	1.95
41–45	159	100	259	13.24	2.30
46–50	133	61	194	9.92	1.72
51–55	114	44	158	8.08	1.40
56–60	80	45	125	6.39	1.11
61–65	28	16	44	2.25	0.39
66–70	33	27	60	3.07	0.53
71–75	22	26	48	2.45	0.43
76–80	15	20	35	1.79	0.31
81–85	7	11	18	0.92	0.16
≥ 86	2	14	16	0.82	0.14
Total	1,205	751	1,956	100.00	17.37

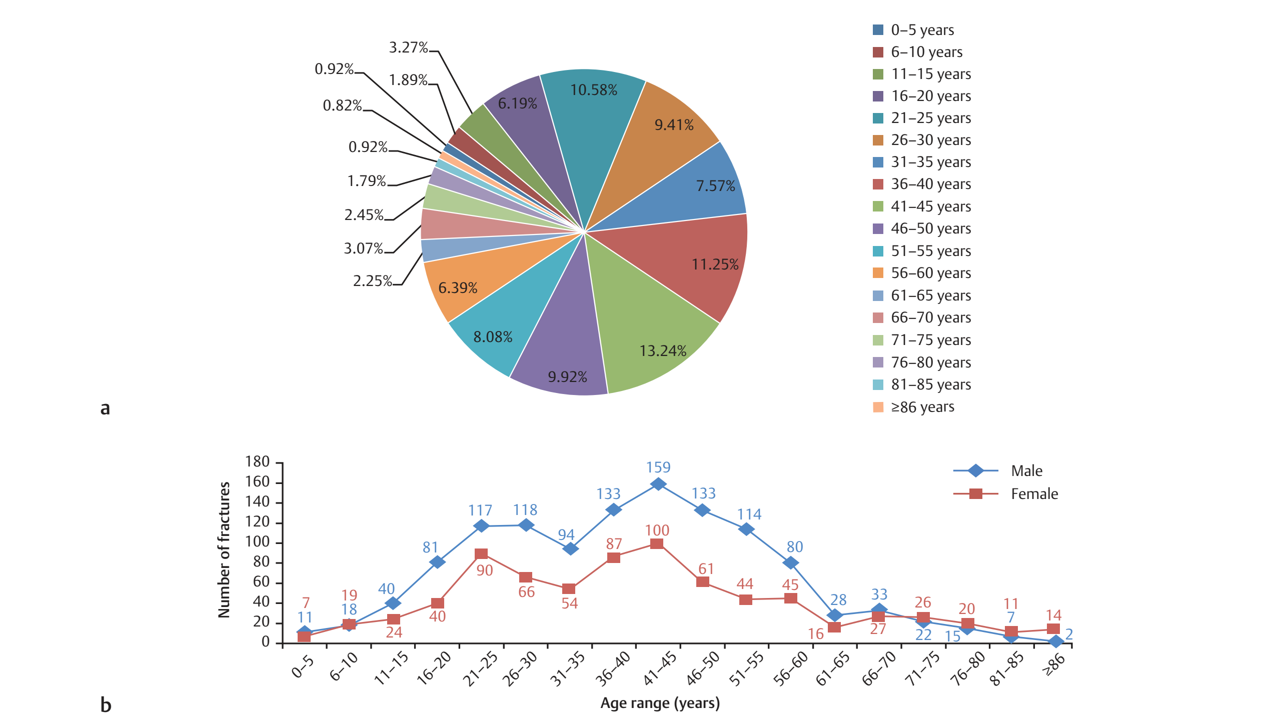


Fig. 7.36 (a) Age distribution of 1,956 Young–Burgess fractures. (b) Age and sex distribution of 1,956 Young–Burgess fractures.

Pelvic Ring Fractures Based on the Young–Burgess Classification by Fracture Type

See ▶ Table 7.22, ▶ Table 7.23, ▶ Fig. 7.37, and ▶ Fig. 7.38.

Table 7.22 Sex and fracture type distribution of 1,956 Young–Burgess fractures

Fracture type	Male	Female	Number of fractures	Percentage in total segment 62 fractures	Percentage in total pelvic ring fractures
LC	342	188	530	27.10	4.71
APC	652	461	1,113	56.90	9.88
VS	112	58	170	8.69	1.51
CM	99	44	143	7.31	1.27
Total	1,205	751	1,956	100.00	17.37

Table 7.23 Sex and fracture group distribution of 1,956 Young–Burgess fractures

Fracture group	Male	Female	Number of fractures	Percentage	Percentage of pelvic ring fractures
LC-I	238	142	380	19.43	3.37
LC-II	94	43	137	7.00	1.22
LC-III	10	3	13	0.66	0.12
APC-I	142	92	234	11.96	2.08
APC-II	375	298	673	34.41	5.98
APC-III	135	71	206	10.53	1.83
VS	112	58	170	8.69	1.51
CM	99	44	143	7.31	1.27
Total	1,205	751	1,956	100.00	17.37

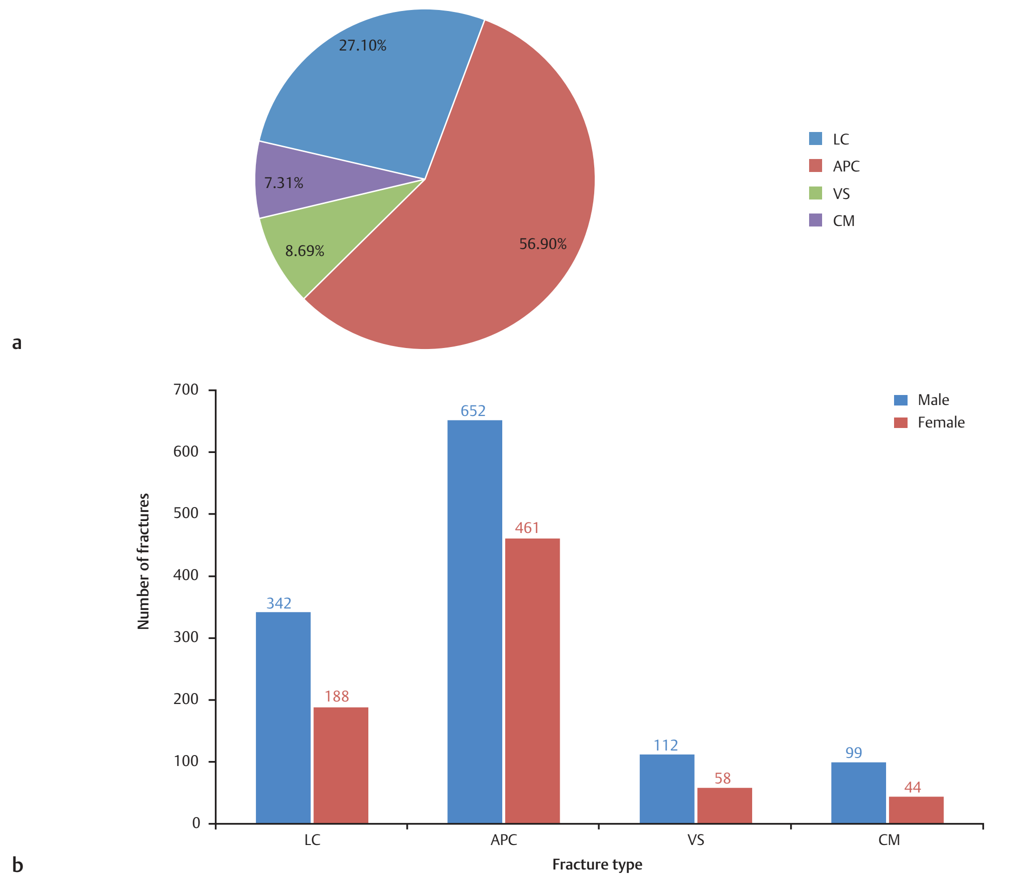


Fig. 7.37 (**a**) Fracture type distribution of 1,956 Young–Burgess fractures. (**b**) Sex and fracture type distribution of 1,956 Young–Burgess fractures.

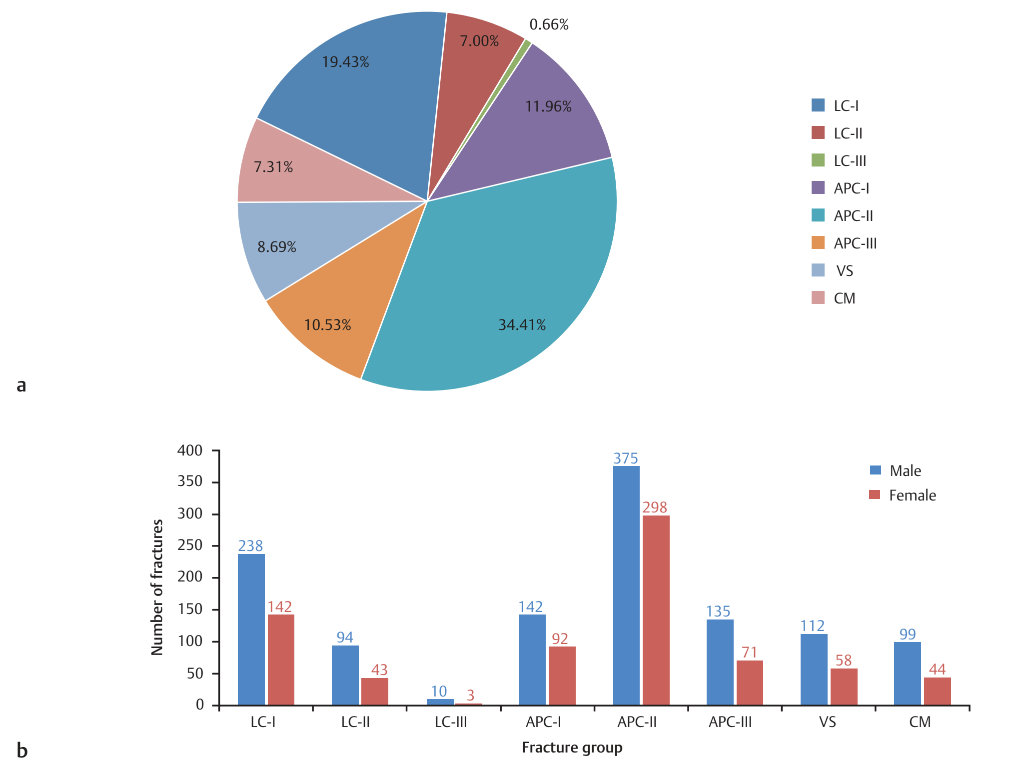
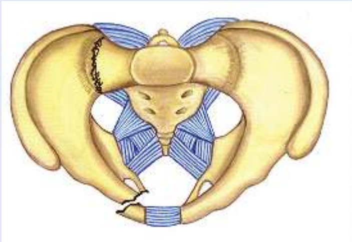
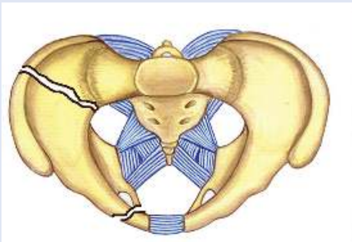
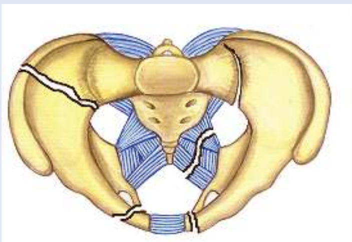


Fig. 7.38 (**a**) Fracture group distribution of 1,956 Young–Burgess fractures. (**b**) Sex and fracture type distribution of 1,956 Young–Burgess fractures.

Lateral compression (LC) injury	
LC-I Ipsilateral sacral buckle fracture, horizontal pubic rami fractures; stable 380 fractures M: 238 (62.63%) F: 142 (37.37%) 19.43% of Young–Burgess	**Young-Burgess LC-I** The injury force is directed posteriorly to the lateral aspect of the hemipelvis, resulting in an ipsilateral sacral buckle fracture and horizontal pubic rami fractures; stable  
LC-II LC-I plus ipsilateral iliac wing fractures or posterior SI joint disruption 137 fractures M: 94 (68.61%) F: 43 (31.39%) 7.00% of Young–Burgess	**Young-Burgess LC-II** The injury force is anteriorly directed to the lateral part of the hemipelvis, resulting in ipsilateral sacral buckle fractures and horizontal pubic rami fractures, which are associated with fracture of the ipsilateral iliac wing or disruption of the ipsilateral posterior SI joint  
LC-III LC- I or II plus contralateral pubic rami fractures or disruption of the sacrotuberous and/or sacrospinous ligament. “Open book” (Type-APC) 13 fractures M: 10 (76.92%) F: 3 (23.08%) 0.66% of Young–Burgess	**Young-Burgess LC-III** The force travels from the ipsilateral side to the contralateral side, resulting in an ipsilateral sacral buckle fracture or iliac fracture with contralateral external rotation. Contralateral vertical pubic rami fractures or disruption of the sacrotuberous and/or sacrospinous ligaments may occur.  

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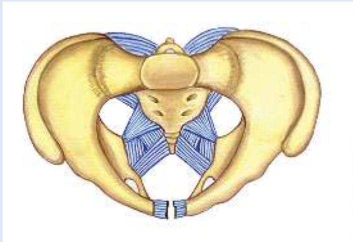
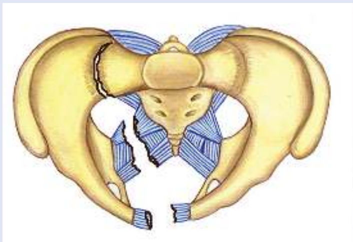
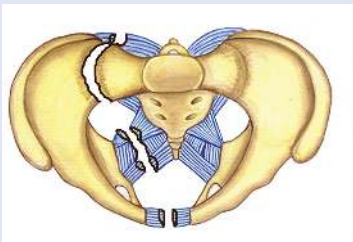
Anteroposterior Compression (APC)	
APC-I Pubic diastasis < 2.5 cm. SI joint and posterior ligaments remain intact, and stability is maintained 234 fractures M: 142 (60.68%) F: 92 (39.32%) 11.96% of Young–Burgess	**Young-Burgess APC-I** Pubic diastasis < 2.5 cm; with no or minimal disruption of the SI joint; stable with no posterior disruption  
APC-II Pubic diastasis > 2.5 cm, vertically oriented rami fractures, or anterior SI joint disruption; posterior SI joint ligament remains intact 673 fractures M: 375 (55.72%) F: 298 (44.28%) 34.41% of Young–Burgess	**Young-Burgess APC-II** Pubic diastasis > 2.5 cm, or vertically oriented rami fractures; disrupted sacrospinous, sacrotuberous and anterior sacroiliac ligaments  
APC-III Type II plus posterior SI joint disruption 206 fractures M: 135 (65.53%) F: 71 (34.47%) 10.53% of Young–Burgess	**Young-Burgess APC-III** Pubic diastasis > 2.5 cm, or vertically oriented rami fractures; complete disruption of the anterior and posterior ligaments yields a rotationally and vertically unstable pelvis  

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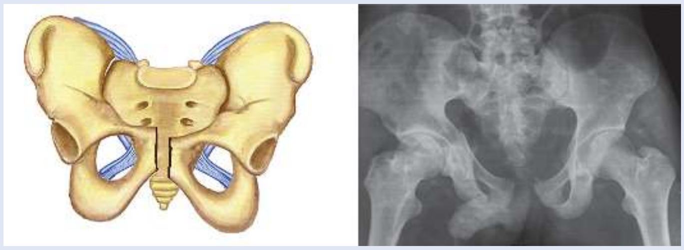
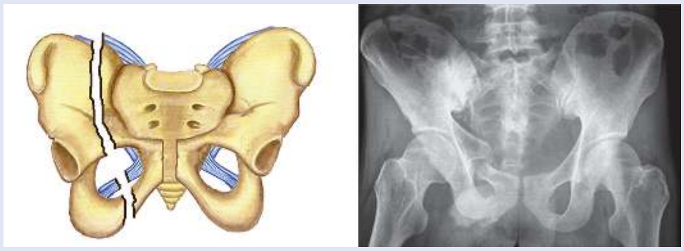
Vertical Shear (VS)

VS Pubic diastasis, vertical pubic rami fractures, SI joint disruption, or vertical displacement of major fragments; adjacent fractures through the iliac wing or sacrum
170 fractures
M: 112 (65.88%)
F: 58 (34.12%)
8.69% of Young–Burgess

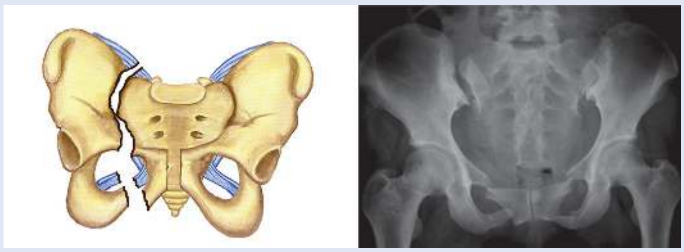
Young-Burgess VS-I Pubic diastasis



Young-Burgess VS-II Vertical pubic rami fractures, vertical displacement, and an iliac fracture



Young-Burgess VS-III Vertical pubic rami fractures, vertical displacement, SI joint disruption, and a sacral fracture

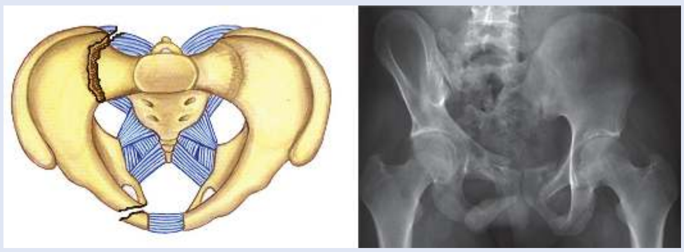


Combined Mechanism (CM)

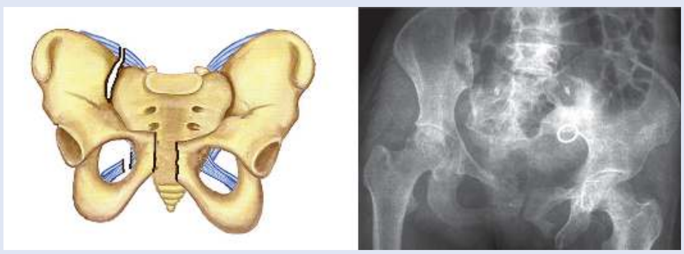
It is always caused by crush injury, and then result in combined injuries. Vertical disruption and lateral compression were the most commonly occurred injury mechanism.

CM Horizontal or vertical fracture of the anterior and/or posterior pelvic ring, involving more than 1 pattern of injury, with different combinations of injury types (LC-VS, LC-APC et al)
143 fractures
M: 99 (69.23%)
F: 44 (30.77%)
7.31% of Young–Burgess

Young-Burgess CM-I Anterolateral force



Young-Burgess CM-II Anterovertical force



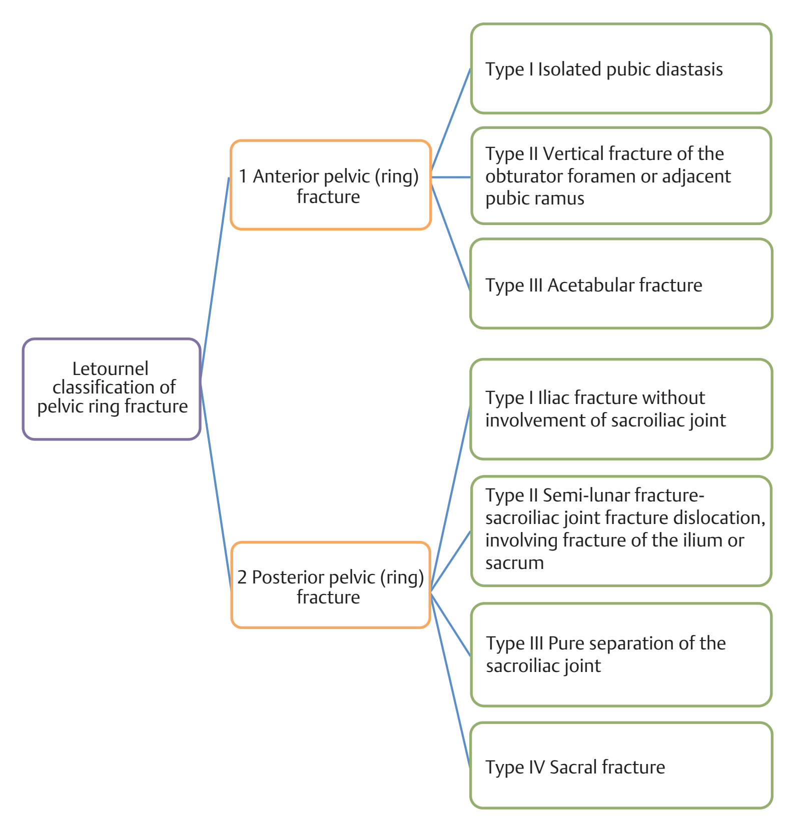


Fig. 7.39 Algorithm.

Letournel Classification of Pelvic Ring Fractures

Letournel devised a classification of pelvic ring fractures into anterior pelvic (ring) fractures and posterior pelvic (ring) fractures, according to the anatomic site of injury. Determination of injury site can help in assessing the severity of the injury and provide a guide in selecting the appropriate treatment (▶ Fig. 7.39).

- Anterior pelvic (ring) fracture:
  - *Type I*: Isolated pubic diastasis
  - *Type II*: Vertical fracture of obturator foramen or adjacent pubic ramus
  - *Type III*: Acetabular fracture
- Posterior pelvic (ring) fracture:
  - *Type I*: Iliac fracture without involvement of sacroiliac joint
  - *Type II*: Semi-lunar fracture and sacroiliac joint fracture-dislocation, involving fracture of ilium or sacrum
  - *Type III*: Pure separation of sacroiliac joint
  - *Type IV*: Sacral fracture

Special Type of Pelvic Ring Fracture: Bilateral Sacroiliac Dislocation with an Intact Anterior Pelvic Ring

This type of injury is rarely seen in practice; it usually occurs when both legs are in hyperflexion. This rare type of injury is characterized by bilateral SI dislocation while the anterior pelvic ring remains intact. Disruption of the pelvic ring with associated avulsion fracture of acetabulum is not a rare type of injury, but it has a different prognosis from pure pelvic fractures, which are more dependent upon the acetabular component than upon the pelvic ring disruption. CT imaging studies reveal that a considerable number of acetabular fractures are associated with sacroiliac disruption and/or pelvic ring fracture.

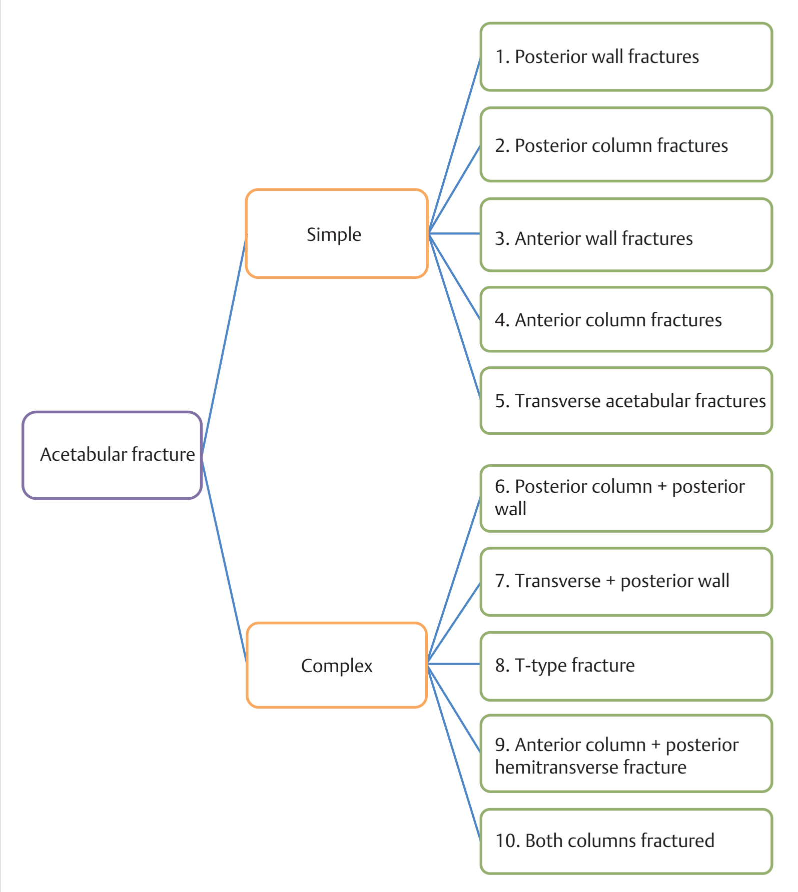


Fig. 7.40 Algorithm.

Letournel–Judet Classification of Acetabular Fractures

Overview

The classification method of Letournel and Judet is the most widely used classification of acetabular fractures in clinical practice and research. It classifies acetabular fractures into two basic types: simple fracture patterns and complex fracture patterns. Simple fracture patterns belong to a group of fractures in which only a wall or column is fractured, while complex patterns are combinations of the simple patterns (▶ Fig. 7.40).

Epidemiological Features of Acetabular Fractures Based on the Letournel–Judet Classification

We retrospectively reviewed 2,905 patients with 2,945 acetabular fractures that fit into the description of the Letournel–Judet classification system over a period of 2 years, from 2010 to 2011. These cases include 90 pediatric patients, each with unilateral injuries, and 2,815 adult patients with a total number of 2,855 acetabular fractures, and 40 patients who sustained bilateral fractures.

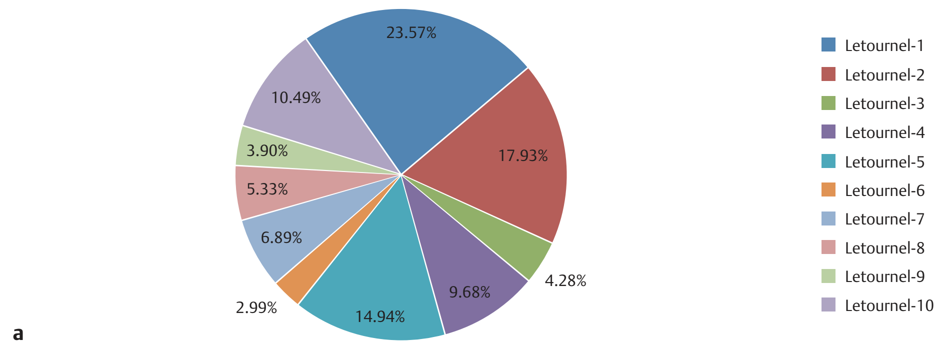
Epidemiological features of acetabular fractures based on the Letournel–Judet classification are the following:

- More males than females
- The most common fracture type of the Letournel type of acetabular fractures is Letournel-1, the same type for males, while the most common fracture type for female is Letournel-2.

See ▶ Table 7.24 and ▶ Fig. 7.41.

Table 7.24 Sex and fracture group distribution of 2,945 acetabular fractures by the Letournel classification

Fracture group	Male	Female	Number of fractures	Percentage	Percentage of fractures of pelvic ring and acetabulum
Letournel-1	531	163	694	23.57	4.77
Letournel-2	325	203	528	17.93	3.63
Letournel-3	86	40	126	4.28	0.87
Letournel-4	194	91	285	9.68	1.96
Letournel-5	315	125	440	14.94	3.02
Letournel-6	79	9	88	2.99	0.60
Letournel-7	152	51	203	6.89	1.39
Letournel-8	110	47	157	5.33	1.08
Letournel-9	80	35	115	3.90	0.79
Letournel-10	242	67	309	10.49	2.12
Total	2,114	831	2,945	100.00	20.23



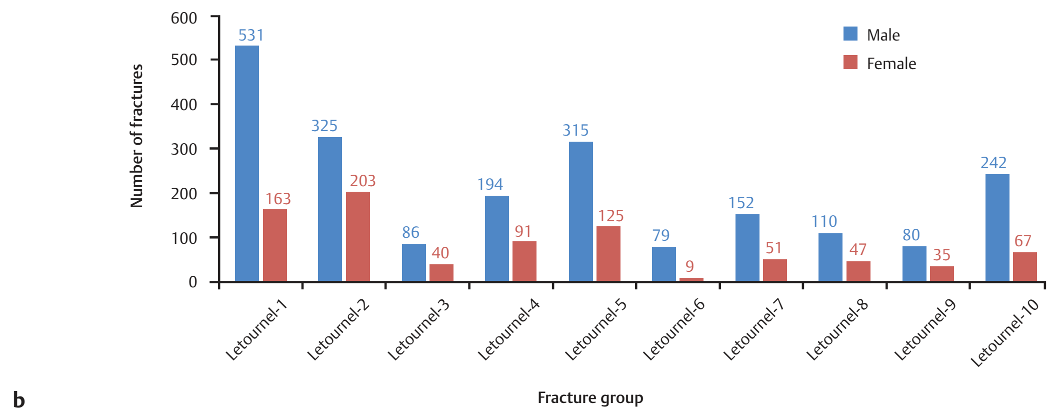
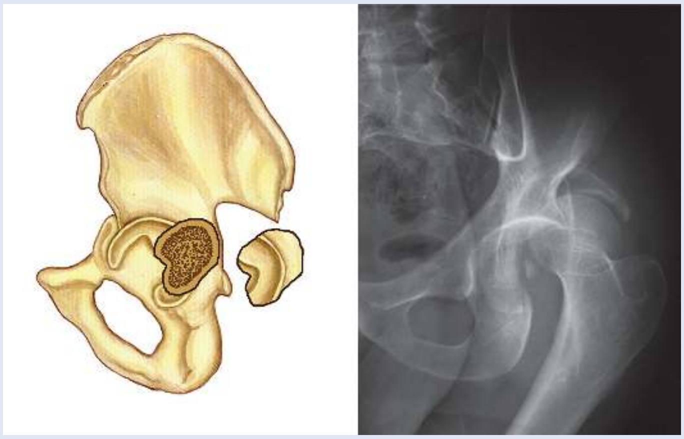
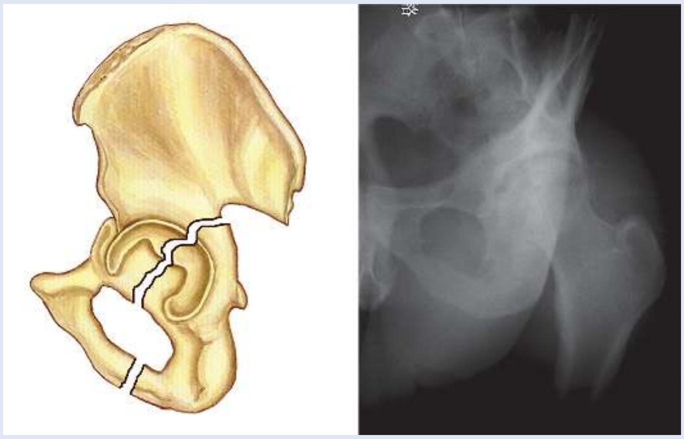
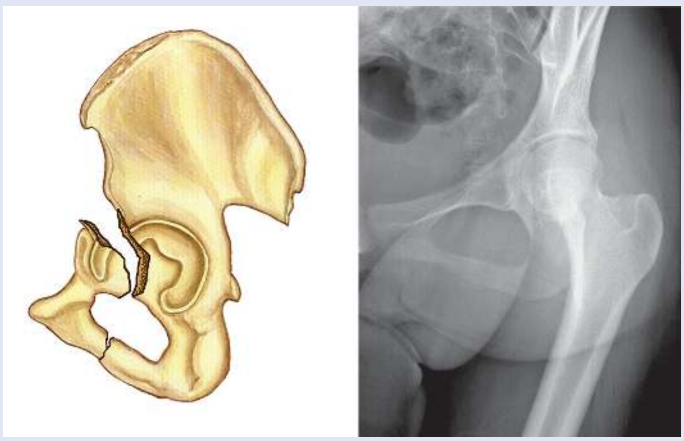
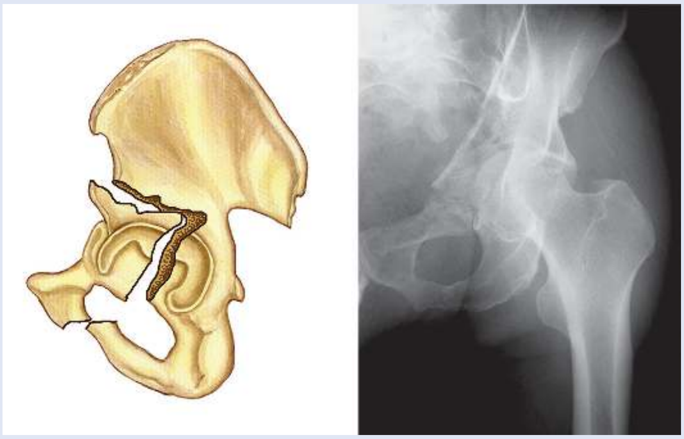


Fig. 7.41 (**a**) Fracture group distribution of 2,945 acetabular fractures by the Letournel classification. (**b**) Sex and fracture group distribution of 2,945 acetabular fractures by the Letournel classification.

Letournel-1 Posterior wall fractures 694 fractures M: 531 (76.51%) F: 163 (23.49%) 23.57% acetabular fractures	**Letournel-1** 
Letournel-2 Posterior column fractures 528 fractures M: 325 (61.55%) F: 203 (38.45%) 17.93% acetabular fractures	**Letournel-2** 
Letournel-3 Anterior wall fractures 126 fractures M: 86 (68.25%) F: 40 (31.75%) 4.28% acetabular fractures	**Letournel-3** 

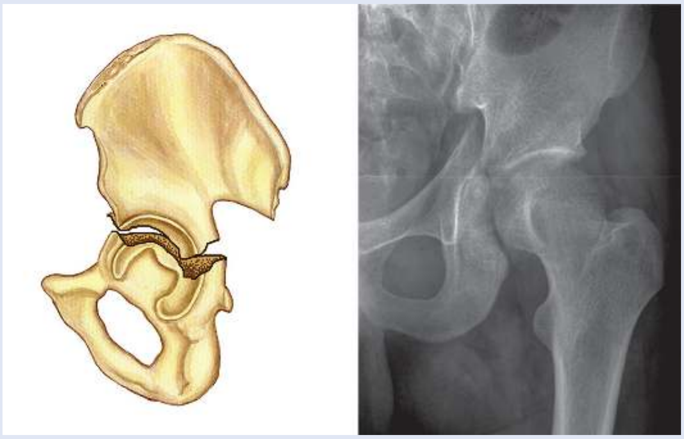
Letournel-4 Anterior column fractures
285 fracture
M: 194 (68.07%)
F: 91 (31.93%)
9.68% acetabular fractures

Letournel-4



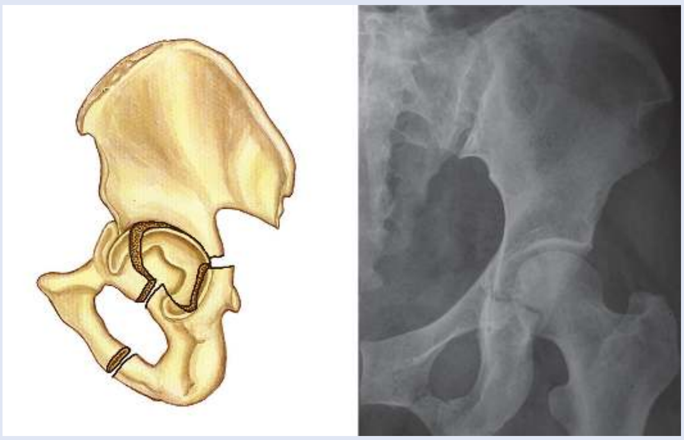
Letournel-5 Transverse acetabular fractures
440 fractures
M: 315 (71.59%)
F: 125 (28.41%)
14.94% acetabular fractures

Letournel-5



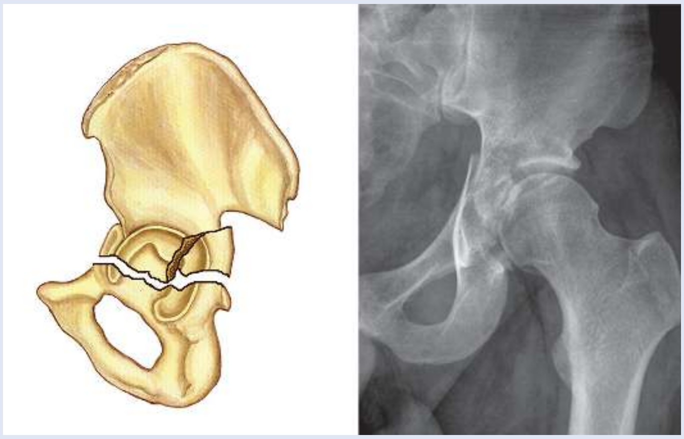
Letournel-6 Posterior wall + posterior column
88 fractures
M: 79 (89.77%)
F: 9 (10.23%)
2.99% acetabular fractures

Letournel-6



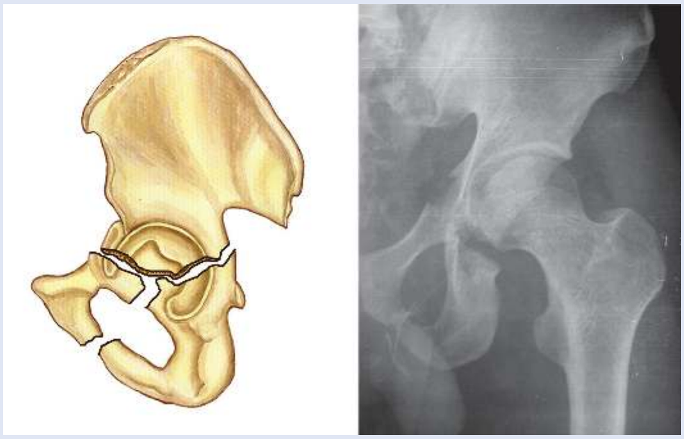
Letournel-7 Transverse + posterior wall
203 fractures
M: 152 (74.88%)
F: 51 (25.12%)
6.89% acetabular fractures

Letournel-7



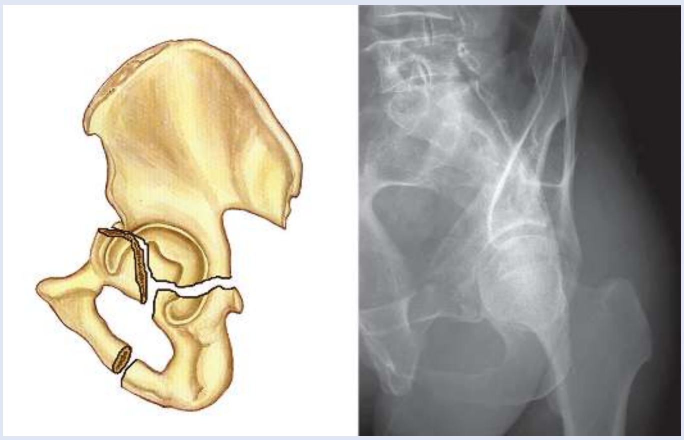
Letournel-8 T-type fractures
157 fractures
M: 110 (70.06%)
F: 47 (29.94%)
5.33% acetabular fractures

Letournel-8



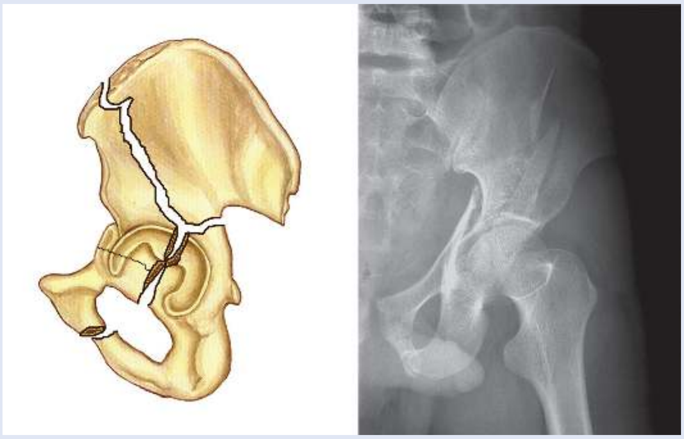
Letournel-9 Anterior column + posterior hemitransverse fractures
115 fractures
M: 80 (69.57%)
F: 35 (30.43%)
3.90% acetabular fractures

Letournel-9



Letournel-10 Both column fractures
309 fractures
M: 242 (78.32%)
F: 67 (21.68%)
10.49% acetabular fractures

Letournel-10



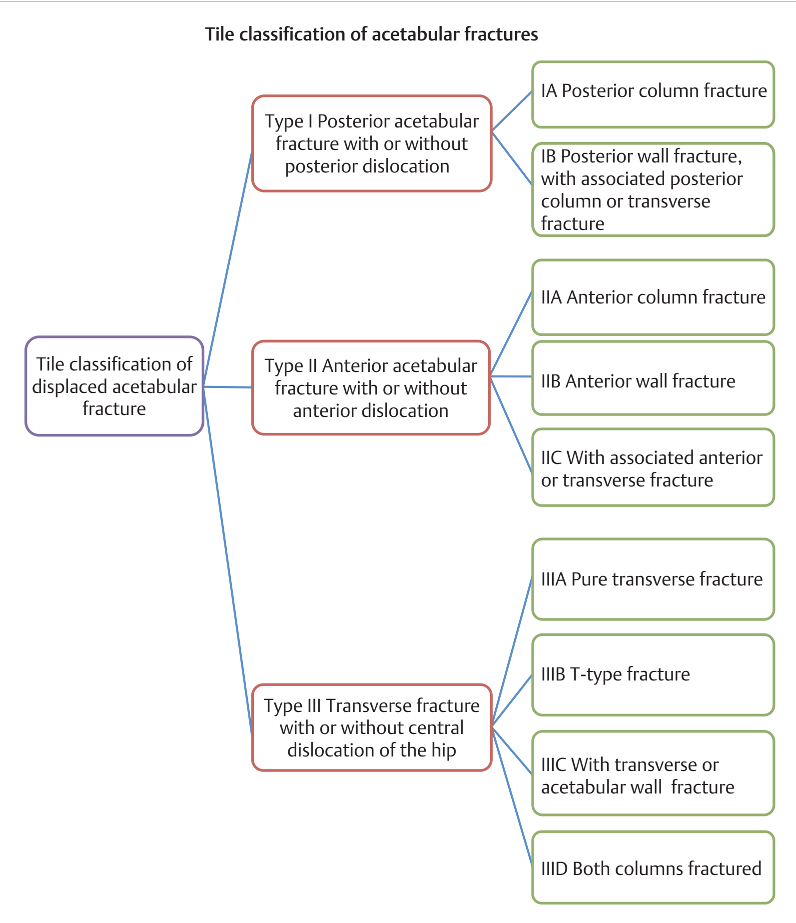


Fig. 7.42 Algorithm.

■ Tile Classification of Acetabular Fractures

- Nondisplaced acetabular fracture
- Displaced acetabular fracture. It is further divided into three main types (▶ Fig. 7.42):
  - *Type I*: fracture of the posterior part of the acetabulum with or without posterior dislocation
  - *Type IA*: posterior column fracture
  - *Type IB*: posterior wall fracture with associated posterior column or transverse fractures
  - *Type II:* fracture of anterior part of the acetabulum with or without anterior dislocation
  - *Type IIA*: anterior column fracture
  - *Type IIB*: anterior wall fracture

– *Type IIC*: with associated anterior or transverse fractures
– *Type III:* transverse fracture with or without central dislocation of the hip
– *Type IIIA*: pure transverse fracture
– *Type IIIB*: T-type fractures
– *Type IIIC*: with associated transverse or acetabular wall fractures
– *Type IIID*: bilateral column fractures

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8 Fractures of the Hand

Jialiang Guo, Lei Liu, and Chenni Ji

Overview of Hand Fractures

Anatomic Features

The skeleton of the hand consists of 8 small carpal bones (wrist), 5 metacarpals (palm), 14 phalanges (fingers), and 2 sesamoid bones (▶ Fig. 8.1). The carpus is made up of eight carpal bones, which are arranged into two rows: proximal and distal rows. The proximal row from lateral to medial contains: the scaphoid, lunate, triquetral, and pisiform bones; all of these except the pisiform bone are part of the radiocarpal joint. The distal row contains, in the same order: the trapezium, trapezoid, capitate, and hamate bones, which are all involved in the formation of the carpometacarpal joints. The metacarpus consists of five cylindric bones, each of which is made up of three parts: a body, base, and head. There are 14 phalanges on each hand: 3 on each finger, and 2 on the thumb. Each finger has a proximal, middle, and distal phalange except the pollex, which has only proximal and distal phalanx.

Fig. 8.1 The skeleton of the hand.

OTA Classification and Coding System for Hand Fractures

Based on the Orthopaedic Trauma Association (OTA) classification for fractures, a hand fracture is coded as number "7," and the numeric codes for fractures of each individual bone are as follows: 71: lunate; 72: scaphoid; 73: capitate; 74: hamate; 75: carpal bone on the ulnar side (triquetral and pisiform bones); 76: carpal bone on the radial side (trapezium and trapezoid bones); 77: metacarpal bones; 78: phalanx bones; 79: multiple hand fractures (▶ Fig. 8.2).

Epidemiologic Features of Hand Fractures in the China National Fracture Study

A total of 144 patients with 145 hand fractures were investigated in the China National Fracture Study (CNFS). The fractures accounted for 8.17% of all patients with fractures and 7.91% of all types of fractures. The population-weighted incidence rate of pelvic ring and acetabular fractures was 27 per 100,000 population.

The epidemiologic features of hand fractures in the CNFS are as follows:

- More males than females
- More right-side injuries than left-side injuries
- The highest risk age group is 15–64 years
- The phalanx fracture is the most common hand fractures
- Injuries occurred most commonly via falls and crushing injury

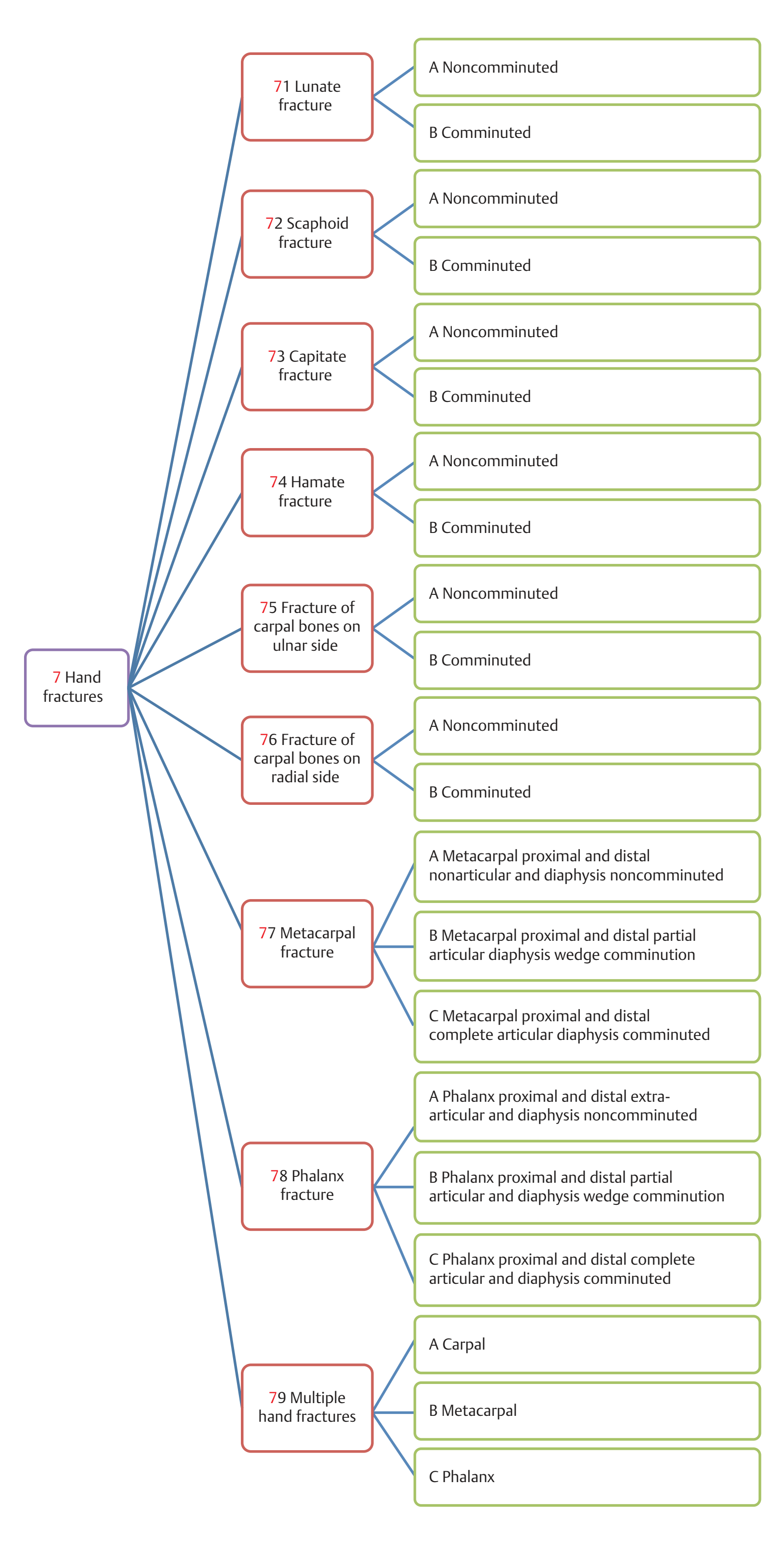

Fig. 8.2 Algorithm.

8

■ Hand Fractures by Sex in CNFS

See ▶ Table 8.1 and ▶ Fig. 8.3.

Table 8.1 Sex distribution of 144 patients with hand fractures in the China National Fracture Study

Sex	Number of patients	Percentage
Male	83	57.64
Female	61	42.36
Total	144	100.00

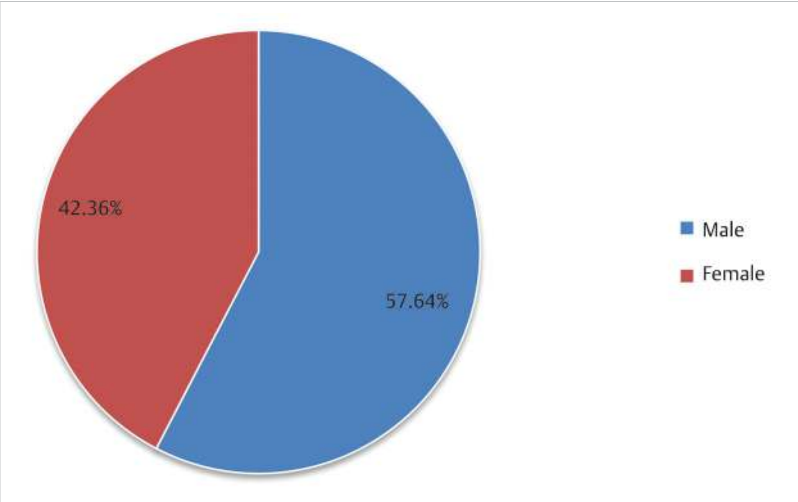

Fig. 8.3 Sex distribution of 144 patients with hand fractures in the China National Fracture Study (CNFS).

■ Hand Fractures by Injury Side in CNFS

See ▶ Table 8.2 and ▶ Fig. 8.4.

Table 8.2 Injury side distribution of 144 patients with hand fractures in the China National Fracture Study

Injured side	Number of patients	Percentage
Left	64	44.44
Right	79	54.86
Bilateral	1	0.69
Total	144	100.00

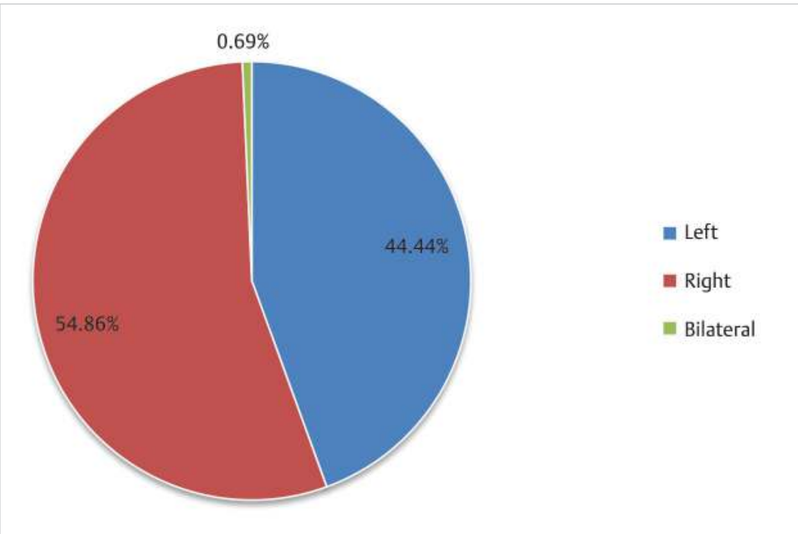

Fig. 8.4 Injury side distribution of 144 patients with hand fractures in the China National Fracture Study (CNFS).

■ Hand Fractures by Age in CNFS

See ▸ Table 8.3 and ▸ Fig. 8.5.

Table 8.3 Age distribution of 144 patients with hand fractures in the China National Fracture Study

Age group (years)	Male	Female	Total	Percentage
0–14	2	4	6	4.17
15–64	72	47	119	82.64
≥65	9	10	19	13.19
Total	83	61	144	100.00

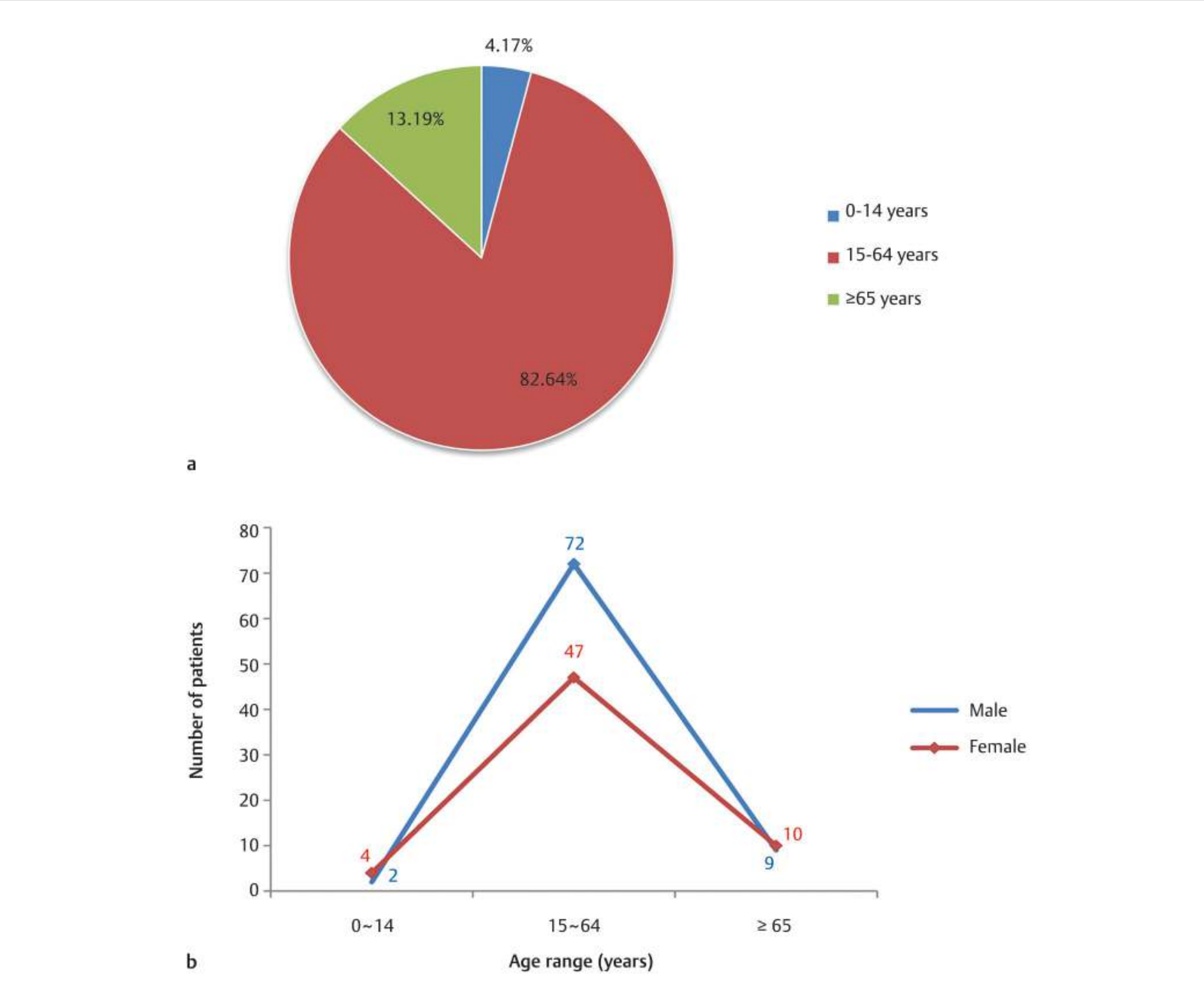

Fig. 8.5 (**a**) Age distribution of 144 patients with hand fractures in the China National Fracture Study (CNFS). (**b**) Age and sex distribution of 144 patients with hand fractures in the CNFS.

8

■ Hand Fractures by Location in CNFS

See ► Table 8.4 and ► Fig. 8.6.

Table 8.4 Segment distribution of 144 patients with hand fractures in the China National Fracture Study

Segment	Male	Female	Total	Percentage
71–76	5	7	12	8.28
77	11	14	25	17.24
78	55	28	83	57.24
79	12	13	25	17.24
Total	83	62	145	100.00

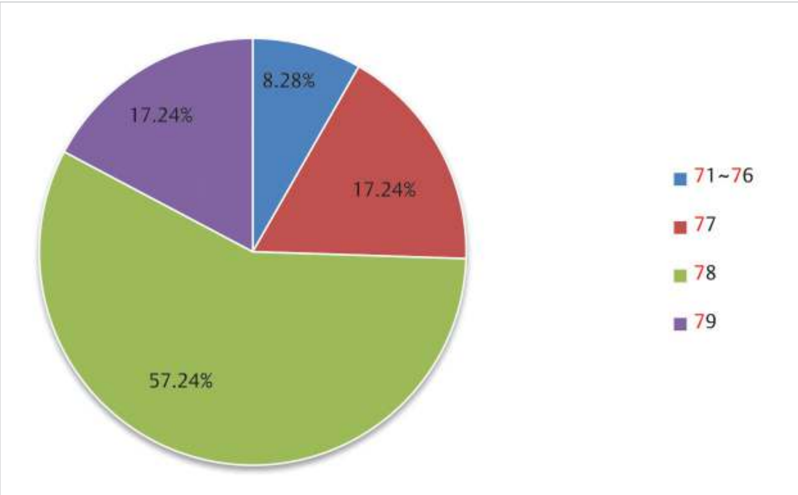

Fig. 8.6 Segment distribution of 144 patients with hand fractures in the China National Fracture Study (CNFS).

Hand Fractures by Causal Mechanisms in CNFS

See ▶ Table 8.5 and ▶ Fig. 8.7.

Table 8.5 Causal mechanisms distribution of 144 patients with hand fractures in the China National Fracture Study

Causal mechanisms	Male	Female	Total	Percentage
Traffic accident	8	10	18	33.96
Slip, trip, or fall	10	20	30	56.60
Fall from heights	4	0	4	7.55
Crushing injury	1	0	1	1.89
Total	23	30	53	100.00

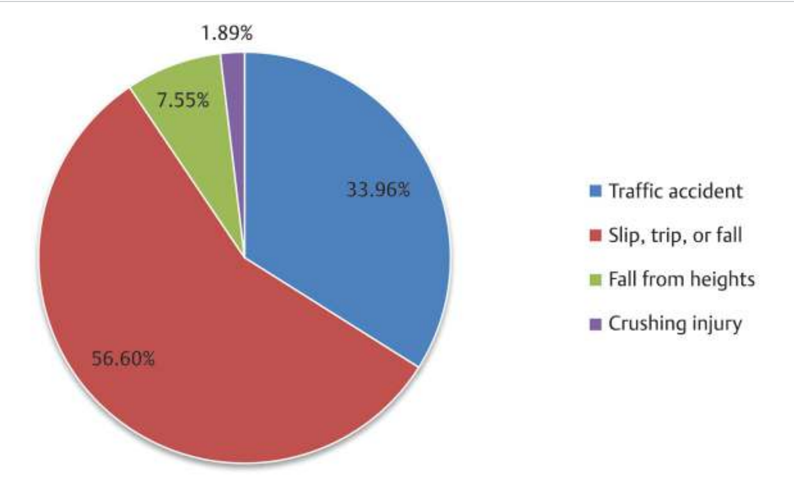

Fig. 8.7 Causal mechanisms distribution of 144 patients with hand fractures in the China National Fracture Study (CNFS).

Clinical Epidemiologic Features of Hand Fractures

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A total of 62,555 patients with 63,730 hand fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 15.08% of all fractured patients and 14.76% of all types of fractures. Among these 62,555 patients, there were 4,847 children with 4,881 hand fractures, accounting for 8.87% of pediatric patients with fractures, and 8.50% of all types of fractures in children. The rest of the 57,708 adult patients had 58,849 fractures, representing 16.02% of adult patients with fractures, and 15.72% of all types of fractures in adults.

Epidemiologic features of hand fractures are as follows:

- More males than females
- More right-side than left-side injuries
- The high-risk age group is 21–25 years, the same age group for males whereas the high-risk age group for females is 36–40 years
- Phalanx fractures are the most common fractures of the hand

■ Hand Fractures by Sex

See ▶ Table 8.6 and ▶ Fig. 8.8.

Table 8.6 Sex distribution of 62,555 patients with hand fractures

Sex	Number of patients	Percentage
Male	48,799	78.01
Female	13,756	21.99
Total	62,555	100.00

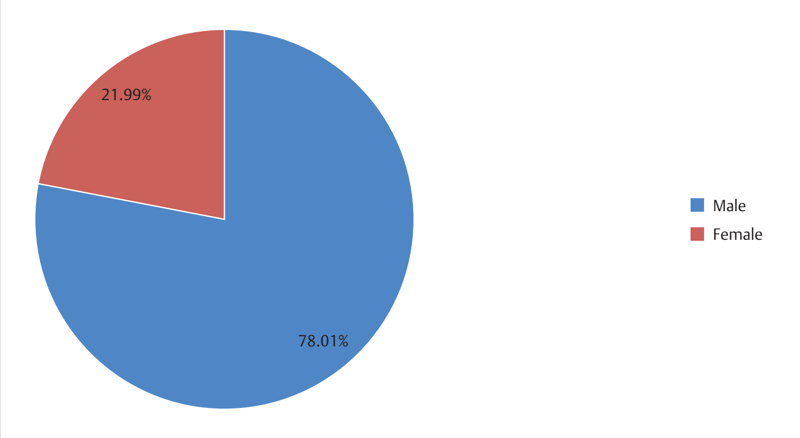


Fig. 8.8 Sex distribution of 62,555 patients with hand fractures.

■ Hand Fractures by Fracture Side

See ▶ Table 8.7 and ▶ Fig. 8.9.

Table 8.7 Fracture side distribution of 62,555 patients with hand fractures

Fracture side	Number of patients	Percentage
Left	30,291	48.42
Right	31,999	51.15
Bilateral	265	0.42
Total	62,555	100.00

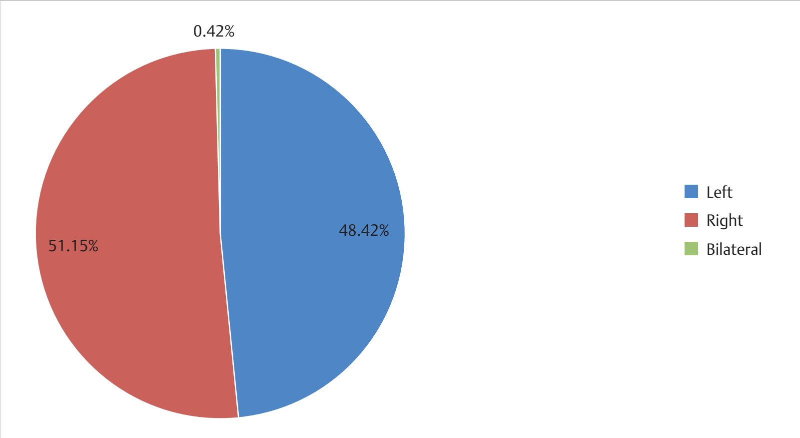


Fig. 8.9 Fracture side distribution of 62,555 patients with hand fractures.

■ Hand Fractures by Age Group

See ▶ Table 8.8 and ▶ Fig. 8.10.

Table 8.8 Age and sex distribution of 62,555 patients with hand fractures

Age group (years)	Male	Female	Number of patients	Percentage
0–5	1,031	510	1,541	2.46
6–10	943	435	1,378	2.20
11–15	1,591	337	1,928	3.08
16–20	5,327	868	6,195	9.90
21–25	7,499	1,147	8,646	13.82
26–30	5,972	1,218	7,190	11.49
31–35	4,995	1,314	6,309	10.09
36–40	5,697	1,840	7,537	12.05
41–45	5,172	1,811	6,983	11.16
46–50	4,006	1,383	5,389	8.61
51–55	2,633	893	3,526	5.64
56–60	2,052	794	2,846	4.55
61–65	926	455	1,381	2.21
66–70	371	298	669	1.07
71–75	292	192	484	0.77
76–80	170	161	331	0.53
81–85	75	64	139	0.22
≥ 86	47	36	83	0.13
Total	48,799	13,756	62,555	100.00

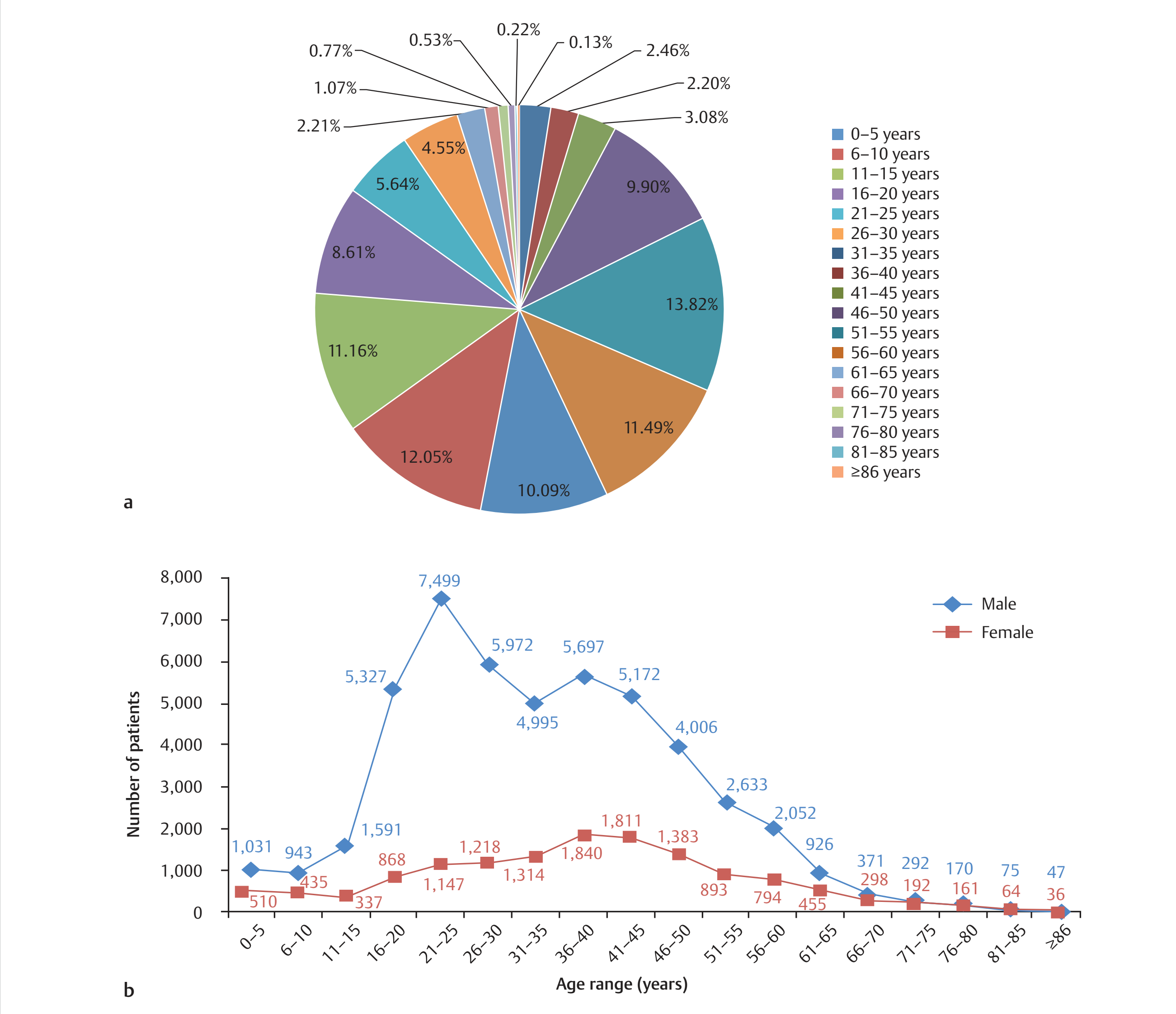


Fig. 8.10 (**a**) Age distribution of 62,555 patients with hand fractures. (**b**) Age and sex distribution of 62,555 patients with hand fractures.

8

■ Hand Fractures by Fracture Location

Hand Fractures by Locations in Adults Based on OTA Classification

See ▶ Table 8.9 and ▶ Fig. 8.11.

Table 8.9 Fracture location distribution of 58,849 hand fractures in adults

Fracture location	Number of fractures	Percentage
71–76 (Carpals)	3,064	5.21
77 (Metacarpals)	10,145	17.24
78 (Phalanx)	33,843	57.51
79 (Multiple)	11,797	20.05
Total	58,849	100.00

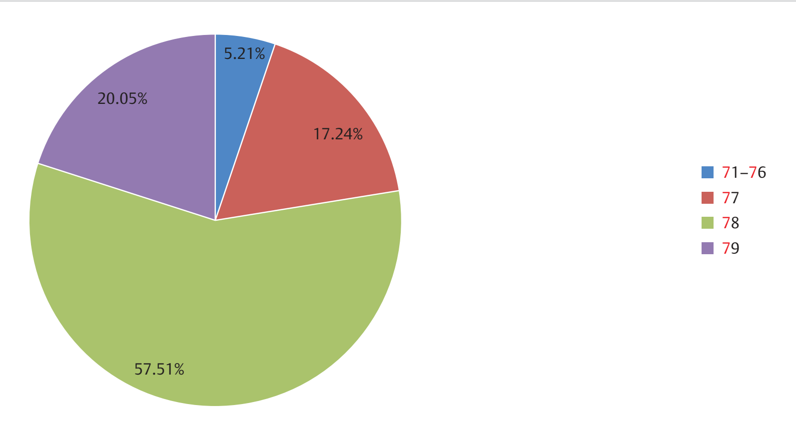


Fig. 8.11 Fracture location distribution of 58,849 hand fractures in adults.

Hand Fractures by Locations in Children

See ▶ Table 8.10 and ▶ Fig. 8.12.

Table 8.10 Fracture location distribution of 4,881 hand fractures in children

Fracture location	Number of fractures	Percentage
Carpals	95	1.95
Metacarpals	884	18.11
Phalanx	3,902	79.94
Total	4,881	100.00

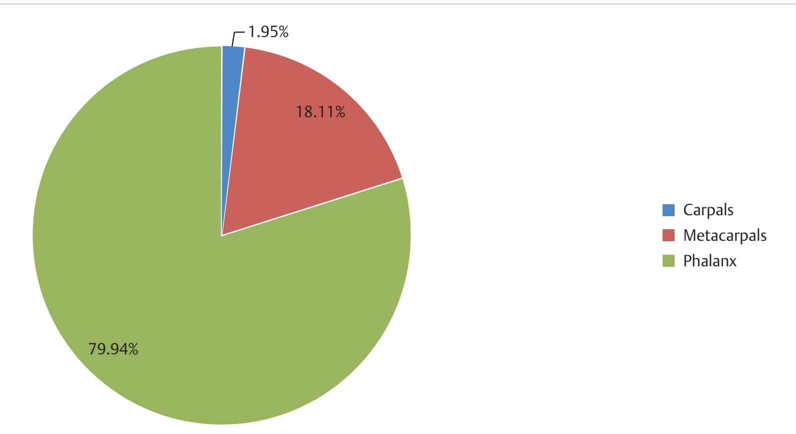


Fig. 8.12 Fracture location distribution of 4,881 hand fractures in children.

Carpal Fractures (Segments 71–76)

Anatomic Features

There are eight carpal bones, arranged in two rows. Those of the proximal row, from lateral to medial, are scaphoid, lunate, triangular, and pisiform; those of the distal row, in the same order, are the trapezium, trapezoid, capitate, and hamate. From the proximal row, the superior articular surface of the scaphoid, lunate, and triangular are connected by ligaments, present a convex surface, and articulate with the inferior surface of the radius and articular disk, forming the radiocarpal joint; the distal row of carpal bones articulates with the proximal bases of the five metacarpal bones, forming the carpometacarpal joints.

Carpals are short bones; each bone (except the pisiform) has six surfaces. The anterior and posterior surfaces, which have ligamentous attachment, are rough. The surfaces where the carpal bones make contact with contiguous bones are all articular, thus covered with articular cartilage, and are involved in the formation of the joint. The construction of these short bones provides complex but limited movement.

OTA Classification of Carpal Fractures

Carpal fractures are classified based on OTA classification as follows: 71: lunate; 72: scaphoid; 73: capitate; 74: hamate; 75: ulnar carpal bones; and 76: radial carpal bones (▶ Fig. 8.13).

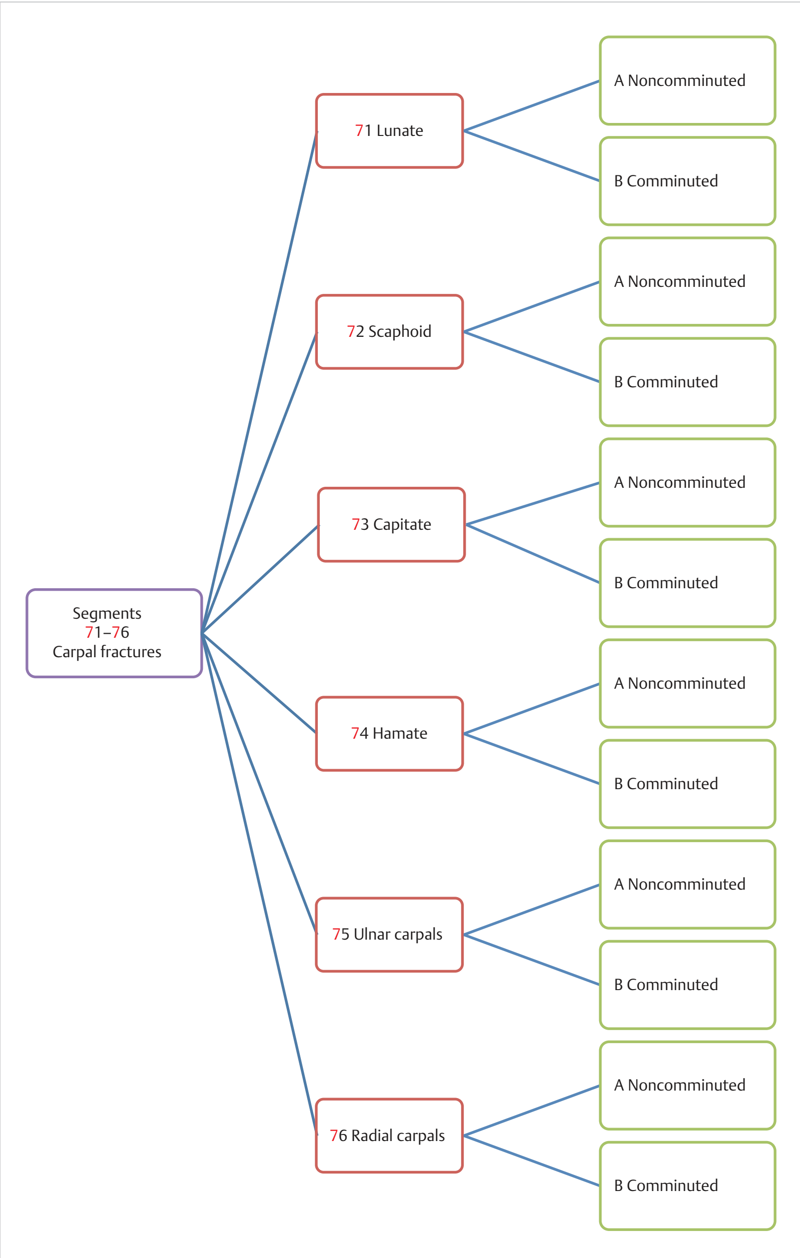


Fig. 8.13 Algorithm.

Clinical Epidemiologic Features of Carpal Fractures (71–76)

A total of 3,057 patients with 3,064 carpal fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 5.30% of all adult patients with fractures and 5.21% of hand fractures in adults. Their epidemiologic features are as follows:

- More males than females
- The high-risk age group is 21–25 years, the same age group for males whereas the high-risk age group for females is 56–60 years
- Scaphoid fractures (72) are the most common of carpal bone fractures (71–76)

Carpal Fractures (Segments 71–76) by Sex

See ▶ Table 8.11 and ▶ Fig. 8.14.

Table 8.11 Sex distribution of 3,057 patients with fractures of carpal bones (segments 71–76)

Sex	Number of patients	Percentage
Male	2,284	74.71
Female	773	25.29
Total	3,057	100.00

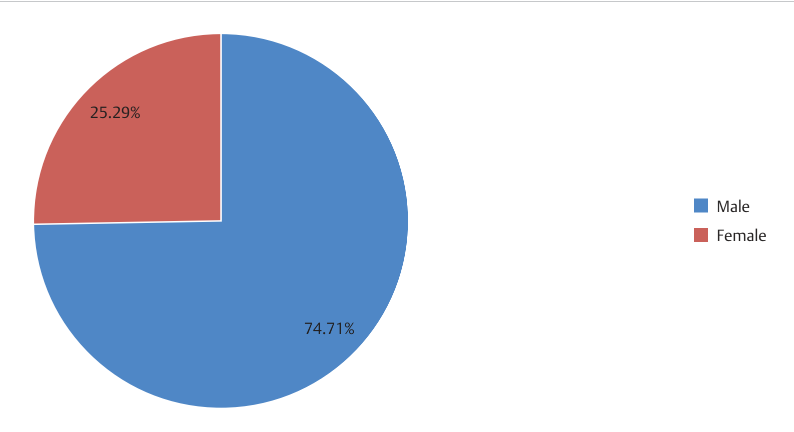


Fig. 8.14 Sex distribution of 3,057 patients with carpal fractures.

■ Carpal Fractures (Segments 71–76) by Age Group

See ► Table 8.12 and ► Fig. 8.15.

Table 8.12 Age and sex distribution of 3,057 patients with fractures of the carpal bones (segments 71–76)

Age group (years)	Male	Female	Number of patients	Percentage
16–20	291	47	338	11.06
21–25	405	62	467	15.28
26–30	360	49	409	13.38
31–35	243	57	300	9.81
36–40	252	82	334	10.93
41–45	201	77	278	9.09
46–50	168	86	254	8.31
51–55	112	83	195	6.38
56–60	80	100	180	5.89
61–65	58	45	103	3.37
66–70	23	38	61	2.00
71–75	41	25	66	2.16
76–80	28	16	44	1.44
81–85	18	4	22	0.72
≥ 86	4	2	6	0.20
Total	2,284	773	3,057	100.00

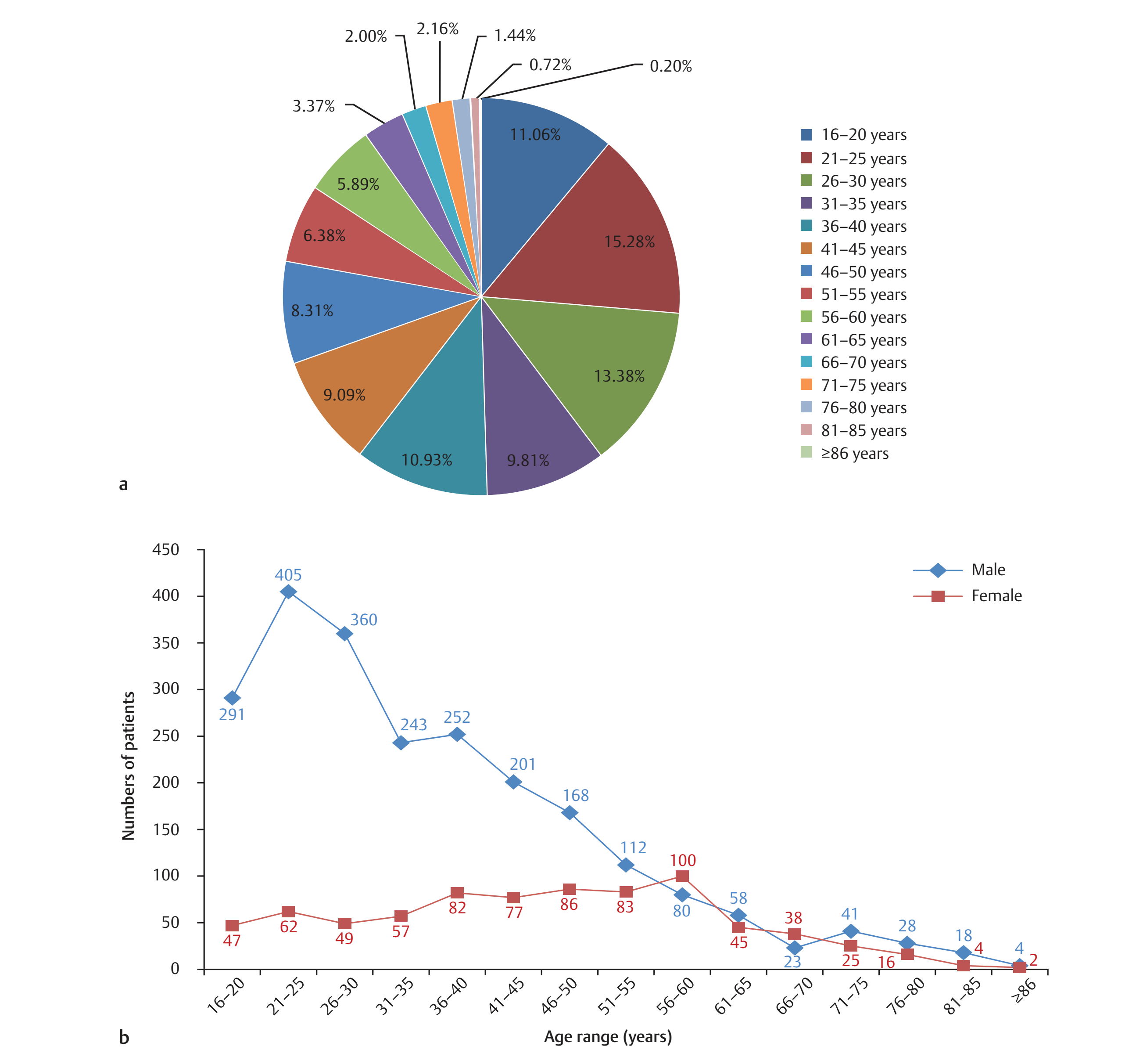


Fig. 8.15 (**a**) Age distribution of 3,057 patients with carpal fractures. (**b**) Age and sex distribution of 3,057 patients with carpal fractures.

Carpal Fractures (Segments 71–76) by Fracture Type

See ▶ Table 8.13, ▶ Table 8.14, ▶ Fig. 8.16, and ▶ Fig. 8.17.

Table 8.13 Sex and fracture type distribution of 3,064 fractures of carpal bones (segments 71–76)

Fracture type	Male	Female	Number of fractures	Percentage
71 (Lunate)	82	34	116	3.79
72 (Scaphoid)	1,634	471	2,105	68.70
73 (Capitate)	104	53	157	5.12
74 (Hamate)	104	34	138	4.50
75 (Ulnar carpal bones)	247	118	365	11.91
76 (Radial carpal bones)	119	64	183	5.97
Total	2,290	774	3,064	100.00

Table 8.14 Sex and fracture group distribution of 3,064 fractures of carpal bones (segments 71–76)

Fracture group	Male	Female	Number of fractures	Percentage of carpal bone fractures (segments 71–76)	Percentage of fractures of the hand in adults
71-A	69	28	97	3.17	0.16
71-B	13	6	19	0.62	0.03
72-A	1,419	419	1,838	59.99	3.12
72-B	215	52	267	8.71	0.45
73-A	76	36	112	3.66	0.19
73-B	28	17	45	1.47	0.08
74-A	93	30	123	4.01	0.21
74-B	11	4	15	0.49	0.03
75-A	213	99	312	10.18	0.53
75-B	34	19	53	1.73	0.09
76-A	94	51	145	4.73	0.25
76-B	25	13	38	1.24	0.06
Total	2,290	774	3,064	100.00	5.21

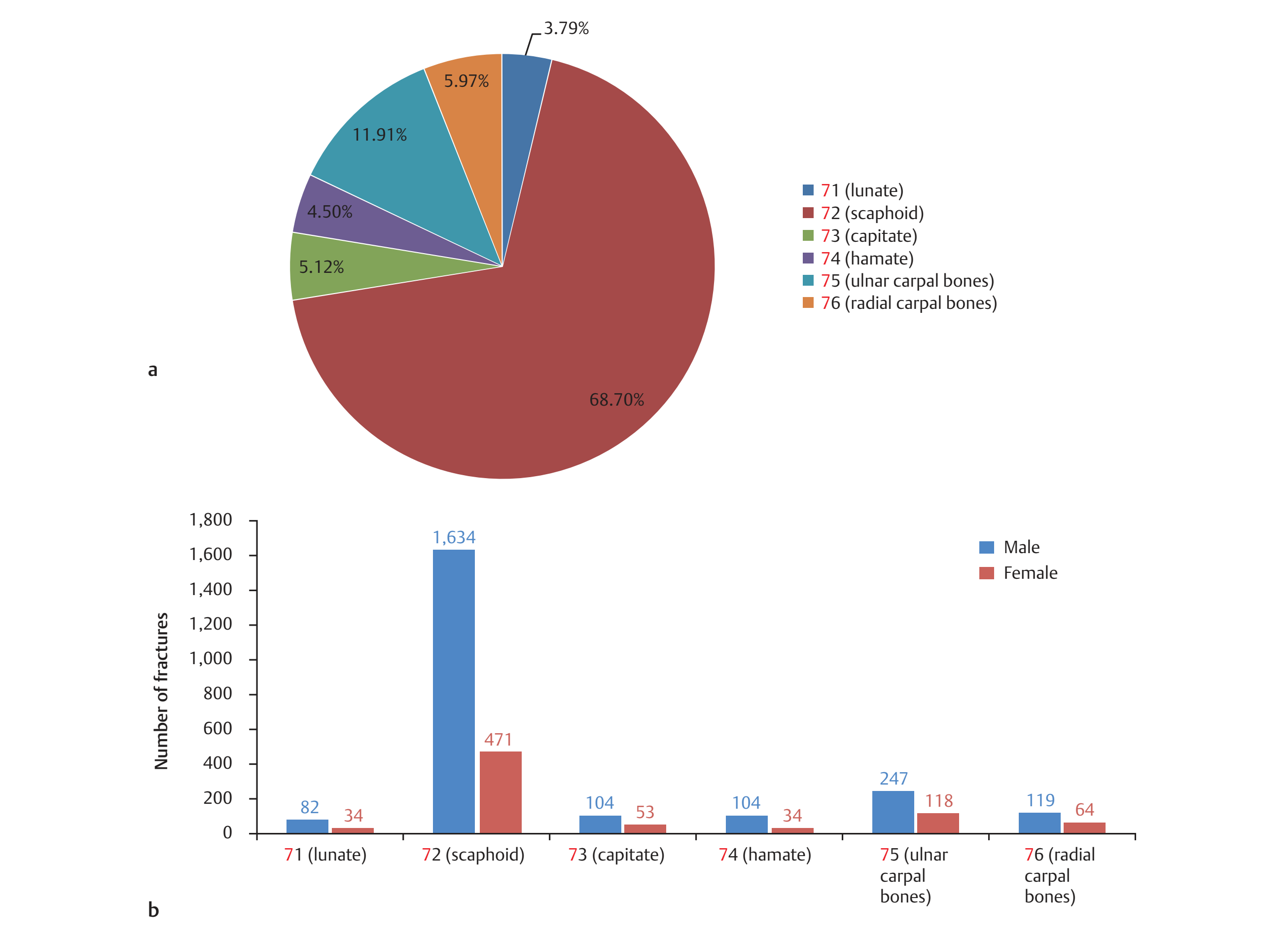


Fig. 8.16 (**a**) Fracture type distribution of 3,064 fractures of carpal bones (segments 71–76). (**b**) Sex and fracture type distribution of 3,064 fractures of carpal bones (segments 71–76).

8

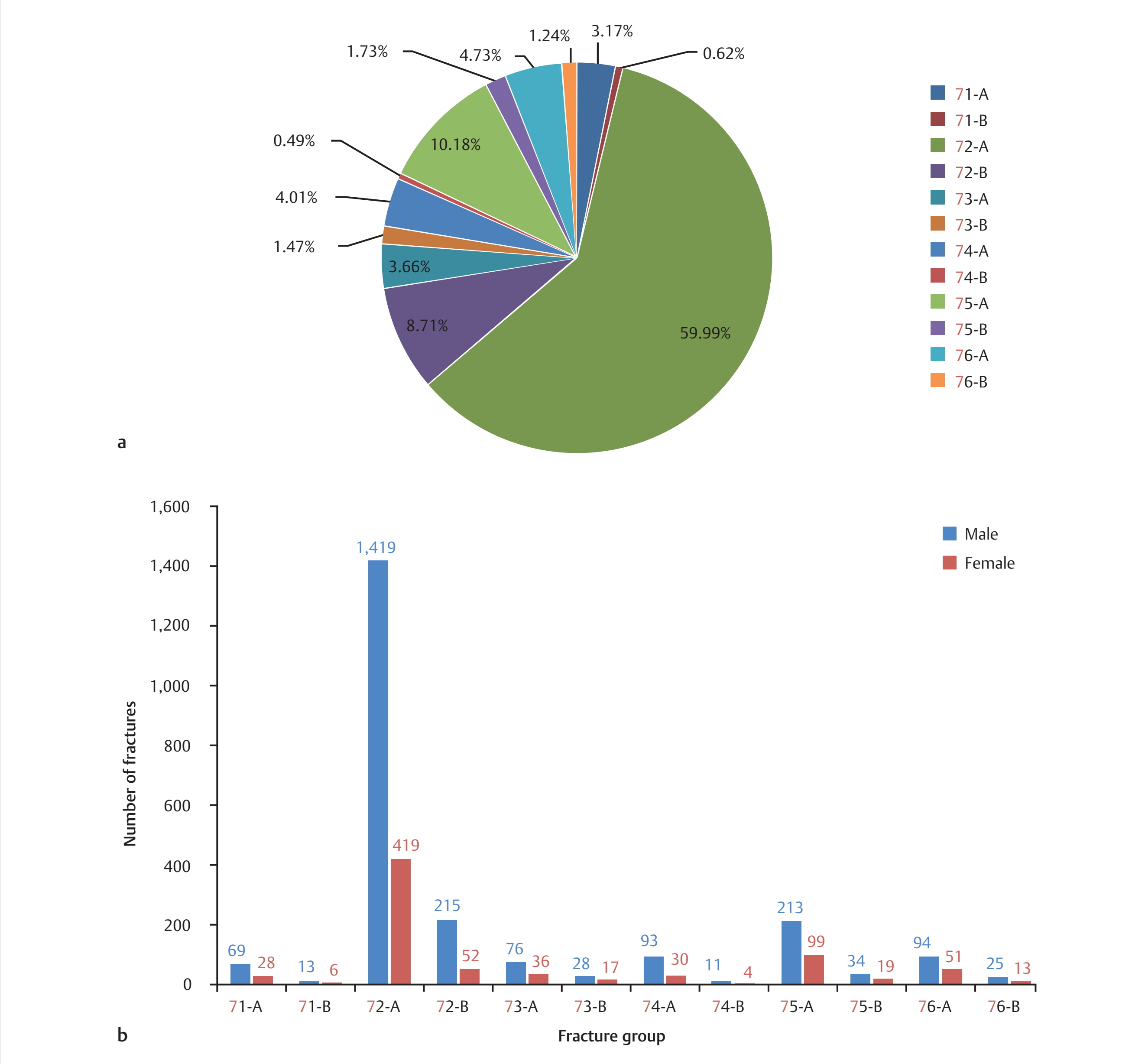


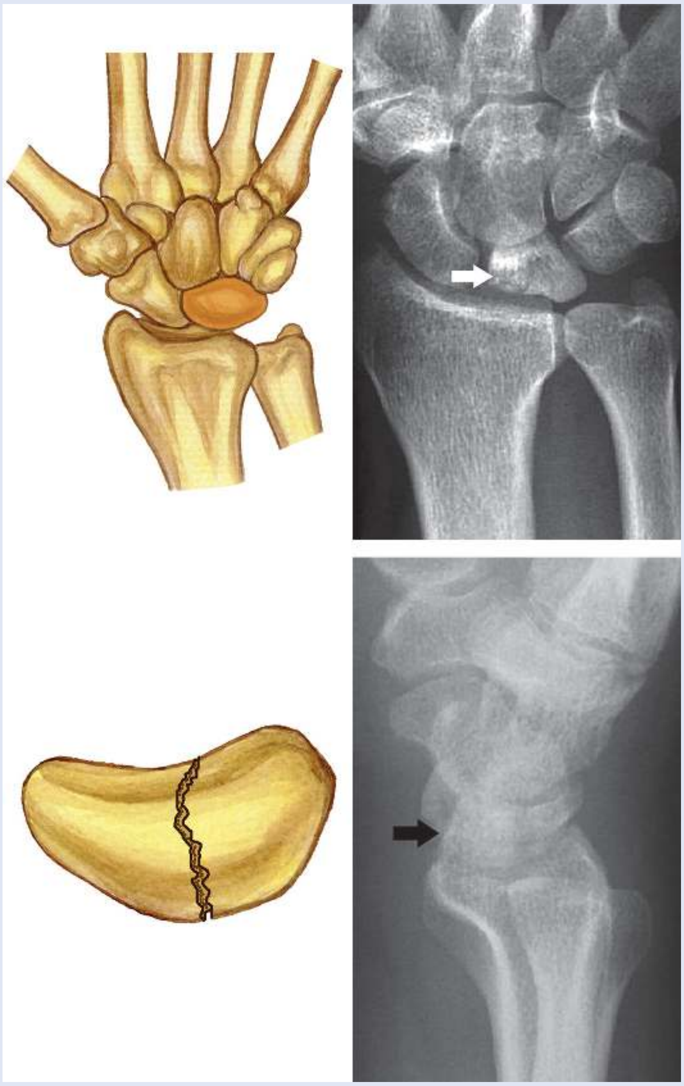
Fig. 8.17 (**a**) Fracture group distribution of 3,064 fractures of carpal bones (segments 71–76). (**b**) Sex and fracture group distribution of 3,064 fractures of carpal bones (segments 71–76).

8

71 Lunate fractures

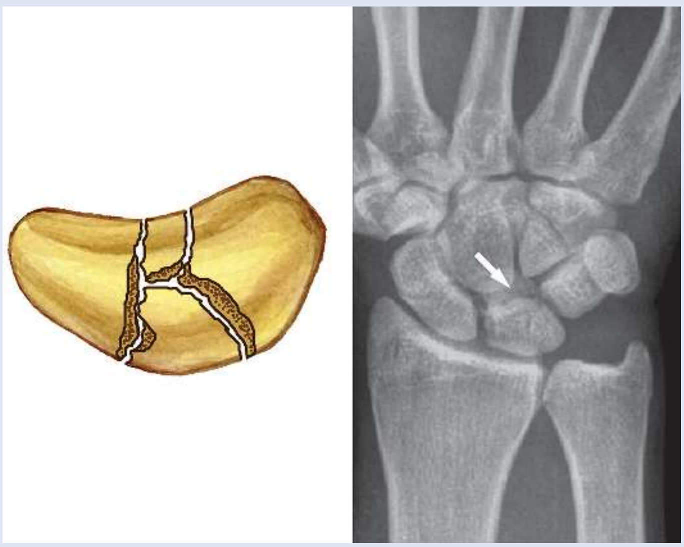
71-A Noncomminuted
97 fractures
M: 69 (71.13%)
F: 28 (28.87%)
0.03% of total adult fractures
0.16% of adult hand fractures
3.17% of adult carpal fractures
83.62% of adult lunate fractures

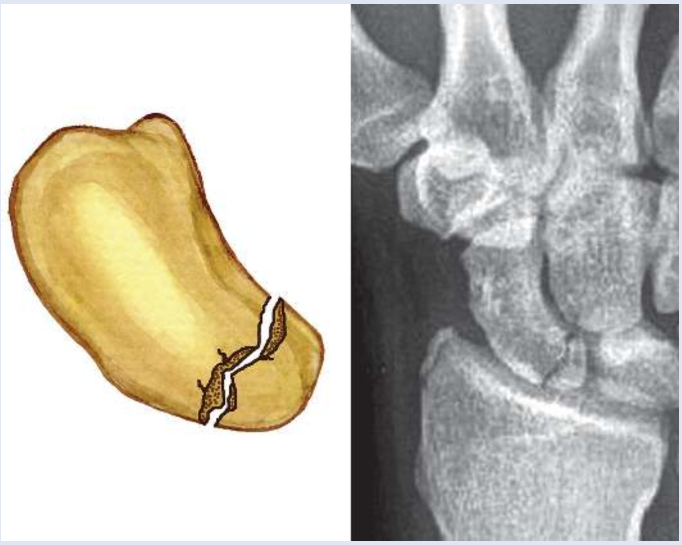
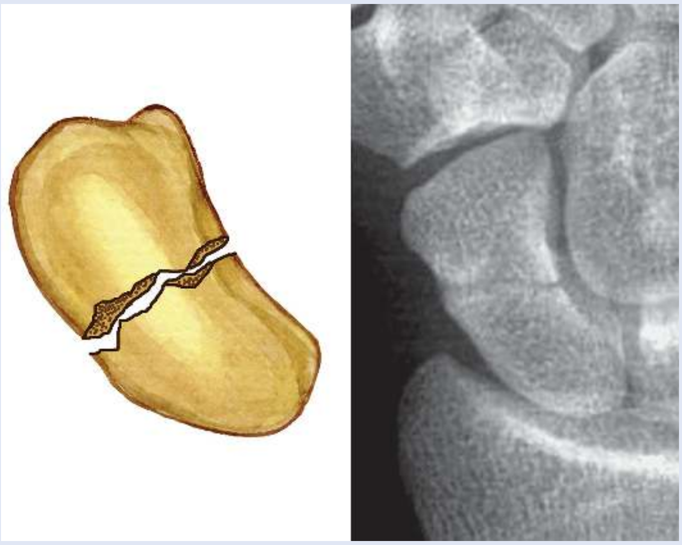
71-A Anteroposterior (AP) and lateral views



71-B Comminuted
19 fractures
M: 13 (68.42%)
F: 6 (31.58)
0.01% of total adult fractures
0.03% of adult hand fractures
0.62% of adult carpal fractures
16.38% of adult lunate fractures

71-B

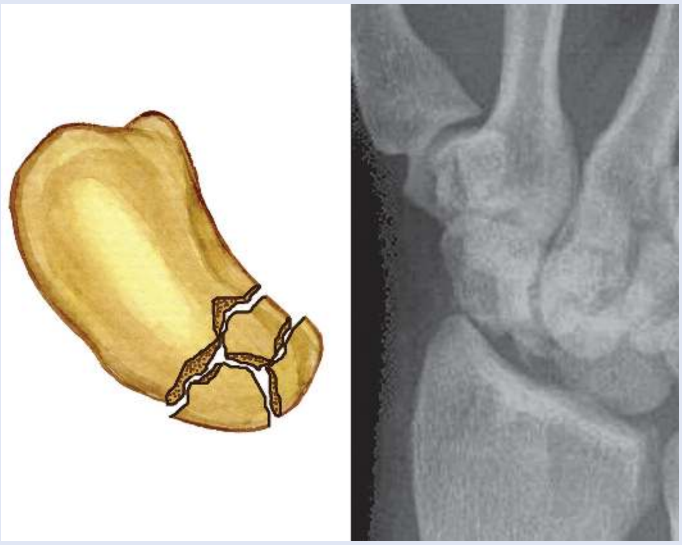


72 Scaphoid fractures	
72-A Noncomminuted 1,838 fractures M: 1,419 (77.20%) F: 419 (22.80%) 0.49% of total adult fractures 3.12% of adult hand fractures 59.99% of adult carpal fractures 87.32% of adult scaphoid fractures	**72-A1** Proximal pole 
	72-A2 Waist 
	72-A3 Distal pole 

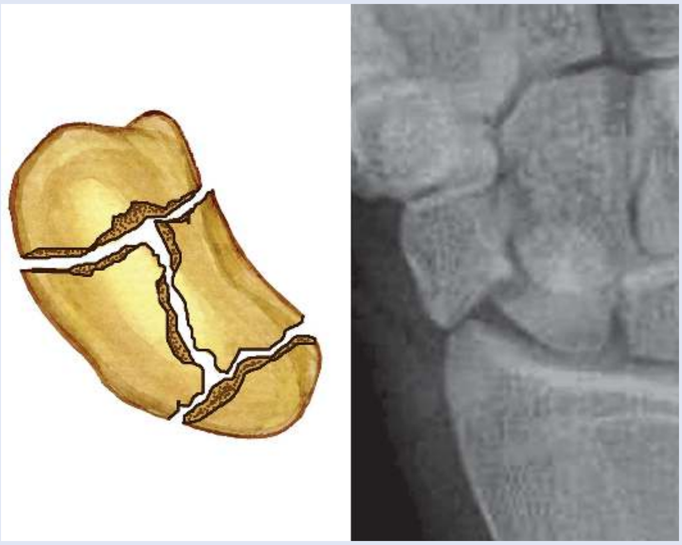
72 Scaphoid fractures

72-B Comminuted
267 fractures
M: 215 (80.52%)
F: 52 (19.48%)
0.07% of total adult fractures
0.45% of adult hand fractures
8.71% of adult carpal fractures
12.68% of adult scaphoid fractures

72-B1 Proximal pole



72-B2 Waist



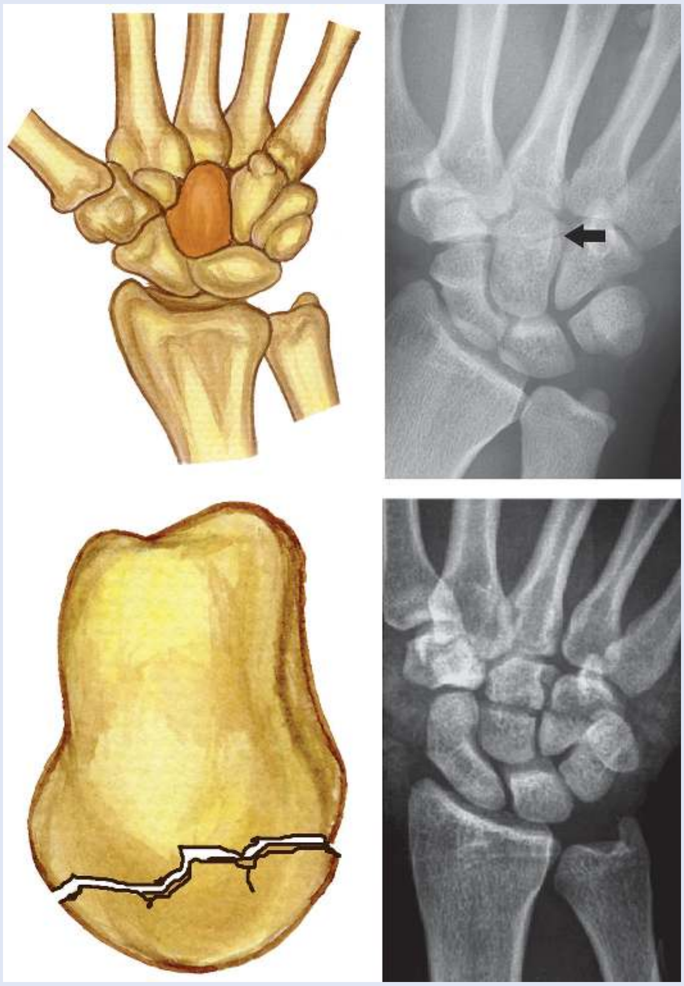
72-B3 Distal pole

8

73 Capitate fractures

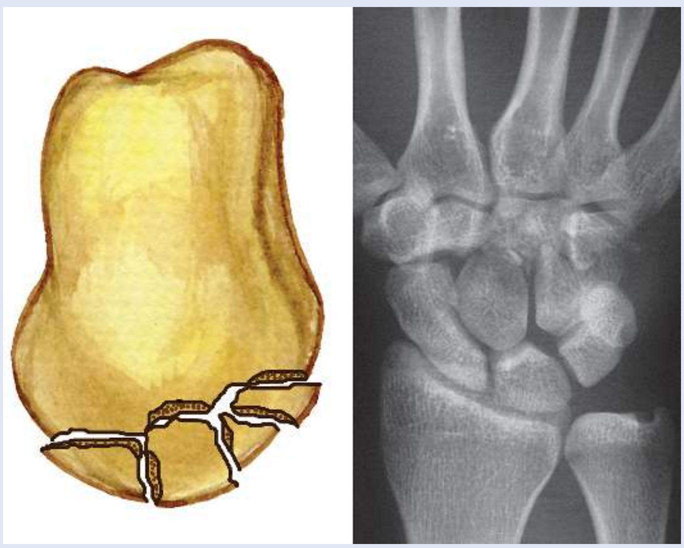
73-A Noncomminuted
112 fractures
M: 76 (67.86%)
F: 36 (32.14%)
0.03% of total adult fractures
0.19% of adult hand fractures
3.66% of adult carpal fractures
71.34% of adult capitate fractures

73-A AP and lateral views



73-B Comminuted
45 fractures
M: 28 (62.22%)
F: 17 (37.38%)
0.01% of total adult fractures
0.08% of total hand fractures
1.47% of total carpal fractures
28.66% of total capitate fractures

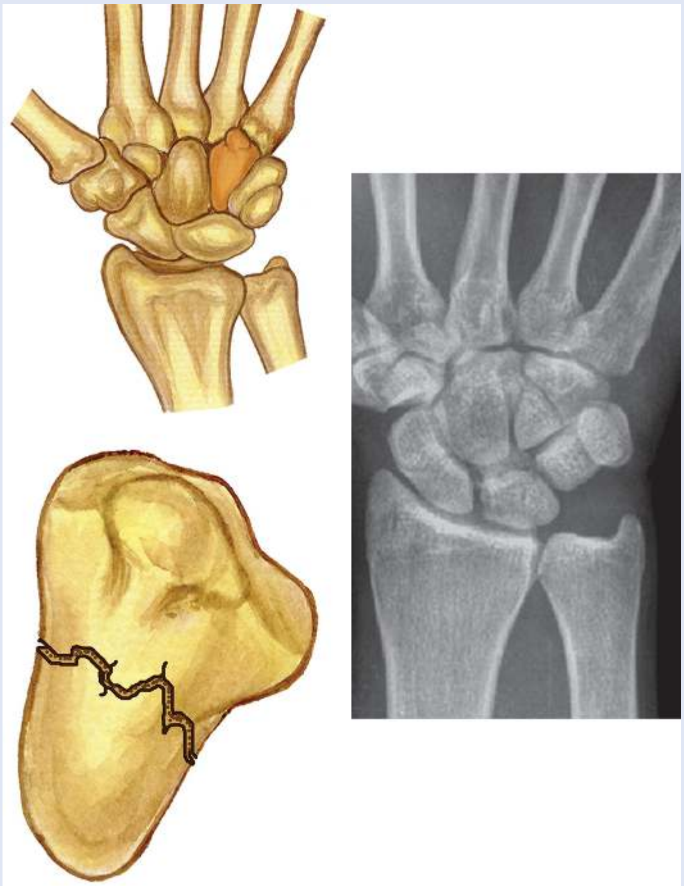
73-B



74 Hamate fractures

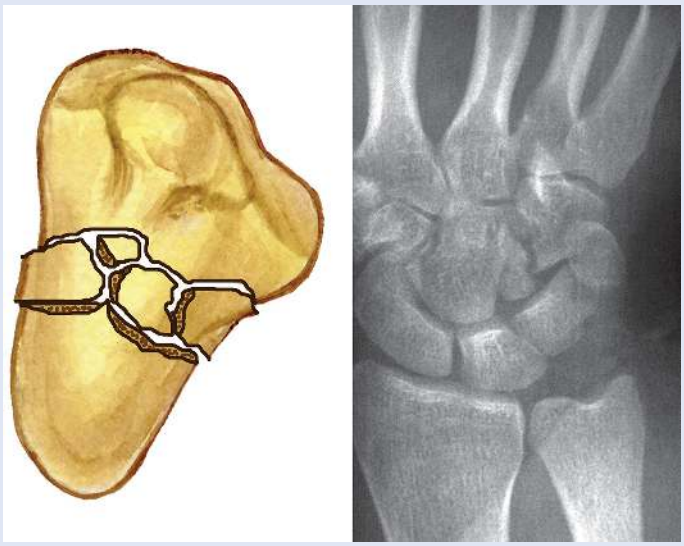
74-A Noncomminuted
123 fractures
M: 93 (75.61%)
F: 30 (24.39%)
0.03% of total adult fractures
0.21% of total hand fractures
4.01% of total carpal fractures
89.13% of total hamate fractures

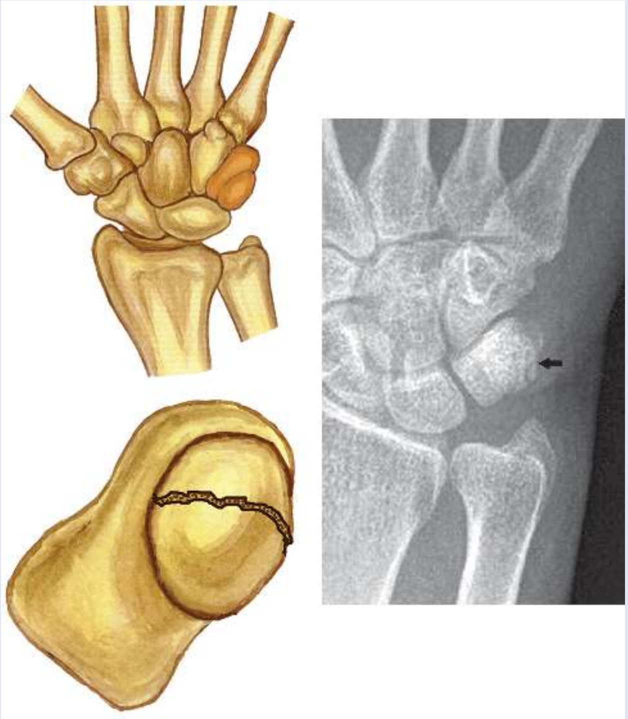
74-A



74-B Comminuted
15 fractures
M: 11 (73.33%)
F: 4 (26.67%)
0.004% of total adult fractures
0.03% of total hand fractures
0.49% of total carpal fractures
10.87% of total hamate fractures

74-B

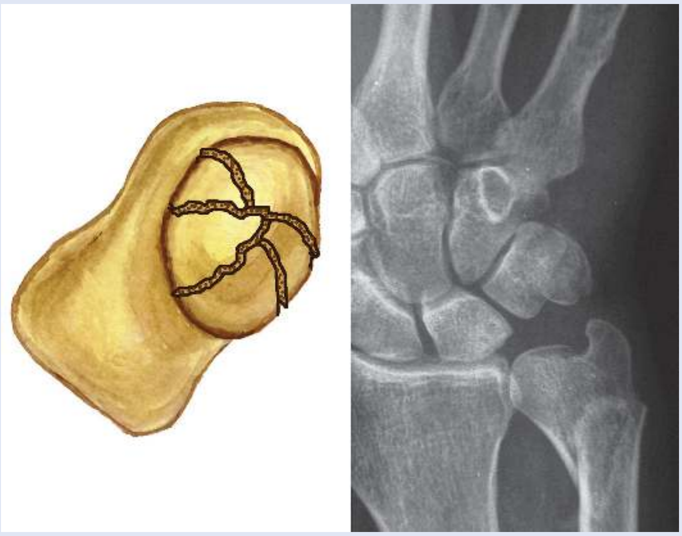


75 Ulnar carpal fractures (triquetrum, pisiform)	
75-A Noncomminuted 312 fractures M: 213 (68.27%) F: 99 (31.73%) 0.08% of total adult fractures 0.53% of adult hand fractures 10.18% of adult carpal fractures 85.48% of adult ulnar carpal fractures	**75-A1** Pisiform  **75-A2** Triquetrum: AP and lateral views 

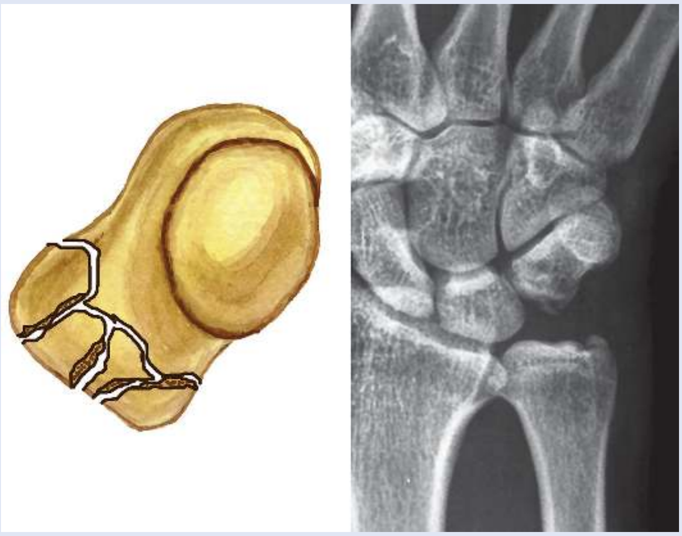
75 Ulnar carpal fractures (triquetrum, pisiform)

75-B Comminuted
53 fractures
M: 34 (64.15%)
F: 19 (35.85%)
0.01% of total adult fractures
0.09% of adult hand fractures
1.73% of adult carpal fractures
14.52% of adult ulnar carpal fractures

75-B1 Pisiform



75-B2 Triquetrum



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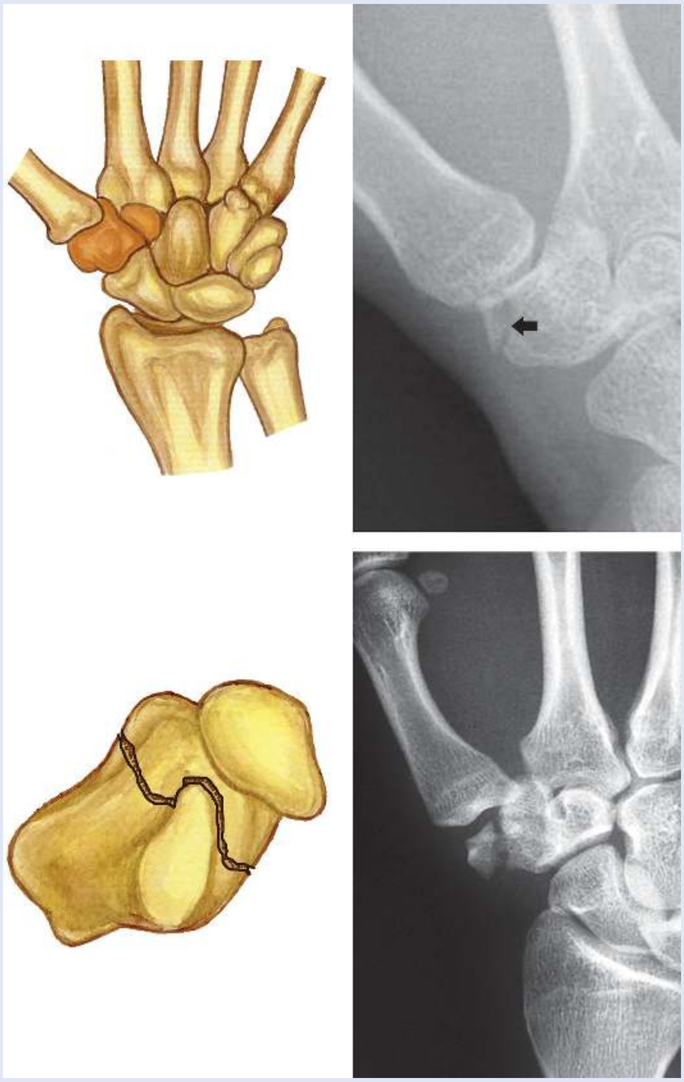
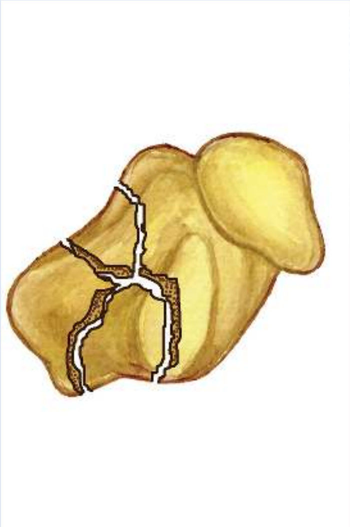
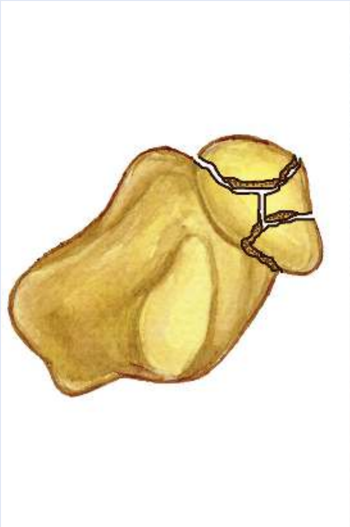
76 Radial carpal fractures (trapezium, trapezoid)	
76-A Noncomminuted 145 fractures M: 94 (64.83%) F: 51 (35.17%) 0.04% of total adult fractures 0.25% of adult hand fractures 4.73% of adult carpal fractures 79.23% of adult radial carpal fractures	**76-A1** Trapezium: AP and lateral views  **76-A2** Trapezoid 

76 Radial carpal fractures (trapezium, trapezoid)	
76-B Comminuted 38 fractures M: 25 (65.79%) F: 13 (34.21%) 0.01% of total adult fractures 0.06% of adult hand fractures 1.24% of adult carpal fractures 20.77% of adult radial carpal fractures	**76-B1** Trapezium   **76-B2** Trapezoid  

Injury Mechanism

Most carpal fractures are a result of axial loading on the outstretched palm and an extended wrist, for example, from a fall on an outstretched hand or motor-vehicle collision. A direct blow to the dorsum of the hand, a crush injury, or cutting through the dorsum of the hand can also cause this type of injury.

Diagnosis

Most patients present with history of a fall on an outstretched hand, or a traumatic event like a motor-vehicle accident. If palpation of each carpal bone and the intercarpal ligaments elicit pain and apparent local tenderness, then one should strongly suspect the presence of fractures. Where carpal fracture is suspected, X-rays of AP, lateral, and oblique views are needed. Bone scans and computed tomography (CT) scans are sometimes helpful if the plain X-ray is inconclusive for fracture.

Treatment

Most carpal fractures, except scaphoid, can be treated with nonsurgical intervention. The indications for nonsurgical treatment are as follows:

- Nondisplaced carpal fracture
- Stable wrist joint injury, with less than 2 mm fracture displacement
- Stable wrist joint injury, with less than 1 mm intra-articular fracture step-off
- Isolated ligamentous rupture, in elderly low-demand patients
- Hamate fracture with the hook intact
- Pisiform fracture

The treatment principle for scaphoid fractures is discussed in the next section of this chapter.

Further Classification for Scaphoid Fractures

Anatomic Features and Coding System

The scaphoid bone is the largest bone of the wrist bone's proximal row. It is situated between the hand and forearm at the radial side of the carpus, and plays an important role in the formation of the radiocarpal joint. The scaphoid bone received its name from its resemblance to a boat, its long axis being from above, downward, lateralward, and forward. The dorsal surface has a rough groove, and a rounded projection called a tubercle, which is elevated at its lower and lateral part, and is directed forward; it gives attachment to the transverse carpal ligament and is sometimes the origin of a few fibers of the abductor pollicis brevis. The scaphoid has a central narrowing or waist, which is at high risk for fracture.

The proximal pole of the scaphoid is completely covered with cartilage, and receives a very limited vascular supply from a ligamentous structure (radioscapholunate ligament), in contrast to the distal two-thirds of the bone, which appears to have its own abundant blood supply. Therefore, any displaced fracture involving the proximal half of the scaphoid will severely jeopardize the vascularity of the proximal portion and may result in increased risk of avascular necrosis of that portion of the bone.

Based on AO classification, scaphoid fractures are classified into three subtypes: A, Avulsion fracture of the tubercle; B, Fracture of the waist; and C, Multiple fragments or comminuted fractures.

Russe classified scaphoid fractures as horizontal oblique, transverse, or vertical oblique, based on the direction of the fracture line.

Clinical Epidemiologic Features of Scaphoid Fractures in Adults

A total of 2,101 adult patients with 2,105 scaphoid fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, accounting for 68.73% of all adult patients with carpal fractures and 68.70% of carpal fractures in adults. Their epidemiologic features are as follows:

- The number of men greatly outweighs the number of women
- The high-risk age group is 21–25 years, the same age group for men while there is no apparent high-risk age group for women
- The waist of the scaphoid is the most frequent fracture site

■ Scaphoid Fractures by Sex

See ▶ Table 8.15 and ▶ Fig. 8.18.

Table 8.15 Sex distribution of 2,101 patients with scaphoid fractures

Sex	Number of patients	Percentage
Male	1,630	77.58
Female	471	22.42
Total	2,101	100.00

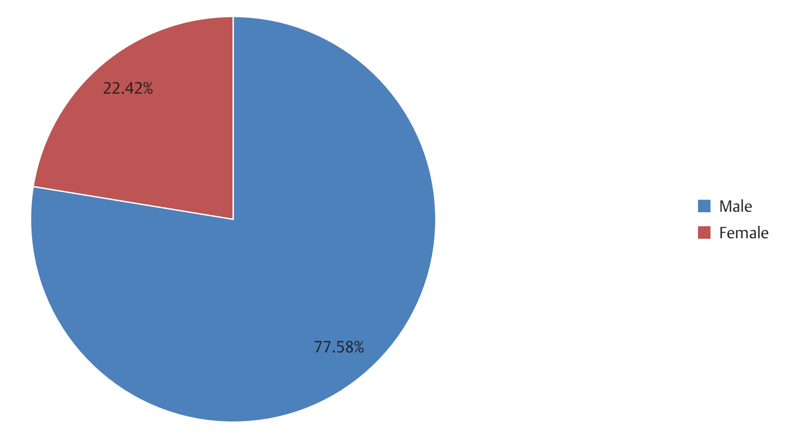


Fig. 8.18 Sex distribution of 2,101 patients with scaphoid fractures.

■ Scaphoid Fractures by Age Group

See ▶ Table 8.16 and ▶ Fig. 8.19.

Table 8.16 Age and sex distribution of 2,101 patients with scaphoid fractures

Age group (years)	Male	Female	Number of fractures	Percentage
16–20	214	37	251	11.95
21–25	322	44	366	17.42
26–30	276	31	307	14.61
31–35	177	34	211	10.04
36–40	180	50	230	10.95
41–45	141	47	188	8.95
46–50	102	61	163	7.76
51–55	68	44	112	5.33
56–60	54	60	114	5.43
61–65	38	26	64	3.05
66–70	14	14	28	1.33
71–75	22	11	33	1.57
76–80	13	10	23	1.09
81–85	8	1	9	0.43
≥ 86	1	1	2	0.10
Total	1,630	471	2,101	100.00

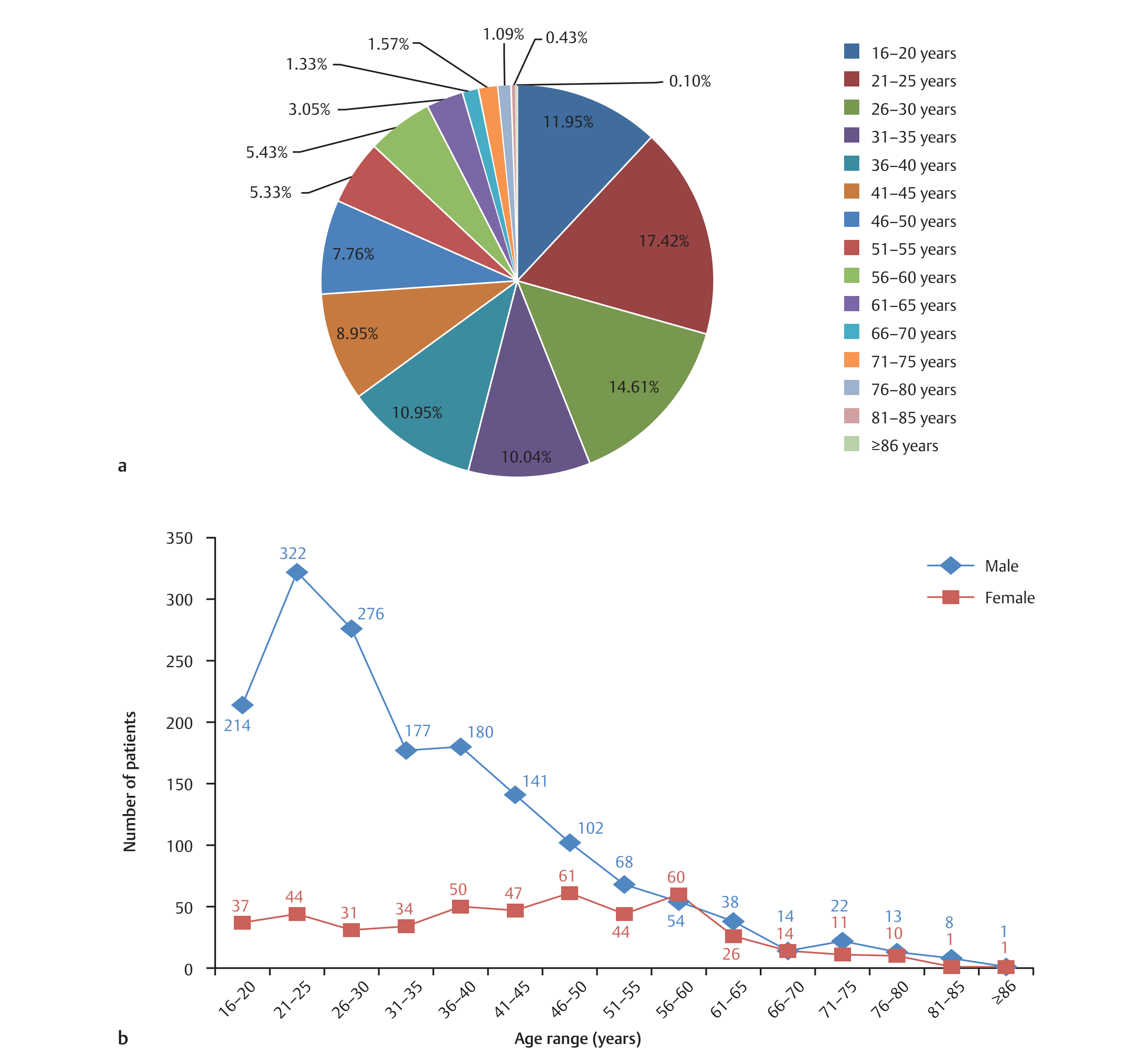


Fig. 8.19 (**a**) Age distribution of 2,101 patients with scaphoid fracture. (**b**) Age and sex distribution of patients with scaphoid fractures.

■ Scaphoid Fractures by Fracture Type Based on AO Classification

See ▶ Table 8.17 and ▶ Fig. 8.20.

Table 8.17 Sex and fracture type distribution of 2,105 scaphoid fractures based on AO classification

Fracture type	Male	Female	Number of fractures	Percentage	Percentage of carpal fractures	Percentage of hand fractures
A	233	79	312	14.82	10.18	0.53
B	1,272	365	1,637	77.77	53.43	2.78
C	129	27	156	7.41	5.09	0.27
Total	1,634	471	2,105	100.00	68.70	3.58

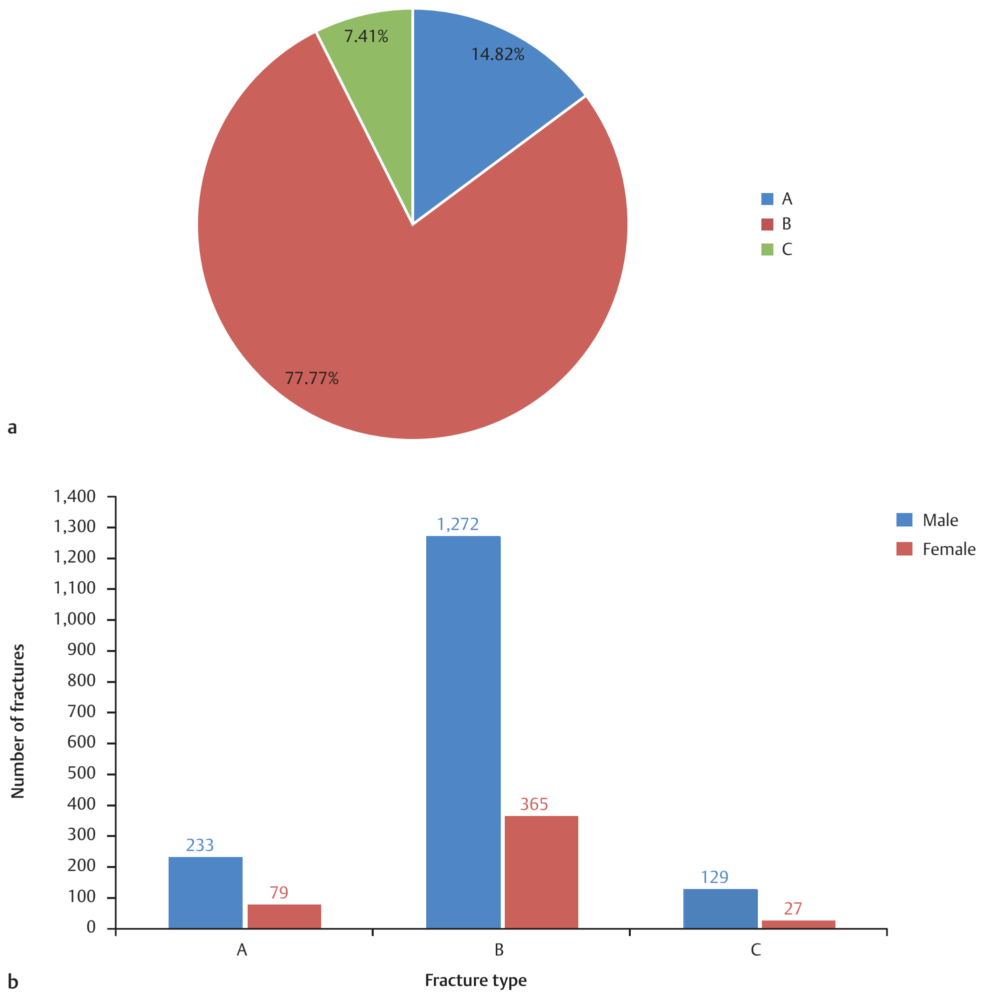


Fig. 8.20 (a) Fracture type distribution of 2,105 scaphoid fractures based on AO classification. (b) Fracture type distribution of 2,105 scaphoid fractures based on AO classification.

■ Scaphoid Fractures by Fracture Type Based on Russe Classification

See ▶ Table 8.18 and ▶ Fig. 8.21.

Table 8.18 Fracture pattern distribution of 2,105 scaphoid fractures by Russe classification

Fracture pattern	Male	Female	Number of fractures	Percentage	Percentage of carpal fractures	Percentage of hand fractures
Horizontal	698	197	895	42.52	29.21	1.52
Transverse	865	257	1,122	53.30	36.62	1.91
Vertical	71	17	88	4.18	2.87	0.15
Total	1,634	471	2,105	100.00	68.70	3.58

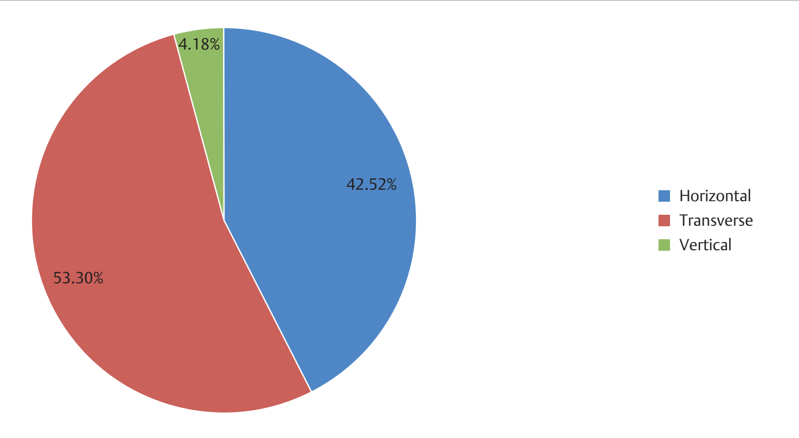
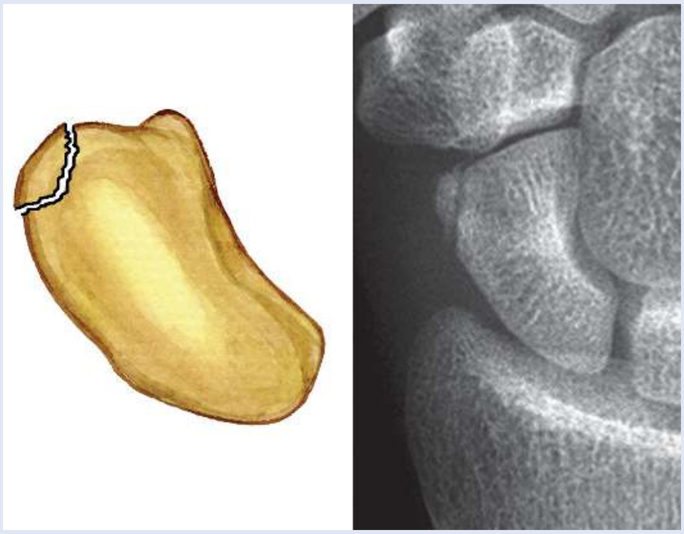
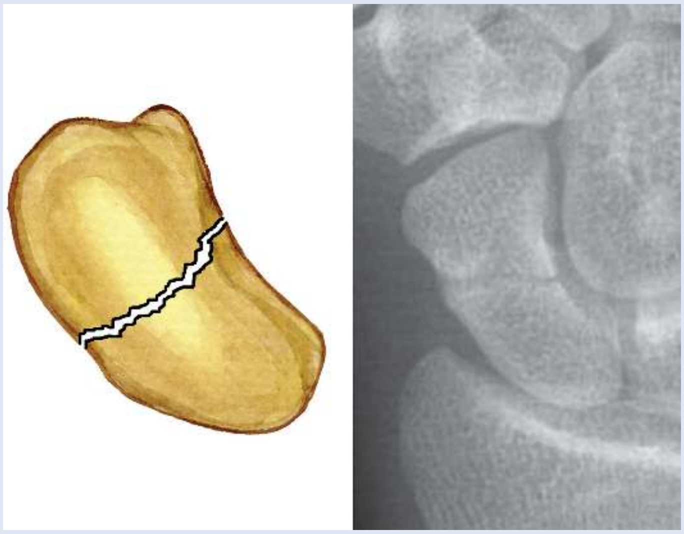
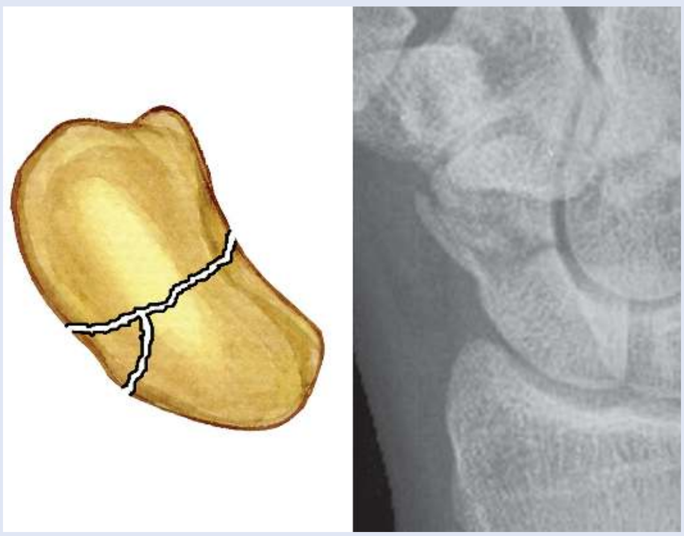
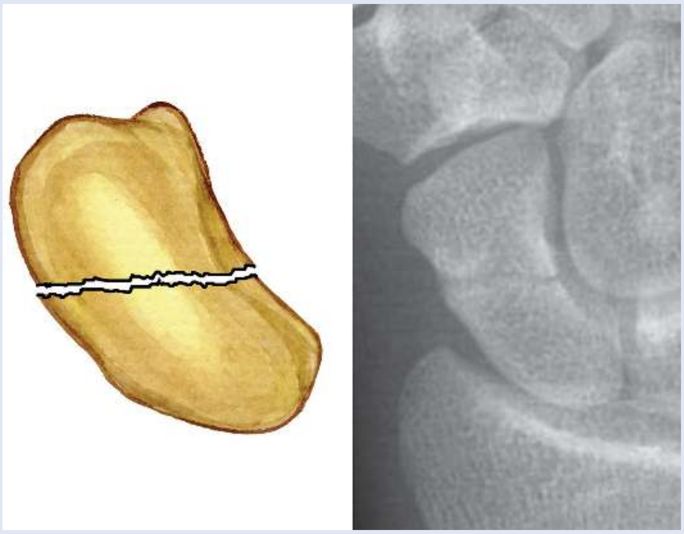
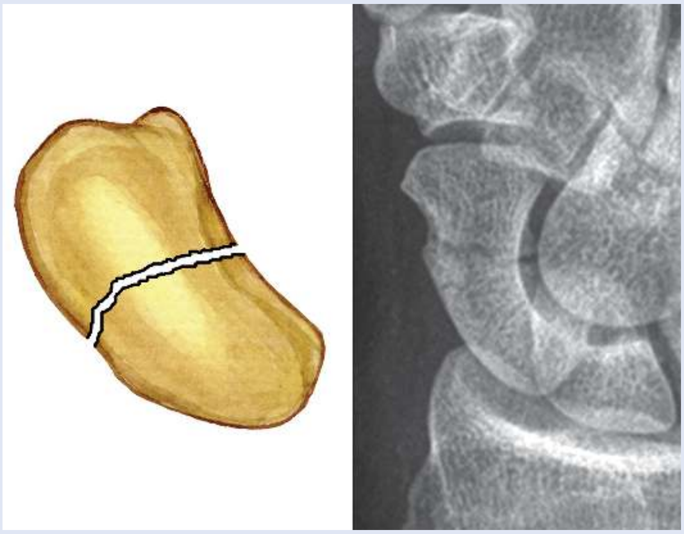
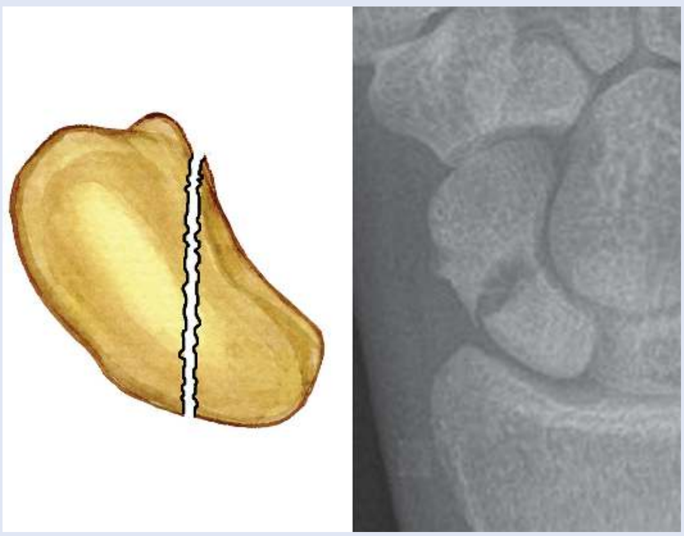


Fig. 8.21 Fracture pattern distribution of 2,105 scaphoid fractures by Russe classification.

AO classification of scaphoid fractures	
Type-A 312 fractures M: 233 (74.68%) F: 79 (25.32%) 0.08% of total adult fractures 0.53% of adult hand fractures 10.18% of adult carpal fractures 14.82% of adult scaphoid fractures	**AO Type-A** Avulsion fracture of tubercle 
Type-B 1,637 fractures M: 1,272 (77.70%) F: 365 (22.30%) 0.44% of total adult fractures 2.78% of adult hand fractures 53.43% of adult carpal fractures 77.77% of adult scaphoid fractures	**AO Type-B** Waist fractures 
Type-C 156 fractures M: 129 (82.69%) F: 27 (17.31%) 0.04% of total adult fractures 0.27% of adult hand fractures 5.09% of adult carpal fractures 7.41% of adult scaphoid fractures	**AO Type-C** Multiple fragments or comminuted fractures 

Russe classification of scaphoid fractures	
Horizontal 895 fractures M: 698 (77.99%) F: 197 (22.01%) 0.24% of total adult fractures 1.52% of adult hand fractures 29.21% of adult carpal fractures 42.52% of adult scaphoid fractures	**Russe–Horizontal** 
Transverse 1,122 fractures M: 865 (77.09%) F: 257 (22.91%) 0.30% of total adult fractures 1.91% of adult hand fractures 36.62% of adult carpal fractures 53.30% of adult scaphoid fractures	**Russe–Transverse** 
Vertical 88 fractures M: 71 (80.68%) F: 17 (19.32%) 0.02% of total adult fractures 0.15% of adult hand fractures 2.87% of adult carpal fractures 4.18% of adult scaphoid fractures	**Russe–Vertical** 

Injury Mechanism

The scaphoid usually fractures secondary to excessive compression, which produces changes in the scaphoid itself or its surrounding structures. Because of the anatomic features of the waist of the scaphoid—thin and across two rows of carpal bones—it tends to fracture easily when subject to compression-force injuries. The typical injury mechanism is a fall on the outstretched hand, with the wrist in extension and radial deviation.

Diagnosis

Patients usually present with history of a fall, with the wrist in dorsiflexion, or a traumatic event. Dorsal wrist pain is elicited when the wrist is dorsiflexed. Tenderness is usually present in the area under the styloid process of the radius, in the area of the volar scaphoid tubercle, or in the anatomic snuffbox. There may be discomfort or pain elicited from the scaphoid with percussion of the head of the second and third metacarpal bones. X-rays help to rule out a scaphoid fracture. Standard radiographs should include posteroanterior (PA), lateral, oblique, and ulnar-deviated “clenched fist” PA views. The fracture may not be visible on plain radiographs initially. If plain radiographs are inconclusive but a scaphoid fracture is still suspected, a CT scan can be done or the radiographs should be repeated in 1 to 2 weeks; by then, the bone will have had a chance to undergo visible resorptive changes as a response to the fracture, making the fracture visible on X-ray.

Treatment

Stable scaphoid fractures or fractures that can be manually reduced can be managed nonsurgically. A thumb spica cast is used for 8 to 12 weeks. Failure of nonsurgical treatment or acutely displaced scaphoid fractures warrant open reduction and internal fixation, usually with a Kirschner wire (K-wire) or screws (cannulated or Herbert screws). To make sure the bones are healing, a long arm cast might be needed for 6 to 8 weeks after surgery, followed by a short-arm thumb spica cast for another 6 to 8 weeks.

Metacarpal Fractures (Segment 77)

Anatomic Features

Each metacarpus consists of three parts: a body, head, and base. The base articulates with the carpus, and with the adjoining metacarpal bones. The body is prismoid in form and curved, so as to be convex in the longitudinal direction posteriorly, and concave anteriorly. The medial and lateral surfaces are concave for the attachment of the interossei. There is a tubercle on either side of the head for attachment of the collateral ligaments of the metacarpophalangeal joint. The dorsal surface, which is broad and flat, supports the extensor tendons.

OTA Classification of Metacarpal Fractures

Based on OTA classification, metacarpal fractures are classified as the following: 77-A, metacarpal proximal and distal extra-articular and diaphysis noncomminuted; 77-B, metacarpal proximal and distal partial articular and diaphysis wedge comminuted; and 77-C, metacarpal proximal and distal complete articular and diaphysis comminuted (▶ Fig. 8.22).

Clinical Epidemiologic Features of Metacarpal Fractures in Adults (Segment 77)

A total of 10,124 adult patients with 10,145 metacarpal fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied: the fractures accounted for 17.54% of all adult patients with hand fractures and 17.24% of hand fractures in adults. Their epidemiologic features are as follows:

- More males than females
- The high-risk age group is 21–25 years, the same age group for males, whereas the high-risk age groups for females are 36–40 years and 41–45 years
- The most commonly seen fracture type is type 77-A, the same for both males and females
- The most commonly seen fracture group is group 77-A2, the same for both males and females
- The number of fractures of the fifth metacarpal outweighs the number of any other metacarpal fracture

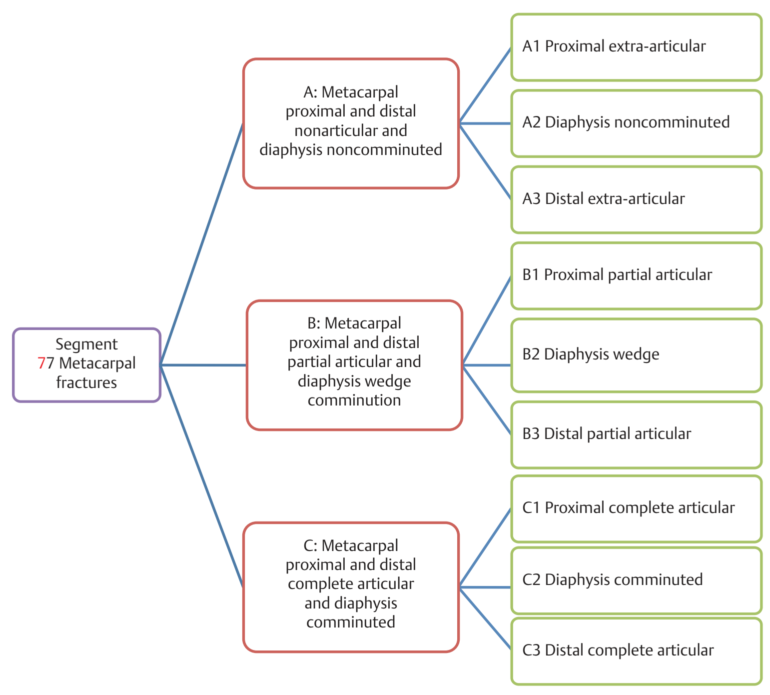


Fig. 8.22 Algorithm.

■ Metacarpal Fractures (Segment 77) by Sex

See ▶ Table 8.19 and ▶ Fig. 8.23.

Table 8.19 Sex distribution of 10,124 patients with metacarpal bone (segment 77) fractures

Sex	Number of patients	Percentage
Male	8,392	82.89
Female	1,732	17.11
Total	10,124	100.00

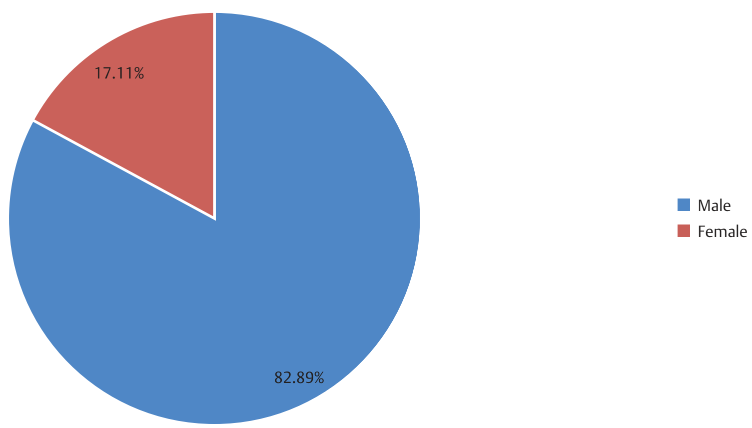


Fig. 8.23 Sex distribution of 10,124 patients with metacarpal bone (segment 77) fractures.

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■ Metacarpal Fractures (Segment 77) by Age Group

See ▶ Table 8.20 and ▶ Fig. 8.24.

Table 8.20 Age and sex distribution of 10,124 patients with fractures of metacarpal bone (segment 77)

Age group (years)	Male	Female	Number of patients	Percentage
16–20	1,136	104	1,240	12.25
21–25	1,666	177	1,843	18.20
26–30	1,376	149	1,525	15.06
31–35	1,004	178	1,182	11.68
36–40	882	200	1,082	10.69
41–45	771	201	972	9.60
46–50	572	160	732	7.23
51–55	369	145	514	5.08
56–60	283	148	431	4.26
61–65	143	89	232	2.29
66–70	70	77	147	1.45
71–75	59	39	98	0.97
76–80	42	42	84	0.83
81–85	14	17	31	0.31
≥ 86	5	6	11	0.11
Total	8,392	1,732	10,124	100.00

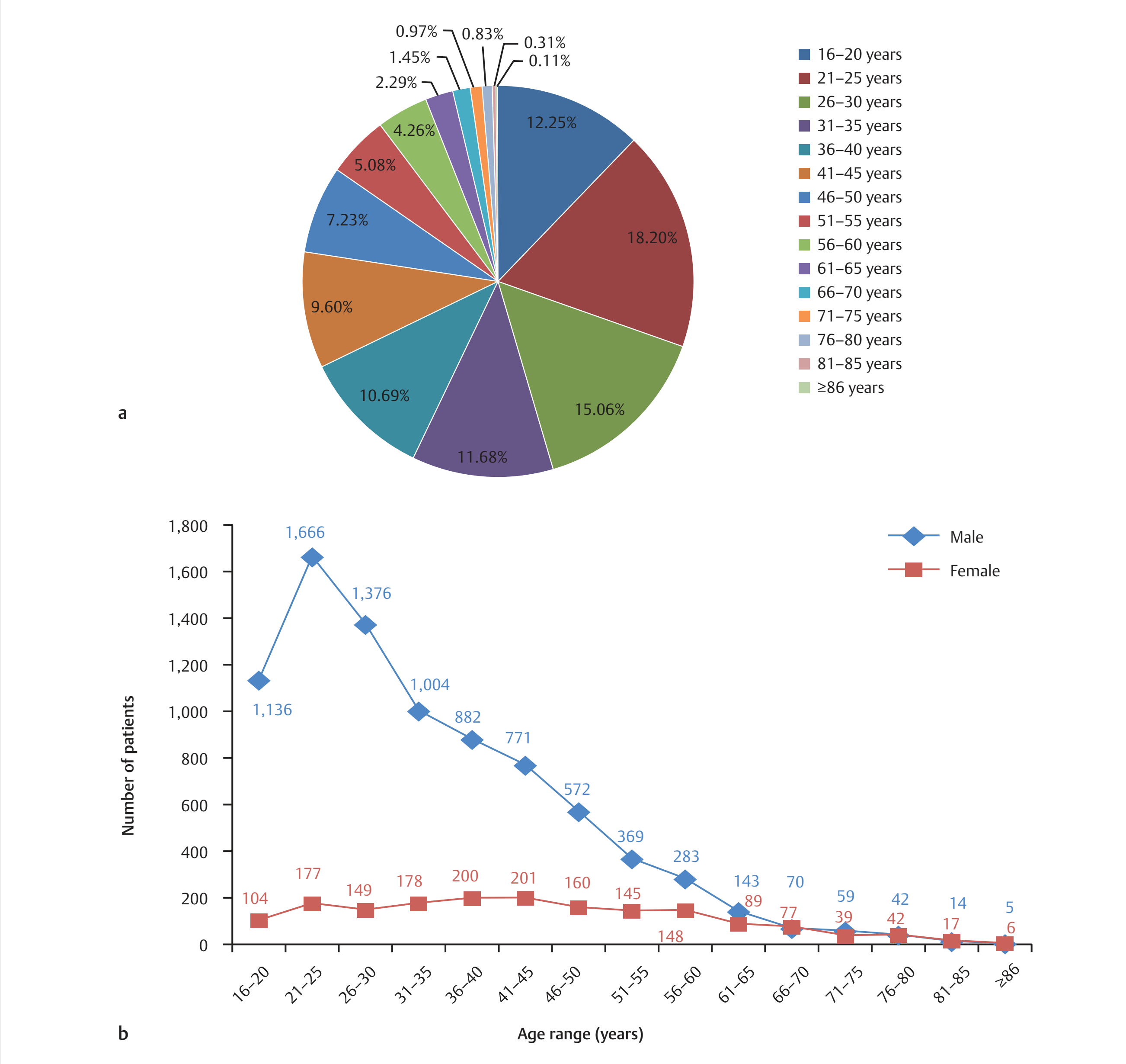

Fig. 8.24 (**a**) Age distribution of 10,124 patients with fractures of metacarpal bones (segment 77). (**b**) Age and sex distribution of 10,124 patients with fractures of metacarpal bones (segment 77).

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■ Metacarpal Fractures (Segment 77) by Fracture Type

See ▶ Table 8.21, ▶ Table 8.22, ▶ Fig. 8.25, and ▶ Fig. 8.26.

Table 8.21 Sex and fracture type distribution of 10,145 fractures of metacarpal bones (segment 77)

Fracture type	Male	Female	Number of fractures	Percentage
77-A	5,975	1,190	7,165	70.63
77-B	1,687	412	20,99	20.69
77-C	749	132	881	8.68
Total	8,411	1,734	10,145	100.00

Table 8.22 Sex and fracture group distribution of 10,145 fractures of metacarpal bones (segment 77)

Fracture group	Male	Female	Number of fractures	Percentage
77-A1	1,488	318	1,806	17.80
77-A2	2,443	573	3,016	29.73
77-A3	2,044	299	2,343	23.10
77-B1	993	248	1,241	12.23
77-B2	446	105	551	5.43
77-B3	248	59	307	3.03
77-C1	406	53	459	4.52
77-C2	242	54	296	2.92
77-C3	101	25	126	1.24
Total	8,411	1,734	10,145	100.00

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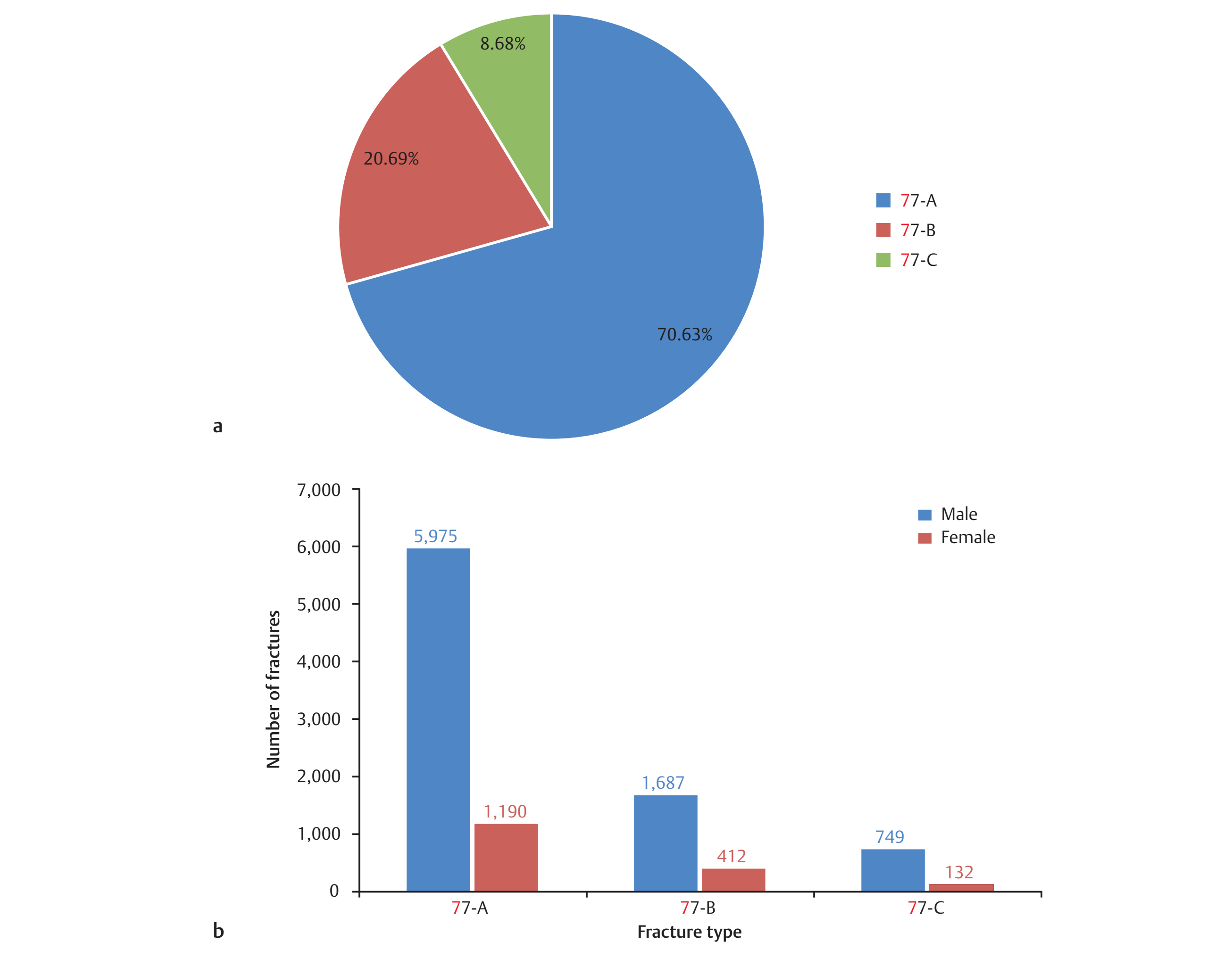

Fig. 8.25 (a) Fracture type distribution of 10,145 fractures of metacarpal bones (segment 77). (b) Sex and fracture type distribution of 10,145 fractures of metacarpal bones (segment 77).

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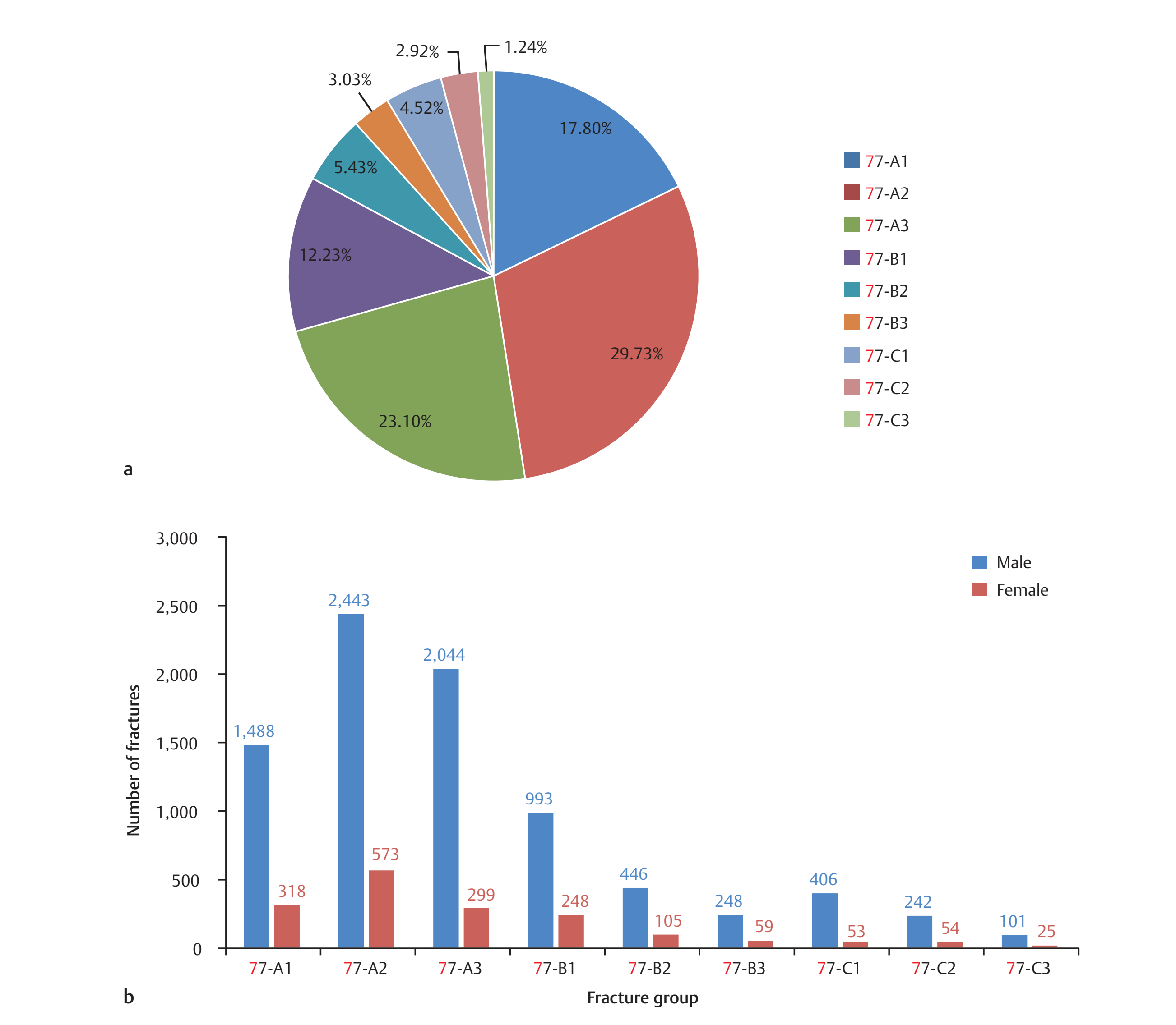


Fig. 8.26 (a) Fracture group distribution of 10,145 fractures of metacarpal bones (segment 77). (b) Sex and fracture group distribution of 10,145 fractures of metacarpal bones (segment 77).

■ Metacarpal Fractures by Individual Metacarpal Bone

See ▶ Table 8.23 and ▶ Fig. 8.27.

Table 8.23 Sex distribution of 10,145 metacarpal fractures by individual metacarpal bone

Number of metacarpal	Male	Female	Number of fractures	Percentage
1st	1,453	322	1,775	17.50
2nd	907	190	1,097	10.81
3rd	727	200	927	9.14
4th	1,569	397	1,966	19.38
5th	3,755	625	4,380	43.17
Total	8,411	1,734	10,145	100.00

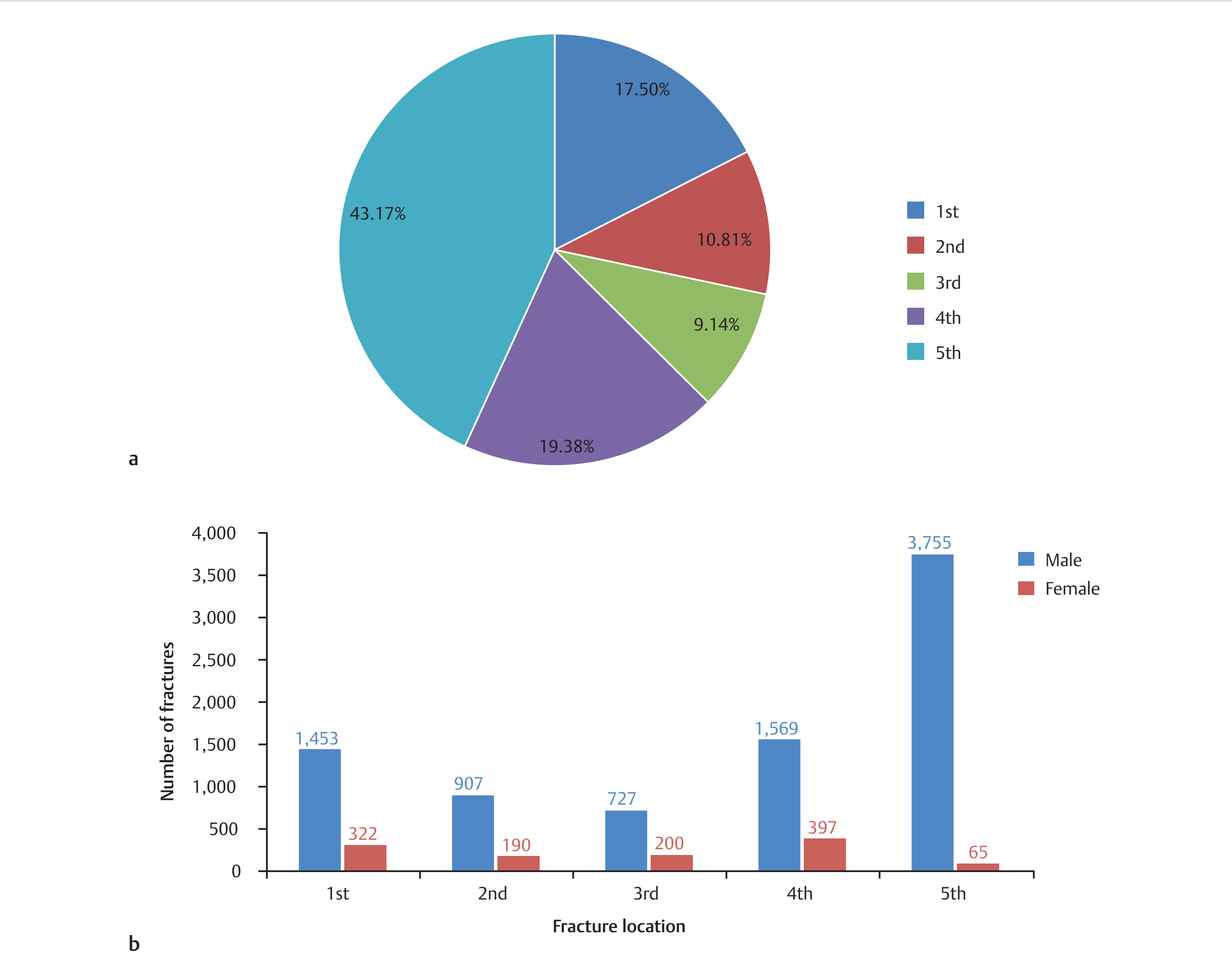
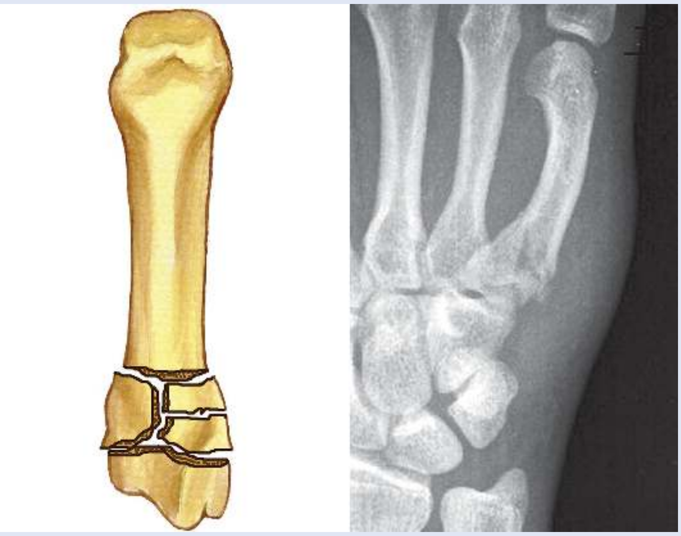


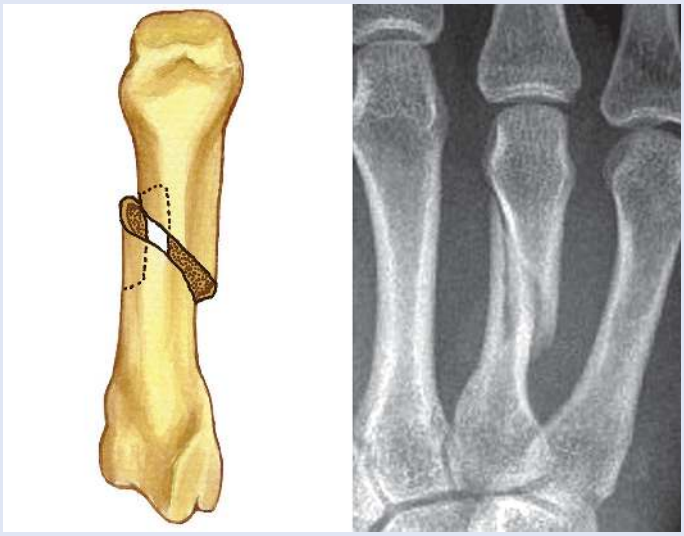
Fig. 8.27 (**a**) Distribution of 10,145 fractures of metacarpal bones by individual metacarpal bone. (**b**) Sex distribution of 10,145 fractures of metacarpal bones by individual metacarpal bone.

77-A: Metacarpal proximal and distal nonarticular and diaphysis noncomminuted	
77-A1 Proximal extra-articular 1,806 fractures M: 1,488 (82.39%) F: 318 (17.61%) 0.48% of total adult fractures 3.07% of adult hand fractures 17.80% of adult metacarpal fractures 25.21% of type 77-A fractures	**77-A1.1** Simple  **77-A1.2** Wedge or comminuted 

77-A: Metacarpal proximal and distal nonarticular and diaphysis noncomminuted

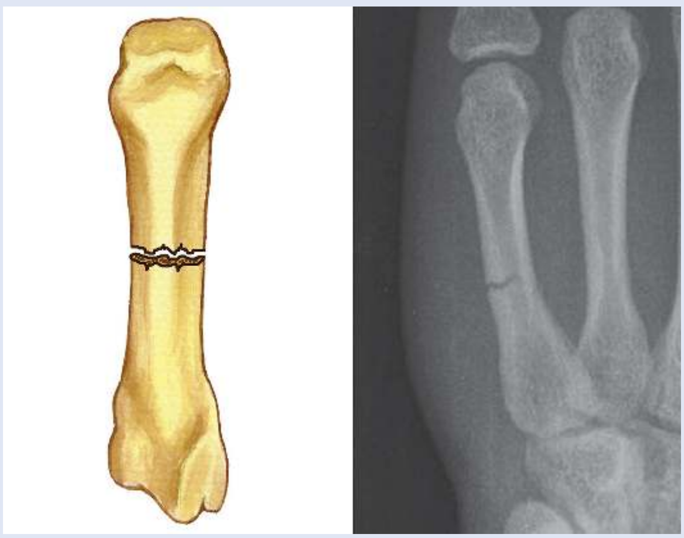
77-A2 Diaphysis noncomminuted
3,016 fractures
M: 2,443 (81.00%)
F: 573 (19.00%)
0.81% of total adult fractures
5.12% of adult hand fractures
29.73% of adult metacarpal fractures
42.09% of type 77-A fractures

77-A2.1 Spiral



77-A2.2 Oblique

77-A2.3 Transverse

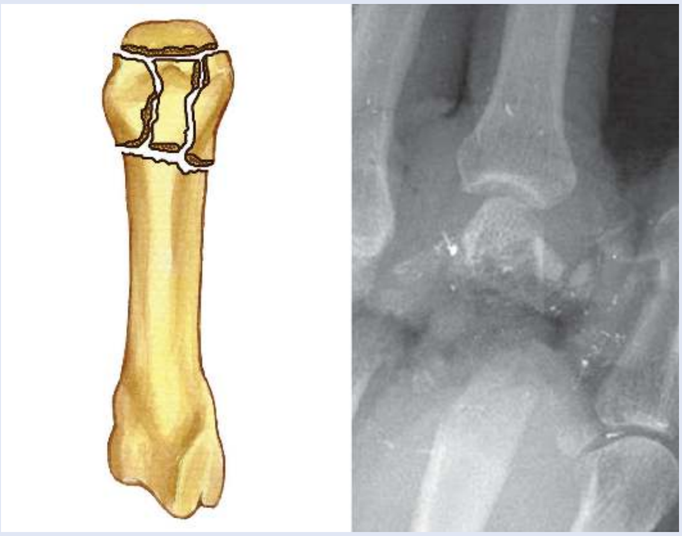


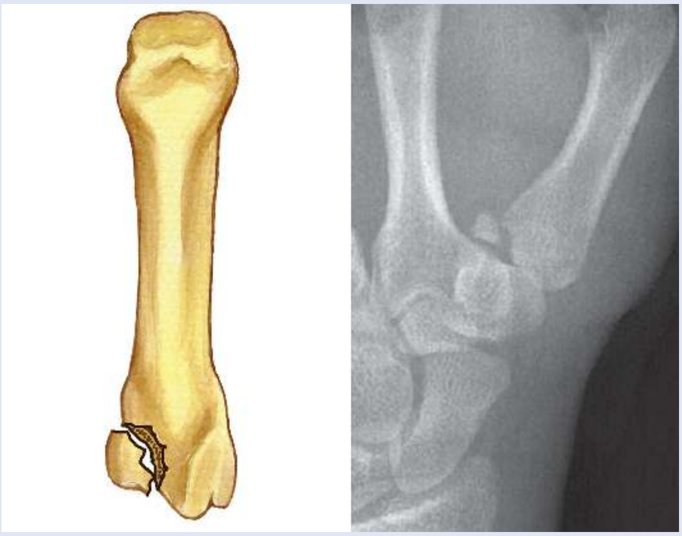
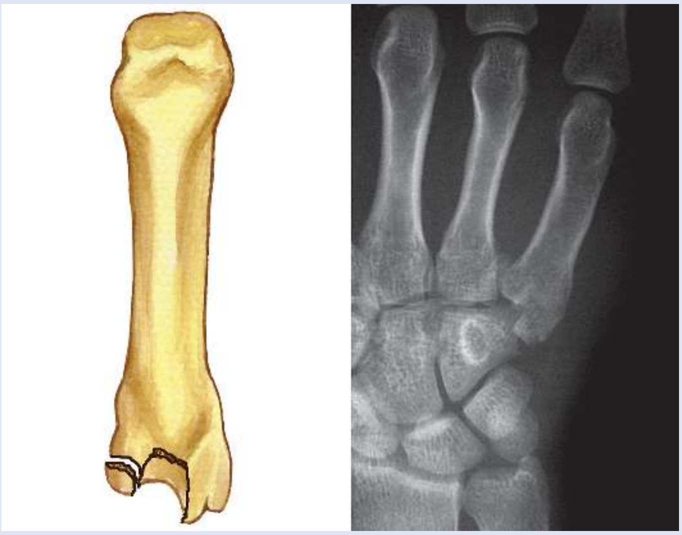
77-A: Metacarpal proximal and distal nonarticular and diaphysis noncomminuted

77-A3 Distal extra-articular
2,343 fractures
M: 2,044 (87.24%)
F: 299 (12.76%)
0.63% of total adult fractures
3.98% of adult hand fractures
23.10% of adult metacarpal fractures
32.70% of type 77-A fractures

77-A3.1 Simple

77-A3.2 Comminuted



77-B: Metacarpal proximal and distal partial articular and diaphysis wedge comminution	
77-B1 Proximal partial articular 1,241 fractures M: 993 (80.02%) F: 248 (19.98%) 0.33% of total adult fractures 2.11% of adult hand fractures 12.23% of adult metacarpal fractures 59.12% of type 77-B fractures	**77-B1.1** Avulsion or split 
	77-B1.2 Depression 
	77-B1.3 Split/depression 

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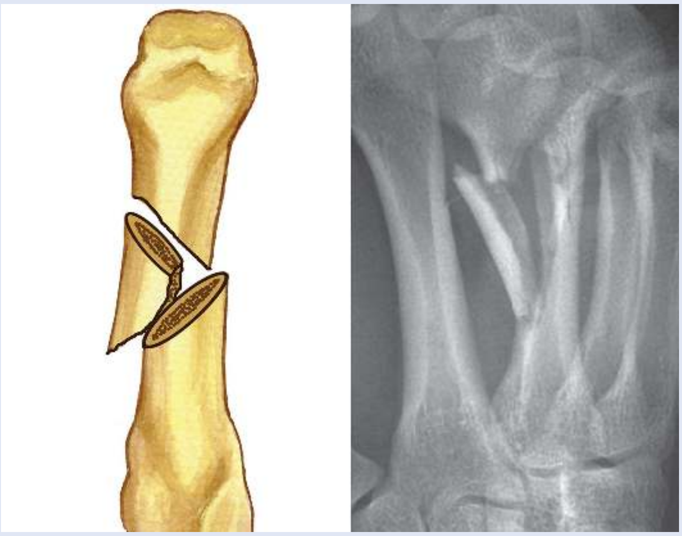
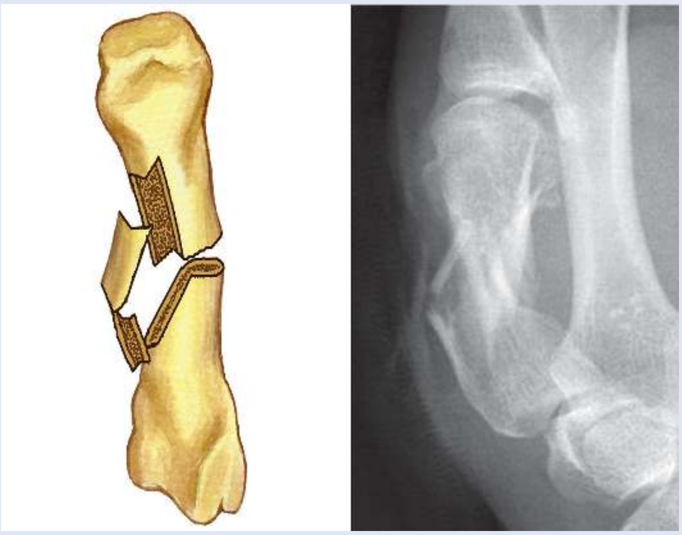
77-B: Metacarpal proximal and distal partial articular and diaphysis wedge comminution	
77-B2 Diaphysis wedge 551 fractures M: 446 (80.94%) F: 105 (19.06) 0.15% of total adult fractures 0.94% of adult hand fractures 5.43% of adult metacarpal fractures 26.25% of type 77-B fractures	**77-B2.1** Spiral wedge 
	77-B2.2 Bending wedge 
	77-B2.3 Comminuted 

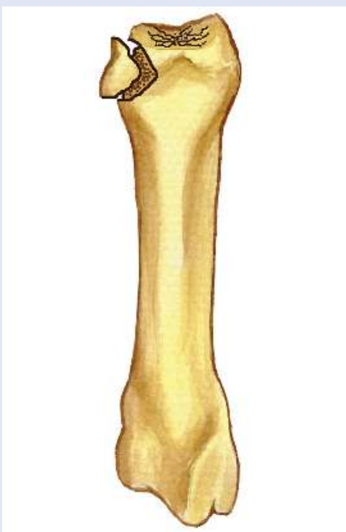
77-B: Metacarpal proximal and distal partial articular and diaphysis wedge comminution

77-B3 Distal partial articular
307 fractures
M: 248 (80.78%)
F: 59 (19.22%)
0.08% of total adult fractures
0.52% of adult hand fractures
3.03% of adult metacarpal fractures
14.63% of type 77-B fractures

77-B3.1 Avulsion or split


77-B3.2 Depression

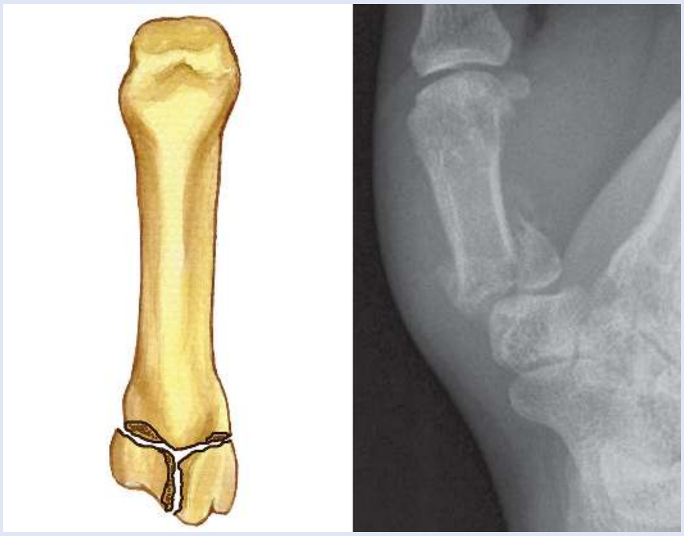

77-B3.3 Split/depression



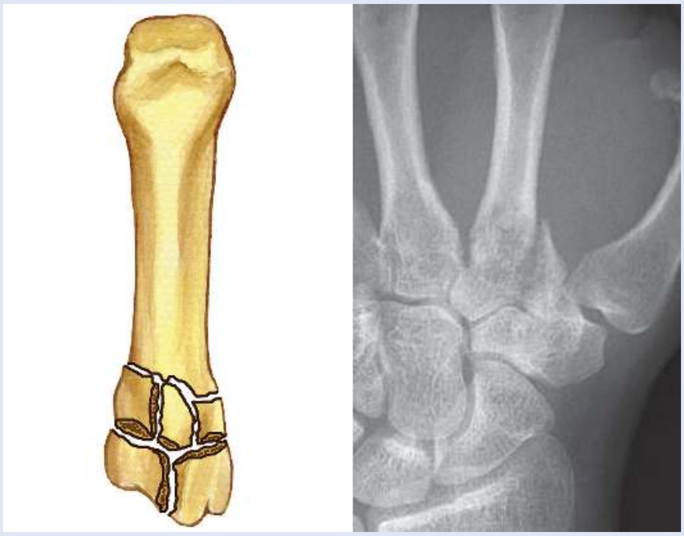

77-C: Metacarpal proximal and distal complete articular and diaphysis comminuted

77-C1 Proximal complete articular
459 fractures
M: 406 (88.45%)
F: 53 (11.55%)
0.12% of total adult fractures
0.78% of adult hand fractures
4.52% of adult metacarpal fractures
52.10% of type 77-C fractures

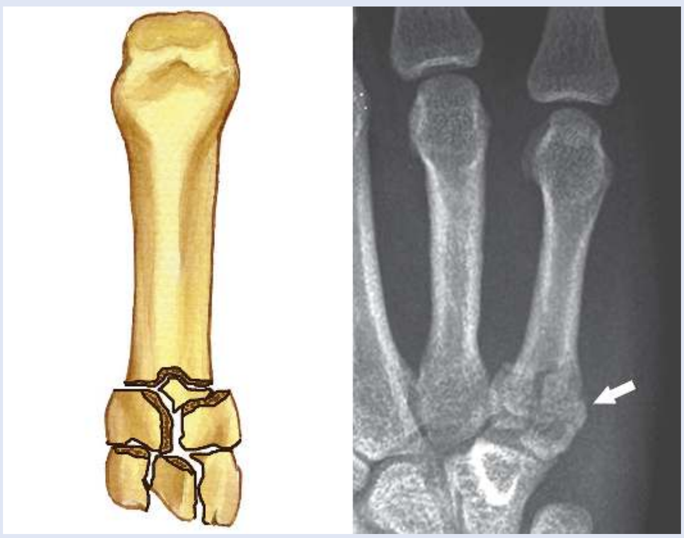
77-C1.1 Noncomminuted articular and metaphysis



77-C1.2 Noncomminuted articular, comminuted metaphysis



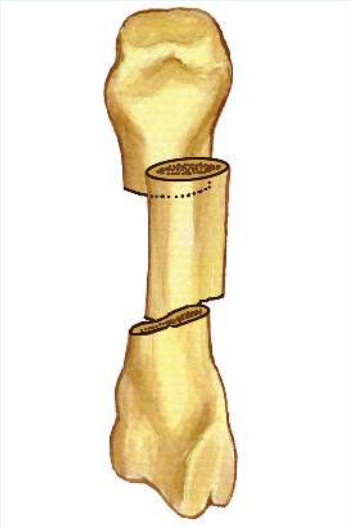
77-C1.3 Comminuted articular



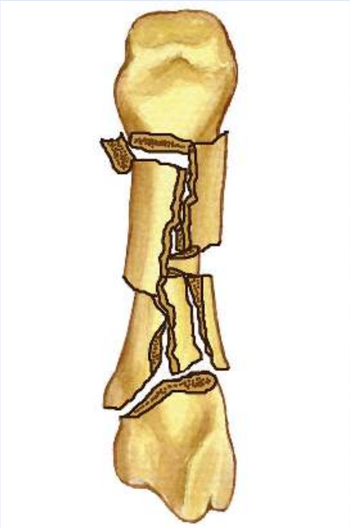
77-C: Metacarpal proximal and distal complete articular and diaphysis comminuted

77-C2 Diaphysis comminuted
296 fractures
M: 242 (81.76%)
F: 54 (18.24%)
0.08% of total adult fractures
0.50% of adult hand fractures
2.92% of adult metacarpal fractures
33.60% of type 77-C fractures

77-C2.1 Segmental



77-C2.2 Complex comminuted

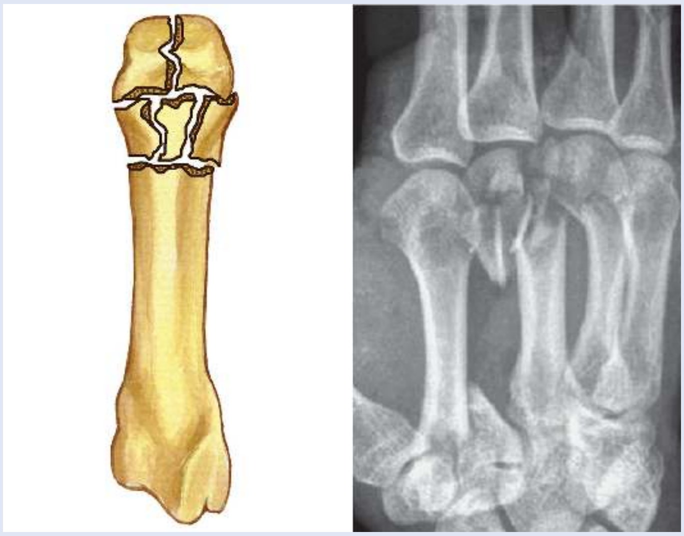


77-C: Metacarpal proximal and distal complete articular and diaphysis comminuted

77-C3 Distal articular
126 fractures
M: 101 (80.16%)
F: 25 (19.84%)
0.03% of total adult fractures
0.21% of adult hand fractures
1.24% of adult metacarpal fractures
14.30% of type 77-C fractures

77-C3.1 Simple articular/metaphysis

77-C3.2 Simple articular/comminuted metaphysis



77-C3.3 Comminuted articular

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Injury Mechanism

Fractures of metacarpals generally occur with a straightforward history of trauma. Injury to the first metacarpal shaft occurs when an axial or torsional force is transmitted through a partially flexed thumb metacarpal. Because of the pull of the thenar muscles and the abductor pollicis longus, the proximal fragment may be angularly displaced dorsally and radially, with the thumb in adduction. Rotational deformity of the thumb may also be present. Fractures of the second to fifth metacarpals usually occur as a result of compression or torsional force injuries.

Diagnosis

Diagnosis is usually directed by trauma history and clinical examination. Pain, swelling, deformity, tenderness, and loss of motion are common with any fractures or dislocation. Standard radiographs including AP and lateral views of the hand should be performed to help define the nature of the fracture, and the degree of the displacement.

Treatment

Most metacarpal fractures can be managed nonoperatively, utilizing closed reduction and casting or splinting, with a good long-term clinical outcome. Indications for open reduction and internal fixation (plating or K-wire), or closed reduction and percutaneous wire fixation include the following: (1) displaced intra-articular fractures; (2) avulsion fractures associated with torn ligaments or tendons; (3) failure to achieve or maintain acceptable reduction using closed techniques; (4) multiple hand fractures; and (5) open fractures.

Further Classification of Base Fracture of the First Metacarpal Bone

Anatomic Features and Classification

The base of the first metacarpal bone presents a concavo-convex surface, which forms the carpometacarpal joint of the thumb, with its reciprocal articular surface formed by the greater multangular bone. The joint, having saddle-shaped surfaces, is capable of moving in all directions, which allows the thumb freedom of motion, described as: extension and flexion (parallel to the palm), abduction and adduction (at right angles to the palm), as well as some rotation. The joint is surrounded by a thick but loose joint capsule that is reinforced by several ligaments. The laxity of the joint capsule permits a great amount of movement by the thumb.

Fractures of the base of the first metacarpal are particularly common. Based on the X-ray appearance, fractures of the thumb metacarpal are classified into four types:

- *Type I* injury is a fracture-dislocation of the base of the thumb metacarpal, a so-called "Bennett's fracture." This injury usually occurs as a result of axially directed forces or torsional forces transmitted through the partially flexed metacarpal shaft. A proximal metacarpal fragment maintains its ulnar aspect attachment to the trapezium via the volar ligament. The distal aspect of the metacarpal is usually subluxated radially and dorsally by the adductor pollicis. The proximal aspect of this fragment is pulled proximally by the abductor pollicis longus.
- *Type II* injuries are known as "Rolando fractures" and can be thought of as a comminuted version of a Bennett fracture, in which the fragments may form a T or Y pattern at the base of the metacarpal.
- *Type III* fractures are extra-articular, either transverse or, less commonly, oblique.
- *Type IV* fractures are extra-articular pediatric injuries involving the proximal physis, and are not commonly associated with dislocation.

Clinical Epidemiologic Features of Fractures of the Base of the First Metacarpal Bone

A total of 1,243 patients with 1,244 fractures of the base of first metacarpal bone were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, accounting for 1.99% of all patients with hand fractures and 1.95% of hand fractures.

Epidemiologic features of fractures of the base of the first metacarpal bone are as follows:

- More males than females
- The high-risk age group is 21–25 years, the same age group for males and the high-risk age group for females is 51–55 years
- Type III fractures are the most common type of the base of the first metacarpal bone fractures

■ Fractures of the Base of the First Metacarpal Bone by Sex

See ▶ Table 8.24 and ▶ Fig. 8.28.

Table 8.24 Sex distribution of 1,243 patients with fractures of the base of the first metacarpal bone

Sex	Number of patients	Percentage
Male	1,016	81.74
Female	227	18.26
Total	1,243	100.00

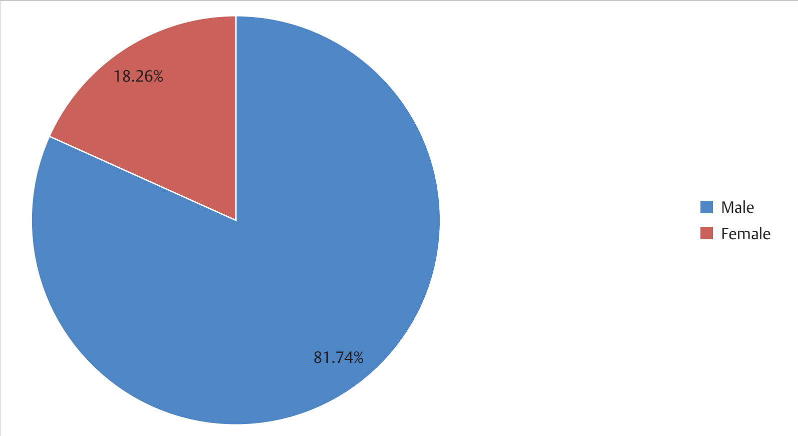

Fig. 8.28 Sex distribution of 1,243 patients with fractures of the base of the first metacarpal bone.

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■ Fractures of the Base of the First Metacarpal Bone by Age Group

See ▶ Table 8.25 and ▶ Fig. 8.29.

Table 8.25 Age and sex distribution of 1,243 patients with fractures of the base of the first metacarpal bone

Age group (years)	Male	Female	Number of patients	Percentage
0–5	6	1	7	0.56
6–10	9	0	9	0.72
11–15	20	11	31	2.49
16–20	88	5	93	7.48
21–25	143	13	156	12.55
26–30	134	14	148	11.91
31–35	115	10	125	10.06
36–40	119	20	139	11.18
41–45	103	20	123	9.90
46–50	99	24	123	9.90
51–55	62	32	94	7.56
56–60	57	25	82	6.60
61–65	21	14	35	2.82
66–70	11	17	28	2.25
71–75	14	8	22	1.77
76–80	10	10	20	1.61
81–85	4	2	6	0.48
≥ 86	1	1	2	0.16
Total	1,016	227	1,243	100

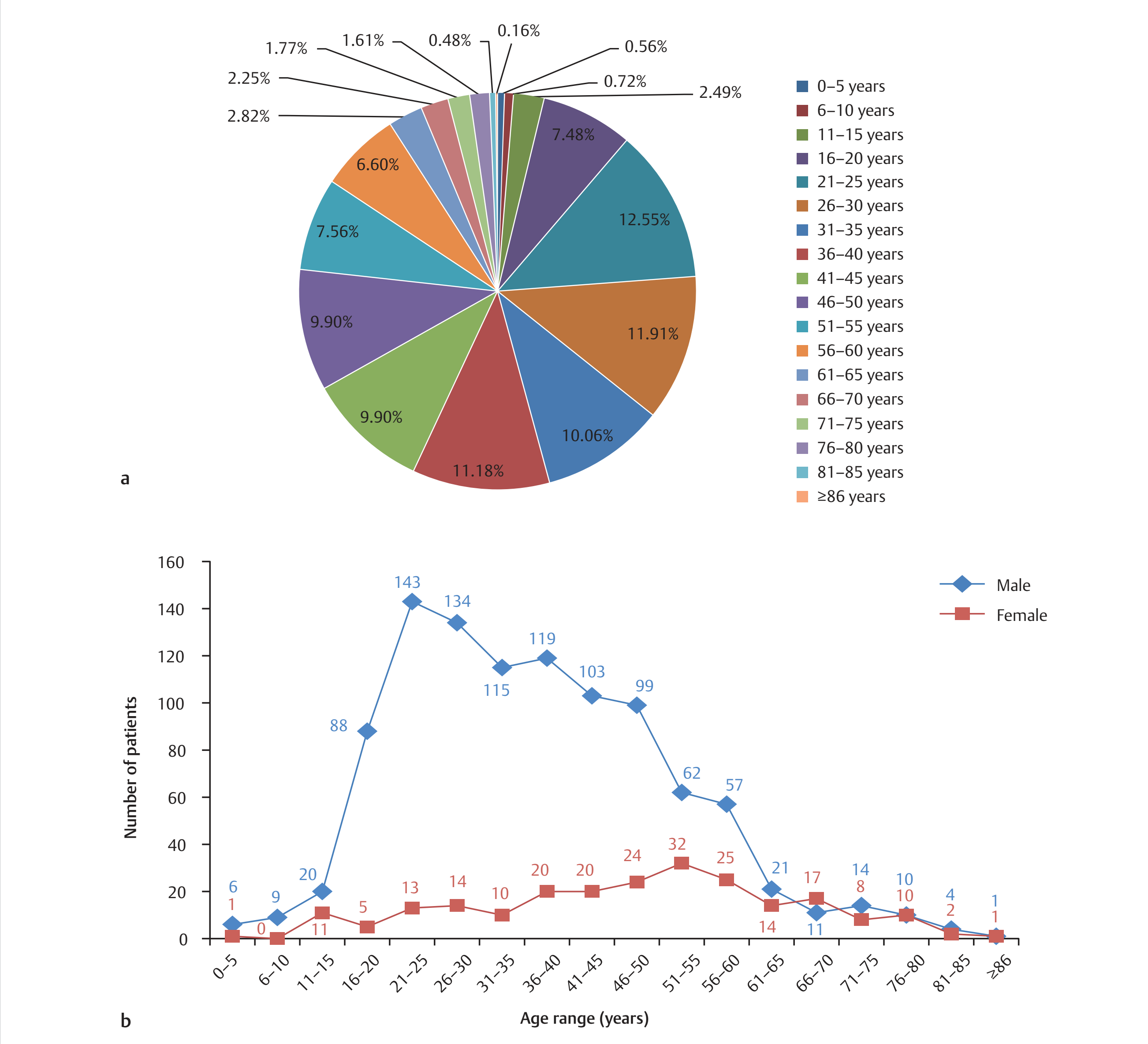


Fig. 8.29 (**a**) Age distribution of 1,243 patients with fractures of the base of the first metacarpal bone. (**b**) Age and sex distribution of 1,243 patients with fractures of the base of the first metacarpal bone.

■ Fractures of the Base of the First Metacarpal Bone by Fracture Type

See ► Table 8.26 and ► Fig. 8.30.

Table 8.26 Fracture type distribution of 1,244 fractures of the base of the first metacarpal bone

Fracture type	Male	Female	Number of fractures	Percentage	Percentage of metacarpal fractures	Percentage of hand fractures
I	385	95	480	38.59	4.38	0.75
II	135	17	152	12.22	1.39	0.24
III	462	103	565	45.42	5.16	0.89
IV	35	12	47	3.78	0.43	0.07
Total	1,017	227	1,244	100.00	11.36	1.95

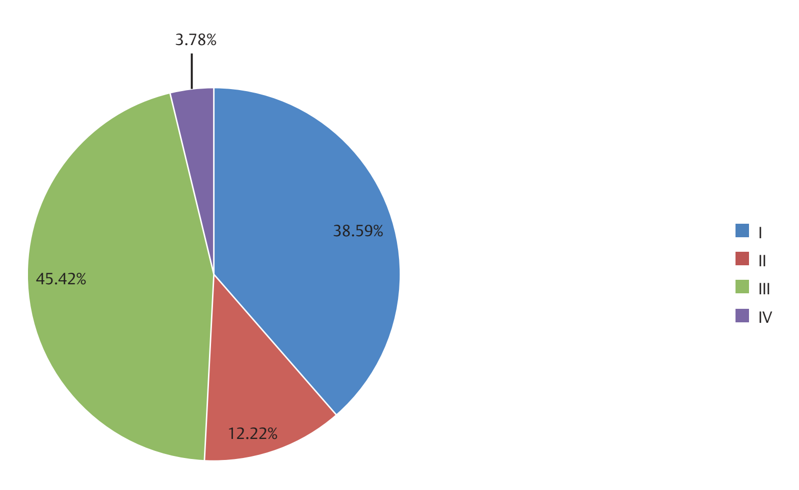
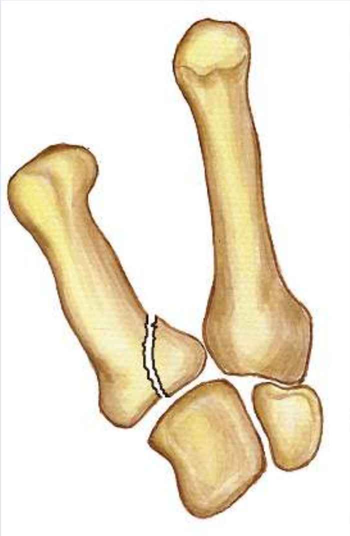
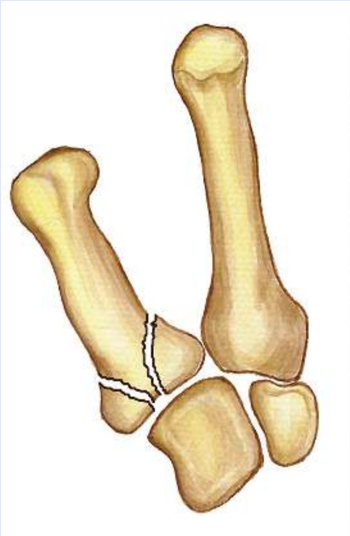
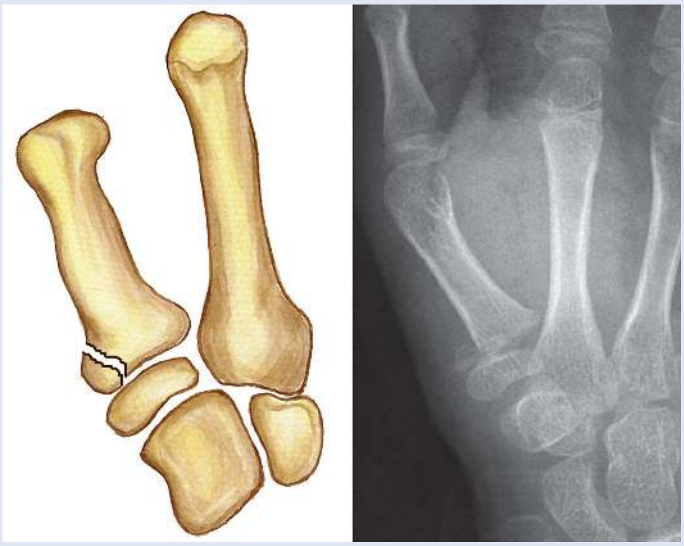


Fig. 8.30 Fracture type distribution of 1,244 fractures of the base of the first metacarpal bone.

Fractures of the base of the first metacarpal bone	
Type I 480 fractures M: 385 (80.21%) F: 95 (19.79%) 0.11% of total fractures 0.75% of hand fractures 4.38% of all metacarpal fractures 25.28% of the 1st metacarpal fractures 38.59% of the base of the 1st metacarpal fractures	**Type I**  
Type II 152 fractures M: 135 (88.82%) F: 17 (11.18%) 0.04% of total fractures 0.24% of hand fractures 1.39% of all metacarpal fractures 8.00% of the 1st metacarpal fractures 12.22% of the base of the 1st metacarpal fractures	**Type II**  

Fractures of the base of the first metacarpal bone	
Type III 565 fractures M: 462 (81.77%) F: 103 (18.23%) 0.13% of total fractures 0.89% of hand fractures 5.16% of all metacarpal bone fractures 29.75% of the 1st metacarpal fractures 45.42% of the base of the 1st metacarpal fractures	**Type III** 
Type IV 47 fractures M: 35 (74.47%) F: 12 (25.53%) 0.01% of total fractures 0.07% of hand fractures 0.43% of all metacarpal bone fractures 2.47% of the 1st metacarpal fractures 3.78% of the base of the 1st metacarpal fractures	**Type IV** 

Injury Mechanism

This type of injury usually occurs from indirect force. The distal fragment is usually adducted and displaced volarly secondary to the pull of the flexor pollicis longus and adductor pollicis. The thumb carpometacarpal joint is a saddle-shaped joint. When the ulnar aspect of the thumb's metacarpal base is fractured, the small triangle-shaped fragment remains in its correct anatomic region, and the main body of the first metacarpal is typically displaced radially and dorsally, due to the pull of the thumb extensors.

Diagnosis

Usually, it is not difficult to make a diagnosis with a straightforward trauma history and clinical examination. Swelling, pain, tenderness over the base of the thumb, loss of function (thumb opposition and abduction), and radial and dorsal angulation of the thumb base are common symptoms that indicate the presence of fracture. There is no apparent impairment in the motion of the metacarpophalangeal joints and interphalangeal joints. The diagnosis should be confirmed by radiographs, and CT scan if indicated.

Treatment

Closed reduction can be initiated but it is usually difficult to maintain the reduction. If the reduction is adequate and can maintain stability, a short arm cast is applied so as to exclude the web space for 4 to 6 weeks. Open reduction and internal fixation or percutaneous K-wire fixation should be attempted if the fracture does not reduce adequately, or it is too difficult to maintain the reduction. The fixator should be removed as soon as radiographic features show healing of the fractures. During rehabilitation, exercise with an active range of motion should be encouraged.

Phalanx Fractures (Segment 78)

Anatomic Features

There are 14 phalanges on each hand: 3 of each of the 4 fingers, and 2 of the thumb. The three types of phalanges are: the proximal phalanx, the middle phalanx (not present in the thumb), and the distal phalanx. The phalanges are all long tubular bones, each having a base, shaft, and head (also called the trochlea of the phalanx). The head of the distal phalanx is pointed, with a palmar tuberosity for attachment of the finger pulp. The shaft resides between the head and the base. On the base of each phalanx is a concave surface for articulations. The shaft is wider at the base and tapers toward the head in all phalanges. The palmar surface is slightly concave, while the dorsal surface is convex and flat on either side.

OTA Classification of Phalanx Fractures

The OTA classified phalanx fractures into three types as follows: 78-A: phalanx proximal and distal extra-articular and diaphysis noncomminuted; 78-B: phalanx proximal and distal partial articular and diaphysis wedge comminuted; and 78-C: phalanx proximal and distal complete articular and diaphysis comminuted (▶ Fig. 8.31).

Clinical Epidemiologic Features of Phalanx Fractures (Segment 78)

A total of 33,737 adult patients with 33,843 phalanx fractures were treated in 83 hospitals of China over a 2-year period from

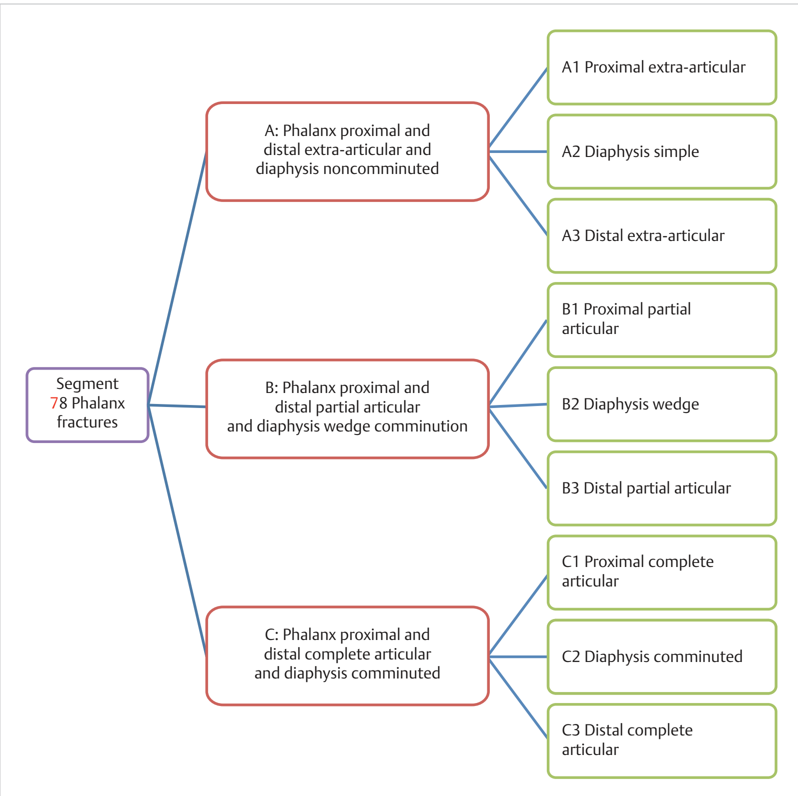


Fig. 8.31 Algorithm.

2010 to 2011. All cases were reviewed and statistically studied, accounting for 58.46% of all adult patients with hand fractures and 57.51% of all hand fractures in adults. Their epidemiologic features are as follows:

- More males than females
- The high-risk age group is 21–25 years, the same age group for males while the high-risk age group for females is 36–40 years
- The most common phalanx fracture is type 78-A, the same fracture type for both males and females
- The most common fracture group is group 78-A3, the same fracture group for both males and females
- Fractures of the index phalanx are more common than those of other phalanges

Phalanx Fractures by Sex

See ▶ Table 8.27 and ▶ Fig. 8.32.

Table 8.27 Sex distribution of 33,737 patients with phalanx fractures (segment 78)

Sex	Number of patients	Percentage
Male	26,112	77.40
Female	7,625	22.60
Total	33,737	100.00

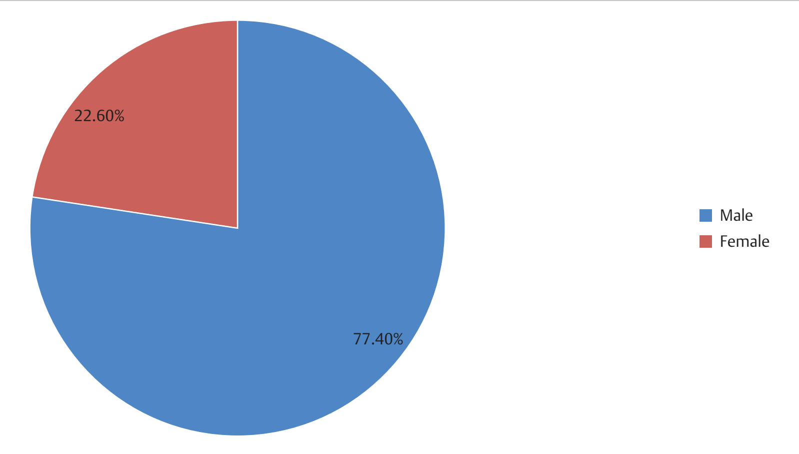


Fig. 8.32 Sex distribution of 33,737 patients with phalanx fractures (segment 78).

■ Phalanx Fractures by Age Group

See ▶ Table 8.28 and ▶ Fig. 8.33.

Table 8.28 Age and sex distribution of 33,737 patients with phalanx fractures (segment 78)

Age group (years)	Male	Female	Number of patients	Percentage
16–20	2,953	540	3,493	10.35
21–25	4,127	710	4,837	14.34
26–30	3,176	806	3,982	11.80
31–35	2,827	813	3,640	10.79
36–40	3,498	1,178	4,676	13.86
41–45	3,160	1,115	4,275	12.67
46–50	2,465	861	3,326	9.86
51–55	1,630	513	2,143	6.35
56–60	1,241	440	1,681	4.98
61–65	548	257	805	2.39
66–70	202	148	350	1.04
71–75	134	100	234	0.69
76–80	79	82	161	0.48
81–85	35	38	73	0.22
≥ 86	37	24	61	0.18
Total	26,112	7,625	33,737	100.00

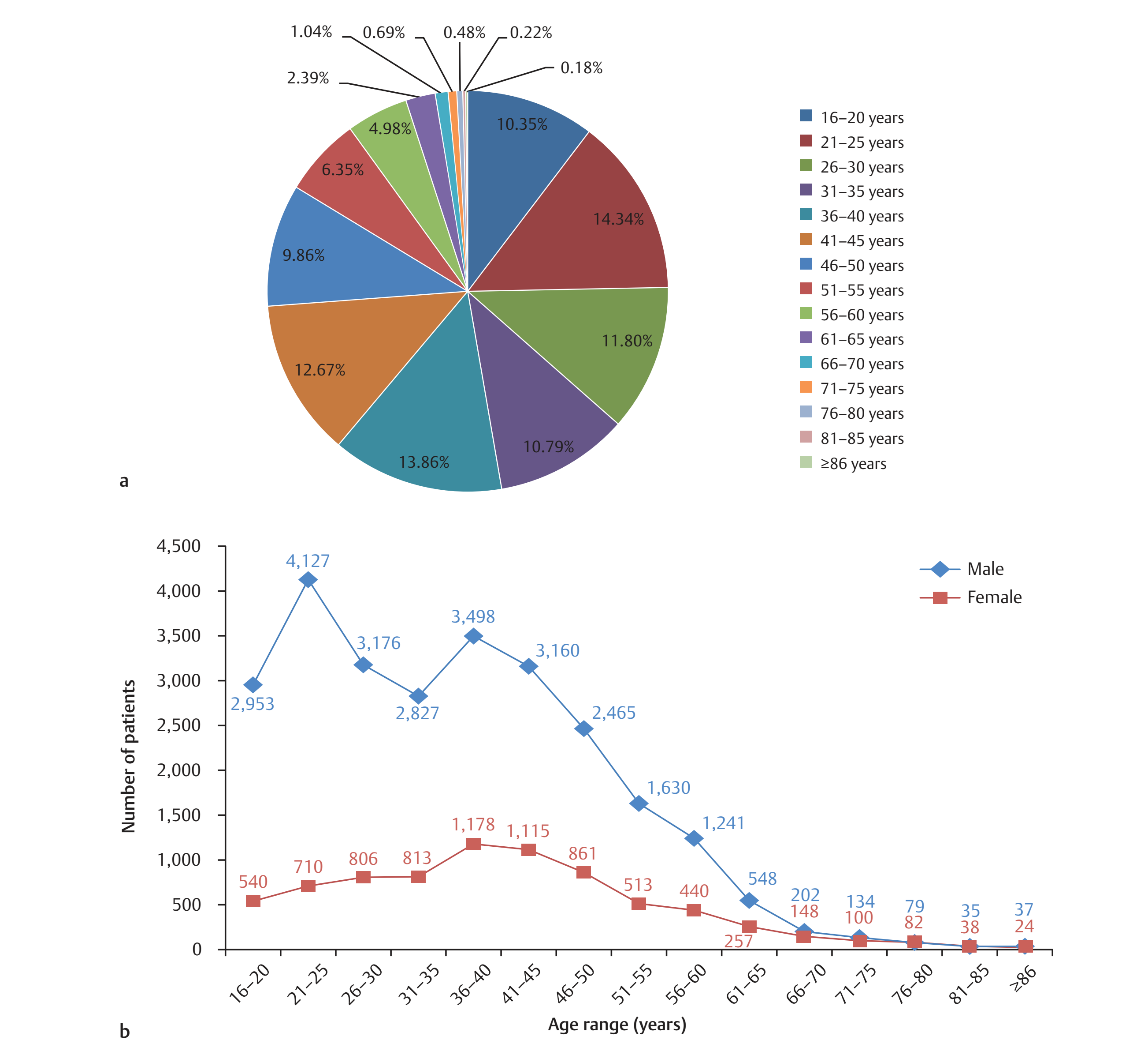


Fig. 8.33 (a) Age distribution of 33,737 patients with phalanx fractures (segment 78). (b) Age and sex distribution of 33,737 patients with phalanx fractures (segment 78).

8

■ Phalanx Fractures by Fracture Type

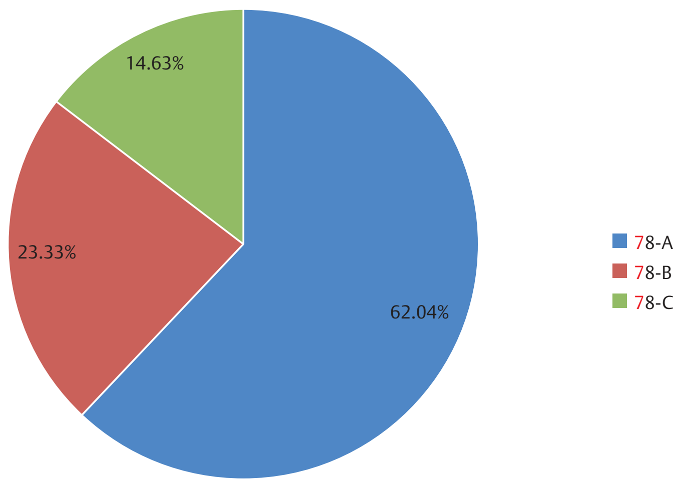
See ► Table 8.29, ► Table 8.30, ► Fig. 8.34, and ► Fig. 8.35.

Table 8.29 Sex and fracture type distribution of 33,843 fractures of phalanx (segment 78)

Fracture type	Male	Female	Number of fractures	Percentage
78-A	16,334	4,662	20,996	62.04
78-B	5,964	1,933	7,897	23.33
78-C	3,898	1,052	4,950	14.63
Total	26,196	7,647	33,843	100.00

Table 8.30 Sex and fracture group distribution of 33,843 fractures of phalanx (segment 78)

Fracture group	Male	Female	Number of fractures	Percentage
78-A1	2,733	826	3,559	10.52
78-A2	4,567	1,250	5,817	17.19
78-A3	9,034	2,586	1,1620	34.34
78-B1	2,797	1,103	3,900	11.52
78-B2	1,278	283	1,561	4.61
78-B3	1,889	547	2,436	7.20
78-C1	1,114	306	1,420	4.20
78-C2	1,899	523	2,422	7.16
78-C3	885	223	1,108	3.27
Total	26,196	7,647	33,843	100.00



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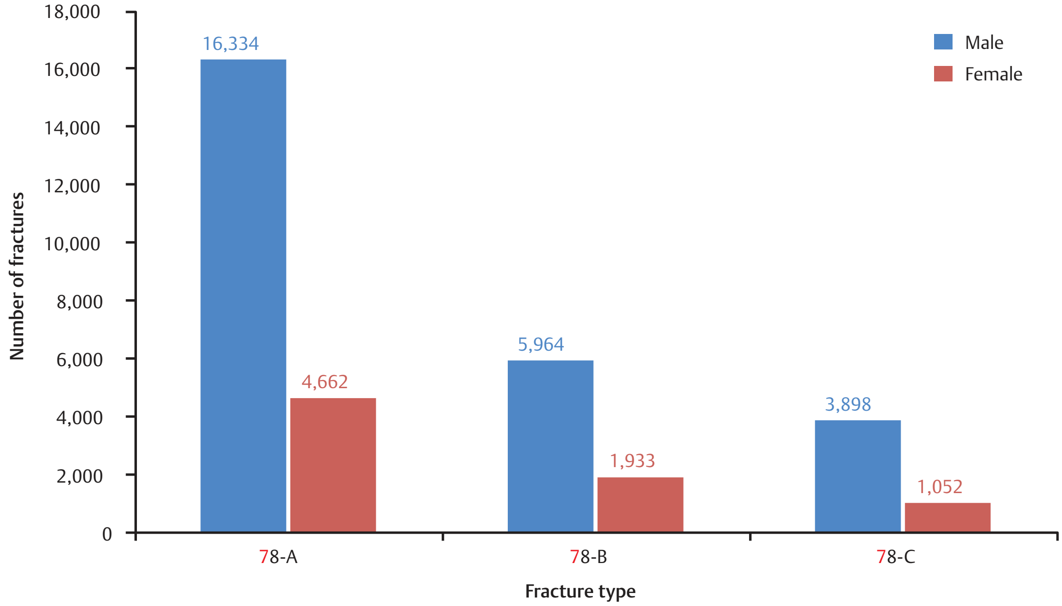


b

Fig. 8.34 (**a**) Fracture type distribution of 33,843 fractures of phalanx (segment 78). (**b**) Sex and fracture type distribution of 33,843 fractures of phalanx (segment 78).

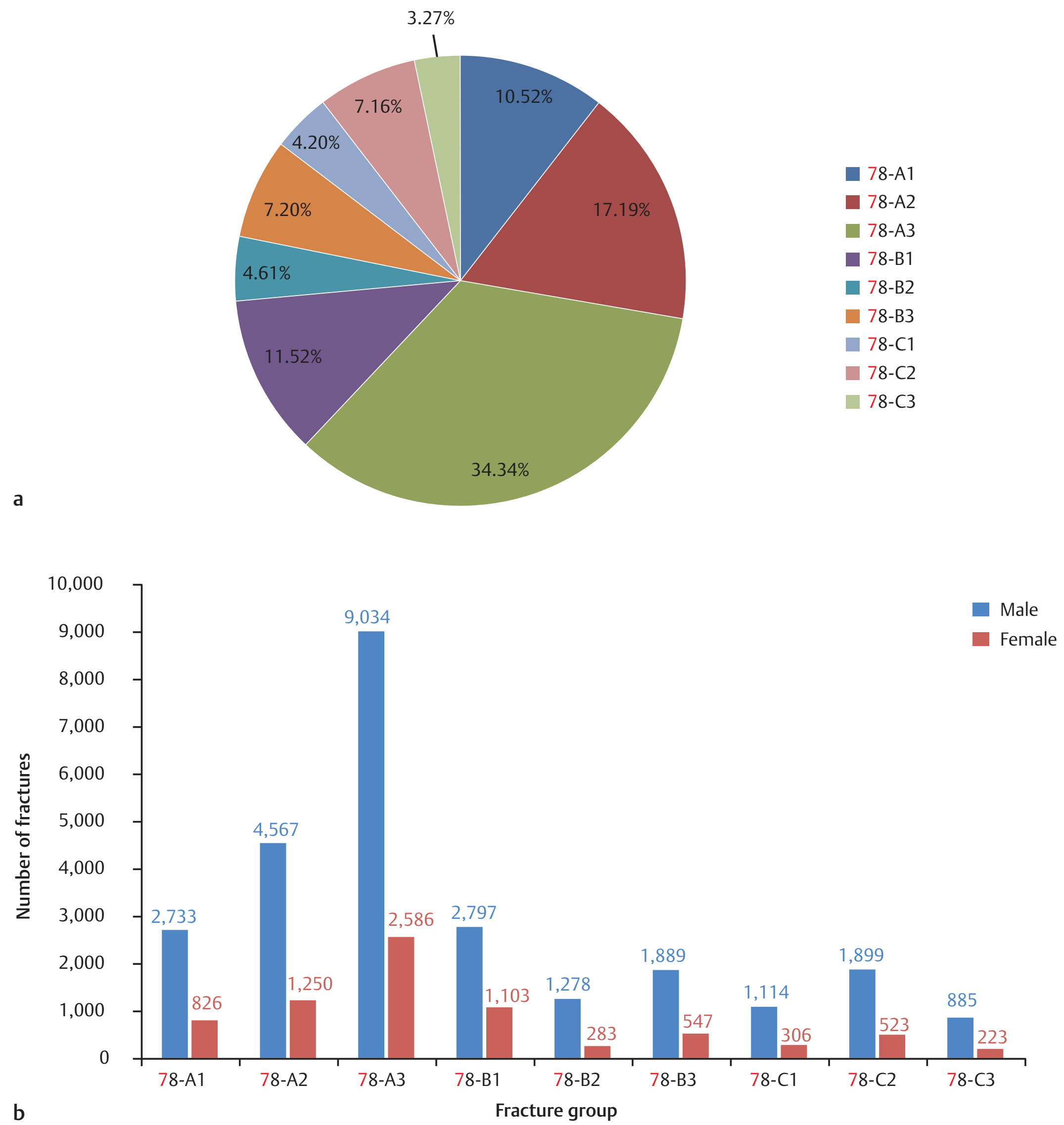


Fig. 8.35 (**a**) Fracture group distribution of 33,843 fractures of phalanx (segment 78). (**b**) Sex and fracture group distribution of 33,843 fractures of phalanx (segment 78).

■ Phalanx Fractures by Individual Finger

See ▶ Table 8.31 and ▶ Fig. 8.36.

Table 8.31 Sex distribution of 33,843 phalanx fractures by individual finger

Finger	Male	Female	Number of fractures	Percentage	Percentage of hand fractures
Thumb	5,203	1,330	6,533	19.30	11.10
Index	6,498	1,945	8,443	24.95	14.35
Middle	5,200	1,625	6,825	20.17	11.60
Ring	4,522	1,431	5,953	17.59	10.12
Little	4,773	1,316	6,089	17.99	10.35
Total	26,196	7,647	33,843	100.00	57.51

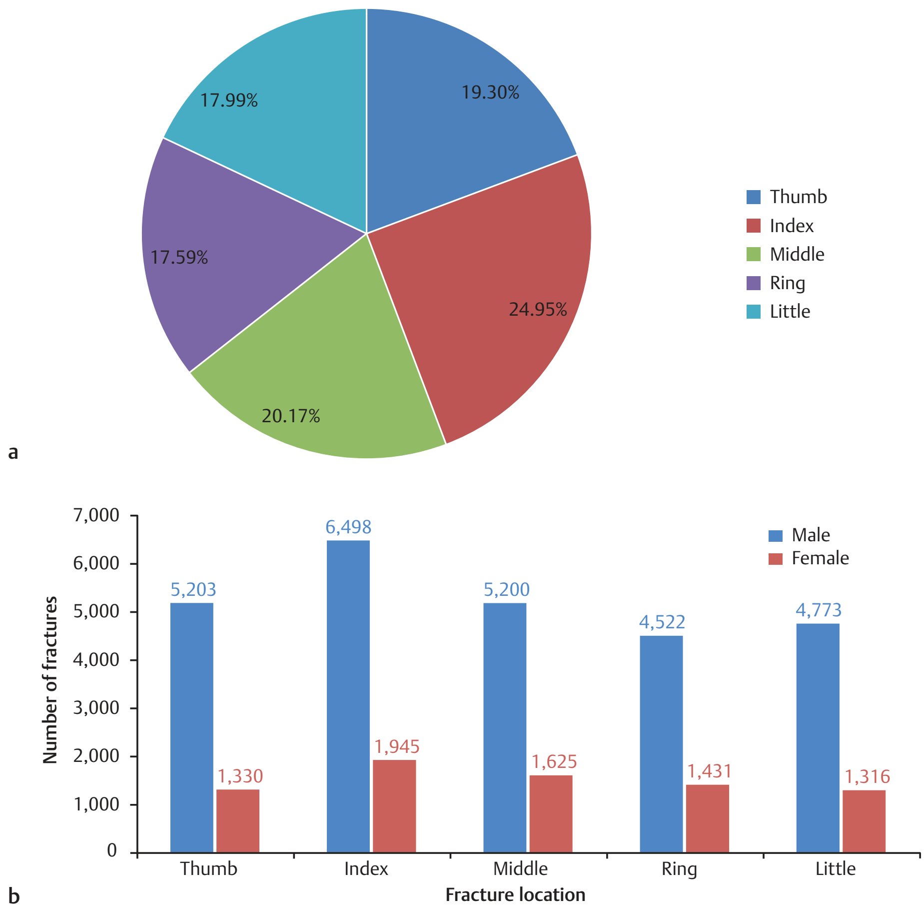
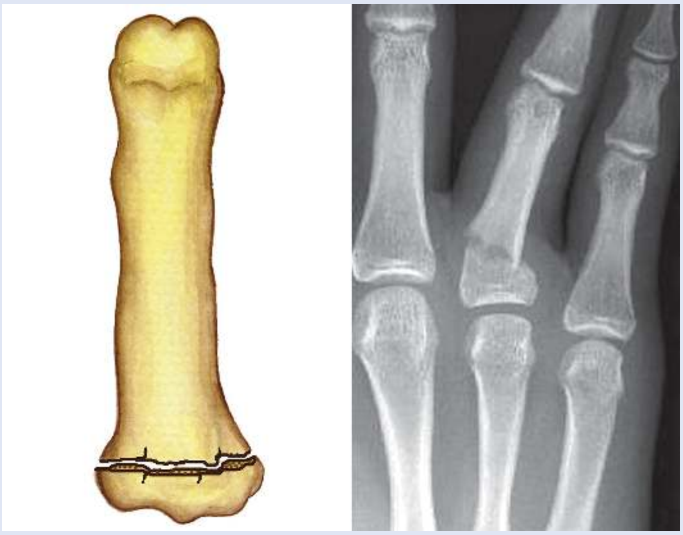


Fig. 8.36 (**a**) Distribution of 33,843 phalanx fractures by individual finger. (**b**) Sex distribution of 33,843 phalanx fractures by individual finger.

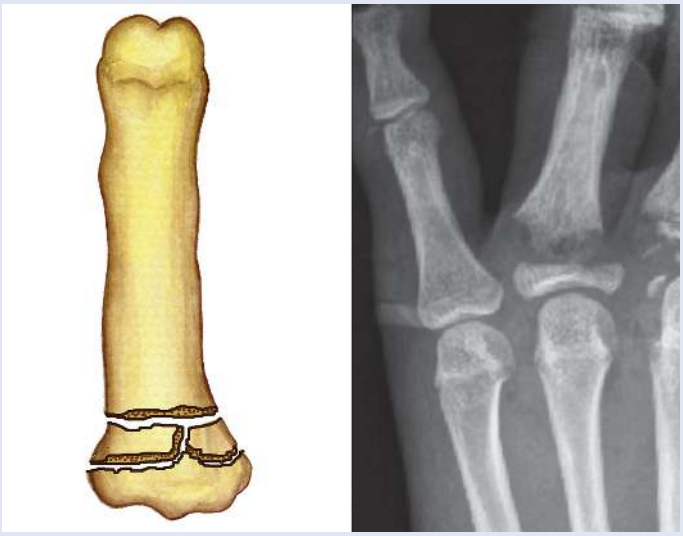
78-A: Phalanx proximal and distal extra-articular and diaphysis noncomminuted

78-A1 Proximal extra-articular
3,559 fractures
M: 2,733 (76.79%)
F: 826 (23.21%)
0.95% of total adult fractures
6.05% of adult hand fractures
10.52% of adult phalanx fractures
16.95% of type 78-A fractures

78-A1.1 Extra-articular, simple



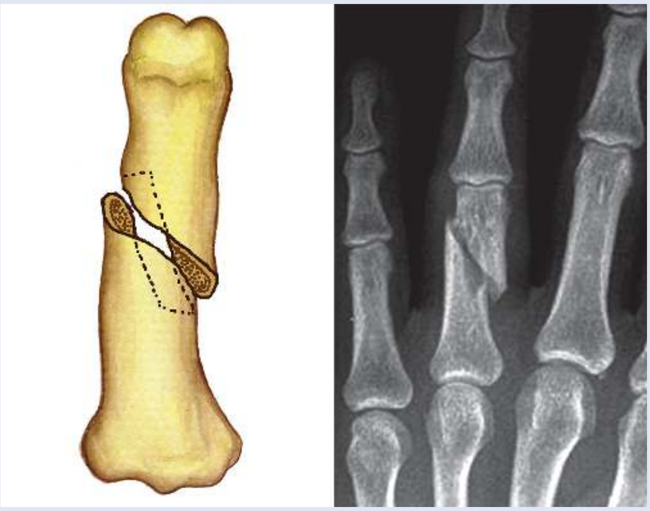
78-A1.2 Extra-articular, comminuted



78-A: Phalanx proximal and distal extra-articular and diaphysis noncomminuted

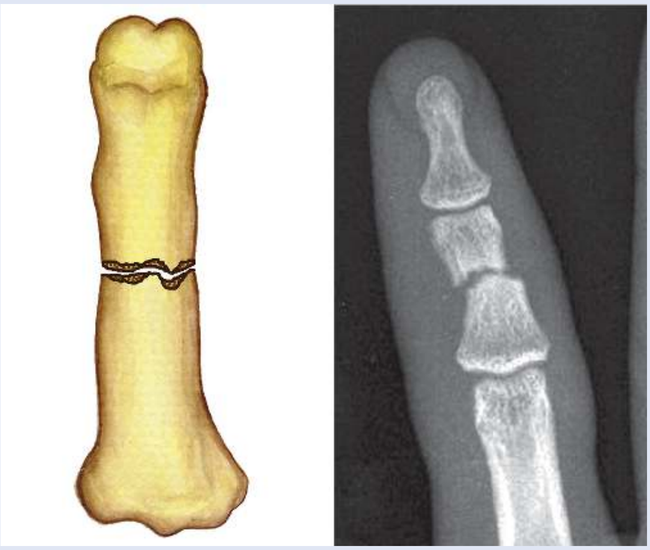
78-A2 Diaphysis noncomminuted
5,817 fractures
M: 4,567 (78.51%)
F: 1,250 (21.49%)
1.55% of total adult fractures
9.88% of adult hand fractures
17.19% of adult phalanx fractures
27.71% of type 78-A fractures

78-A2.1 Spiral



78-A2.2 Oblique

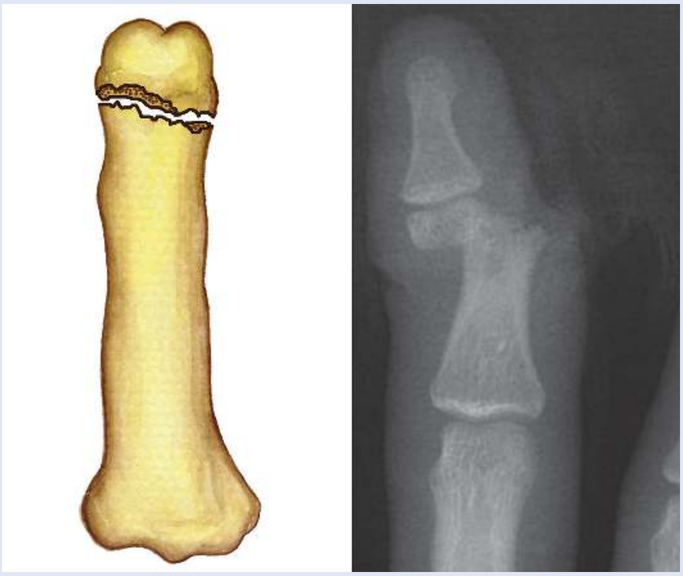
78-A2.3 Transverse



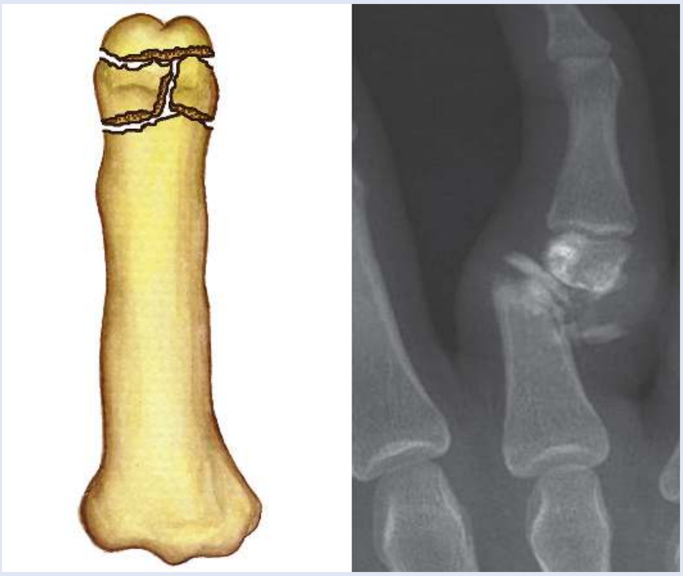
78-A: Phalanx proximal and distal extra-articular and diaphysis noncomminuted

78-A3 Distal extra-articular
11,620 fractures
M: 9,034 (77.75%)
F: 2,586 (22.25%)
3.10% of total adult fractures
19.75% of adult hand fractures
34.34% of adult phalanx fractures
55.34% of type 78-A fractures

78-A3.1 Spiral, simple



78-A3.2 Comminuted

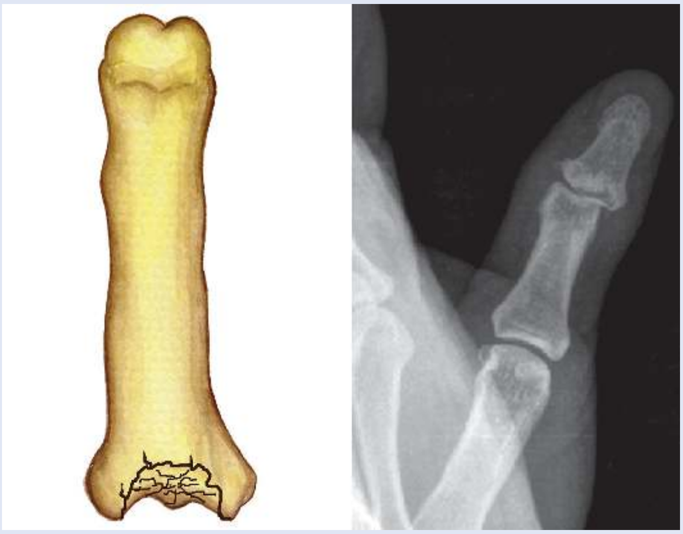


78-B: Phalanx proximal and distal partial articular and diaphysis wedge comminution

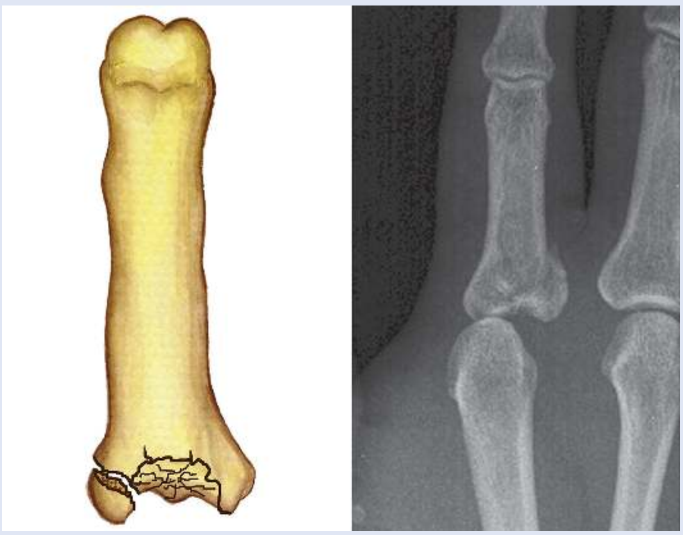
78-B1 Proximal partial articular
3,900 fractures
M: 2,797 (71.72%)
F: 1,103 (28.28%)
1.04% of total adult fractures
6.63% of adult hand fractures
11.52%of adult phalanx fractures
49.39% of type 78-B fractures

78-B1.1 Avulsion or split

78-B1.2 Depression



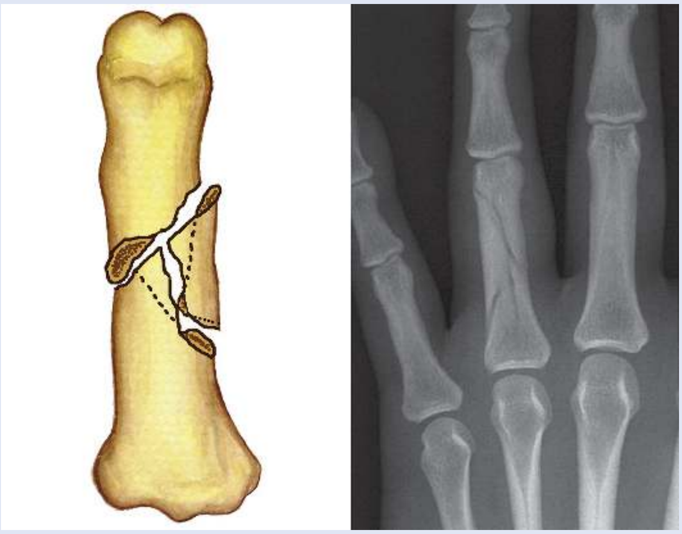
78-B1.3 Split/depression



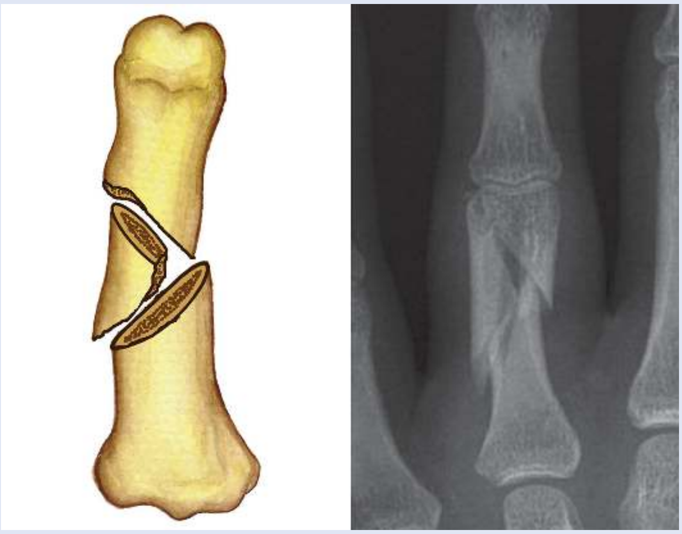
78-B: Phalanx proximal and distal partial articular and diaphysis wedge comminution

78-B2 Diaphysis wedge
1,561 fractures
M: 1,278 (81.87%)
F: 283 (18.13%)
0.42% of total adult fractures
2.65% of adult hand fractures
4.61% of adult phalanx fractures
19.77% of type 78-B fractures

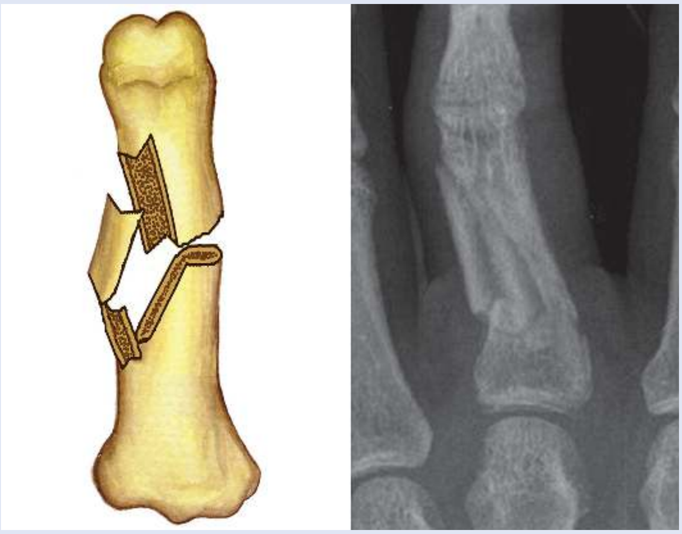
78-B2.1 Spiral



78-B2.2 Bending



78-B2.3 Fragmented



78-B: Phalanx proximal and distal partial articular and diaphysis wedge comminution

78-B3 Distal partial articular
2,436 fractures
M: 1,889 (77.55%)
F: 547 (22.45%)
0.65% of total adult fractures
4.14% of adult hand fractures
7.20% of adult phalanx fractures
30.85% of type 78-B fractures

78-B3.1 Avulsion or split

78-B3.2 Depression

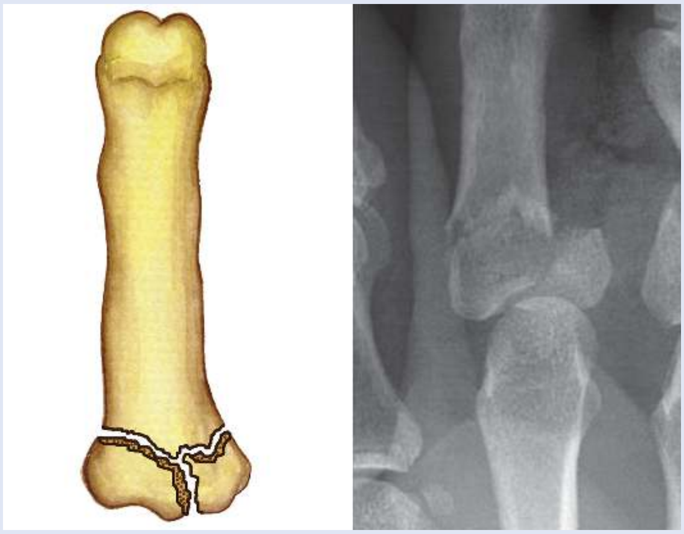
78-B3.3 Split/depression

78-C: Phalanx proximal and distal complete articular and diaphysis comminuted

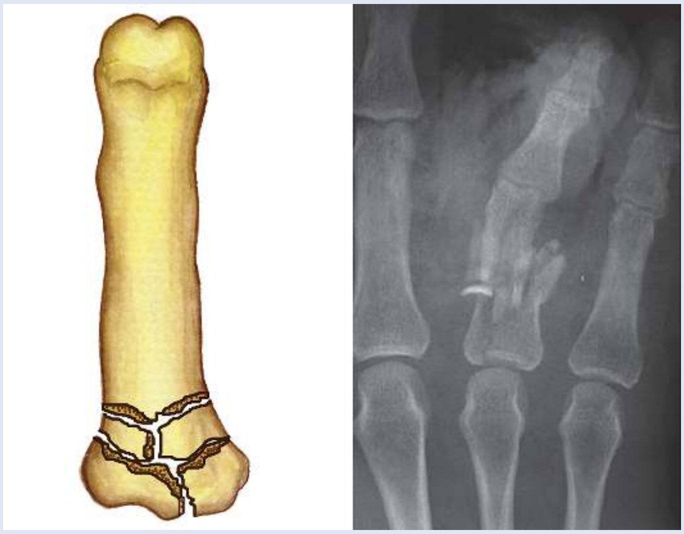
78-C1 Proximal complete articular

1,420 fractures
M: 1,114 (78.45%)
F: 306 (21.55%)
0.38% of total adult fractures
2.41% of adult hand fractures
4.20% of adult phalanx fractures
28.69% of type 78-C fractures

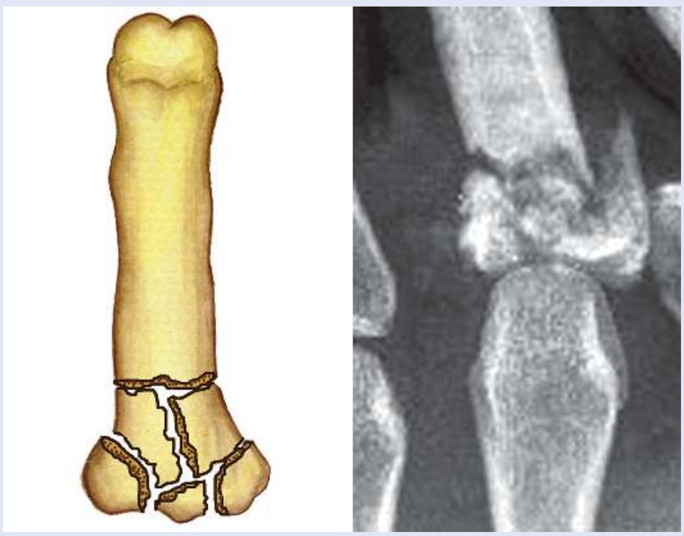
78-C1.1 Noncomminuted articular metaphysis

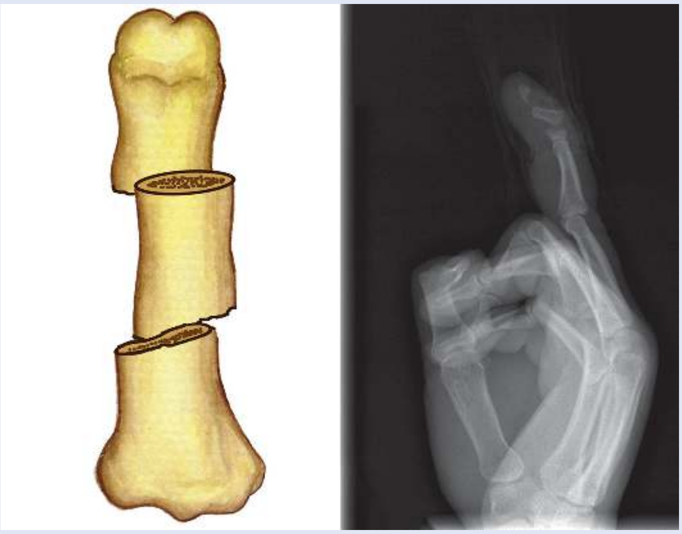
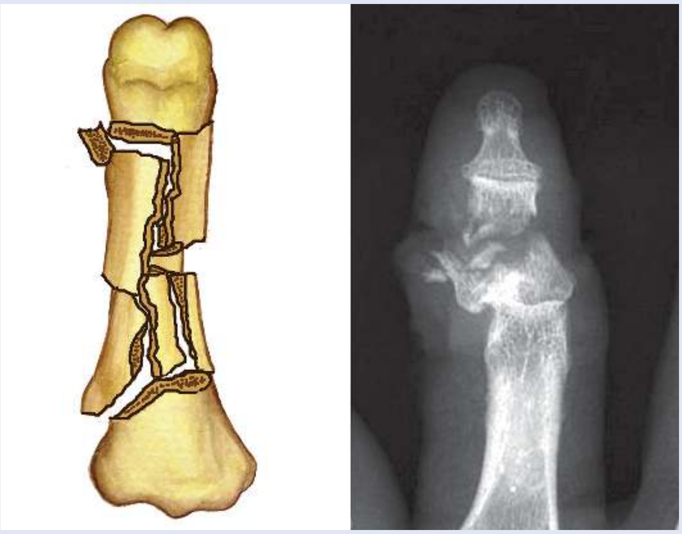


78-C1.2 Noncomminuted articular/comminuted metaphysis



78-C1.3 Comminuted articular and metaphysis

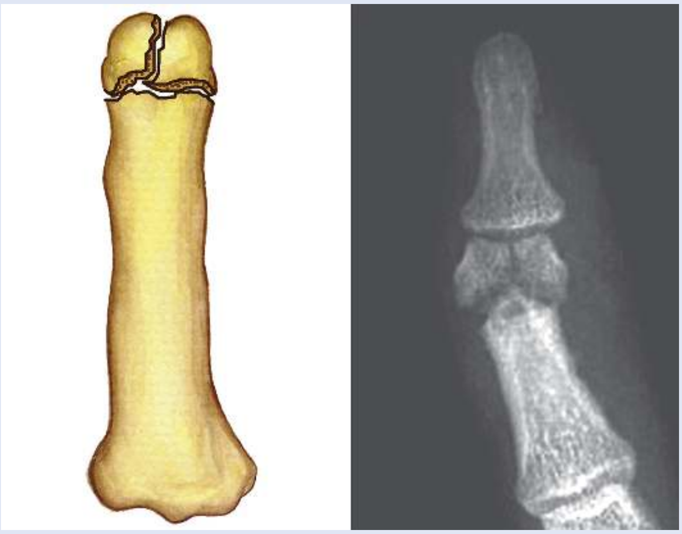


78-C: Phalanx proximal and distal complete articular and diaphysis comminuted	
78-C2 Diaphysis comminuted 2,422 fractures M: 1,899 (78.41%) F: 523 (21.59%) 0.65% of total adult fractures 4.12% of adult hand fractures 7.16% of adult phalanx fractures 48.93% of type 78-C fractures	**78-C2.1** Segmental 
	78-C2.2 Complex comminuted 

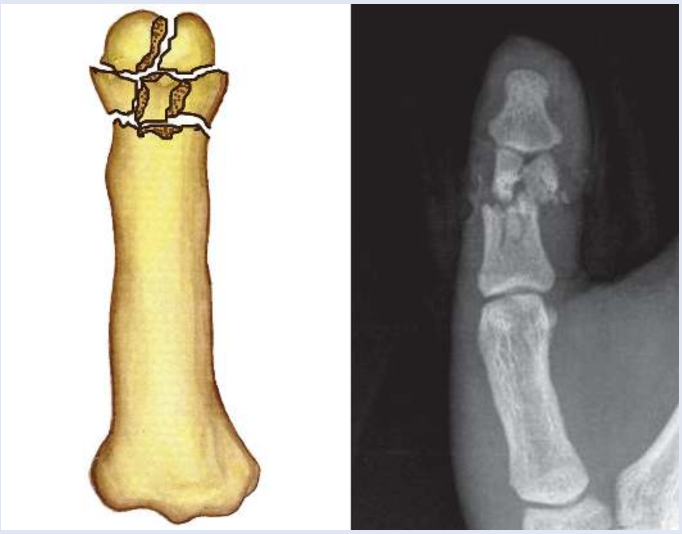
78-C: Phalanx proximal and distal complete articular and diaphysis comminuted

78-C3 Distal articular
1,108 fractures
M: 885 (79.87%)
F: 233 (20.13%)
0.30% of total adult fractures
1.88% of adult hand fractures
3.27% of adult phalanx fractures
22.38% of type 78-C fractures

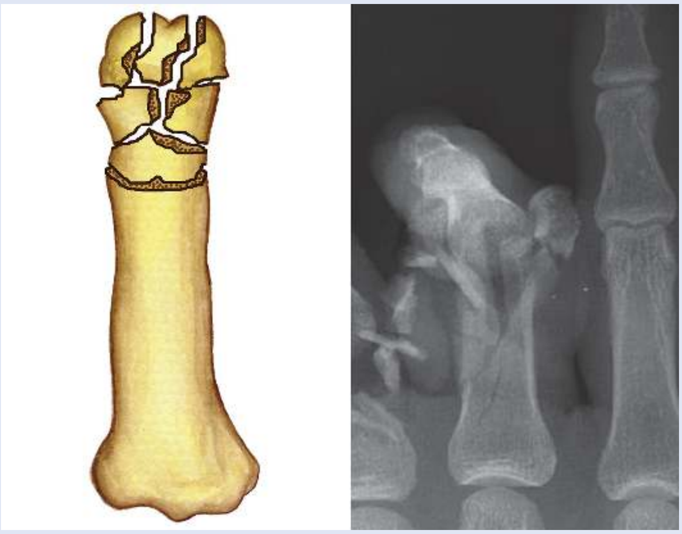
78-C3.1 Noncomminuted articular/metaphysis



78-C3.2 Noncomminuted articular/comminuted metaphysis



78-C3.3 Comminuted articular



Injury Mechanism

This type of injury typically results in dorsal angulation (apex volar) because of the palmar force of the intrinsic muscles on the proximal fragment and the dorsal force of the extensor mechanism on the distal fragment. Middle phalanx base fractures result in dorsal or volar angulation in relation to the insertion of the flexor digitorum superficialis. Fractures that are proximal to the phalanx tendon result in dorsal angulation, while distal fractures result in volar angulation from deforming muscle forces. Most distal phalangeal fractures are results of perpendicular force, as in injuries from a car door, a hammer, or in contact sports. Fractures are often transverse or comminuted.

Diagnosis

Diagnosis is usually not difficult with a clear history of trauma and a thorough clinical examination. Common indications of fracture include pain, swelling, and abnormality of motion, as well as apparent deformities. AP and lateral view radiographs of the hand help confirm the diagnosis.

Treatment

Among the three types of phalanges, fractures of the proximal phalanx have the greatest impact on the function and configuration of the finger, while fractures of the distal phalanx have the least impact. Nondisplaced proximal phalangeal fractures are treated with small splinting for 4 to 6 weeks, followed by motion exercise. For irreducible and unstable fractures (oblique or spiral), open reduction and internal fixation with microplating or K-wire should be considered.

Distal phalangeal fractures are often unicondylar or bicondylar fractures. Isolated nondisplaced unicondylar or bicondylar fractures can be immobilized with the adjacent finger, which acts as a splint. Open reduction using K-wire fixation or microplating should be implemented for displaced condylar fractures after failed attempts at closed reduction. Proximal phalangeal fractures are difficult to reduce, and open reduction using K-wire or microplating is required.

Multiple Fractures (Segment 79)

OTA Classification of Multiple Fractures of the Hand

The OTA classified multiple fractures of the hand into three types: 79-A, multiple fractures of the carpals; 79-B, multiple fractures of the metacarpals; and 79-C, multiple fractures of the phalanges.

Clinical Epidemiologic Features of Multiple Fractures (Segment 79)

A total of 11,504 adult patients with 11,797 multiple fractures of the hand were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, accounting for 19.93% of all adult patients with hand fractures and 20.05% of all hand fractures in adults. Their epidemiologic features are as follows:

- More males than females
- There are two high-risk age groups. One is 21–25 years, the same age group for males. The other is 41–45 years, the same age group for females.
- The most common multiple fracture is type 79-C, the same fracture type for both males and females.

■ Patients with Multiple Fractures by Sex

See ► Table 8.32 and ► Fig. 8.37.

Table 8.32 Sex distribution of 11,504 patients with multiple fractures (segment 79)

Sex	Number of patients	Percentage
Male	9,014	78.36
Female	2,490	21.64
Total	11,504	100.00

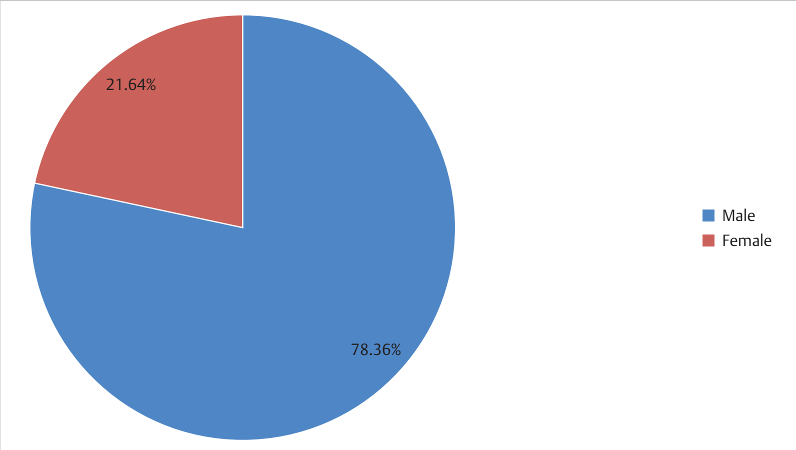


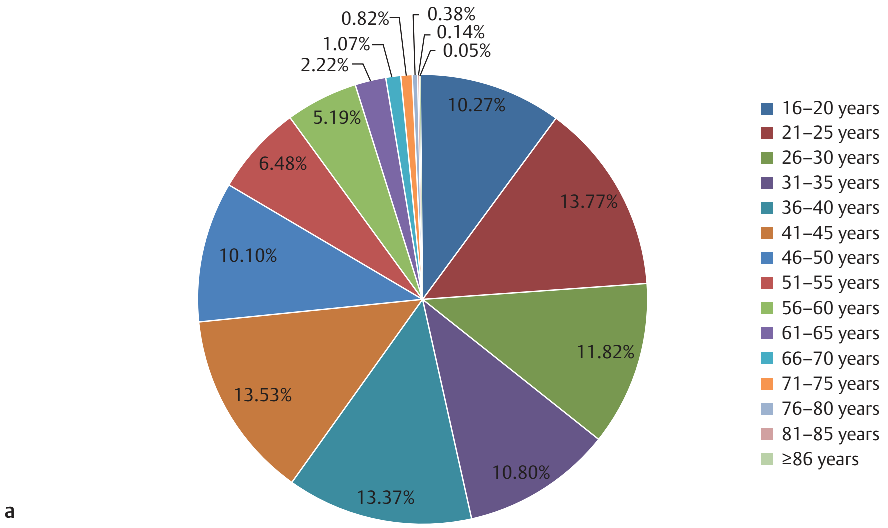
Fig. 8.37 Sex distribution of 11,054 patients with multiple fractures (segment 79).

■ Patients with Multiple Fractures by Age Group

See ▶ Table 8.33 and ▶ Fig. 8.38.

Table 8.33 Age and sex distribution of 11,504 patients with multiple fractures (segment 79)

Age group (years)	Male	Female	Total	Percentage
16–20	999	182	1,181	10.27
21–25	1,376	208	1,584	13.77
26–30	1,134	226	1,360	11.82
31–35	968	275	1,243	10.80
36–40	1,133	405	1,538	13.37
41–45	1,117	439	1,556	13.53
46–50	862	300	1,162	10.10
51–55	569	176	745	6.48
56–60	486	111	597	5.19
61–65	188	67	255	2.22
66–70	83	40	123	1.07
71–75	65	29	94	0.82
76–80	22	22	44	0.38
81–85	10	6	16	0.14
≥ 86	2	4	6	0.05
Total	9,014	2,490	11,504	100.00



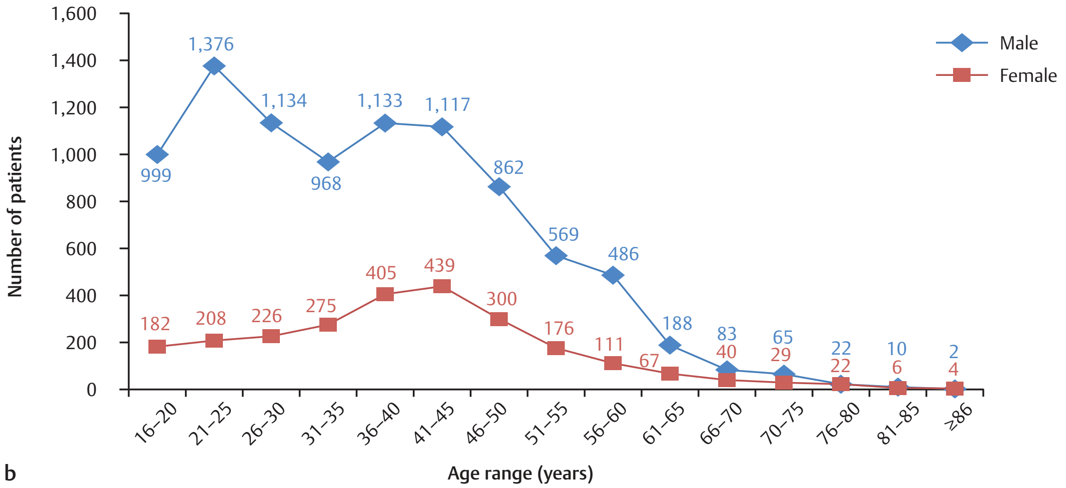


Fig. 8.38 (**a**) Age distribution of 11,054 patients with multiple fractures (segment 79). (**b**) Age and sex distribution of 11,054 patients with multiple fractures (segment 79).

■ Multiple Fractures by Fracture Type

See ▶ Table 8.34 and ▶ Fig. 8.39.

Table 8.34 Sex and fracture type distribution of 11,797 multiple hand fractures (segment 79)

Fracture type	Male	Female	Number of patients	Percentage
79-A	278	75	353	2.99
79-B	1,939	472	2,411	20.44
79-C	7,023	2,010	90,33	76.57
Total	9,240	2,557	11,797	100.00

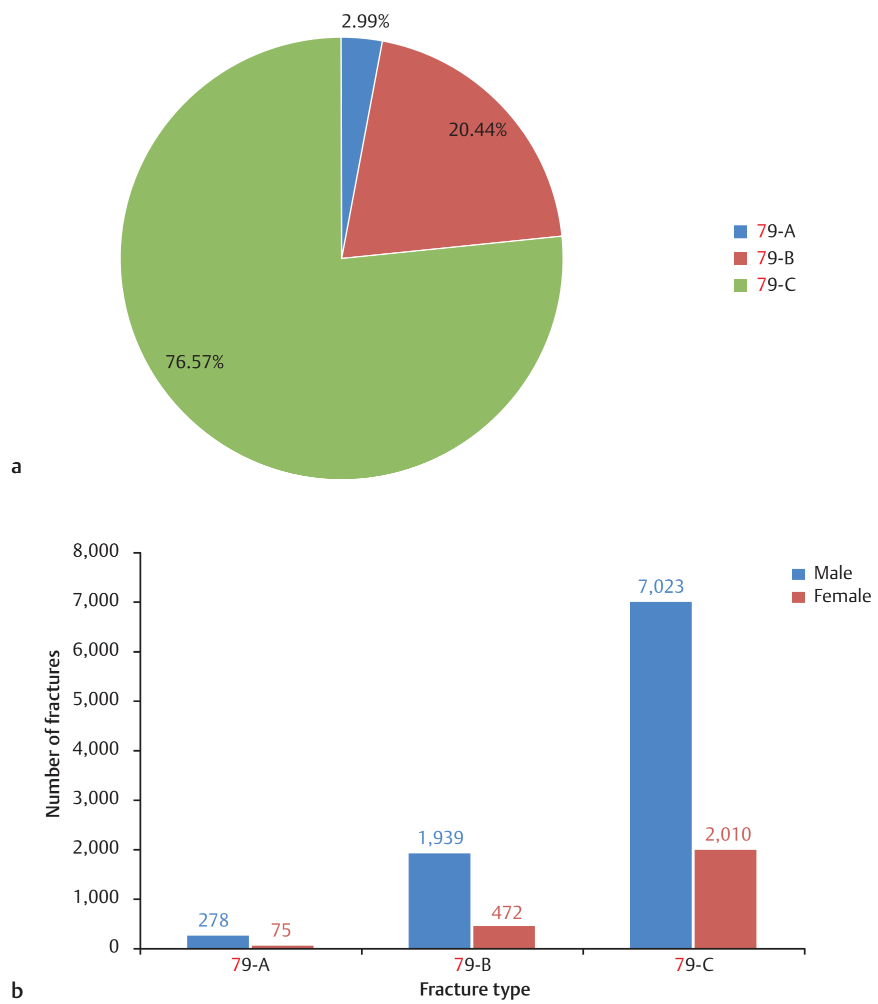


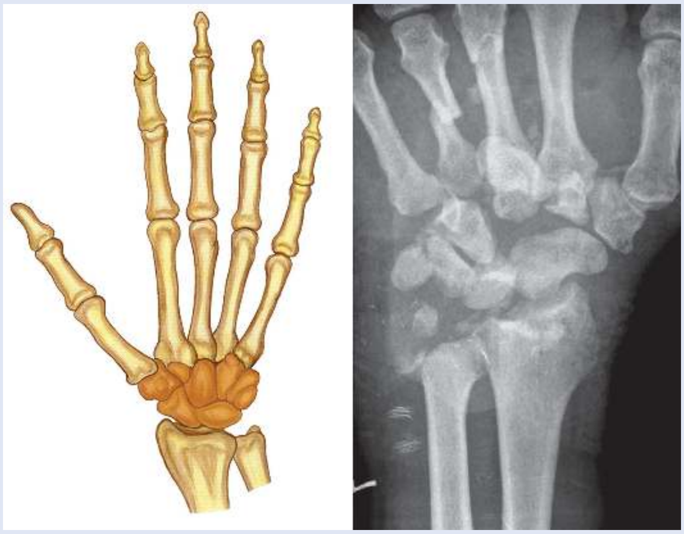
Fig. 8.39 (**a**) Fracture type distribution of 11,797 multiple hand fractures (segment 79). (**b**) Sex and fracture type distribution of 11,797 multiple hand fractures (segment 79).

8

79 Multiple fractures of the hand

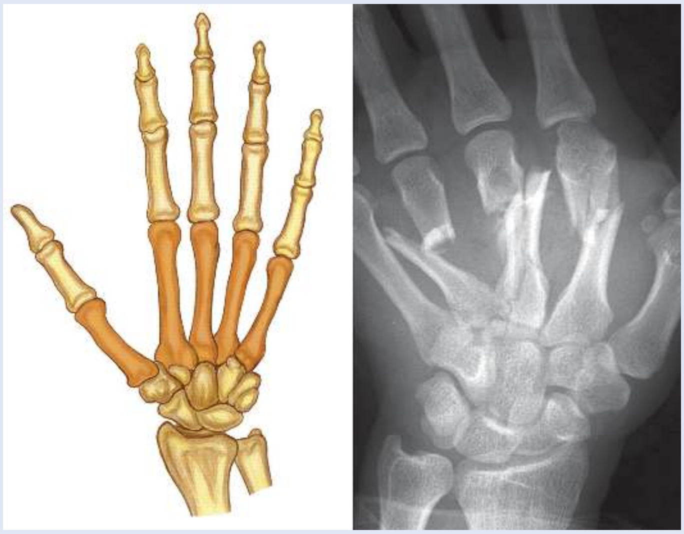
79-A Multiple fractures of carpals
353 fractures
M: 278 (78.75%)
F: 75 (21.25%)
0.09% of total adult fractures
0.60% of adult hand fractures
2.99% of segment 79 fractures

79-A



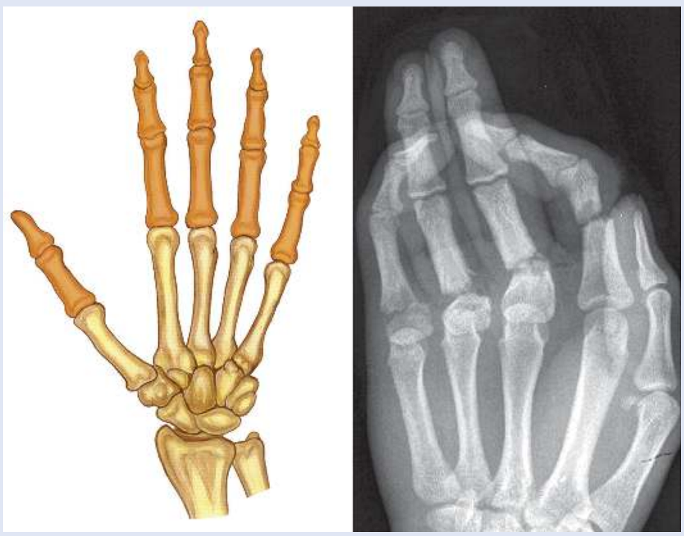
79-B Multiple fractures of metacarpals
2,411 fractures
M: 1,939 (80.42%)
F: 472 (19.58%)
0.64% of total adult fractures
4.10% of adult hand fractures
20.44% of segment 79 fractures

79-B



79-C Multiple fractures of the phalanx
9,033 fractures
M: 7,023 (77.75%)
F: 2010 (22.25%)
2.41% of total adult fractures
15.35% of adult hand fractures
76.57% of segment 79 fractures

79-C



Suggested Readings

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9 Fractures of the Foot

Fei Zhang, Ye Tian, Zongyou Yang, and Tao Liu

Overview of Foot Fractures

Anatomic Features

The foot is made up of a total of 26 bones of different shapes, which are supported by a network of approximately 32 muscles and tendons, 109 ligaments, and 45 articulations. The foot is divided into three sections: the forefoot, midfoot, and hindfoot. The forefoot is composed of 5 metatarsal bones and 14 phalanges which make up the toes. The midfoot consists of five out of a total number of seven tarsal bones, including three cuneiforms, one tarsal navicular, and one cuboid bone. The hindfoot includes the calcaneus and talus bone. There are five metatarsal bones (labeled 1–5 starting at the big toe), each consisting of a shaft or body, and a base and head. The base is wedge-shaped, expanding posteriorly. The head presents a convex articular surface, articulating distally with the phalangeal bones. There are 14 phalangeal bones in the foot, 3 in each toe except the big toe which has 2, and each bone consists of a base, a body, and a head (▶ Fig. 9.1).

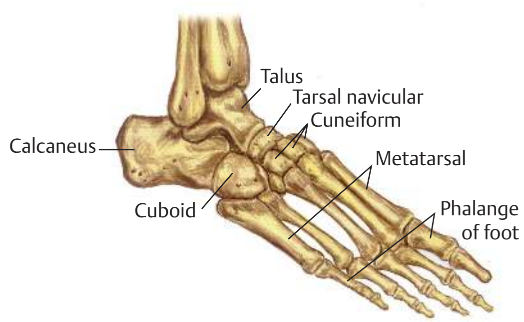

Fig. 9.1 Bones of the foot.

OTA Classification and Coding System for Foot Fractures

According to the Orthopaedic Trauma Association (OTA) classification, a foot fracture is coded as number “8” for its anatomic location; the talus, calcaneus, tarsal navicular, cuboid, cuneiforms, metatarsals, and phalanges are coded as numbers “81,” “82,” “83,” “84,” “85,” “87,” and “88,” respectively. In addition, multiple fractures of the foot are coded as number “89.” The classification varies with individual bones of the foot due to complex anatomic features of each bone (▶ Fig. 9.2).

Epidemiologic Features of Foot Fractures in the China National Fracture Study

A total of 201 patients with 202 foot fractures were investigated in the China National Fracture Study (CNFS). The fractures accounted for 11.40% of all patients with fractures and 11.02% of all types of fractures. The population-weighted incidence rate of foot fractures was 38 per 100,000 population.

The epidemiologic features of foot fractures in the CNFS are as follows:

- More males than females
- More right-side injuries than left-side injuries
- The highest risk age group is 15–64 years
- Injuries occurred most commonly via falls and crushing injury

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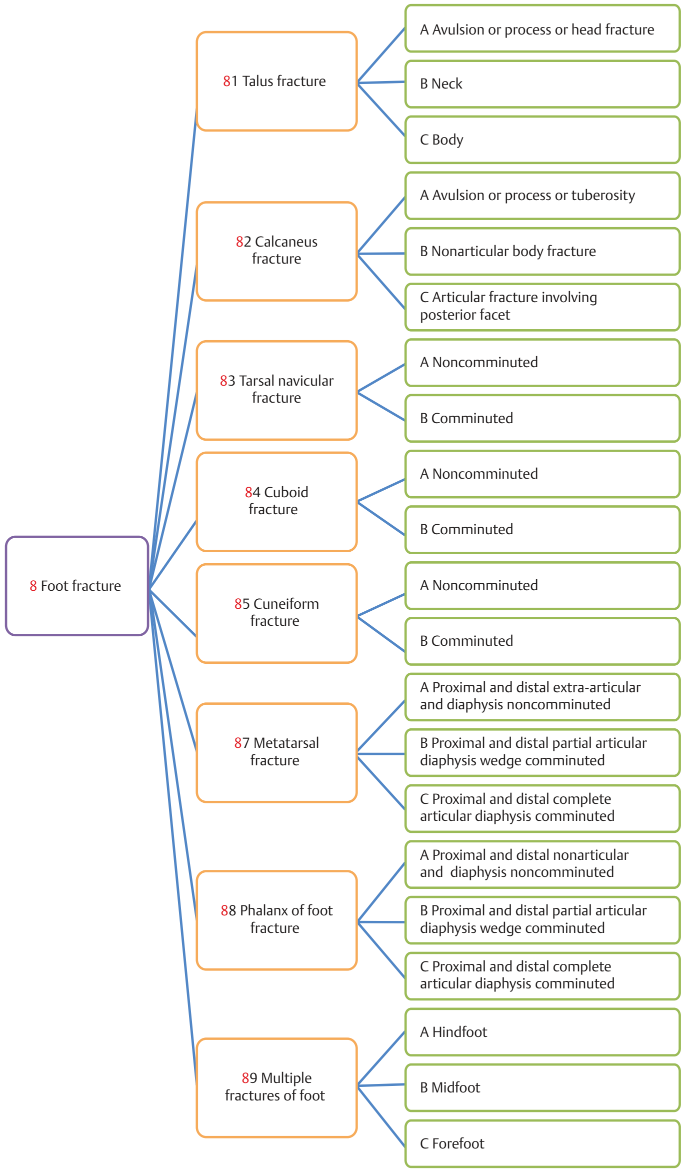


Fig. 9.2 Algorithm.

■ Foot Fractures by Sex

See ▶ Table 9.1 and ▶ Fig. 9.3.

Table 9.1 Sex distribution of 201 patients with foot fractures in CNFS

Sex	Number of patients	Percentage
Male	132	65.67
Female	69	34.33
Total	201	100.00

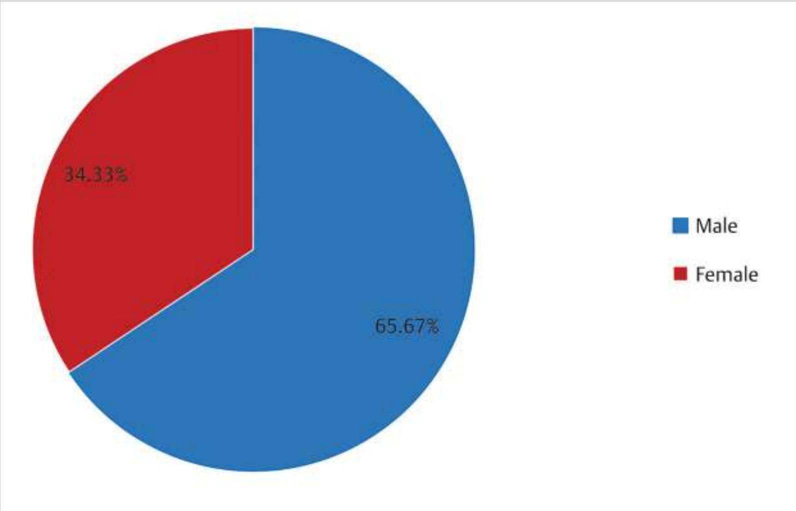


Fig. 9.3 Sex distribution of 201 patients with foot fractures in China National Fracture Study (CNFS).

■ Foot Fractures by Injury Side in CNFS

See ▶ Table 9.2 and ▶ Fig. 9.4.

Table 9.2 Injury side distribution of 201 patients with foot fractures in CNFS

Injured side	Number of patients	Percentage
Left	98	48.76
Right	102	50.75
Bilateral	1	0.5
Total	201	100.00

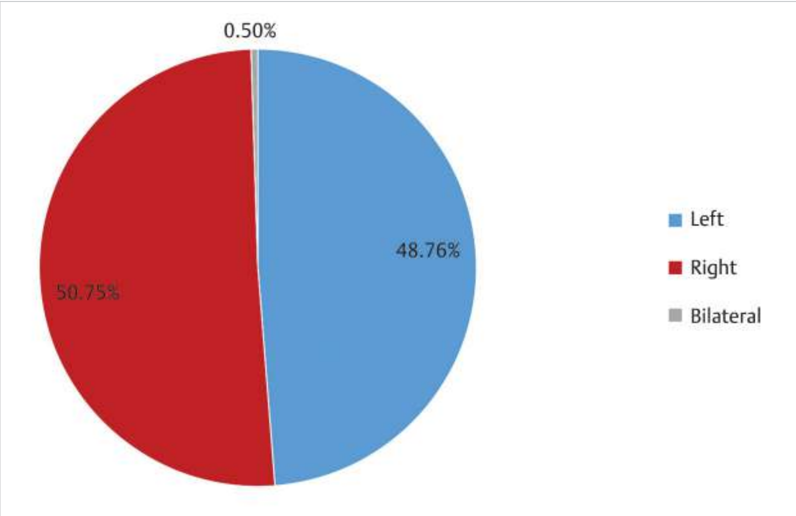


Fig. 9.4 Injury side distribution of 201 patients with foot fractures in China National Fracture Study (CNFS).

■ Age and Sex Distribution of 201 Patients with Foot Fractures in CNFS

See ▶ Table 9.3 and ▶ Fig. 9.5.

Table 9.3 Age and sex distribution of 201 patients with foot fractures in CNFS

Age group (years)	Male	Female	Total	Percentage
0–14	9	2	11	5.47
15–64	111	58	169	84.08
≥65	12	9	21	10.45
Total	132	69	201	100.00

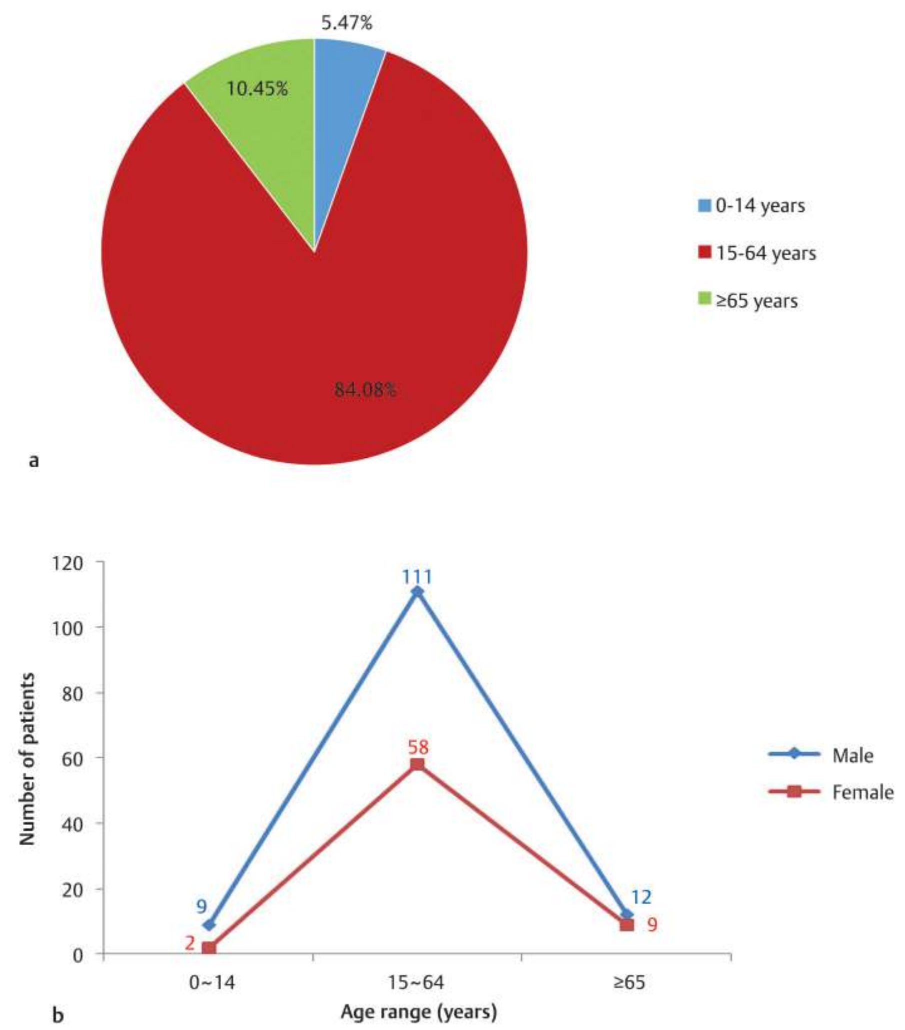


Fig. 9.5 (**a**) Age distribution of 201 patients with foot fractures in China National Fracture Study (CNFS). (**b**) Age and sex distribution of 201 patients with foot fractures in CNFS.

■ Foot Fractures by Location in CNFS

See ▶ Table 9.4 and ▶ Fig. 9.6.

Table 9.4 Segment distribution of 201 patients with foot fractures in CNFS based on AO classification

Segment	Number of fractures	Percentage
81–85	65	32.18
87	51	25.25
88	40	19.8
89	46	22.77
Total	202	100.00

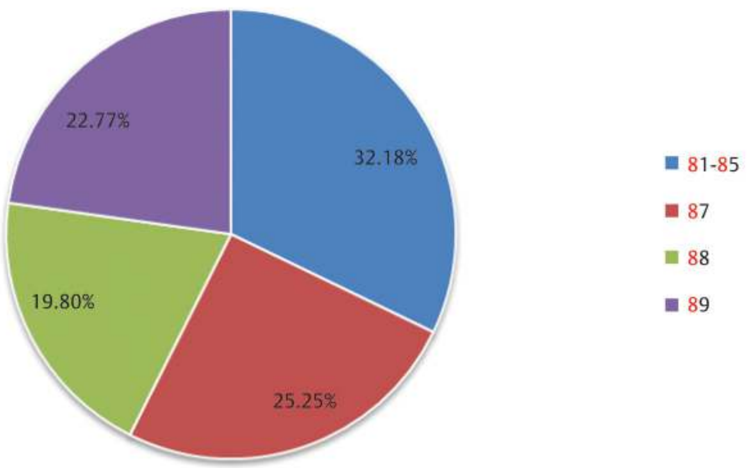


Fig. 9.6 Segment distribution of 201 patients with foot fractures in China National Fracture Study (CNFS).

■ Foot Fractures by Causal Mechanisms in CNFS

See ▶ Table 9.5 and ▶ Fig. 9.7.

Table 9.5 Causal mechanisms distribution of 201 patients with foot fractures in CNFS

Causal mechanisms	Male	Female	Total	Percentage
Traffic accident	16	8	24	11.94
Slip, trip, or fall	36	45	81	40.30
Fall from heights	31	7	38	18.91
Crushing injury	46	9	55	27.36
Sharp trauma	2	0	2	1.00
Blunt force trauma	1	0	1	0.50
Total	132	69	201	100.00

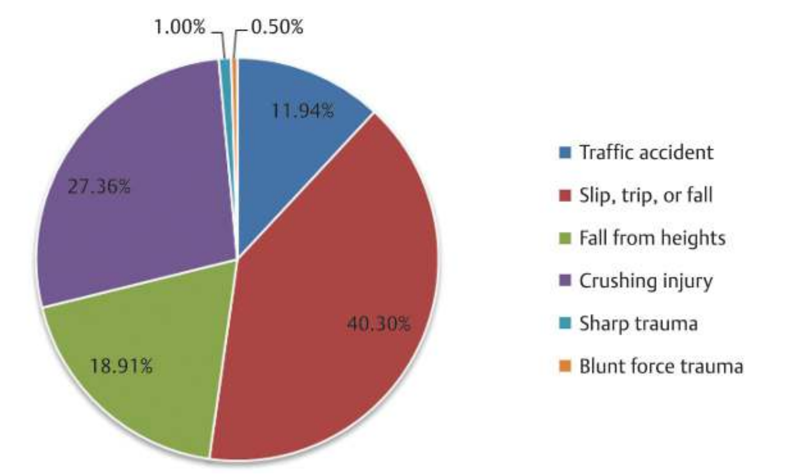


Fig. 9.7 Causal mechanisms distribution of 106 patients with humeral fractures in China National Fracture Study (CNFS).

■ Clinical Epidemiologic Features of Foot Fractures

A total of 39,867 patients with 41,136 foot fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 9.61% of all patients with fractures and 9.53% of all types of fractures. Among these 39,867 patients, there were 2,466 pediatric patients (2,502 foot fractures) and 37,401 adults patients (38,634 foot fractures).

Epidemiologic features of foot fractures are as follows:

- More males than females
- Slightly more left-side than the right-side fractures
- The high-risk age group is 36–40 years, the same age group for males, whereas the high-risk age group for females is 46–50 years
- The most common foot fractures among adults are calcaneus fractures, in contrast to children, where the most common fractures are metatarsal

■ Fractures of Foot by Sex

See ► Table 9.6 and ► Fig. 9.8.

Table 9.6 Sex distribution of 39,867 patients with foot fractures

Sex	Number of patients	Percentage
Male	28,385	71.20
Female	11,482	28.80
Total	39,867	100.00

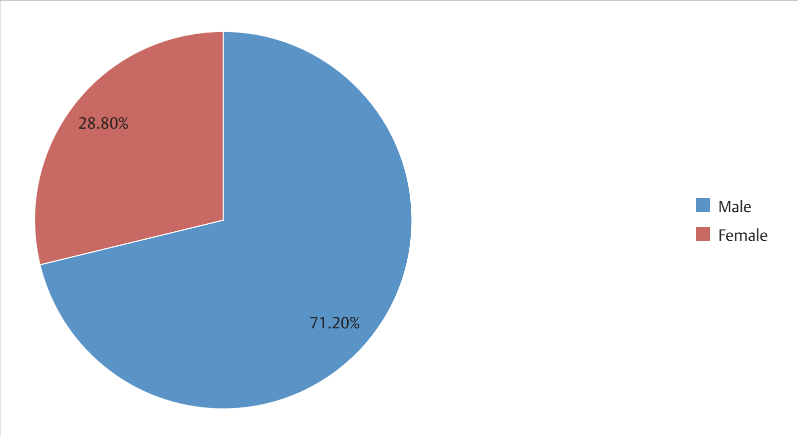


Fig. 9.8 Sex distribution of 39,867 patients with foot fractures.

■ Fractures of the Foot by Fracture Side

See ► Table 9.7 and ► Fig. 9.9.

Table 9.7 Fracture side distribution of 39,867 patients with foot fractures

Fracture side	Number of patients	Percentage
Left	19,331	48.49
Right	19,628	49.23
Bilateral	908	2.28
Total	39,867	100.00

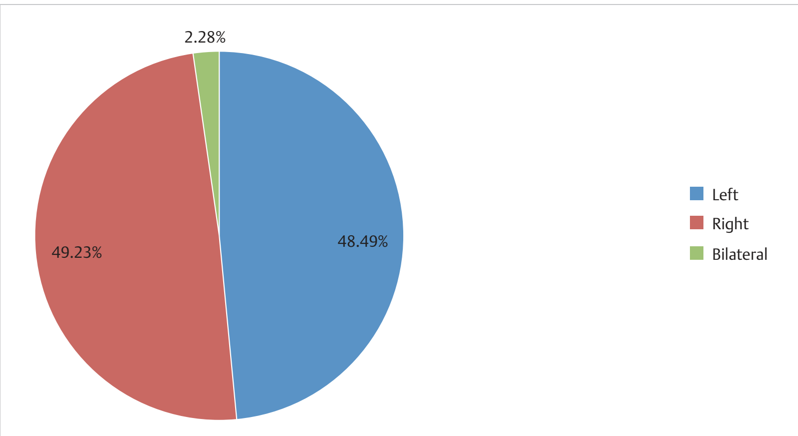


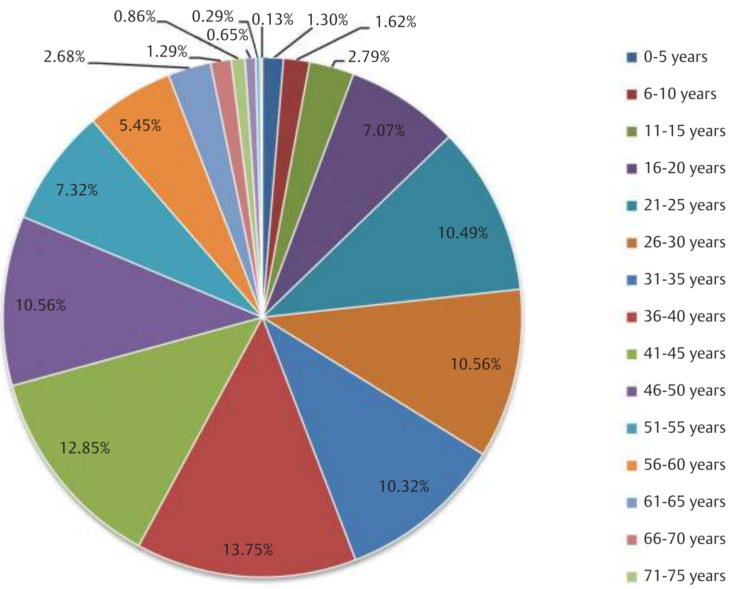
Fig. 9.9 Fracture side distribution of 39,867 patients with foot fractures.

■ Fractures of the Foot by Age Group

See ▶ Table 9.8 and ▶ Fig. 9.10.

Table 9.8 Age and sex distribution of 39,867 patients with foot fractures

Age group (years)	Male	Female	Number of patients	Percentage
0–5	369	193	562	1.41
6–10	460	335	795	1.99
11–15	793	316	1,109	2.78
16–20	2,006	514	2,520	6.32
21–25	2,979	878	3,857	9.67
26–30	2,997	924	3,921	9.84
31–35	2,930	835	3,765	9.44
36–40	3,904	1,104	5,008	12.56
41–45	3,647	1,176	4,823	12.10
46–50	2,998	1,268	4,266	10.70
51–55	2,079	1,116	3,195	8.01
56–60	1,548	1,131	2,679	6.72
61–65	761	648	1,409	3.53
66–70	365	434	799	2.00
71–75	244	293	537	1.35
76–80	184	193	377	0.95
81–85	83	91	174	0.44
≥ 86	38	33	71	0.18
Total	28,385	11,482	39,867	100.00



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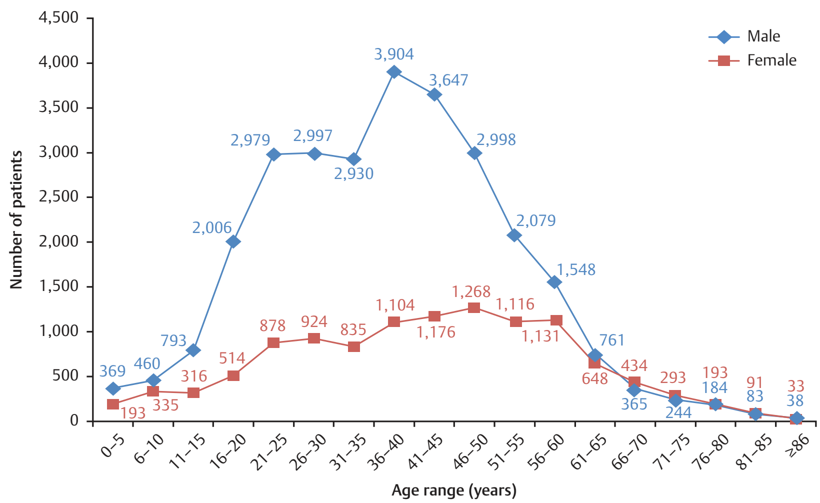

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Fig. 9.10 (**a**) Age distribution of 39,867 patients with foot fractures. (**b**) Age and sex distribution of 39,867 patients with foot fractures.

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■ Foot Fractures in Children and Adults by Individual Foot Bone

See ▶ Table 9.9 and ▶ Fig. 9.11.

Table 9.9 Distribution of 41,136 patients with fractures by individual foot bone in children and adults

Foot bone	Children	Adults	Number of patients	Percentage
Talus	85	1,143	1,228	2.99
Calcaneus	522	11,720	12,242	29.76
Tarsal navicular	63	1,022	1,085	2.64
Cuneiform	28	532	560	1.36
Cuboid	30	552	582	1.41
Metatarsals	832	8,996	9,828	23.89
Phalanges	591	7,397	7,988	19.42
Total	351	7,272	41,136	18.53

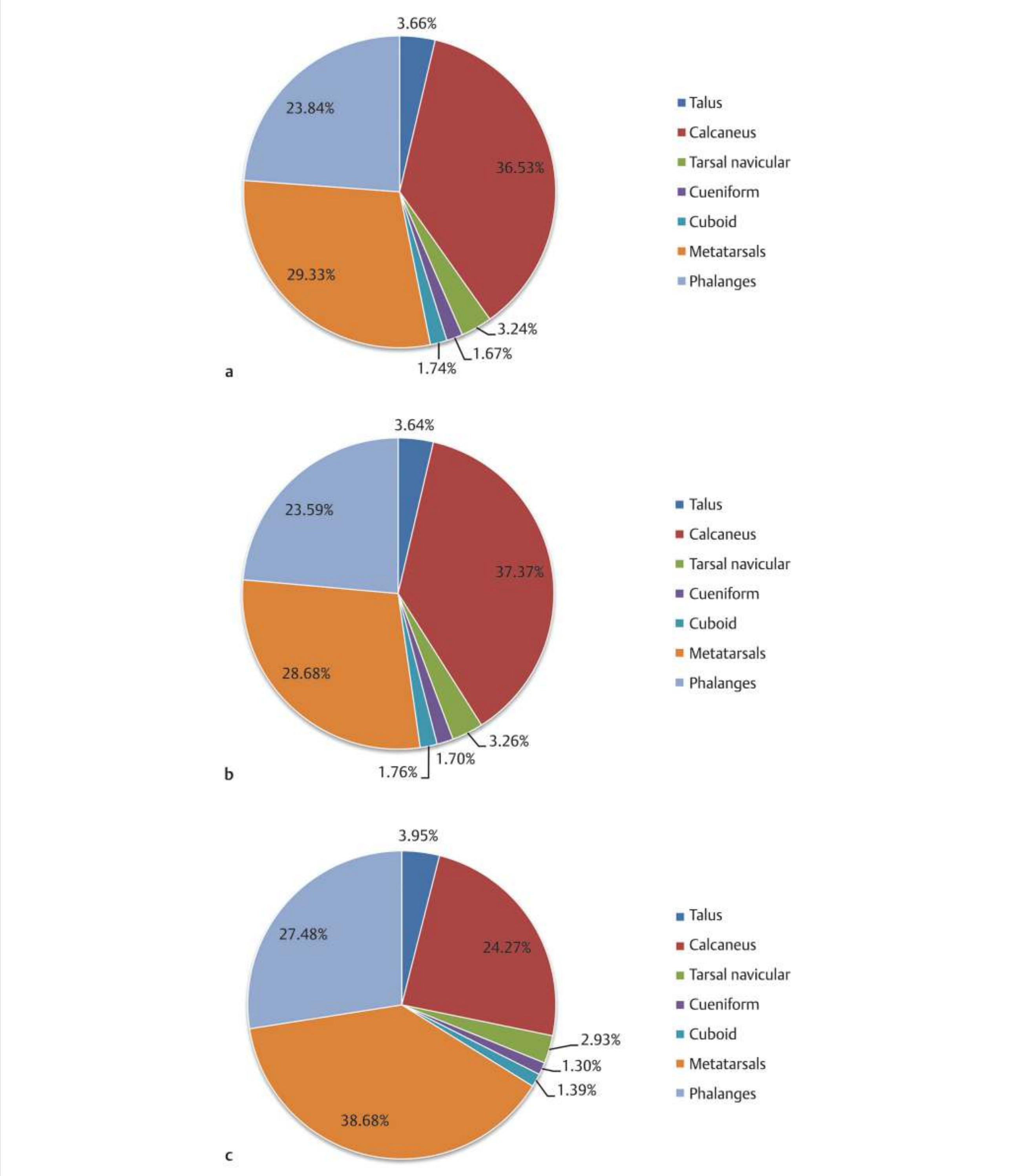


Fig. 9.11 (**a**) Distribution of 41,136 patients with foot fractures by individual foot bone. (**b**) Distribution of 38,634 adult patients with foot fractures by individual foot bone. (**c**) Distribution of 2,502 pediatric patients with foot fractures by individual foot bone.

Talar Fractures (Segment 81)

Anatomic Features

Examining its anatomic region, the talus bone can be subdivided into three parts: head, neck, and body. Between 60 and 70% of the talar surface is articular, forming seven articulations with adjacent bones. The head is semicircular in form, carrying the articulate surface of the navicular bone. The neck, the constricted area between the body and head, is roughened for the attachment of the joint capsule. The irregular body is cuboid in shape, wide in the front and narrow in the back, which gives stability when the ankle is dorsiflexed. While its superior, medial, and lateral articulate surfaces join together to make up the trochlea of the talus, the posterior surface (facies articularis calcanea posterior) is separated by a furrow, the sulcustali, which, together with the sulcus calcanei, forms a cavity, the sinus tarsi. Behind the trochlea is a posterior process with medial and lateral tubercles separated by a groove for the flexor halluces longus tendon. The medial and lateral tubercles provide attachment for the medial talocalcaneal ligament and the posterior talofibular ligament, respectively. The medial articulate surface of the body, which is semilunar in shape, is only half the area of the lateral triangle surface of the body. The lateral surface projects laterally as a broad-based, wedge-shaped prominence, referred to as the lateral talar process, from which the lateral talocalcaneal ligament originates and passes immediately beneath its fibular facet to the lateral surface of the calcaneus.

The subtalar joint consists of three articulating surfaces: the anterior, middle, and posterior facets, with the posterior facet representing the major weight-bearing surface. The anterior and the middle facets usually conjoin as one anterior articulation facet (▶ Fig. 9.12).

OTA Classification of Talar Fractures

Based on the OTA classification, the talus is coded as number “81” for its anatomic location. According to fracture location, talar fractures can be divided into three types: 81-A, avulsion, process, or head fractures; 81-B, neck fractures; and 81-C, body fractures (▶ Fig. 9.13).

Clinical Epidemiologic Features of Talar Fractures

A total of 1,140 adult patients with 1,143 talar fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, including 561 patients with left-side fractures, 576 with right-side fractures, and 3 with bilateral fractures. There were 803 males and 337 females, with a male to female ratio of 2.38:1.

Epidemiologic features of talar fractures are as follows:

- More males than females
- The high-risk age group is 26–30 years, the same age group for males, whereas the high-risk age group for females is 36–40 years
- The most common fracture type is type 81-A, the same type for both males and females
- The most common fracture group is group 81-A2, the same group for males, while the common fracture group for females is group 81-A1

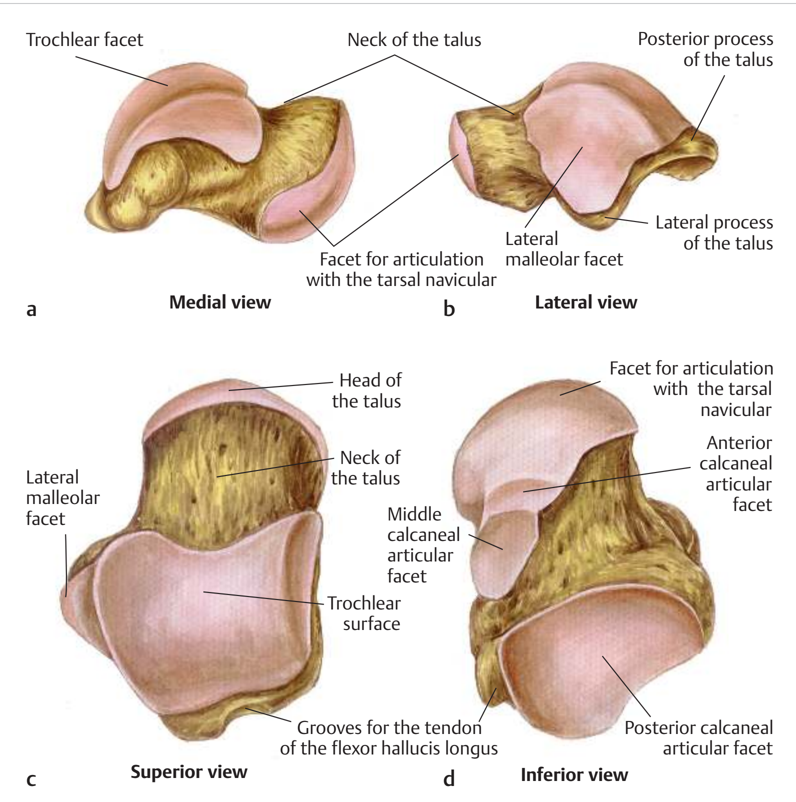


Fig. 9.12 Medial (**a**), lateral (**b**), superior (**c**), and inferior (**d**) views of the talus.

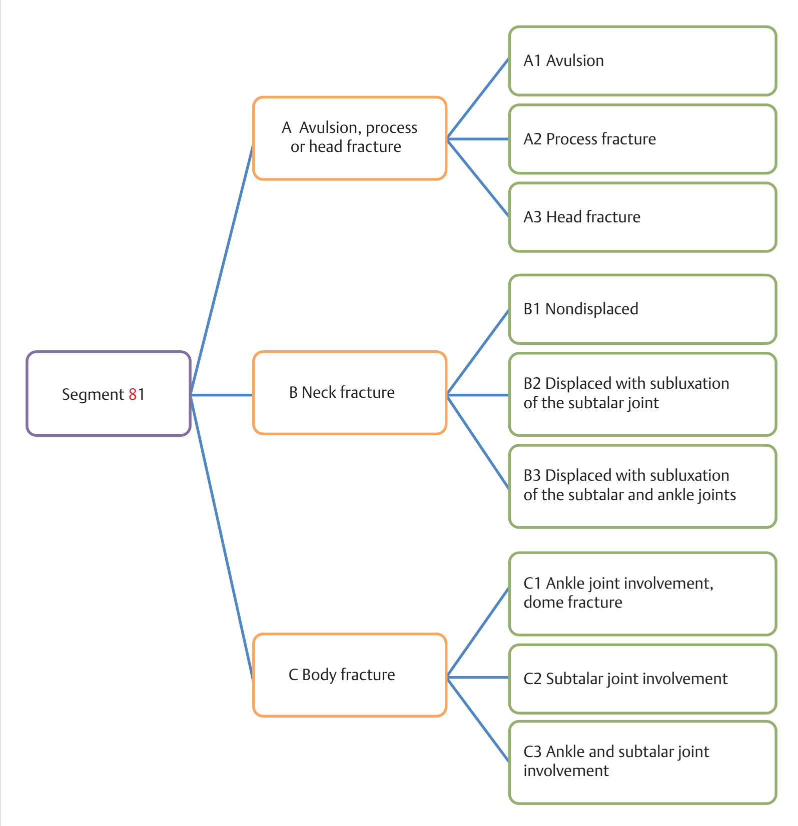


Fig. 9.13 Algorithm.

■ Talar Fractures (Segment 81) by Sex

See ▶ Table 9.10 and ▶ Fig. 9.14.

Table 9.10 Sex distribution of 1,140 patients with talar fractures

Sex	Number of patients	Percentage
Male	803	70.44
Female	337	29.56
Total	1,140	100.00

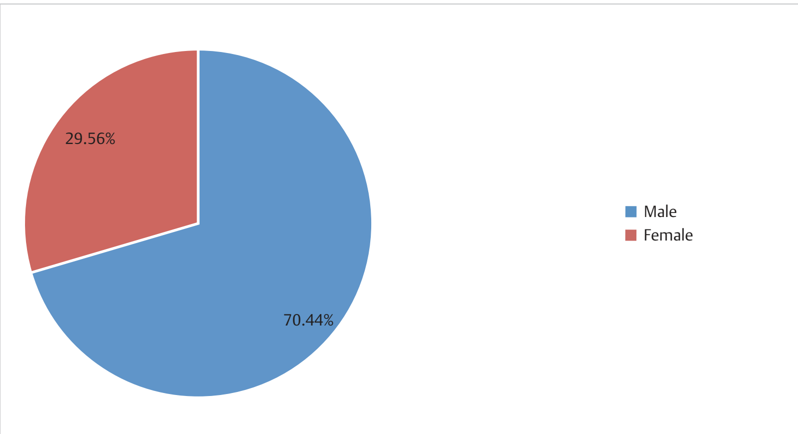


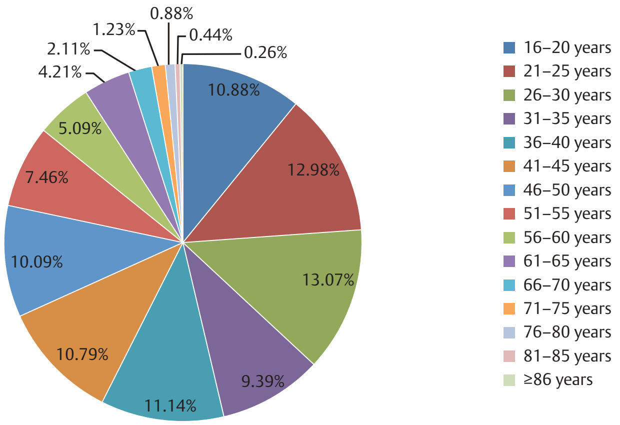
Fig. 9.14 Sex distribution of 1,140 patients with talar fractures.

■ Talar Fractures (Segment 81) by Age Group

See ▶ Table 9.11 and ▶ Fig. 9.15.

Table 9.11 Age and sex distribution of 1,140 patients with talar fractures

Age group (years)	Male	Female	Number of patients	Percentage
16–20	94	30	124	10.88
21–25	113	35	148	12.98
26–30	123	26	149	13.07
31–35	84	23	107	9.39
36–40	87	40	127	11.14
41–45	94	29	123	10.79
46–50	86	29	115	10.09
51–55	53	32	85	7.46
56–60	26	32	58	5.09
61–65	20	28	48	4.21
66–70	12	12	24	2.11
71–75	7	7	14	1.23
76–80	2	8	10	0.88
81–85	0	5	5	0.44
≥ 86	2	1	3	0.26
Total	803	337	1,140	100.00



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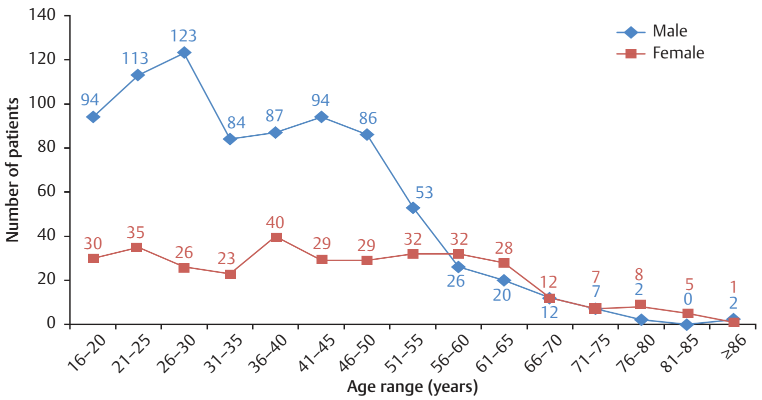

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Fig. 9.15 (**a**) Age distribution of 1,140 patients with talar fractures. (**b**) Age and sex distribution of 1,140 patients with talar fractures.

■ Talar Fractures (Segment 81) by Fracture Type

See ► Table 9.12, ► Table 9.13, ► Fig. 9.16, and ► Fig. 9.17.

Table 9.12 Fracture type distribution of 1,143 talar fractures

Fracture type	Male	Female	Number of fractures	Percentage of talar fractures
81-A	336	195	531	46.46
81-B	276	87	363	31.76
81-C	194	55	249	21.78
Total	806	337	1,143	100.0

Table 9.13 Sex and fracture group distribution of 1,143 talar fractures

Fracture group	Male	Female	Number of fractures	Percentage of talar fractures	Percentage of foot fractures
81-A1	117	92	209	18.29	0.54
81-A2	190	88	278	24.32	0.72
81-A3	29	15	44	3.85	0.11
81-B1	69	38	107	9.36	0.28
81-B2	122	24	146	12.77	0.38
81-B3	85	25	110	9.62	0.28
81-C1	44	18	62	5.42	0.16
81-C2	56	19	75	6.56	0.19
81-C3	94	18	112	9.80	0.29
Total	806	337	1,143	100.00	2.96

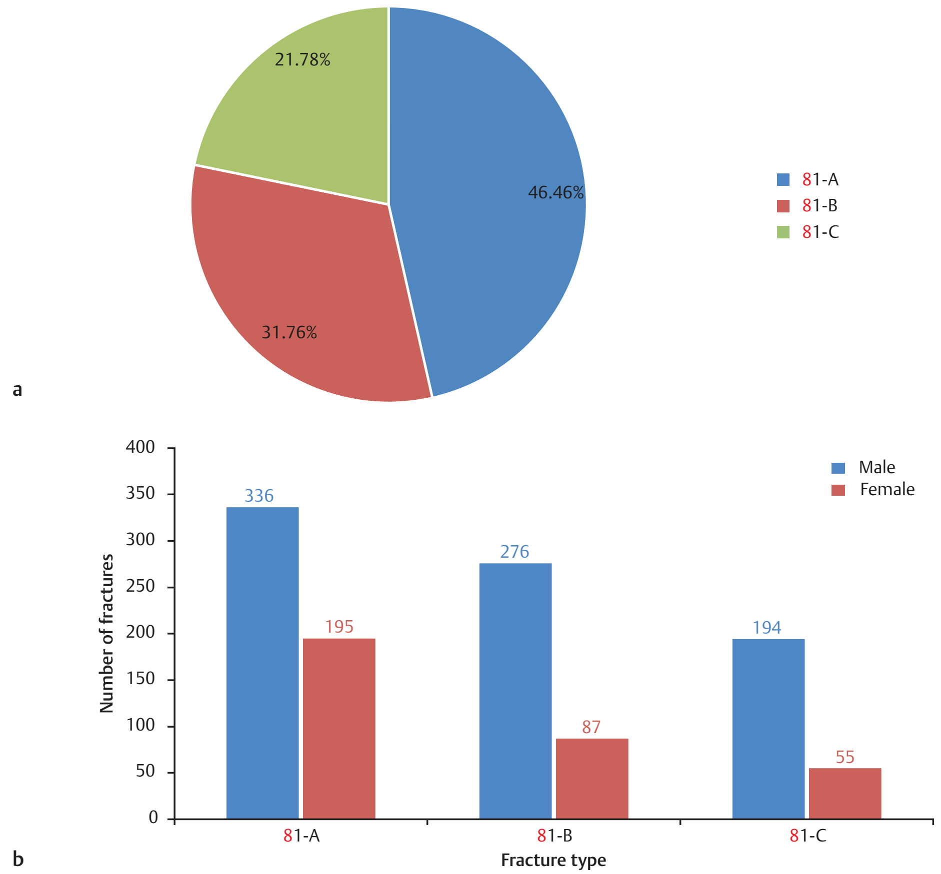


Fig. 9.16 (**a**) Fracture type distribution of 1,143 talar fractures. (**b**) Sex and fracture type distribution of 1,143 talar fractures.

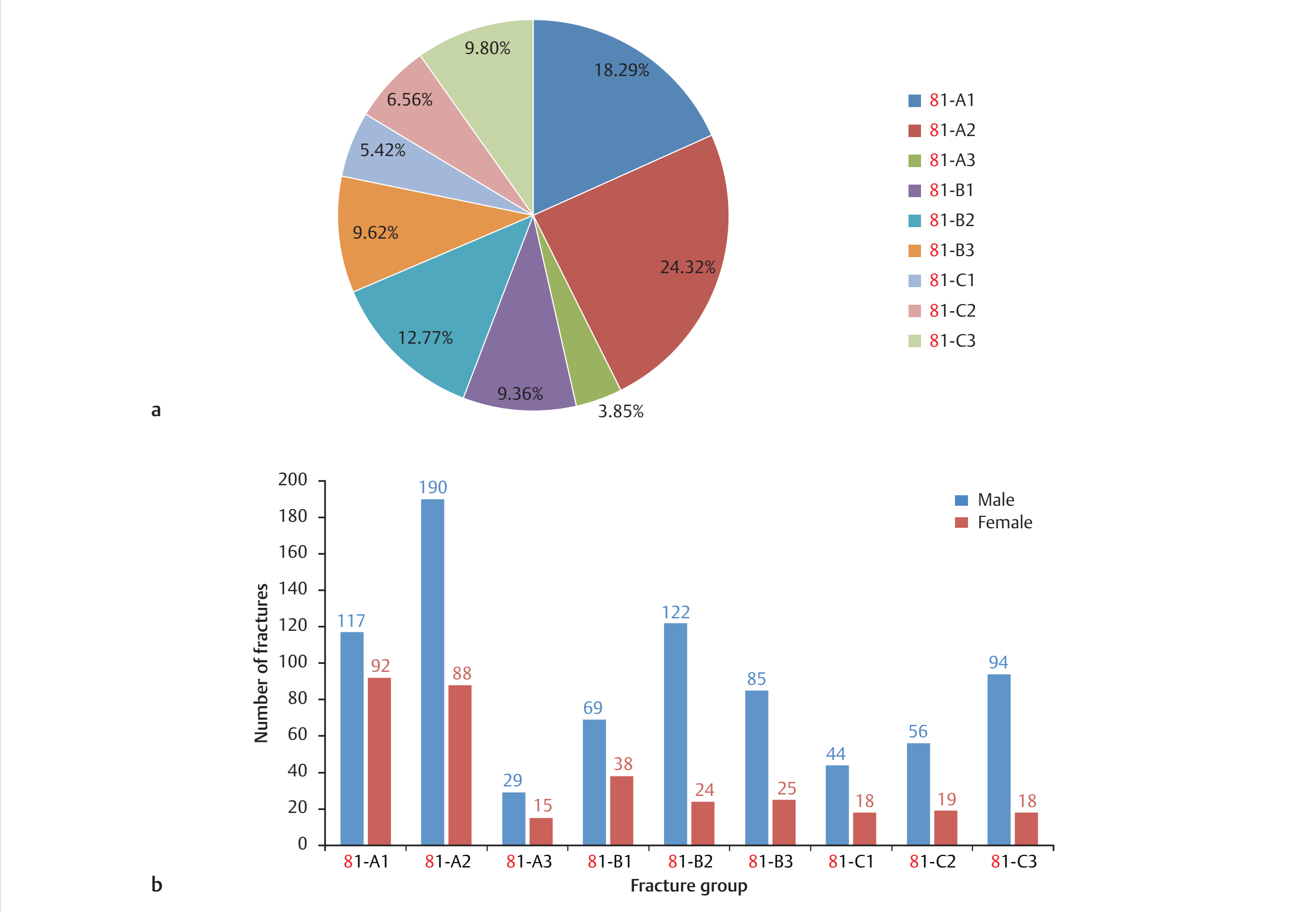
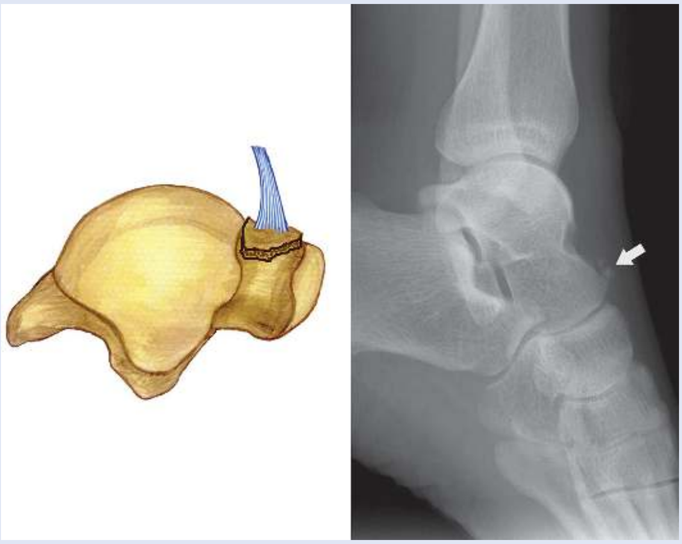


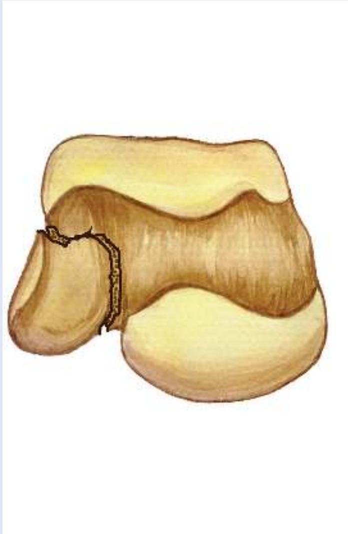
Fig. 9.17 (**a**) Fracture group distribution of 1,143 talar fractures. (**b**) Sex and fracture group distribution of 1,143 talar fractures.

81-A Talus, avulsion, process, or head fractures	
81-A1 Avulsion 209 fractures M: 117 (55.98%) F: 92 (44.02%) 0.06% of total adult fractures 0.54% of adult foot fractures 18.29% of talar fractures 39.36% of type 81-A	**81-A1.1** Anterior  **81-A1.2** Other 

81-A Talus, avulsion, process, or head fractures

81-A2 Process
278 fractures
M: 190 (68.35%)
F: 88 (31.65%)
0.07% of total adult fractures
0.72% of adult foot fractures
24.32% of talar fractures
52.35% of type 81-A

81-A2.1 Lateral

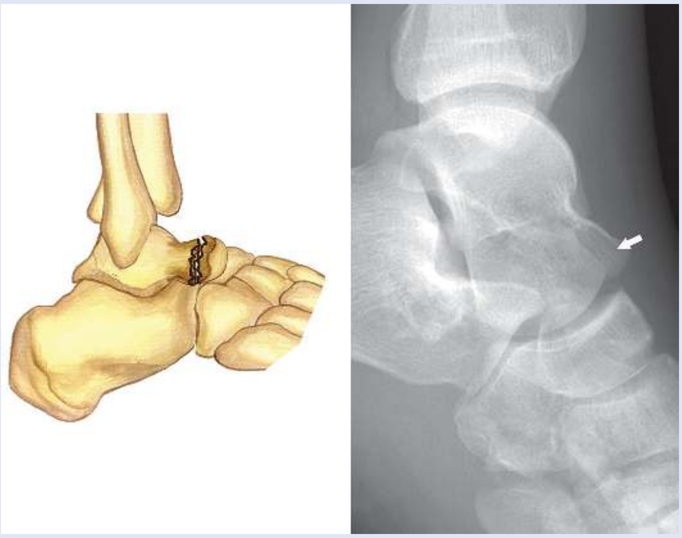


81-A2.2 Posterior

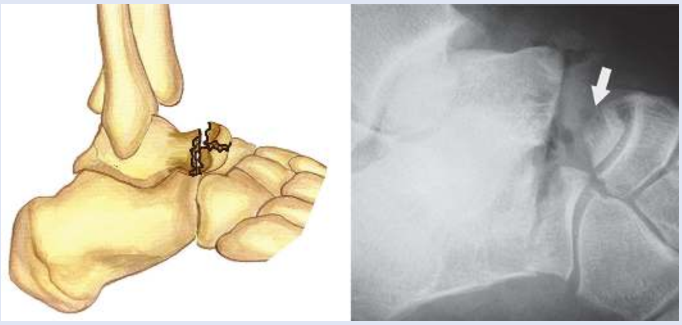
81-A Talus, avulsion, process, or head fractures

81-A3 Head fracture (without neck fracture)
44 fractures
M: 29 (65.91%)
F: 15 (34.09%)
0.01% of total adult fractures
0.11% of adult foot fractures
3.85% of talar fractures
8.29% of type 81-A

81-A3.1 Noncomminuted



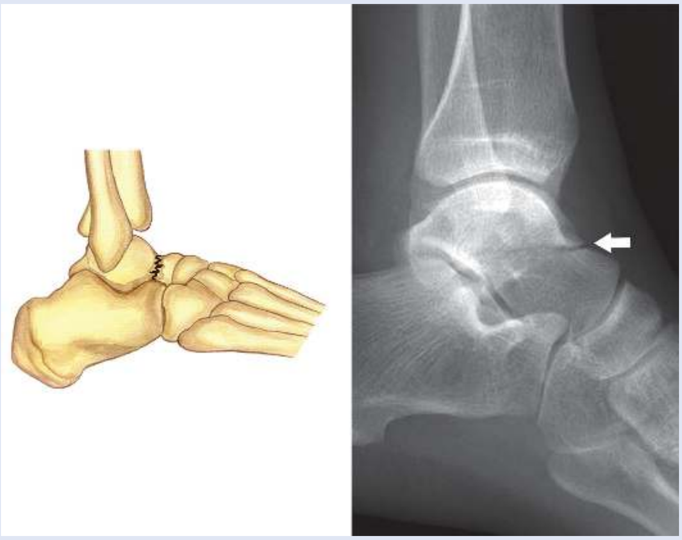
81-A3.2 Comminuted

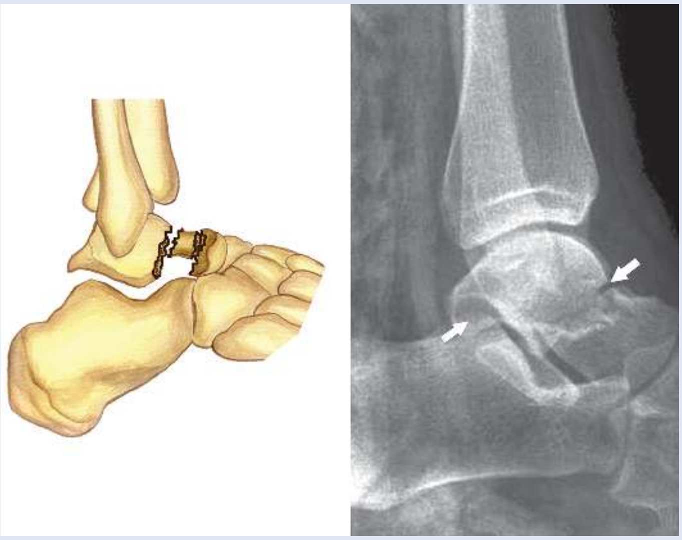


81-B Talus, neck fractures

81-B1 Nondisplaced
107 fractures
M: 69 (64.49%)
F: 38 (35.51%)
0.03% of total adult fractures
0.28% of adult foot fractures
9.36% of talar fractures
29.48% of type 81-B

81-B1 Nondisplaced



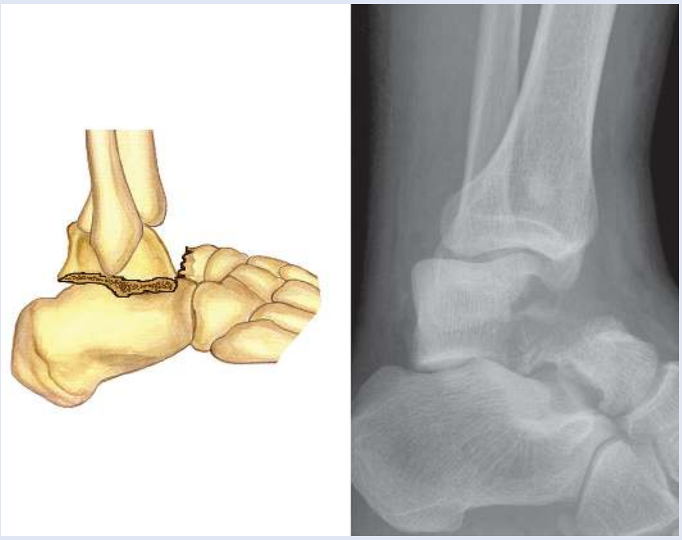
81-B Talus, neck fractures	
81-B2 Displaced with subluxation of subtalar joint 146 fractures M: 122 (83.56%) F: 24 (16.44%) 0.04% of total adult fractures 0.38% of adult foot fractures 12.77% of talar fractures 40.22% of type 81-B	**81-B2.1** Noncomminuted  **81-B2.2** Comminuted  **81-B2.3** Involves talar head 

81-B Talus, neck fractures

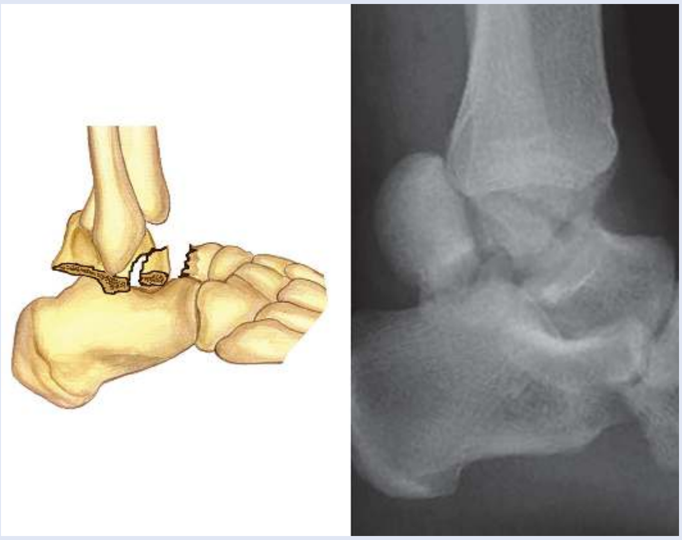
81-B3 Displaced with subluxation of subtalar and ankle joints

110 fractures
M: 85 (77.27%)
F: 25 (22.73%)
0.03% of total adult fractures
0.28% of adult foot fractures
9.62% of talar fractures
30.30% of type 81-B

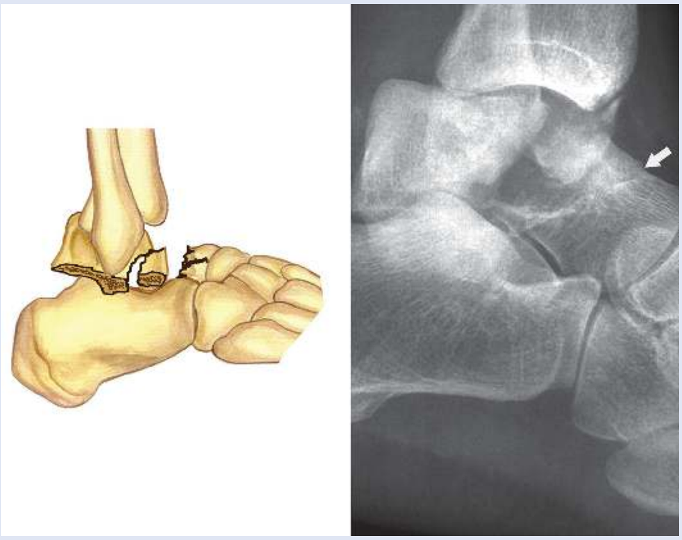
81-B3.1 Noncomminuted



81-B3.2 Comminuted



81-B3.3 Involves talar head

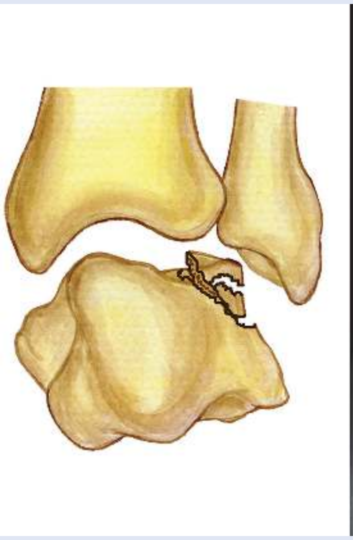


81-C Talus, body fractures

81-C1 Ankle joint involvement, dome fractures
62 fractures
M: 44 (70.97%)
F: 18 (29.03%)
0.02% of total adult fractures
0.16% of adult foot fractures
5.42% of talar fractures
24.90% of type 81-C

81-C1.1 Noncomminuted

81-C1.2 Comminuted

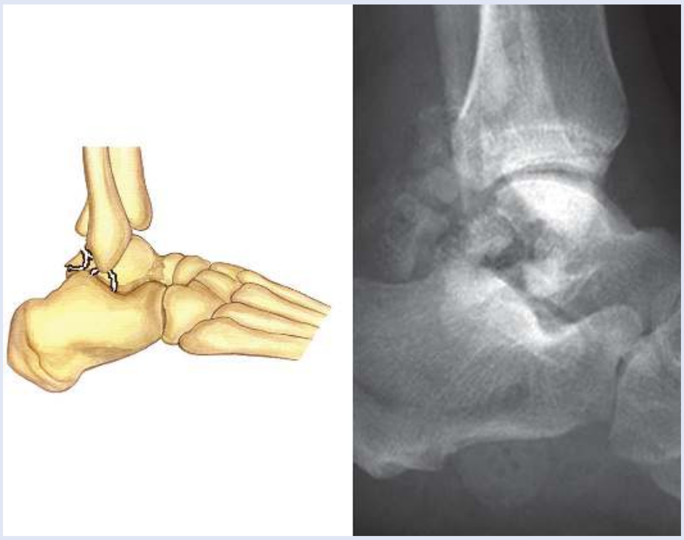


81-C Talus, body fractures

81-C2 Subtalar joint involvement
75 fractures
M: 56 (74.67%)
F: 19 (25.33%)
0.02% of total adult fractures
0.19% of adult foot fractures
6.56% of talar fractures
30.12% of type 81-C

81-C2.1 Noncomminuted

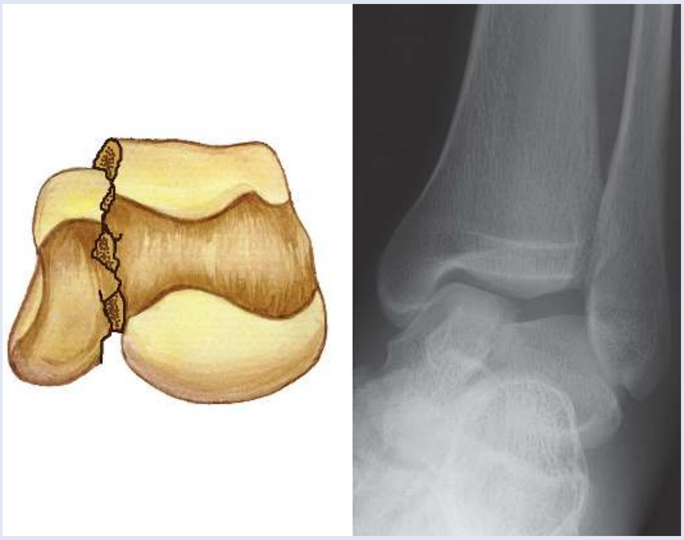
81-C2.2 Comminuted



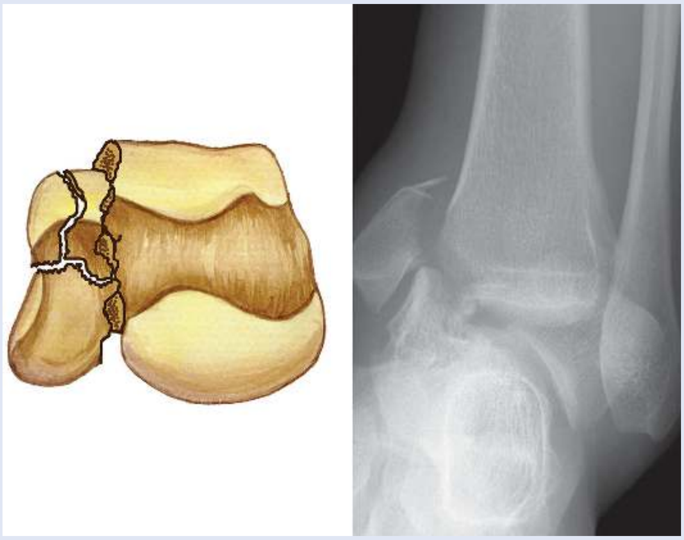
81-C Talus, body fractures

81-C3 Ankle and subtalar joint involvement
112 fractures
M: 94 (83.93%)
F: 18 (16.07%)
0.03% of total adult fractures
0.29% of adult foot fractures
9.80% of talar fractures
44.98% of type 81-C

81-C3.1 Noncomminuted



81-C3.2 Comminuted



Injury Mechanism

Neck fractures are the most common talar fractures. The usual mechanism is associated with hyperdorsiflexion of the ankle as the talar neck impacts the anterior margin of the tibia, as may occur in an automobile accident or a fall from a height. The body of the talus locks in the ankle mortise following a talar neck fracture, and the remaining portion of the foot, including the head and calcaneus, is displaced medially. The continuous axial load may rupture the interosseous talocalcaneal ligament, the posterior talofibular ligament, and the posterior talocalcaneal ligament, causing the body of the talus to move out of the ankle mortise posteromedially. The resultant fracture line will run obliquely upward and laterally.

Body fractures of the talus occur most commonly as a result of axial compression load, as seen in a fall from a significant height. Ankle joint fractures may also accompany this injury. Fractures of the posterior and lateral processes are often results of violent contraction of nearby attached muscles as the injury occurs.

Talar head fractures are relatively uncommon, usually resulting from force transmitted along the metatarsal rays to the talar head.

Diagnosis

Most talar fractures are marked by acute pain, considerable swelling and tenderness, and limited or partially limited motion. If fractures are displaced markedly or the injury results in dislocation, then deformity may be present. The anteroposterior (AP) view of the ankle joint can reveal most talar fractures, while the oblique view provides better visualization of the head and neck of the talus, even with small fragments. It is important to note the extension and direction of fracture displacement and the presence of fractures of adjacent articulations. Particular attention should be given to the ankle mortise, the distal tibia, and the remaining tarsal, to rule out possible fractures. Computed tomography (CT) scan and magnetic resonance imaging (MRI) can better reveal the nature of the fractures and provide accurate assessment of the articular involvement, as well as the degree of fracture displacement.

Treatment

Stable nondisplaced talar body fractures and avulsion fractures can be treated with immobilization by casting. Nondisplaced, unstable fractures and displaced talar body fractures can be managed by fixation of compression screws with minimally invasive techniques. Comminuted fractures can be treated with secondary arthrodesis if there is persistent pain or swelling. Stable, nondisplaced talar neck fractures can be treated nonsurgically, in contrast to displaced talar neck fractures, which require surgical intervention. A displaced talar neck fracture with associated dislocation may be treated first with closed reduction. Emergency open reduction and internal fixation may be indicated if closed reduction fails.

Other Common Classifications of Talar Fractures

Hawkins Classification of Talar Neck Fractures

The Hawkins classification of talar neck fractures is as follows:
- Type I: Nondisplaced
- Type II: Associated subtalar subluxation or dislocation
- Type III: Associated subtalar and ankle dislocation
- Type IV: Canale and Kelley
- Type IV: With associated talonavicular subluxation of dislocation (▶ Fig. 9.18)

Clinical Epidemiologic Features of Talar Fractures According to Fracture Location

A total of 1,143 adult talar fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied. Their epidemiologic features are as follows:
- Talar process fractures are the most common talar fractures
- Type II fractures are the most common type of talar neck fractures
- Talar head fractures are rare, only accounting for 3.85% of talar fractures

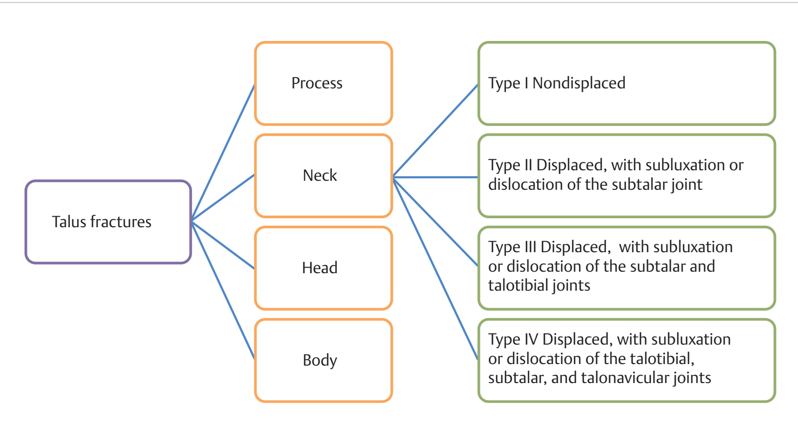


Fig. 9.18 Algorithm.

Talar Fractures by Fracture Location

See ▶ Table 9.14 and ▶ Fig. 9.19.

Table 9.14 Sex and fracture location distribution of 1,143 talar fractures

Fracture location of talus	Male	Female	Number of fractures	Percentage of talar fractures
Process	307	180	487	42.61
Neck	276	87	363	31.76
Head	29	15	44	3.85
Body	194	55	249	21.78
Total	806	337	1,143	100.00

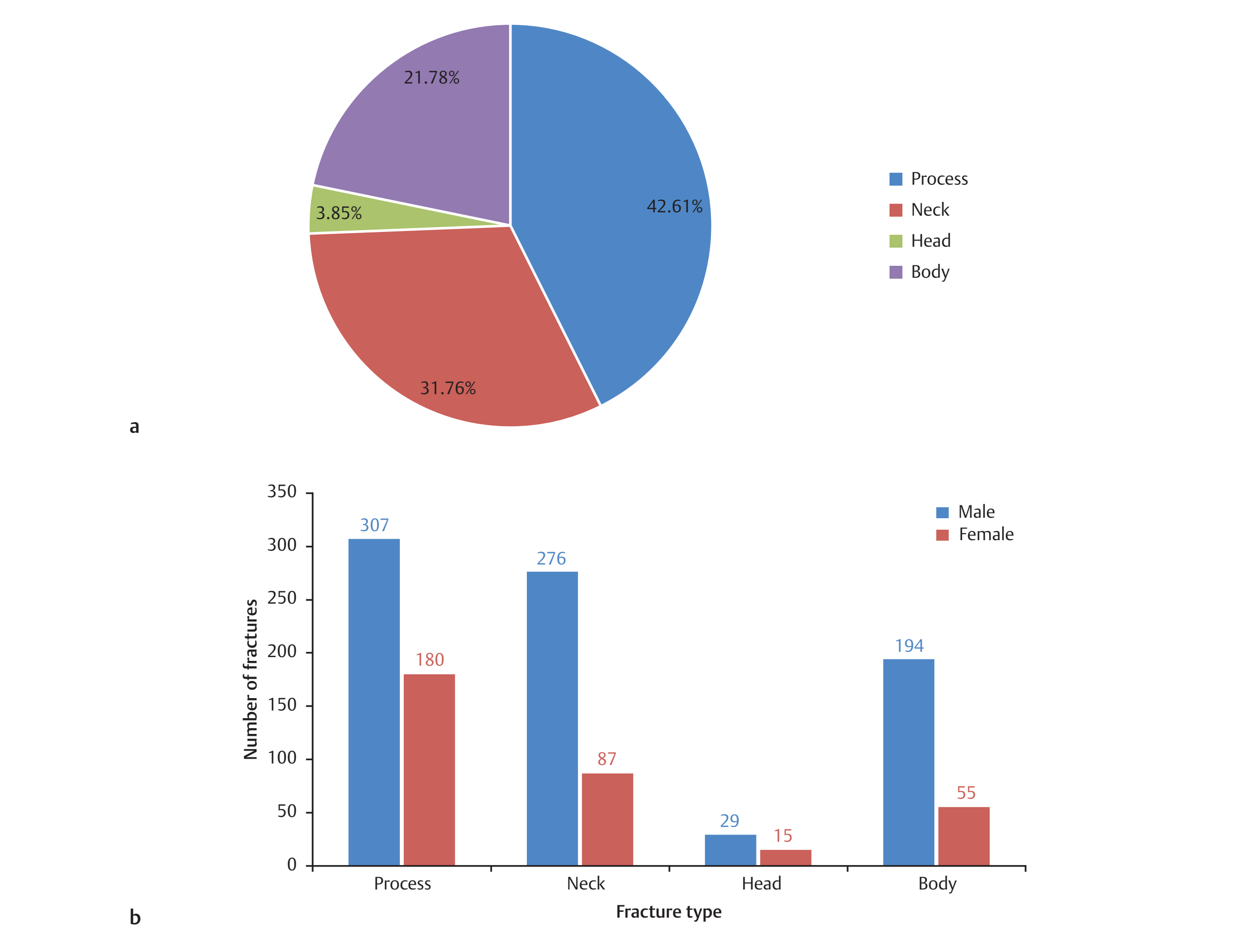
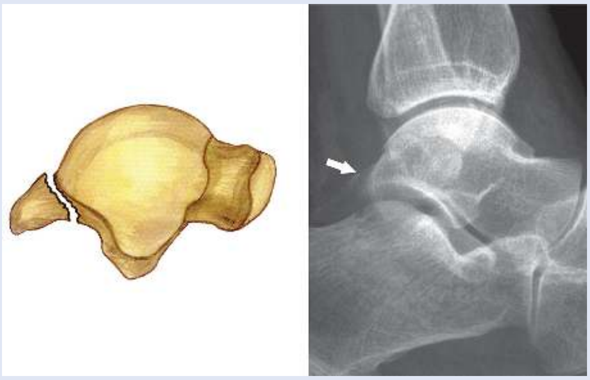
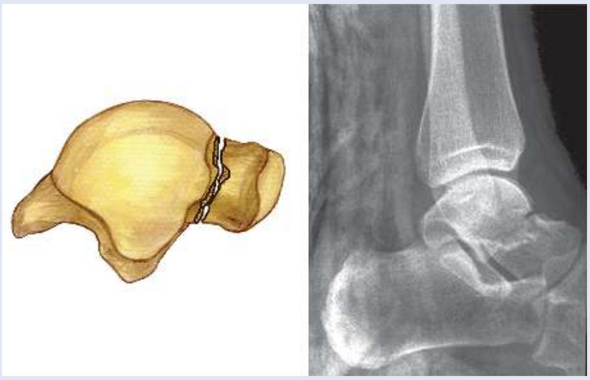
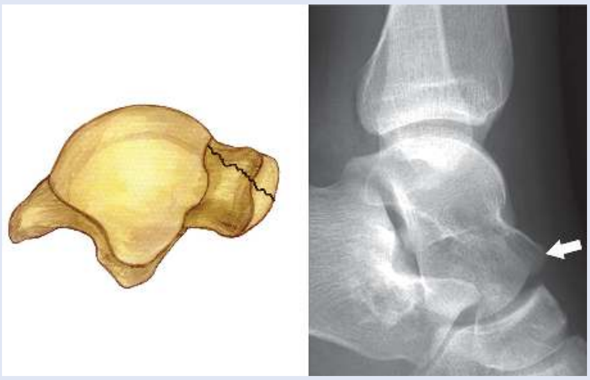
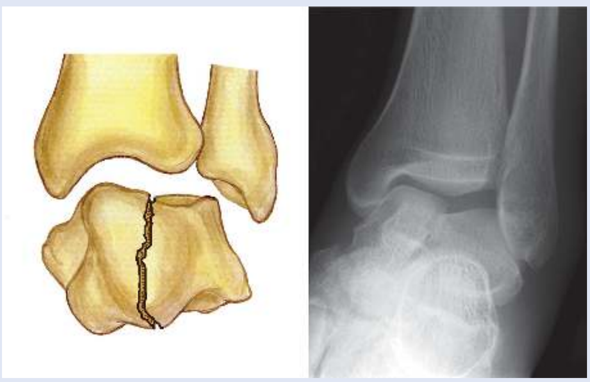
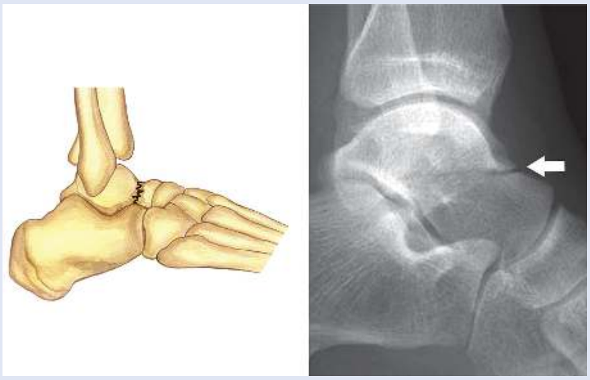
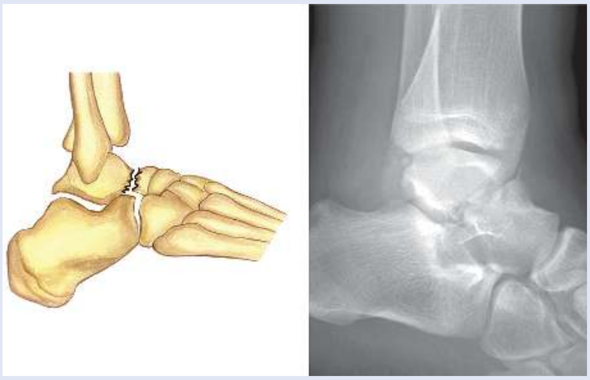
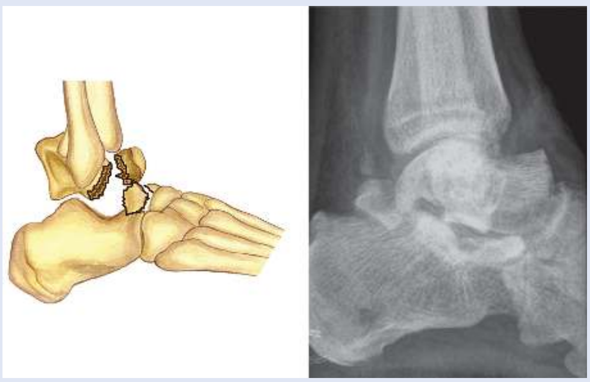


Fig. 9.19 (a) Fracture location distribution of 1,143 talar fractures. (b) Sex and fracture location distribution of 1,143 talar fractures.

Talar fractures	
Fractures of the talar process 487 fractures M: 307 fractures (63.04%) F: 180 fractures (36.96%) 0.13% of total adult fracture 1.26% of adult foot fracture 42.61% of talar fractures	**Talar process fracture** 
Fractures of the talar neck 363 fractures M: 276 (76.03%) F: 87 (23.97%) 0.10% of total adult fracture 0.94% of adult foot fracture 31.76% of talar fractures	**Talar neck fracture** 
Fractures of the talar head 44 fractures M: 29 (65.91%) F: 15 (34.09%) 0.01% of total adult fracture 0.11% of adult foot fracture 3.85% of talar fractures	**Talar head fracture** 
Fractures of the talar body 249 fractures M: 194 (77.91%) F: 55 (22.09%) 0.07% of total adult fracture 0.64% of adult foot fracture 21.78% of talar fractures	**Talar body fracture** 

Talar neck fractures (Hawkins classification)	
Type I Nondisplaced 107 fractures 0.03% of total 0.28% of foot 9.36% of talus 29.48% of talar neck	**Hawkins Type I** 
Type II Displaced, with subluxation and dislocation of the subtalar **joint** 146 fractures 0.04% of total 0.38% of foot 12.77% of talus 40.22% of talar neck	**Hawkins Type II** 
Type III Displaced, with subluxation and dislocation of the subtalar **and talotibial joints** 87 fractures 0.02% of total 0.23% of foot 7.61% of talus 23.97% of talar neck	**Hawkins Type III** 
Type IV Displaced, with subluxation and dislocation of the talotibial, subtalar, and talonavicular joints 23 fractures 0.01% of total 0.06% of foot 2.01% of talus 6.34% of talar neck	**Hawkins Type IV** 

Calcaneal Fractures (Segment 82)

Anatomic Features

The calcaneus is the largest of the tarsal bones; rectangular in shape, it lies inferior to the talus. The calcaneus has six surfaces: superior, inferior, anterior, posterior, medial and lateral. It has three talocalcaneal facets on its upper surface, and one calcaneocuboid facet on its front.

- **Superior:** On its upper surface are three smooth facets, posterior, middle, and anterior, which articulate with the lower surface of the talus to form the subtalar joint. The middle one-third of the surface is the posterior facet, which is large and oval or oblong. It is anteriorly tilted, at an angle of 45 degrees from the midsagittal plane. The middle and anterior facets are located on the medial side of the upper calcaneal surface and are usually continuous with each other. On the medial side of the bone, below the middle talocalcaneal facet, is a shelf-like projection, the sustentaculum tali, which supports the talar neck and also serves for the attachment of several ligaments. The posterior one-third surface of the upper calcaneal surface is roughened and is in between the posterior aspect of the ankle joint and the Achilles tendon.
- **Inferior:** The inferior roughened area of the calcaneus gives attachment for the long plantar ligament and the quadratus-plantae. The plantar-surface forepart of the calcaneus is a small rounded projection known as the small calcaneal tubercle, which gives attachment to the plantar calcaneocuboid ligament. The back part of the planter surface is an eminence called the calcaneal tubercle.
- **Medial:** The medial wall of the calcaneus is depressed. Under the surface of the sustentaculum tali of the calcaneus, there is a groove running obliquely downward from posterior to anterior, which contains the flexor hallucis longus tendon.
- **Lateral:** The lateral wall of the calcaneus is flat and smooth, except for a small ridge called the peroneal tubercle. Passing below the peroneal tubercle of the calcaneus is the groove for peroneus longus tendon.
- **Anterior:** The anterior surface of the calcaneus, which is square in shape, has the smallest surface of all and has a saddle-shaped articulation, forming the calcaneocuboid joint with the cuboid bone.
- **Posterior:** The posterior half of the calcaneus is an oval-shaped projection, which can be subdivided into three parts: upper, middle, and lower. The upper part of the posterior surface of the calcaneus is separated from the Achilles tendon by the subtendinous bursa and fat tissue; the middle part of the posterior surface, broad and rough, is the insertion point of the Achilles tendon; while the lower part is at a forward decline and continues with the calcaneal tuberosity. On the lower edge of the calcaneal tuberosity, on either side, are its lateral and medial processes serving as the origins of the abductor hallucis and abductor digit minimi (▶ Fig. 9.20).

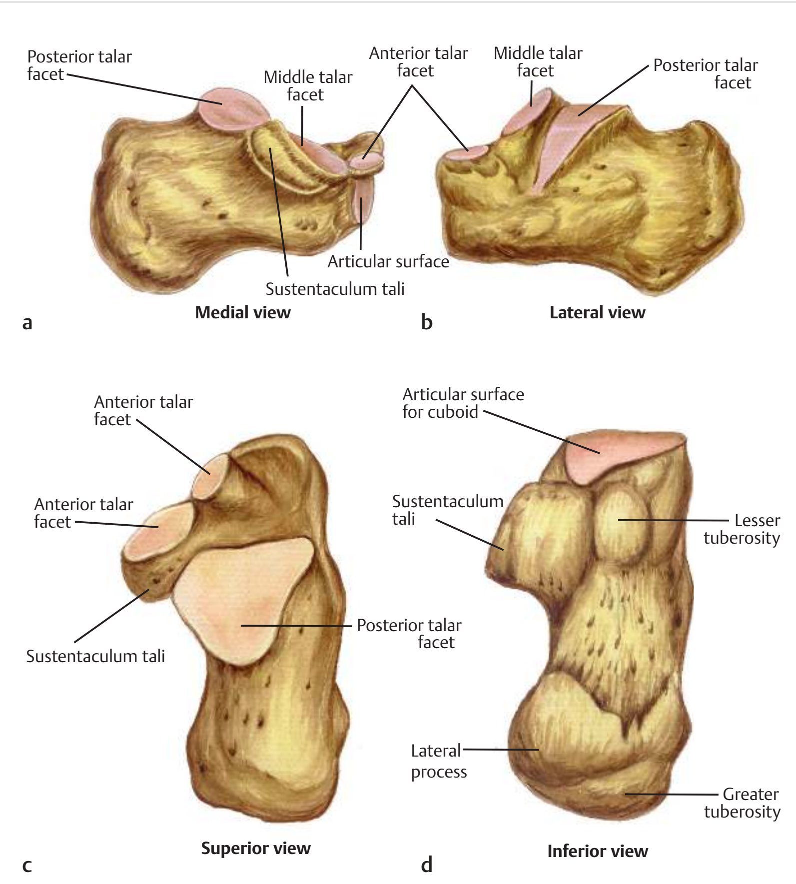


Fig. 9.20 Medial (**a**), lateral (**b**), superior (**c**), and inferior (**d**) views of the calcaneus.

OTA Classification of Calcaneal Fractures

Based on OTA classification, the calcaneus is coded as number "82" for its anatomic location. According to fracture location, calcaneal fractures are classified into three types: 82-A, avulsion, process, or tuberosity; 82-B, extra-articular body fractures; and 82-C, articular fractures involving the posterior facet (▶ Fig. 9.21).

Clinical Epidemiologic Features of Calcaneal Fractures (Segment 82)

A total of 11,008 adult patients with 11,720 calcaneal fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, including 5,092 patients with fractures on the left side, 5,204 on the right side, and 712 bilateral. There were 9,228 males and 1,780 females, with a male to female ratio of 5.18:1.

Epidemiologic features of calcaneal fractures are as follows:

- More males than females
- The high-risk age group is 36–40 years, the same age group for males, whereas the high-risk age groups for female are 36–40 and 46–50 years
- The most common fracture type is type 82-C

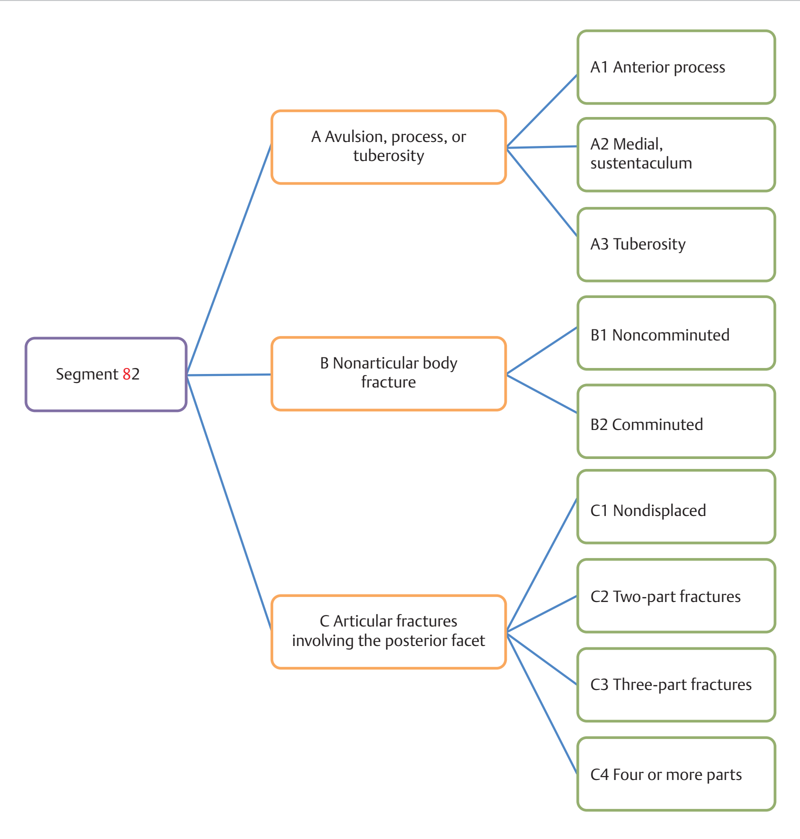


Fig. 9.21 Algorithm.

9

■ Calcaneal Fractures by Sex

See ▶ Table 9.15 and ▶ Fig. 9.22.

Table 9.15 Sex distribution of 11,008 patients with calcaneal fractures

Sex	Number of patients	Percentage
Male	9,228	83.83
Female	1,780	16.17
Total	11,008	100.00

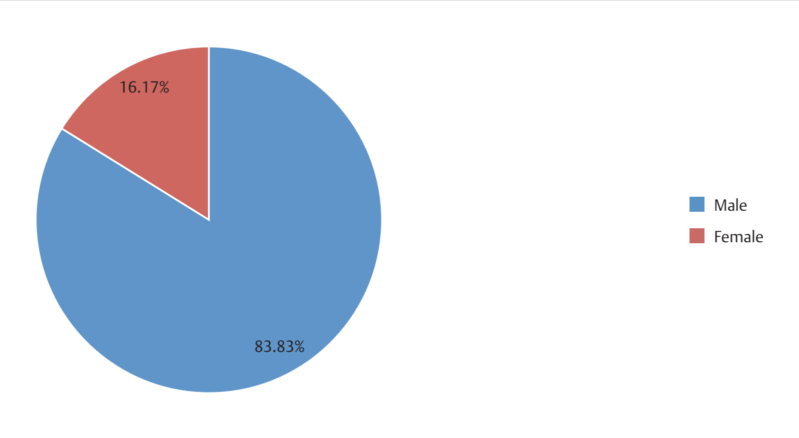


Fig. 9.22 Sex distribution of 11,008 patients with calcaneal fractures.

Calcaneal Fractures by Age Group

See ▶ Table 9.16 and ▶ Fig. 9.23.

Table 9.16 Age and sex distribution of 11,008 patients with calcaneal fractures

Age group (years)	Male	Female	Number of patients	Percentage
16–20	530	103	633	5.75
21–25	774	141	915	8.31
26–30	951	130	1,081	9.82
31–35	1,104	134	1,238	11.25
36–40	1,687	216	1,903	17.29
41–45	1,438	216	1,654	15.03
46–50	1,142	220	1,362	12.37
51–55	674	175	849	7.71
56–60	514	150	664	6.03
61–65	223	95	318	2.89
66–70	97	77	174	1.58
71–75	43	58	101	0.92
76–80	32	40	72	0.65
81–85	14	15	29	0.26
≥ 86	5	10	15	0.14
Total	9,228	1,780	11,008	100.00

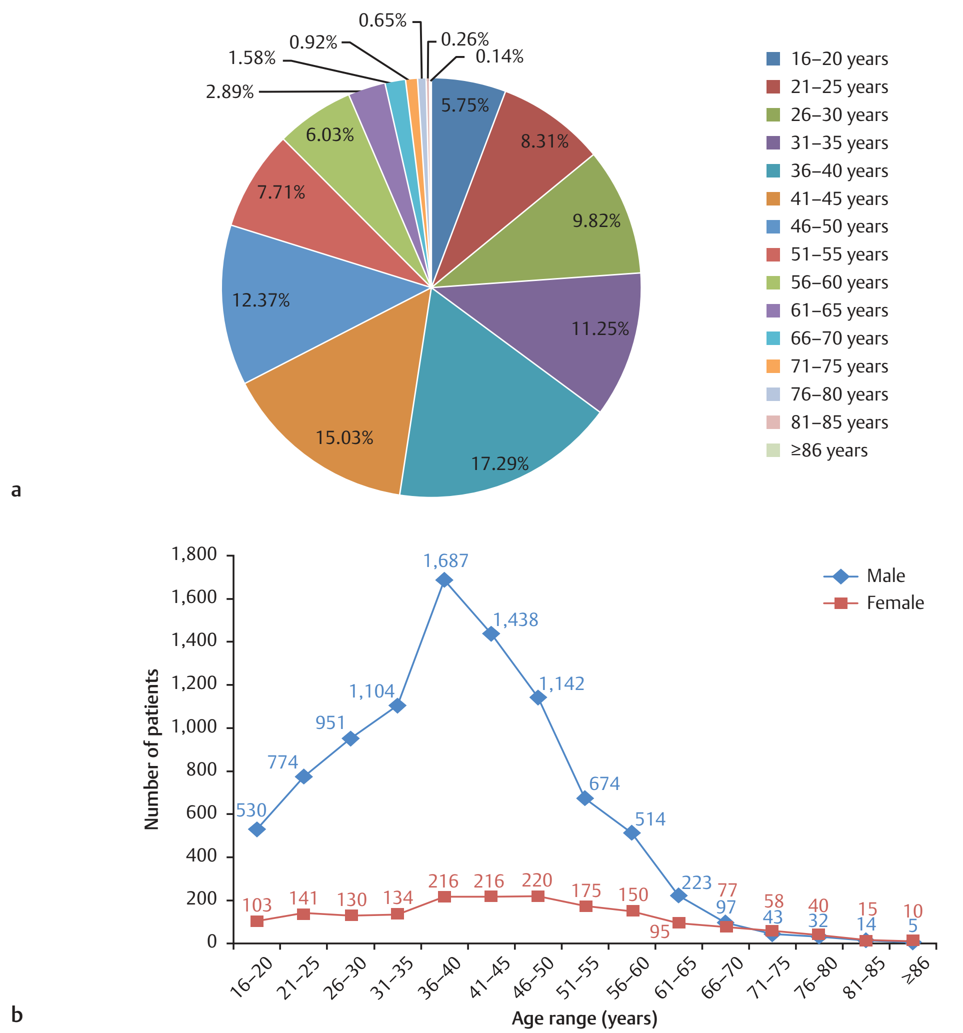


Fig. 9.23 (**a**) Age distribution of 11,008 patients with calcaneal fractures. (**b**) Age and sex distribution of 11,008 patients with calcaneal fractures.

■ Calcaneal Fractures by Fracture Type

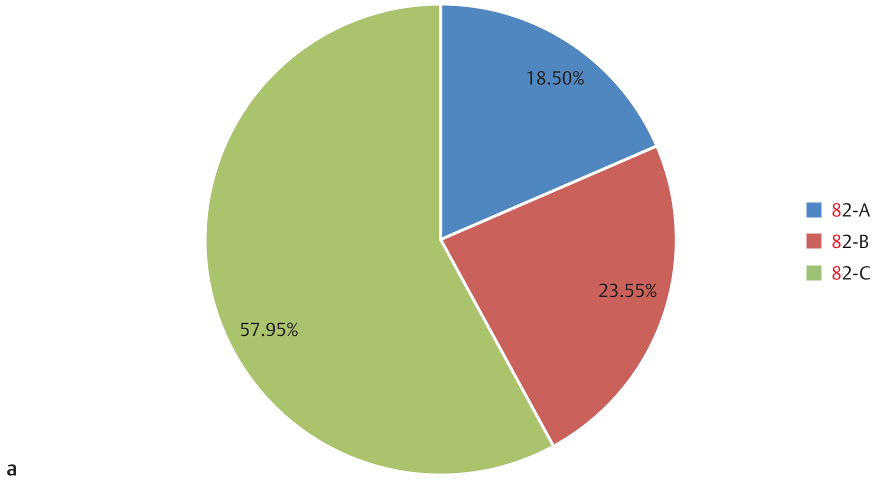
See ▶ Table 9.17, ▶ Table 9.18, ▶ Fig. 9.24, and ▶ Fig. 9.25.

Table 9.17 Sex and fracture type distribution of 11,720 calcaneal fractures

Fracture type	Male	Female	Number of fractures	Percentage of calcaneal fracture
82-A	1,632	536	2,168	18.50
82-B	2,262	498	2,760	23.55
82-C	5,978	814	6,792	57.95
Total	9,872	1,848	11,720	100.00

Table 9.18 Sex and fracture group distribution of 11,720 calcaneal fractures

Fracture group	Male	Female	Number of fractures	Percentage of calcaneal fractures	Percentage of foot fractures
82-A1	451	216	667	5.69	1.73
82-A2	254	85	339	2.89	0.88
82-A3	927	235	1,162	9.91	3.01
82-B1	1,161	275	1,436	12.25	3.72
82-B2	1,101	223	1,324	11.30	3.43
82-C	5,978	814	6,792	57.95	17.58
Total	9,872	1,848	11,720	100.00	30.34



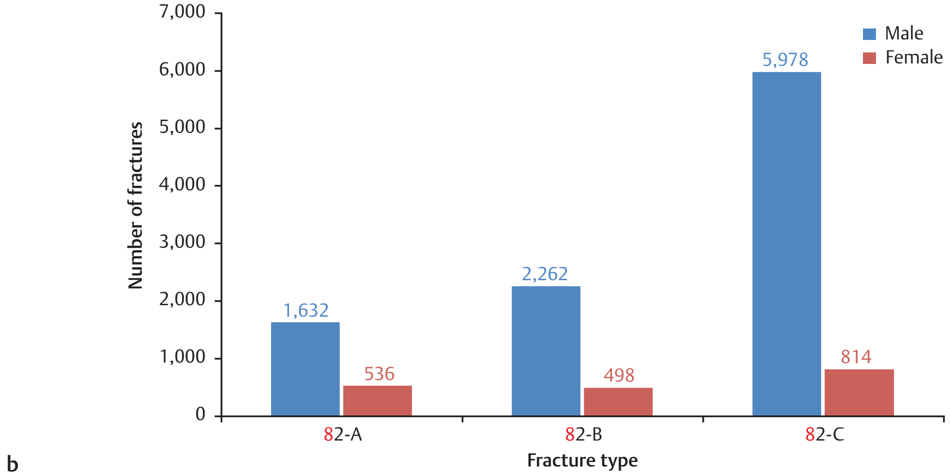


Fig. 9.24 (**a**) Fracture type distribution of 11,720 calcaneal fractures. (**b**) Sex and fracture type distribution of 11,720 calcaneal fractures.

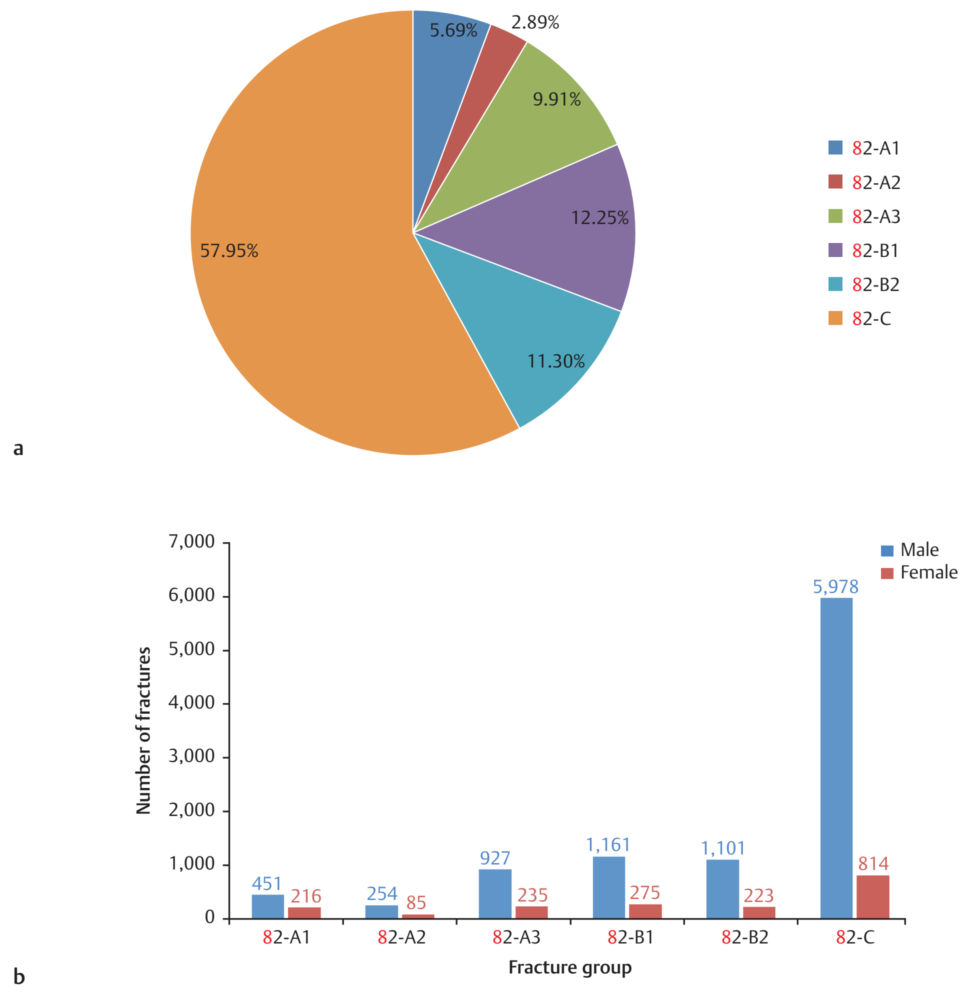
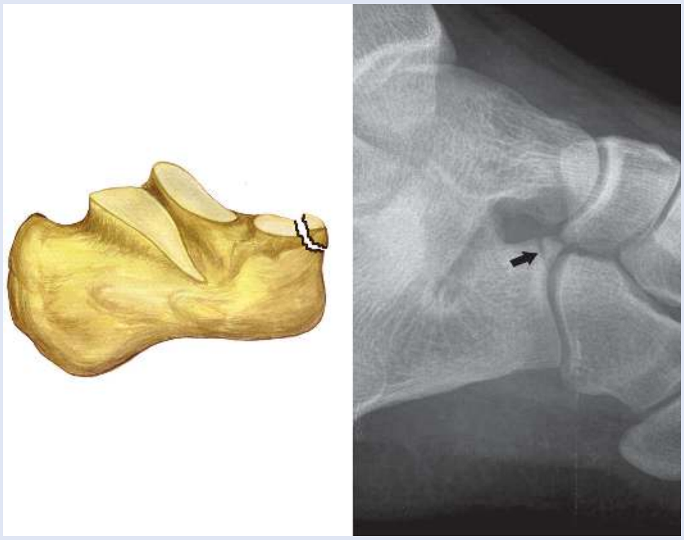


Fig. 9.25 (**a**) Fracture group distribution of 11,720 calcaneal fractures. (**b**) Sex and fracture group distribution of 11,720 calcaneal fractures.

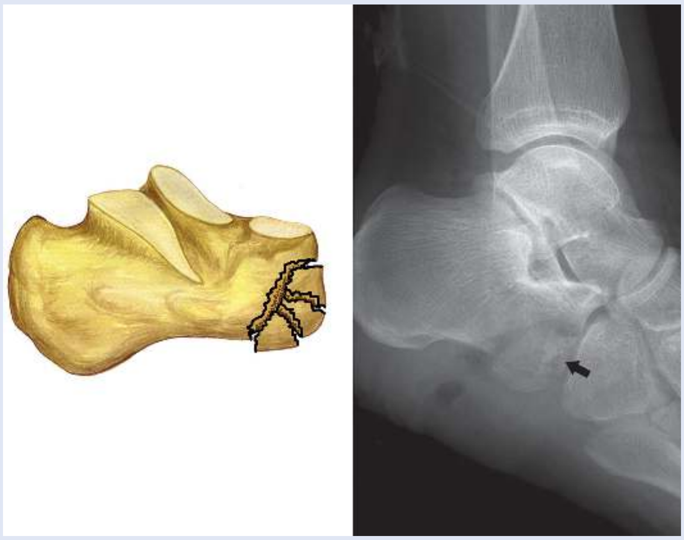
82-A Calcaneus, avulsion, process, or tuberosity

82-A1 Anterior process
667 fractures
M: 451 (67.62%)
F: 216 (32.38%)
0.18% of total adult fractures
1.73% of adult foot fractures
5.69% of calcaneal fractures
30.77% of type 82-A

82-A1.1 Noncomminuted



82-A1.2 Comminuted

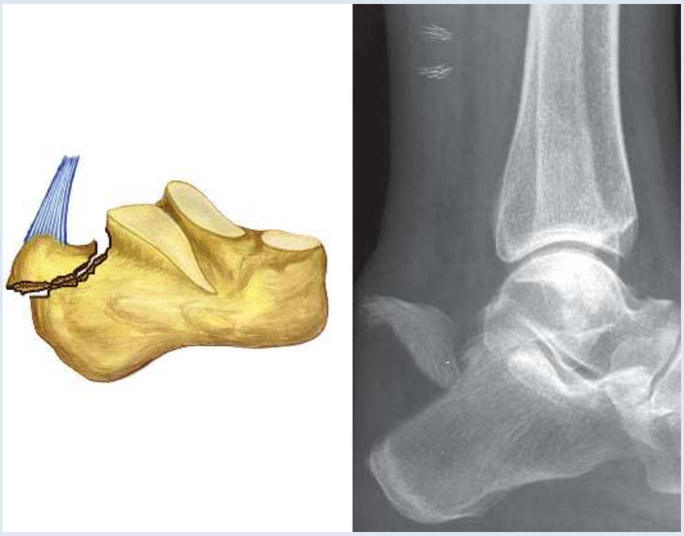


82-A Calcaneus, avulsion, process, or tuberosity	
82-A2 Medial, sustentaculum 339 fractures M: 254 (74.93%) F: 85 (25.07%) 0.09% of total adult fracture 0.88% of adult foot fracture 2.89% of calcaneal fractures 15.64% of type 82-A	**82-A2.1** Noncomminuted  
	82-A2.2 Comminuted  

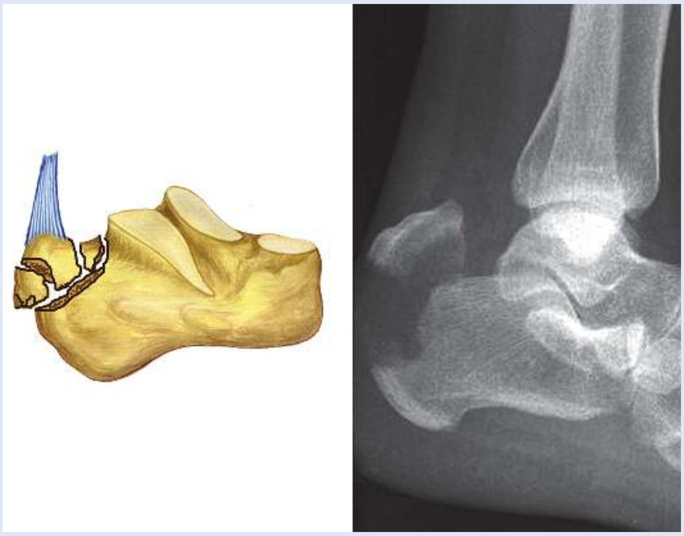
82-A Calcaneus, avulsion, process, or tuberosity

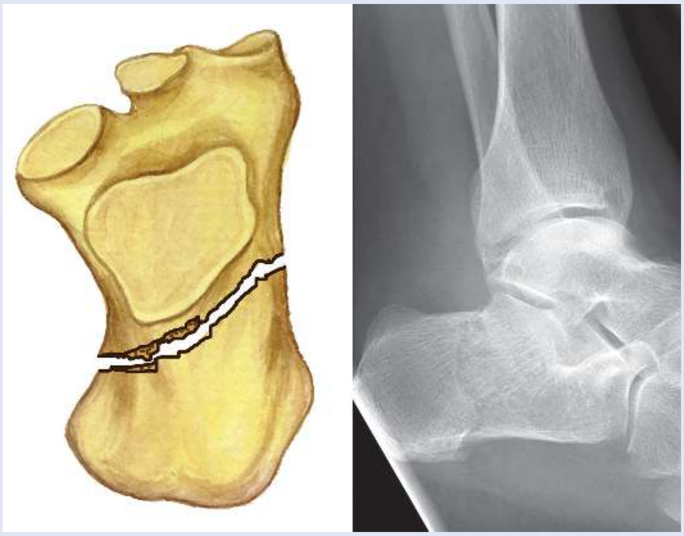
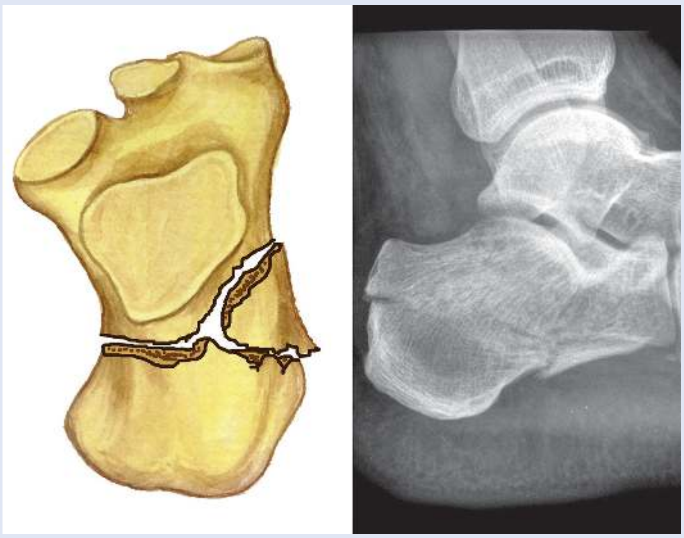
82-A3 Tuberosity
1,162 fractures
M: 927 (79.78%)
F: 235 (20.22%)
0.31% of total adult fracture
3.01% of adult foot fracture
9.91% of calcaneal fractures
53.60% of type 82-A

82-A3.1 Noncomminuted



82-A3.2 Comminuted



82-B Calcaneus, extra-articular body fractures	
82-B1 Noncomminuted 1,436 fractures M: 1,161 (80.85%) F: 275 (19.15%) 0.38% of total adult fractures 3.72% of adult foot fractures 12.25% of calcaneal fractures 52.03% of type 82-B	**82-B1** Noncomminuted 
82-B2 Comminuted 1,324 fractures M: 1,101 (83.16%) F: 223 (16.84%) 0.35% of total adult fractures 3.43% of adult foot fractures 11.30% of calcaneal fractures 47.97% of type 82-B	**82-B2** Comminuted 

82-C Calcaneus, articular fractures involving posterior facet

82-C Articular fractures involving posterior facet
6,792 fractures
M: 5,978 (88.02%)
F: 814 (11.98%)
1.81% of total adult fractures
17.58% of adult foot fractures
57.95% of calcaneal fractures

82-C1 Nondisplaced

82-C2 Two-part fractures

82-C3 Three-part fractures

82-C Calcaneus, articular fractures involving posterior facet

82-C4 Four or more parts

Injury Mechanism

The patterns of foot fractures vary, depending on the direction of the force that acted on the foot and the position of the foot at the time of injury. Fractures of the anterior part of the calcaneus usually involve avulsion and depression of the anterior process, with avulsion being the most common fracture of the anterior process. Avulsion fractures of the anterior process usually result from a strong tensile force from the bifurcate ligament, when axial load is applied at the calcaneus while the foot is dorsiflexed and inverted. Depression fractures of the anterior process usually occur as a result of a strong abduction force on the calcaneocuboid articulation surface.

Avulsion fractures of the calcaneal tuberosity tend to occur from avulsion of the Achilles tendon with its bony insertion, due to an abrupt contraction. Less commonly, it can also be the result of a direct force applied on the calcaneus.

Fracture of the sustentaculum tali is usually caused by an axial loading mechanism, which is directed through the laterally situated plantar tuberosity of the calcaneus with the foot inverted. Calcaneal body fractures are the result of axial loading when the heel hits the ground, as occurs in a fall from height; the fracture line usually is vertical or oblique, passing through the back of the subtalar articulation, and producing simple or comminuted fractures.

Most intra-articular fractures of the calcaneus involve the posterior facet of the subtalar joint, and are caused by an axial loading mechanism, as occurs in a fall from height or motor-vehicle collisions. Besides the axial loading force, rotation forces such as abduction or external rotation forces will also contribute to this type of injury. The axial loading force will produce a fracture line passing along the long axis of the calcaneus, obliquely upwards from medial to lateral. If the axial loading force continues, the cortex of the lateral process of the calcaneus may start to rupture, followed by further fragmentation-, depression-, and displacement-type fractures.

Diagnosis

Patients with a fracture of the calcaneus may present with pain, edema, ecchymosis, deformity of the heel or plantar arch, and an inability to bear weight on the injured foot. Standard radiographic evaluations, including lateral and axial views of the calcaneus, are helpful in revealing general information about the fracture. Lateral radiographs of the foot are needed to evaluate the Bohler and Gissane angle, as well as dislocation of the subtalar joint. Axial views depict the primary and secondary fracture line, posterior facet step-off, and lateral-wall displacement, providing good visualization of the sustentaculum tali. In addition, Broden views of the foot are needed to evaluate the posterior facet of the subtalar joint and can be used as a postoperative evaluation of fracture reduction. CT scans or 3D CT of the calcaneus enable better visualization of the sustentaculum tali and the posterior facet, and are helpful in determining the fracture line and the displacement of the posterior facet. CT can provide valuable information, which is essential in selecting a surgical approach and determining whether the fracture can be reduced and stabilized through internal fixation. For fall injuries, where a foot hits the ground, attention should be given to the presence of a possible hip or spinal injury, because force can transmit along the lower extremities to the pelvis and spine. X-rays can help to rule out other possible injuries and confirm the diagnosis.

- Bohler angle: formed by the intersection of a line drawn from the tuberosity's most cephalic point to the posterior facet's peak point with a line from the latter to the most cephalic part of the anterior process of the calcaneus; a normal range for this angle is 25 to 40 degrees (▶ Fig. 9.26).
- Gissane angle: formed by the intersection of a line drawn along the dorsal aspect of the anterior process of the calcaneus, and a line drawn along the dorsal slope of the posterior facet; a normal value of Gissane angle is 120 to 145 degrees (▶ Fig. 9.27).

Fig. 9.26 Bohler angle.

Fig. 9.27 Gissane angle.

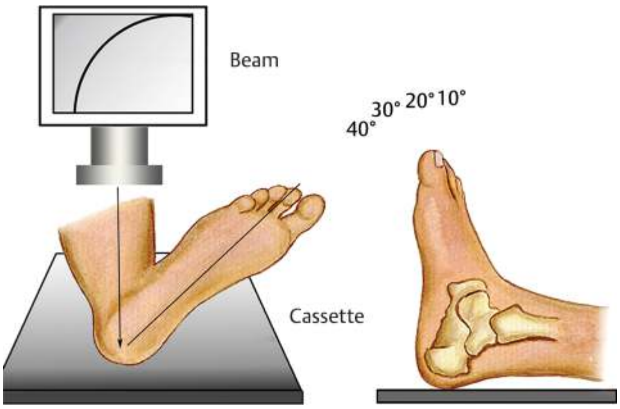


Fig. 9.28 Broden views of the foot.

- Broden views of the foot: internally rotating the leg 45 degrees with the ankle in a neutral position. The beam may then be directed toward the lateral malleolus and advanced cephalad at intervals of 10, 20, 30, and 40 degrees, so as to fully evaluate the posterior facet (▶ Fig. 9.28).

Treatment

The goal of treatment for calcaneal fractures is to restore the congruity of the subtalar joint and Bohler angle, to restore the height and width of the calcaneus as far as possible, and to maintain normal arch height and weight-bearing functionality. Nondisplaced calcaneal fractures require only nonsurgical treatment, while avulsion fractures of the tuberosity and displaced intra-articular fractures should be treated surgically. Commonly used surgical options include: open reduction with internal fixation, and minimally invasive reduction and internal fixation. According to fracture location and pattern, multiple internal fixation devices can be selected, such as the H-plate, Y-plate, 3.5-mm constructive plate, anatomic plate, etc. Noncomminuted calcaneal fractures with a transverse fracture line can be treated with percutaneous reduction by leverage. However, internal fixation is still needed in some cases, even if reduction was obtained by percutaneous leverage. A group of talented orthopaedic surgeons led by Yingze Zhang has developed a minimally invasive internal fixation technique with plates, screws, and a compression system to treat calcaneal fractures and obtain a favorable clinical outcome.

Other Classifications for Calcaneal Fractures

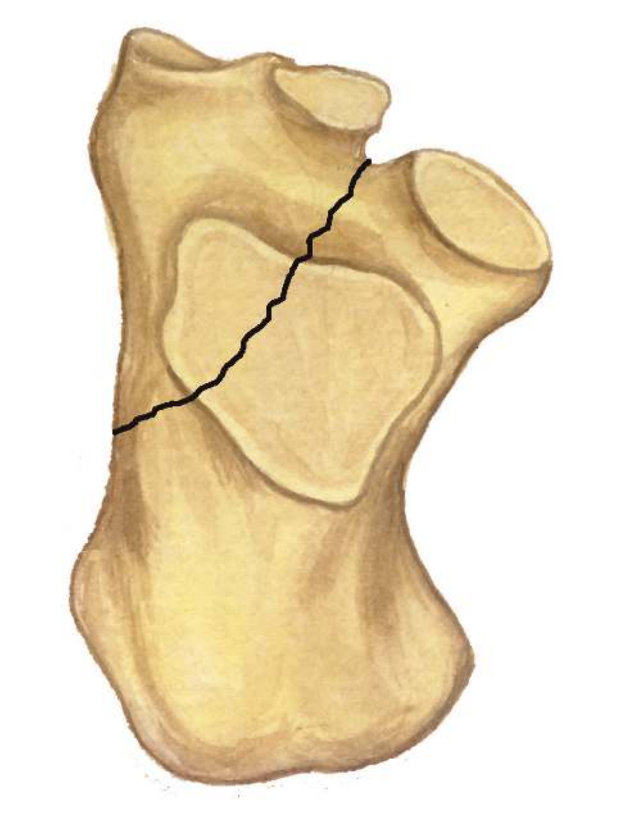
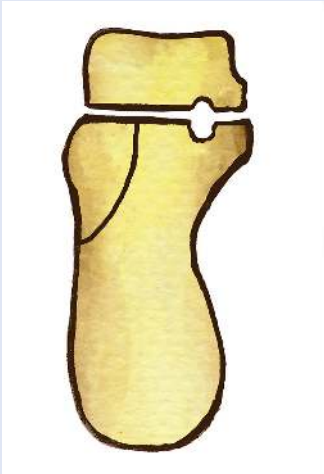
Traditional Classification: Essex-Lopresti Classification

- Type I: extra-articular calcaneal fractures, accounting for 42.05% of calcaneal fractures (so-called tongue-type injury)
- Type II: intra-articular fractures involving the subtalar joint, accounting for 57.95% of calcaneal fractures (so-called joint-depression-type injury, equivalent to type 82-C of the OTA classification)

Sanders Classification

Sanders classification of calcaneal fractures is based on fracture pattern—essentially the number and location of calcaneal posterior facet articular fracture fragments through the widest portion of the posterior facet as seen on coronal CT. Sanders classified calcaneal fractures into four types:

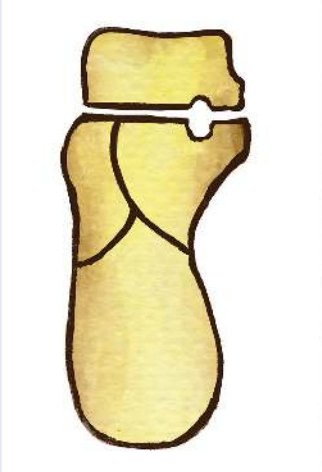
- Type I: fractures are nondisplaced.
- Type II: fractures are two-part fractures of the posterior facet, and are further classified into three subtypes, based on location of the fracture line: IIa, IIb, and IIc.
- Type III: fractures are three-part fractures of the posterior facet, and are further classified into three subtypes, based on location and extension of the depression: IIIab, IIIac, and IIIbc.
- Type IV: fractures are highly comminuted with four or more fractures of the posterior facet.

Sanders classification (intra-articular calcaneal fractures)	
Sanders Type I Nondisplaced 	**Sanders I**  

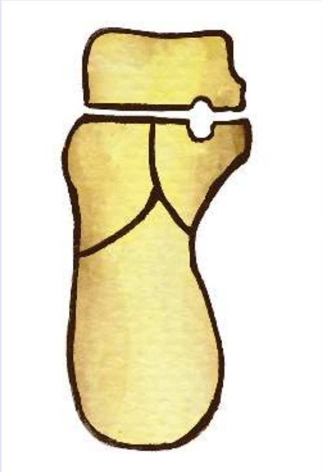
Sanders classification (intra-articular calcaneal fractures)

Sanders Type II Two-part fractures of the posterior facet

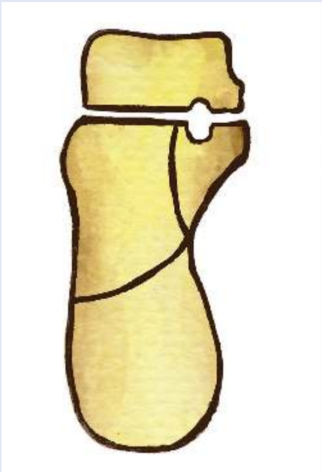
Sanders IIa



Sanders IIb

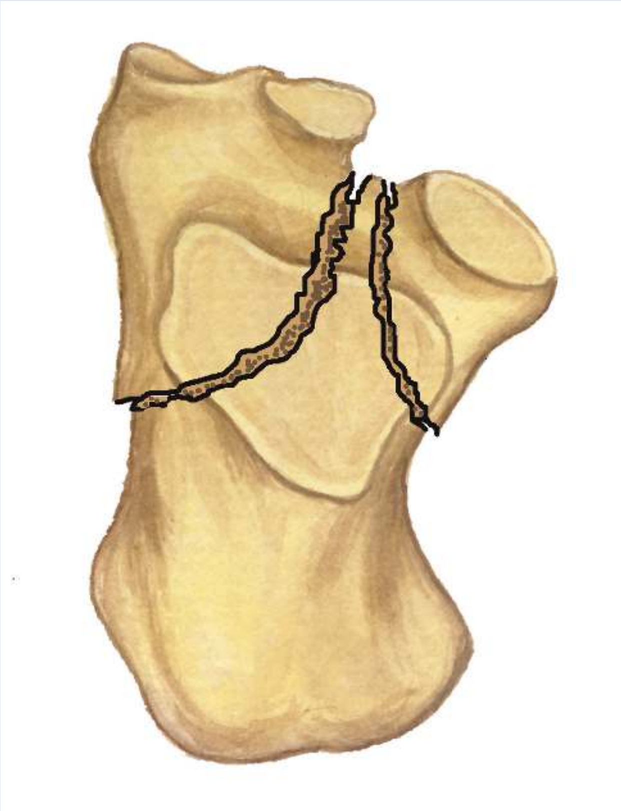


Sanders IIc

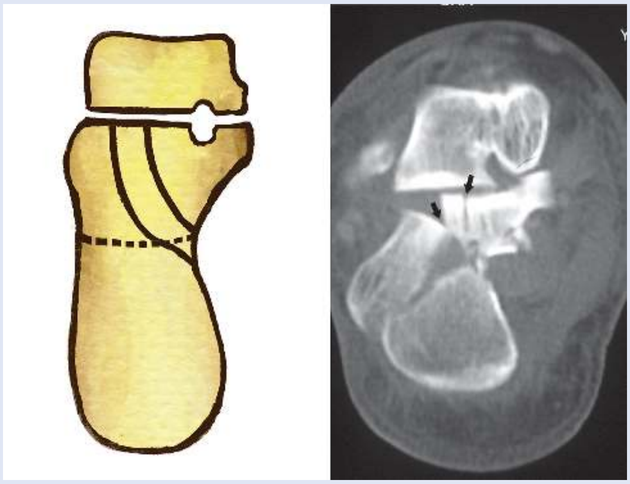


Sanders classification (intra-articular calcaneal fractures)

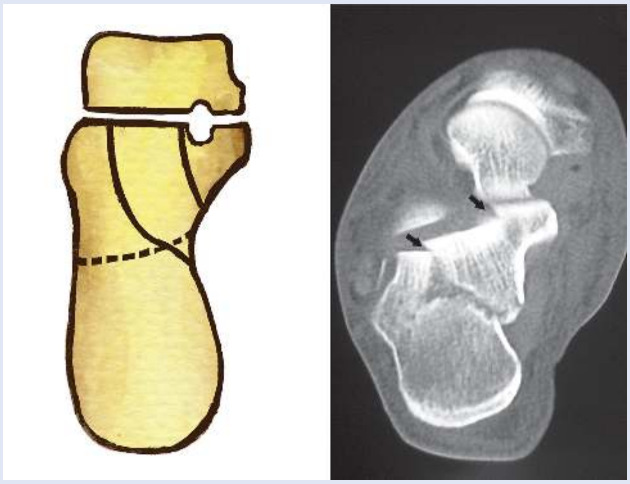
Sanders Type III Three-part fractures of the posterior facet



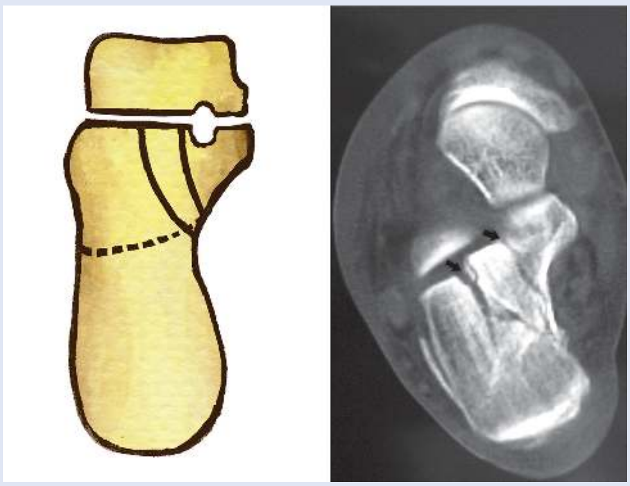
Sanders IIIab

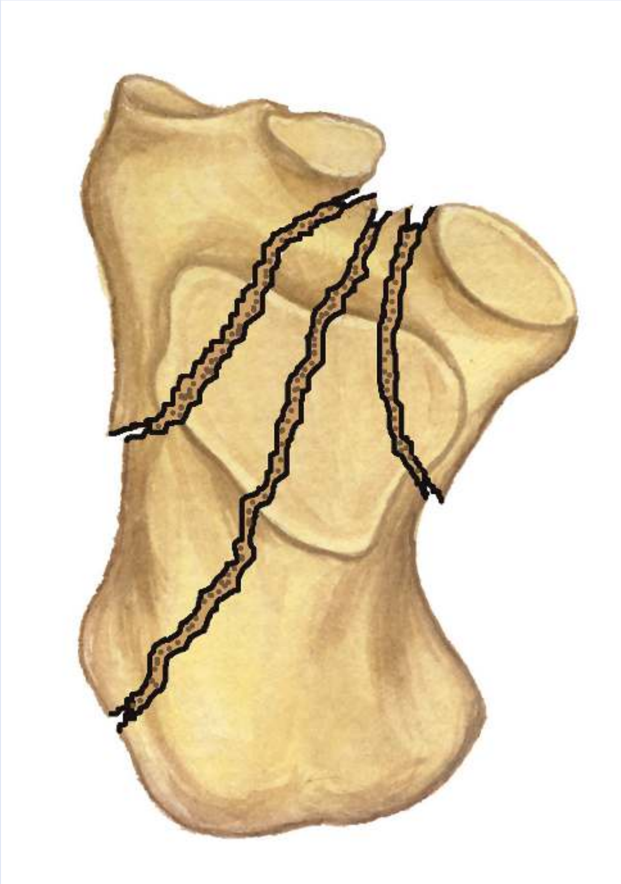
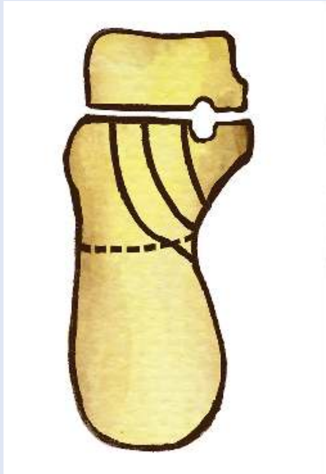


Sanders IIIac



Sanders IIIbc



Sanders classification (intra-articular calcaneal fractures)	
Sanders Type IV Highly comminuted fractures with four or more fragments of the posterior facet 	**Sanders IV**  

Fractures of the Tarsal Navicular Bone (Segment 83)

Anatomic Features

The tarsal navicular is a flattened, oval, boat-shaped bone between the talus posteriorly and the three cuneiform bones anteriorly. It is wide on the medial side and narrow on the lateral side. The posterior surface of the tarsal navicular is oval and concave, and articulates with the rounded head of the talus. The anterior surface is convex from side to side and has three facets for articulation with the three cuneiform bones. The dorsal surface is convex and rough for the attachment of a number of ligaments, such as the talonavicular ligament, dorsal cuneonavicular ligaments, and dorsal cuboideonavicular ligament. The plantar surface is concave and irregular. The medial surface presents a rounded tuberosity, the lower part of which gives attachment to part of the tendon of the tibialis posterior. The rough lateral surface is the attachment site of the calcaneonavicular band of the bifurcated ligament, and occasionally presents a small facet for articulation with the cuboid bone. The navicular bone, situated at the middle of the tarsus, is on the top of the medial longitudinal arch, and transmits the entire body weight from the ankle joint to the first three metatarsal bones (▶ Fig. 9.29).

OTA Classification of Tarsal Navicular Fractures

Based on OTA classification, the tarsal navicular is coded as number "83" for its anatomic location. Tarsal navicular fractures are classified into two types: 83-A: noncomminuted; and 83-B: comminuted (▶ Fig. 9.30).

Clinical Epidemiologic Features of Tarsal Navicular (Segment 83)

A total of 1,017 adult patients with 1,022 tarsal navicular fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, including 509 patients with fractures on the left side, 503 on the right, and 5 bilateral. There were 590 males and 427 females, with a male to female ratio of 1.38:1.

Epidemiologic features of tarsal navicular fractures are as follows:

- More males than females
- The high-risk age group is 31–35 years; the risk in the age group 31–35 years is highest for males while 26–30 years and 31–35 years are highest for females
- The most common fracture type is type 83-A

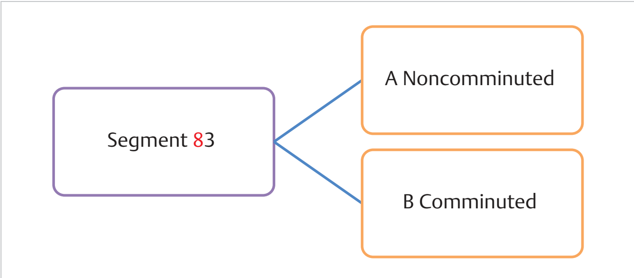


Fig. 9.30 Algorithm.

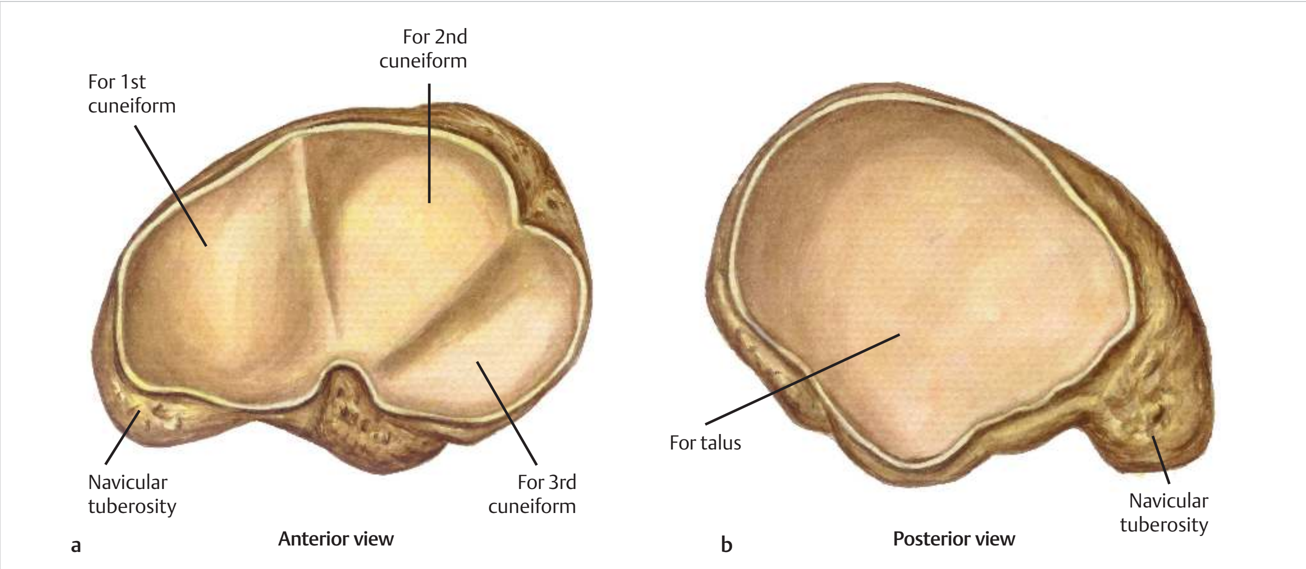


Fig. 9.29 Anterior (a) and posterior (b) views of the tarsal navicular bone.

■ Tarsal Navicular Fractures (Segment 83) by Sex

See ▶ Table 9.19 and ▶ Fig. 9.31.

Table 9.19 Sex distribution of 1,017 patients with tarsal navicular fractures

Sex	Number of patients	Percentage
Male	590	58.01
Female	427	41.99
Total	1,017	100.00

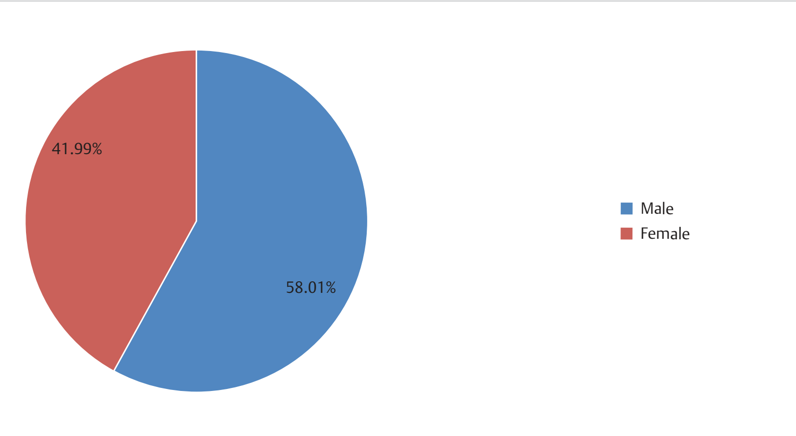


Fig. 9.31 Sex distribution of 1,017 patients with tarsal navicular fractures.

■ Tarsal Navicular Fractures (Segment 83) by Age Group

See ▶ Table 9.20 and ▶ Fig. 9.32.

Table 9.20 Age and sex distribution of 1,017 patients with tarsal navicular fractures

Age group (years)	Male	Female	Number of patients	Percentage
16–20	60	32	92	9.05
21–25	72	41	113	11.11
26–30	67	48	115	11.31
31–35	79	48	127	12.49
36–40	72	45	117	11.50
41–45	67	44	111	10.91
46–50	58	40	98	9.64
51–55	49	37	86	8.46
56–60	28	28	56	5.51
61–65	8	26	34	3.34
66–70	9	16	25	2.46
71–75	7	10	17	1.67
76–80	8	10	18	1.77
81–85	4	2	6	0.59
≥ 86	2	0	2	0.20
Total	590	427	1,017	100.00

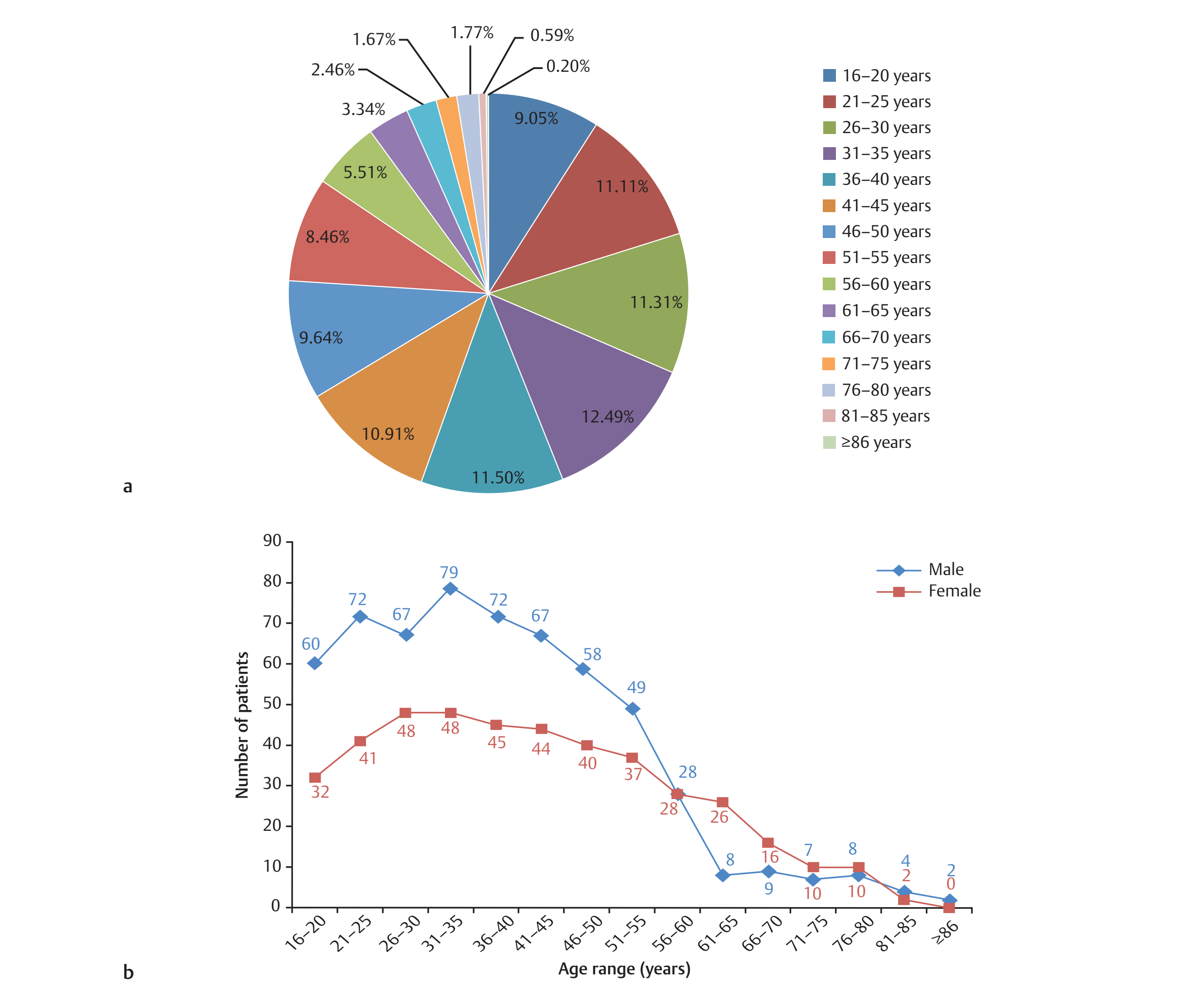


Fig. 9.32 (**a**) Age distribution of 1,017 patients with tarsal navicular fractures. (**b**) Age and sex distribution of 1,017 patients with tarsal navicular fractures.

9

■ Tarsal Navicular Fractures (Segment 83) by Fracture Type

See ► Table 9.21 and ► Fig. 9.33.

Table 9.21 Sex and fracture type distribution of 1,022 tarsal navicular fractures

Fracture type	Male	Female	Number of fractures	Percentage of tarsal navicular fractures
83-A	449	368	817	79.94
83-B	145	60	205	20.06
Total	594	428	1,022	100.00

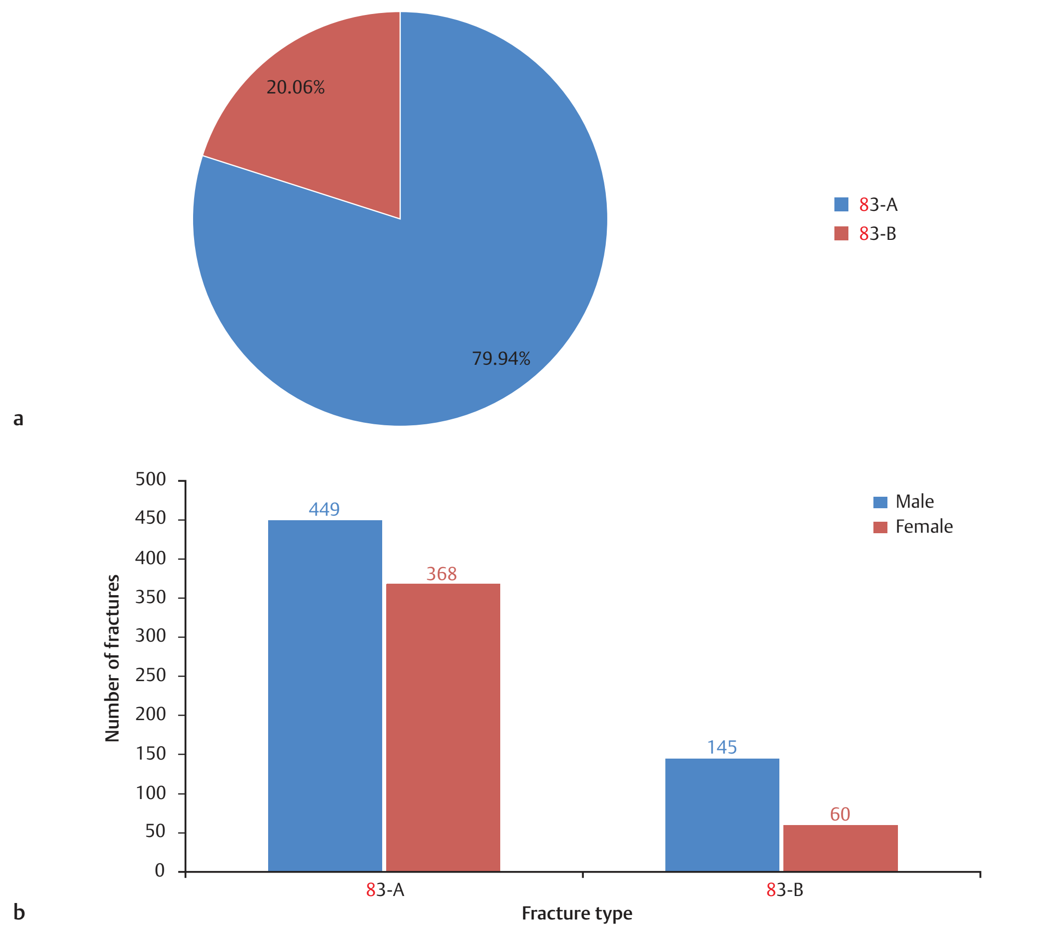


Fig. 9.33 (**a**) Fracture type distribution of 1,022 tarsal navicular fractures. (**b**) Sex and fracture type distribution of 1,022 tarsal navicular fractures.

83 Tarsal navicular fractures	
83-A Noncomminuted 817 fractures M: 449 (54.96%) F: 368 (45.04%) 0.22% of total adult fractures 2.11% of adult foot fractures 79.94% of tarsal navicular fractures	**83-A** Noncomminuted 

83 Tarsal navicular fracture	
83-B Comminuted 205 fractures M: 145 (70.73%) F: 60 (29.27%) 0.05% of total adult fractures 0.53% of adult foot fractures 20.06% of tarsal navicular fractures	**83-B** Comminuted 

Injury Mechanism

Avulsion fracture is the most common fracture of the navicular bone. Dorsal lip fracture typically occurs as a result of tension of the dorsal talonavicular ligament, secondary to plantar flexion with inversion or eversion injuries. Navicular tuberosity avulsion fractures typically result from sudden eversion and/or valgus injuries, which lead to a sudden increased stress on the posterior tibial tendon. Usually, cuboid compression fractures occur concomitantly due to the resulting compression of the lateral column and tensile stretching of the medial column. Depending on the direction of the impacting force, navicular body fractures can occur in the horizontal, coronal, or sagittal plane. Subluxation of the talonavicular joint may be present if fractures are displaced.

Diagnosis

Patients usually present with pain, swelling over the navicular bone, partial to complete limitation of motion, and deformity if there is marked fracture displacement or dislocation. Standard X-rays, including AP, oblique, and lateral views of the foot, generally show the fracture. Attention should be given to the position of the navicular bone in relation to its adjacent tarsal bones. CT scans or MRI should be considered if indicated.

9

Treatment

Nondisplaced navicular fractures can be treated with short-leg casting for 6 weeks. If fractures involve 20 to 30% of the articulation surface, or the proximal tuberosity has been displaced by more than 5 mm, open reduction and internal fixation with K-wire or screws should be considered. Displaced body fractures of the navicular bone require open reduction and internal fixation with screws. Arthrodesis of navicular articulations are indicated in severely comminuted intra-articular fractures.

Cuboid Fractures (Segment 84)

Anatomic Features

The cuboid bone is irregularly cubical in shape, and is situated at the lateral side of the foot. The posterior surface has a saddle-shaped articular surface, for articulation with the anterior surface of the calcaneus; its inferomedial angle projects backward as a process which underlies and supports the anterior end of the calcaneus. On the middle and upper part of the medial surface, there is a smooth oval facet, for articulation with the third cuneiform. The remainder of its surface is rough, and is the attachment site of the strong interosseous cuneocuboid ligament and cuboid navicular ligament. The lateral surface presents a deep groove formed by the beginning of the peroneal sulcus. The rough dorsal surface is the attachment site of multiple ligaments: the dorsal calcaneocuboid ligament, dorsal cuboideonavicular ligament, and dorsal cuneocuboid ligament. The plantar surface has a prominent ridge, to which the long plantar ligament is attached; the ridge ends laterally in an eminence, the cuboid tuberosity (▶ Fig. 9.34).

OTA Classification of Cuboid Fractures

Based on OTA classification, the cuboid bone is coded as number "84" for its anatomic location. Cuboid fractures are classified into two types: 84-A, noncomminuted; and 84-B, comminuted (▶ Fig. 9.35).

Clinical Epidemiologic Features of Cuboid Fractures

A total of 532 adult patients with 532 cuboid fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, including 260 patients with fractures on the left side, 272 on the right, and no bilateral fractures. There were 310 males and 222 females, with a male to female ratio of 1.40:1.

Epidemiologic features of cuboid fractures are as follows:

- More males than females
- The high-risk age group is 36–40 years, with ages 36–40 years being the highest for males and 26–30 years the highest for females
- The most common fracture type is type 84-A

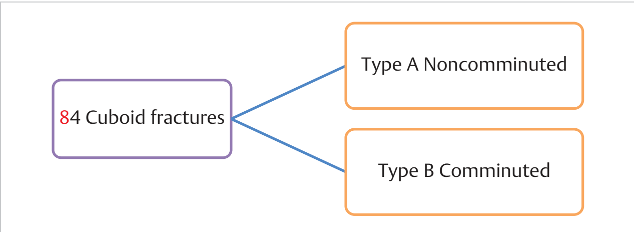


Fig. 9.35 Algorithm.

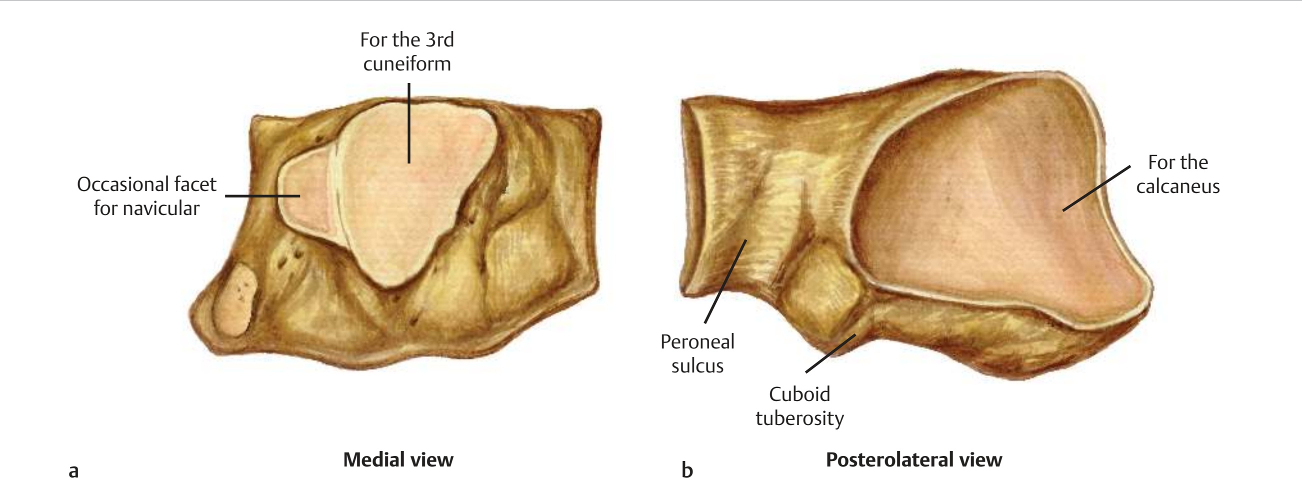


Fig. 9.34 Medial (**a**) and posterolateral (**b**) views of the cuboid bone.

■ Cuboid Fractures (Segment 84) by Sex

See ▶ Table 9.22 and ▶ Fig. 9.36.

Table 9.22 Sex distribution of 532 patients with cuboid fractures

Sex	Number of patients	Percentage
Male	310	58.27
Female	222	41.73
Total	532	100.00

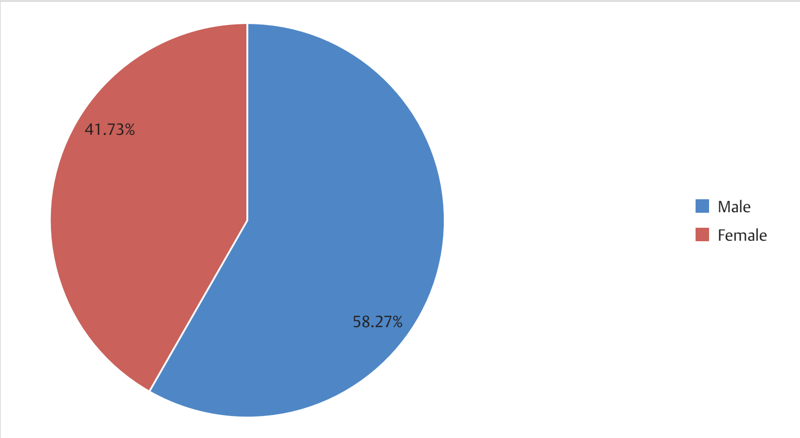


Fig. 9.36 Sex distribution of 532 patients with cuboid fractures.

■ Cuboid Fractures (Segment 84) by Age Group

See ▶ Table 9.23 and ▶ Fig. 9.37.

Table 9.23 Age and sex distribution of 532 patients with cuboid fractures

Age group (years)	Male	Female	Number of patients	Percentage
16–20	22	9	31	5.83
21–25	26	13	39	7.33
26–30	41	27	68	12.78
31–35	36	20	56	10.53
36–40	44	25	69	12.97
41–45	30	25	55	10.34
46–50	33	21	54	10.15
51–55	18	21	39	7.33
56–60	19	26	45	8.46
61–65	17	16	33	6.20
66–70	8	6	14	2.63
71–75	3	7	10	1.88
76–80	10	3	13	2.44
81–85	2	3	5	0.94
≥ 86	1	0	1	0.19
Total	310	222	532	100.00

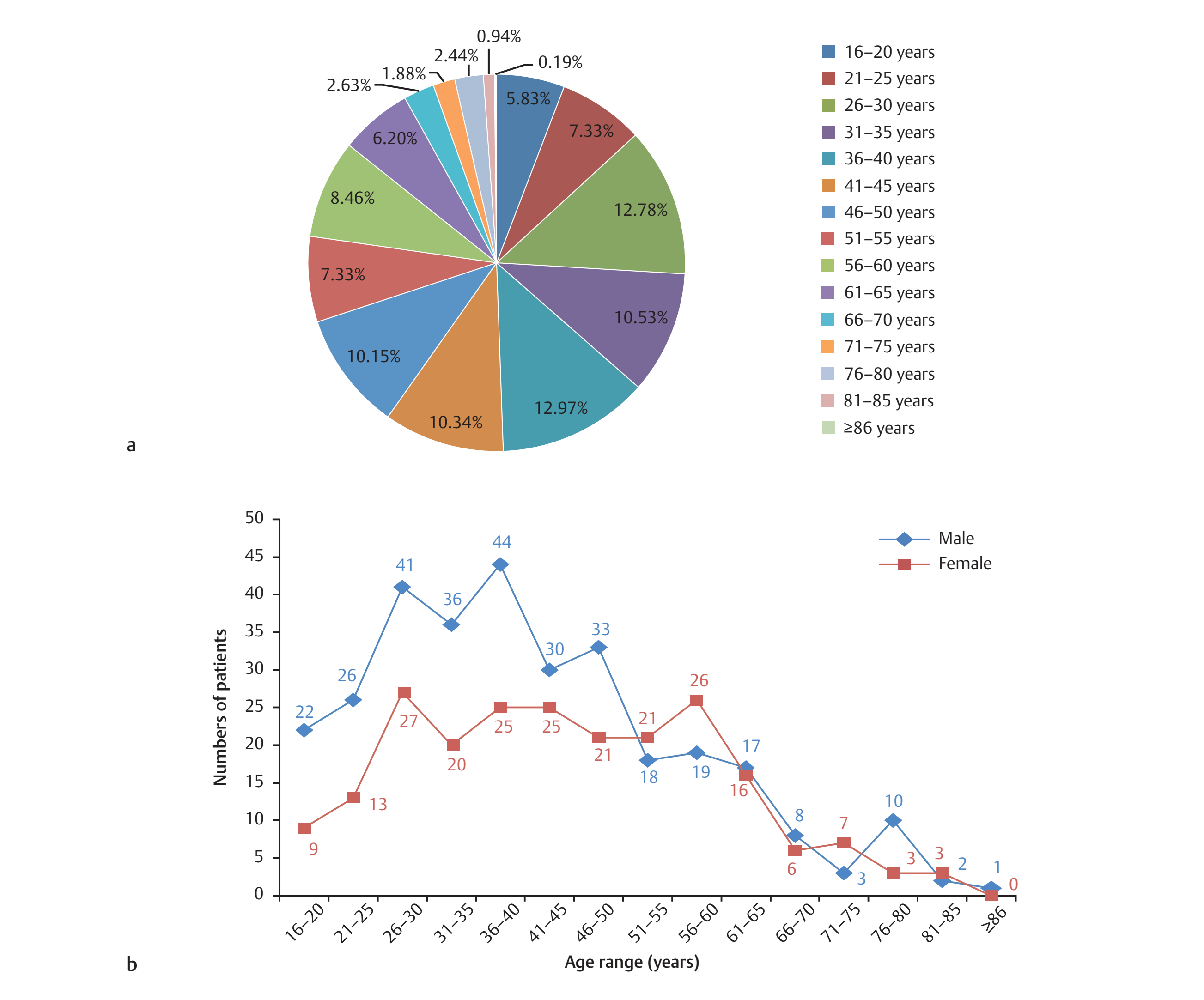


Fig. 9.37 (**a**) Age distribution of 532 patients with cuboid fractures. (**b**) Age and sex distribution of 532 patients with cuboid fractures.

■ Cuboid Fractures (Segment 84) by Fracture Type

See ▶ Table 9.24 and ▶ Fig. 9.38.

Table 9.24 Sex and fracture type distribution of 532 cuboid fractures

Fracture type	Male	Female	Number of fractures	Percentage
84-A	264	179	443	83.27
84-B	46	43	89	16.73
Total	310	222	532	100.00

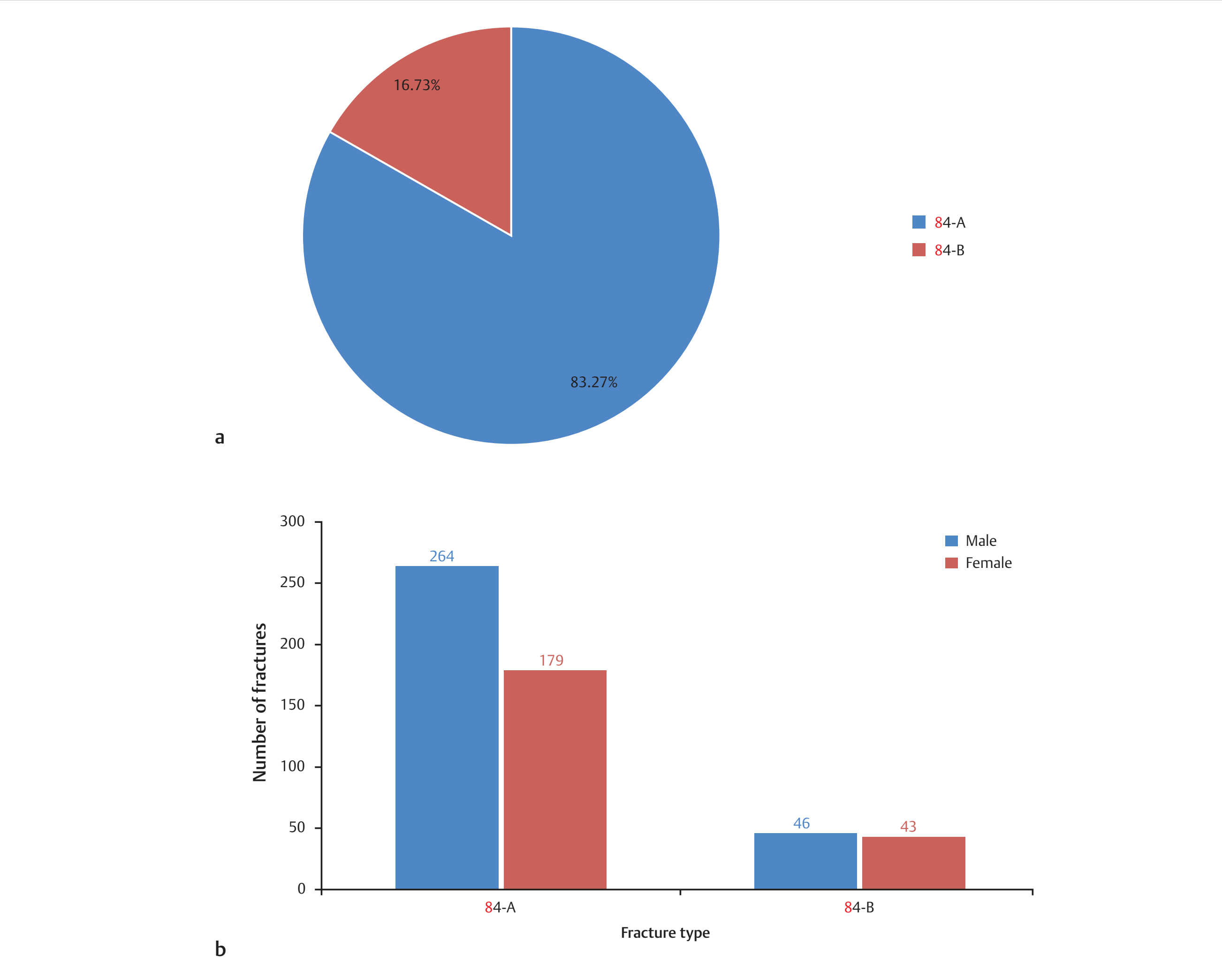
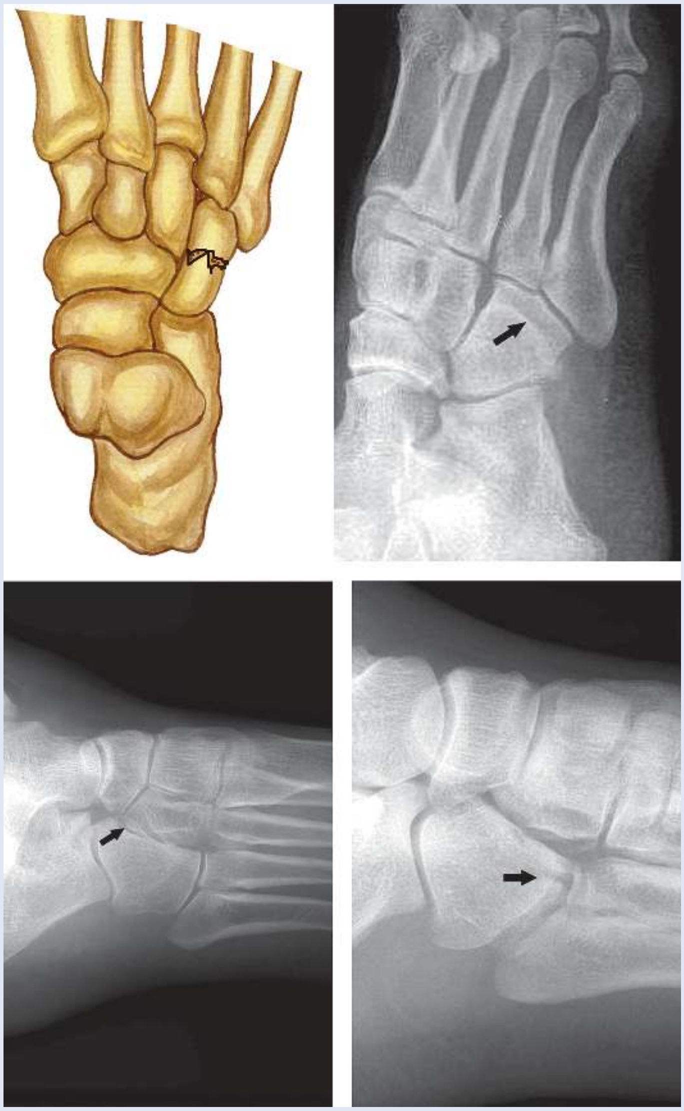


Fig. 9.38 (**a**) Fracture type distribution of 532 cuboid fractures. (**b**) Sex and fracture type distribution of 532 cuboid fractures.

84 Cuboid fractures	
84-A Noncomminuted 443 fractures M: 264 (59.59%) F: 179 (40.41%) 0.12% of total adult fractures 1.15% of adult foot fractures 83.27% of cuboid fractures	**84-A** Noncomminuted 

84 Cuboid fractures	
84-B Comminuted 89 fractures M: 46 (51.69%) F: 43 (48.31%) 0.02% of total adult fractures 0.23% of adult foot fractures 16.73% of cuboid fractures	**84-B** Comminuted 

Injury Mechanism

Isolated fractures to the cuboid are not common, and are usually concomitant with fractures of the cuneiform, calcaneus, or the base of the lateral metatarsal. Fractures of the cuboid can occur through direct or indirect mechanisms. Indirect injury usually occurs when the cuboid is crushed between the calcaneus and metatarsals by forced plantar flexion and abduction. Direct injuries occur by direct blow or high-energy crush injuries to the area. Subluxation or luxation of tarsometatarsal or intertarsal may be seen in this injury. Because the cuboid is protected by surrounding ligamentous tissue and a capsule, total dislocation of the cuboid is rare. Avulsion fractures often occur as a result of ligamentous tension secondary to forced adduction of the cuboid. Compression fractures, so-called "nutcracker-effect" injuries, occur when the cuboid is compressed between the base of the fourth and fifth metatarsals and the calcaneus as a result of severe abduction of the forefoot, or when body weight is transferred to the fixed and plantar-flexed foot. In severe cases, an associated middle tarsal dislocation may occur.

Diagnosis

Physical examination and radiographic evaluation are the tools used to determine the presence of a fracture. Patients may present with swelling, pain over the midfoot area, partial to complete limitation of motion, and deformity if there is marked displacement or dislocation. Standard radiographic views including AP and lateral views of the foot usually confirm the diagnosis. However, an isolated cuboid fracture is rare and is often associated with other fractures and dislocations of the midfoot. Particular attention should be given to associated fractures, to avoid misdiagnosis. CT scan and MRI may be considered if indicated.

Treatment

Nondisplaced cuboid or avulsion fractures can be treated with immobilization by a short-leg cast for 4 to 6 weeks. Fractures with marked displacement, comminuted articular fractures, or subluxation of the cuboid require surgical intervention. Articular arthrodesis should be considered for severe articular comminution. The biological morphology of the foot arch and length of the lateral column should be preserved during the arthrodesis.

Cuneiform Fractures (Segment 85)

Anatomic Features

There are three cuneiform bones in the human foot. They are located between the navicular bone posteriorly and the metatarsals anteriorly. Irregularly cubic in shape, they are designated the medial, intermediate, and lateral cuneiform from medial to lateral. The medial cuneiform bone is the largest of the three. Its dorsal surface is the narrow end of the wedge, directly upward and lateralward; its rough surface is the site of ligament attachment. The rough plantar surface is the site of attachment for the perneus longus, part of the anterior tibialis tendon, and the posterior tibialis. The middle cuneiform, the smallest of the three cuneiforms, has a regular, wedge-like form with its narrow end directed downward. It is situated between the other two cuneiforms, and articulates with the navicular bone posteriorly and the second metatarsal anteriorly. The lateral cuneiform is quadrilateral in shape, its base at the uppermost end. Its rough dorsal surface is the site of attachment for its ligaments; its plantar surface has a rounded margin and serves for the attachment of the plantar muscles (▶ Fig. 9.39).

OTA Classification of Cuneiform Fractures

Based on OTA classification, the cuneiform is coded as number "85" for its anatomic location. Cuneiform fractures are classified into two types: 85-A, non-comminuted fractures; and 85-B, comminuted fractures (▶ Fig. 9.40).

Fig. 9.39 The cuneiform bones in the foot.

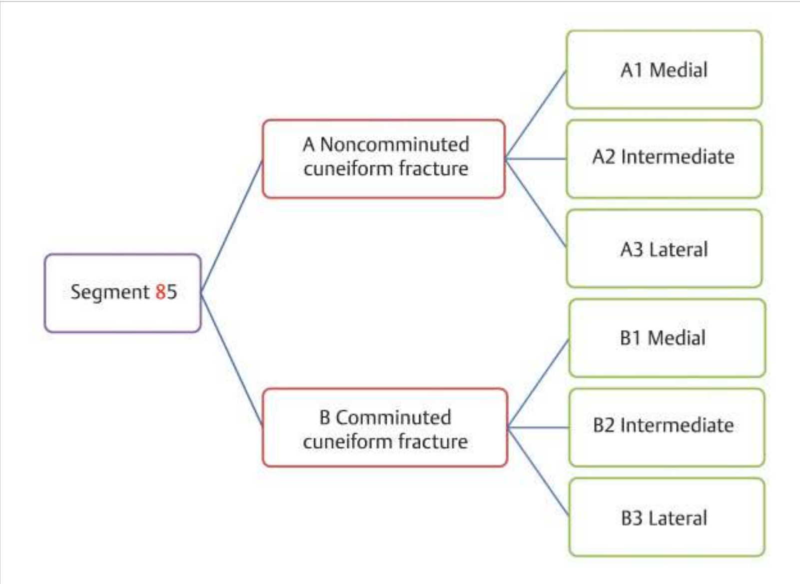


Fig. 9.40 Algorithm.

Clinical Epidemiologic Features of Cuneiform Fractures (Segment 85)

A total of 552 adult patients with 552 cuneiform fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 0.15% of all adult fractures, including 281 patients with fractures on the left side, 271 on the right side. There were 343 males and 209 females, with a male to female ratio of 1.64:1.

Epidemiologic features of cuneiform fractures are as follows:

- More males than females
- The highest-risk age group is 36–40 years, with ages 26–30 years being highest for males and 46–50 being highest for females
- The most common fracture type is type 85-A
- The most common fracture group is group 85-A1
- The medial cuneiform is the most commonly fractured cuneiform

Cuneiform Fractures (Segment 85) by Sex

See ▶ Table 9.25 and ▶ Fig. 9.41.

Table 9.25 Sex distribution of 552 patients with cuneiform fractures

Sex	Number of patients	Percentage
Male	343	62.14
Female	209	37.86
Total	552	100.00

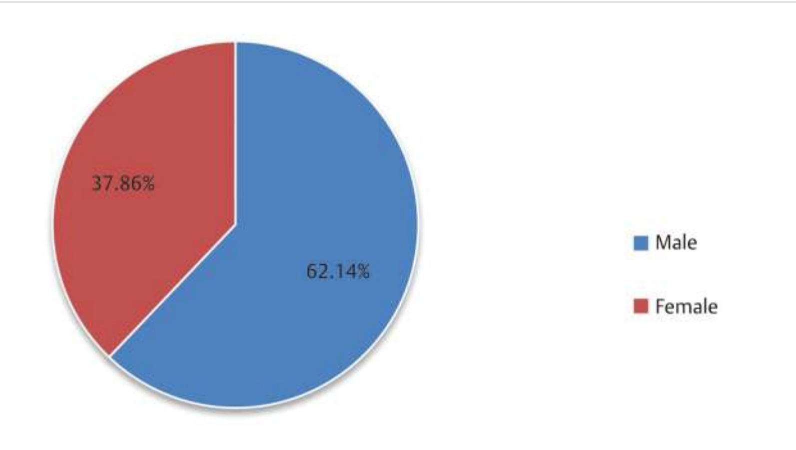


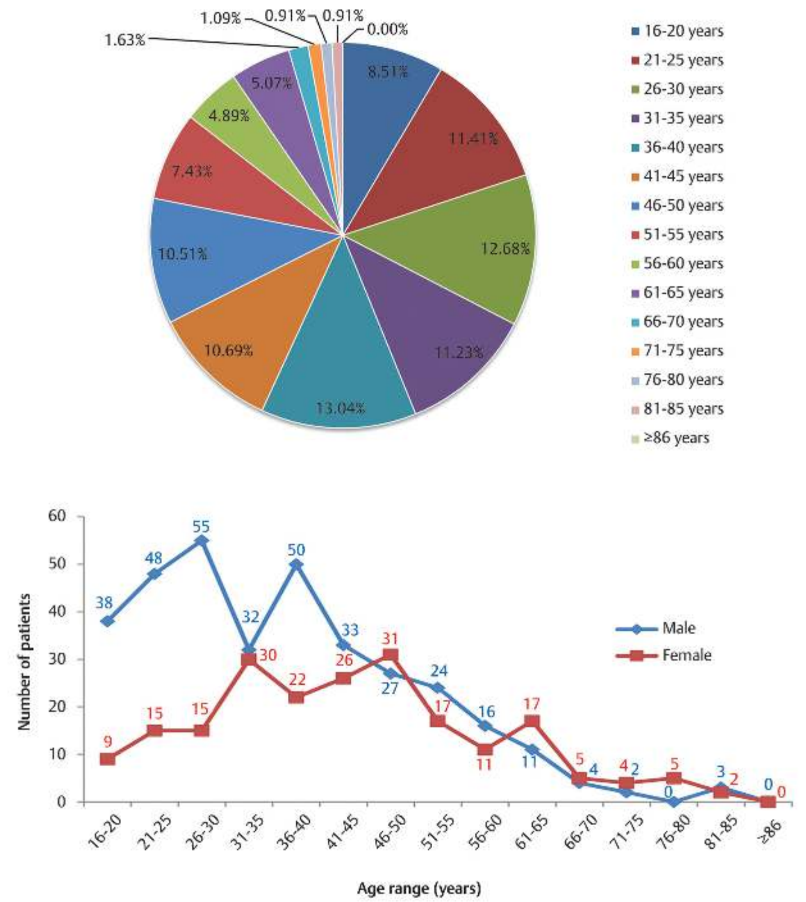
Fig. 9.41 Sex distribution of 552 patients with cuneiform fractures.

■ Cuneiform Fractures (Segment 85) by Age

See ▶ Table 9.26 and ▶ Fig. 9.42.

Table 9.26 Age and sex distribution of 552 patients with cuneiform fractures

Age group (years)	Male	Female	Number of patients	Percentage
16–20	38	9	47	8.51
21–25	48	15	63	11.41
26–30	55	15	70	12.68
31–35	32	30	62	11.23
36–40	50	22	72	13.04
41–45	33	26	59	10.69
46–50	27	31	58	10.51
51–55	24	17	41	7.43
56–60	16	11	27	4.89
61–65	11	17	28	5.07
66–70	4	5	9	1.63
71–75	2	4	6	1.09
76–80	0	5	5	0.91
81–85	3	2	5	0.91
≥ 86	0	0	0	0.00
Total	343	209	552	100.00



a

b

Fig. 9.42 (**a**) Age distribution of 552 patients with cuneiform fractures. (**b**) Age and sex distribution of 552 patients with cuneiform fractures.

■ Cuneiform Fractures (Segment 85) by Fracture Type

See ► Table 9.27, ► Table 9.28, ► Fig. 9.43, and ► Fig. 9.44.

Table 9.27 Sex and fracture type distribution of 552 cuneiform fractures

Fracture type	Male	Female	Number of fractures	Percentage
85-A	282	165	447	80.98
85-B	61	44	105	19.02
Total	343	209	552	100.00

Table 9.28 Sex and fracture group distribution of 552 cuneiform fractures

Fracture group	Male	Female	Number of fractures	Percentage of cuneiform fractures	Percentage of foot fractures
85-A1	216	118	334	60.51	0.86
85-A2	46	25	71	12.86	0.18
85-A3	20	22	42	7.61	0.11
85-B1	42	36	78	14.13	0.20
85-B2	15	4	19	3.44	0.05
85-B3	4	4	8	1.45	0.02
Total	343	209	552	100.00	1.43

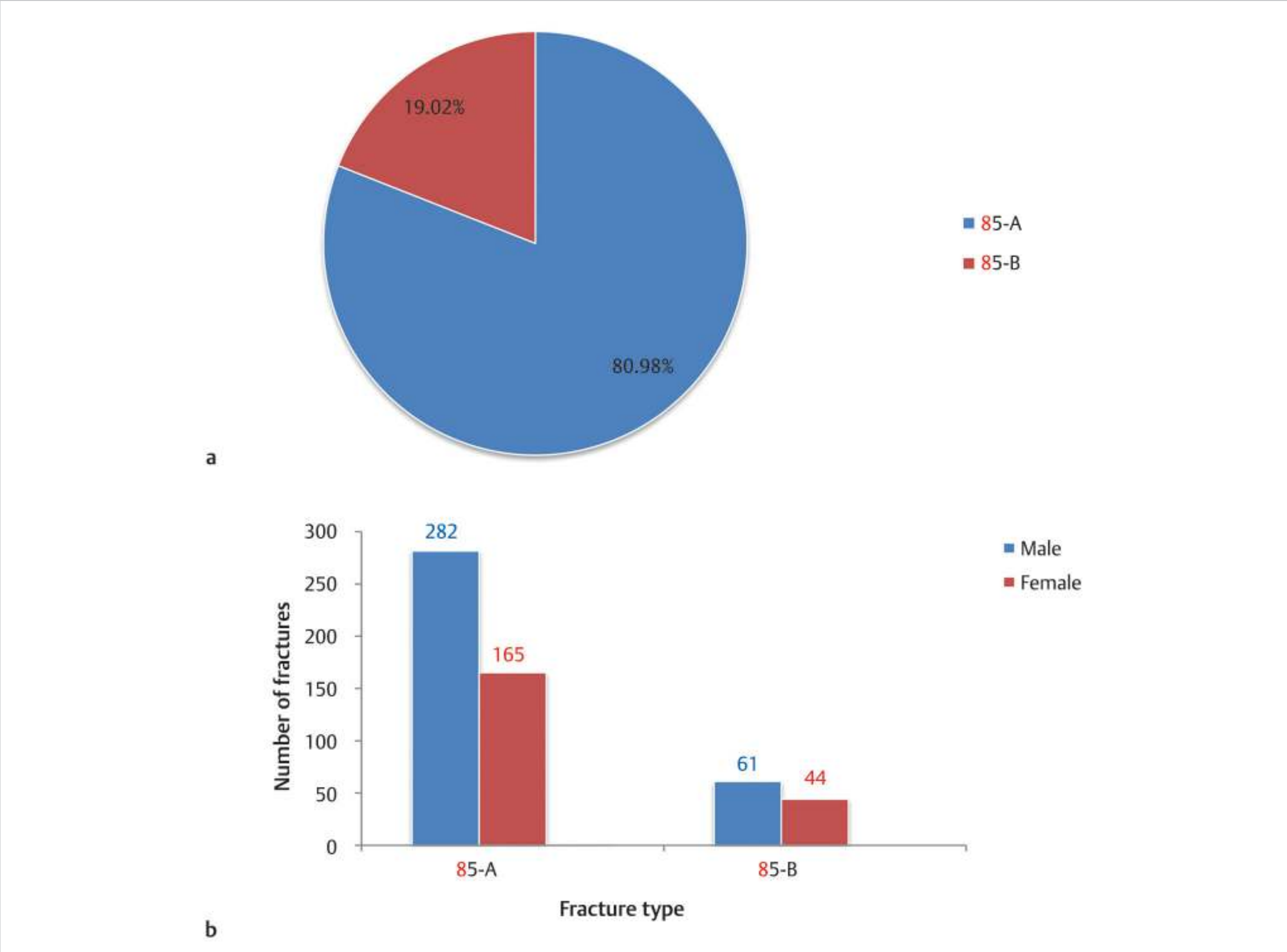


Fig. 9.43 (a) Fracture type distribution of 552 cuneiform fractures. (b) Sex and fracture type distribution of 552 cuneiform fractures.

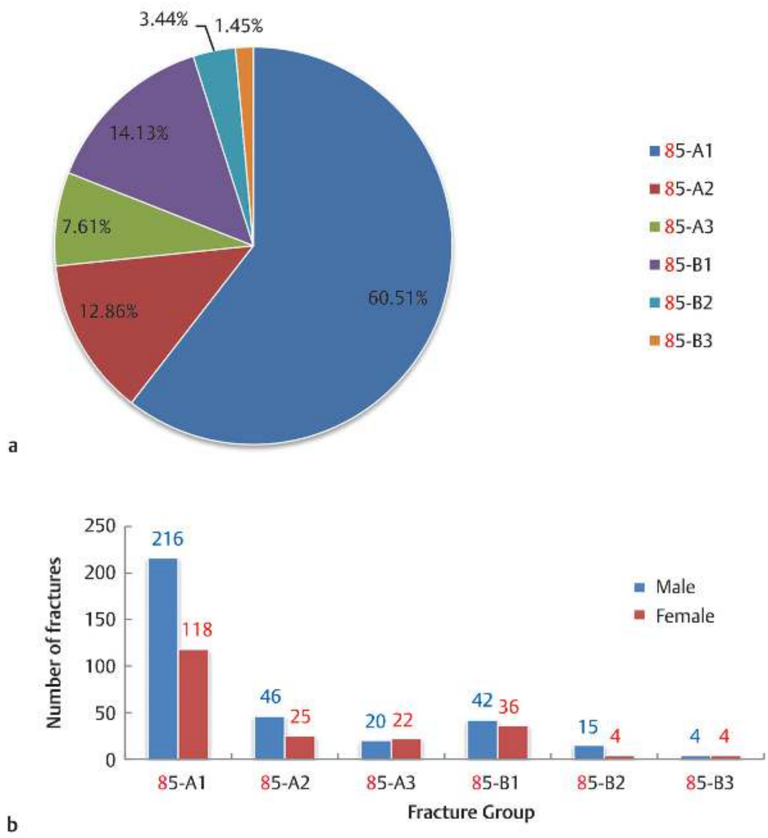


Fig. 9.44 (**a**) Fracture group distribution of 552 cuneiform fractures. (**b**) Sex and fracture group distribution of 552 cuneiform fractures.

■ Cuneiform Fractures (Segment 85) by Individual Cuneiform

See ▶ Table 9.29 and ▶ Fig. 9.45.

Table 9.29 Distribution of 552 cuneiform fractures by individual cuneiform

Cuneiform	Number of fractures	Percentage
Medial	412	74.64
Middle	90	16.30
Lateral	50	9.06
Total	552	100.00

9

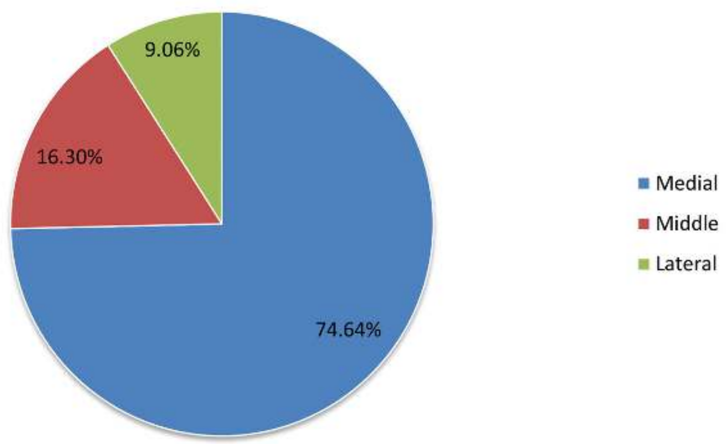


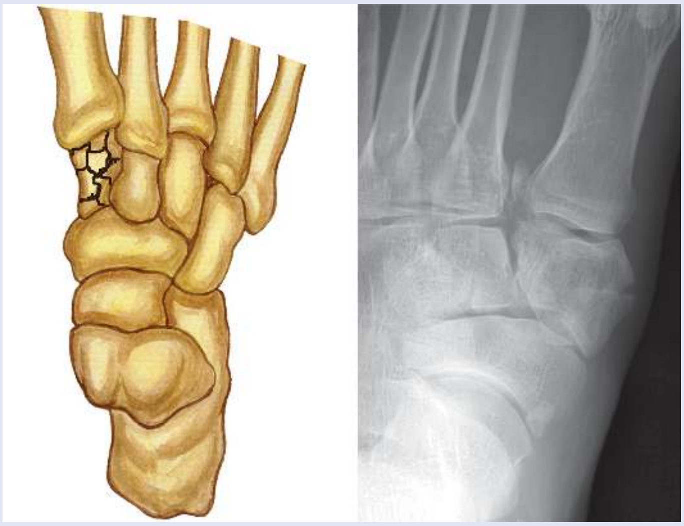
Fig. 9.45 Distribution of 552 cuneiform fractures by individual cuneiform.

85-A Cuneiform, noncomminuted fractures	
85-A Noncomminuted 447 fractures M: 282 (63.09%) F: 165 (36.91%) 0.12% of total adult fractures 1.16% of adult foot fractures 80.98% of cuneiform fractures	**85-A1** Medial   **85-A2** Intermediate   **85-A3** Lateral  

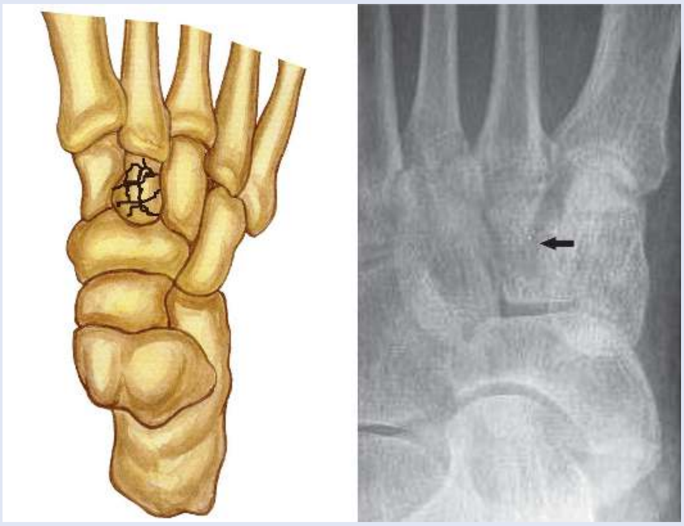
85-B Cuneiform, comminuted fractures

85-B Comminuted
105 fractures
M: 61 (58.10%)
F: 44 (41.90%)
0.03% of total adult fractures
0.27% of adult foot fractures
19.02% of cuneiform fractures

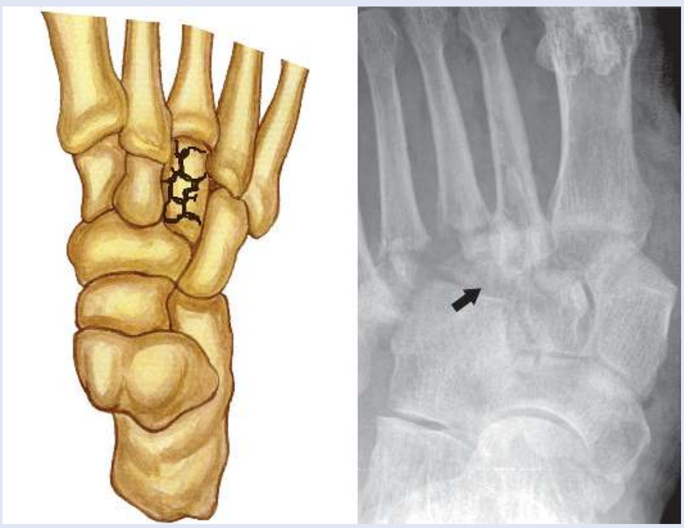
85-B1 Medial



85-B2 Intermediate



85-B3 Lateral



Injury Mechanism

Avulsion cuneiform fracture is the most common type of cuneiform fracture, and usually occurs as a result of abrupt tensile force of the intertarsal ligament secondary to the combination of plantar flexion, inversion, and abduction of the foot. Some patients may present with subluxation or dislocation of the cuneiform.

Diagnosis

History and physical examination plus radiographs make the diagnosis. Patients present with swelling, pain over the midfoot area, partial-to-complete limitation of motion, and deformity if there is marked displacement or dislocation. Radiographs of the foot, including AP, lateral, and oblique views, can usually confirm the diagnosis. If plain radiographs are inconclusive, then CT and MRI are indicated.

Treatment

Nondisplaced cuneiform fractures or those with associated subluxation or dislocation of the intertarsal joints can be treated with a short leg walking cast for 4 to 6 weeks, if the reduction can be achieved successfully by manipulative methods. Open reduction and internal fixation or arthrodesis is indicated for comminuted fractures or fractures with dislocated tarsometarsal or intertarsal joints that cannot be reduced manually.

Metatarsal Fractures (Segment 87)

Anatomic Features

The metatarsus consists of five short tubular bones, each having three parts: a base, a body, and a head. Although individually different, all five metatarsal bones share common characteristics. The base, or posterior extremity, is wedge shaped, and broader behind than in front, articulating proximally with the tarsal bones, and with the continuous metatarsal bones on its sides. Its rough dorsal and plantar surfaces are sites of attachment of its ligaments. The distal part of the metatarsal bone is the head or anterior extremity, which presents a convex articular surface that articulates with the phalanx. On each side of the head, there is a depression, surmounted by a tubercle, for the attachment of the ligaments and capsule. Between the head and the base is the prismoid-shaped body, which tapers gradually from the tarsal to the phalangeal extremity. The body presents three surfaces: medial, lateral, and dorsal. The dorsal surface has a flattened area in the middle, while the medial and lateral surfaces are broad and concave; all three surfaces are attached by muscles (▶ Fig. 9.46).

Fig. 9.46 Bones of the metatarsus.

OTA Classification of Metatarsal Fractures

Based on OTA classification, the metatarsus is coded as number “87” for its anatomic location. Metatarsal fractures are classified into three types: 87-A, metatarsal proximal, distal extra-articular, and diaphysis noncomminuted; 87-B, metatarsal proximal, distal partial articular, and diaphysis wedge comminuted; and 87-C, metatarsal proximal, distal complete, and articular diaphysis comminuted (▶ Fig. 9.47).

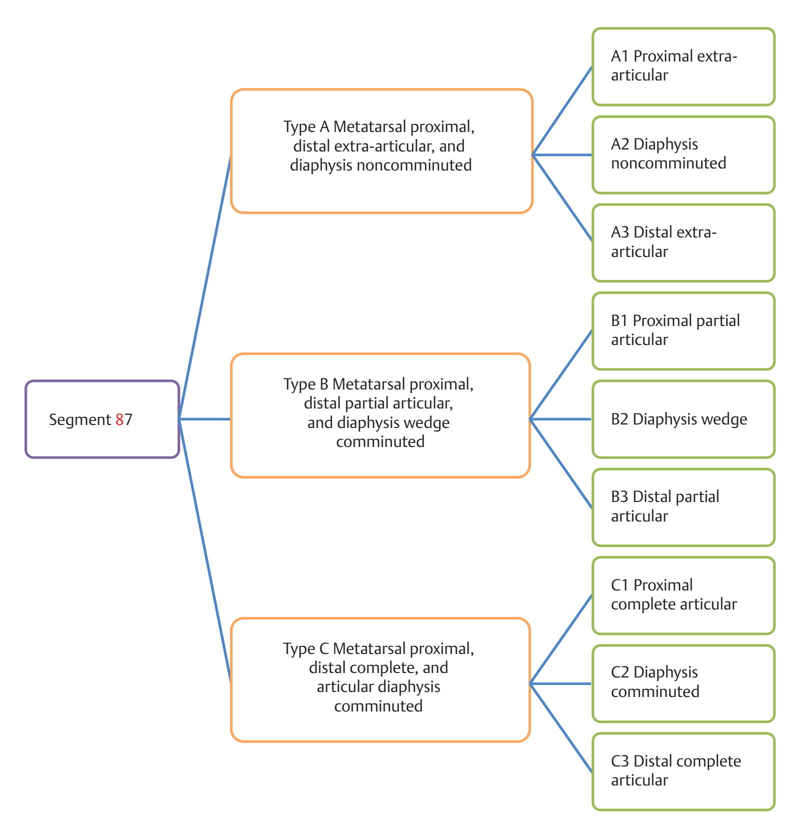


Fig. 9.47 Algorithm.

Clinical Epidemiologic Features of Metatarsal Fractures (Segment 87)

A total of 8,996 adult patients with 8,996 metatarsal fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 2.50% of all adult patients with fractures, including 4,599 patients with fractures on the left side, 4,397 on the right side. There were 4,960 males and 4,036 females, with a male to female ratio of 1.23:1.

Epidemiological features of metatarsal fractures are as follows:

- More males than females
- The highest-risk age group is 41–45 years, with males aged 41–45 years and females aged 56–60 years at the highest risk
- The most common fracture type is type 87-B
- The most common fracture group is group 87-B1
- The fifth metatarsal is the most frequently fractured metatarsal
- The proximal metatarsal metaphysis is the most often fractured metatarsal component

■ Metatarsal Fractures (Segment 87) by Sex

See ▶ Table 9.30 and ▶ Fig. 9.48.

Table 9.30 Sex distribution of 8,996 patients with metatarsal fractures

Sex	Number of patients	Percentage
Male	4,960	55.14
Female	4,036	44.86
Total	8,996	100.00

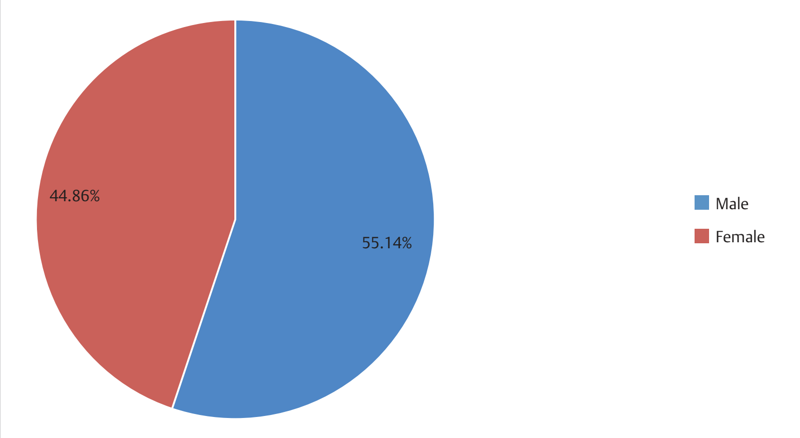


Fig. 9.48 Sex distribution of 8,996 patients with metatarsal fractures.

■ Metatarsal Fractures (Segment 87) by Age

See ▶ Table 9.31 and ▶ Fig. 9.49.

Table 9.31 Age and sex distribution of 8,996 patients with metatarsal fractures

Age group (years)	Male	Female	Number of patients	Percentage
16–20	393	153	546	6.07
21–25	561	292	853	9.48
26–30	523	350	873	9.70
31–35	508	260	768	8.54
36–40	598	345	943	10.48
41–45	619	427	1,046	11.63
46–50	491	497	988	10.98
51–55	431	502	933	10.37
56–60	346	514	860	9.56
61–65	181	284	465	5.17
66–70	108	173	281	3.12
71–75	90	120	210	2.33
76–80	71	74	145	1.61
81–85	28	34	62	0.69
≥ 86	12	11	23	0.26
Total	4,960	4,036	8,996	100.00

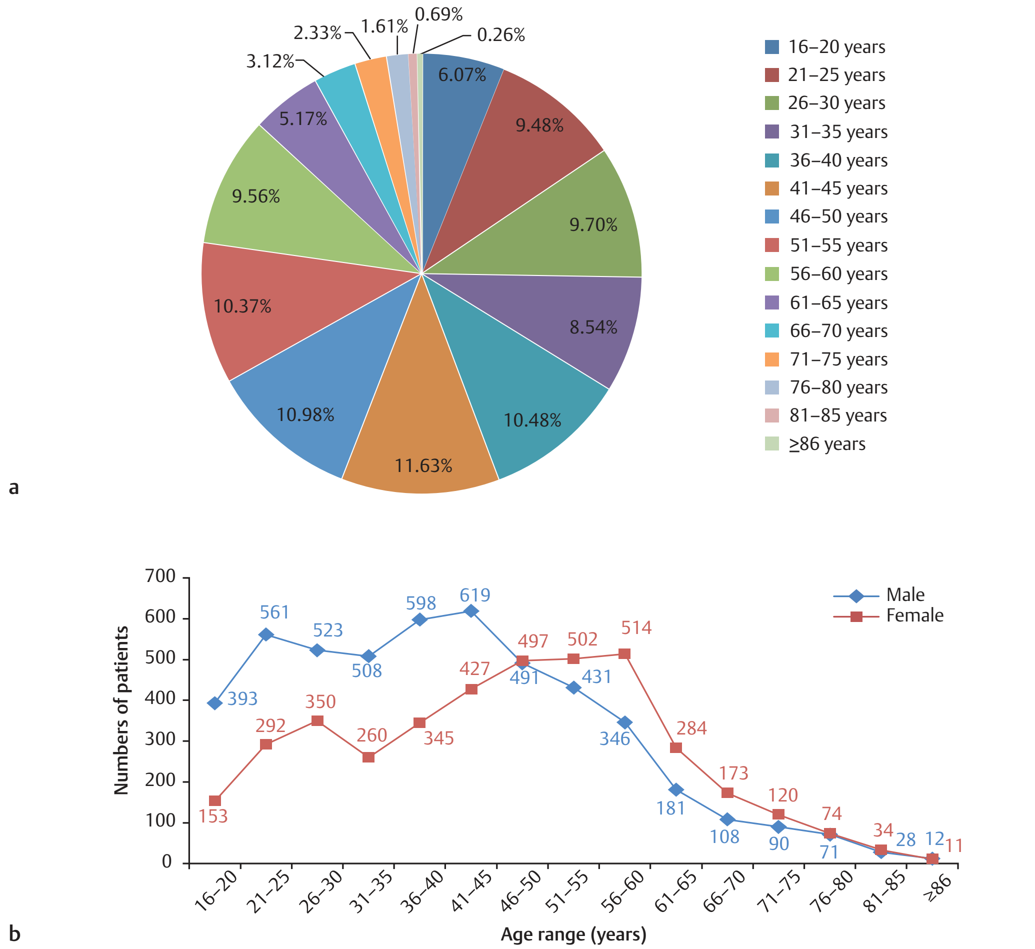


Fig. 9.49 (**a**) Age distribution of 8,996 patients with metatarsal fractures. (**b**) Age and sex distribution of 8,996 patients with metatarsal fractures.

9

■ Metatarsal Fractures (Segment 87) by Fracture Type

See ▶ Table 9.32, ▶ Table 9.33, ▶ Fig. 9.50, and ▶ Fig. 9.51.

Table 9.32 Sex and fracture type distribution of 8,996 metatarsal fractures

Fracture type	Male	Female	Number of fractures	Percentage
87-A	2,160	1,441	3,601	40.03
87-B	2,462	2,402	4,864	54.07
87-C	338	193	531	5.90
Total	4,960	4,036	8,996	100.00

Table 9.33 Sex and fracture group distribution of 8,996 metatarsal fractures

Fracture group	Male	Female	Number of fractures	Percentage of metatarsal fractures	Percentage of foot fractures
87-A1	1,011	798	1,809	20.11	4.68
87-A2	603	291	894	9.94	2.31
87-A3	546	352	898	9.98	2.32
87-B1	2,235	2,266	4,501	50.03	11.65
87-B2	156	95	251	2.79	0.65
87-B3	71	41	112	1.24	0.29
87-C1	173	116	289	3.21	0.75
87-C2	127	55	182	2.02	0.47
87-C3	38	22	60	0.67	0.16
Total	4,960	4,036	8,996	100.00	23.29

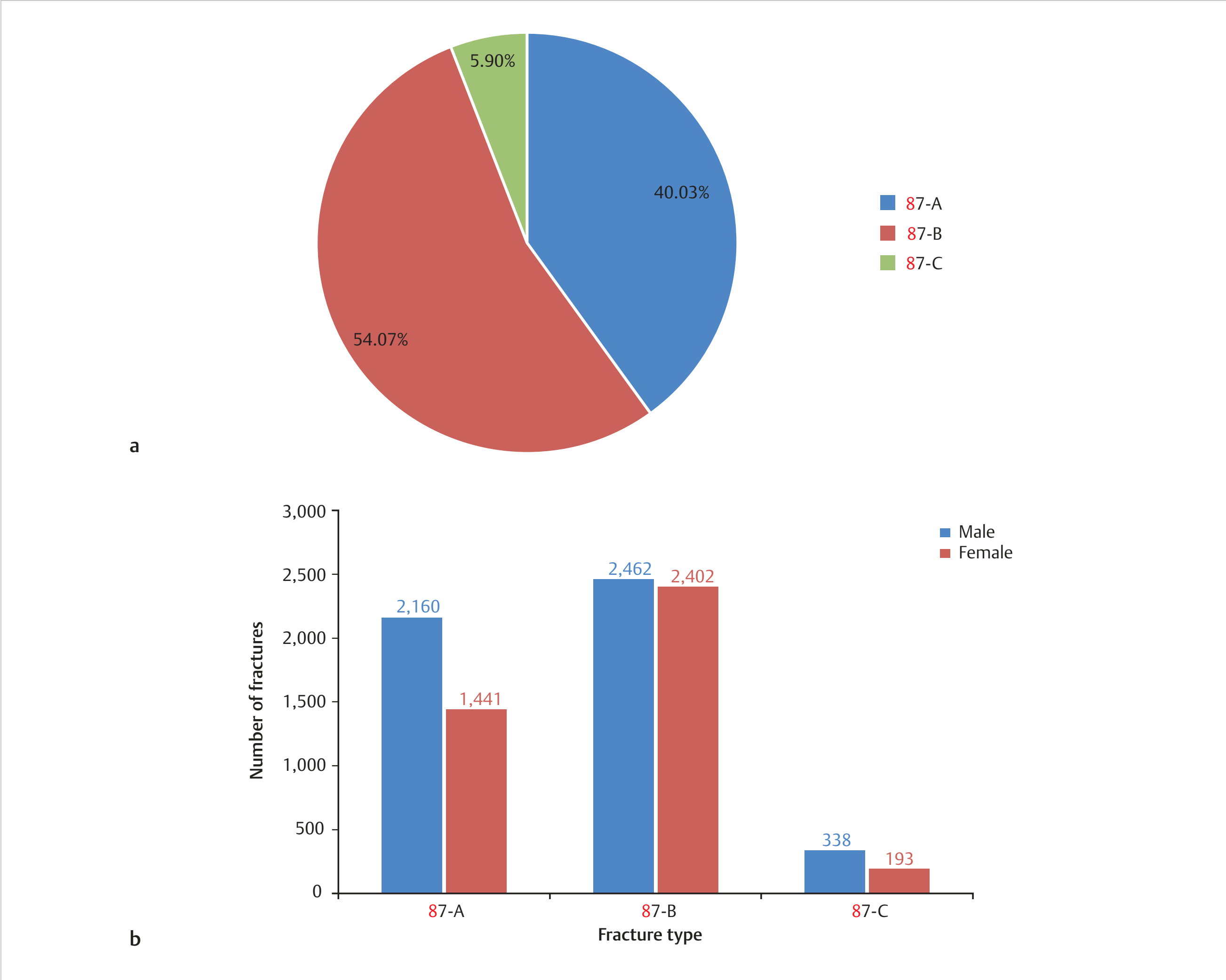


Fig. 9.50 (**a**) Fracture type distribution of 8,996 metatarsal fractures. (**b**) Sex and fracture type distribution of 8,996 metatarsal fractures.

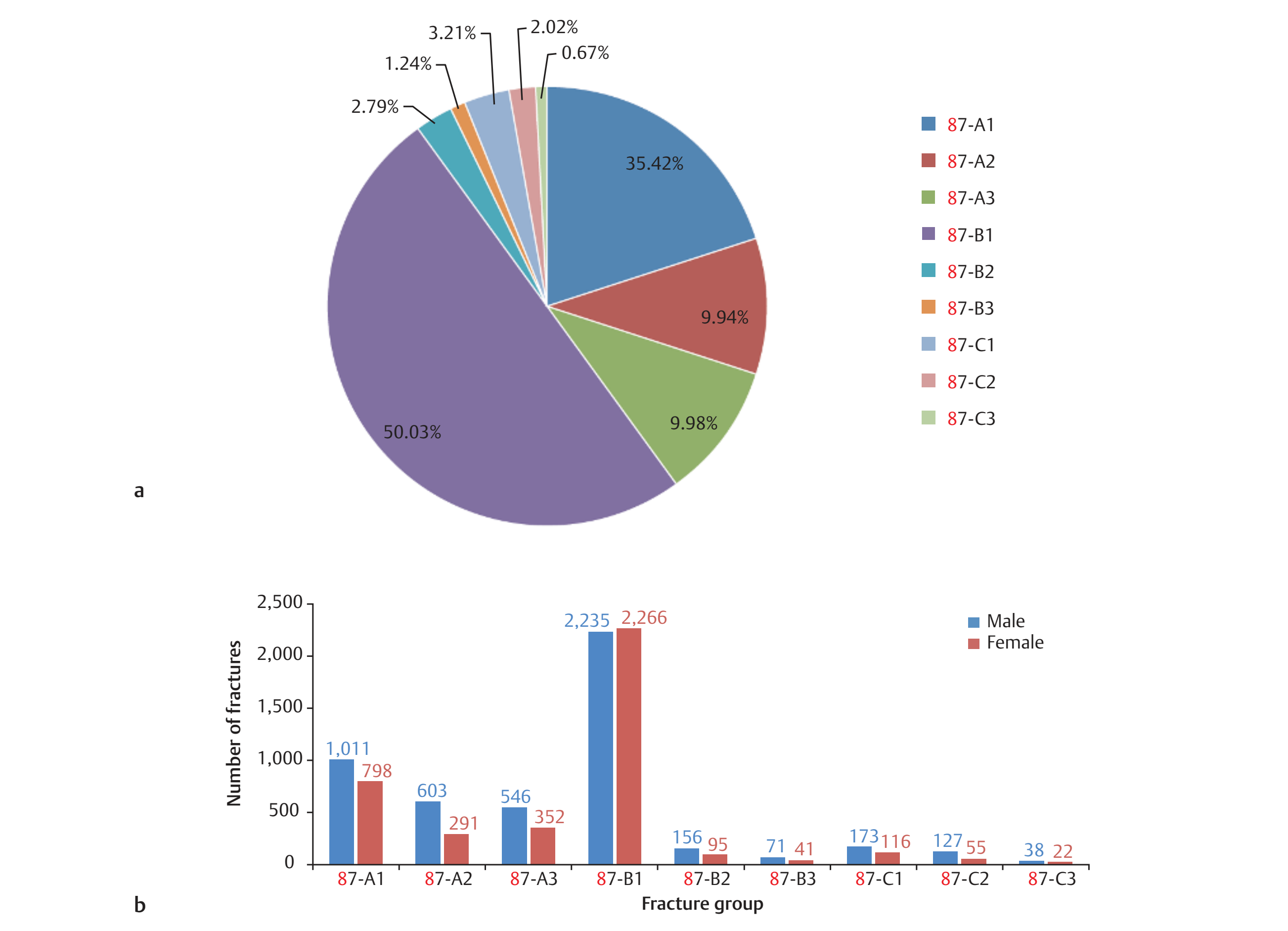


Fig. 9.51 (**a**) Fracture group distribution of 8,996 metatarsal fractures. (**b**) Sex and fracture group distribution of 8,996 metatarsal fractures.

9

■ Metatarsal Fractures (Segment 87) by Individual Metatarsal Bones

See ▶ Table 9.34 and ▶ Fig. 9.52.

Table 9.34 Distribution of 8,996 metatarsal fractures by the number of the metatarsal bones

Metatarsal number	Number of fractures	Percentage of metatarsal fractures
1st	813	9.04
2nd	744	8.27
3rd	652	7.25
4th	418	4.65
5th	6,369	70.80
Total	8,996	100.00

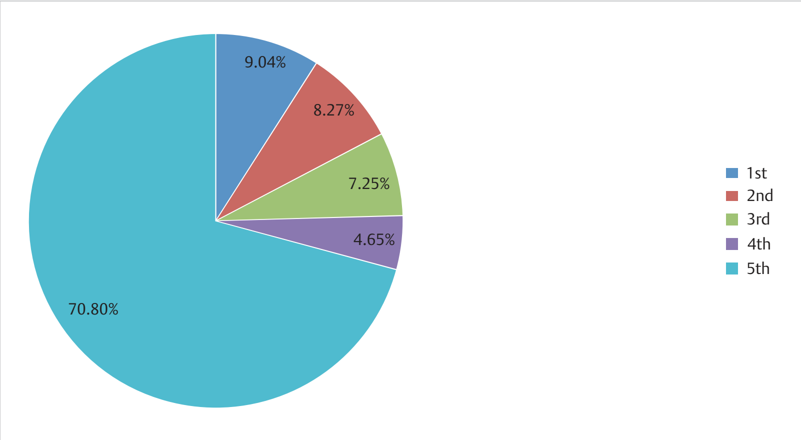


Fig. 9.52 Distribution of 8,996 metatarsal fractures by the number of the metatarsal bones.

■ Metatarsal Fractures by Segment (Segment 87)

See ▶ Table 9.35 and ▶ Fig. 9.53.

Table 9.35 Sex and fracture segment distribution of 8,996 metatarsal fractures

Fracture segment	Male	Female	Number of fractures	Percentage
Proximal	3,419	3,180	6,599	73.35
Diaphysis	886	441	1,327	14.75
Distal	655	415	1,070	11.89
Total	4,960	4,036	8,996	100.00

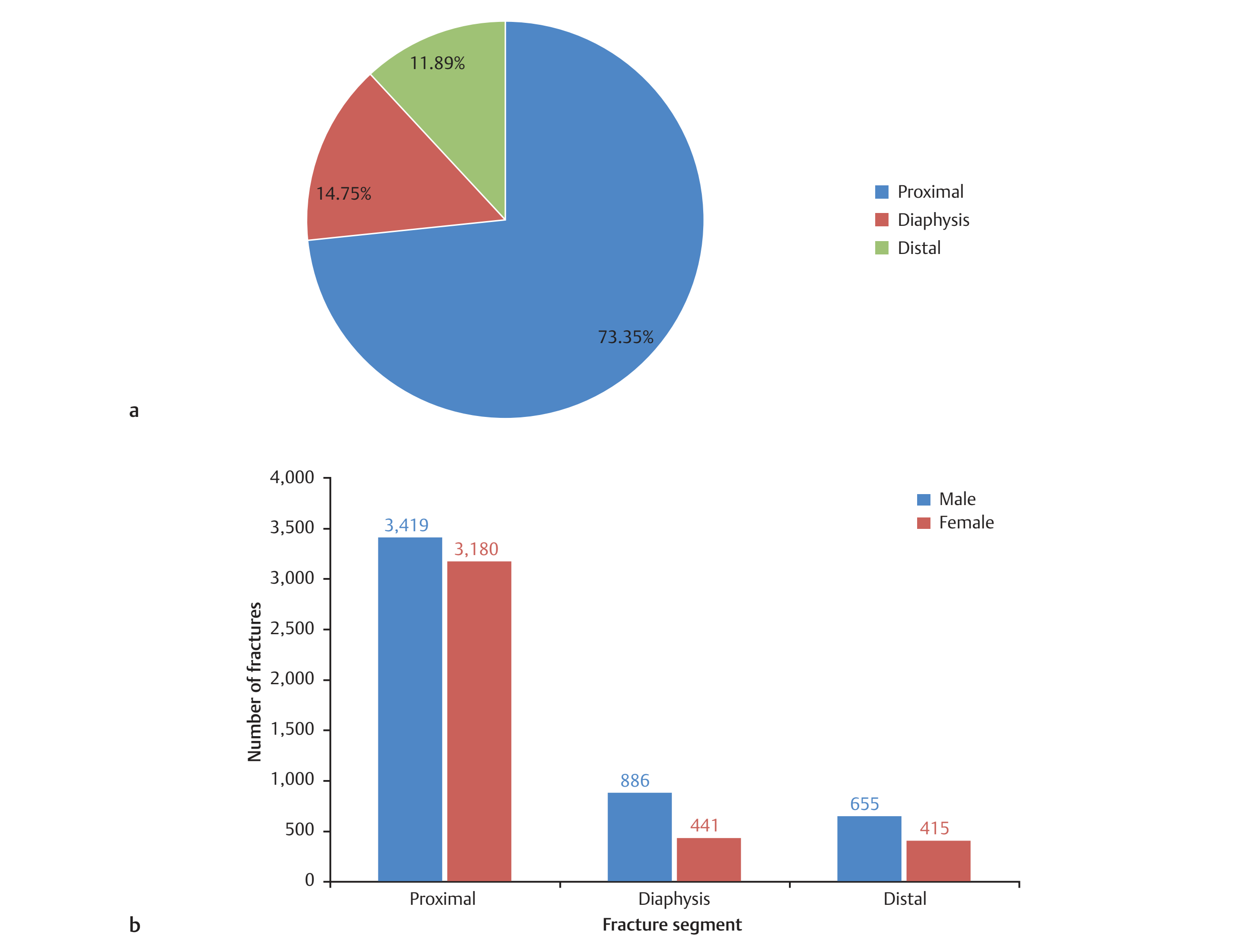
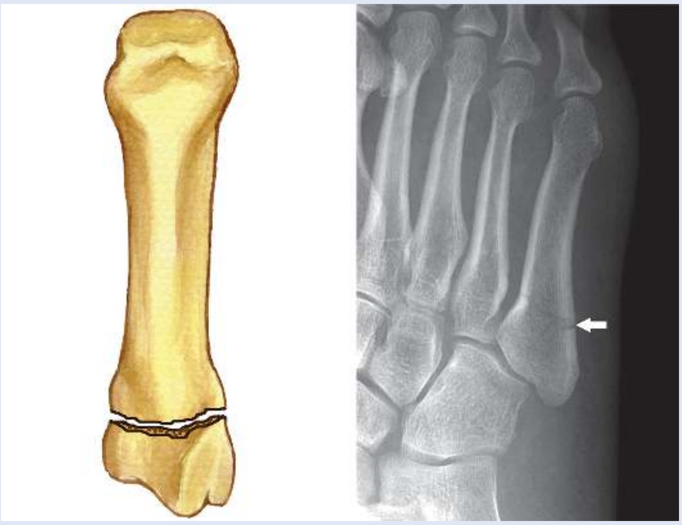
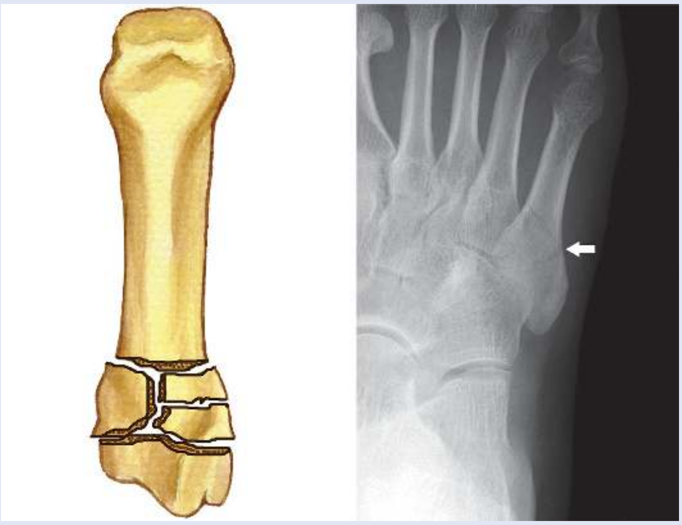


Fig. 9.53 (a) Fracture segment distribution of 8,996 metatarsal fractures. (b) Sex and fracture segment distribution of 8,996 metatarsal fractures.

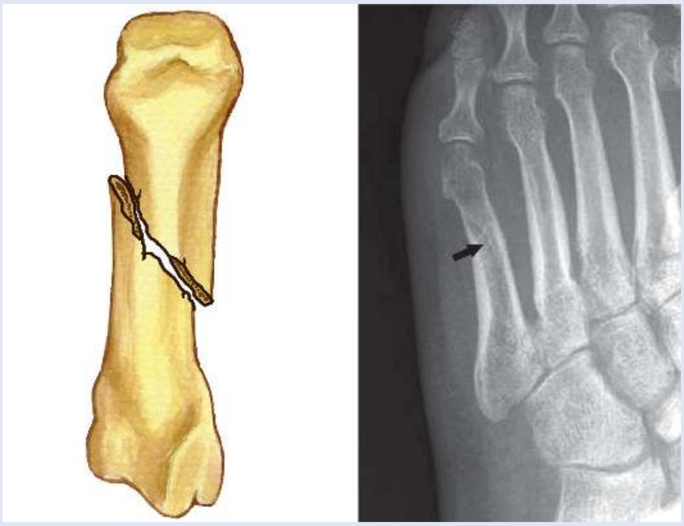
87-A Metatarsal proximal, distal extra-articular, and diaphysis noncomminuted	
87-A1 Proximal extra-articular 1,809 fractures M: 1,011 (55.89%) F: 798 (44.11%) 0.48% of total adult fractures 4.68% of adult foot fractures 20.11% of metatarsal fractures 50.24% of type 87-A	**87-A1.1** Noncomminuted  **87-A1.2** Comminuted 

87-A Metatarsal proximal, distal extra-articular, and diaphysis noncomminuted

87-A2 Diaphysis noncomminuted
894 fractures
M: 603 (67.45%)
F: 291 (32.55%)
0.24% of total adult fractures
2.31% of adult foot fractures
9.94% of metatarsal fractures
24.83% of type 87-A

87-A2.1 Spiral

87-A2.2 Oblique



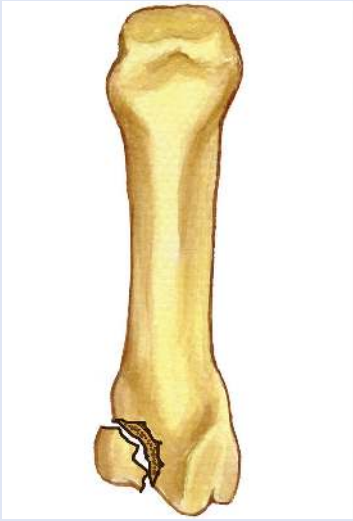
87-A2.3 Transverse

87-A Metatarsal proximal, distal extra-articular, and diaphysis noncomminuted	
87-A3 Distal extra-articular 898 fractures M: 546 (60.80%) F: 352 (39.20%) 0.24% of total adult fractures 2.32% of adult foot fractures 9.98% of metatarsal fractures 24.94% of type 87-A	**87-A3.1** Noncomminuted  **87-A3.2** Comminuted 

87-B Metatarsal proximal, distal partial articular, and diaphysis wedge comminuted

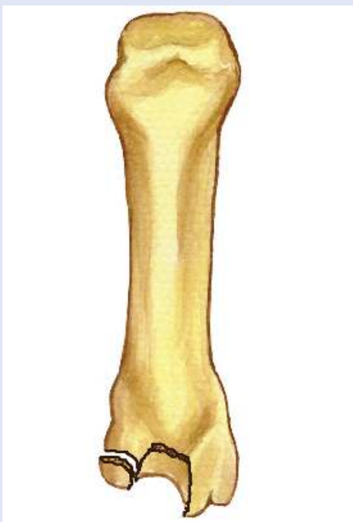
87-B1 Proximal partial articular
4,501 fractures
M: 2,235 (49.66%)
F: 2,266 (50.34%)
1.20% of total adult fractures
11.65% of adult foot fractures
50.03% of metatarsal fractures
92.54% of type 87-B

87-B1.1 Avulsion or split




87-B1.2 Depression

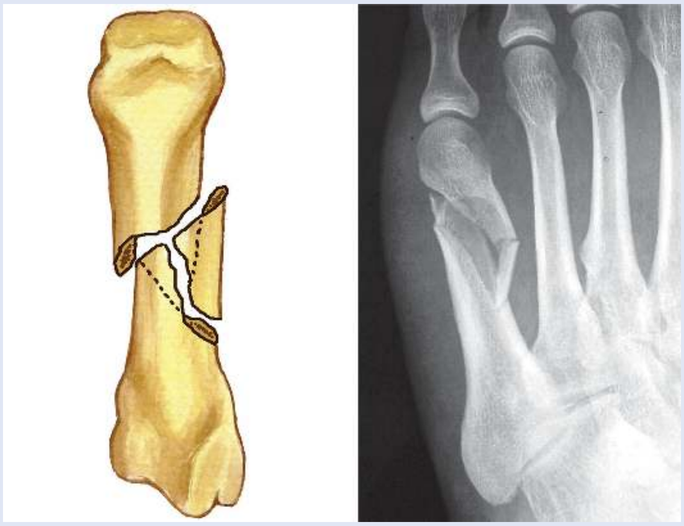

87-B1.3 Split/depression




87-B Metatarsal proximal, distal partial articular, and diaphysis wedge comminuted

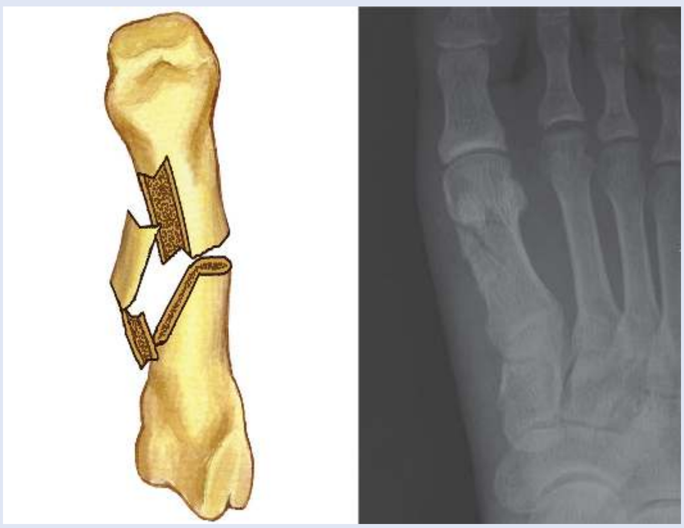
87-B2 Diaphysis wedge
251 fractures
M: 156 (62.15)
F: 95 (37.85%)
0.07% of total adult fractures
0.65% of adult foot fractures
2.79% of metatarsal fractures
5.16% of type 87-B

87-B2.1 Spiral



87-B2.2 Bending

87-B2.3 Comminuted wedge



87-B Metatarsal proximal, distal partial articular, and diaphysis wedge comminuted

87-B3 Distal partial articular
112 fractures
M: 71 (63.39%)
F: 41 (36.61%)
0.03% of total adult fractures
0.29% of adult foot fractures
1.24% of metatarsal fractures
2.30% of type 87-B

87-B3.1 Avulsion or split

87-B3.2 Depression

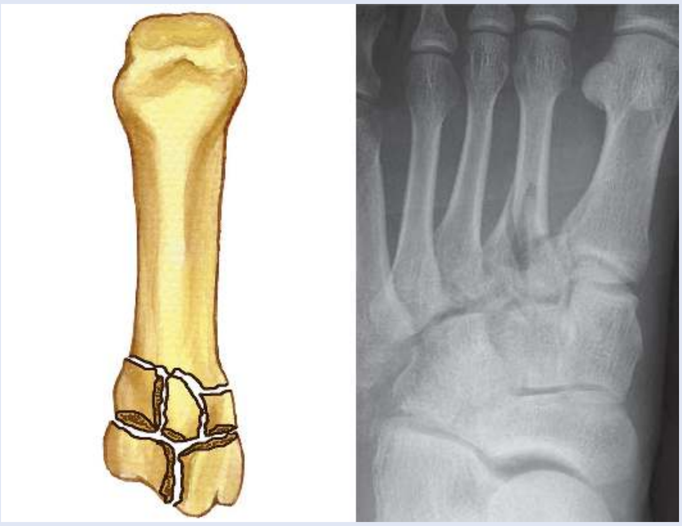
87-B3.3 Split/depression

87-C Metatarsal proximal, distal complete articular, and diaphysis comminuted

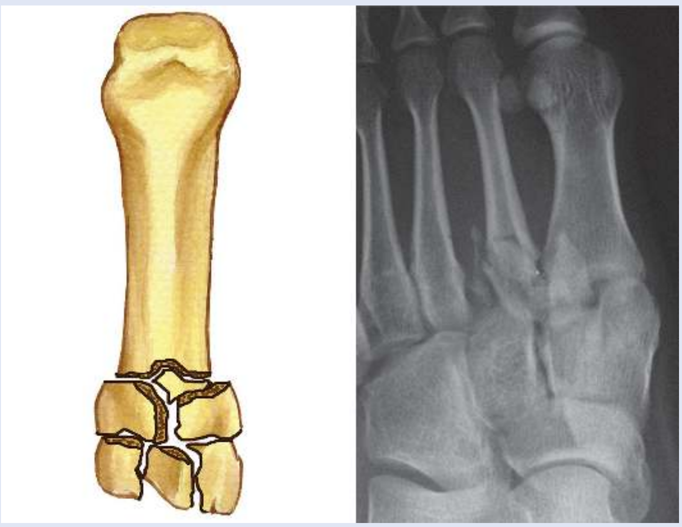
87-C1 Proximal complete articular
289 fractures
M: 173 (59.86%)
F: 116 (40.14%)
0.08% of total adult fractures
0.75% of adult foot fractures
3.21% of metatarsal fractures
54.43% of type 87-C

87-C1.1 Noncomminuted articular and metaphysis

87-C1.2 Noncomminuted articular, comminuted metaphysis



87-C1.3 Comminuted articular

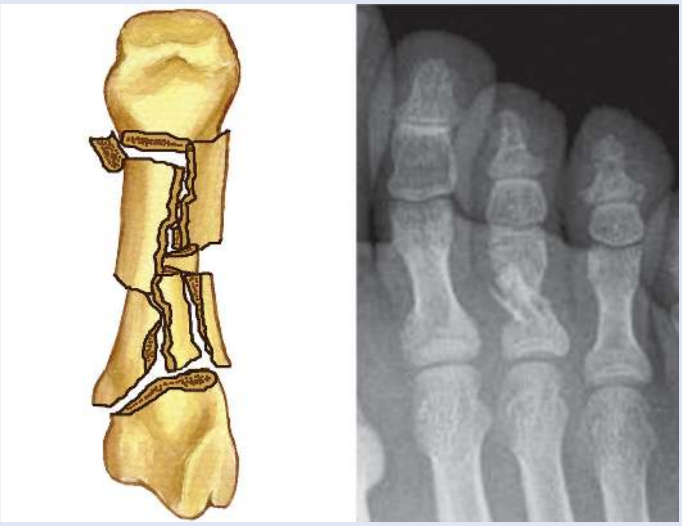


87-C Metatarsal proximal, distal complete articular, and diaphysis comminuted

87-C2 Diaphysis comminuted
182 fractures
M: 127 (69.78%)
F: 55 (30.22%)
0.05% of total adult fractures
0.47% of adult foot fractures
2.02% of metatarsal fractures
34.27% of type 87-C

87-C2.1 Segmental

87-C2.2 Complex comminuted



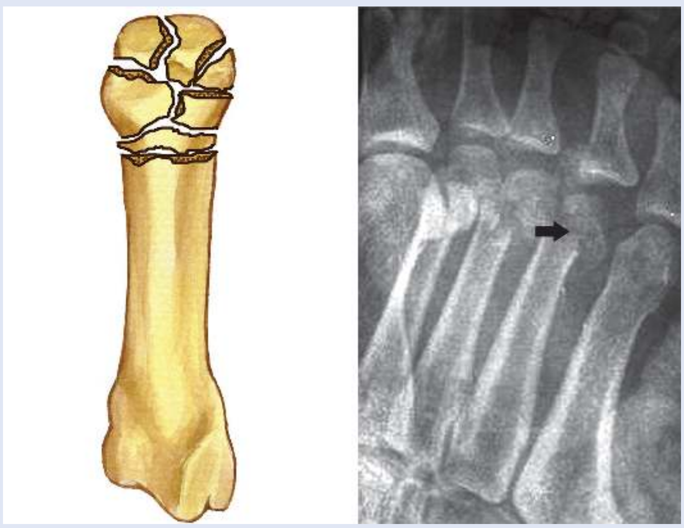
87-C Metatarsal proximal, distal complete articular, and diaphysis comminuted

87-C3 Distal articular
60 fractures
M: 38 (63.33%)
F: 22 (36.67%)
0.02% of total adult fractures
0.16% of adult foot fractures
0.67% of metatarsal fractures
11.30% of type 87-C

87-C3.1 Simple articular/metaphysis

87-C3.2 Simple articular/comminuted metaphysis

87-C3.3 Comminuted articular



Injury Mechanism

Fractures of the metatarsal usually occur as a result of direct trauma from dropping a heavy object on an extremity, or having an extremity crushed by a car. Although the second, third, and fourth metatarsal bones are often injured from direct mechanisms, multiple fractures may present as well. Indirect trauma after torsional stress may result in spiral fractures. Fractures of the base of the fifth metatarsal bone are often caused by forced inversion of the foot, which produces substantial tension on the peroneus brevis tendon. The inferoposterior displacement of the distal fragment following the base fracture will likely compress or injure the plantar arterial arch. Transverse, oblique, or comminuted fractures of the metatarsal shaft may occur, depending on the magnitude and direction of the impacting force. A single-shaft fracture of the second to fourth metatarsals is weakly associated with marked displacement, while metatarsal neck fractures are often associated with inferoposterior displacement of the distal fragment, resulting in the lowering of the metatarsal head and a decreased weight-bearing capacity of the foot.

Diagnosis

Trauma history, physical examination findings, and radiographic evaluation usually lead to a diagnosis. Patients commonly present with pain, swelling, and ecchymosis over the forefoot area. Deformity may occur if there is marked displacement or dislocation. Various levels of motion limitation may be present, depending on the severity of the injury. Physical examination findings include local tenderness on palpation, abnormality of motion, and presence of bony crepitus. Standard radiographs include the AP, lateral, and oblique views of the foot, which are the most often used investigations required for the diagnosis of fractures. Particular attention should be paid on the direction of the fracture line, involvement of the articulation, presence of displacement, and the number of the fractures.

Treatment

Fractures of the bases of the second to the fourth metatarsal bones are often associated with dislocations and are often unstable. The inferoposterior displacement of the distal fragment may disturb the blood supply of the forefoot. Emergent closed reduction should be performed followed by casting as soon as possible to avoid any interruption of blood supply. If closed reduction fails, then an intramedullary (IM) pin can be inserted from the head of the metatarsal bone across the fracture line into the tarsal bone for internal fixation. Isolated fractures of the base of the fifth metatarsal can be immobilized with the foot in abduction, following by application of a bandage or cast for 4 to 6 weeks. Range-of-motion exercises can be initiated after the external fixation device is removed.

Single nondisplaced metatarsal shaft fractures can be treated by casting for 4 to 6 weeks. Multiple metatarsal shaft fractures with displacement should be treated with closed reduction first; if closed reduction fails, open reduction and internal fixation is indicated with insertion of an intramedullary pin from the inferior part of the head for 4 to 6 weeks.

Displaced metatarsal neck fractures can be treated by closed reduction initially, followed by casting if the reduction is successful; if not, open reduction and internal fixation are indicated. Particular attention should be given to the avoidance of dorsal angulation of the distal fragment. Weight-bearing exercises should start as soon as radiographs show adequate fracture healing.

Phalangeal Fractures (Segment 88)

Anatomic Features

The phalanges of the foot can be divided into three segments according to their distance from the body: proximal, intermediate (the big toe does not have middle phalanx), and distal phalanges. Each phalanx has a base, a shaft, and a head. The interphalangeal articulations of the foot are ginglymoid joints, and each has a plantar and two collateral ligaments. They are second to the ankle joint as the most mobile joints in the body, and are easy targets for injuries due to their anatomical location (► Fig. 9.54).

OTA Classification of Phalangeal Fractures

Based on OTA classification, the phalanx is coded as number “88” for its anatomic location. Phalangeal fractures are classified into three types: 88-A, phalanx proximal and distal extra-articular, and diaphysis noncomminuted; 88-B, phalanx proximal and distal partial articular, and diaphysis wedge comminuted; and 88-C, phalanx proximal and distal complete articular, and diaphysis comminuted (► Fig. 9.55).

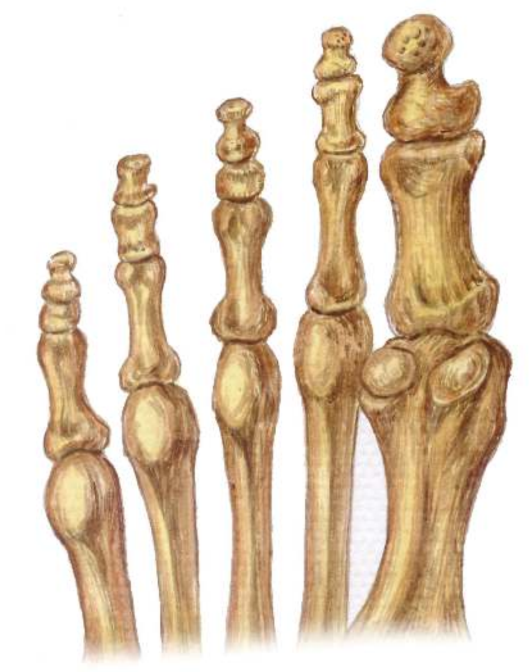


Fig. 9.54 The phalanges of the foot.

Clinical Epidemiologic Features of Phalangeal Fractures (Segment 88)

A total of 7,397 adult patients with 7,397 phalanx fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 2.05% of all patients with fractures, including 3,591 patients with fractures on the left side, 3,806 on the right side. There were 5,243 males and 2,154 females, with a male to female ratio of 2.43:1.

Epidemiological features of phalanx fractures are as follows:

- More males than females
- The high-risk age group is 21–25 years, with ages 21–25 years the highest for males and 36–40 years the highest for females
- The most common fracture type is type 88-A
- The most common fracture group is group 88-A3
- The first digit is the most commonly fractured foot digit
- The distal phalanx is the most commonly fractured phalanx

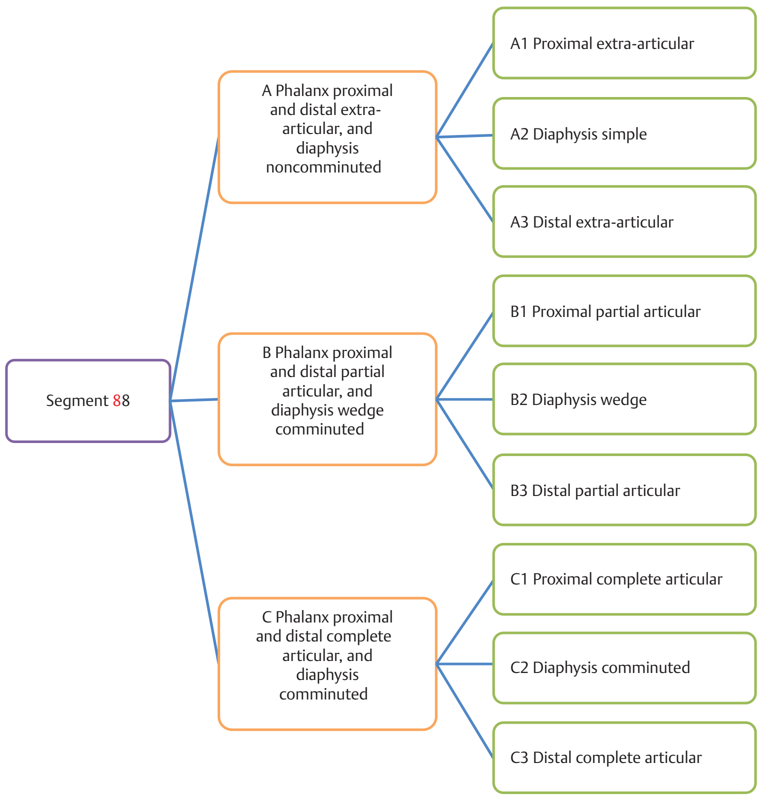


Fig. 9.55 Algorithm.

■ Phalanx Fractures (Segment 88) by Sex

See ▶ Table 9.36 and ▶ Fig. 9.56.

Table 9.36 Sex distribution of 7,397 patients with fractures of the phalanx of the foot

Sex	Number of patients	Percentage
Male	5,243	70.88
Female	2,154	29.12
Total	7,397	100.00

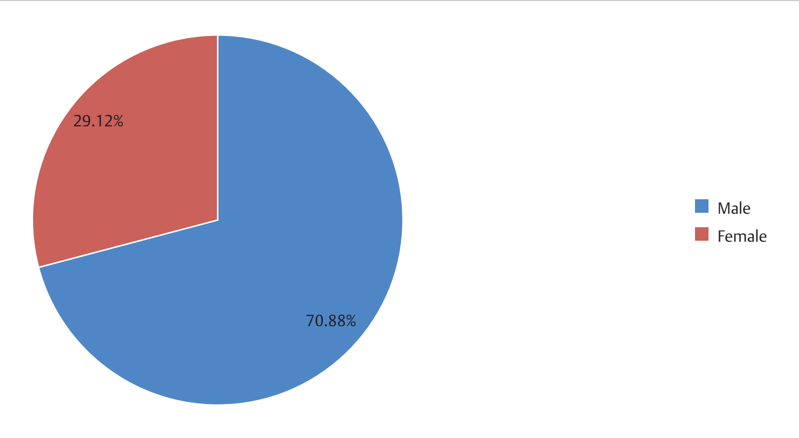


Fig. 9.56 Sex distribution of 7,397 patients with fractures of the phalanx of the foot.

■ Phalanx Fractures (Segment 88) by Age Group

See ▶ Table 9.37 and ▶ Fig. 9.57.

Table 9.37 Age and sex distribution of 7,397 patients with fractures of the phalanx of the foot

Age group (years)	Male	Female	Number of patients	Percentage
16–20	489	89	578	7.81
21–25	714	236	950	12.84
26–30	648	225	873	11.80
31–35	551	190	741	10.02
36–40	674	264	938	12.68
41–45	674	232	906	12.25
46–50	544	249	793	10.72
51–55	388	200	588	7.95
56–60	296	214	510	6.89
61–65	141	101	242	3.27
66–70	40	64	104	1.41
71–75	41	45	86	1.16
76–80	22	24	46	0.62
81–85	14	16	30	0.41
≥ 86	7	5	12	0.16
Total	5,243	2,154	7,397	100.00

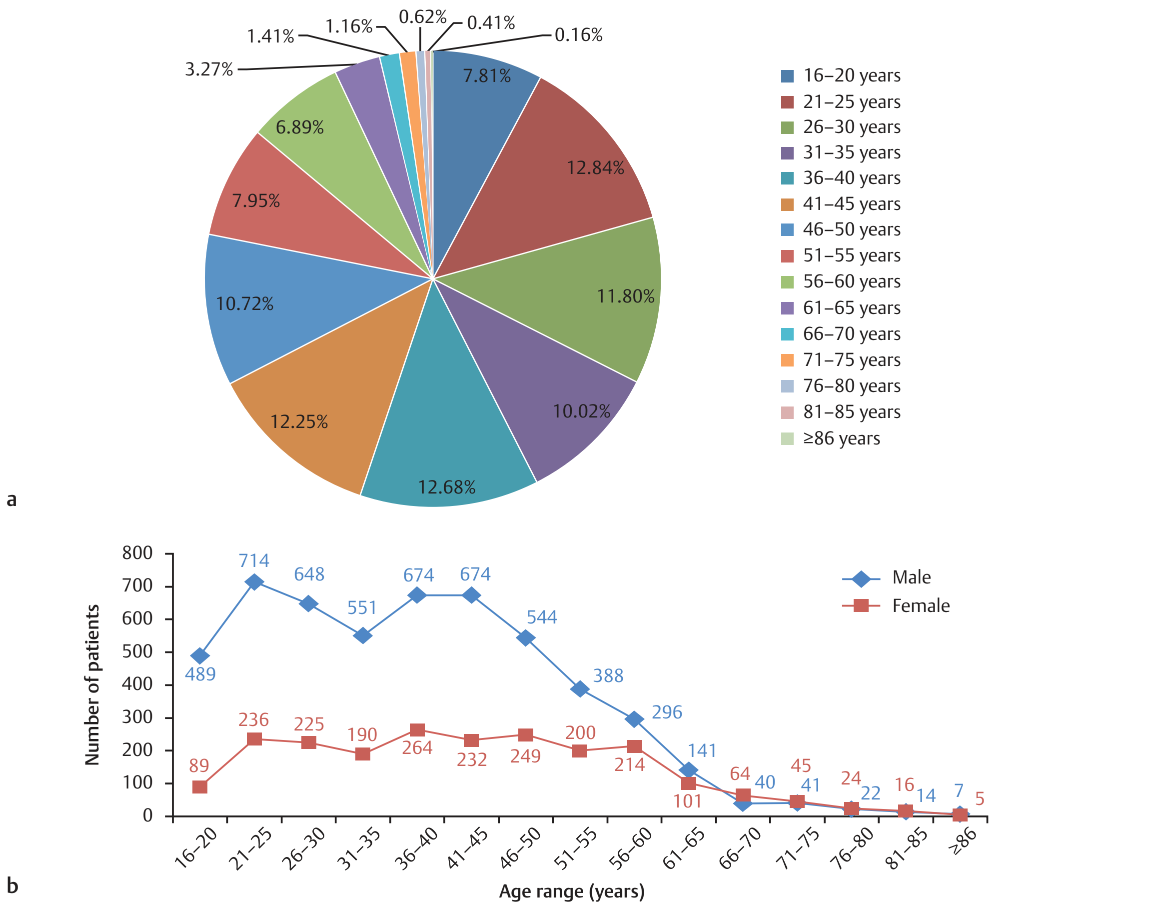


Fig. 9.57 (**a**) Age distribution of 7,397 patients with fractures of the phalanx of the foot. (**b**) Age and sex distribution of 7,397 patients with fractures of the phalanx of the foot.

9

■ Phalanx Fractures (Segment 88) by Fracture Type

See ▶ Table 9.38, ▶ Table 9.39, ▶ Fig. 9.58, and ▶ Fig. 9.59.

Table 9.38 Sex and fracture type distribution of 7,397 fractures of the phalanx of the foot

Fracture type	Male	Female	Number of fractures	Percentage
88-A	2,637	1,122	3,759	50.82
88-B	1,536	755	2,291	30.97
88-C	1,070	277	1,347	18.21
Total	5,243	2,154	7,397	100.00

Table 9.39 Sex and fracture group distribution of 7,397 fractures of the phalanx of the foot

Fracture group	Male	Female	Number of fractures	Percentage of phalanx fractures	Percentage of foot fractures
88-A1	299	194	493	6.66	1.28
88-A2	903	439	1,342	18.14	3.47
88-A3	1,435	489	1,924	26.01	4.98
88-B1	827	441	1,268	17.14	3.28
88-B2	242	80	322	4.35	0.83
88-B3	467	234	701	9.48	1.81
88-C1	205	65	270	3.65	0.70
88-C2	448	103	551	7.45	1.43
88-C3	417	109	526	7.11	1.36
Total	5,243	2,154	7,397	100.00	19.15

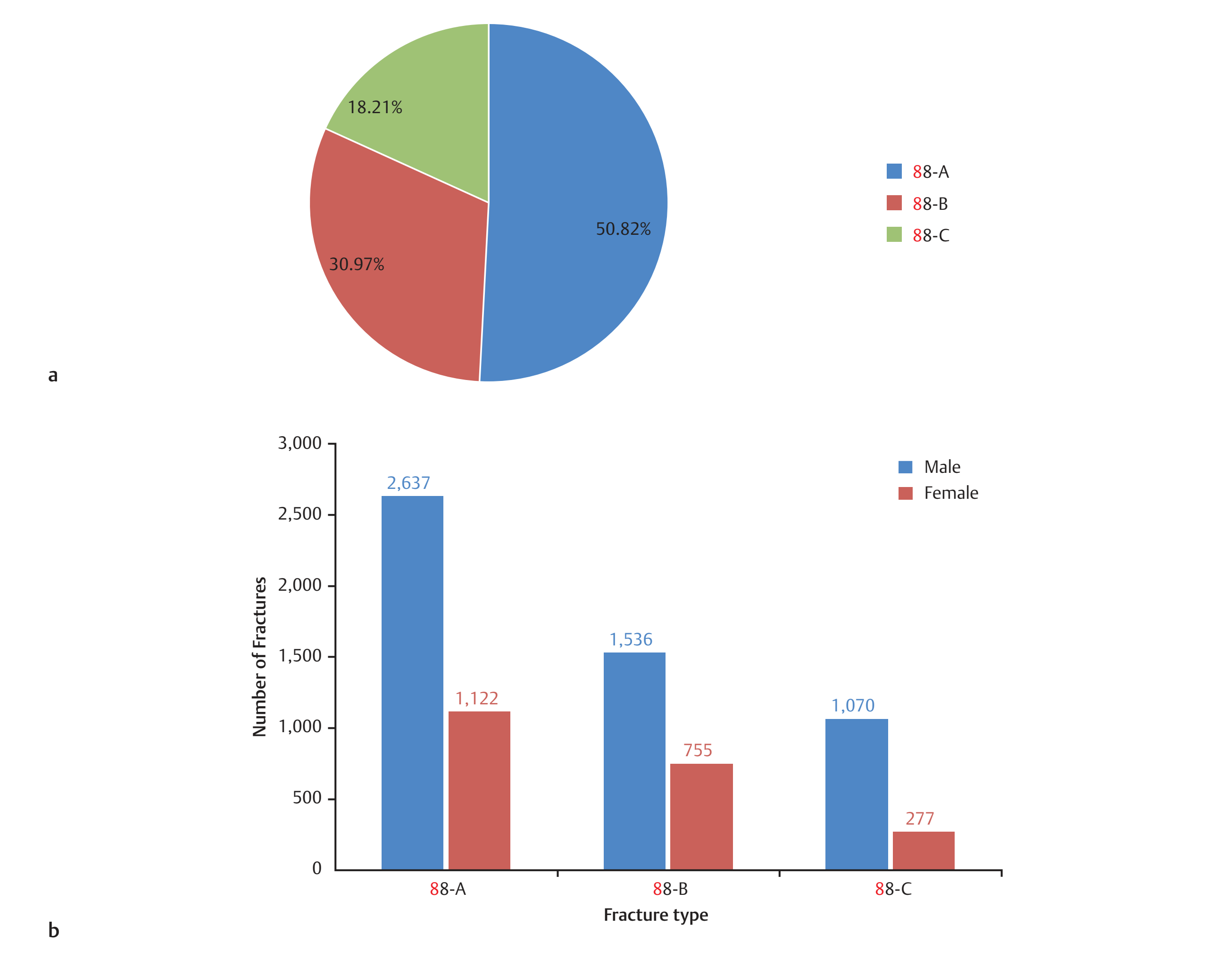


Fig. 9.58 (**a**) Fracture type distribution of 7,397 fractures of the phalanx of the foot. (**b**) Sex and fracture type distribution of 7,397 fractures of the phalanx of the foot.

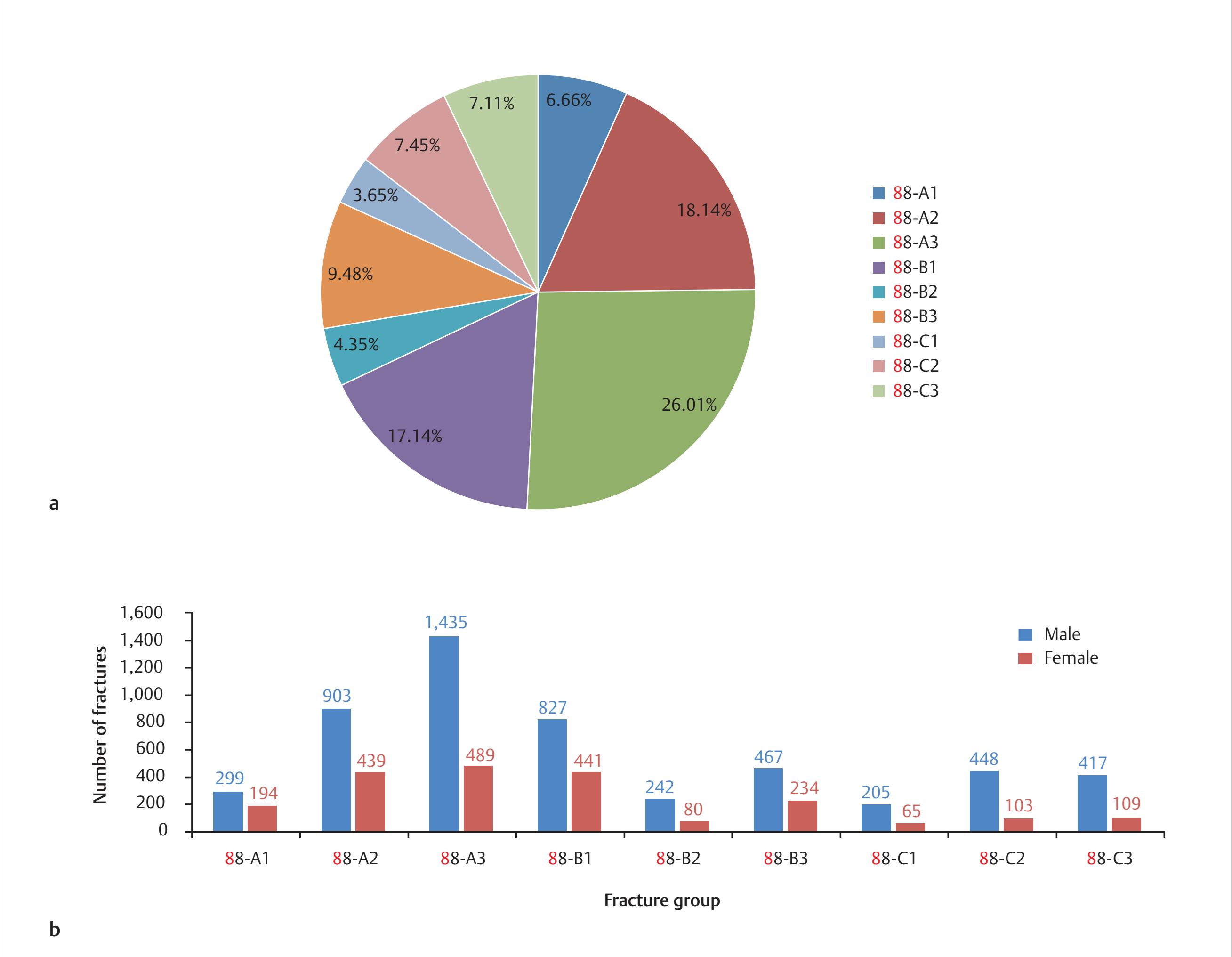


Fig. 9.59 (**a**) Fracture group distribution of 7,397 fractures of the phalanx of the foot. (**b**) Sex and fracture group distribution of 7,397 fractures of the phalanx of the foot.

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■ Phalanx Fractures (Segment 88) by Individual Foot Digit

See ▶ Table 9.40 and ▶ Fig. 9.60.

Table 9.40 Distribution of 7,397 fractures of the phalanx of the foot by individual foot digit

The number of the phalanx of the foot	Number of digits with fractures	Percentage of phalangeal fractures
1st	4,637	62.69
2nd	700	9.46
3rd	414	5.60
4th	401	5.42
5th	1,245	16.83
Total	7,397	100.00

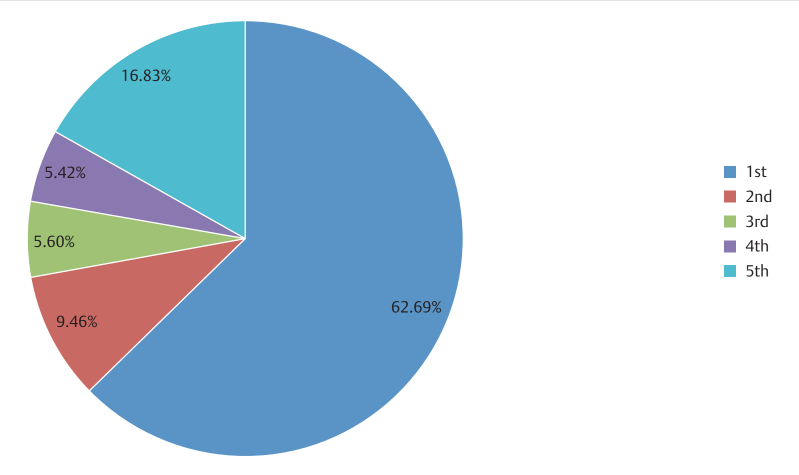


Fig. 9.60 Distribution of 7,397 fractures of the phalanx of the foot by individual foot digit.

■ Phalanx Fractures by Segment (Segment 88)

See ▶ Table 9.41 and ▶ Fig. 9.61.

Table 9.41 Sex and fracture segment distribution of 7,397 fractures of the phalanx of the foot

Fracture segment	Male	Female	Number of fractures	Percentage
Proximal	1,331	700	2,031	27.46
Diaphysis	1,593	622	2,215	29.94
Distal	2,319	832	3,151	42.60
Total	5,243	2,154	7,397	100.00

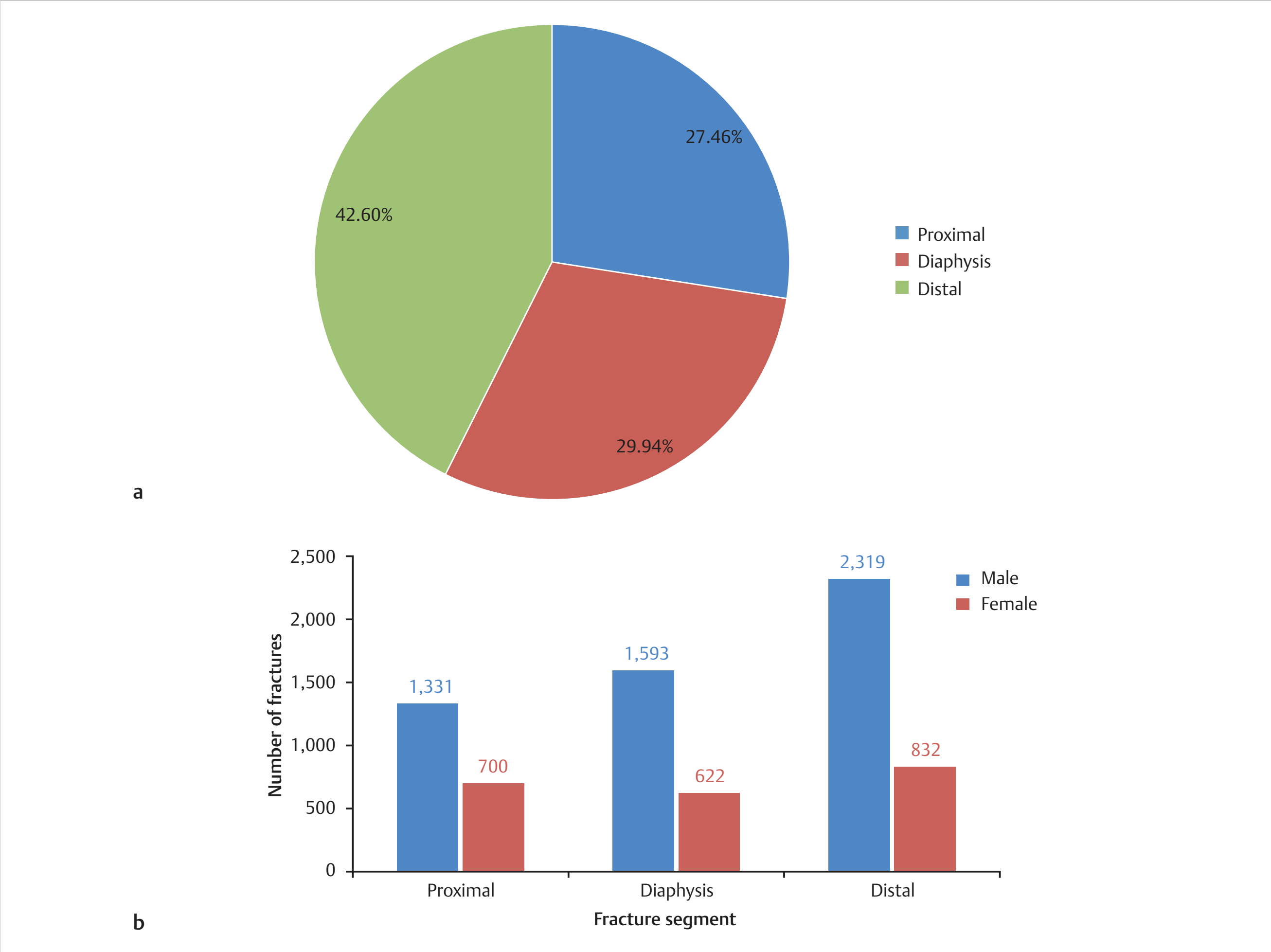
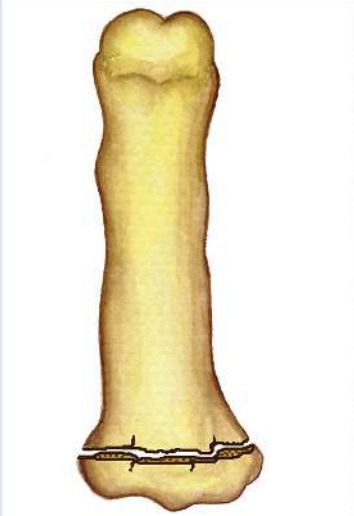
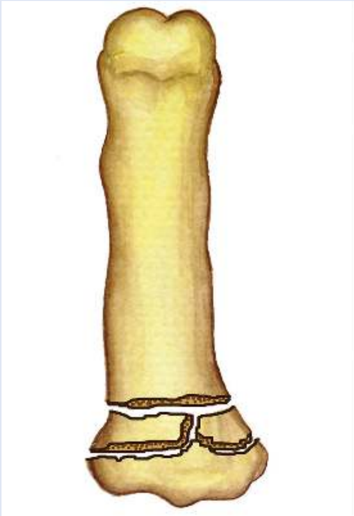


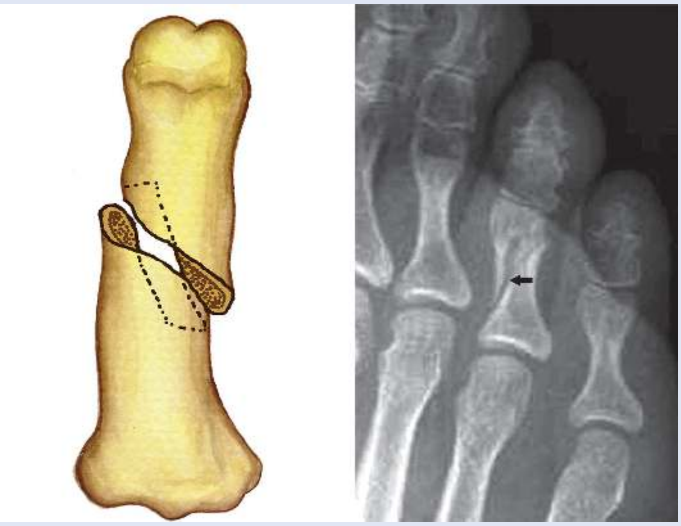
Fig. 9.61 (a) Fracture segment distribution of 7,397 fractures of the phalanx of the foot. (b) Sex and fracture segment distribution of 7,397 fractures of the phalanx of the foot.

88-A Phalanx proximal and distal extra-articular, and diaphysis noncomminuted	
88-A1 Proximal extra-articular 493 fractures M: 299 (60.65%) F: 194 (39.35%) 0.13% of total adult fractures 1.28% of adult foot fractures 6.66% of phalanx fractures 13.12% of type 88-A	**88-A1.1** Noncomminuted  **88-A1.2** Comminuted 

88-A Phalanx proximal and distal extra-articular, and diaphysis noncomminuted

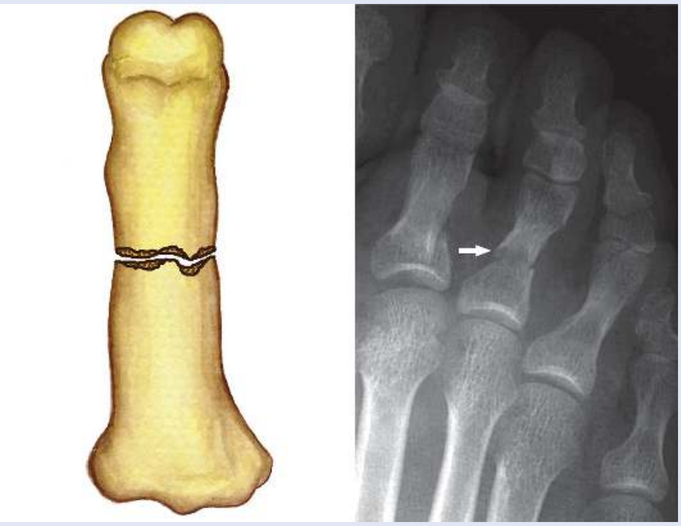
88-A2 Diaphysis simple
1,342 fractures
M: 903 (67.29%)
F: 439 (32.71%)
0.36% of total adult fractures
3.47% of adult foot fractures
18.14% of phalanx fractures
35.70% of type 88-A

88-A2.1 Spiral



88-A2.2 Oblique

88-A2.3 Transverse

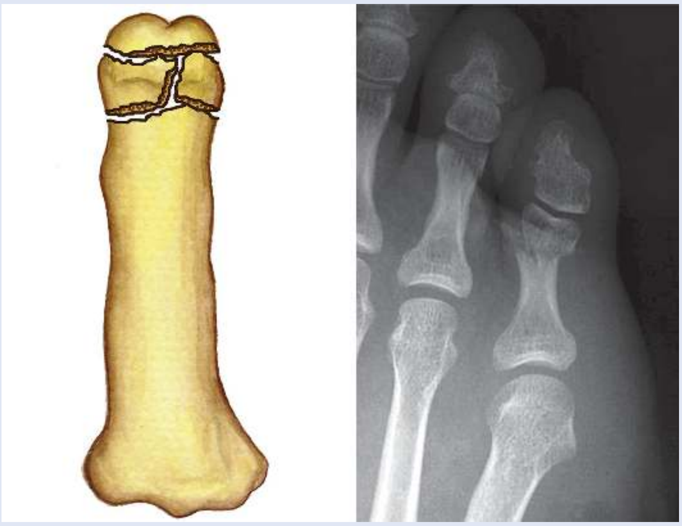


88-A Phalanx proximal and distal extra-articular, and diaphysis noncomminuted

88-A3 Distal extra-articular
1,924 fractures
M: 1,435 (74.58%)
F: 489 (25.42%)
0.51% of total adult fractures
4.98% of adult foot fractures
26.01% of phalanx fractures
51.18% of type 88-A

88-A3.1 Noncomminuted

88-A3.2 Comminuted



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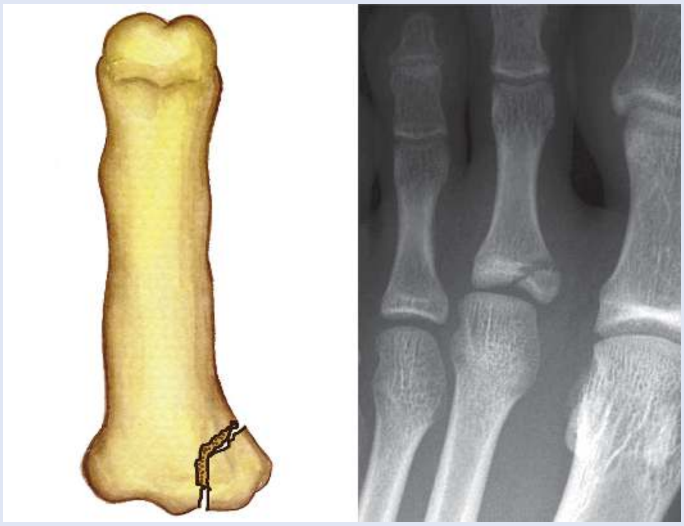
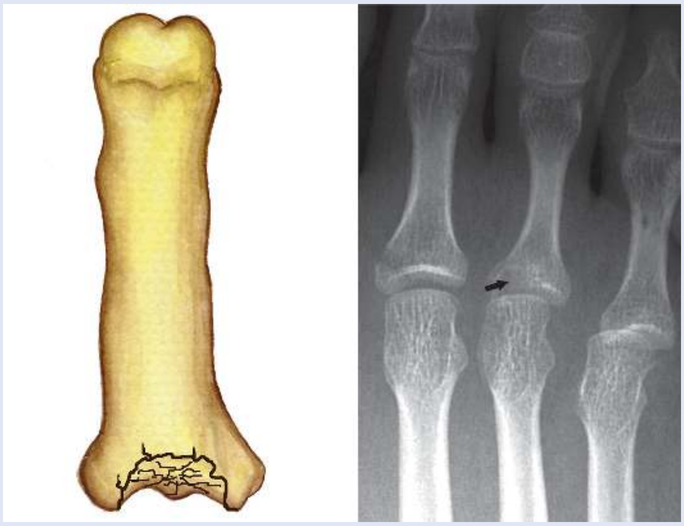
88-B Phalanx proximal and distal partial articular, and diaphysis wedge comminuted

88-B1 Proximal partial articular
1,268 fractures
M: 827 (65.22%)
F: 441 (34.78%)
0.34% of total adult fractures
3.28% of adult foot fractures
17.14% of phalanx fractures
55.35% of type 88-B

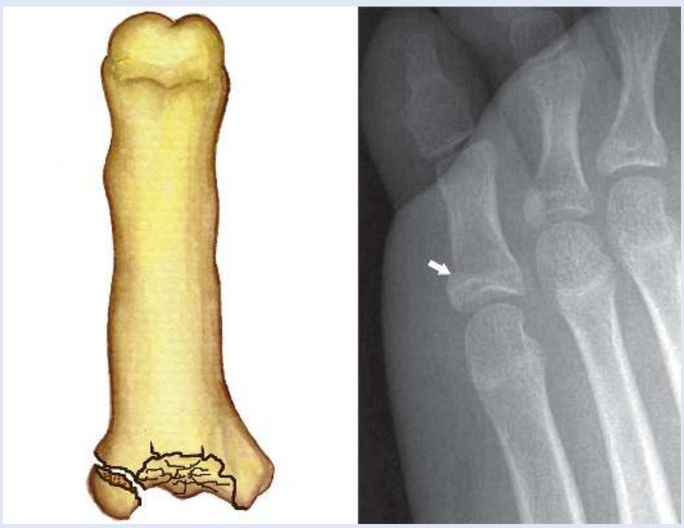
88-B1.1 Avulsion or split



88-B1.2 Depression



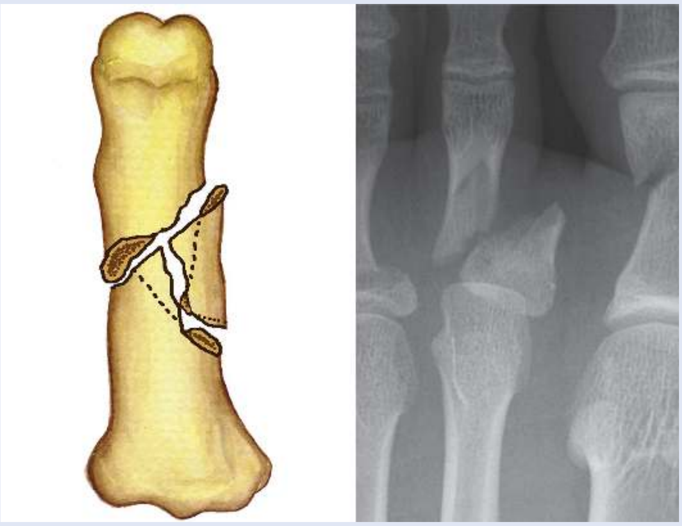
88-B1.3 Split/depression



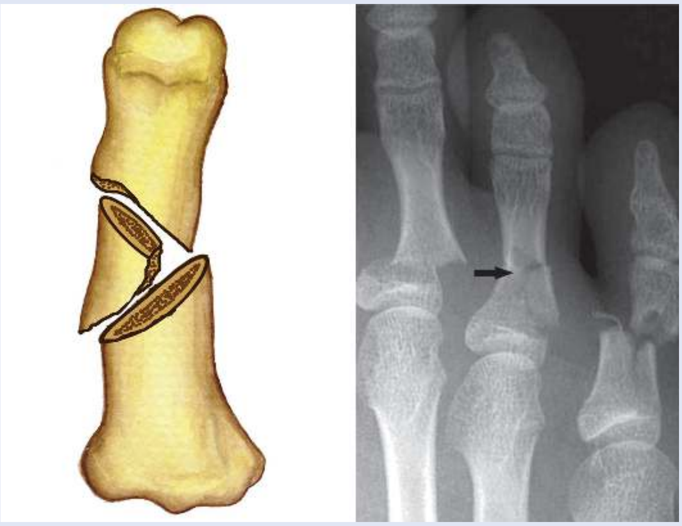
88-B Phalanx proximal and distal partial articular, and diaphysis wedge comminuted

88-B2 Diaphysis wedge
322 fractures
M: 242 (75.16%)
F: 80 (24.84%)
0.09% of total adult fractures
0.83% of adult foot fractures
4.35% of phalanx fractures
14.05% of type 88-B

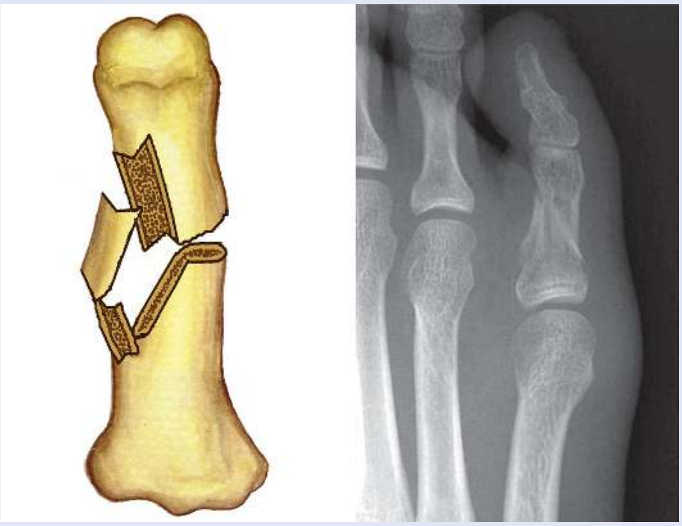
88-B2.1 Spiral



88-B2.2 Bending



88-B2.3 Fragmented



88-B Phalanx proximal and distal partial articular, and diaphysis wedge comminuted

88-B3 Distal partial articular
701 fractures
M: 467 (66.62%)
F: 234 (33.38%)
0.19% of total adult fractures
1.81% of adult foot fractures
9.48% of phalanx fractures
30.60% of type 88-B

88-B3.1 Avulsion or split

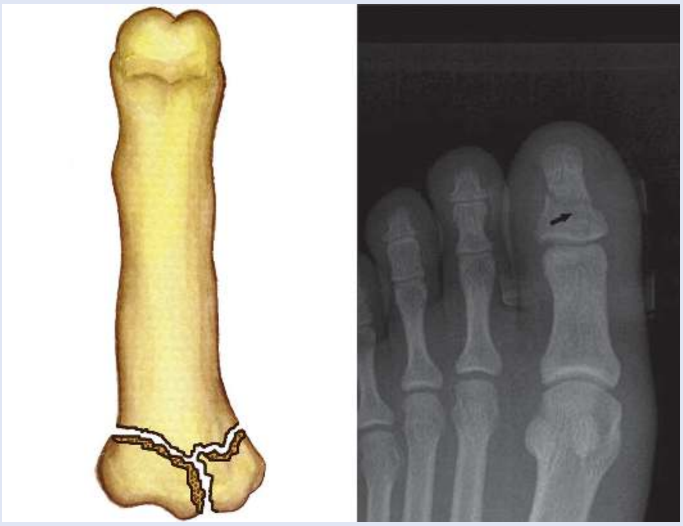
88-B3.2 Depression

88-B3.3 Split/depression

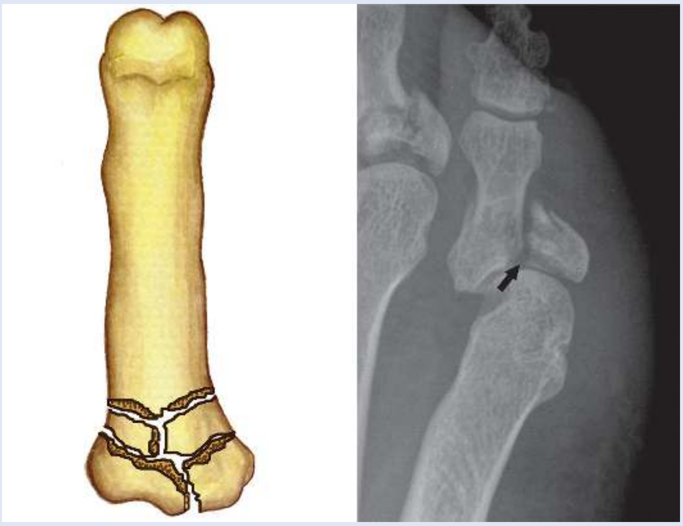
88-C Phalanx proximal and distal complete articular, and diaphysis comminuted

88-C1 Proximal complete articular
270 fractures
M: 205 (75.93%)
F: 65 (24.07%)
0.07% of total adult fractures
0.70% of adult foot fractures
3.65% of phalanx fractures
20.04% of type 88-C

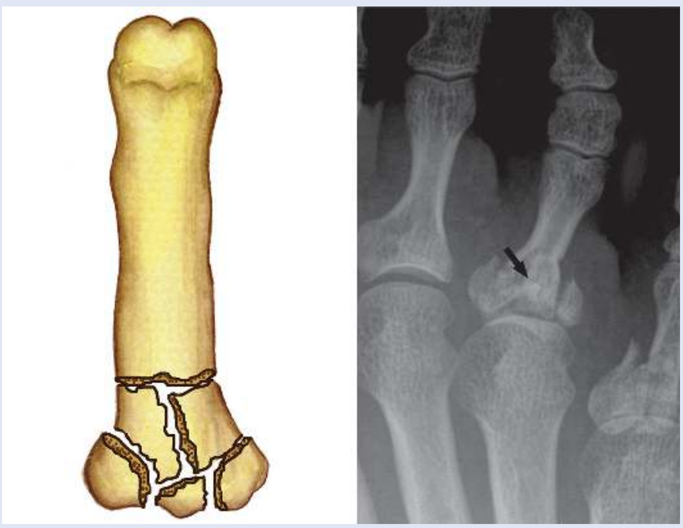
88-C1.1 Noncomminuted articular/metaphysis



88-C1.2 Noncomminuted articular/comminuted metaphysis



88-C1.3 Comminuted articular and metaphysis

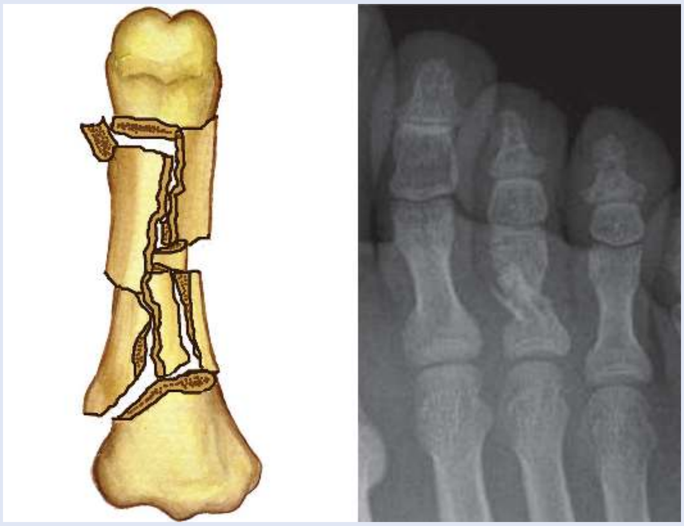


88-C Phalanx proximal and distal complete articular, and diaphysis comminuted

88-C2 Diaphysis comminuted
551 fractures
M: 448 (81.31%)
F: 103 (18.69%)
0.15% of total adult fractures
1.43% of adult foot fractures
7.45% of phalanx fractures
40.91% of type 88-C

88-C2.1 Segmental

88-C2.2 Complex comminuted

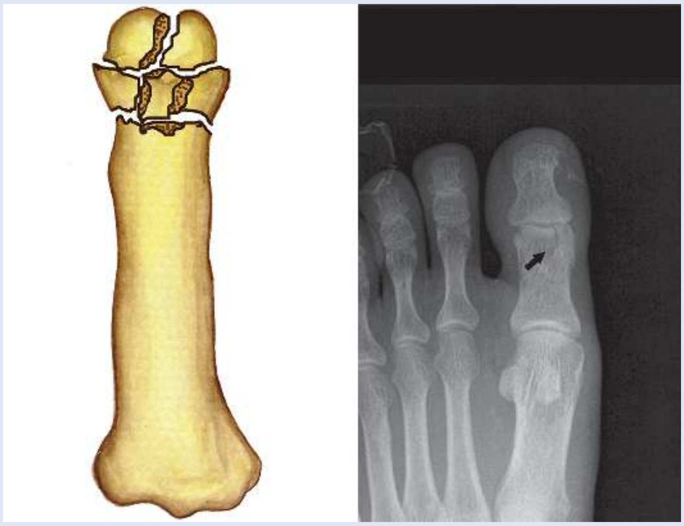


88-C Phalanx proximal and distal complete articular, and diaphysis comminuted

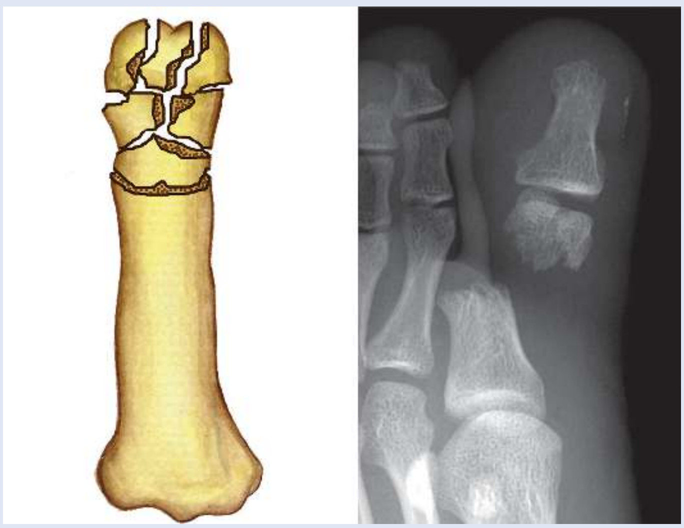
88-C3 Distal complete articular
526 fractures
M: 417 (79.28%)
F: 109 (20.72%)
0.14% of total adult fractures
1.36% of adult foot fractures
7.11% of phalanx fractures
39.05% of type 88-C

88-C3.1 Noncomminuted articular/metaphysis

88-C3.2 Noncomminuted articular comminuted metaphysis



88-C3.3 Comminuted articular



Injury Mechanism

Fractures and dislocation of the phalanx usually occur as a result of direct trauma, such as from a heavy object falling on an extremity, kicking a hard surface, or crush injuries. A direct blow to the area will lead to comminuted fractures or longitudinal fractures, and is associated with open fractures and toenail damage. Kicking a hard surface usually results in transverse or oblique fractures. Depression fractures or avulsion of the capsular ligament are often associated with indirect trauma, as seen in soccer or ballet when the metatarsophalangeal joints are forcibly plantar flexed.

Diagnosis

Due to the anatomic location of the phalanx, diagnosis usually can be made without much difficulty. Swelling, pain, ecchymosis, or deformity may be present. Radiographs usually confirm the presence of a fracture.

Treatment

Nondisplaced phalangeal fractures do not require specific treatment; instead 2 to 3 weeks of bed rest is usually required before beginning to walk again. A displaced single phalangeal fracture should be treated with closed reduction, and the fractured digit should be taped to an adjacent digit for immobilization, which permits early active motion. After reduction, most phalangeal fractures can be treated by cast plating, using a plate made by extending the casting material beyond the distal toes; this process prohibits plantar flexion and limits dorsiflexion. Weight-bearing exercise, started at 2 to 3 weeks after the immobilization, is recommended. Caution is necessary to correct rotational deformity and to avoid dorsal or palmar angulation, thereby minimizing functional limitation due to misalignment of the digit.

Multiple Fractures of the Foot (Segment 89)

Based on OTA classification, multiple fractures of the foot are coded as number "89," which is divided into three types: 89-A, multiple fracture of the hindfoot; 89-B, multiple fracture of the midfoot; and 89-C, multiple fracture of the forefoot (▶ Fig. 9.62).

Clinical Epidemiologic Features of Multiple Fractures of the Foot (Segment 89) by OTA Classification

A total of 7,272 adult patients with multiple fractures of the foot were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. Epidemiologic features of multiple foot fractures are as follows:

- More males than females
- The most common fracture type is type 89-C; thus, multiple fractures of the forefoot occur most often.

See ▶ Table 9.42 and ▶ Fig. 9.63.

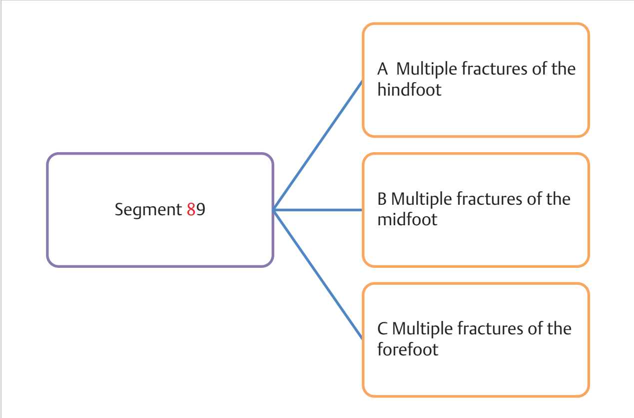


Fig. 9.62 Algorithm.

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Table 9.42 Sex and fracture type distribution of 7,272 multiple foot fractures

Fracture type	Male	Female	Number of patients	Percentage
89-A	236	59	295	4.06
89-B	644	193	837	11.51
89-C	4,801	1,339	6,140	84.43
Total	5,681	1,591	7,272	100.00

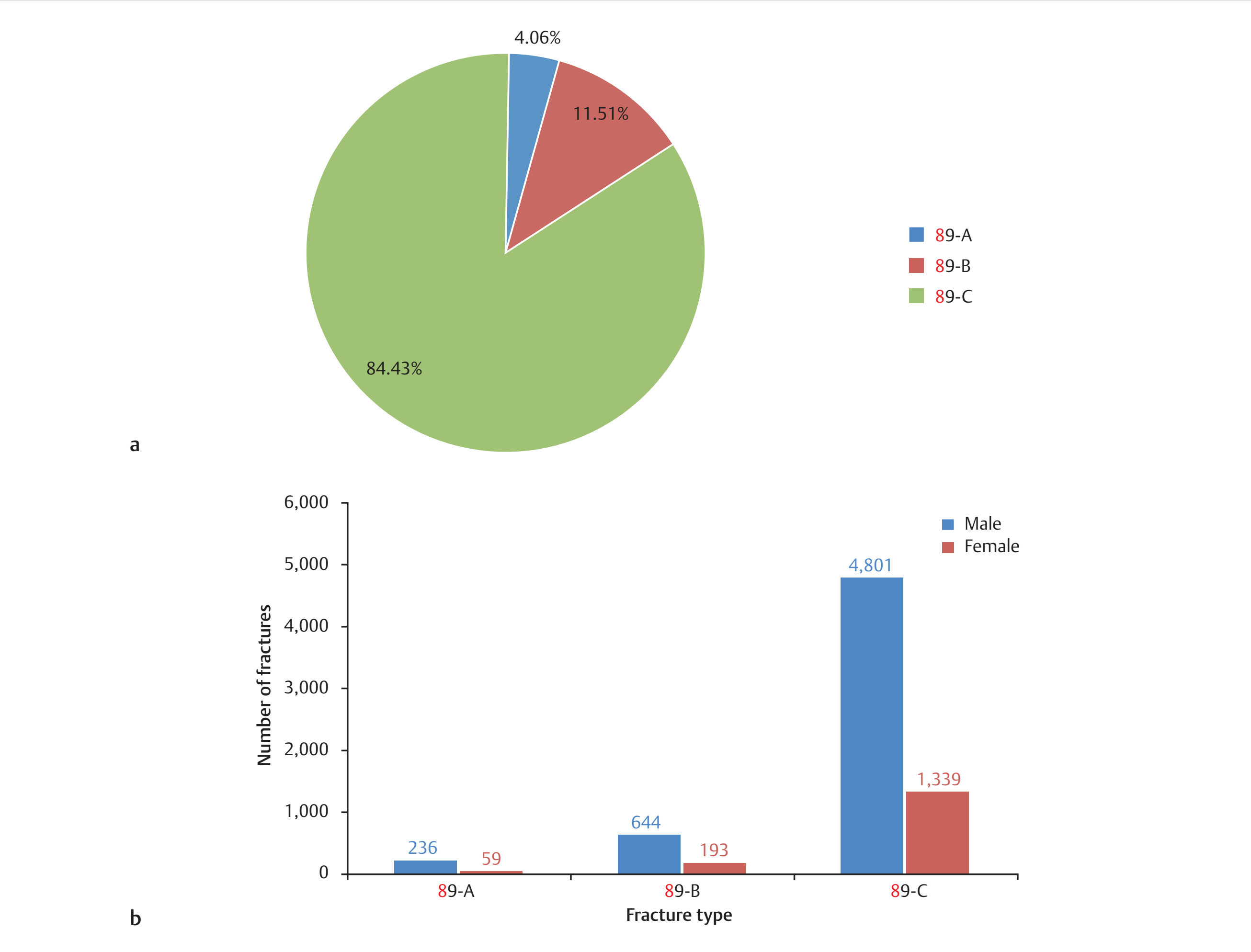

Fig. 9.63 (a) Fracture type distribution of 7,272 multiple foot fractures. (b) Sex and fracture type distribution of 7,272 multiple foot fractures.

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89 Multiple fractures of the foot	
89 Multiple fractures of the foot 7,272 fractures M: 5,681 (78.12%) F: 1,591 (21.88%)	**89-A** Hindfoot   **89-B** Midfoot   **89-C** Forefoot  

Suggested Readings

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10 Fractures of the Patella, Clavicle, and Scapula

Bing Yin, Shilun Li, and Zhaoyu Chen

Fractures of the Patella (Segment 34)

Anatomic Features

The patella is the largest sesamoid bone in the human body and is an important component of the knee joint. It serves to increase the leverage of the quadriceps femoris as a fulcrum, protects the front of the joint, and maintains joint stability. It is a flat, triangular bone; its superior border is thick, while the medial and lateral borders are thinner, and it gives attachment to the tendon of the quadriceps femoris and the medial and lateral patellar retinacula. The lateral borders converge below to the apex, which gives attachment to the ligamentum patellae; the anterior surface is convex and rough, and covered by the expansion from the tendon of the quadriceps femoris; the posterior surface is a smooth, oval, articular area, and for the most part is covered with smooth, slippery cartilage; it is divided into two facets, medial and lateral, by a vertical ridge. Each facet is further subdivided into three facets: superior, middle, and inferior. Lateral to the inner facet is another longitudinal facet. These seven facets in total make contacts with the femur at various angles during the extension–flexion of the knee joint (▶ Fig. 10.1).

OTA Classification and Coding System for Patellar Fractures

Based on Orthopaedic Trauma Association (OTA) classification, the patella is coded as number "34" for its anatomic location. Patellar fractures are classified into three types according to the fracture pattern: type A, extra-articular; type B, partial articular, vertical; and type C, complete articular, nonvertical (▶ Fig. 10.2; ▶ Fig. 10.3).

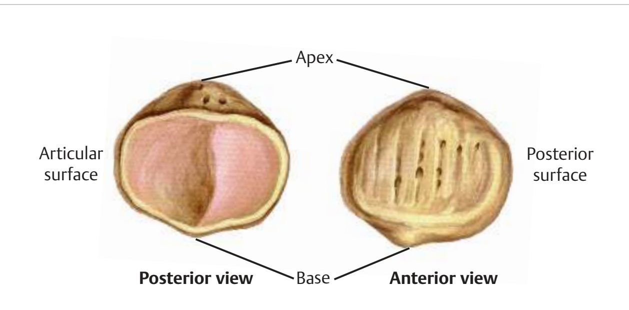

Fig. 10.1 The patella.

Epidemiologic Features of Patellar Fractures in the China National Fracture Study

A total of 69 patients with 69 patellar fractures were investigated in the China National Fracture Study (CNFS). The fractures accounted for 3.91% of all patients with fractures and 3.76% of all types of fractures. The population-weighted incidence rate of patellar fractures was 13 per 100,000 population in 2014.

The epidemiologic features of patellar fractures in the CNFS are as follows:

- More males than females
- More right-side injuries than left-side injuries
- The highest-risk age group is 15–64 years
- Injuries occurred most commonly via slips, trips, or falls

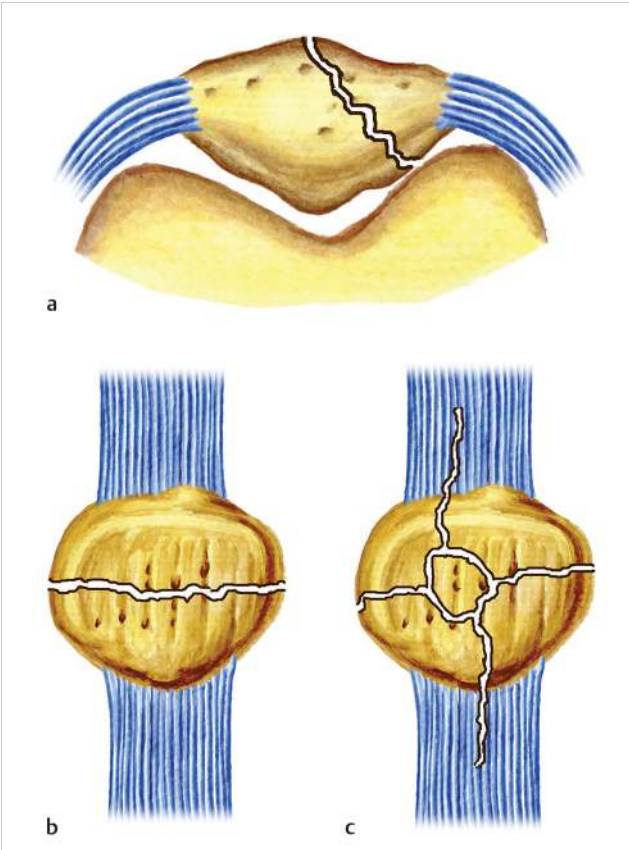

Fig. 10.2 (a–c) Patellar fractures.

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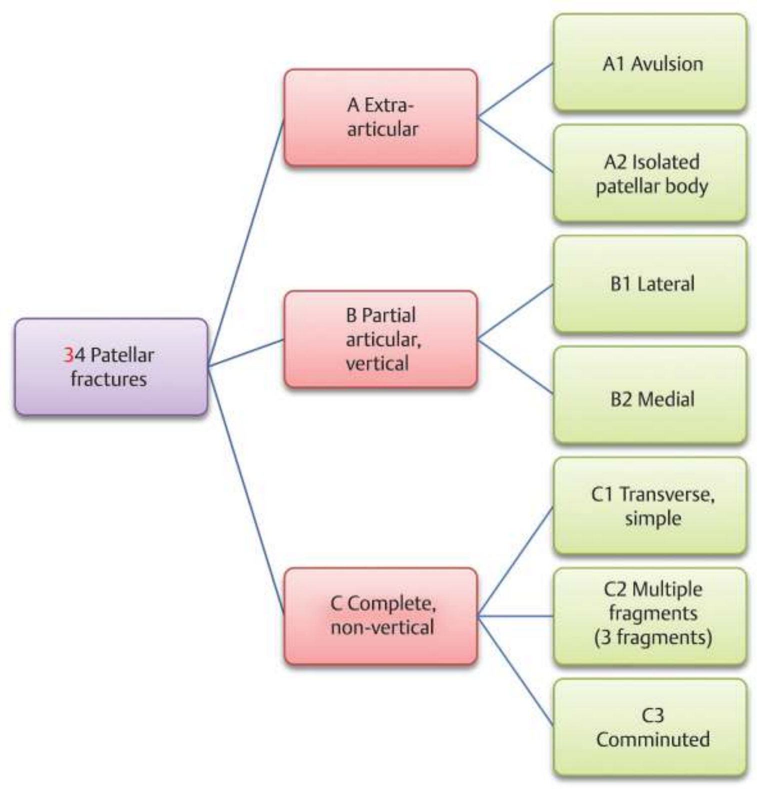


Fig. 10.3 Algorithm.

Patellar Fracture by Sex

See ▶ Table 10.1 and ▶ Fig. 10.4.

Table 10.1 Sex distribution of 69 patients with patellar fractures in CNFS

Sex	Number of patients	Percentage
Male	35	50.72
Female	34	49.28
Total	69	100.00

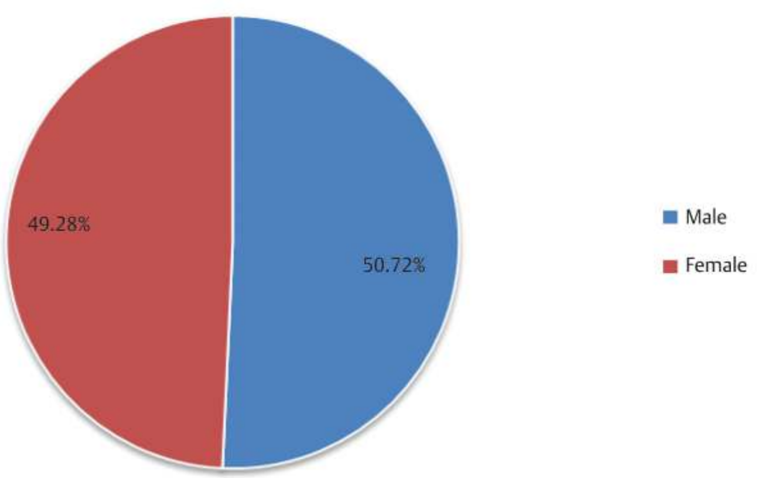


Fig. 10.4 Sex distribution of 69 patients with patellar fractures in China National Fracture Study (CNFS).

■ Patellar Fractures by Injury Side in CNFS

See ▶ Table 10.2 and ▶ Fig. 10.5.

Table 10.2 Injury side distribution of 69 patients with patellar fractures in CNFS

Injured side	Number of patients	Percentage
Left	32	46.38
Right	37	53.62
Total	69	100.00

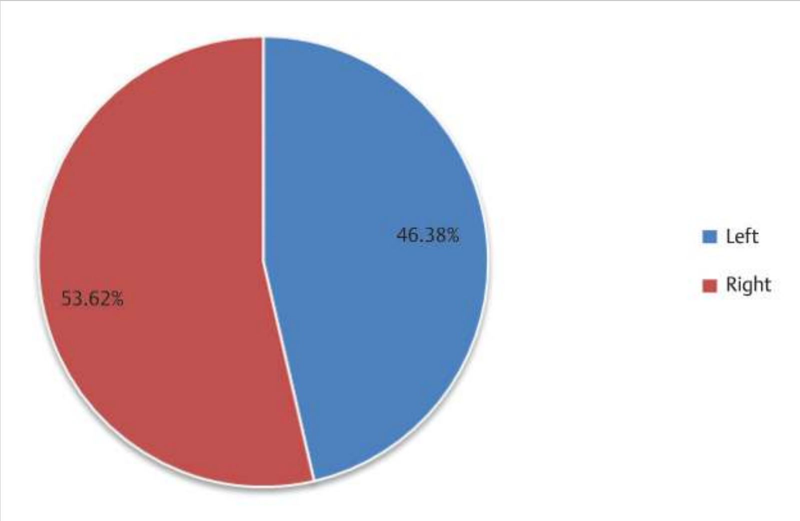


Fig. 10.5 Injury side distribution of 69 patients with patellar fractures in China National Fracture Study (CNFS).

■ Patellar Fractures by Age Group and Sex in CNFS

See ▶ Table 10.3 and ▶ Fig. 10.6.

Table 10.3 Age and sex distribution of 69 patients with patellar fractures in CNFS

Age group (years)	Male	Female	Total	Percentage
0–14	1	2	3	4.35
15–64	26	23	49	71.01
≥65	8	9	17	24.64
Total	35	34	69	100.00

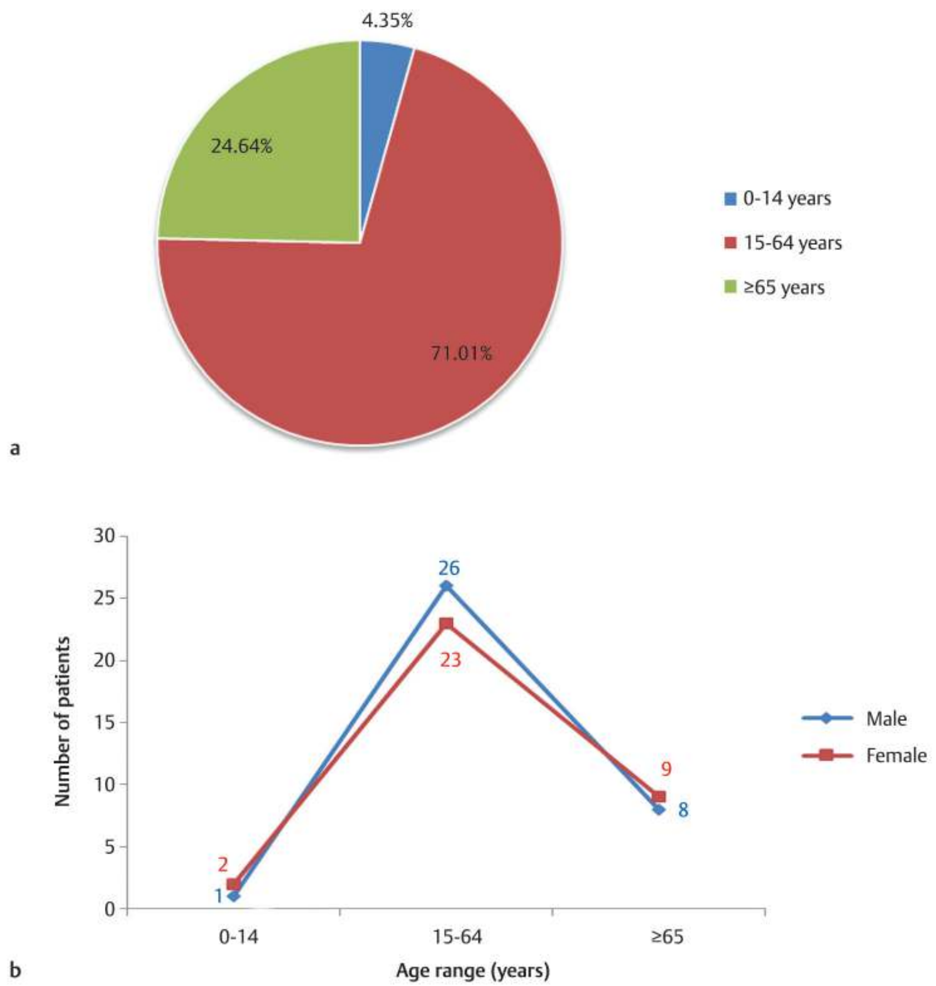


Fig. 10.6 (**a**) Age distribution of 69 patients with patellar fractures in China National Fracture Study (CNFS). (**b**) Age and sex distribution of 69 patients with patellar fractures in CNFS.

Patellar Fractures by Causal Mechanisms in CNFS

See ▶ Table 10.4 and ▶ Fig. 10.7.

Table 10.4 Causal mechanisms distribution of 69 patients with patellar fractures in CNFS

Causal mechanisms	Male	Female	Total	Percentage
Traffic accident	11	2	13	18.84
Slip, trip, or fall	19	29	48	69.57
Fall from heights	3	3	6	8.70
Crushing injury	2	0	2	2.90
Total	35	34	69	100.00

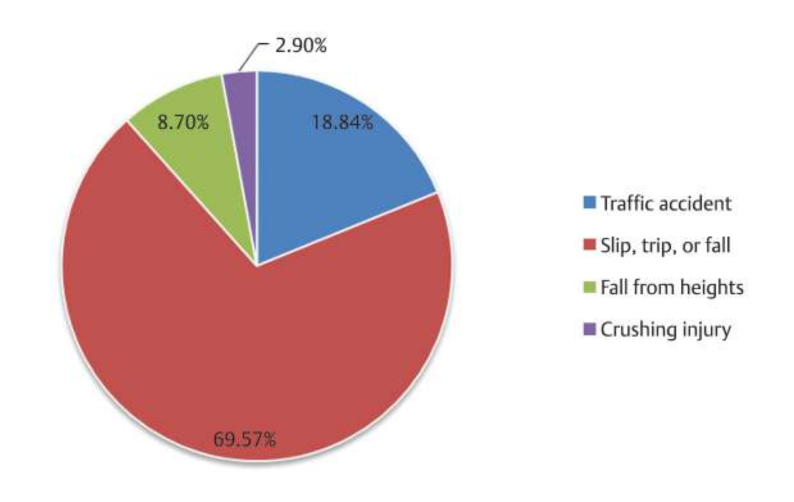


Fig. 10.7 Causal mechanisms distribution of 69 patients with patellar fractures in China National Fracture Study (CNFS).

Clinical Epidemiologic Features of Patellar Fractures (Segment 34)

A total of 11,332 patients with 11,378 patellar fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, accounting for 2.73% of all patients with fractures, and 2.63% of all kinds of fractures, respectively; of a total 11,332 patients, there were 279 pediatric patients (290 patellar fractures) and 11,053 adult patients with 11,088 fractures.

Epidemiologic features of patellar fractures are the following:

- More males than females
- More left-side than right-side fractures
- The high-risk age group is 41–50 years, the same age group for males, while for females the high-risk age group is 51–60 years
- The most common fracture type is type 34-C, the same fracture type for both males and females
- The most common fracture group is group 34-C1, the same fracture group for both males and females

■ Patellar Fractures by Sex

See ▶ Table 10.5 and ▶ Fig. 10.8.

Table 10.5 Sex distribution of 11,332 patients with patellar fractures

Sex	Number of patients	Percentage
Male	6,791	59.93
Female	4,541	40.07
Total	11,332	100.00

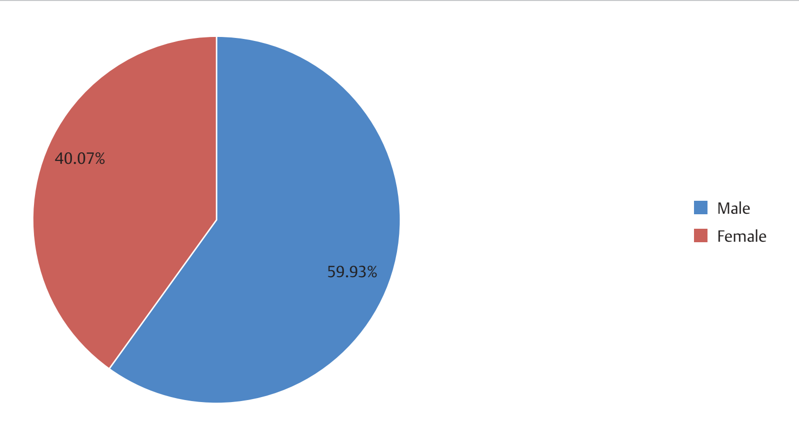


Fig. 10.8 Sex distribution of 11,332 patients with patellar fractures.

■ Patellar Fractures by Fracture Side

See ▶ Table 10.6 and ▶ Fig. 10.9.

Table 10.6 Fracture side distribution of 11,332 patients with patellar fractures

Fracture side	Number of patients	Percentage
Left	5,972	52.70
Right	5,314	46.89
Bilateral	46	0.41
Total	11,332	100.00

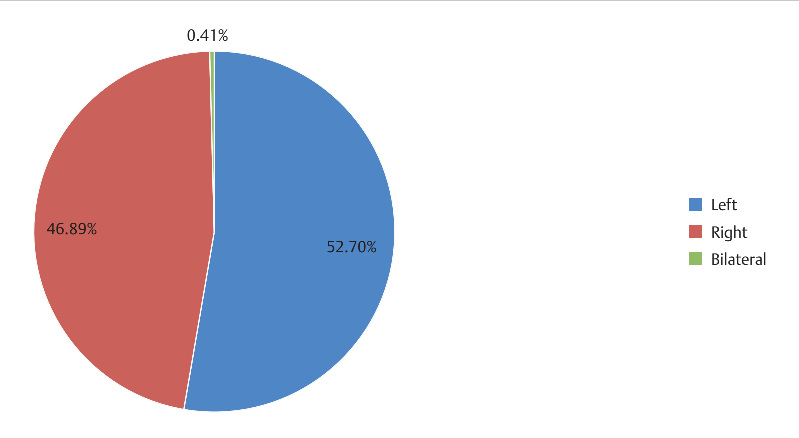


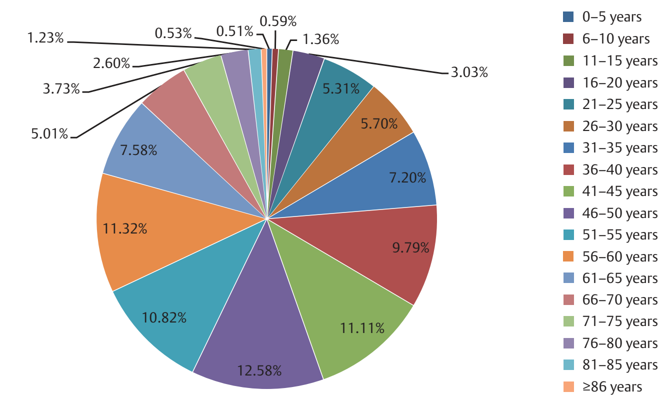
Fig. 10.9 Fracture side distribution of 11,332 patients with patellar fractures.

■ Patellar Fractures by Age Group

See ▶ Table 10.7 and ▶ Fig. 10.10.

Table 10.7 Age and sex distribution of 11,332 patients with patellar fractures

Age group (years)	Male	Female	Number of patients	Percentage
0–5	41	17	58	0.51
6–10	51	16	67	0.59
11–15	121	33	154	1.36
16–20	278	65	343	3.03
21–25	456	146	602	5.31
26–30	482	164	646	5.70
31–35	567	249	816	7.20
36–40	772	337	1,109	9.79
41–45	861	398	1,259	11.11
46–50	886	539	1,425	12.58
51–55	634	592	1,226	10.82
56–60	579	704	1,283	11.32
61–65	388	471	859	7.58
66–70	230	338	568	5.01
71–75	182	241	423	3.73
76–80	144	151	295	2.60
81–85	91	48	139	1.23
≥ 86	28	32	60	0.53
Total	6,791	4,541	11,332	100.00



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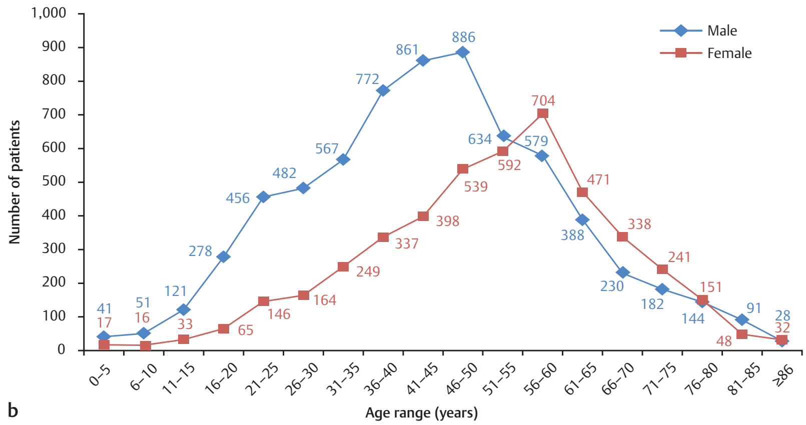

b

Fig. 10.10 (**a**) Age distribution of 11,332 patients with patellar fractures. (**b**) Age and sex distribution of 11,332 patients with patellar fractures.

■ Adult Patellar Fractures by Fracture Type

See ▶ Table 10.8 and ▶ Fig. 10.11.

Table 10.8 Fracture type distribution of 11,088 adult patellar fractures

Fracture type	Male	Female	Number of fractures	Percentage of talus
34-A	1,034	767	1,801	16.24
34-B	701	481	1,182	10.66
34-C	4,872	3,233	8,105	73.10
Total	6,607	4,481	11,088	100.00

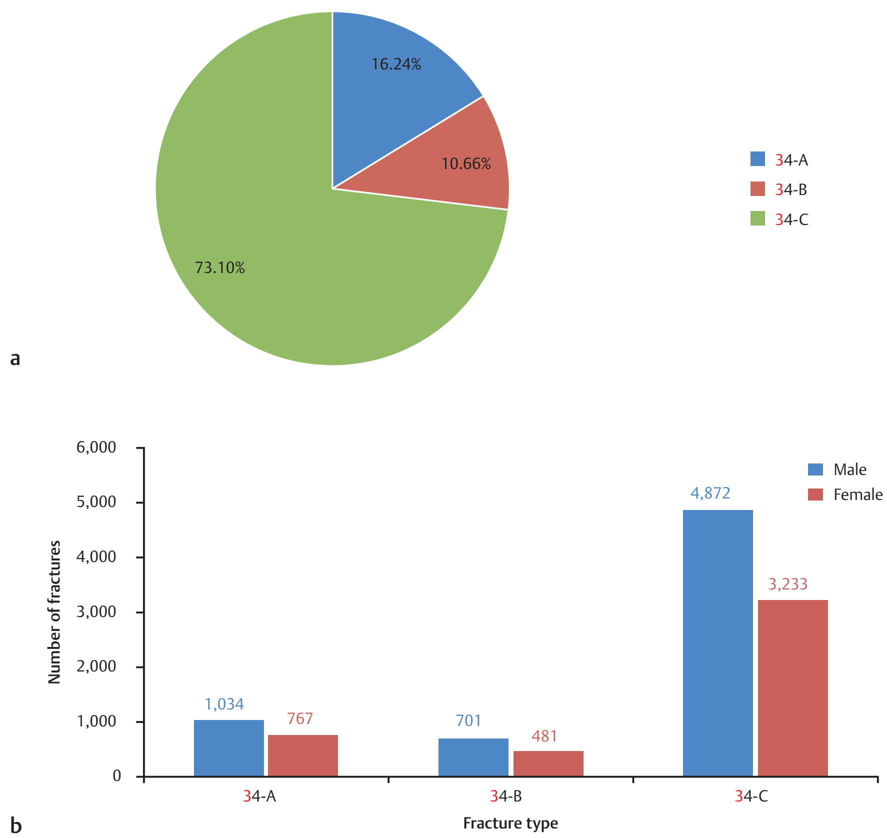

Fig. 10.11 (**a**) Fracture type distribution of 11,088 adult patellar fractures by Orthopaedic Trauma Association (OTA) classification. (**b**) Sex and fracture type distribution of 11,088 adult patellar fractures by OTA classification.

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■ Adult Patellar Fractures by Fracture Group

See ▶ Table 10.9 and ▶ Fig. 10.12.

Table 10.9 Fracture group and sex distribution of 11,088 adult patellar fractures

Fracture group	Male	Female	Number of fractures	Percentage
34-A1	852	610	1,462	13.19
34-A2	182	157	339	3.06
34-B1	461	293	754	6.80
34-B2	240	188	428	3.86
34-C1	2,443	2,073	4,516	40.73
34-C2	930	490	1,420	12.81
34-C3	1,499	670	2,169	19.56
Total	6,607	4,481	11,088	100.00

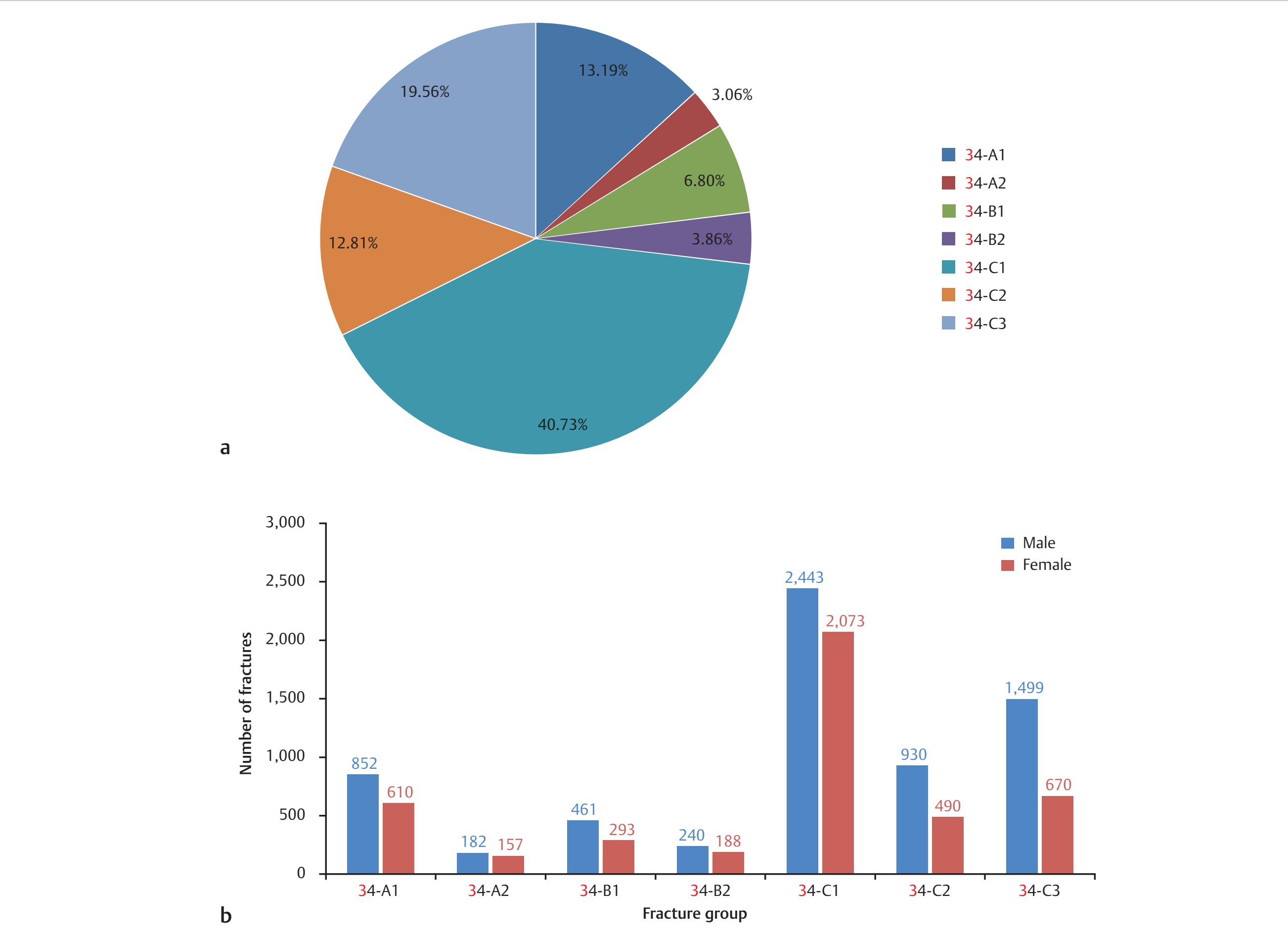
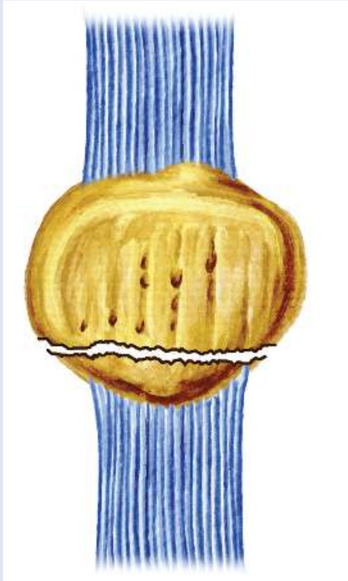


Fig. 10.12 (**a**) Fracture group distribution of 11,088 adult patellar fractures by Orthopaedic Trauma Association (OTA) classification. (**b**) Sex and fracture group distribution of 11,088 adult patellar fractures by OTA classification.

34-A Patella, extra-articular fractures

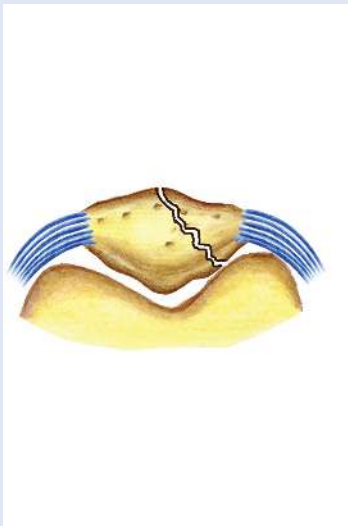
34-A1 Avulsion
1,462 fractures
M: 852 (58.28%)
F: 610 (41.72%)
0. 39% of total adult fractures
13.19% of adult patellar fractures
81.18% of adult type 34-A fractures

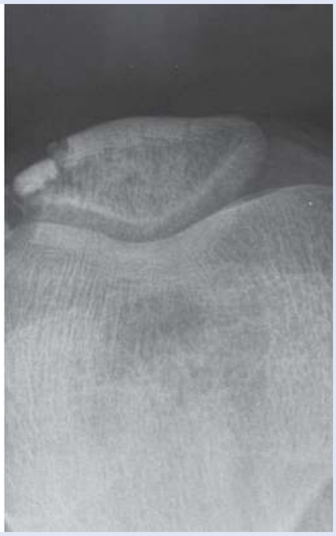
34-A1 Avulsion



34-A2 Isolated patellar body
339 fractures
M: 182 (53.69%)
F: 157 (46.31%)
0. 09% of total adult fractures
3.06% of adult patellar fractures
18.82% of adult type 34-A fractures

34-A2 Body fractures simple: axial view of patella





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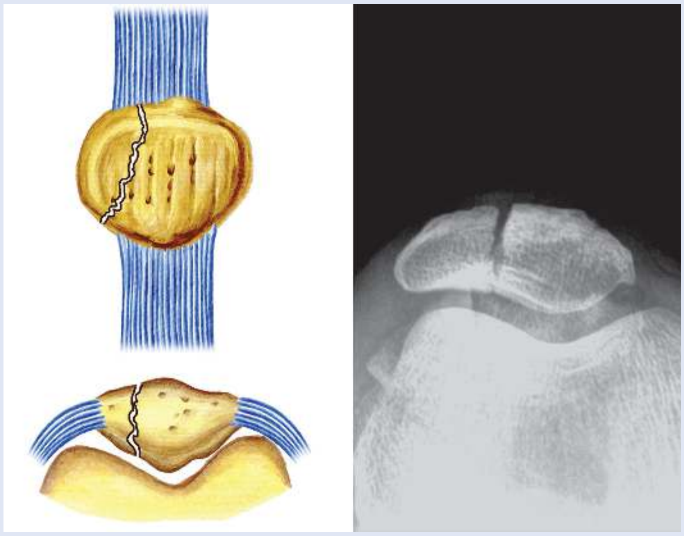
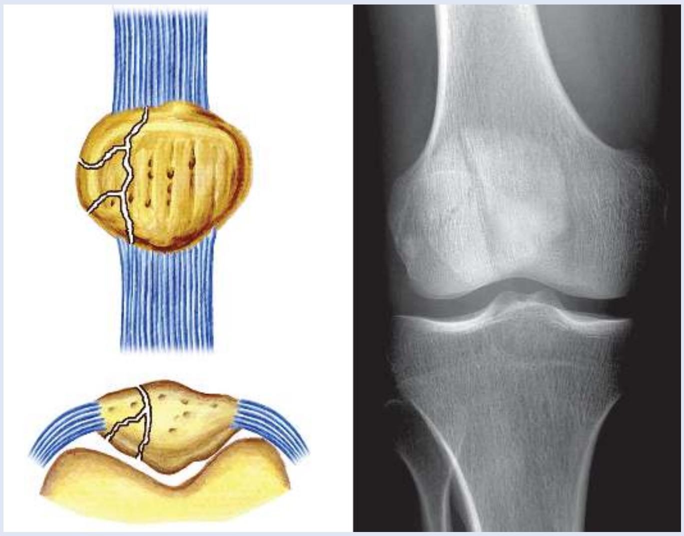
34-B Patella, partial articular fractures, vertical

34-B1 Lateral
754 fractures
M: 461 (61.14%)
F: 293 (38.86%)
0.20% of total adult fractures
6.80% of adult patellar fractures
63.79% of adult type 34-B fractures

34-B1.1 Simple: axial view of patella



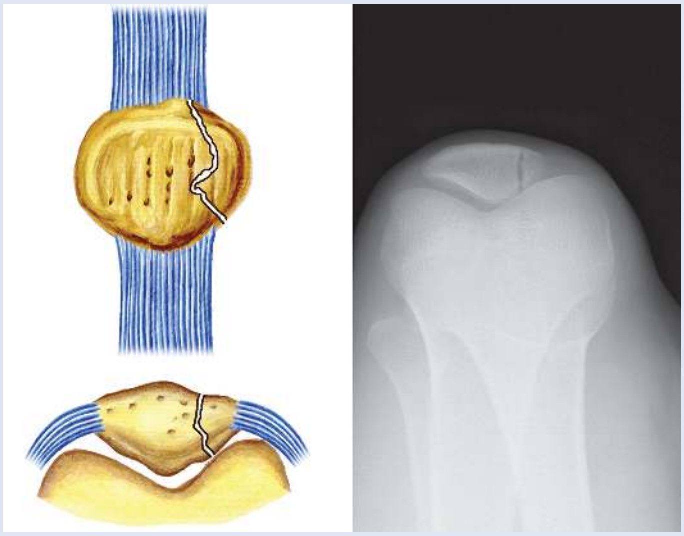
34-B1.2 Comminuted



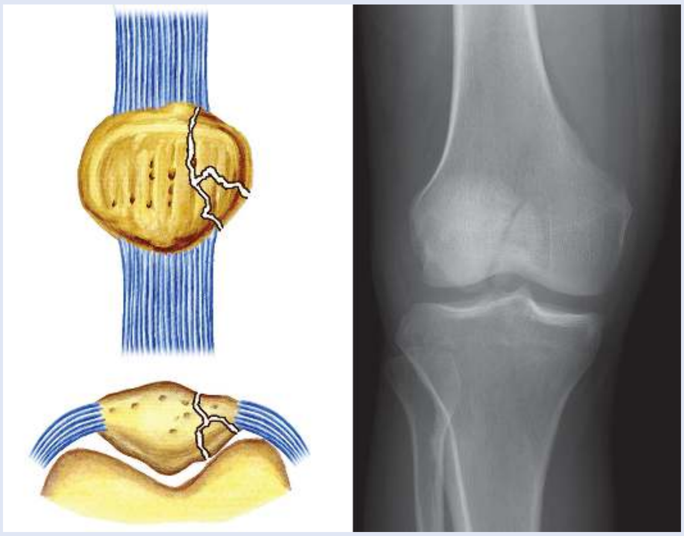
34-B Patella, partial articular fractures, vertical

34-B2 Medial
428 fractures
M: 240 (56.07%)
F: 188 (43.93%)
0.11% of total adult fractures
3.86% of adult patellar fractures
36.21% of adult type 34-B fractures

34-B2.1 Simple: axial view of patella



34-B2.2 Comminuted



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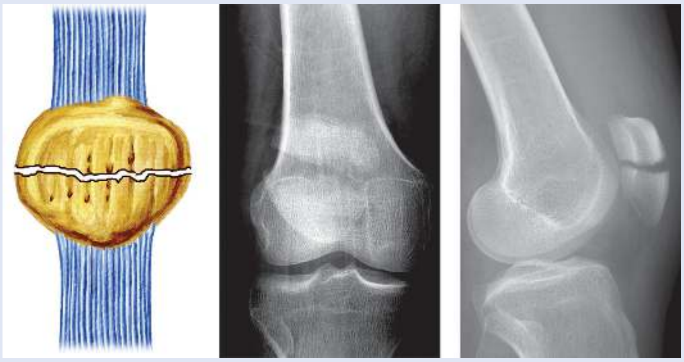
34-C Patella, complete articular fractures, nonvertical

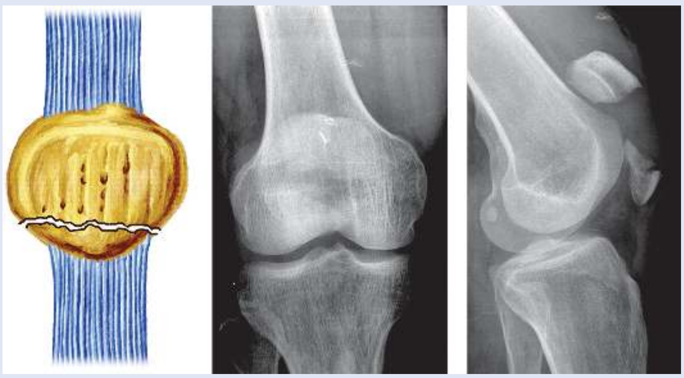
34-C1 Transverse, simple
4,516 fractures
M: 2,443 (54.10%)
F: 2,073 (45.90%)
1.21% of total adult fractures
40.73% of adult patellar fractures
55.72% of adult type 34-C fractures

34-C1.1 Middle



34-C1.2 Proximal

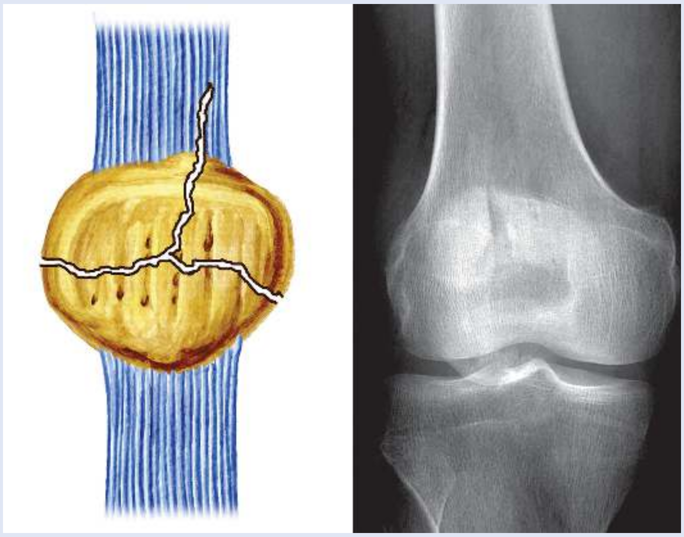
34-C1.3 Distal



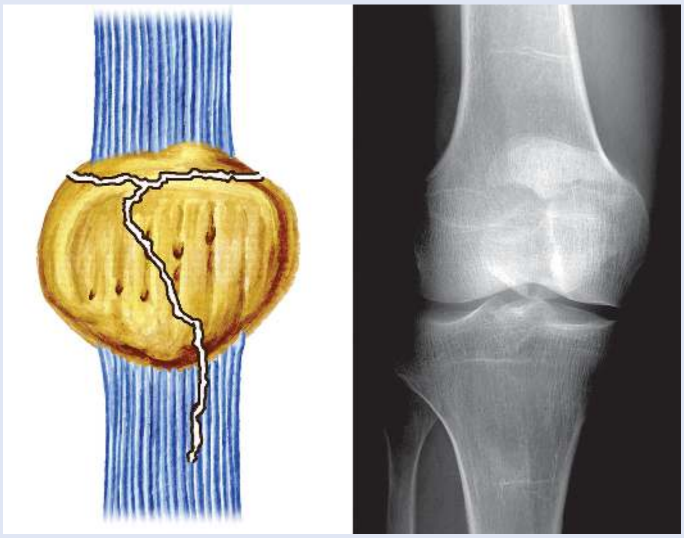
34-C Patella, complete articular fractures, nonvertical

34-C2 Transverse, fragmented (with three fragments)
1,420 fractures
M: 930 (65.49%)
F: 490 (34.51%)
0.38% of total adult fractures
12.81% of adult patellar fractures
17.52% of adult type 34-C fractures

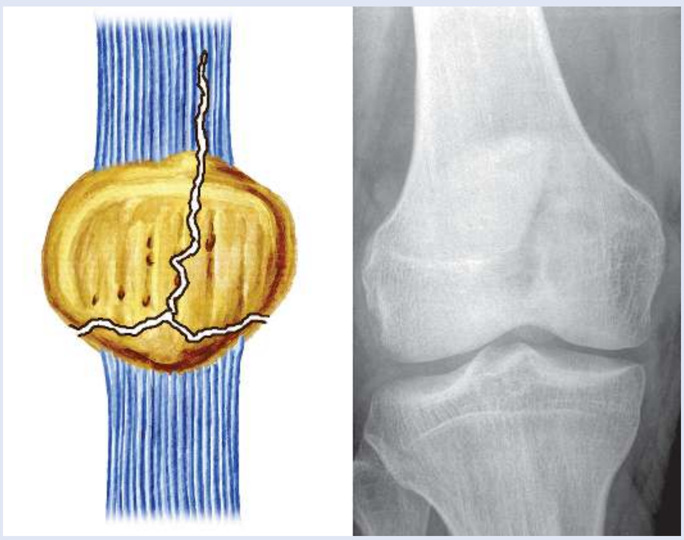
34-C2.1 Middle

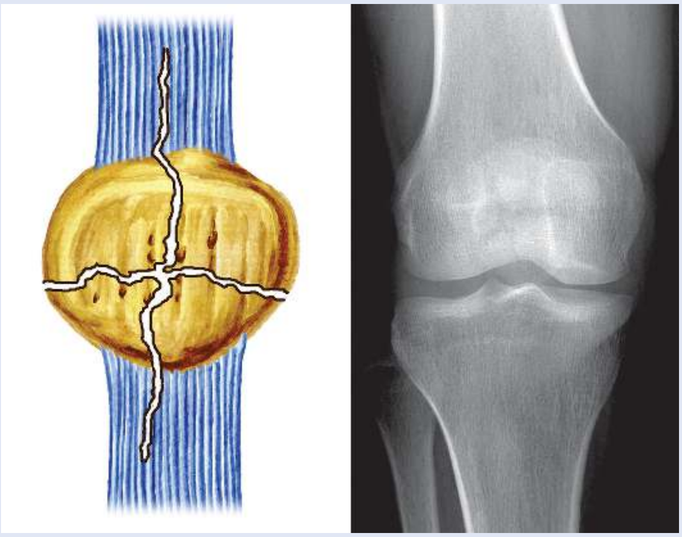
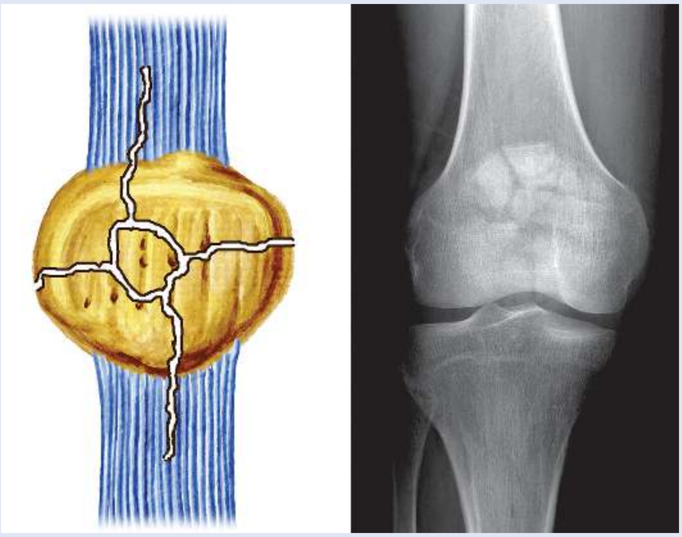


34-C2.2 Proximal



34-C2.3 Distal



34-C Patella, complete articular fractures, nonvertical	
34-C3 Comminuted (with > 3 fragments) 2,169 fractures M: 1,499 (69.11%) F: 670 (30.89%) 0.58% of total adult fractures 19.56% of adult patellar fractures 26.76% of adult type 34-C fractures	**34-C3.1** With 4 fragments  **34-C3.2** With > 4 fragments 

Injury Mechanism

Transverse fractures of the patella and avulsion fractures of the superior and inferior poles are often caused by indirect mechanisms, seen in hyperflexion of the knee due to sudden tensile force of the quadriceps. Comminuted, vertical, and oblique fractures are more clearly associated with direct mechanisms, such as from direct blows and crush injuries. The energy of the impacting force, which results in comminuted fractures of the patella, may also cause damage to the articular cartilage of both the patella and the femoral condyles.

Diagnosis

Patellar fractures usually present with a history of trauma. Physical examination reveals ecchymosis over the anterior aspect of the knee, hemarthrosis, swelling, tenderness, and partial to complete limitation of knee joint mobility. If fracture displacement is present, then a gap between fragments and retropatellar crepitus can be noted. Radiographs of anteroposterior (AP) and lateral views of the knee joint usually confirm the diagnosis. If vertical or border fractures are clinically suspected, an axial view or computed tomography (CT) scan of the knee joint may be indicated. Magnetic resonance imaging (MRI) is necessary for comminuted patellar fractures due to damage of the articular cartilage of both the patella and the femoral condyles. The diagnosis of a vertical fracture of the patella should be differentiated from that of a patellar variation. Vertical fractures present with a clear trauma history, positive physical examination findings, fracture lines, and a jagged surface of the broken ends: this is in contrast to variations of the patella (binary or trinary patella), which are known to have wide gaps, smooth broken ends, or mild to absent physical signs/syndrome. In addition, the thin layer of cortex may be exposed.

Treatment

If the fracture is displaced by less than 3 mm, or the intra-articular step-off is less than 2 mm, then the fracture may be treated with a nonoperative modality. However, for elderly patients, operative management with rigid internal fixation should be considered to allow early postoperative mobilization and to minimize knee fibro-adhesive scar formation. In young healthy patients, patellar fractures can be treated with immobilization followed by casting, external fixation devices, and tuck loop fixation, etc. Surgical treatment is advised for displaced fractures, which are defined as fractures that have an intra-articular step-off of more than 2 mm or a separation of more than 3 mm. Additional caution should be taken for pediatric patients with patellar fractures when considering an operative approach because operative procedures have the potential to damage growth cartilage, and subsequently impact the growth and development of the patella. Because children have a greater potential for tissue bone repair and molding, fractures with marked displacement, or even with a comminuted pattern, should initially be treated with nonoperative management. Partial surgical removal of the patella should be considered for severe comminuted fractures that are not able to be anatomically reduced. Severe comminuted patellar fractures in elderly patients should be treated with primary total surgical removal of the patella.

Further Classifications of Patellar Fractures: The Regazzoni Classification

Based on the fracture location, pattern, and presence of displacement, Regazzoni classified patellar fractures into three types, with three subgroups for each fracture type:

- *Type A*: Vertical fracture: A1, with no displacement; A2, with displacement; A3, comminuted.
- *Type B*: Transverse fracture: B1, avulsion fracture of the superior and inferior poles of the patella (< 5 mm in diameter of the superior pole, < 15 mm in diameter of the inferior pole); B2, simple; B3, comminuted.
- *Type C*: Comminuted fractures: C1, with no displacement; C2, with displacement of less than 2 mm; C3, burst fractures with displacement of more than 2 mm.

Clinical Epidemiologic Features of Patellar Fractures by the Regazzoni Classification

A total of 11,088 adult patellar fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011; all cases were reviewed and statistically studied. Their epidemiologic features are as follows:

- More males than females
- The most common fracture type was Type B (Transverse)

See ▶ Table 10.10 and ▶ Fig. 10.13.

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Table 10.10 Sex and fracture type distribution of 11,088 adult patellar fractures by Regazzoni classification

Fracture type	Male	Female	Number of fractures	Percentage
A	701	481	1,182	10.66
B	4,407	3,330	7,737	69.78
C	1,499	670	2,169	19.56
Total	6,607	4,481	11,088	100.00

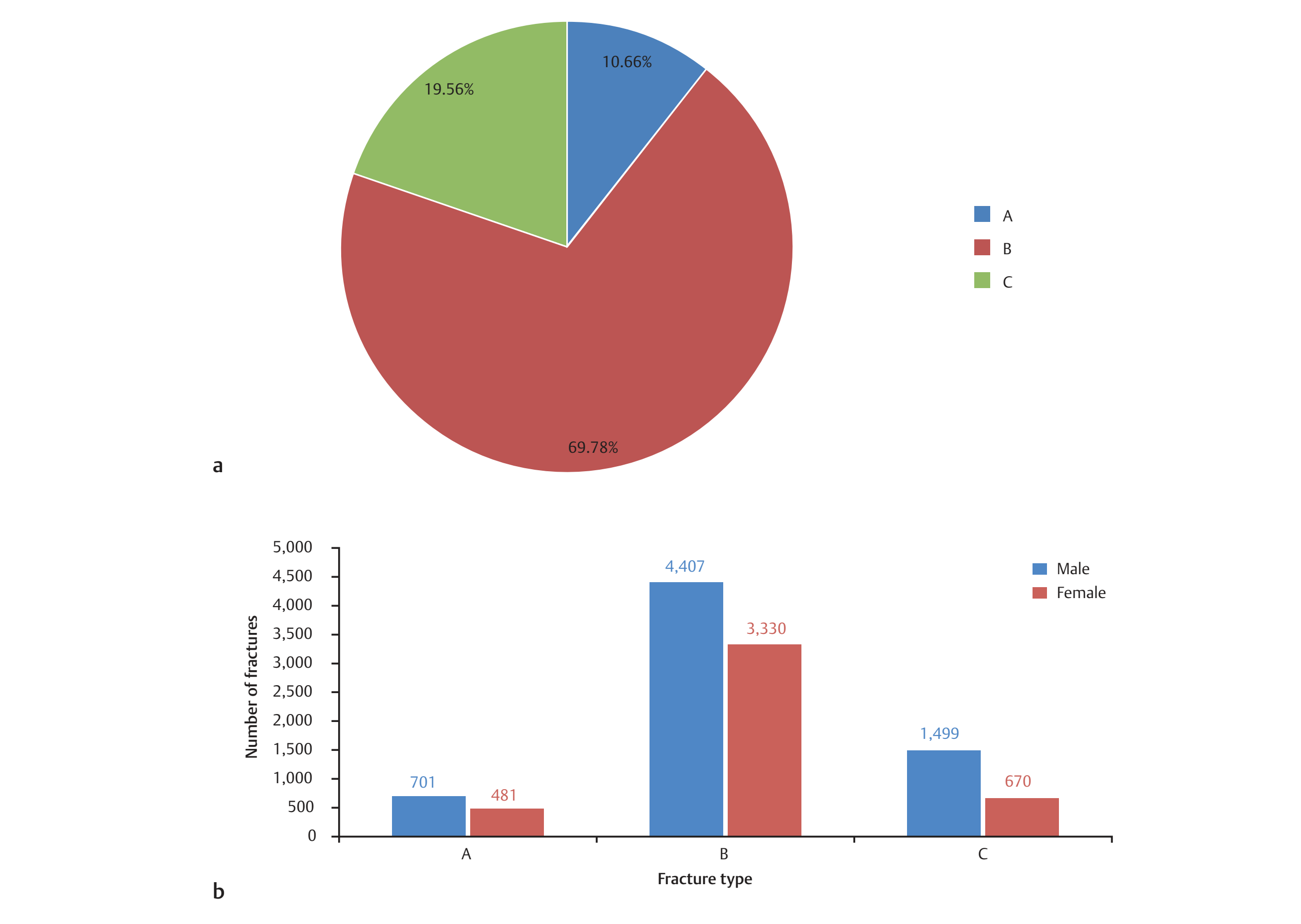
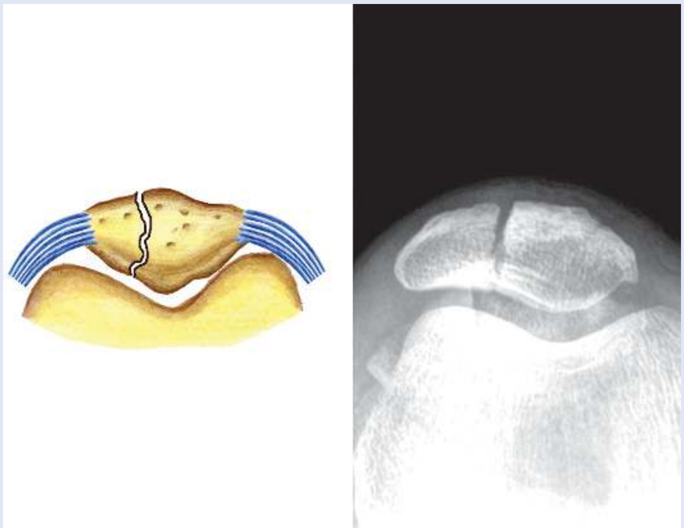


Fig. 10.13 (**a**) Fracture type distribution of 11,088 adult patellar fractures by Regazzoni classification. (**b**) Sex and fracture type distribution of 11,088 adult patellar fractures by Regazzoni classification.

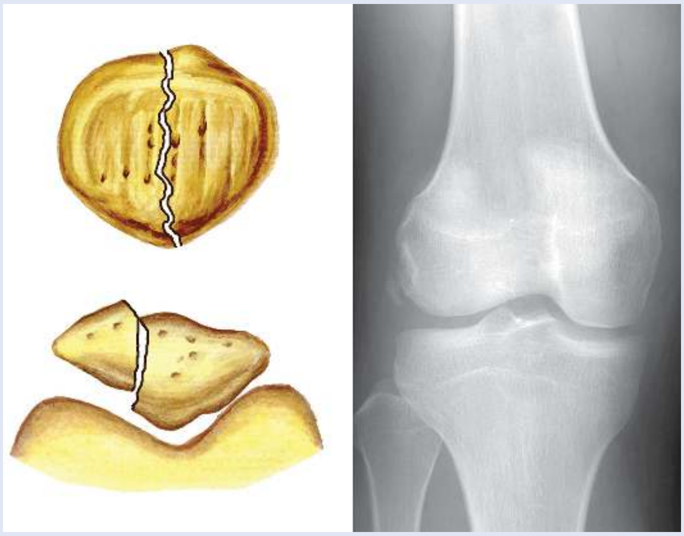
Regazzoni classification of patellar fractures

Type A Vertical
1,182 fractures
M: 701 (59.31%)
F: 481 (40.69%)
0.32% of total adult fractures
10.66% of adult patellar fractures

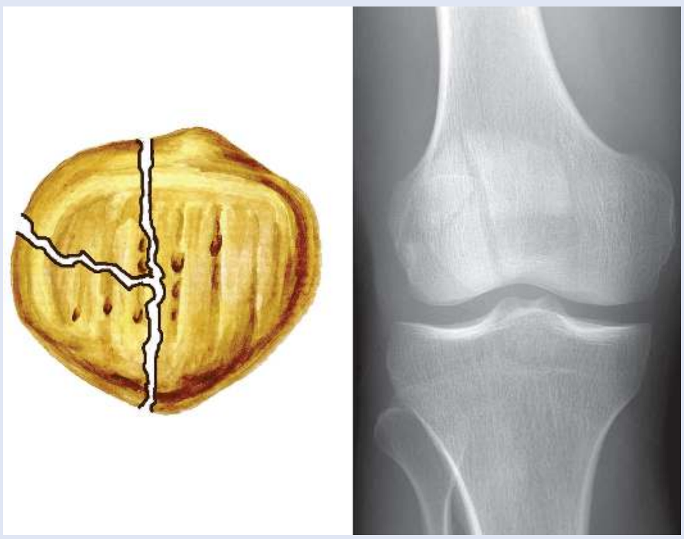
Regazzoni A1 Without displacement



Regazzoni A2 With displacement



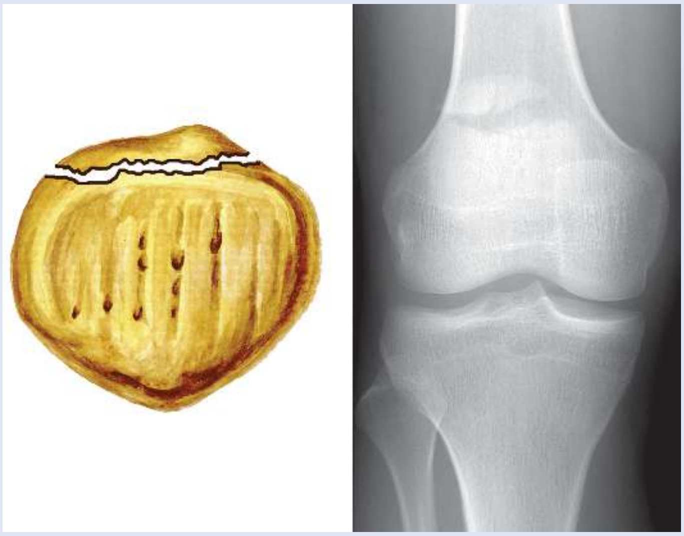
Regazzoni A3 Comminuted



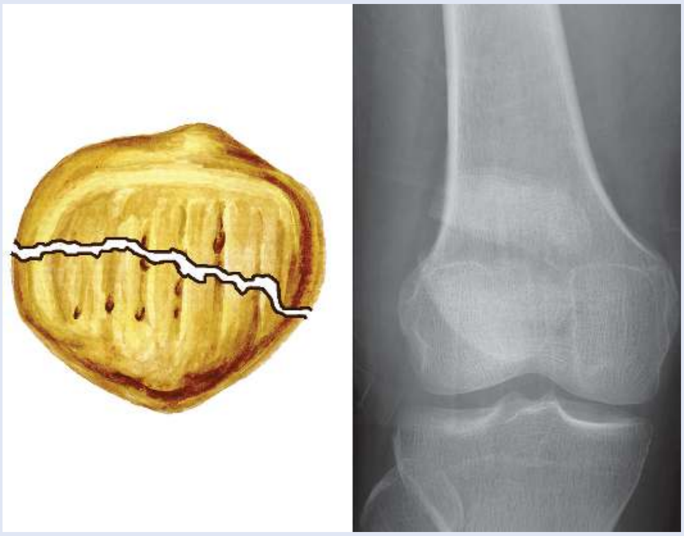
Regazzoni classification of patellar fractures

Type-B Transverse
7,737 fractures
M: 4,407 (56.96%)
F: 3,330 (43.04%)
2.07% of total adult fractures
69.78% of adult patellar fractures

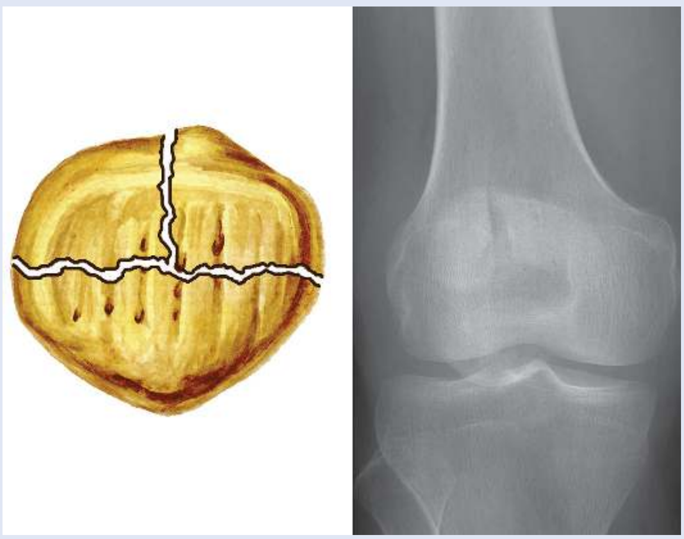
Regazzoni B1 Avulsion fracture of superior and inferior poles (< 5 mm in diameter of superior pole) (< 15 mm in diameter of inferior pole)

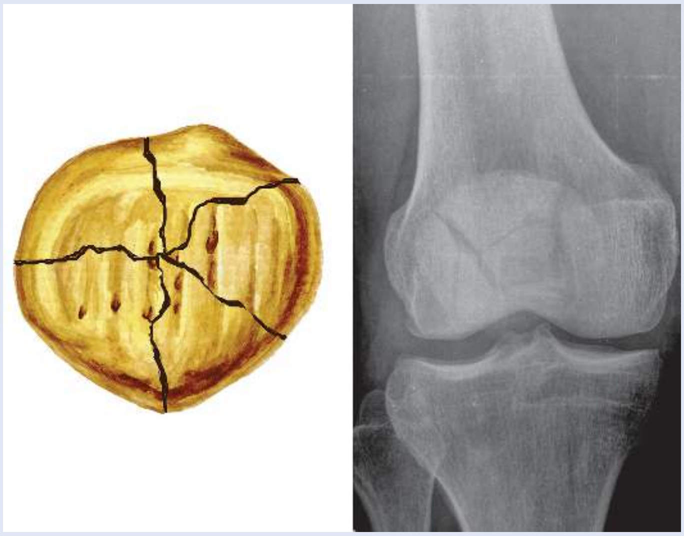
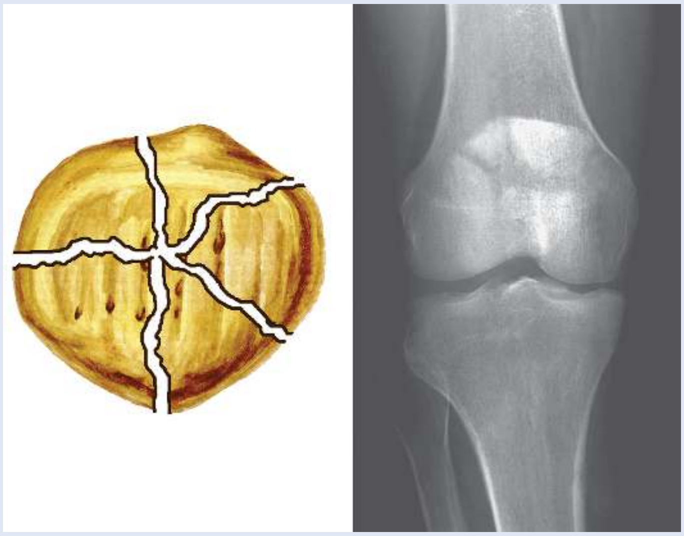
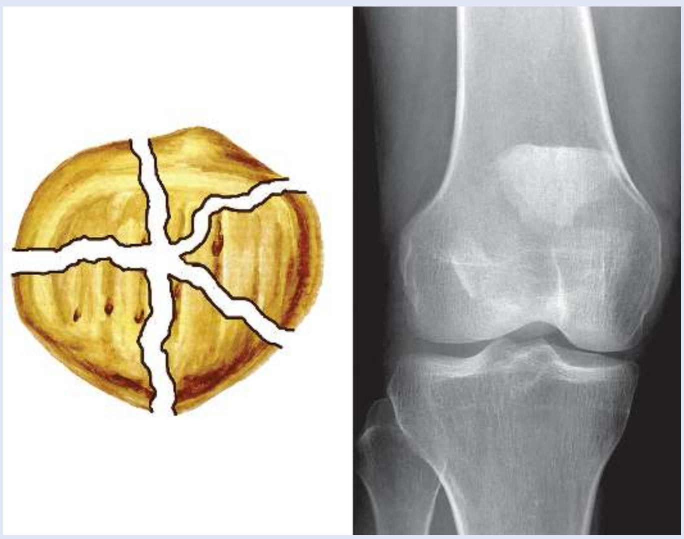


Regazzoni B2 Simple



Regazzoni B3 Comminuted



Regazzoni classification of patellar fractures	
Type C Comminuted fractures 2,169 fractures M: 1,499 (69.11%) F: 670 (30.89%) 0.58% of total adult fractures 19.56% of adult patellar fractures	**Regazzoni C1** Without marked displacement  **Regazzoni C2** With displacement of < 2 mm  **Regazzoni C3** Combined with burst fractures with displacement of > 2 mm 

10

Clavicle Fractures (Segment 15)

Anatomic Features

The clavicle forms the anterior portion of the shoulder girdle, and is placed nearly horizontally at the upper and anterior part of the thorax. It serves as the only direct bony attachment of the arm to the trunk. The clavicle is connected strongly to a number of muscles and accordingly to facets, most of which are essential for the stability of the shoulder girdle. It is a long bone, curved somewhat like the letter “S” in the superior view, but appears straight in the anterior view. The lateral third of the clavicle is flattened from above and downward, to accommodate the attachment and traction of muscles; furthermore, its middle third is tubular, and its medial third has a prismatic form to withstand the axial compression load and traction (▶ Fig. 10.14).

The lateral third of the clavicle provides attachment for the trapezius and deltoid muscles. On the posterior–superior border of the medial third is a rough area for attachment of the sternocleidomastoid muscle. The clavicular portion of the pectoralis major originates from the anterior surface of medial border of the medial third. The subclavius muscle originates from the inferior border of the middle third of the clavicle and inserts on the first rib, just dorsal to the subclavian surface (▶ Fig. 10.15).

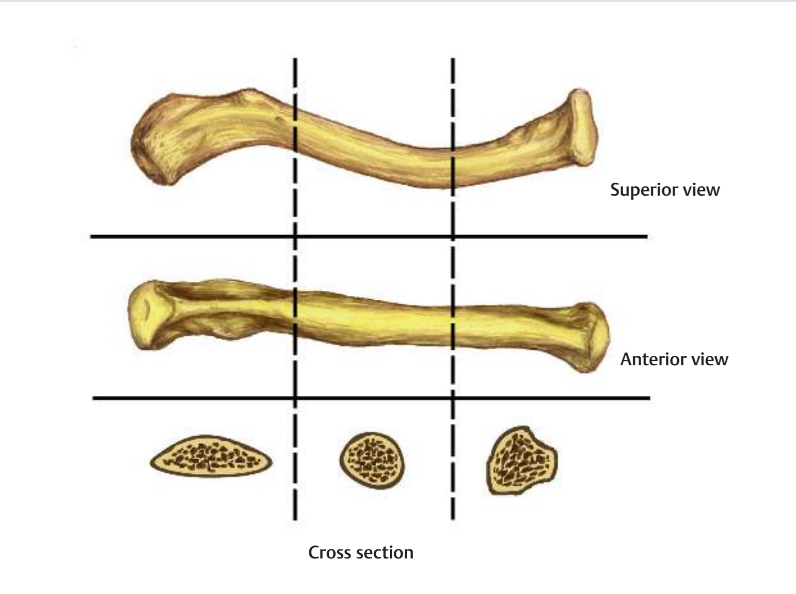


Fig. 10.14 The clavicle.

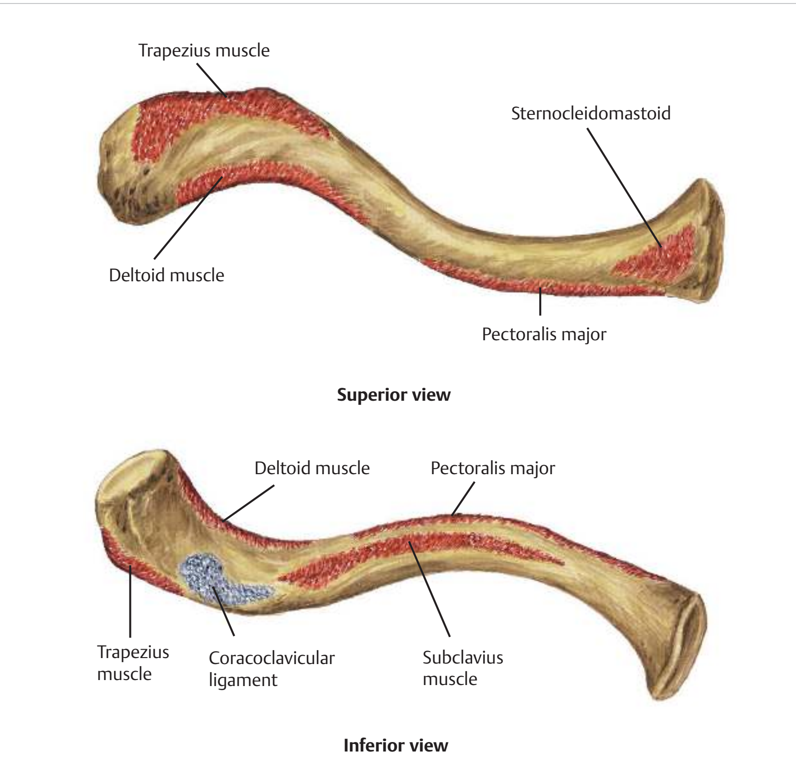


Fig. 10.15 Muscle attachments of the clavicle.

Anatomic Features and Muscular Attachment of the Clavicle

From an anatomic point of view, four factors that result in the displacement of clavicle fractures can be summarized as follows:

1. The proximal fragment is typically displaced upward because of the pull of the sternocleidomastoid muscle.
2. Although there may be some upward movement of the clavicle due to the pull of the trapezius muscle, the major displacement is caused by the downward pull of the upper extremity, since most patients would not be able to withstand the weight of the upper arm due to the pain.
3. However, if the upward pull of the trapezius muscle surpasses the weight of the upper arm, or patients are using a sling to support the arm, then the distal fragment may also be displaced upward.
4. The pull of the pectoralis major, pectoralis minor, and latissimus dorsi draw the distal fragment medially (▶ Fig. 10.16).

The clavicle articulates medially with the clavicular notch of the manubrium sterni, forming the sternoclavicular joint, which is supported by the anterior and posterior sternoclavicular and interclavicular ligaments. The lateral end of the clavicle articulates with the acromion of the scapula, forming the acromioclavicular joint, which is stabilized by the acromioclavicular, coracoacromial, and coracoclavicular ligaments; these three ligaments form the coracoacromial arch. The coracoclavicular ligament consists of two fasciculi, the trapezoid and conoid ligaments, which are attached between the coracoid process of the scapula and the underside of the clavicle; they primarily provide stabilization to the acromioclavicular joint and prevent superior dislocation of the shoulder joint (▶ Fig. 10.17).

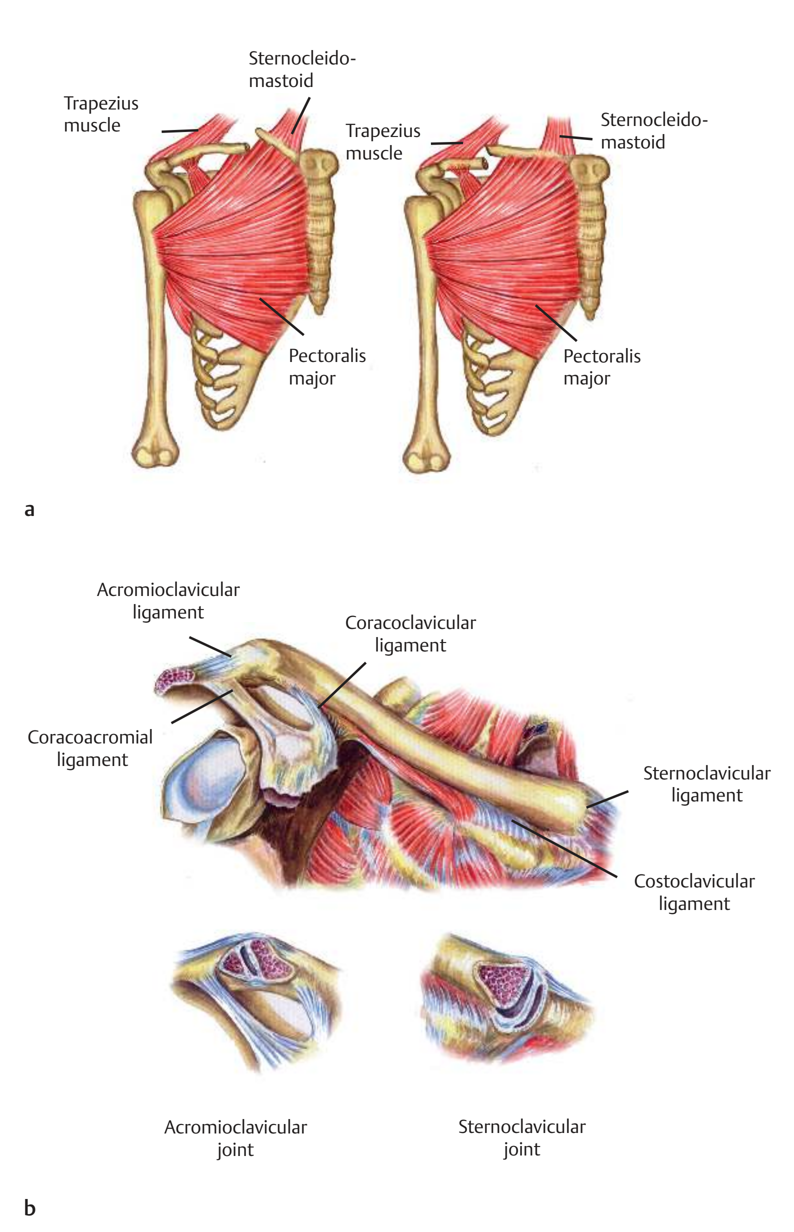


Fig. 10.16 (**a**) Fracture displacement of the clavicle. (**b**) Joint and ligaments of the clavicle.

OTA Classification and Coding System for Clavicle Fractures

Based on OTA classification, the clavicle is coded as number "15" for its anatomic location, and is divided into three segments according to the Heim Square method: proximal, shaft, and distal. The OTA classification of clavicle fractures is as shown in ▶ Fig. 10.18.

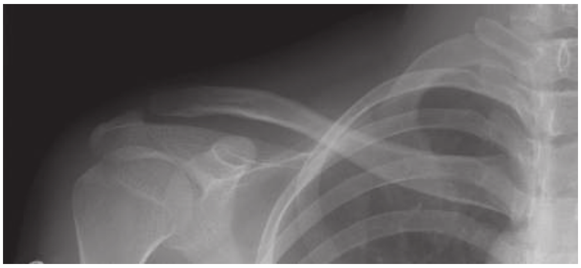


Fig. 10.17 Radiograph of the clavicle.

Epidemiologic Features of Clavicle Fractures in the China National Fracture Study

A total of 89 patients with 89 clavicle fractures were investigated in the CNFS. The fractures accounted for 5.05% of all patients with fractures and 4.86% of all types of fractures. The population-weighted incidence rate of clavicle fractures was 16 per 100,000 population in 2014.

The epidemiologic features of clavicle fractures in the CNFS are as follows:

- More males than females
- More left-side injuries than right-side injuries
- The highest-risk age group is 15–64 years
- Injuries occurred most commonly via slips, trips, or falls and traffic accident

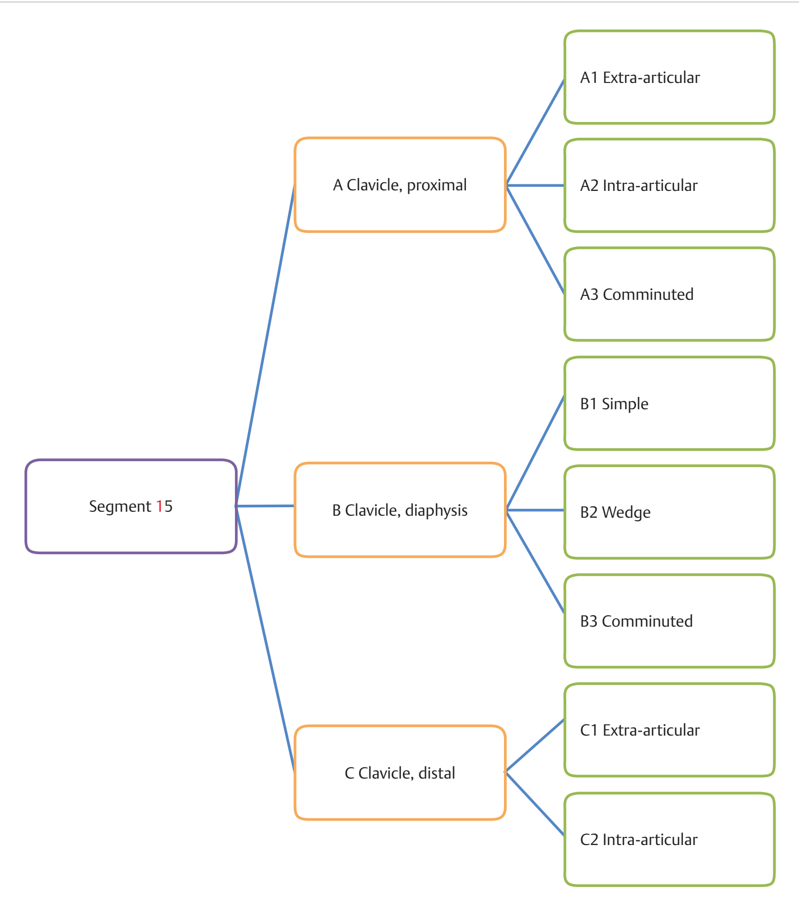


Fig. 10.18 Algorithm.

■ Clavicle Fracture by Sex

See ▶ Table 10.11 and ▶ Fig. 10.19.

Table 10.11 Sex distribution of 89 patients with clavicle fractures in CNFS

Sex	Number of patients	Percentage
Male	57	64.04
Female	32	35.96
Total	89	100.00

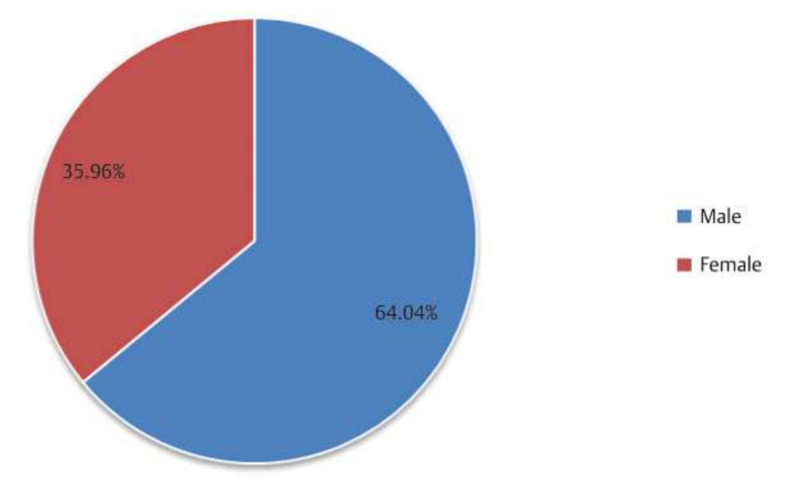


Fig. 10.19 Sex distribution of 89 patients with clavicle fractures in China National Fracture Study (CNFS).

■ Clavicle Fracture by Injury Side in CNFS

See ▶ Table 10.12 and ▶ Fig. 10.20.

Table 10.12 Injury side distribution of 89 patients with clavicle fractures in CNFS

Injured side	Number of patients	Percentage
Left	45	50.56
Right	44	49.44
Total	89	100.00

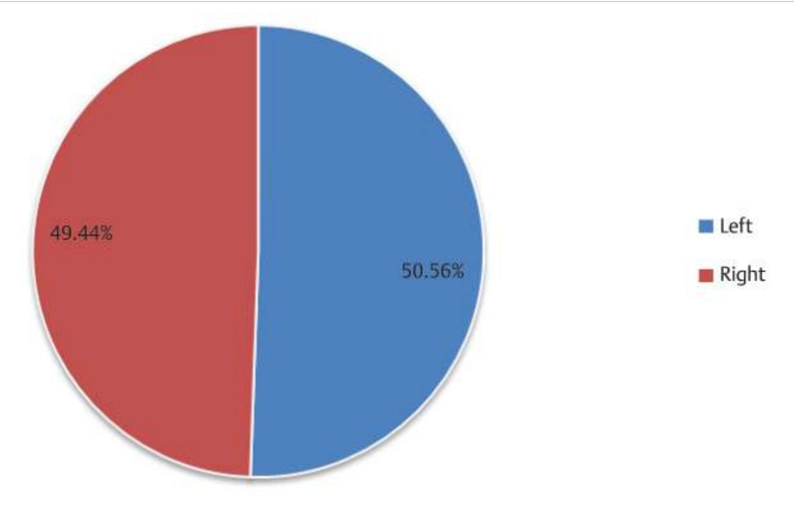


Fig. 10.20 Injury side distribution of 89 patients with clavicle fractures in China National Fracture Study (CNFS).

■ Clavicle Fracture by Age Group and Sex in CNFS

See ▶ Table 10.13 and ▶ Fig. 10.21.

Table 10.13 Age and sex distribution of 89 patients with clavicle fractures in CNFS

Age group (years)	Male	Female	Total	Percentage
0–14	2	2	4	4.49
15–64	52	26	78	87.64
≥ 65	3	4	7	7.87
Total	57	32	89	100.00

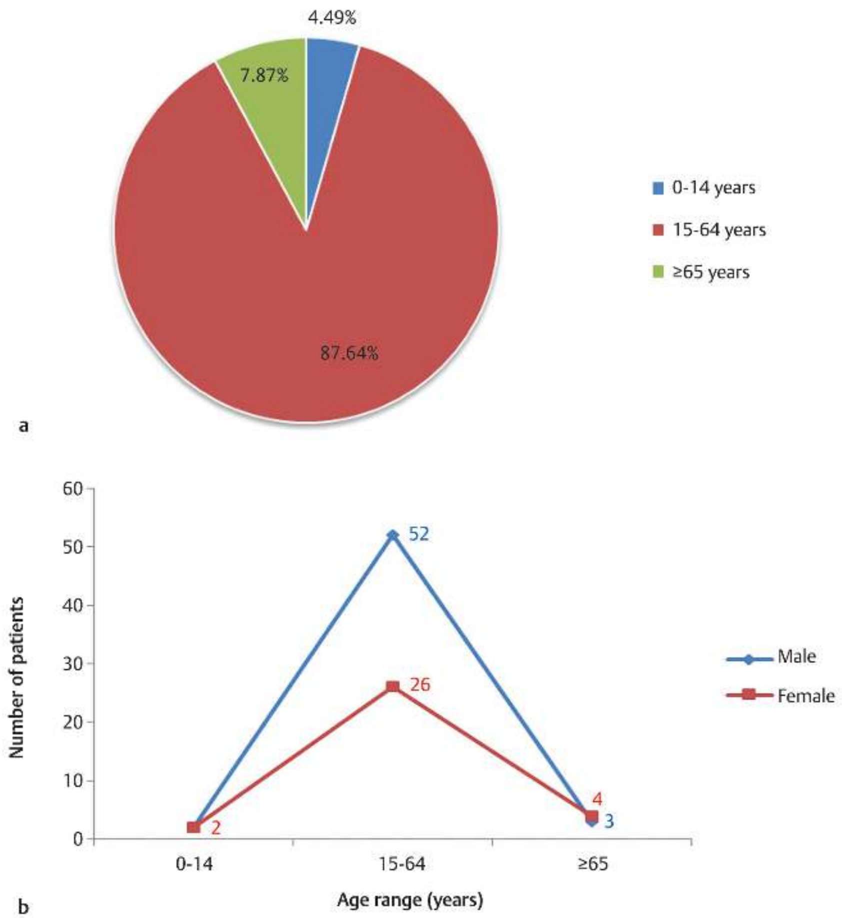


Fig. 10.21 (**a**) Age distribution of 89 patients with clavicle fractures in China National Fracture Study (CNFS). (**b**) Age and sex distribution of 89 patients with clavicle fractures in CNFS.

Clavicle Fracture by Causal Mechanisms in CNFS

See ▶ Table 10.14 and ▶ Fig. 10.22.

Table 10.14 Causal mechanisms distribution of 89 patients with clavicle fractures in CNFS

Causal mechanisms	Male	Female	Total	Percentage
Traffic accident	25	12	37	41.57
Slip, trip, or fall	27	17	44	49.44
Fall from heights	3	1	4	4.49
Crushing injury	2	2	4	4.49
Total	57	32	89	100.00

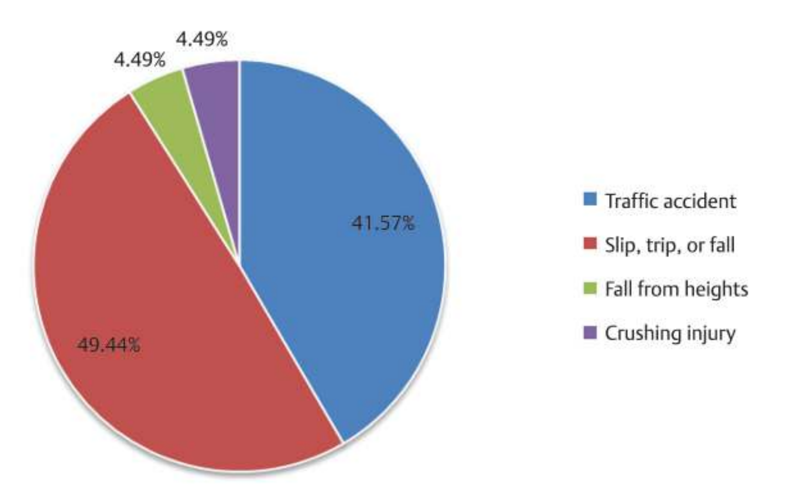


Fig. 10.22 Causal mechanisms distribution of 89 patients with clavicle fractures in China National Fracture Study (CNFS).

Clinical Epidemiologic Features of Clavicle Fractures (Segment 15)

A total of 18,502 patients with 18,587 clavicle fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied, accounting for 4.46% of all patients with fractures and 4.30% of all kinds of fractures, respectively. Among 18,502 patients, there were 4,424 pediatric patients (4,430 clavicle fractures) and 14,078 adult patients with 14,157 clavicle fractures.

Epidemiologic features of clavicle fractures are as follows:

- More males than females
- More left side than right side fractures
- The high-risk age group is 0–5 years, the same age group for females, while for males the high-risk age group is 41–50 years
- The most common fracture type is Type B

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Clavicle Fractures by Sex

See ▶ Table 10.15 and ▶ Fig. 10.23.

Table 10.15 Sex distribution of 18,502 patients with clavicle fractures

Sex	Number of patients	Percentage
Male	12,827	69.33
Female	5,675	30.67
Total	18,502	100.00

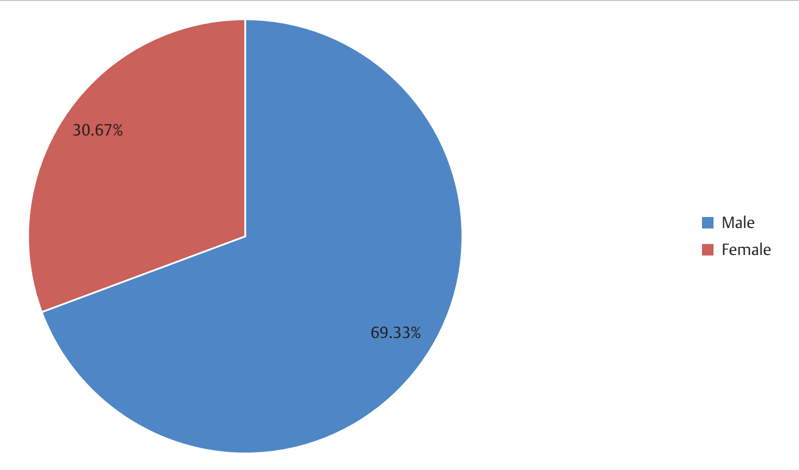

Fig. 10.23 Sex distribution of 18,502 patients with clavicle fractures.

Clavicle Fractures by Fracture Side

See ▶ Table 10.16 and ▶ Fig. 10.24.

Table 10.16 Fracture side distribution of 18,502 patients with clavicle fractures

Fracture side	Number of patients	Percentage
Left	10,100	54.59
Right	8,317	44.95
Bilateral	85	0.46
Total	18,502	100.00

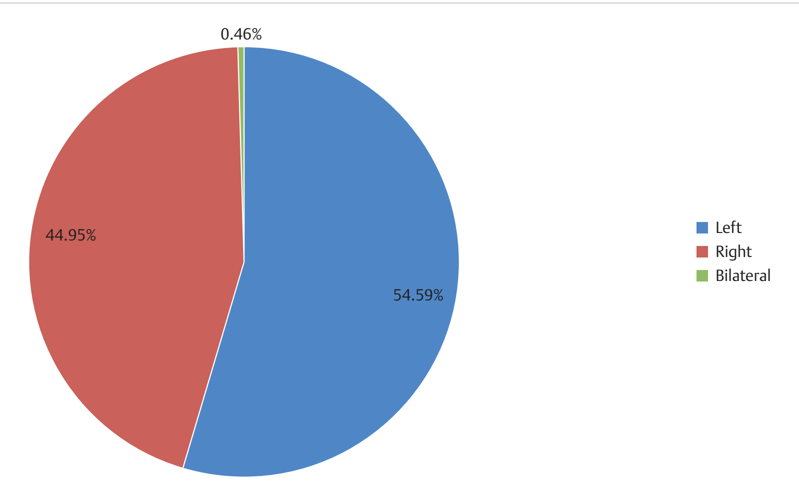

Fig. 10.24 Fracture side distribution of 18,502 patients with clavicle fractures.

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Clavicle Fractures by Age Group

See ▶ Table 10.17 and ▶ Fig. 10.25.

Table 10.17 Age and sex distribution of 18,502 patients with clavicle fractures

Age group (years)	Male	Female	Number of patients	Percentage
0–5	1,183	883	2,066	11.17
6–10	869	407	1,276	6.90
11–15	804	278	1,082	5.85
16–20	760	250	1,010	5.46
21–25	892	352	1,244	6.72
26–30	913	320	1,233	6.66
31–35	978	351	1,329	7.18
36–40	1,093	376	1,469	7.94
41–45	1,396	381	1,777	9.60
46–50	1,224	362	1,586	8.57
51–55	908	379	1,287	6.96
56–60	776	392	1,168	6.31
61–65	381	333	714	3.86
66–70	235	216	451	2.44
71–75	164	169	333	1.80
76–80	122	114	236	1.28
81–85	78	68	146	0.79
≥ 86	51	44	95	0.51
Total	12,827	5,675	18,502	100.00

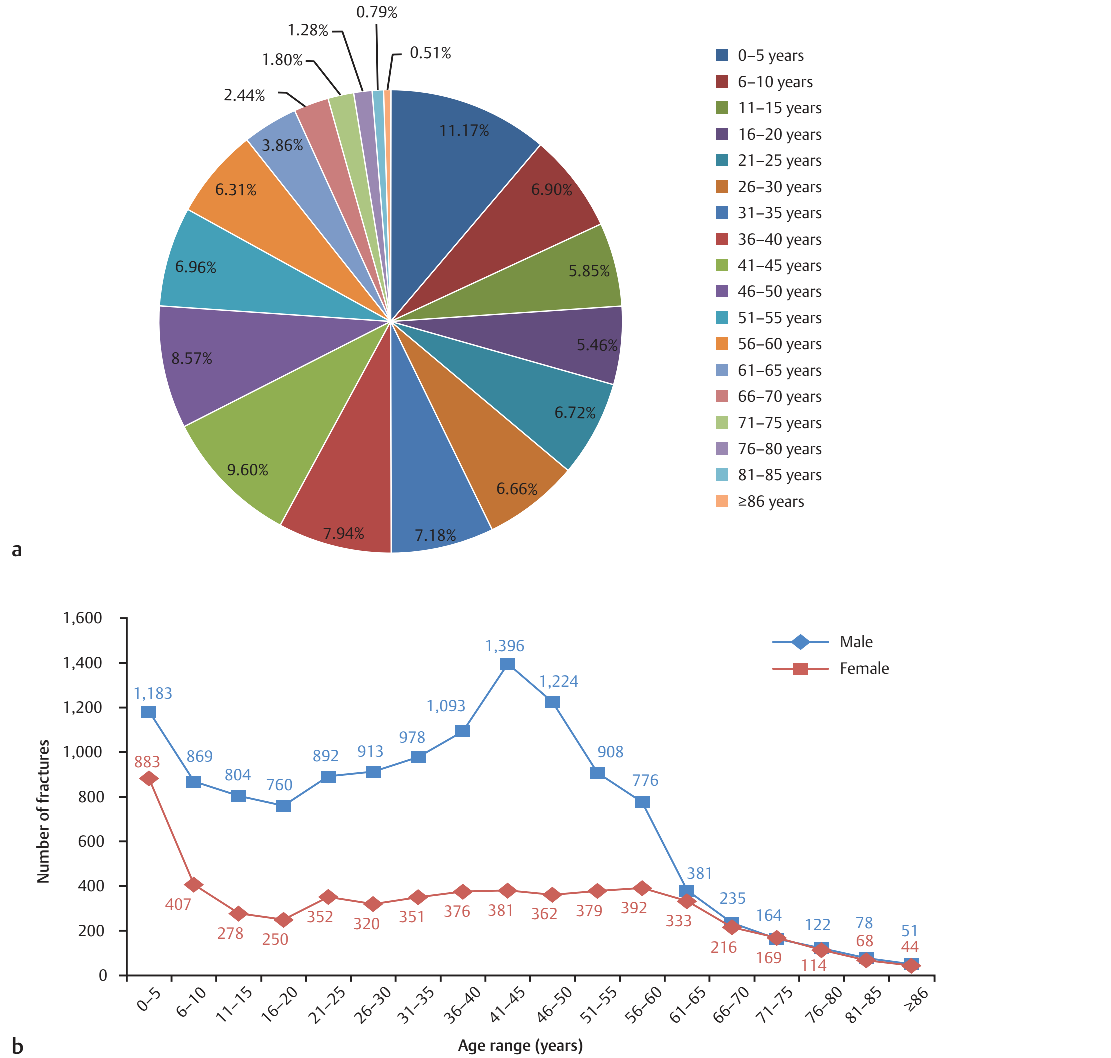


Fig. 10.25 (**a**) Age distribution of 18,502 patients with clavicle fractures. (**b**) Age and sex distribution of 18,502 patients with clavicle fractures.

10

■ Clavicle Fractures by Fracture Type Based on OTA Classification

See ▶ Table 10.18 and ▶ Fig. 10.26.

Table 10.18 Sex and fracture type distribution of 14,157 clavicle fractures by OTA classification

Fracture type	Male	Female	Number of fractures	Percentage
15-A	183	60	243	1.72
15-B	7,472	2,835	10,307	72.80
15-C	2,370	1,237	3,607	25.48
Total	10,025	4,132	14,157	100.00

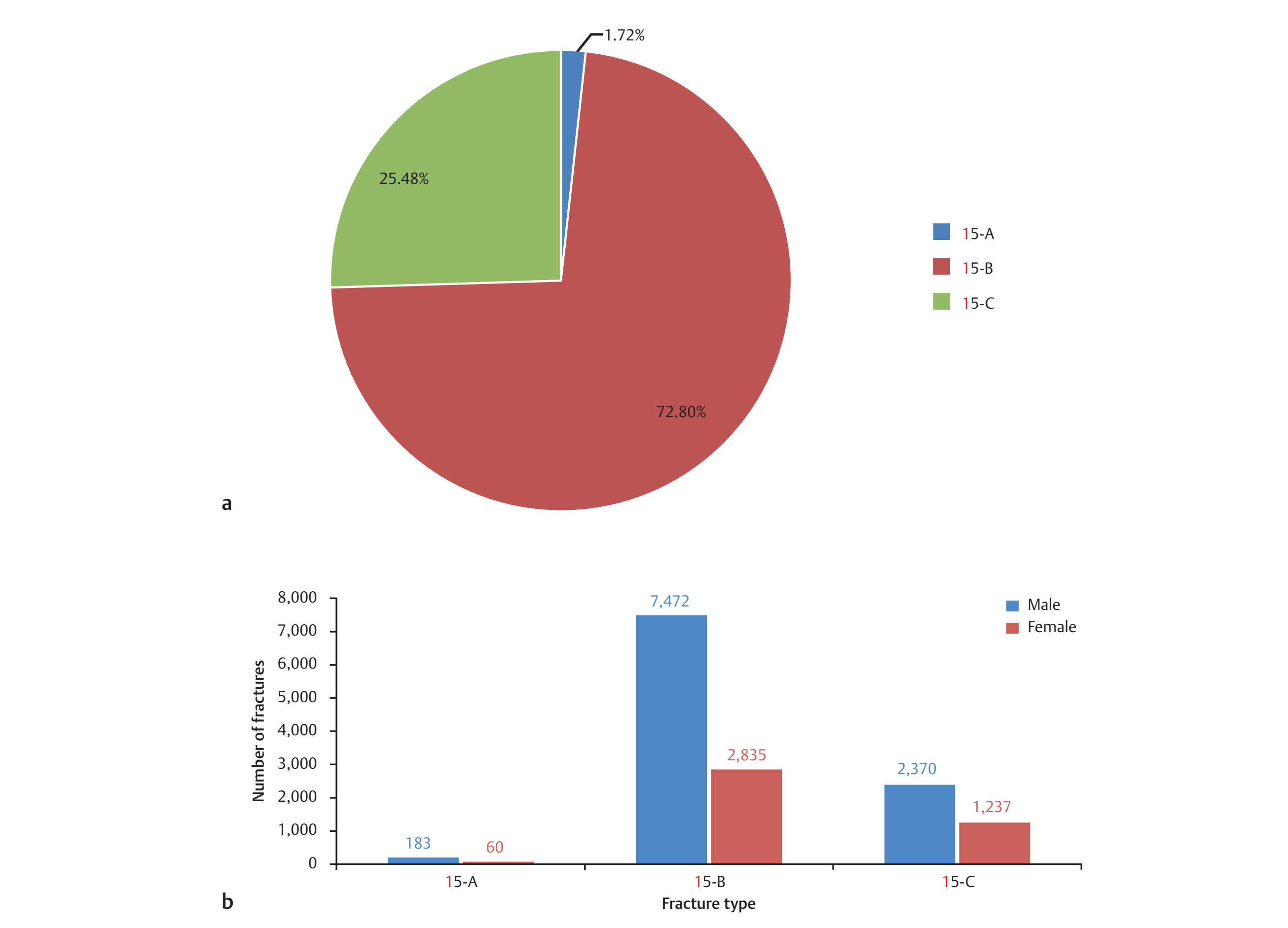
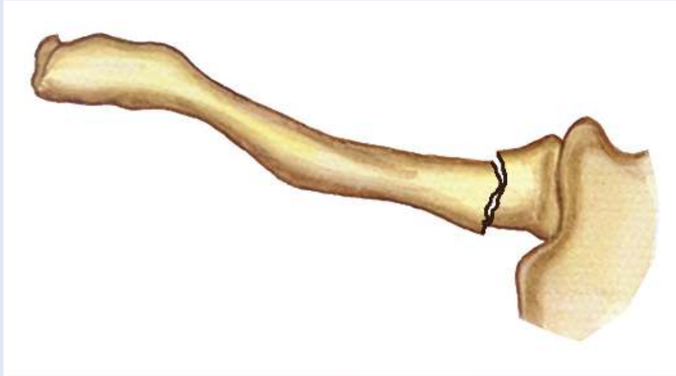
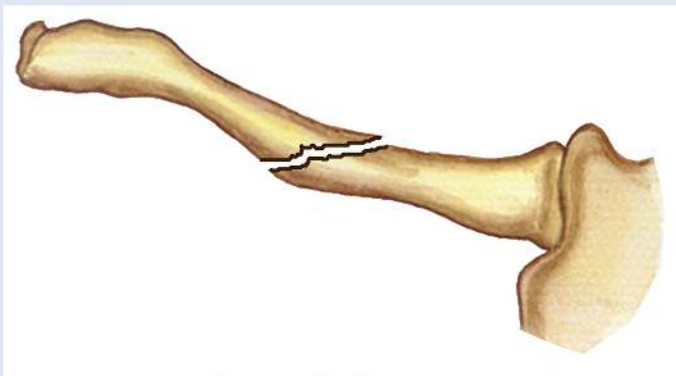


Fig. 10.26 (a) Fracture type distribution of 14,157 clavicle fractures by Orthopaedic Trauma Association (OTA) classification. (b) Sex and fracture type distribution of 14,157 adult clavicle fractures by OTA classification.

10

OTA classification of clavicle fractures	
15-A Proximal 243 fractures M: 183 (75.31%) F: 60 (24.69%) 1.72% of adult clavicle fractures 0.06% of total adult fractures	**15-A** (15-A1 Extra-articular; 15-A2 Intra-articular; 15-A3 Comminuted)  
15-B Diaphysis 10,307 fractures M: 7,472 (72.49%) F: 2,835 (27.51%) 72.80% of adult clavicle fractures 2.75% of total adult fractures	**15-B1** Simple  

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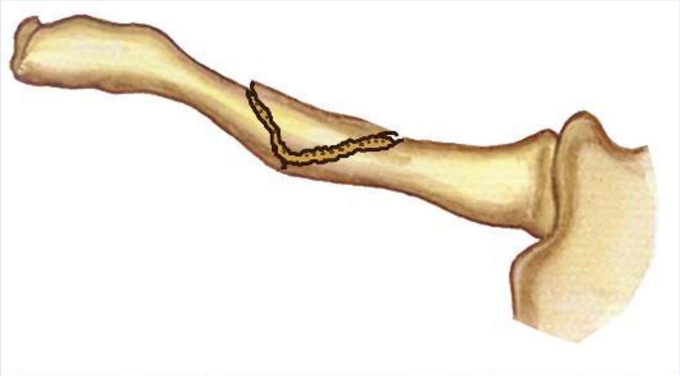
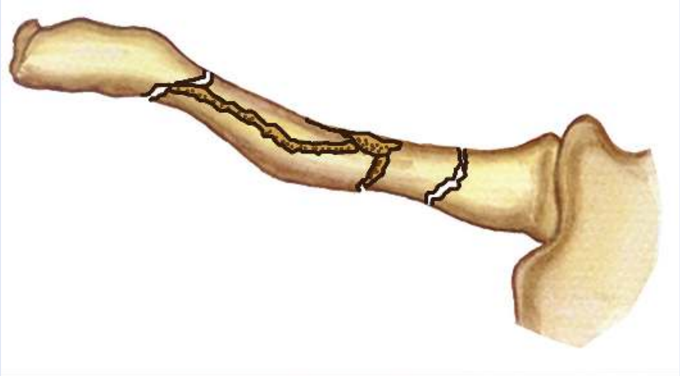
OTA classification of clavicle fractures	
	15-B2 Wedge



15-B3 Comminuted



OTA classification of clavicle fractures

15-C Distal
3,607 fractures
M: 2,370 (65.71%)
F: 1,237 (34.29%)
25.48% of adult clavicle fractures
0.96% of total adult fractures

15-C1 Extra-articular

15-C2 Intra-articular

Injury Mechanism

Clavicle fractures in adults and youths usually occur as a result of a direct force from high-energy trauma. In children and elderly patients, indirect trauma with a low force of energy is the common mechanism. The most common mechanism of injury is a fall onto the shoulder or onto an outstretched hand, whereby the force of the fall is transmitted up the arm through the shoulder to the clavicle.

Diagnosis

Adult patients with clavicle fractures will present with obvious swelling and deformity along the clavicle. Fractures without displacement, commonly seen in pediatric patients, usually do not present obvious deformity. Physicians should perform visual examination and palpation along the clavicle to determine the fracture line. Patients typically present with the following signs: worsening loss of shoulder mobility, actively supporting the elbow and forearm with the opposite hand, and tilting of one's head to the affected side.

A standard AP view of the clavicle usually confirms the diagnosis of a fracture. X-rays should include the acromioclavicular and sternoclavicular joints to rule out any associated injury of adjacent structures. Surrounding structures such as the scapula and ribs should be inspected for injury as well. In addition, an oblique view of the clavicle is helpful in defining the direction and degree of the displacement. The apical lordotic view (an AP view with the tube tilted 45 degrees cephalad) can minimize overlap of the thoracic structures and allow for better assessment of the clavicle fracture.

Treatment

If the fracture is displaced, then an operative approach may be the best choice. There are several indications for operative management of clavicle fractures:

- Fracture of the lateral clavicle with associated torn coracoclavicular ligaments
- Gross displacement and angulation of the fracture with tenting of skin
- Comminuted fracture of the middle third or if there is marked displacement
- Injury to the brachial plexus or subclavian artery by a fragment of bone following fracture of the clavicle
- Patients unable to withstand long periods of immobilization
- Open clavicle fractures
- Occurring concurrently with multiple associated injuries
- Nonunion of clavicle fractures
- For cosmetic purposes
- Incarceration of soft tissue between widely spaced fragments
- Posterior displacement of the proximal fragment to the sternum, and difficultly reducing and maintaining the reduction

The operative approach is best among minimally invasive methods, especially when treating female patients. The forms of available internal fixation for clavicle fractures are plate, screw, IM nail, memory alloy internal fixation, tension band, and Kirschner wire (K-wire).

Nondisplaced clavicle fractures can be treated nonsurgically. A "figure-of-eight" bandage and cast, clavicle strap, or simple sling can provide comfort and immobilization.

Further Classifications of Clavicle Fractures

The Allman Classification of Clavicle Fractures

Based on the Allman classification, the clavicle fractures are divided into three types: middle third injuries (Allman I), lateral third injuries (Allman II), and medial third injuries (Allman III). Each group is further divided into two subgroups (▶ Fig. 10.27): (a) those with no displacement and (b) those with displacement. The middle third group has an additional subgroup, (c) comminuted fractures. The Allman classification is the most common classification system for clavicle fractures (▶ Fig. 10.28).

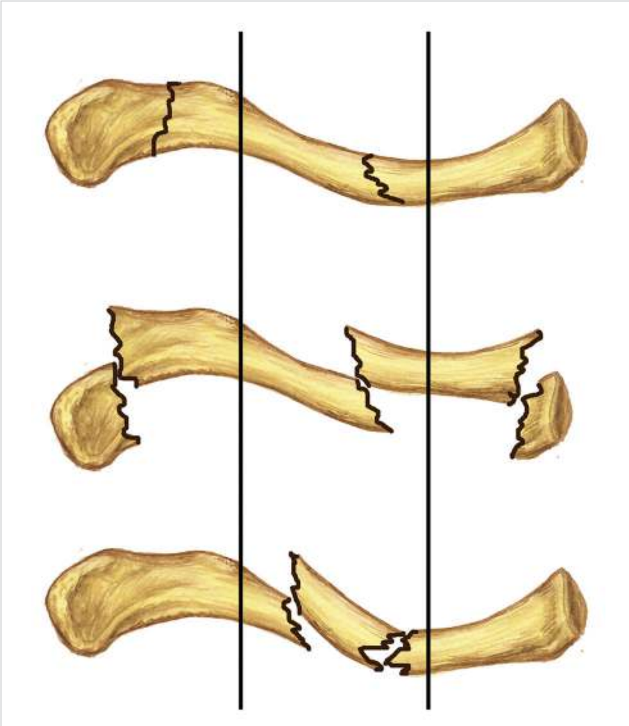


Fig. 10.27 The Allman classification of clavicle fractures.

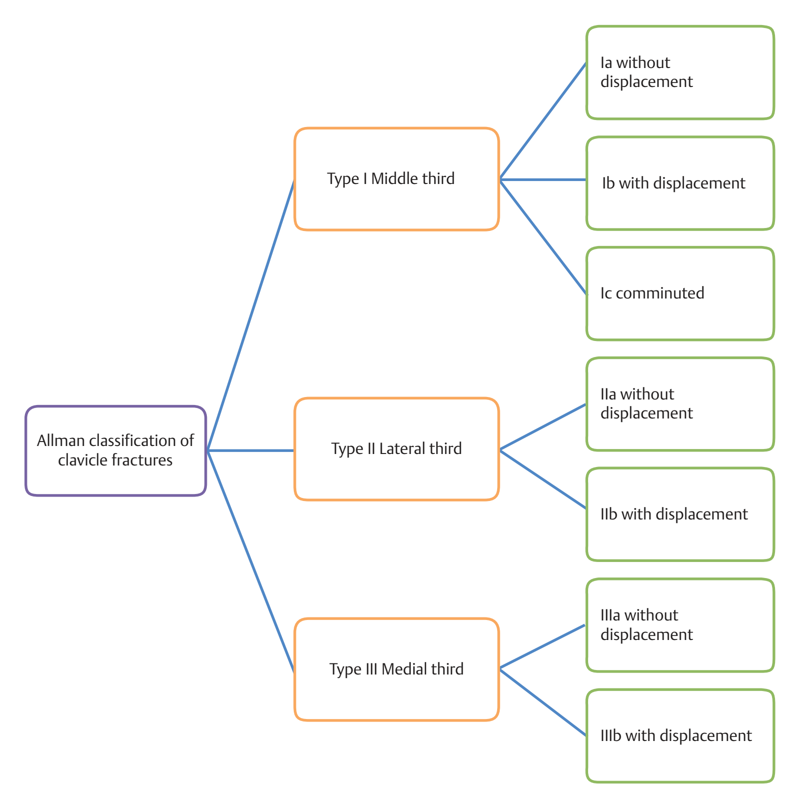


Fig. 10.28 Algorithm.

Clinical Epidemiologic Features of Clavicle Fractures by the Allman Classification

A total of 14,157 clavicle fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011; all cases were reviewed and statistically studied. Their epidemiologic features are as follows:

- More males than females
- The most common fracture type is Type I, while Type Ib is the most common subgroup

See ▶ Table 10.19, ▶ Table 10.20, ▶ Fig. 10.29, and ▶ Fig. 10.30.

Table 10.19 Sex and fracture type distribution of 14,157 clavicle fractures by Allman classification

Fracture type	Male	Female	Number of fractures	Percentage
I	7,403	2,801	10,204	72.08
II	2,308	1,178	3,486	24.62
III	314	153	467	3.30
Total	10,025	4,132	14,157	100.00

Table 10.20 Sex and fracture subtype distribution of 14,157 clavicle fractures by Allman classification

Fracture type	Male	Female	Number of fractures	Percentage
Ia	1,885	758	2,643	18.67
Ib	3,302	1,259	4,561	32.22
Ic	2,216	784	3,000	21.19
IIa	1,103	572	1,675	11.83
IIb	1,205	606	1,811	12.79
IIIa	186	102	288	2.03
IIIb	128	51	179	1.26
Total	10,025	4,132	14,157	100.00

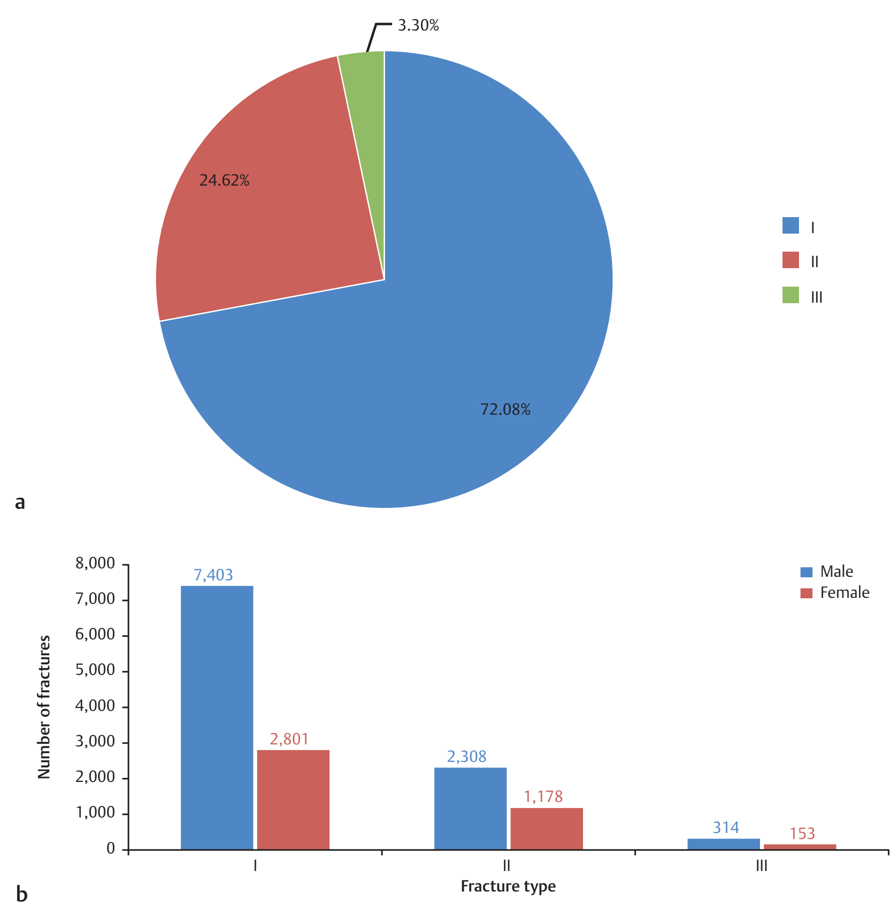


Fig. 10.29 (**a**) Fracture type distribution of 14,157 clavicle fractures by Allman classification. (**b**) Sex and fracture type distribution of 14,157 clavicle fractures by Allman classification.

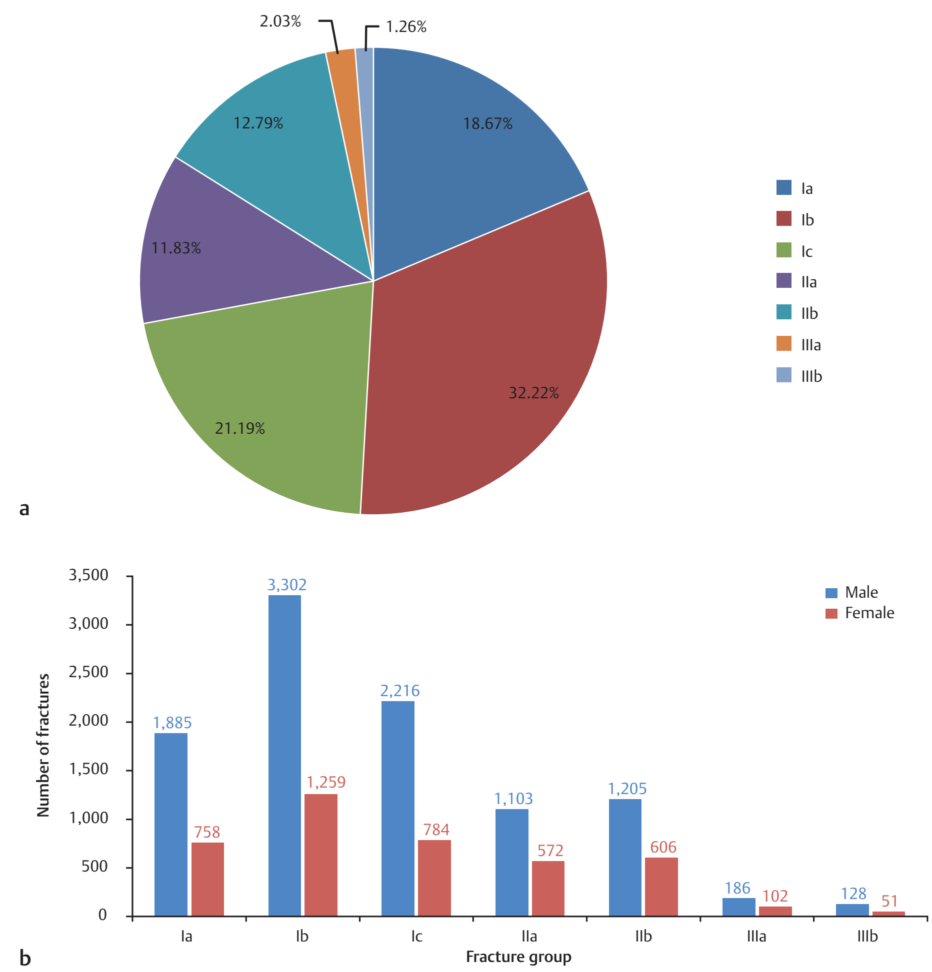


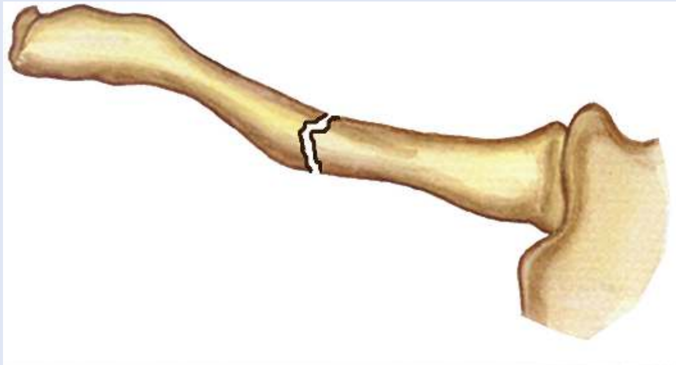
Fig. 10.30 (**a**) Fracture subtype distribution of 14,157 clavicle fractures by Allman classification. (**b**) Sex and fracture subtype distribution of 14,157 clavicle fractures by Allman classification.

10

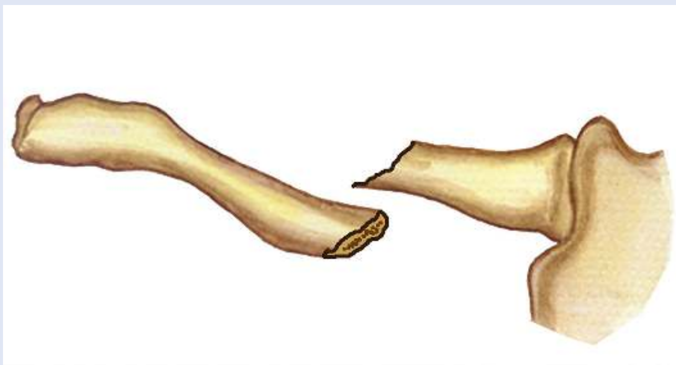
The Allman classification of clavicle fractures

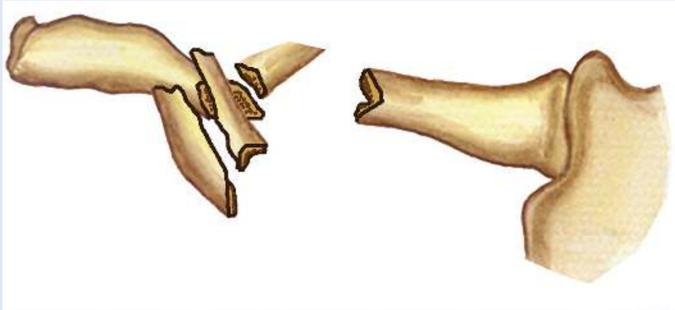
Type I Middle third
10,204 fractures
M: 7,403 (72.55%)
F: 2,801 (27.45%)
72.08% of adult clavicle fractures
2.73% of total adult fractures

Allman Ia With no displacement



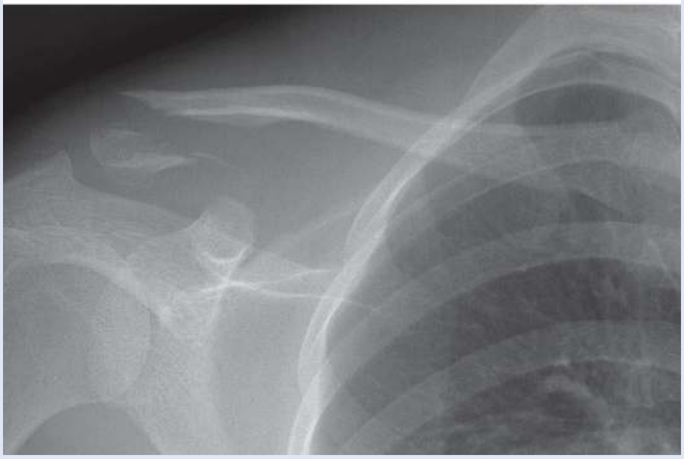
Allman Ib With displacement



The Allman classification of clavicle fractures	
	Allman Ic Comminuted  
Type II Lateral third 3,486 fractures M: 2,308 (66.21%) F: 1,178 (33.79%) 24.62% of adult clavicle fractures 0.93% of total adult fractures	**Allman IIa** With no displacement  

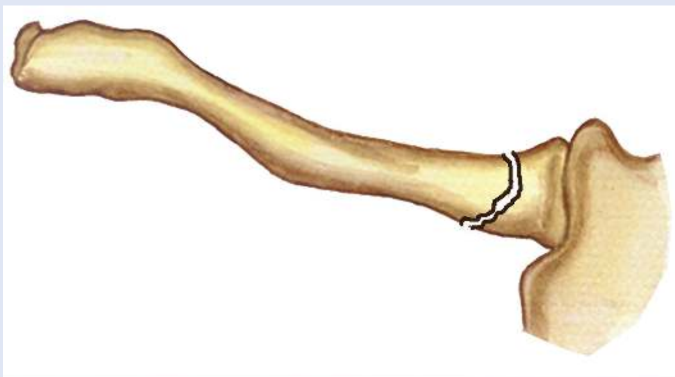
The Allman classification of clavicle fractures

Allman IIb With displacement



Type III Medial third
467 fractures
M: 314 (67.24%)
F: 153 (32.76%)
3.30% of adult clavicle fractures
0.12% of total adult fractures

Allman IIIa With no displacement



The Allman classification of clavicle fractures	
	Allman IIIb With displacement  

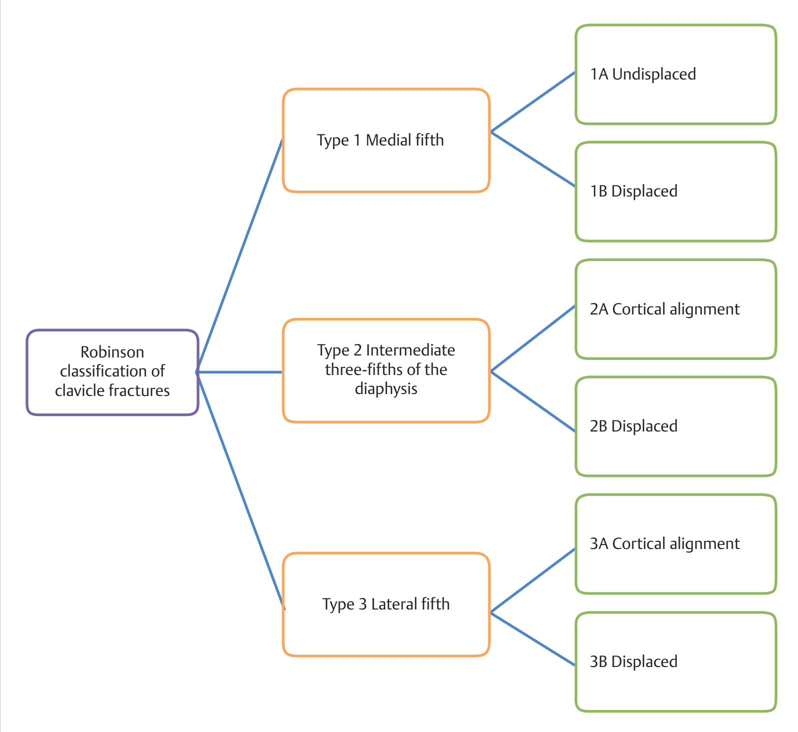


Fig. 10.31 Algorithm.

■ The Robinson Classification of Clavicle Fractures

In 1988, Robinson proposed the following classification scheme for clavicle fractures:

- *Type 1*: fractures of the medial fifth
- *Type 2*: diaphyseal fractures
- *Type 3*: fractures of the outer fifth (the fifth of the bone lateral to a vertical line drawn upward from the center of the base of the coracoid process, a point normally marked by the conoid tuberosity)

Each type of fracture was broken down further into two subtypes, A and B, depending on displacement (greater or less than 100% translation) of the major fragments. Type 1A and type 1B fractures were further subdivided into (1) extra-articular or (2) intra-articular. Type 2A fractures were subdivided according to the presence of angulation but in all these injuries there was residual bony contact. Two subgroups of type 2B were simple or wedge comminuted fractures (type 2B1), and isolated segmental or segmentally comminuted fractures (type 2B2). Type 3A and type 3B fractures were also subdivided according to their articular involvement (▶ Fig. 10.31).

■ Clinical Epidemiologic Features of Clavicle Fractures by the Robertson Classification

A total of 14,157 clavicle fractures were treated in 83 hospitals of China from 2010 to 2011. The epidemiologic features of clavicle fractures by the Robinson classification are:

- More males than females
- The most common fracture type is type 2

See ▶ Table 10.21 and ▶ Fig. 10.32.

Table 10.21 Sex and fracture type distribution of 14,157 clavicle fractures by Robinson classification

Fracture type	Male	Female	Number of fractures	Percentage
1	164	55	219	1.55
2	7,523	2,839	10,362	73.19
3	2,338	1,238	3,576	25.26
Total	10,025	4,132	14,157	100.00

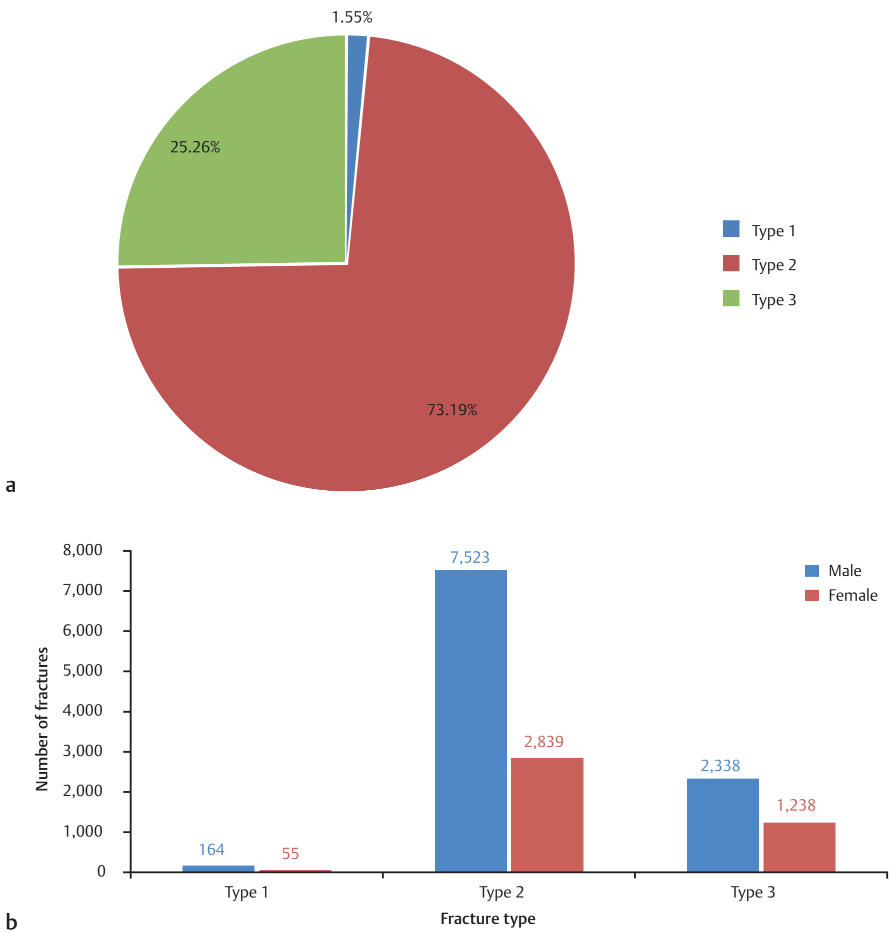
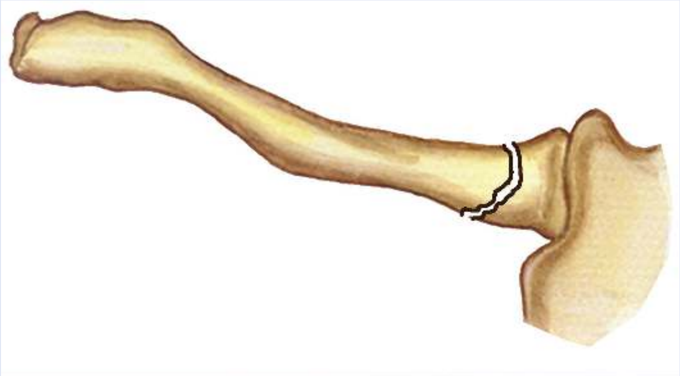


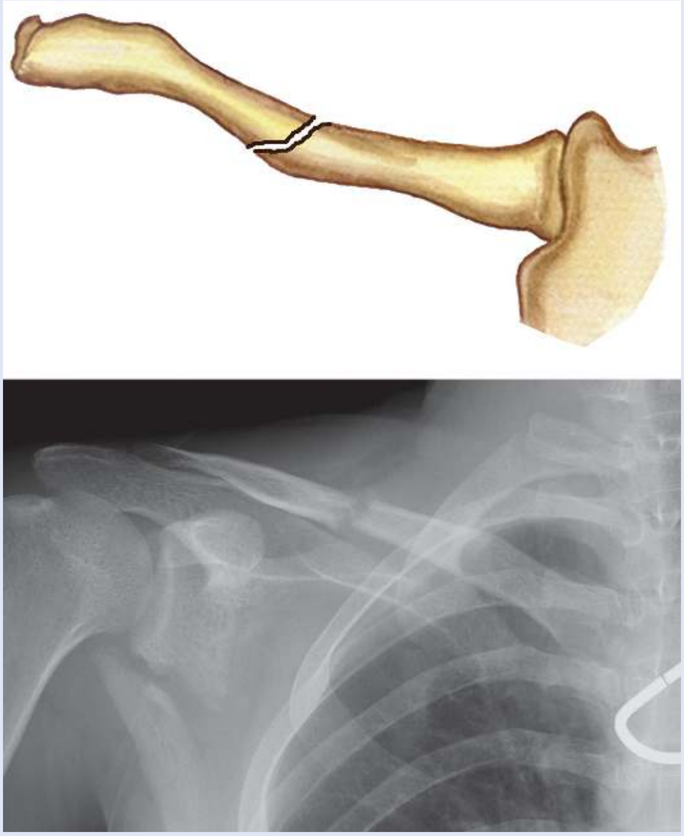
Fig. 10.32 (**a**) Fracture type distribution of 14,157 clavicle fractures by Robinson classification. (**b**) Sex and fracture type distribution of 14,157 clavicle fractures by Robinson classification.

The Robinson classification of clavicle fractures	
Type 1 Medial fifth 219 fractures M: 164 (74.89%) F: 55 (25.11%) 1.55% of adult clavicle fractures 0.06% of total adult fractures	**Robinson 1A** Nondisplaced fractures  
	Robinson 1B Displaced fractures  

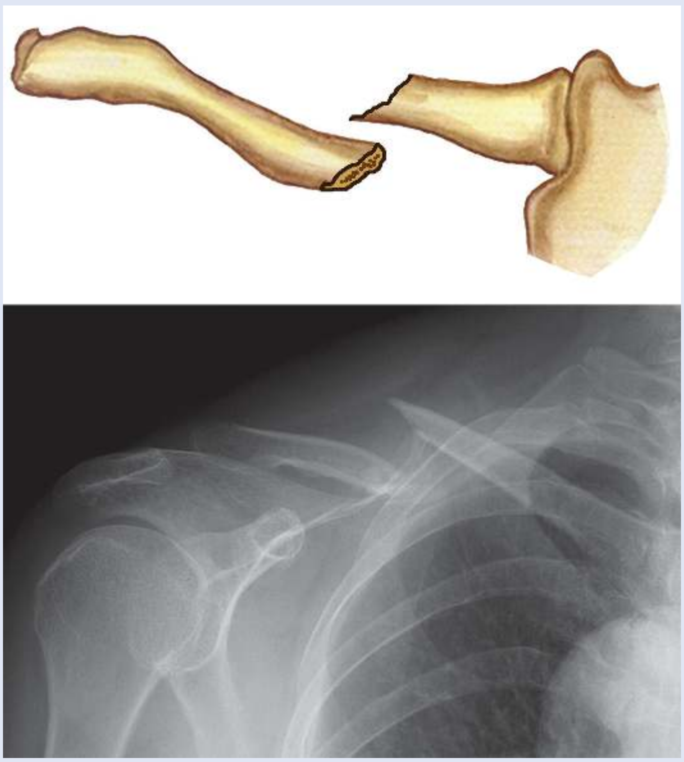
The Robinson classification of clavicle fractures

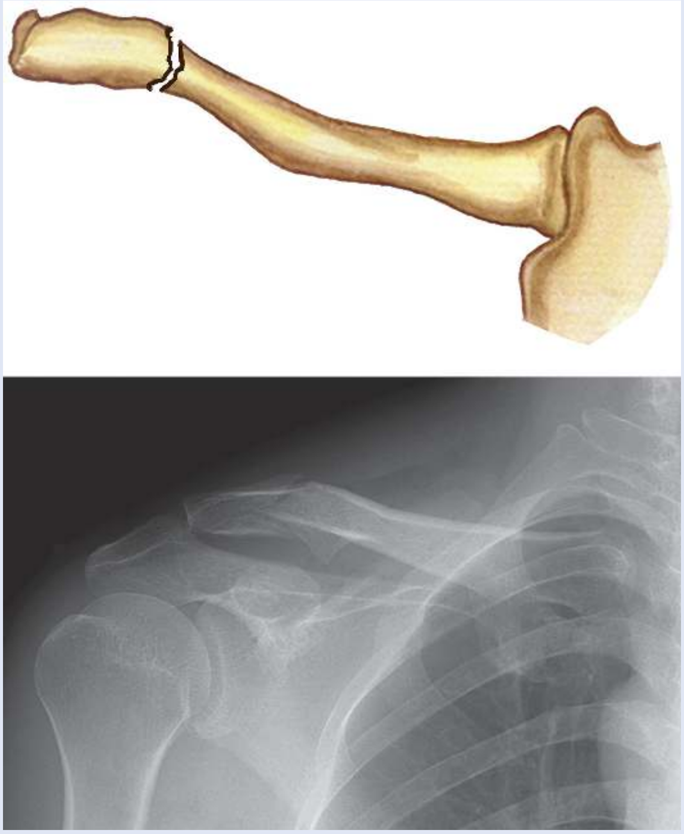
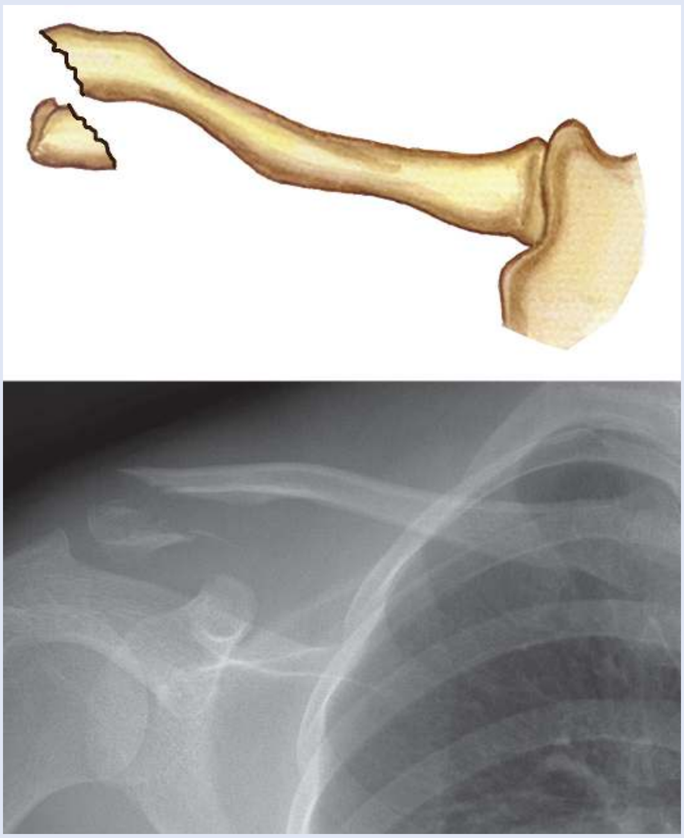
Type 2 Intermediate three-fifths of diaphysis
10,362 fractures
M: 7,523 (72.60%)
F: 2,839 (27.40%)
73.19% of adult clavicle fractures
2.77% of total adult fractures

Robinson 2A Cortical alignment fractures



Robinson 2B Displaced fractures



The Robinson classification of clavicle fractures	
Type 3 Lateral fifth 3,576 fractures M: 2,338 (65.38%) F: 1,238 (34.62%) 25.26% of adult clavicle fractures 0.96% of total adult fractures	**Robinson 3A** Cortical alignment fractures 
	Robinson 3B Displaced fractures 

Scapular Fractures (Segment 14)

Scapular fractures are uncommon and usually result from major blunt trauma. These fractures not only affect shoulder motion but are also associated with other injuries.

Anatomic Features

The scapula forms the posterior part of the shoulder girdle, the anterior part of which is formed by the clavicle. Prominent areas of the scapula serve as attachment points for many muscles and ligaments, each of which provides support and protection for the scapula. The supraspinatus muscle lies in the supraspinatous fossa. The infraspinatous fossa below the spine is mostly covered by the infraspinatus muscle. The anterior surface of the scapula facing the ribs has a broad concavity, the subscapular fossa; the medial two-thirds of this fossa is marked by an oblique ridge that serves as the attachment site of the subscapularis. There are a few projections from the border of the scapula—coracoid process, acromion, and the glenoid cavity; the coracobrachialis and short head of the biceps muscles originate from the coracoid, and the pectoralis minor inserts on the coracoid. Scapular fractures are more closely associated with fragment displacement and fracture deformity due to the pull of the three muscles attached to the coracoid.

The acromion first projects lateralward and then curves forward and upward, so as to overhang the glenoid cavity. The medial border of the acromion presents a small, oval surface for articulation with the acromial end of the clavicle. The supraspinatus and infraspinatus muscles both pass beneath the acromion and insert on the greater tubercle of the humerus. On the lateral angle of the scapula is a shallow articular surface, the glenoid fossa, which articulates with the head of the humerus. The margins of the cavity surface, which give attachment to a fibrocartilaginous structure and the glenoid labrum, are slightly raised, thereby deepening the cavity. The tendon of the long head of the biceps brachii attaches to the scapula at the supraglenoid tubercle, while the long head of the triceps brachii muscle arises from the infraglenoid tubercle of the scapula. While passing through the spinoglenoid notch to supply the infraspinatus, the suprascapular nerve and vessels are susceptible to traction injuries, which occur from fracture-displacement of the glenoid cavity or shoulder joint manipulation from the posterior approach (▶ Fig. 10.33).

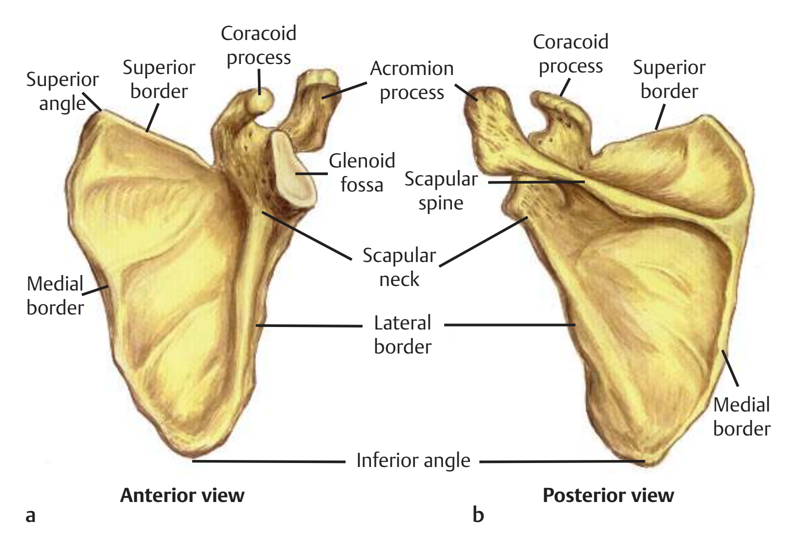


Fig. 10.33 The scapula: anterior (**a**) and posterior (**b**) views.

OTA Classification and Coding System for Scapular Fractures

Based on OTA classification, the scapula is coded as number "14" for its anatomic location. Scapular fractures are classified into three types: type A, extra-articular; type B, partial articular; and type C, complete articular (▶ Fig. 10.34).

Epidemiologic Features of Scapular Fractures in the China National Fracture Study

A total of 26 patients with 26 scapular fractures were investigated in the CNFS. The fractures accounted for 1.47% of all patients with fractures and 1.42% of all types of fractures. The population-weighted incidence rate of scapular fractures was 5 per 100,000 population in 2014. The epidemiologic features of scapular fractures in the CNFS are as follows:

- More males than females
- More left-side injuries than right-side injuries
- The highest risk age group is 15–64 years
- The proximal scapular fracture is the most common femoral fracture
- Injuries occurred most commonly via traffic accident and crushing injury

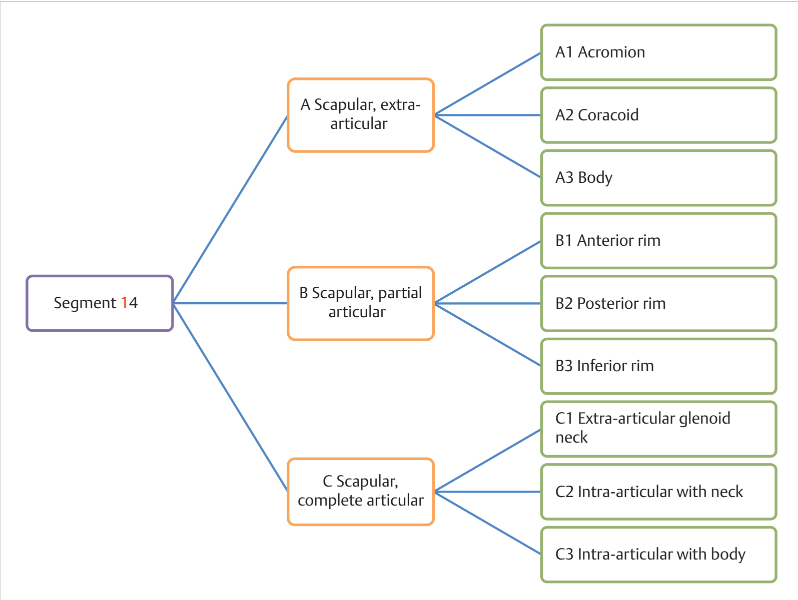


Fig. 10.34 Algorithm.

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■ Scapular Fracture by Sex

See ▶ Table 10.22 and ▶ Fig. 10.35.

Table 10.22 Sex distribution of 26 patients with scapular fractures in CNFS

Sex	Number of patients	Percentage
Male	16	61.54
Female	10	38.46
Total	26	100.00

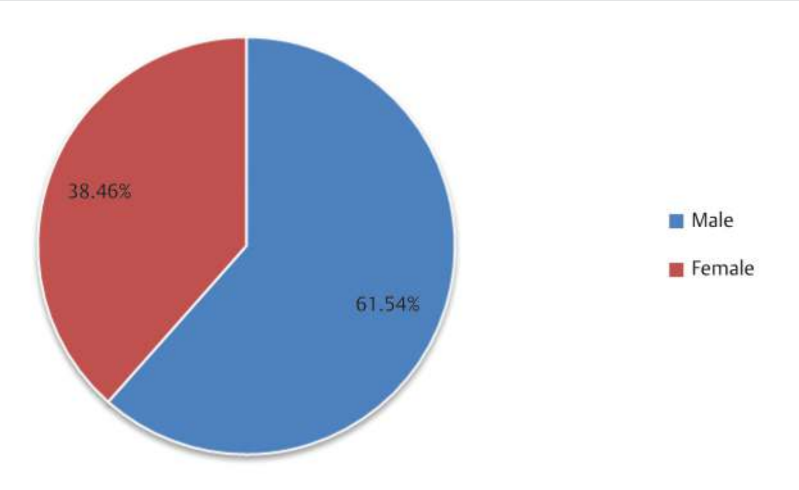

Fig. 10.35 Sex distribution of 26 patients with scapular fractures in China National Fracture Study (CNFS).

■ Scapular Fracture by Injury Side in CNFS

See ▶ Table 10.23 and ▶ Fig. 10.36.

Table 10.23 Injury side distribution of 26 patients with scapular fractures in CNFS

Injured side	Number of patients	Percentage
Left	14	53.85
Right	12	46.15
Total	26	100.00

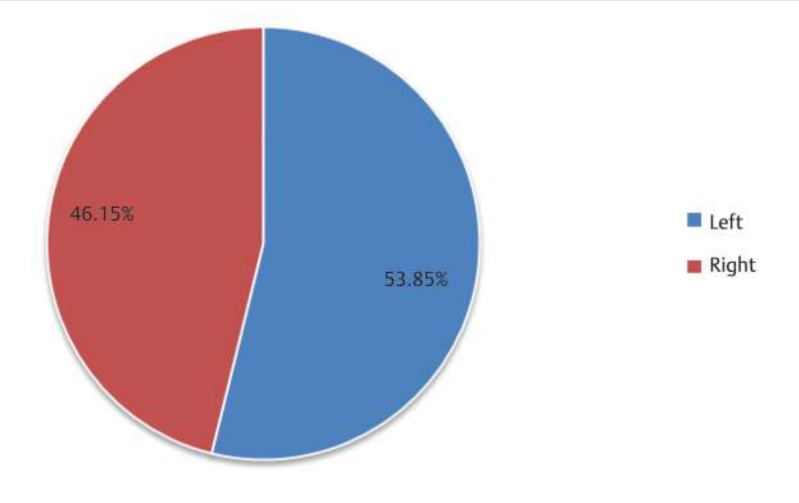

Fig. 10.36 Injury side distribution of 26 patients with scapular fractures in China National Fracture Study (CNFS).

■ Scapular Fracture by Age Group and Sex in CNFS

See ▶ Table 10.24 and ▶ Fig. 10.37.

Table 10.24 Age and sex distribution of 26 patients with scapular fractures in CNFS

Age group (years)	Male	Female	Total	Percentage
0–14	0	0	0	0.00
15–64	13	8	21	80.77
≥65	3	2	5	19.23
Total	16	10	26	100.00

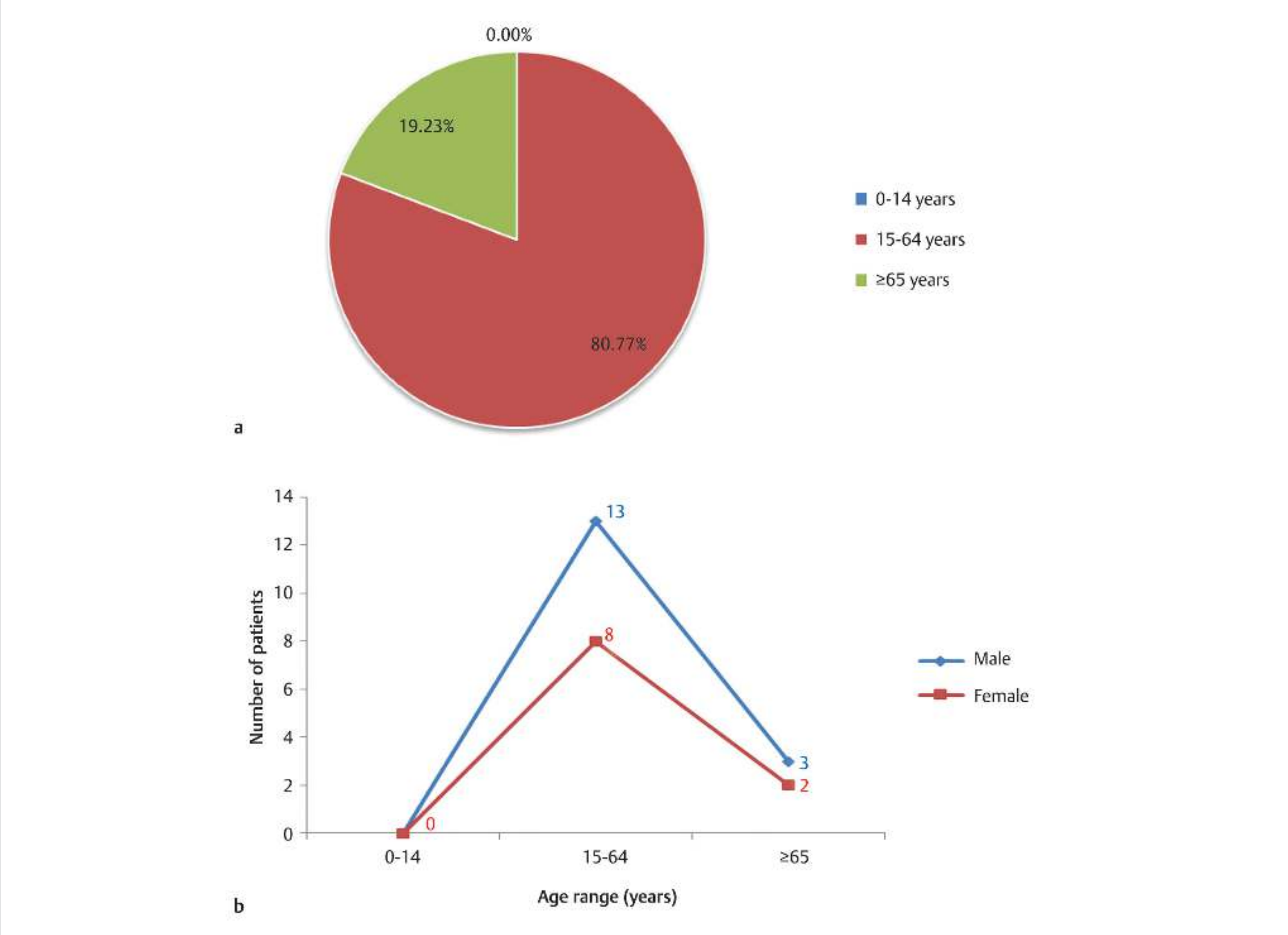

Fig. 10.37 (**a**) Age distribution of 26 patients with scapular fractures in China National Fracture Study (CNFS). (**b**) Age and sex distribution of 26 patients with scapular fractures in CNFS.

Scapular Fracture by Causal Mechanisms in CNFS

See ▶ Table 10.25 and ▶ Fig. 10.38.

Table 10.25 Causal mechanisms distribution of 26 patients with scapular fractures in CNFS

Causal mechanisms	Male	Female	Total	Percentage
Traffic accident	4	4	8	30.77
Slip, trip, or fall	4	1	5	19.23
Fall from heights	3	1	4	15.38
Crushing injury	4	3	7	26.92
Sharp trauma	0	1	1	3.85
Blunt force trauma	1	0	1	3.85
Total	16	10	26	100.00

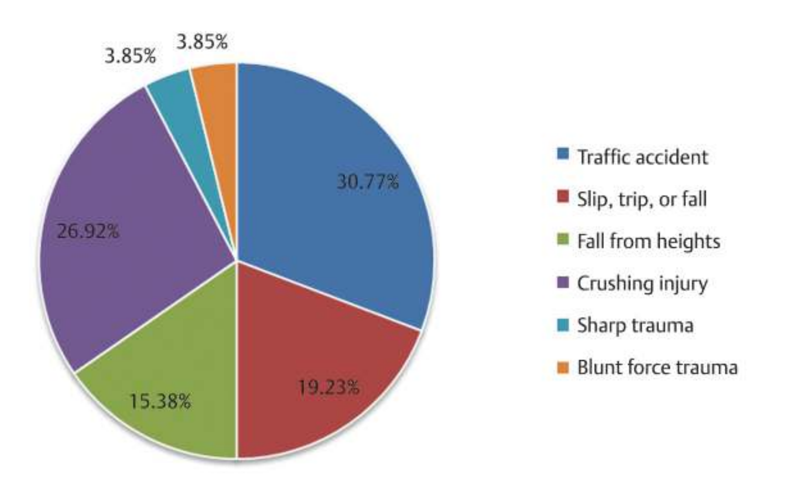

Fig. 10.38 Causal mechanisms distribution of 26 patients with scapular fractures in China National Fracture Study (CNFS).

Epidemiologic Features of Scapular Fractures (Segment 14)

A total of 3,107 patients with 3,123 scapular fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011. All cases were reviewed and statistically studied; the fractures accounted for 0.75% of all patients with fractures, and 0.72% of all kinds of fractures, respectively; among 3,107 patients, there were 150 pediatric patients (151 scapular fractures) and 2,957 adult patients with 2,972 scapular fractures. Epidemiologic features of scapular fractures are as follows:

- More males than females
- More left-side than right-side injuries
- The high-risk age group is 41–45 years, the same age group for males, while for females, the high-risk age group is 46–50 years
- The most common fracture type is type 14-A, the same fracture type for both males and females
- The most common fracture group is group 14-A3, the same fracture group for both males and females

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■ Scapular Fractures by Sex

See ▶ Table 10.26 and ▶ Fig. 10.39.

Table 10.26 Sex distribution of 3,107 patients with scapular fractures

Sex	Number of patients	Percentage
Male	2,349	75.60
Female	758	24.40
Total	3,107	100.00

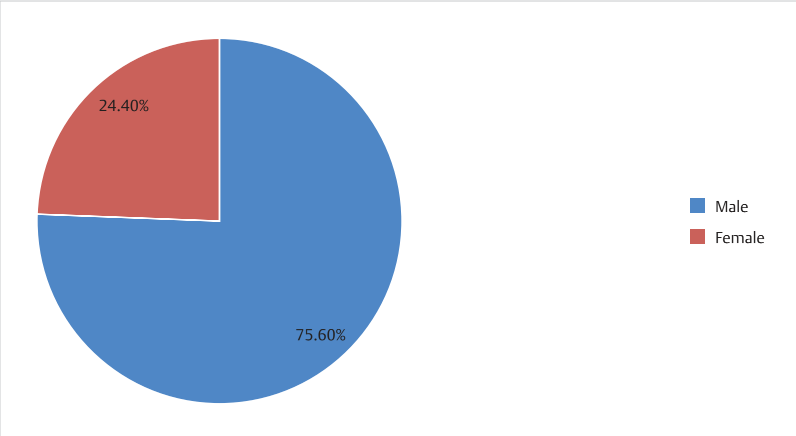

Fig. 10.39 Sex distribution of 3,107 patients with scapular fractures.

■ Scapular Fractures by Fracture Side

See ▶ Table 10.27 and ▶ Fig. 10.40.

Table 10.27 Fracture side distribution of 3,107 patients with scapular fractures

Fracture side	Number of patients	Percentage
Left	1,601	51.53
Right	1,490	47.96
Bilateral	16	0.51
Total	3,107	100.00

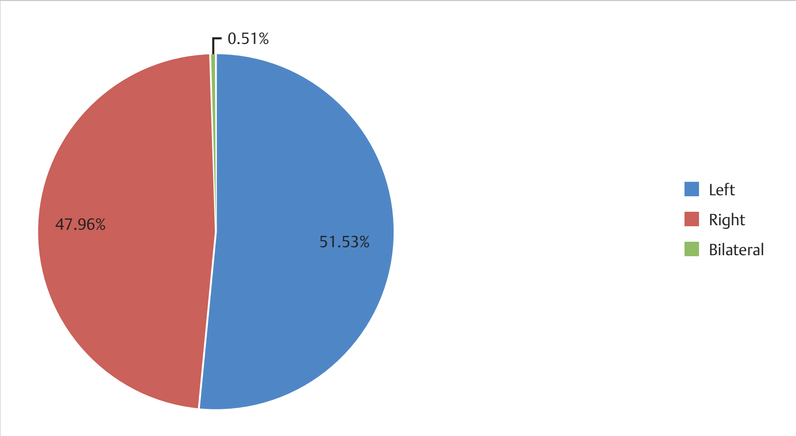

Fig. 10.40 Fracture side distribution of 3,107 patients with scapular fractures.

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■ Scapular Fractures by Age Group

See ▶ Table 10.28 and ▶ Fig. 10.41.

Table 10.28 Age and sex distribution of 3,107 patients with scapular fractures

Age group (years)	Male	Female	Number of patients	Percentage
0–5	13	9	22	0.71
6–10	20	9	29	0.93
11–15	72	27	99	3.19
16–20	137	21	158	5.09
21–25	165	30	195	6.28
26–30	208	29	237	7.63
31–35	221	51	272	8.75
36–40	246	85	331	10.65
41–45	358	83	441	14.19
46–50	264	86	350	11.26
51–55	192	67	259	8.34
56–60	202	80	282	9.08
61–65	98	51	149	4.80
66–70	75	50	125	4.02
71–75	33	38	71	2.29
76–80	26	24	50	1.61
81–85	9	11	20	0.64
≥ 86	10	7	17	0.55
Total	2,349	758	3,107	100.00

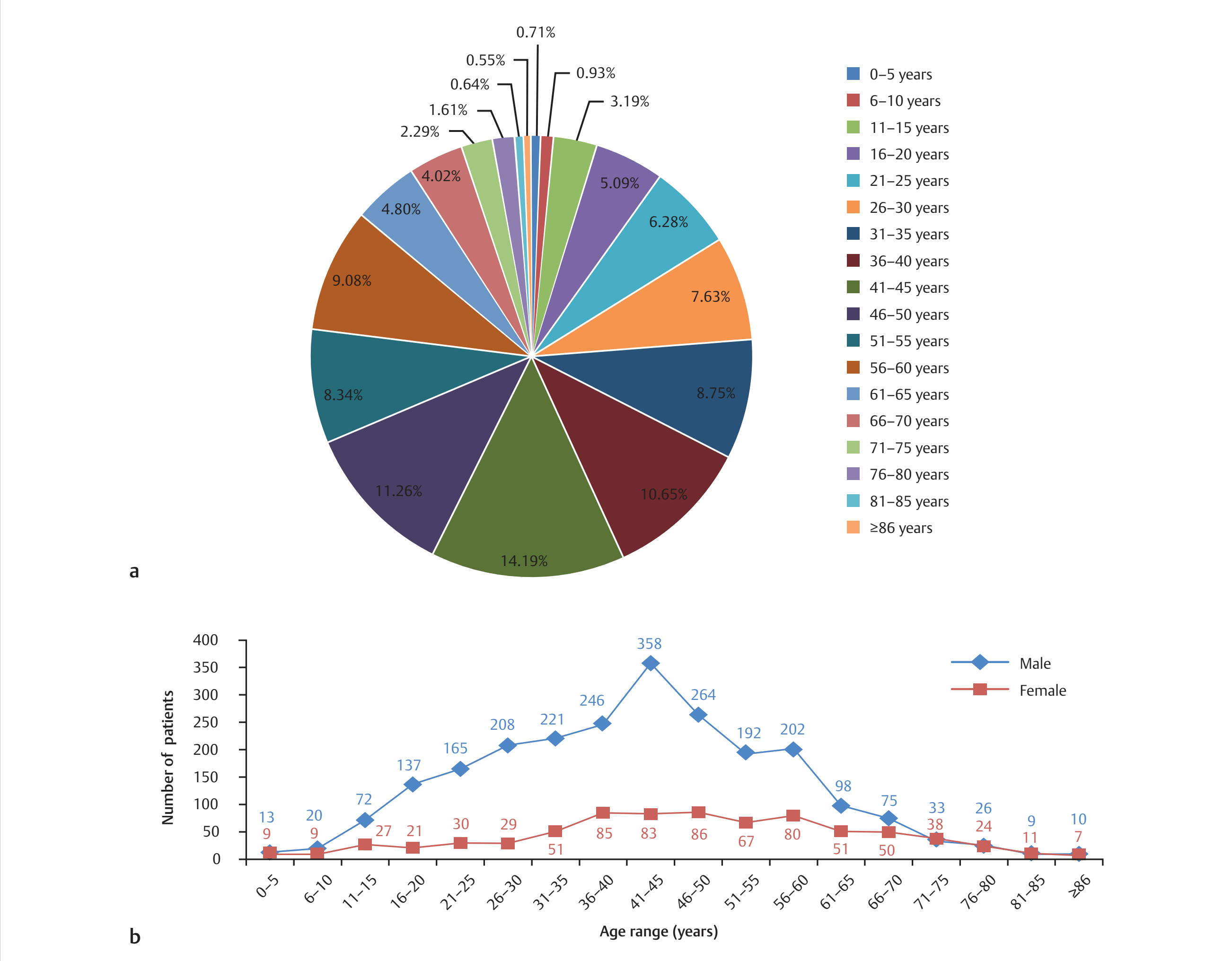

Fig. 10.41 (a) Age distribution of 3,107 patients with scapular fractures. (b) Age and sex distribution of 3,107 patients with scapular fractures.

■ Adult Scapular Fractures by Fracture Type

See ► Table 10.29, ► Table 10.30, ► Fig. 10.42, and ► Fig. 10.43.

Table 10.29 Fracture type distribution of 2,972 adult scapular fractures

Fracture type	Male	Female	Number of fractures	Percentage
14-A	1,425	409	1,834	61.71
14-B	257	117	374	12.58
14-C	575	189	764	25.71
Total	2,257	715	2,972	100.00

Table 10.30 Sex and fracture group distribution of 2,972 scapular fractures

Fracture group	Male	Female	Number of patients	Percentage
14-A1	412	127	539	18.14
14-A2	128	49	177	5.96
14-A3	885	233	1,118	37.62
14-B1	36	24	60	2.02
14-B2	40	27	67	2.25
14-B3	181	66	247	8.31
14-C1	362	125	487	16.39
14-C2	68	18	86	2.89
14-C3	145	46	191	6.43
Total	2,257	715	2,972	100.00

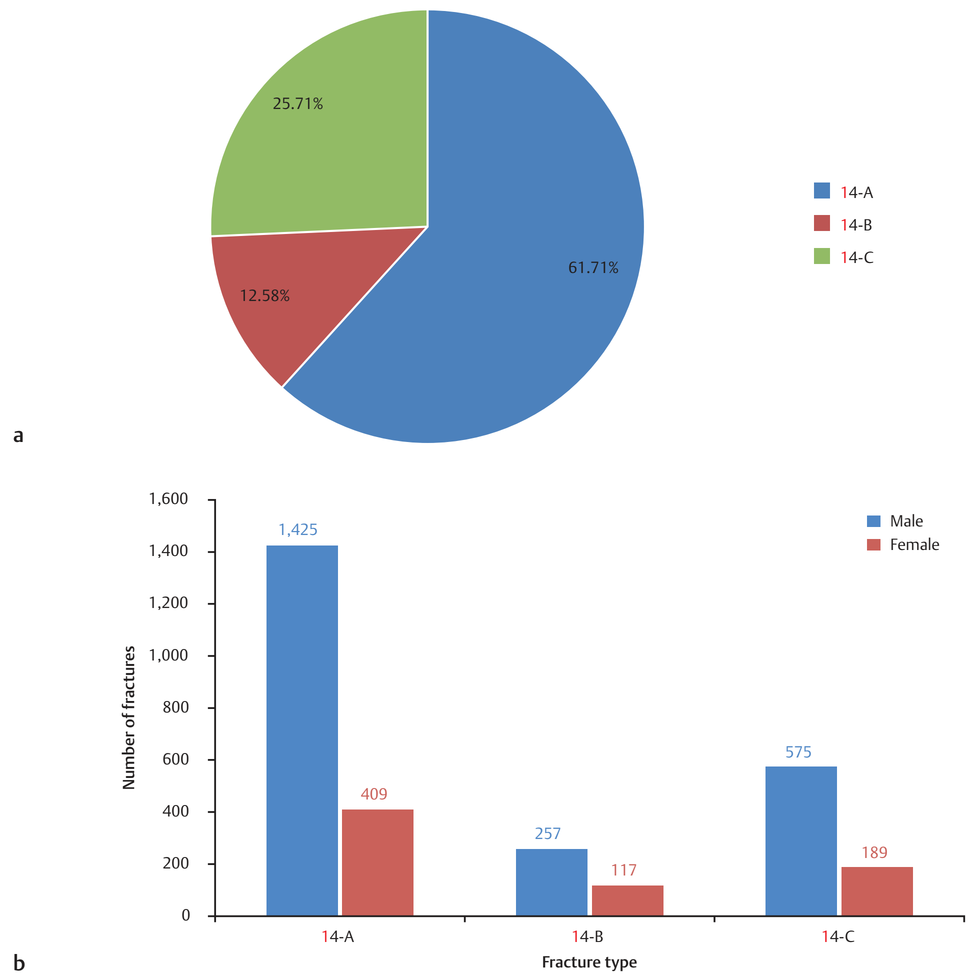

Fig. 10.42 (**a**) Fracture type distribution of 2,972 scapular fractures. (**b**) Sex and fracture type distribution of 2,972 scapular fractures.

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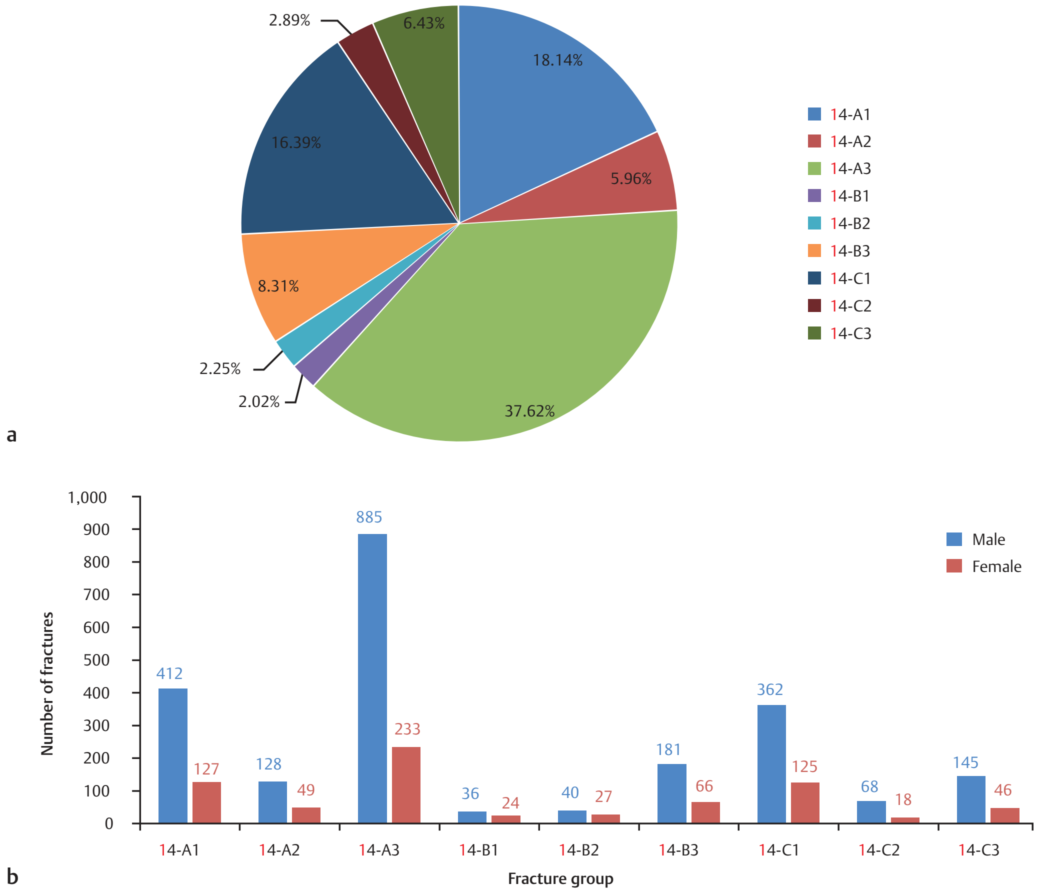
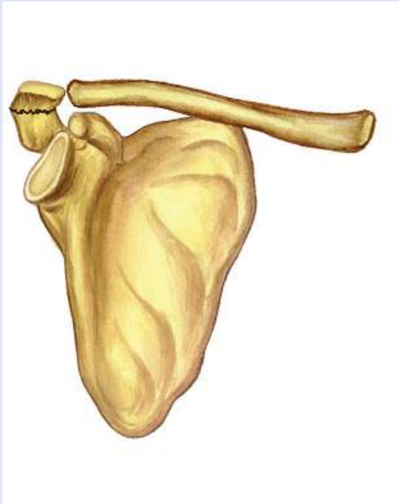


Fig. 10.43 (**a**) Fracture group distribution of 2,972 scapular fractures. (**b**) Sex and fracture group distribution of 2,972 scapular fractures.

14-A Scapula, Extra-articular Fractures

14-A1 Acromion
539 fractures
M: 41 (76.44%)
F: 127 (23.56%)
0.14% of total adult fractures
18.14% of adult scapular fractures
29.39% of type 14-A

14-A1.1 Simple

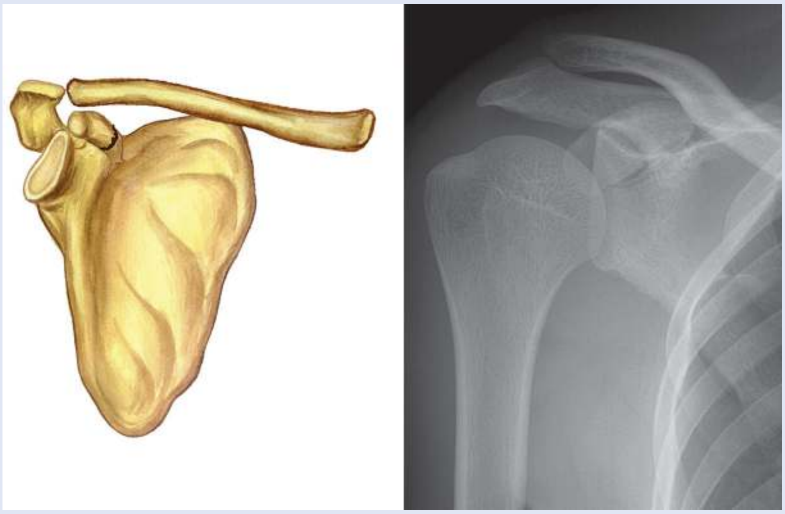


14-A1.2 Comminuted

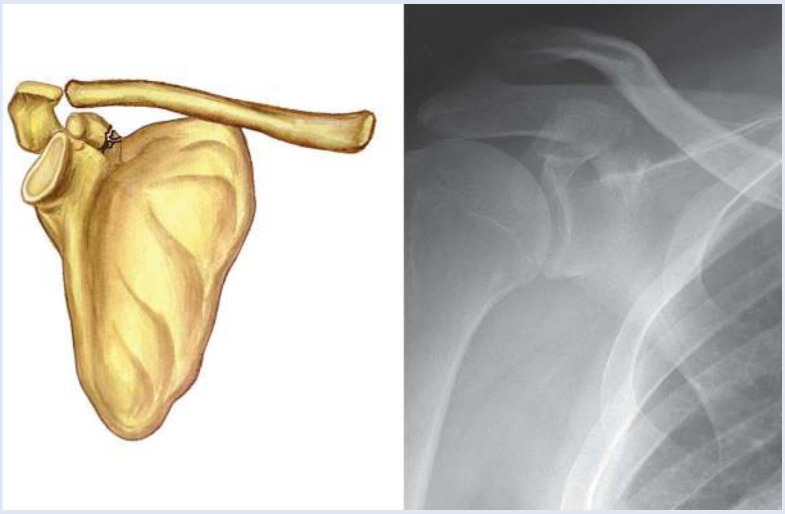
14-A Scapula, extra-articular fractures

14-A2 Coracoid
177 fractures
M: 12 (72.32%)
F: 49 (27.68%)
0.05% of total adult fractures
5.96% of adult scapular fractures
9.65% of type 14-A

14-A2.1 Simple



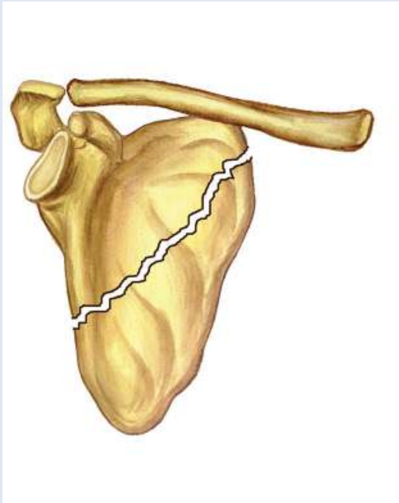
14-A2.2 Comminuted



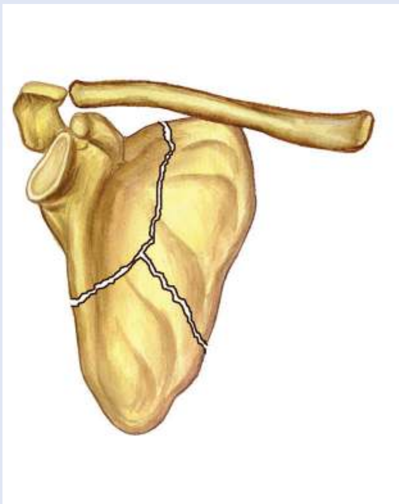
14-A Scapula, extra-articular fractures

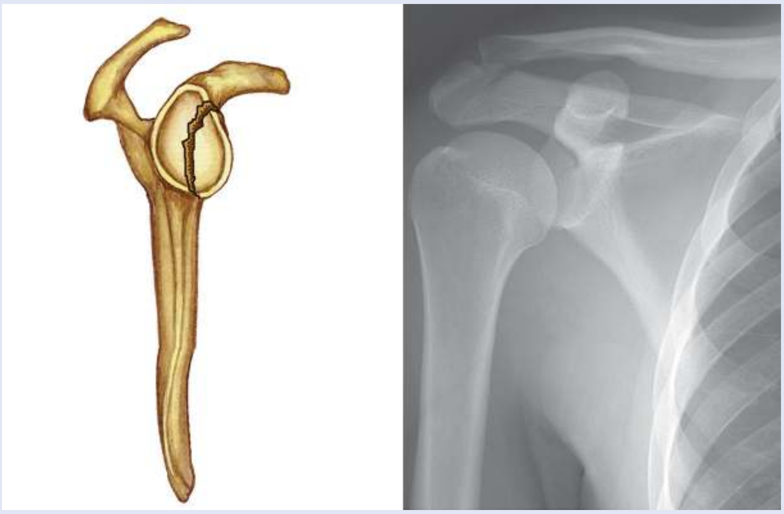
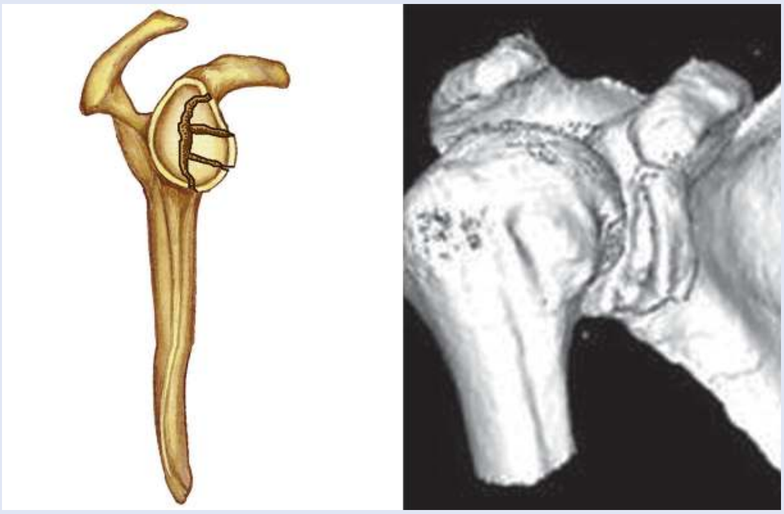
14-A3 Body
1,118 fractures
M: 885 (79.16%)
F: 233 (20.84%)
0.30% of total adult fractures
37.62% of adult scapular fractures
60.96% of type 14-A

14-A3.1 Simple



14-A3.2 Comminuted

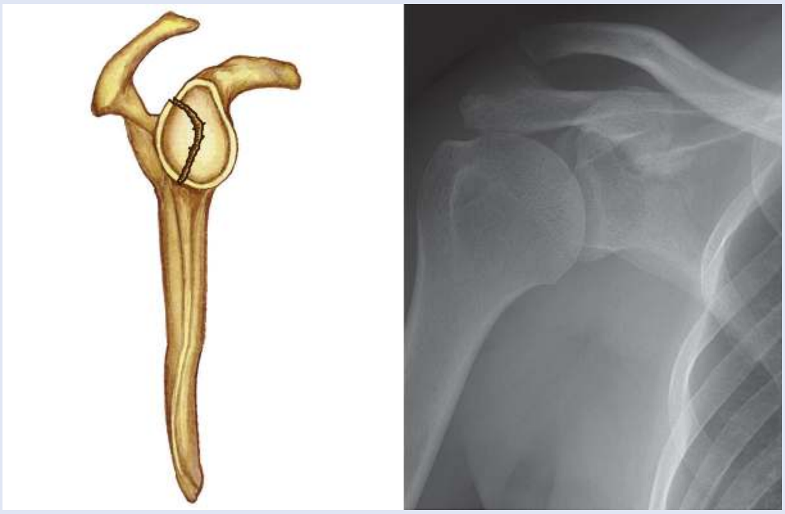


14-B Scapula, partial-articular fractures	
14-B1 Anterior rim 60 fractures M: 36 (60.00%) F: 24 (40.00%) 0.02% of total adult fractures 2.02% of adult scapular fractures 16.04% of type 14-B	**14-B1.1** Simple 
	14-B1.2 Comminuted 

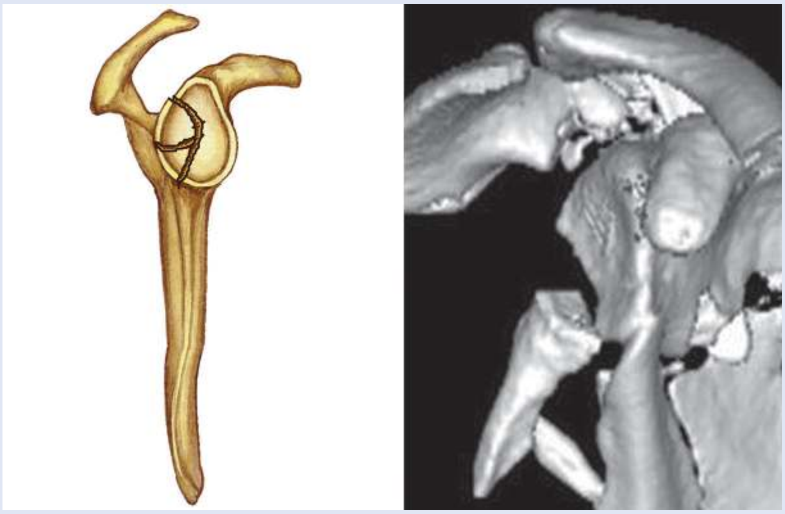
14-B Scapula, partial-articular fractures

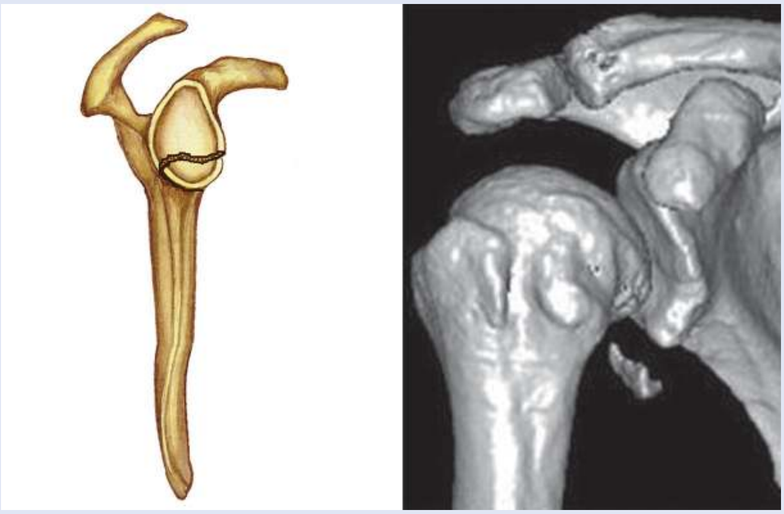
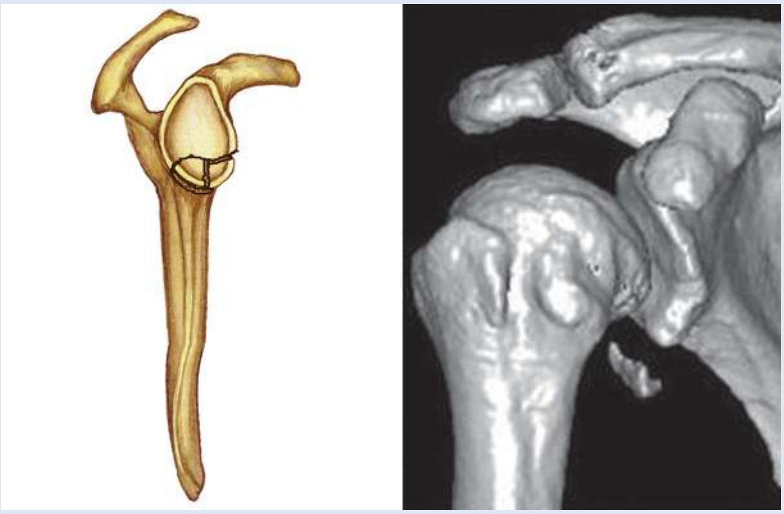
14-B2 Posterior rim
67 fractures
M: 40 (59.70%)
F: 27 (40.30%)
0.02% of total adult fractures
2.25% of adult scapular fractures
17.91% of type 14-B

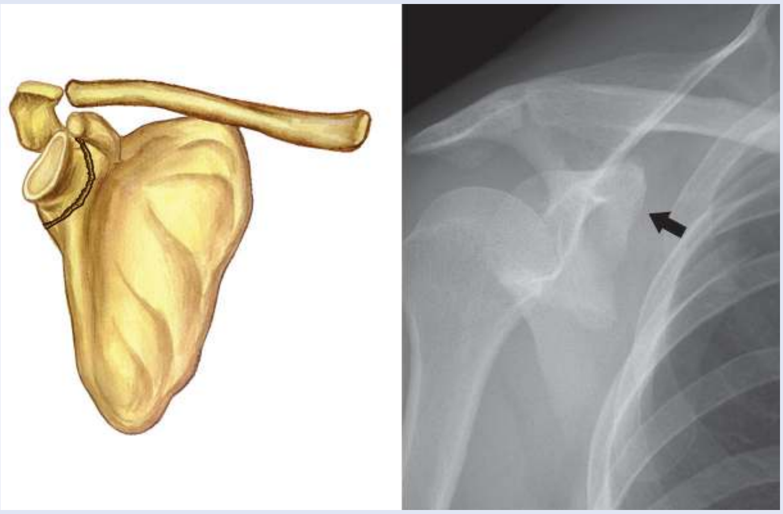
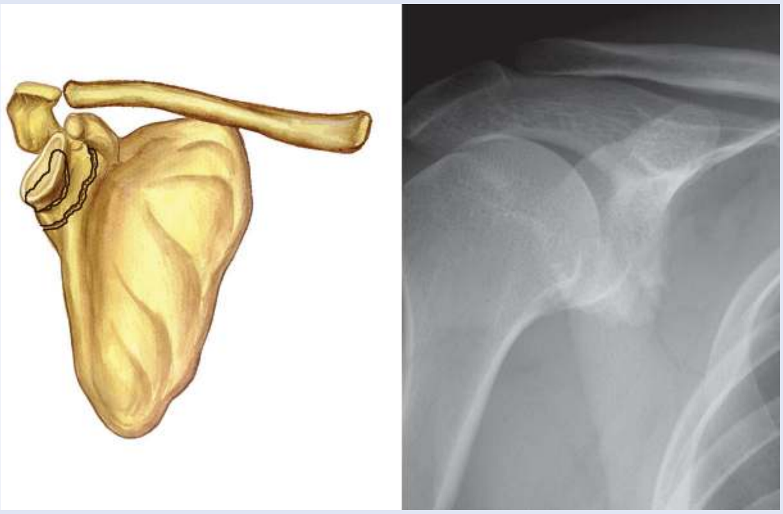
14-B2.1 Simple



14-B2.2 Comminuted



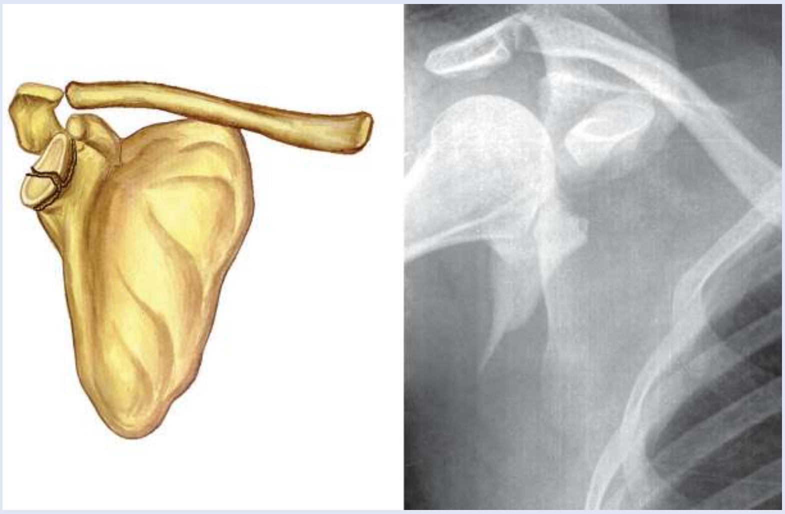
14-B Scapula, partial-articular fractures	
14-B3 Inferior rim 247 fractures M: 181 (73.28%) F: 66 (26.72%) 0.07% of total adult fractures 8.31% of adult scapular fractures 66.04% of type 14-B	**14-B3.1** Simple  **14-B3.2** Comminuted 

14-C Scapula, complete-articular fractures	
14-C1 Extra-articular glenoid neck 487 fractures M: 362 (74.33%) F: 125 (25.67%) 0.13% of total adult fractures 16.39% of adult scapular fractures 63.74% of type 14-C	**14-C1.1** Simple  **14-C1.2** Comminuted 

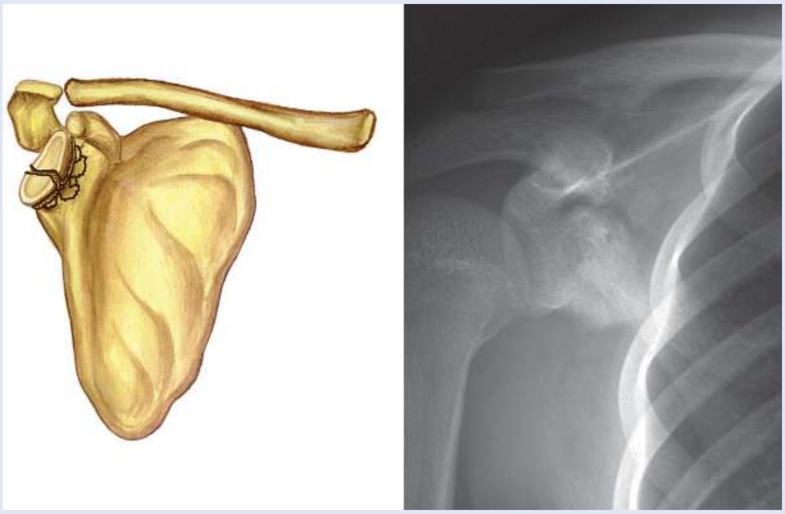
14-C Scapula, complete-articular fractures

14-C2 Intra-articular with neck
86 fractures
M: 68 (79.07%)
F: 18 (20.93%)
0.02% of total adult fractures
2.89% of adult scapular fractures
11.26% of type 14-C

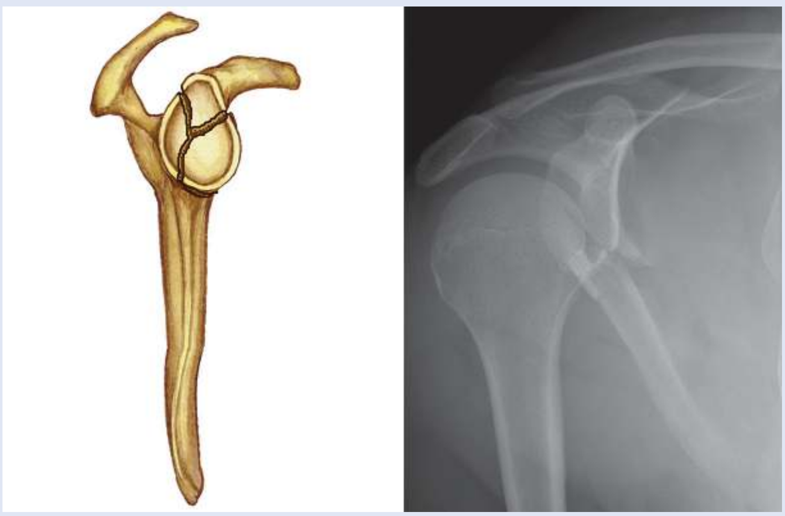
14-C2.1 Intra-articular simple, neck simple

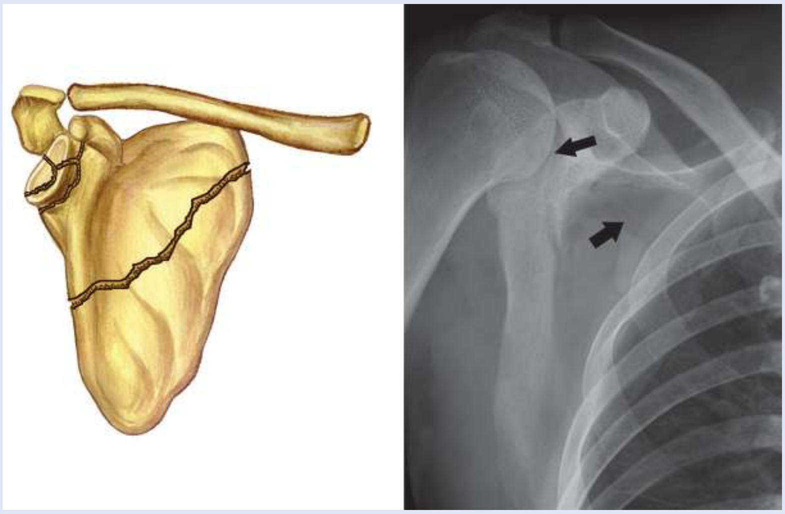


14-C2.2 Intra-articular simple, neck comminuted



14-C2.3 Articular comminuted



14-C Scapula, complete-articular fractures	
14-C3 Intra-articular with body 191 fractures M: 145 (75.92%) F: 46 (24.08%) 0.05% of total adult fractures 6.43% of adult scapular fractures 25.00% of type 14-B	14-C3 

Injury Mechanism

Typically, scapular fractures result from high-energy trauma. Extensive muscle coverage serves as a cushion against any impact force and protects the scapula from low-energy trauma. Avulsion fractures of the coracoid and the superior angle of the scapula may be caused by tensile traction from the attached muscles.

Diagnosis

Patients with scapular fractures usually present with a clear trauma history. Physical examination reveals swelling, pain, tenderness, crepitus, and ecchymosis over the scapular region. The affected arm is usually adducted, and pain is aggravated by shoulder movement, especially while lifting the arm up to the side.

Scapular fractures are easy to be misdiagnosed due to the presence of other obvious injuries. Studies report that the misdiagnosis rate of scapular fractures is as high as 43% when based on primary plain radiographic films alone. In practice, when patients complain of pain over the shoulder area after a traumatic event, particularly when there are concomitant fractures of multiple ribs or a pneumohemothorax, the scapula should be inspected for possible injury.

An AP view of the shoulder or a chest radiograph is usually adequate to detect scapular fractures. For further classification, one should obtain lateral and axillary views of the shoulder/scapula. If an intra-articular injury is suspected, then a CT scan or 3D-CT will allow for better detection of fractures. If soft tissue injuries of the shoulder are clinically suspected, MRI is indicated.

Treatment

Scapular fractures are usually accompanied by multiple injuries from high-energy trauma. Medical treatment should aim to care for life-threatening injuries and stabilize the cardiopulmonary system prior to operative fixation of scapular fractures. Scapular fractures with minimal or no displacement should be treated nonsurgically. Treatment is for symptomatic purposes. Short-term immobilization in a sling and swathe bandage is provided for comfort. Early shoulder motion exercise within moderation should be initiated as pain subsides. Open reduction and internal fixation should be performed for fractures with marked displacement or with compromised shoulder motion to restore shoulder function and prevent the development of traumatic arthritis.

For displaced glenoid neck fractures, closed reduction is utilized followed by immobilization with an abduction splint or traction when the patient is in bed. The affected arm should be externally rotated to maintain the anatomic reduction. If closed reduction or traction fails, then operative treatment should be considered.

For glenoid rim fractures, if the intra-articular step-off is greater than 5 to 8 mm, or if the triceps is torn and needs repair, then operative reduction and internal fixation is required. Restoration of the articulation congruence is essential to prevent development of posttraumatic arthritis by cleaning up bone debris left on the articular surface.

Further Classifications of Scapular Fractures

Coracoid Process Fractures

In 1995, Eyres and colleagues proposed a classification scheme for coracoid process fractures. The fractures are classified into five types according to the degree of extension of the fractures into the base of the coracoid. Types I, II, and III, which are often caused by avulsion injuries, do not involve the body of the scapula. Type IV fractures involve the body of the scapula, while type V fractures involve the glenoid fossa; both types of fractures are typically caused by shearing injuries.

In addition, in 1997 Ogawa et al classified coracoid fractures into two types (▶ Fig. 10.44):

- *Type I*: basal fractures of the coracoid and fractures behind the attachment of the coracoclavicular ligament with disturbance of the scapuloclavicular connection.
- *Type II*: avulsion fractures of the coracoid and fractures anterior to the attachment of the coracoclavicular ligament with no disturbance of the scapuloclavicular connection.

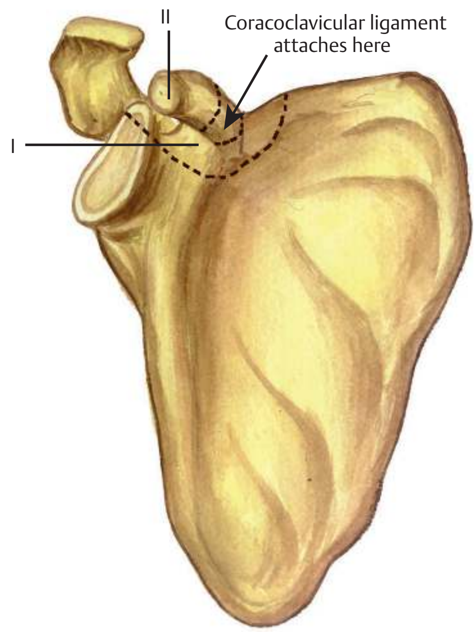


Fig. 10.44 Types of Ogawa fractures of the coracoid.

Clinical Epidemiologic Features of Coracoid Process Fractures

A total of 183 coracoid fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011; the fractures accounted for 5.86% of scapular fractures. Their epidemiologic features are as follows:

- More males than females
- The high-risk age group is 46–50 years

Coracoid Fractures by Sex

See ▶ Table 10.31 and ▶ Fig. 10.45.

Table 10.31 Sex distribution of 183 coracoid fractures

Sex	Number of fractures	Percentage
Male	128	69.95
Female	55	30.05
Total	183	100.00

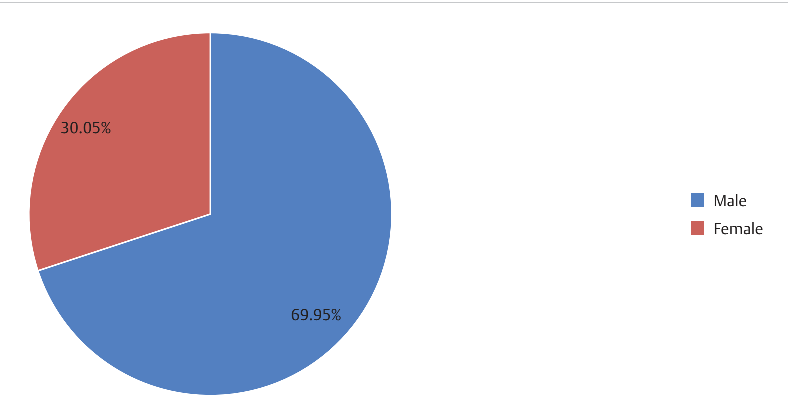


Fig. 10.45 Sex distribution of 183 coracoid fractures.

■ Coracoid Fractures by Age Group

See ▶ Table 10.32 and ▶ Fig. 10.46.

Table 10.32 Age and sex distribution of 183 coracoid fractures

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	0	1	1	0.55
6–10	3	2	5	2.73
11–15	4	3	7	3.83
16–20	7	6	13	7.10
21–25	15	3	18	9.84
26–30	12	0	12	6.56
31–35	14	4	18	9.84
36–40	9	6	15	8.20
41–45	14	4	18	9.84
46–50	14	7	21	11.48
51–55	13	2	15	8.20
56–60	11	8	19	10.38
61–65	0	2	2	1.09
66–70	4	2	6	3.28
71–75	2	2	4	2.19
76–80	4	1	5	2.73
81–85	1	2	3	1.64
≥ 86	1	0	1	0.55
Total	128	55	183	100.00

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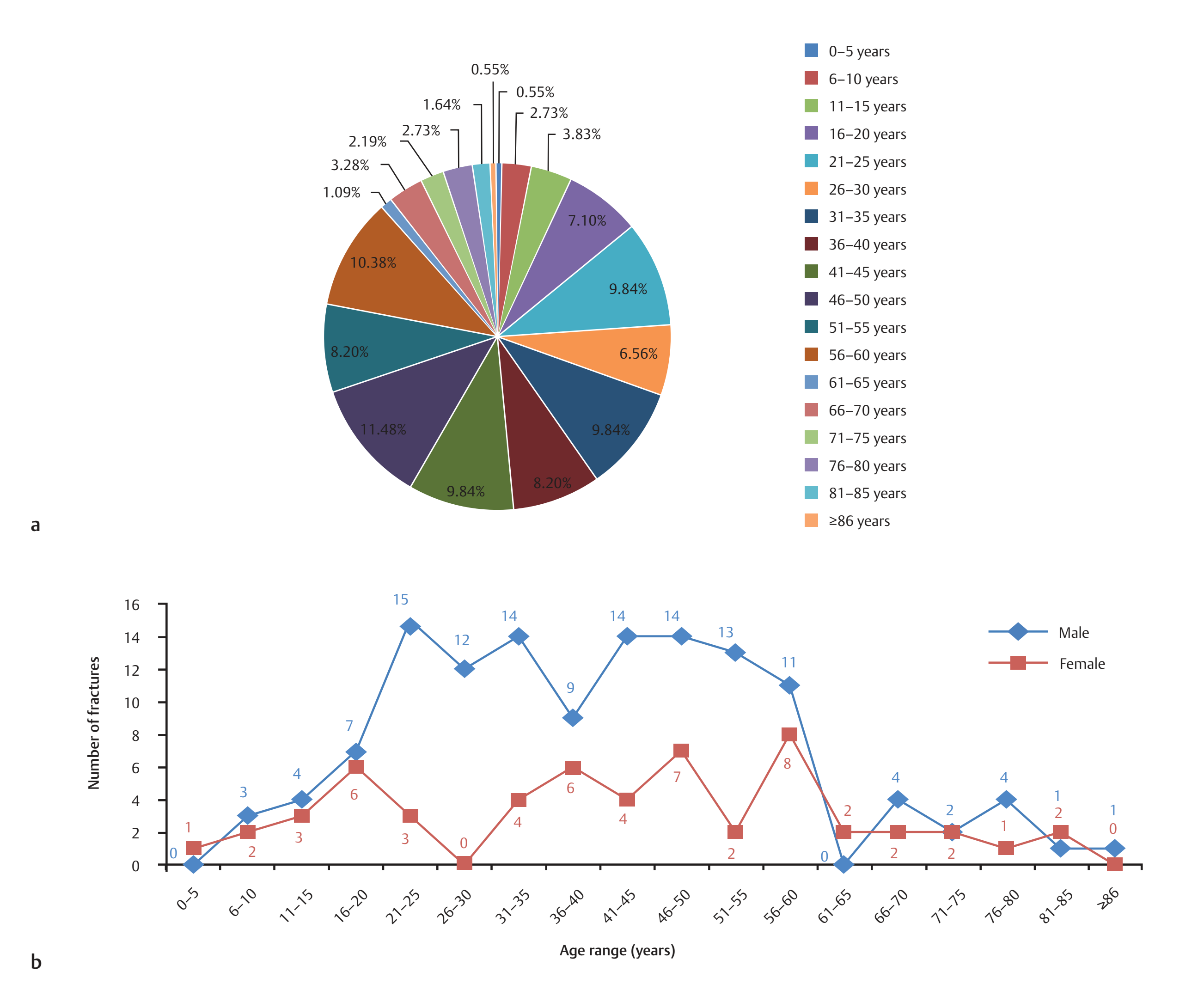


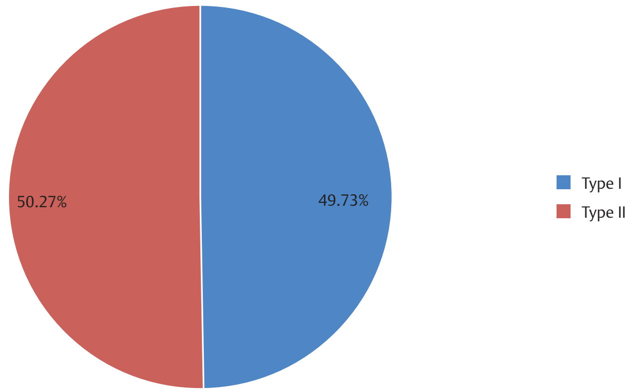
Fig. 10.46 (**a**) Age distribution of 183 coracoid fractures. (**b**) Age and sex distribution of 183 coracoid fractures.

■ Coracoid Fractures by Fracture Type

See ► Table 10.33 and ► Fig. 10.47.

Table 10.33 Sex and fracture type distribution of 183 coracoid fractures

Fracture type	Male	Female	Number of fractures	Percentage
I	68	23	91	49.73
II	60	32	92	50.27
Total	128	55	183	100.00



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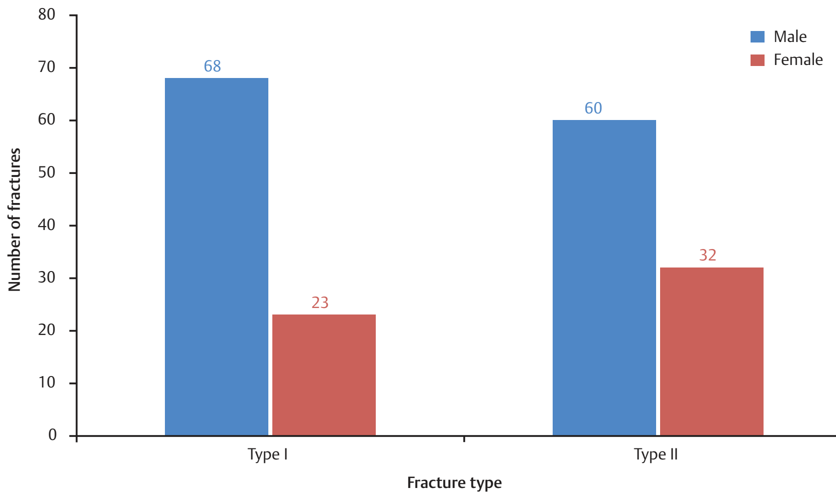
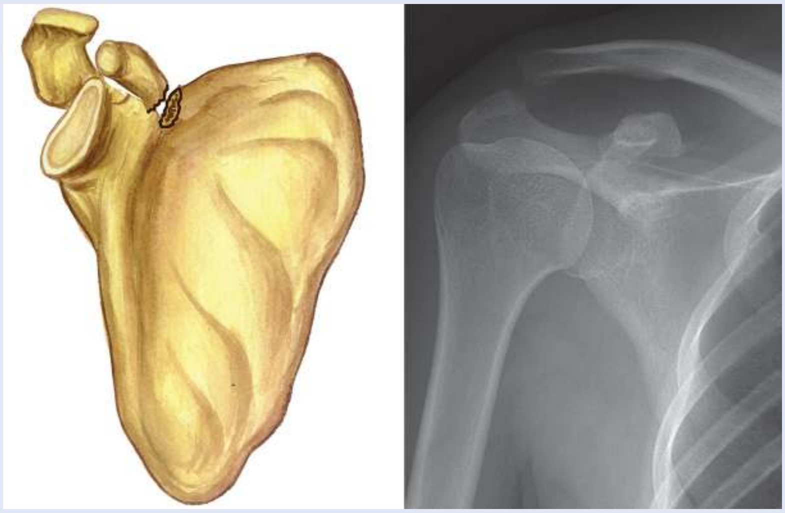
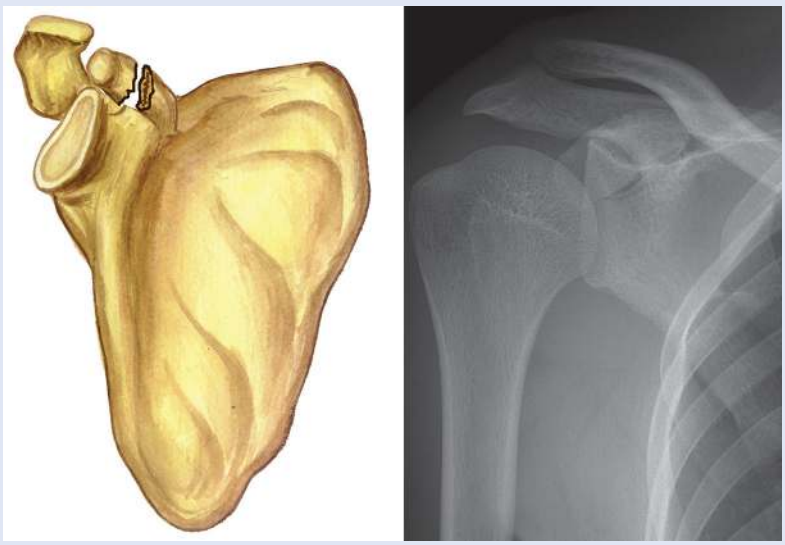
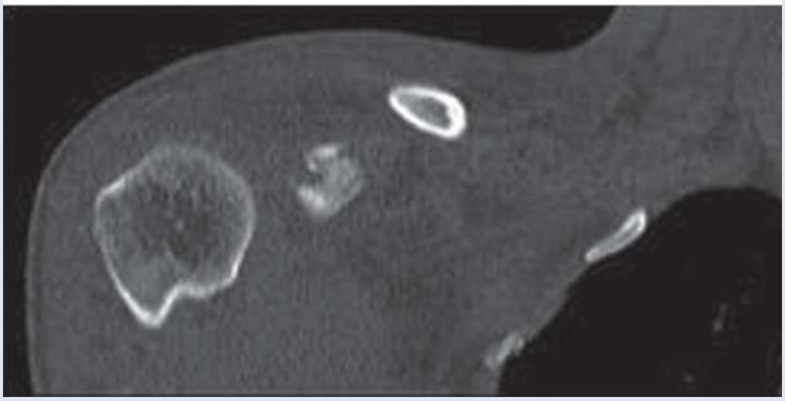


b

Fig. 10.47 (a) Fracture type distribution of 183 coracoid fractures. (b) Sex and fracture type distribution of 183 coracoid fractures.

Coracoid process fractures Types I–V	
Type I: Coracoid tip or epiphyseal fracture	**Coracoid Type I** 
Type II: Mid process	**Coracoid Type II** 
Type III: Basal fracture	**Coracoid Type III** 

Coracoid process fractures Types I–V	
Type IV: Involvement of the superior body of the scapula	**Coracoid Type IV**  
Type V: Extension into the glenoid fossa	**Coracoid Type V**   

Ogawa classification of coracoid fractures	
Type I Basal fracture 91 fractures M: 68 (74.73%) F: 23 (25.27%) 49.73% of coracoid	**Ogawa Type I**  
Type II Avulsion fracture 92 fractures M: 60 (65.22%) F: 32 (34.78%) 50.27% of coracoid	**Ogawa Type II**   

■ Acromion Fractures

Acromion fractures usually occur in two anatomic zones (▶ Fig. 10.48). Fractures of zone I are classified into three types:

- *Type IA*: avulsion fractures
- *Type IB*: nondisplaced fractures
- *Type II*: displaced fractures with no reduction of the subacromial space
- *Type III*: displaced fractures, with reduction of the subacromial space

Fractures of zone II are basal fractures of the acromion.

Clinical Epidemiologic Features of Acromion Fractures

A total of 592 acromion fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011; the fractures accounted for 18.96% of scapular fractures. Their epidemiologic features are as follows:

- More males than females
- The high-risk age group is 16–20 years
- Fractures occur mostly in zone I, with type IB as the most common fracture type

Fig. 10.48 Two zones of acromion fractures.

■ Acromion Fractures by Sex

See ▶ Table 10.34 and ▶ Fig. 10.49.

Table 10.34 Sex distribution of 592 acromion fractures

Sex	Number of fractures	Percentage
Male	450	76.01
Female	142	23.99
Total	592	100.00

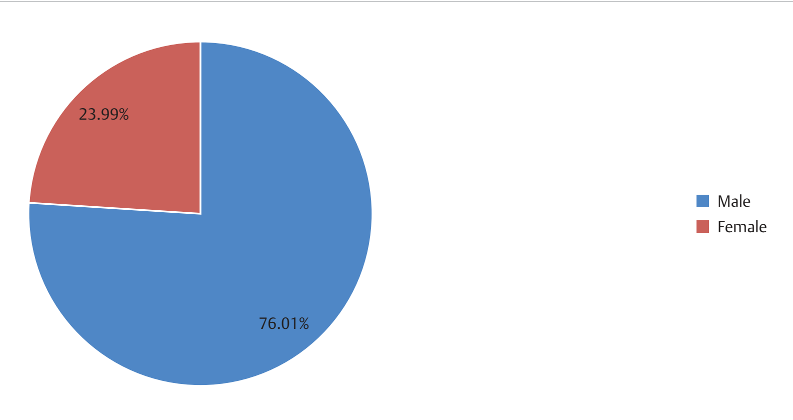


Fig. 10.49 Sex distribution of 592 acromion fractures.

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■ Acromion Fractures by Age Group

See ▶ Table 10.35 and ▶ Fig. 10.50.

Table 10.35 Age and sex distribution of 592 acromion fractures

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	0	2	2	0.34
6–10	5	1	6	1.01
11–15	28	10	38	6.42
16–20	70	4	74	12.50
21–25	42	10	52	8.78
26–30	31	3	34	5.74
31–35	49	6	55	9.29
36–40	43	12	55	9.29
41–45	51	21	72	12.16
46–50	37	18	55	9.29
51–55	30	8	38	6.42
56–60	28	13	41	6.93
61–65	15	7	22	3.72
66–70	9	6	15	2.53
71–75	5	10	15	2.53
76–80	4	6	10	1.69
81–85	2	2	4	0.68
≥ 86	1	3	4	0.68
Total	450	142	592	100.00

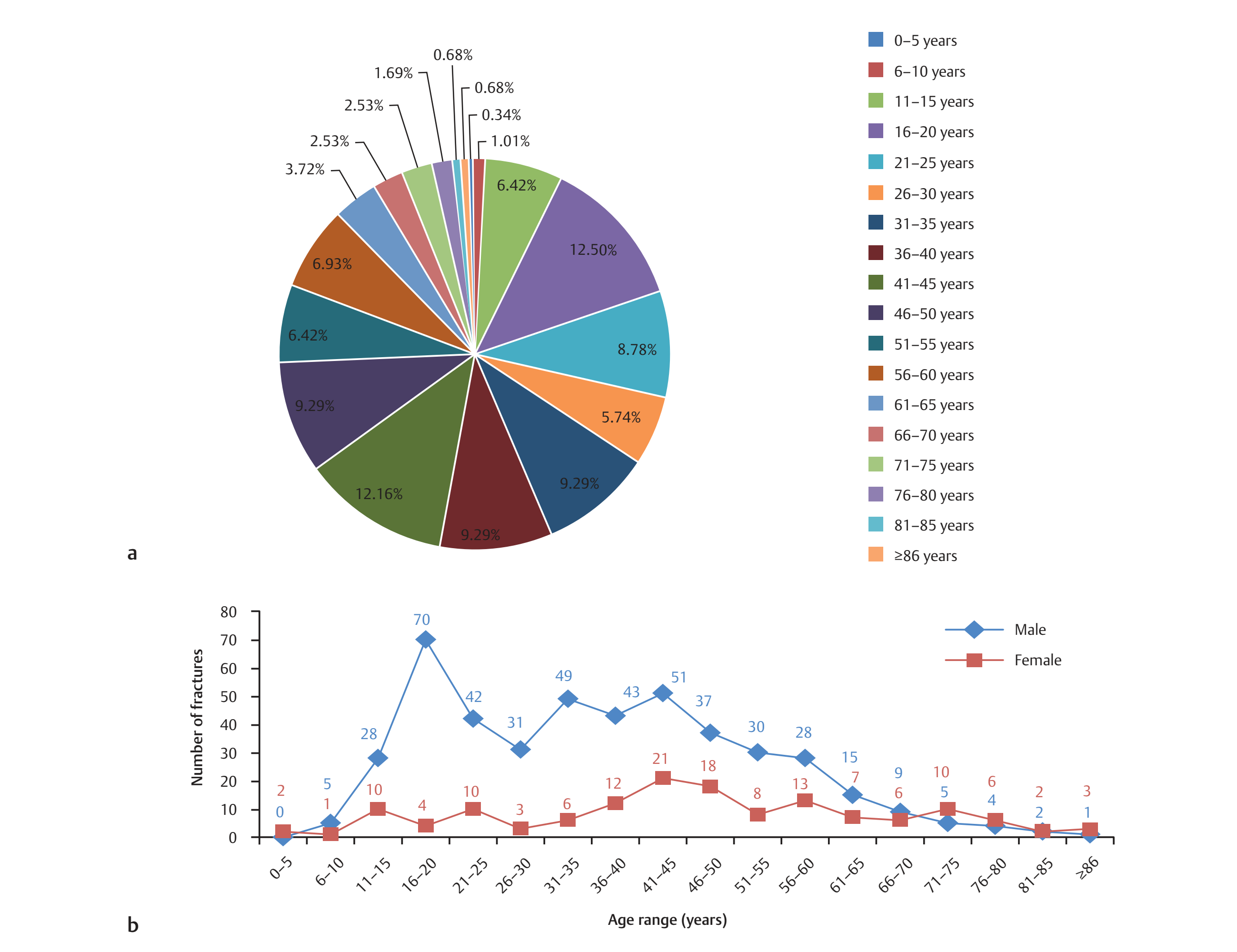

Fig. 10.50 (**a**) Age distribution of 592 acromion fractures. (**b**) Age and sex distribution of 592 acromion fractures.

■ Acromion Fractures by Fracture Type

See ▶ Table 10.36 and ▶ Fig. 10.51.

Table 10.36 Fracture type distribution of 592 acromion fractures

Fracture type		Male	Female	Number of fractures	Percentage
Zone I	Type IA	140	43	183	30.91
	Type IB	151	48	199	33.61
	Type II	65	22	87	14.70
	Type III	32	9	41	6.93
Zone II		62	20	82	13.85
Total		450	142	592	100

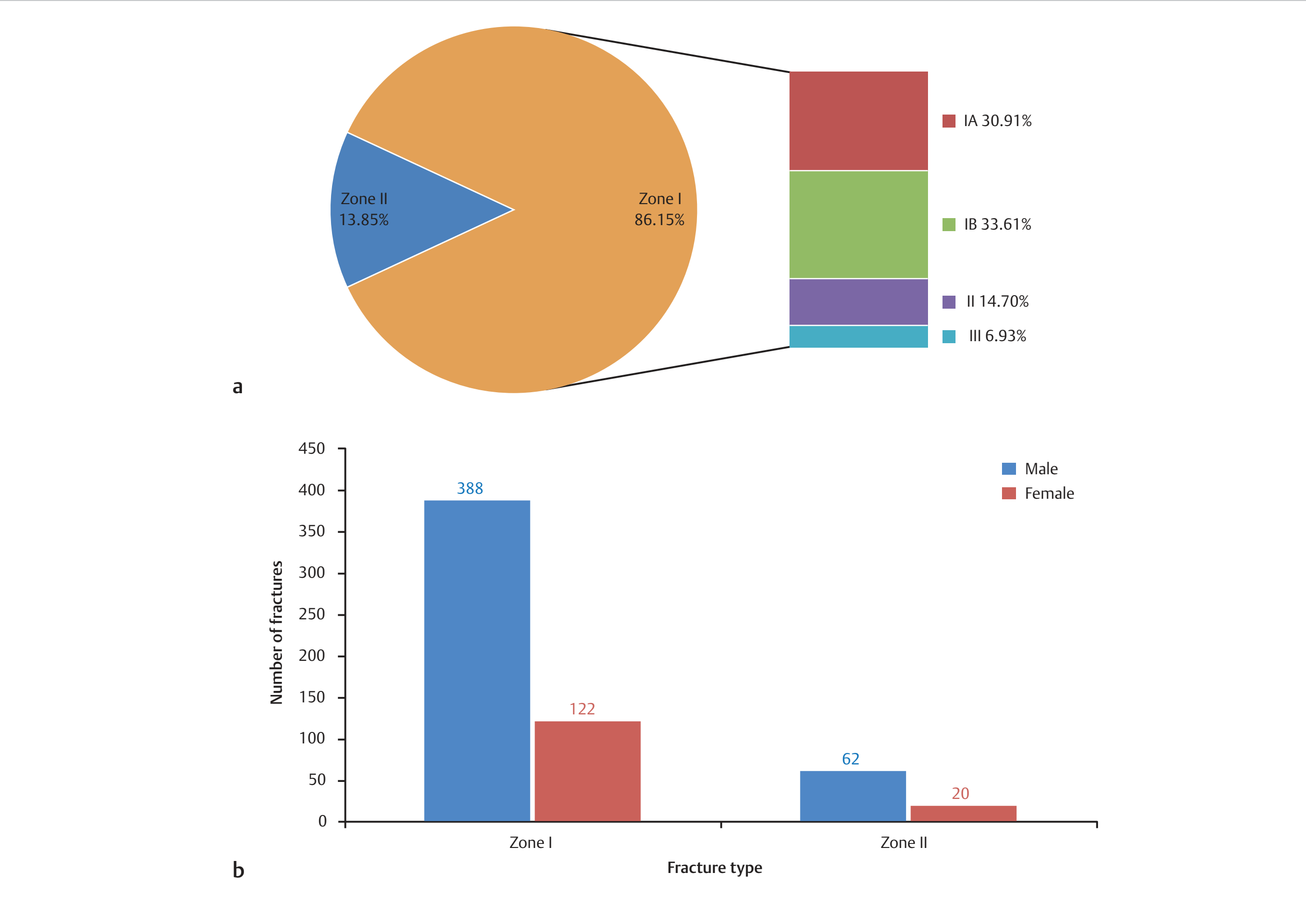

Fig. 10.51 (**a**) Fracture type distribution of 592 acromion fractures. (**b**) Sex and fracture type distribution of 592 acromion fractures.

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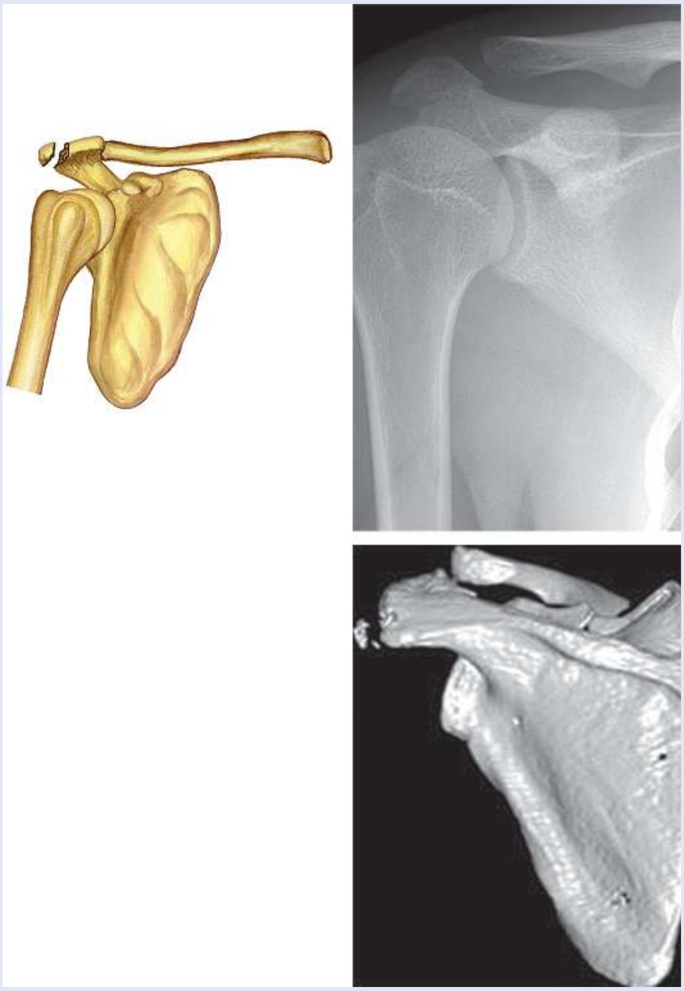
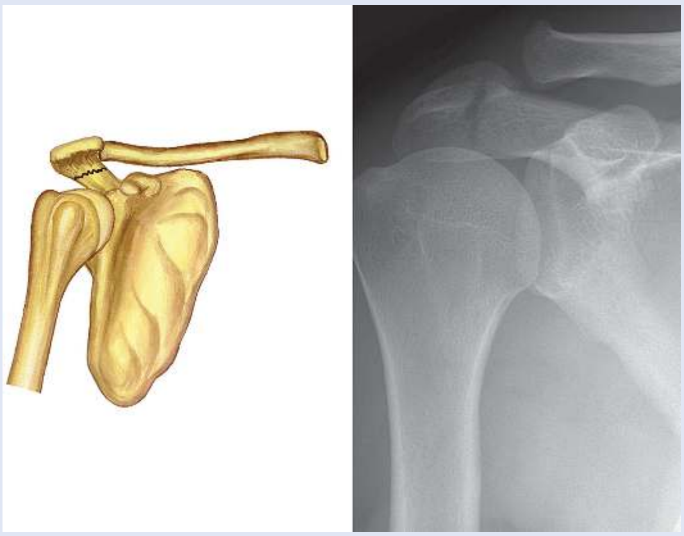
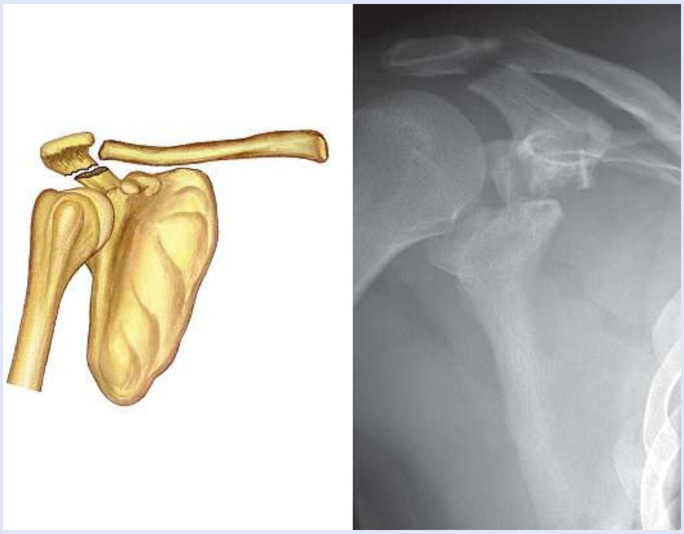
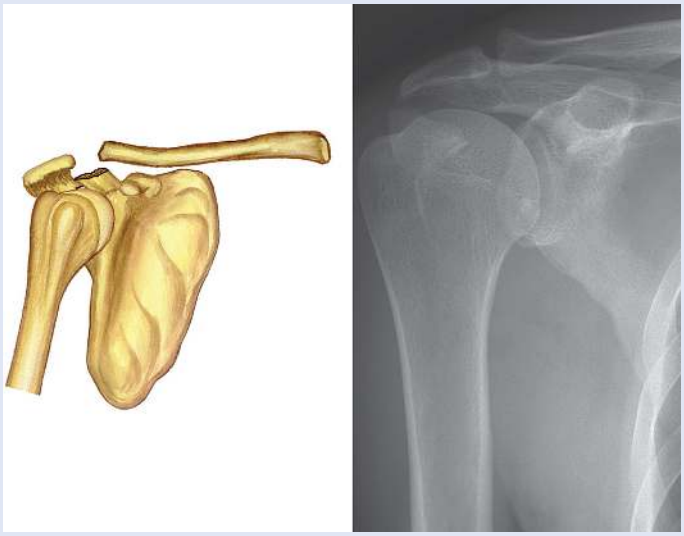
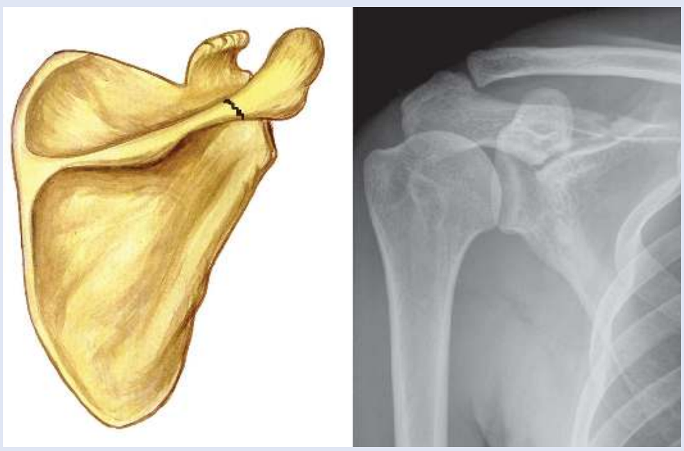
Classification of acromion fractures		
Zone I 510 fractures M: 388 (76.08%) F: 122 (23.92%) 86.15% of acromion	**Type IA Avulsion fractures** 183 fractures M: 140 (76.50%) F: 43 (23.50%) 35.88% of Zone I 30.91% of acromion	**Acromion Zone I Type IA** 
	Type IB Nondisplaced fractures 199 fractures M: 151 (75.88%) F: 48 (24.12%) 39.02% of Zone I 33.61% of acromion	**Acromion Zone I Type IB** 

Classification of acromion fractures		
	Type II Displaced fractures with no reduction of the subacromial space 87 fractures M: 65 (74.71%) F: 22 (25.29%) 17.06% of Zone I 14.70% of acromion	**Acromion Zone I Type II** 
	Type III Displaced fractures with reduction of the subacromial space 41 fractures M: 32 (78.05%) F: 9 (21.95%) 8.04% of Zone I 6.93% of acromion	**Acromion Zone I Type III** 
Zone II Basal fractures of the acromion 82 fractures M: 62 (75.61%) F: 20 (24.39%) 13.85% of acromion		**Acromion Zone II** 

■ Scapular Neck Fractures

Miler and coworkers classified scapular neck fractures into three types according to degree and directionality (translational or angulatory) of displacement.

- *Type I*: Anatomic neck fractures. The fracture line lies between the acromion-basal portion of the scapular spine (spinoglenoid notch) and the lateral coracoid. After the fracture occurs, the distal fragment and upper arm lose bony support from the clavicle and are usually displaced lateralward and downward, due to the persistent pull of the long head of the triceps, which originates on infraglenoid tubercle. Closed reduction alone cannot restore the anatomic alignment of the bony fragments (▶ Fig. 10.52).
- *Type II*: Surgical neck fractures involving the base of the acromion or the scapular spine. The fracture line runs downward and lateralward from the suprascapular notch medial to the coracoid process, and crosses the neck to the inferior glenoid. The lateral angle of the scapula can be displaced significantly; the degree of displacement is based upon the presence of an associated ipsilateral clavicle fracture and/or a coracoclavicular ligament tear. The latter results in the "functional imbalance" of the superior suspensory shoulder complex (SSCS) and instability of the entire shoulder and arm. When the coracoclavicular ligament tears, the distal fragment along with the shoulder separate from the clavicle due to muscle traction and the weight of the upper limb, which is displaced forward, downward, and rotated medially. Clinically, ipsilateral fractures of the clavicle and scapular neck, or dislocation of the acromioclavicular joint, are called floating shoulder injuries.
- *Type III*: Transverse fractures of the inferior scapular neck. The fracture line extends from the inferior portion of the scapular spine to the medial border of the scapula. Additionally, this type of fracture is classified into two subtypes:
  - *Stable fracture:* Fracture displacement of less than 1 cm with angulations of less than 40 degrees.
  - *Unstable fracture:* Fracture displacement of greater than 1 cm with angulations of more than 40 degrees.

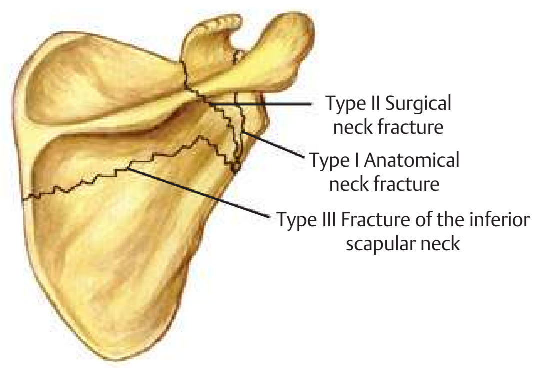


Fig. 10.52 Types of scapular neck fractures.

Clinical Epidemiologic Features of Scapular Neck Fractures

A total number of 841 scapular neck fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011; the fractures accounted for 26.93% of scapular fractures. Their epidemiologic features are as follows:

- More males than females
- The high-risk age group is 41–45 years
- Surgical neck fractures are the most common type of scapular neck fractures, the majority of which are stable fractures

10

■ Scapular Neck Fractures by Sex

See ▶ Table 10.37 and ▶ Fig. 10.53.

Table 10.37 Sex distribution of 841 scapular neck fractures

Sex	Number of fractures	Percentage
Male	643	76.46
Female	198	23.54
Total	841	100.00

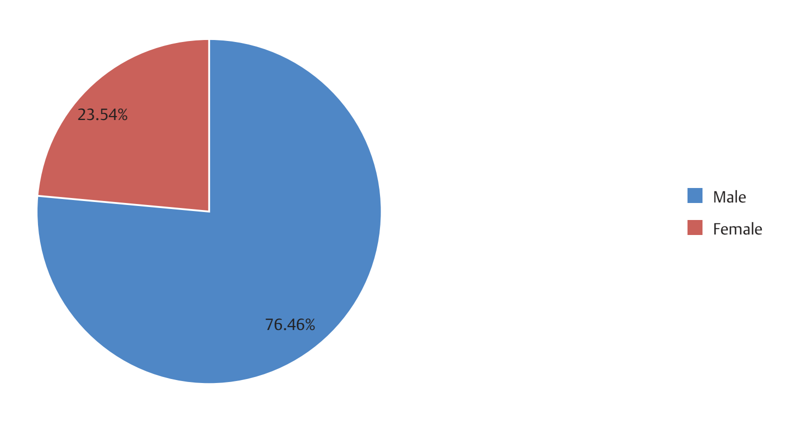


Fig. 10.53 Sex distribution of 841 scapular neck fractures.

■ Scapular Neck Fractures by Age Group

See ▶ Table 10.38 and ▶ Fig. 10.54.

Table 10.38 Age and sex distribution of 841 scapular neck fractures

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	4	1	5	0.59
6–10	3	0	3	0.36
11–15	6	1	7	0.83
16–20	17	4	21	2.50
21–25	32	6	38	4.52
26–30	79	9	88	10.46
31–35	60	16	76	9.04
36–40	80	35	115	13.67
41–45	116	19	135	16.05
46–50	80	16	96	11.41
51–55	51	22	73	8.68
56–60	45	27	72	8.56
61–65	30	14	44	5.23
66–70	20	17	37	4.40
71–75	9	7	16	1.90
76–80	7	2	9	1.07
81–85	2	2	4	0.48
≥ 86	2	0	2	0.24
Total	643	198	841	100.00

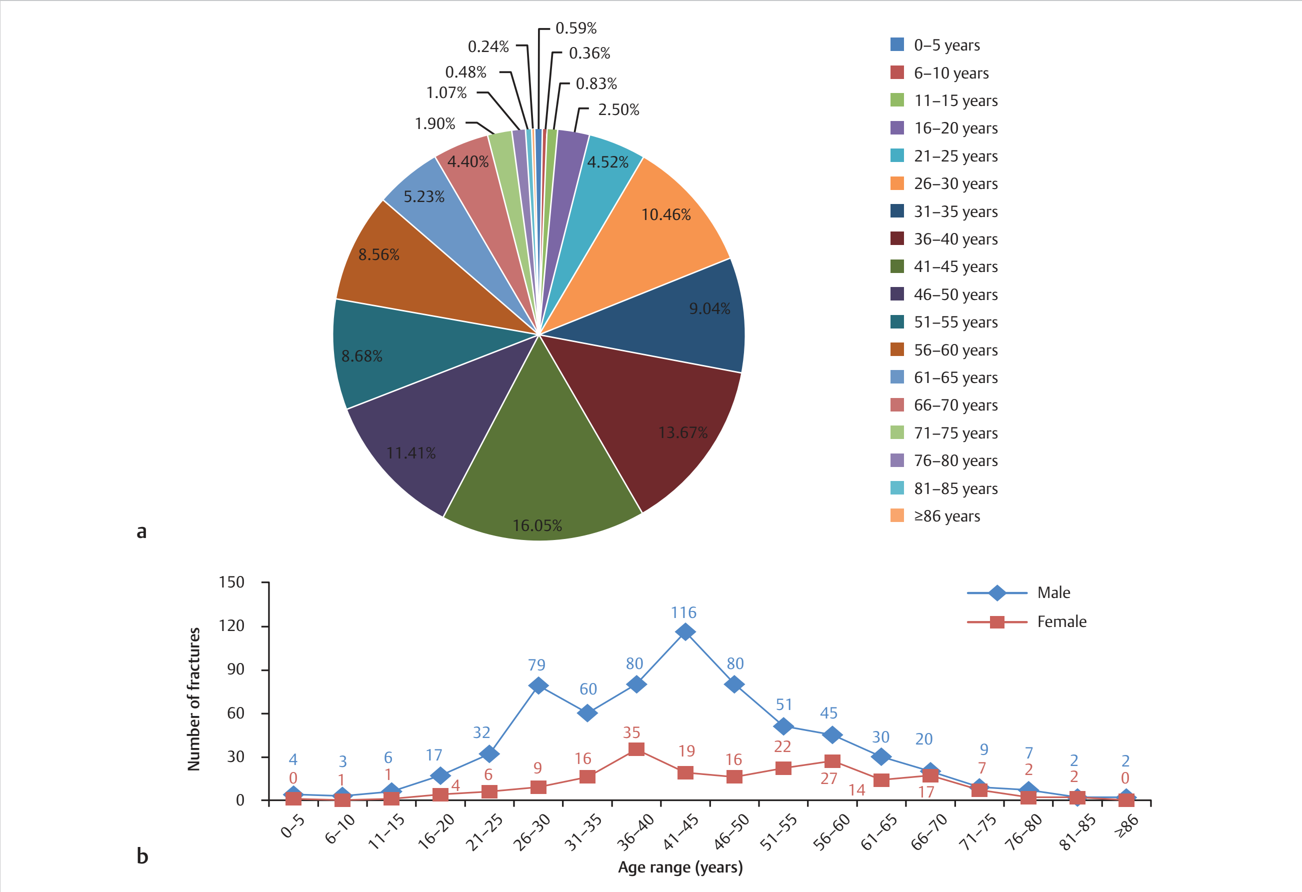


Fig. 10.54 (**a**) Age distribution of 841 scapular neck fractures. (**b**) Sex and age distribution of 841 scapular neck fractures.

■ Scapular Neck Fractures by Fracture Type

See ▶ Table 10.39, ▶ Table 10.40, ▶ Fig. 10.55, and ▶ Fig. 10.56.

Table 10.39 Sex and fracture type distribution of 841 scapular neck fractures by fracture line direction

Fracture type	Male	Female	Number of fractures	Percentage
I	87	30	117	13.91
II	269	97	366	43.52
III	287	71	358	42.57
Total	643	198	841	100.00

Table 10.40 Sex and fracture type distribution of 841 scapular neck fractures by degree of fracture displacement

Fracture type	Male	Female	Number of fractures	Percentage
Stable	311	119	430	51.13
Unstable	332	79	411	48.87
Total	643	198	841	100.00

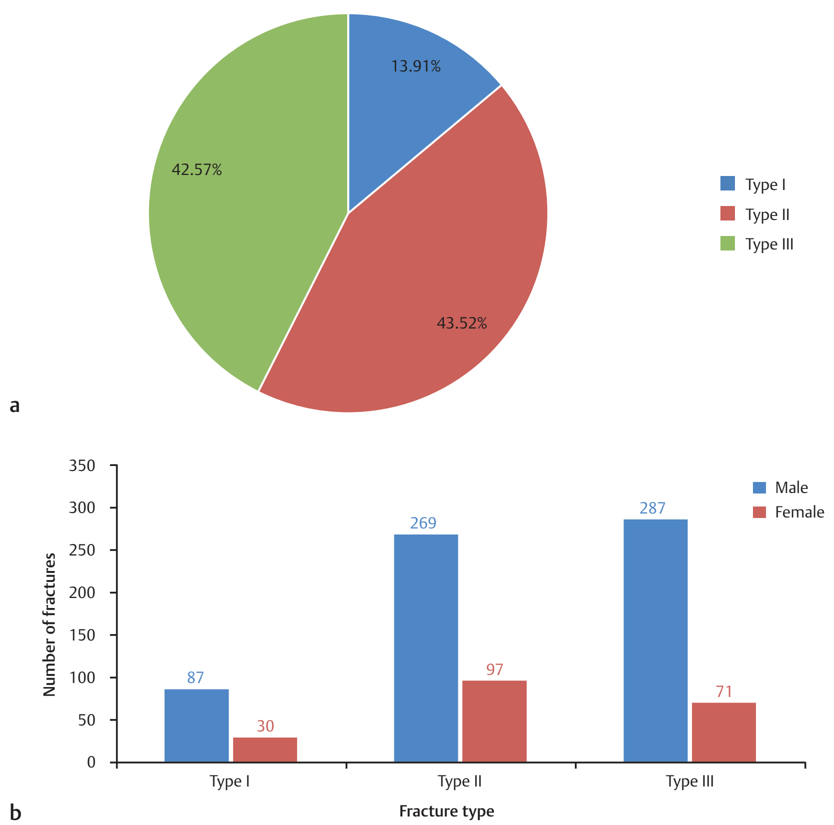


Fig. 10.55 (**a**) Fracture type distribution of 841 scapular neck fractures. (**b**) Sex and fracture type distribution of 841 scapular neck fractures.

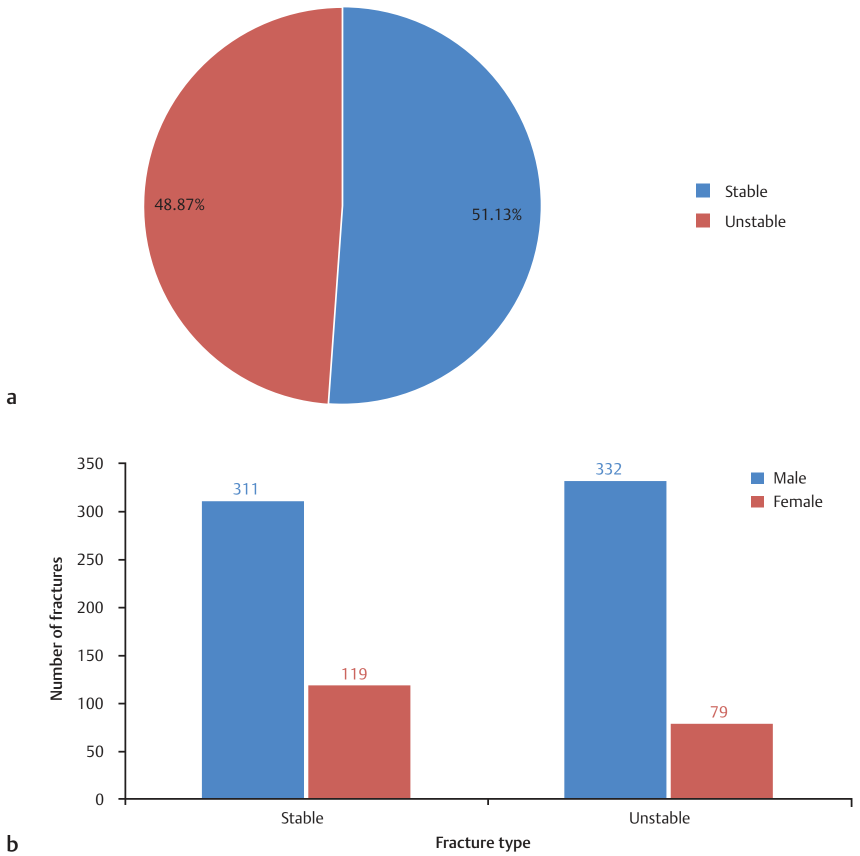
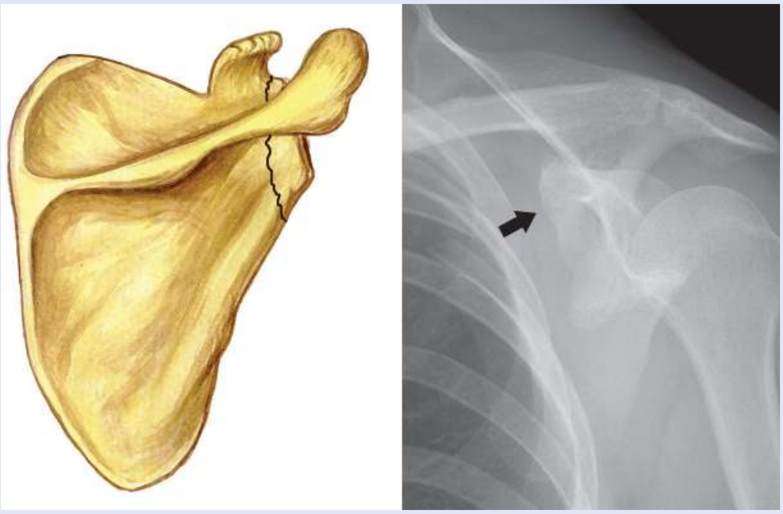
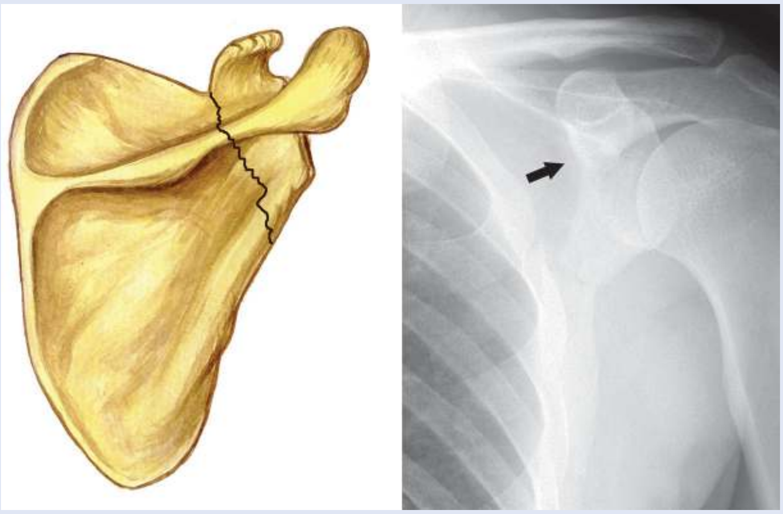
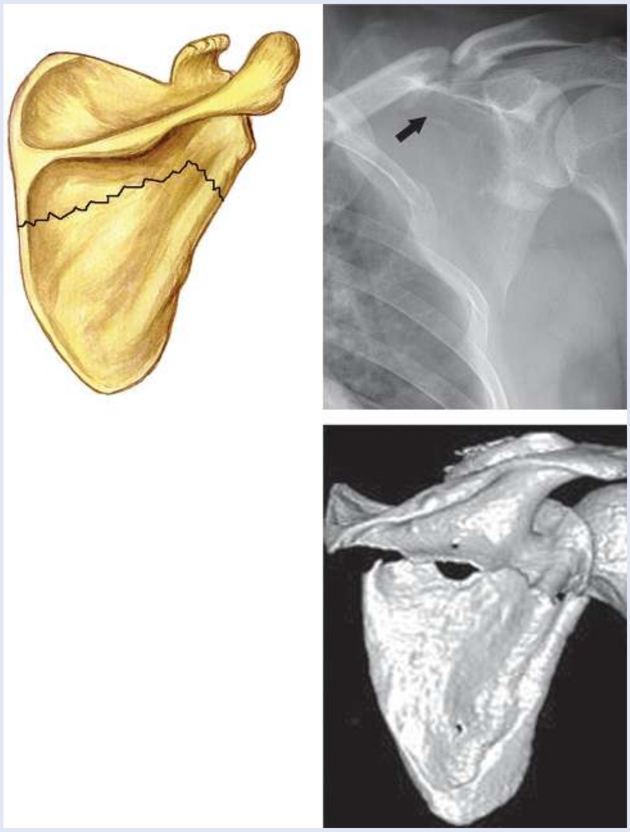


Fig. 10.56 (**a**) Fracture type distribution of 841 scapular neck fractures. (**b**) Sex and fracture type distribution of 841 scapular neck fractures.

Classification of scapular neck fractures	
Anatomic neck fractures 117 fractures M: 87 (74.36%) F: 30 (25.64%) 13.91% of scapular neck	**Scapular anatomic neck fractures** 
Surgical neck fractures 366 fractures M: 269 (73.50%) F: 97 (26.50%) 43.52% of scapular neck	**Scapular surgical neck fractures** 

Classification of scapular neck fractures	
Inferior neck fractures 358 fractures M: 287 (80.17%) F: 71 (19.83%) 42.57% of scapular neck	**Scapular inferior neck fractures** 

Glenoid Fractures

Ideberg classified glenoid fractures into six types based on fracture location and injury mechanism:

- *Type I*: fractures of the glenoid rim:
  - *Type Ia*: anterior
  - *Type Ib*: posterior
- *Type II*: with an external force applied, the humeral head impacts the glenoid fossa obliquely downward, resulting in fractures through the glenoid fossa:
  - *Type IIa*: transverse fracture through the glenoid fossa exiting inferiorly
  - *Type IIb*: oblique fracture through the glenoid fossa exiting inferiorly
- *Type III*: an external force presses the humeral head against the glenoid fossa obliquely upward, resulting in oblique fractures through the glenoid that exit at the superior border of the scapula. This type is often associated with acromioclavicular fractures or dislocations.
- *Type IV*: a transverse fracture line exits through the medial border of the scapula. This fracture type results from impaction of the humeral head into the center of the glenoid fossa; of two resulting fragments, the smaller one is at the top, the larger one on the bottom.
- *Type V*: combination of a types II, III, and IV patterns. The major fracture line extends from the glenoid fossa to the medial border of the scapula, and is commonly caused by a strong external force:
  - *Type Va*: combination of types II and IV patterns
  - *Type Vb*: combination of types III and IV patterns
  - *Type Vc*: combination of types II, III, and IV patterns
- *Type VI*: severe comminution of the glenoid surface.

Clinical Epidemiologic Features of Glenoid Fractures

A total of 519 glenoid fractures were treated in 83 hospitals of China over a 2-year period from 2010 to 2011; the fractures accounted for 16.62% of scapular fractures. Their epidemiologic features are as follows:

- More males and females
- The high-risk age group is 41–45 years
- The most common fracture type is type II

Glenoid Fractures by Sex

See ▶ Table 10.41 and ▶ Fig. 10.57.

Table 10.41 Sex distribution of 519 glenoid fractures

Sex	Number of fractures	Percentage
Male	371	71.48
Female	148	28.52
Total	519	100.00

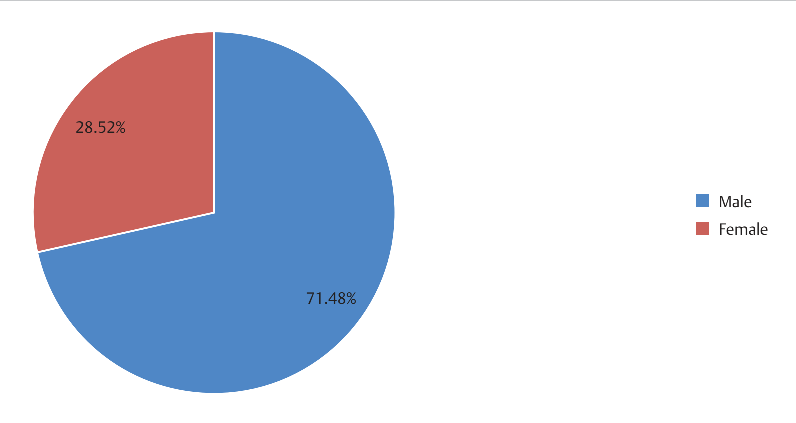


Fig. 10.57 Sex distribution of 519 glenoid fractures.

■ Glenoid Fractures by Age Group

See ▶ Table 10.42 and ▶ Fig. 10.58.

Table 10.42 Age and sex distribution of 519 glenoid fractures

Age group (years)	Male	Female	Number of fractures	Percentage
0–5	0	0	0	0.00
6–10	0	0	0	0.00
11–15	4	3	7	1.35
16–20	16	2	18	3.47
21–25	25	2	27	5.20
26–30	31	6	37	7.13
31–35	26	8	34	6.55
36–40	37	15	52	10.02
41–45	47	17	64	12.33
46–50	41	17	58	11.18
51–55	38	15	53	10.21
56–60	37	17	54	10.40
61–65	29	8	37	7.13
66–70	20	11	31	5.97
71–75	8	13	21	4.05
76–80	6	8	14	2.70
81–85	3	4	7	1.35
≥ 86	3	2	5	0.96
Total	371	148	519	100.00

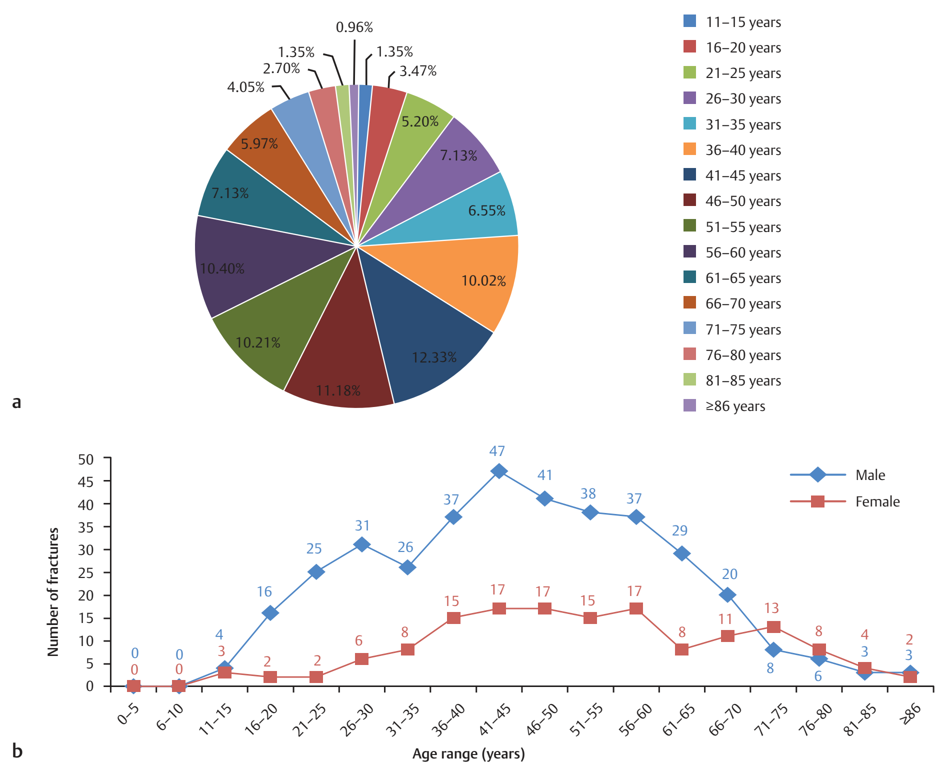


Fig. 10.58 (a) Age distribution of 519 glenoid fractures. (b) Age and sex distribution of 591 glenoid fractures.

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■ Glenoid Fractures by Fracture Type

See ▶ Table 10.43 and ▶ Fig. 10.59.

Table 10.43 Sex and fracture type distribution of 519 glenoid fractures

Fracture type	Male	Female	Number of fractures	Percentage
I	61	42	103	19.85
II	163	54	217	41.81
III	27	10	37	7.13
IV	24	11	35	6.74
V	66	23	89	17.15
VI	30	8	38	7.32
Total	371	148	519	100.00

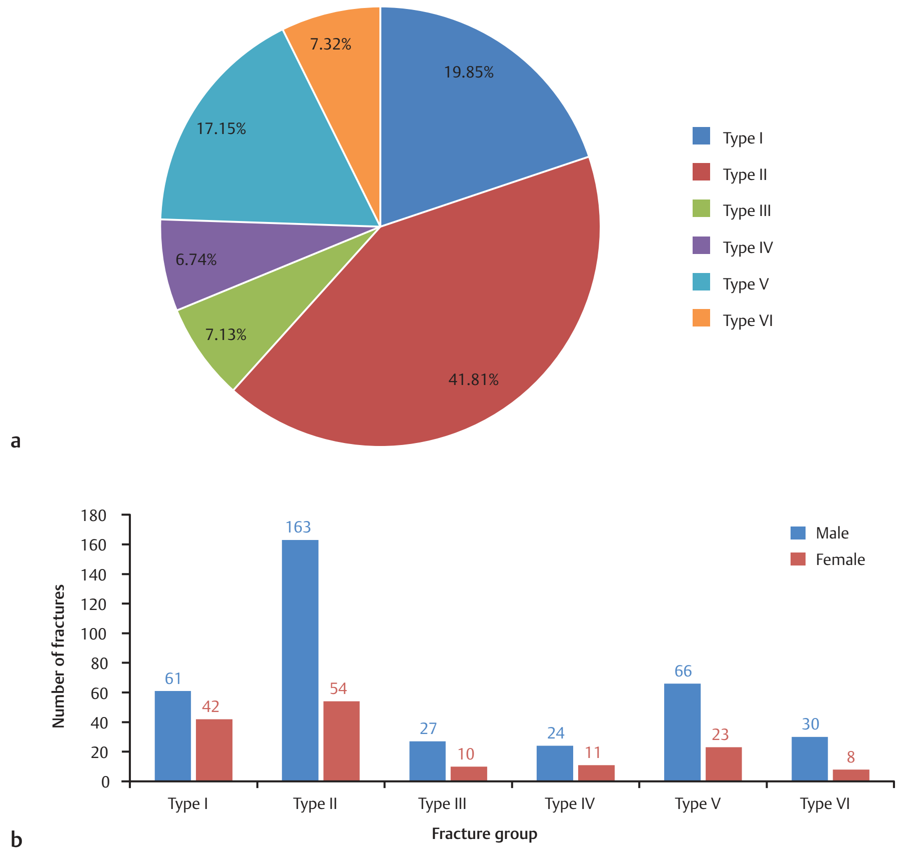
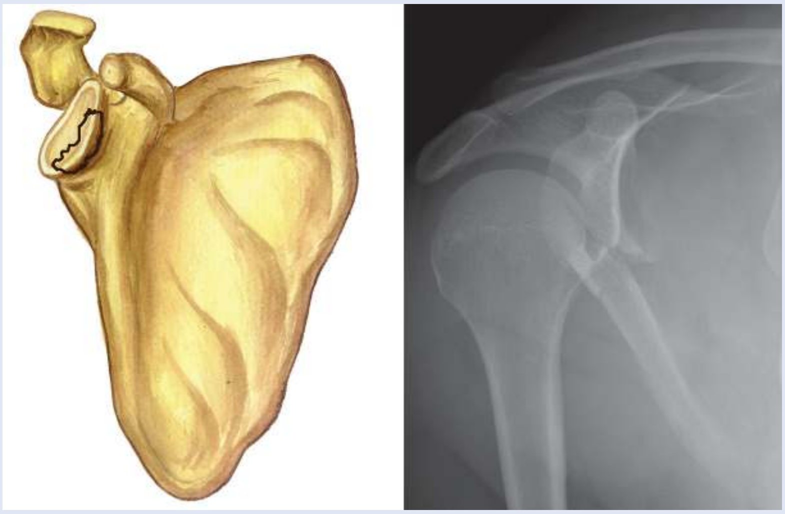
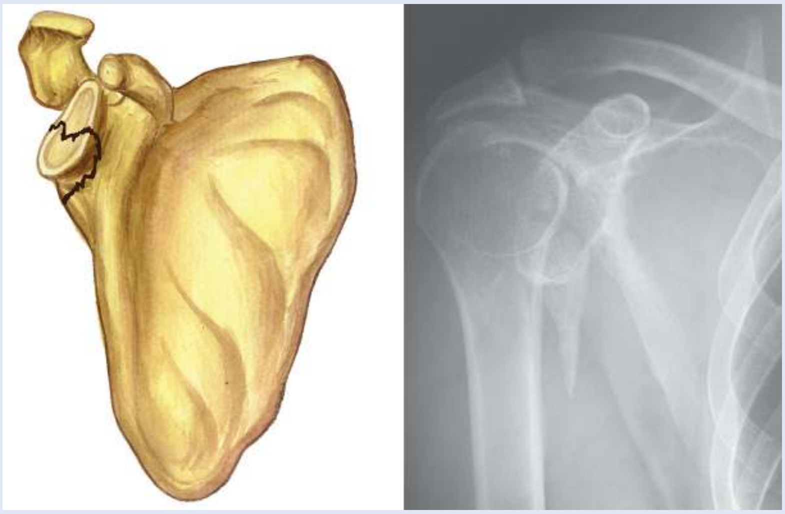
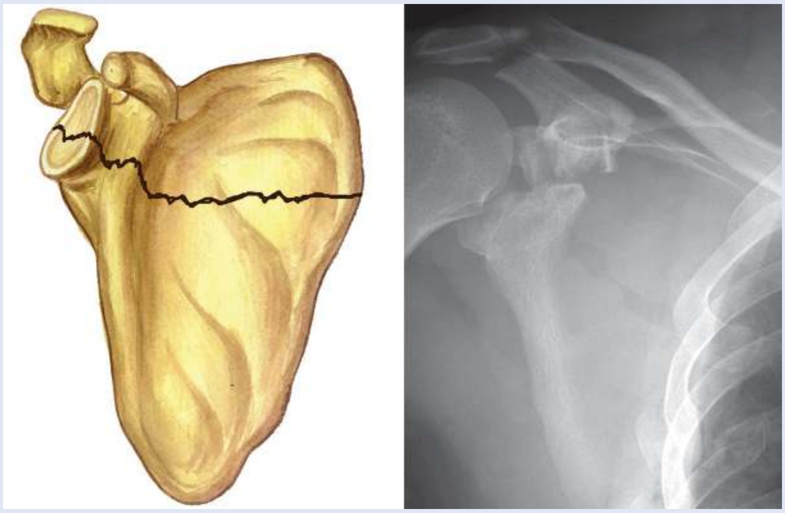
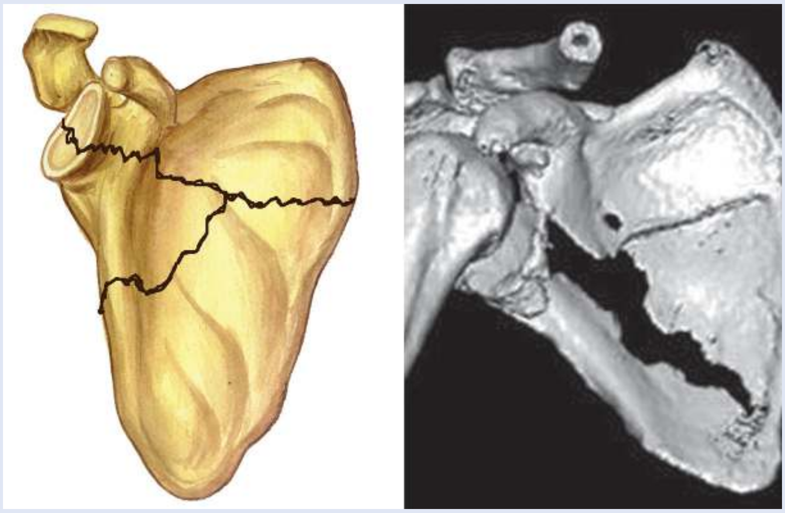
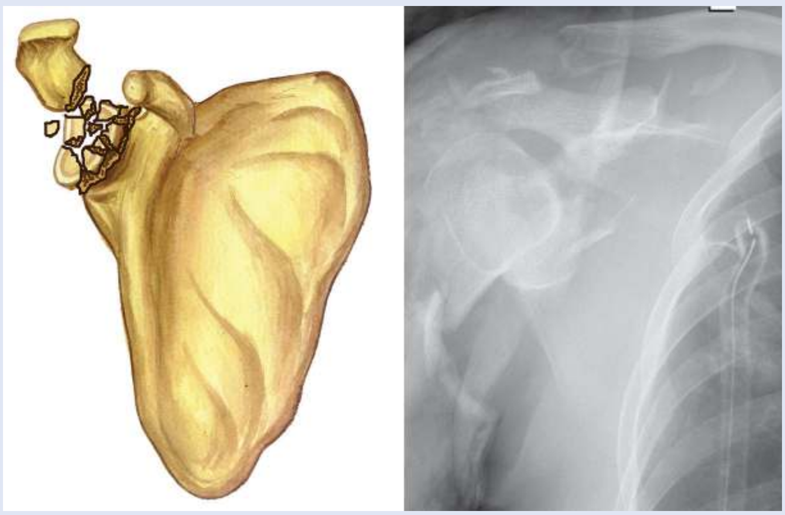


Fig. 10.59 (**a**) Fracture type distribution of 591 glenoid fractures. (**b**) Sex and fracture type distribution of 591 glenoid fractures.

Ideberg classification of glenoid fractures	
Type I Glenoid rim 103 fractures M: 61 (59.22%) F: 42 (40.78%) 19.85% of glenoid	**Ideberg Type I** 
Type II Fracture line exiting inferior part of glenoid fossa 217 fractures M: 163 (75.12%) F: 54 (24.88%) 41.81% of glenoid	**Ideberg Type II** 
Type III Fracture line exiting superior part of glenoid fossa 37 fractures M: 27 (72.97%) F: 10 (27.03%) 7.13% of glenoid	**Ideberg Type III** 

10

Ideberg classification of glenoid fractures	
Type IV Transverse fracture from the glenoid fossa to the medial border of the scapula 35 fractures M: 24 (68.57%) F: 11 (31.43%) 6.74% of glenoid	**Ideberg Type IV** 
Type V Combination of fractures of the glenoid fossa and the body of the scapula 89 fractures M: 66 (74.16%) F: 23 (25.84%) 17.15% of glenoid	**Ideberg Type V** 
Type VI Severe comminution of the glenoid fossa 38 fractures M: 30 (78.95%) F: 8 (21.05%) 7.32% of glenoid	**Ideberg Type VI** 

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11 Epidemiologic Features of Fractures in Taiwan Between 2011 and 2013

Tao Zhang, Pan Hu, Xiaodong Cheng, and Peizhi Yuwen

Introduction to the Taiwan Study

A total of 390,133 patients with 424,645 fractures were investigated in Taiwan between 2011 and 2013. Among the 390,133 patients, 199,804 were males and 190,329 were females. The epidemiologic features of fractures in Taiwan are discussed in this chapter.

Fractures by Sex

In general, there were more males than females (▶ Table 11.1; ▶ Fig. 11.1). There were more males in the patients below 55 years and more females in the subjects aged older than 55 years (▶ Table 11.2; ▶ Fig. 11.2).

Table 11.1 Sex distribution of 390,133 patients with fractures

Sex	Number of patients	Percentage
Male	199,804	51.21
Female	190,329	48.79
Total	390,133	100.00

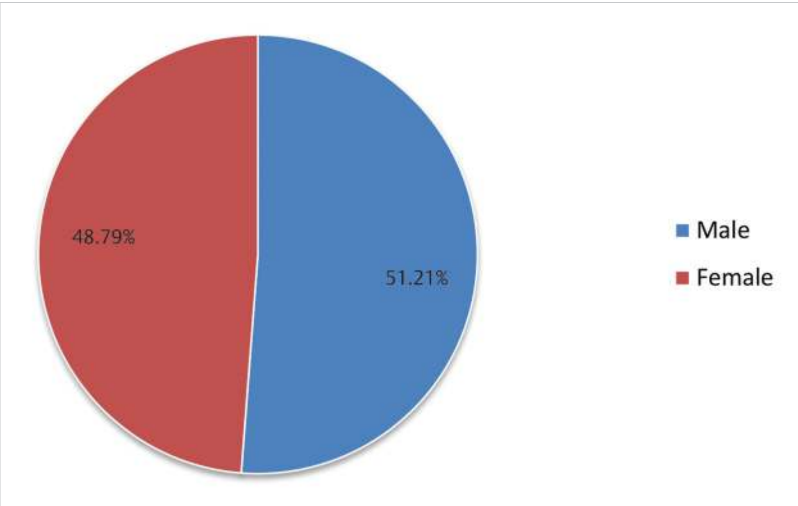

Fig. 11.1 Sex distribution of 390,133 patients with fractures.

Table 11.2 Age and sex distribution of 390,133 patients with fractures

Age group (years)	Male	Female	Total	Percentage
0–5	1,454	1,093	2,547	0.65
6–10	4,026	2,039	6,065	1.55
11–15	8,824	2,209	11,033	2.83
16–20	16,431	6,209	22,640	5.80
21–25	14,350	5,880	20,230	5.19
26–30	12,964	5,120	18,084	4.64
31–35	13,584	5,437	19,021	4.88
36–40	12,991	5,588	18,579	4.76
41–45	13,872	6,323	20,195	5.18
46–50	15,063	9,079	24,142	6.19
51–55	14,919	14,325	29,244	7.50
56–60	13,729	18,680	32,409	8.31
61–65	10,881	17,666	28,547	7.32
66–70	8,186	15,564	23,750	6.09
71–75	9,303	19,827	29,130	7.47
76–80	9,399	20,324	29,723	7.62
81–85	10,805	18,337	29,142	7.47
≥ 86	9,023	16,629	25,652	6.58
Total	199,804	190,329	390,133	100.00

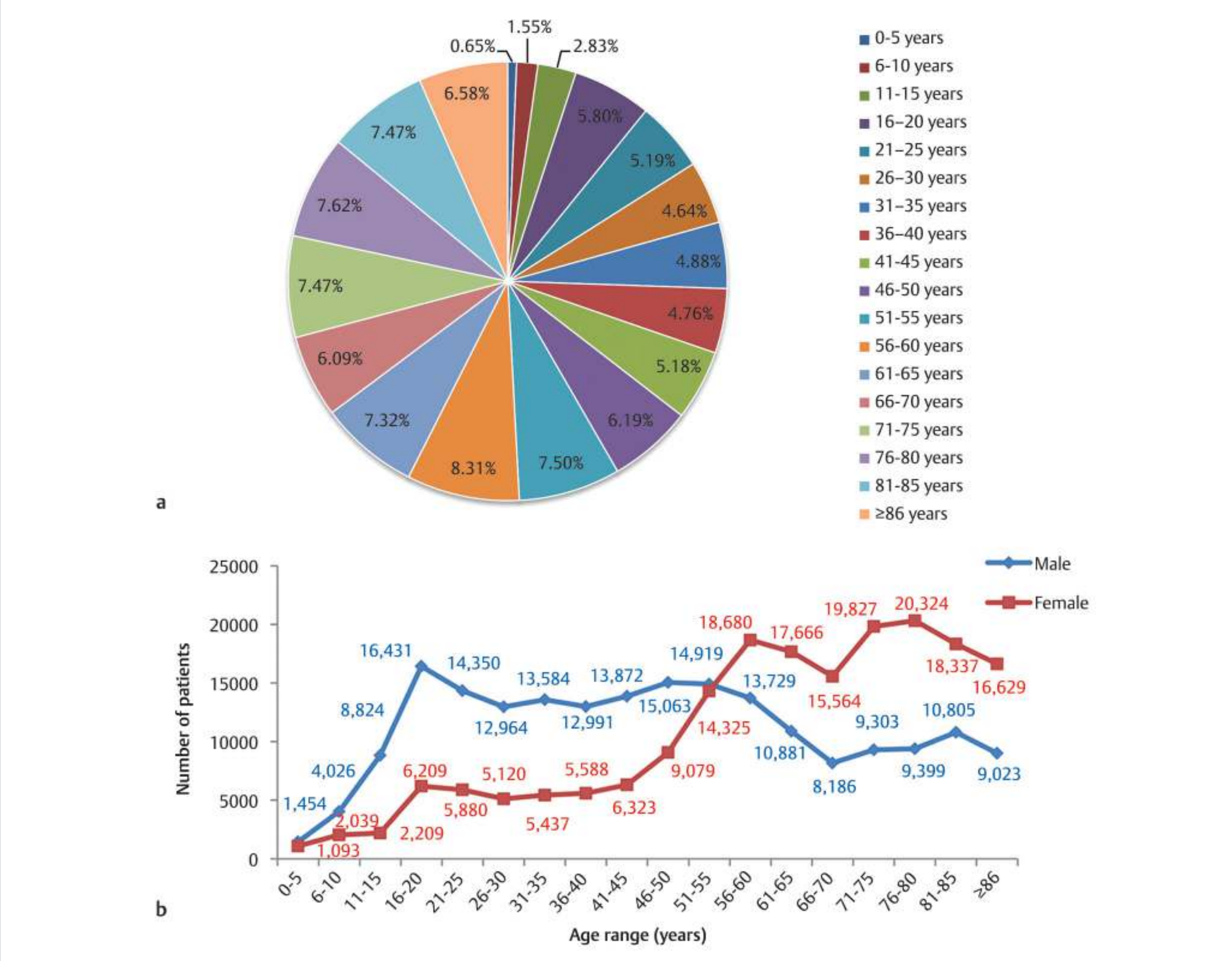

Fig. 11.2 (**a**) Age distribution of 390,133 patients with fractures. (**b**) Age and sex distribution of 390,133 patients with fractures.

Fractures by Age Group and Sex

Patients with Humeral Fractures

A total of 29,620 patients with humeral fractures were treated in Taiwan over a 3-year period from 2011 to 2013. The fractures accounted for 7.59% of all patients with fractures. In general, there were more males than females (▶ Table 11.3; ▶ Fig. 11.3). There were more males in the patients below 50 years and more females in the subjects aged older than 50 years.

Table 11.3 Age and sex distribution of 29,620 patients with humeral fractures

Age group (years)	Male	Female	Total	Percentage
0–5	683	606	1,289	4.35
6–10	1,336	693	2,029	6.85
11–15	839	256	1,095	3.70
16–20	657	334	991	3.35
21–25	644	337	981	3.31
26–30	559	322	881	2.97
31–35	660	378	1,038	3.50
36–40	684	418	1,102	3.72
41–45	803	468	1,271	4.29
46–50	903	728	1,631	5.51
51–55	940	1,220	2,160	7.29
56–60	818	1,714	2,532	8.55
61–65	632	1,778	2,410	8.14
66–70	505	1,554	2,059	6.95
71–75	570	1,890	2,460	8.31
76–80	512	1,744	2,256	7.62
81–85	510	1,414	1,924	6.50
≥ 86	402	1,109	1,511	5.10
Total	12,657	16,963	29,620	100.00

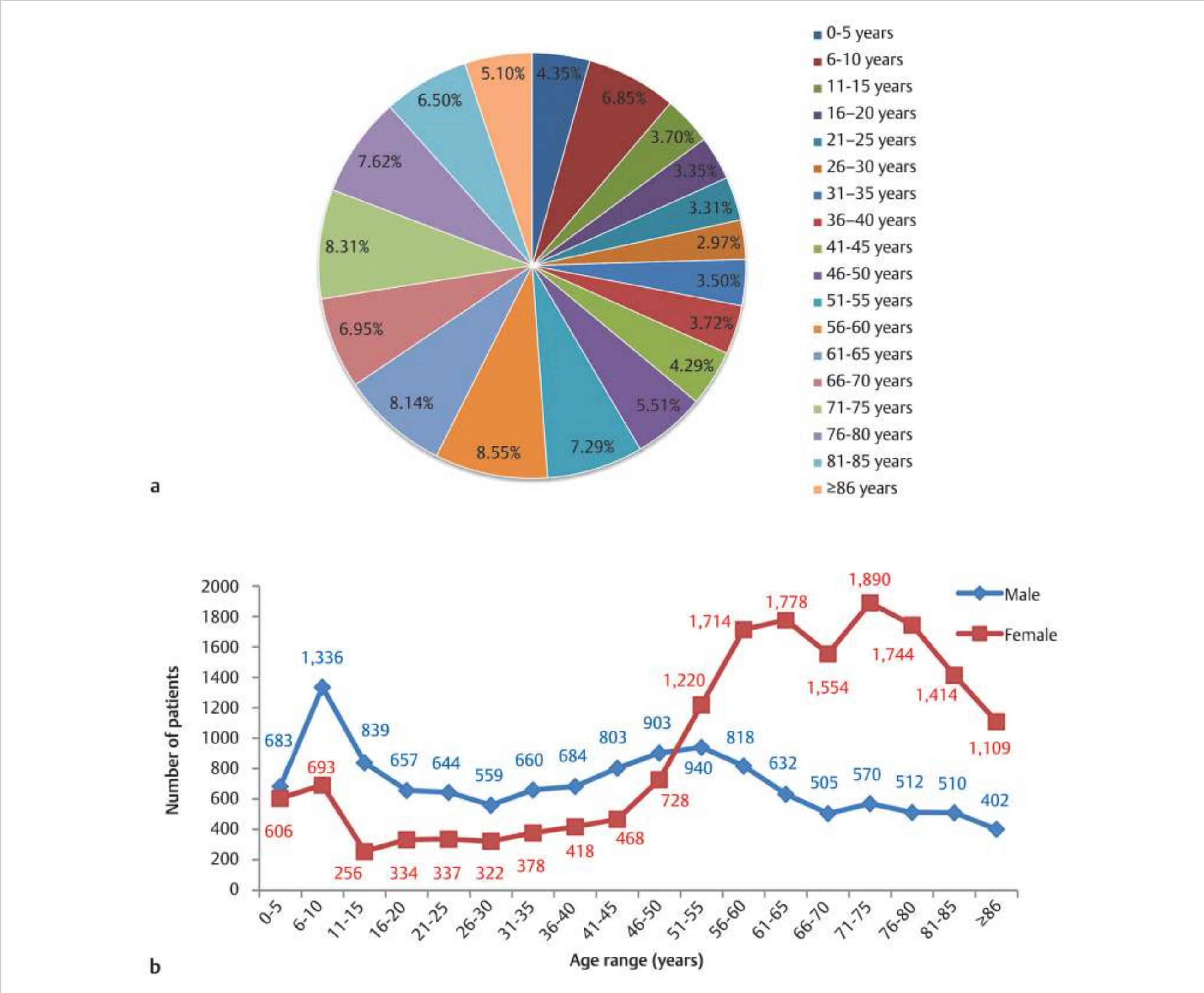

Fig. 11.3 (**a**) Age distribution of 29,620 patients with humeral fractures. (**b**) Age and sex distribution of 29,620 patients with humeral fractures.

11

Patients with Ulnar and Radial Fractures

A total of 77,738 patients with ulnar and radial fractures were treated in Taiwan over a 3-year period from 2011 to 2013. The fractures accounted for 19.93% of all patients with fractures. In general, there were more females than males (▶ Table 11.4; ▶ Fig. 11.4). There were more males in the patients below 50 years and more females in the subjects aged older than 50 years.

Table 11.4 Age and sex distribution of 77,738 patients with ulnar and radial fractures

Age group (years)	Male	Female	Total	Percentage
0–5	345	216	561	0.72
6–10	1,931	846	2,777	3.57
11–15	4,713	729	5,442	7.00
16–20	3,822	1,096	4,918	6.33
21–25	2,770	1,096	3,866	4.97
26–30	2,325	882	3,207	4.13
31–35	2,347	938	3,285	4.23
36–40	2,307	1,023	3,330	4.28
41–45	2,468	1,226	3,694	4.75
46–50	2,671	2,043	4,714	6.06
51–55	2,617	4,068	6,685	8.60
56–60	2,270	5,801	8,071	10.38
61–65	1,644	5,430	7,074	9.10
66–70	1,036	4,263	5,299	6.82
71–75	1,041	4,553	5,594	7.20
76–80	771	3,611	4,382	5.64
81–85	663	2,352	3,015	3.88
≥ 86	437	1,387	1,824	2.35
Total	36,178	41,560	77,738	100.00

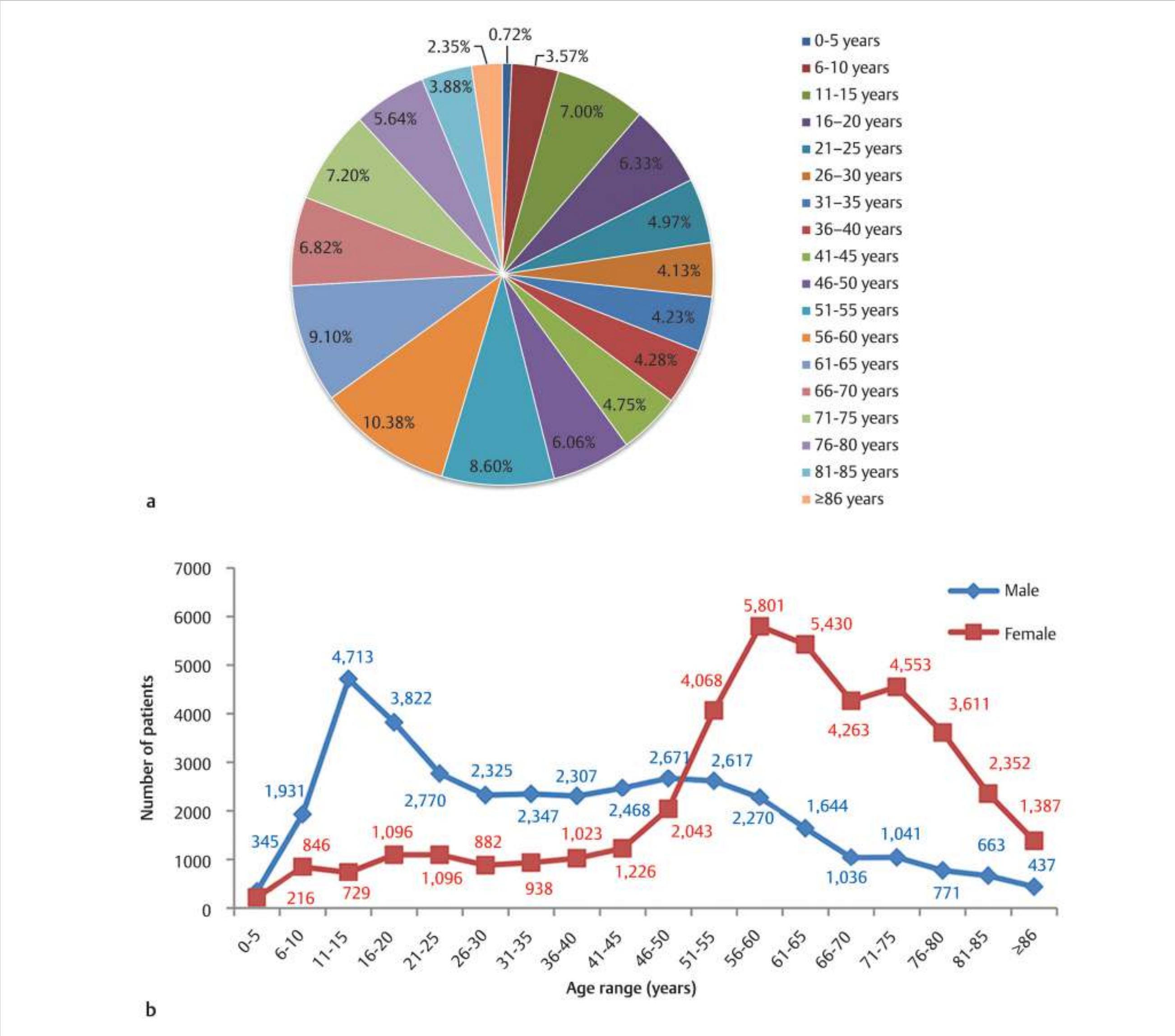

Fig. 11.4 (**a**) Age distribution of 77,738 patients with ulnar and radial fractures. (**b**) Age and sex distribution of 77,738 patients with ulnar and radial fractures.

Patients with Femoral Fractures

A total of 87,012 patients with femoral fractures were treated in Taiwan over a 3-year period from 2011 to 2013. The fractures accounted for 22.30% of all patients with fractures. In general, there were more females than males (▶ Table 11.5; ▶ Fig. 11.5). There were more males in the patients below 55 years and more females in the subjects aged older than 55 years.

Table 11.5 Age and sex distribution of 87,012 patients with femoral fractures

Age group (years)	Male	Female	Total	Percentage
0–5	171	98	269	0.31
6–10	173	119	292	0.34
11–15	461	200	661	0.76
16–20	2,424	887	3,311	3.81
21–25	1,685	649	2,334	2.68
26–30	1,186	403	1,589	1.83
31–35	1,118	365	1,483	1.70
36–40	1,024	348	1,372	1.58
41–45	1,148	421	1,569	1.80
46–50	1,445	723	2,168	2.49
51–55	1,766	1,306	3,072	3.53
56–60	1,985	1,999	3,984	4.58
61–65	2,056	2,495	4,551	5.23
66–70	2,086	3,283	5,369	6.17
71–75	3,237	6,135	9,372	10.77
76–80	4,312	8,661	12,973	14.91
81–85	6,020	9,929	15,949	18.33
≥ 86	5,822	10,872	16,694	19.19
Total	38,119	48,893	87,012	100.00

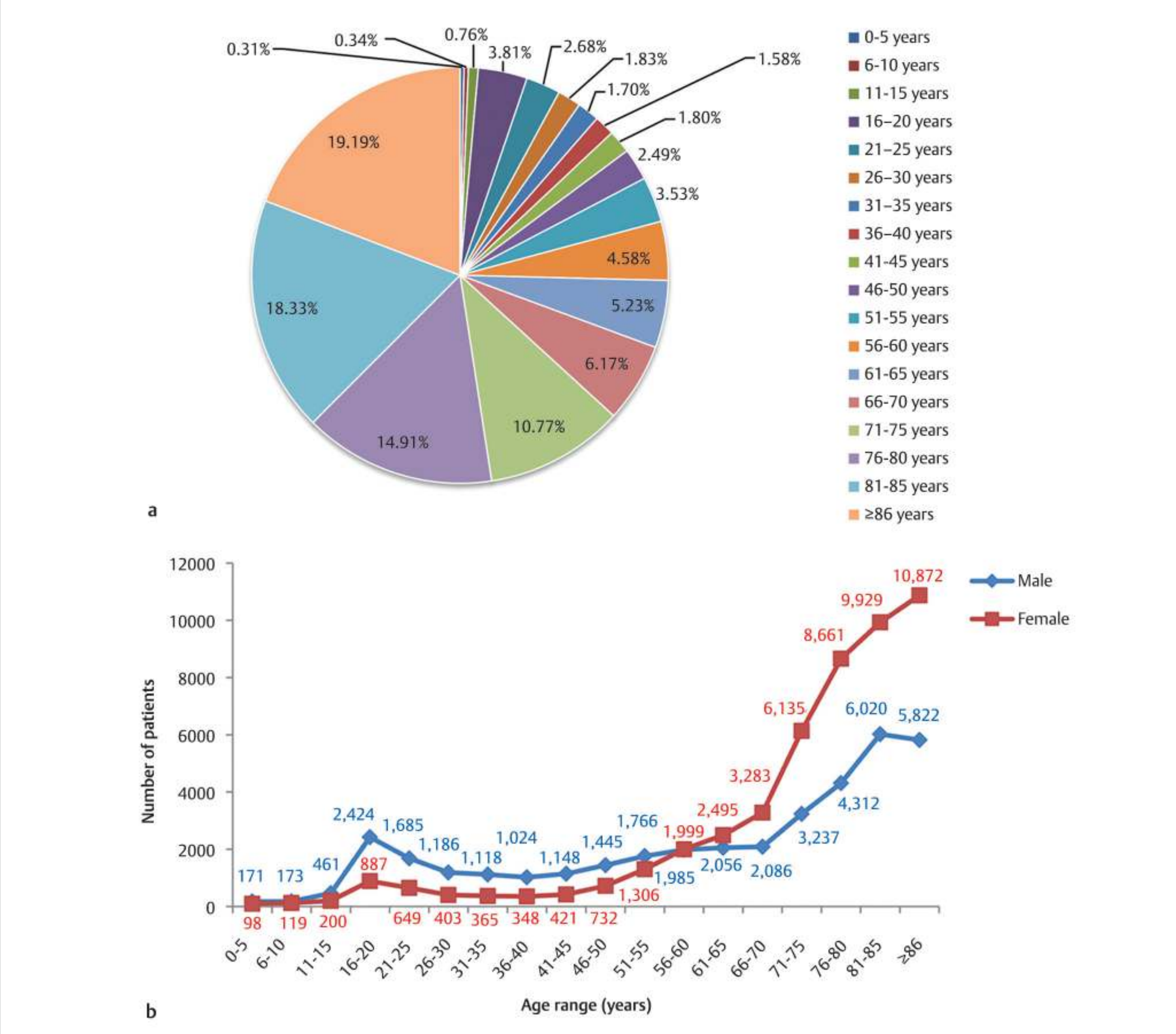

Fig. 11.5 (**a**) Age distribution of 87,012 patients with femoral fractures. (**b**) Age and sex distribution of 87,012 patients with femoral fractures.

Patients with Tibia and Fibula Fractures

A total of 57,801 patients with fractures of the tibia and fibula were treated in Taiwan over a 3-year period from 2011 to 2013. The fractures accounted for 14.82% of all patients with fractures. In general, there were more males than females (▶ Table 11.6; ▶ Fig. 11.6). There were more males in the patients below 50 years and more females in the subjects aged older than 50 years.

Table 11.6 Age and sex distribution of 57,801 patients with tibia and fibula fractures

Age group (years)	Male	Female	Total	Percentage
0–5	122	87	209	0.36
6–10	331	219	550	0.95
11–15	1,215	474	1,689	2.92
16–20	3,256	1,632	4,888	8.46
21–25	2,720	1,459	4,179	7.23
26–30	2,353	1,241	3,594	6.22
31–35	2,399	1,347	3,746	6.48
36–40	2,448	1,376	3,824	6.62
41–45	2,507	1,633	4,140	7.16
46–50	2,749	2,029	4,778	8.27
51–55	2,657	2,869	5,526	9.56
56–60	2,408	3,319	5,727	9.91
61–65	1,832	2,703	4,535	7.85
66–70	1,373	1,975	3,348	5.79
71–75	1,275	1,790	3,065	5.30
76–80	929	1,127	2,056	3.56
81–85	603	648	1,251	2.16
≥ 86	290	406	696	1.20
Total	31,467	26,334	57,801	100.00

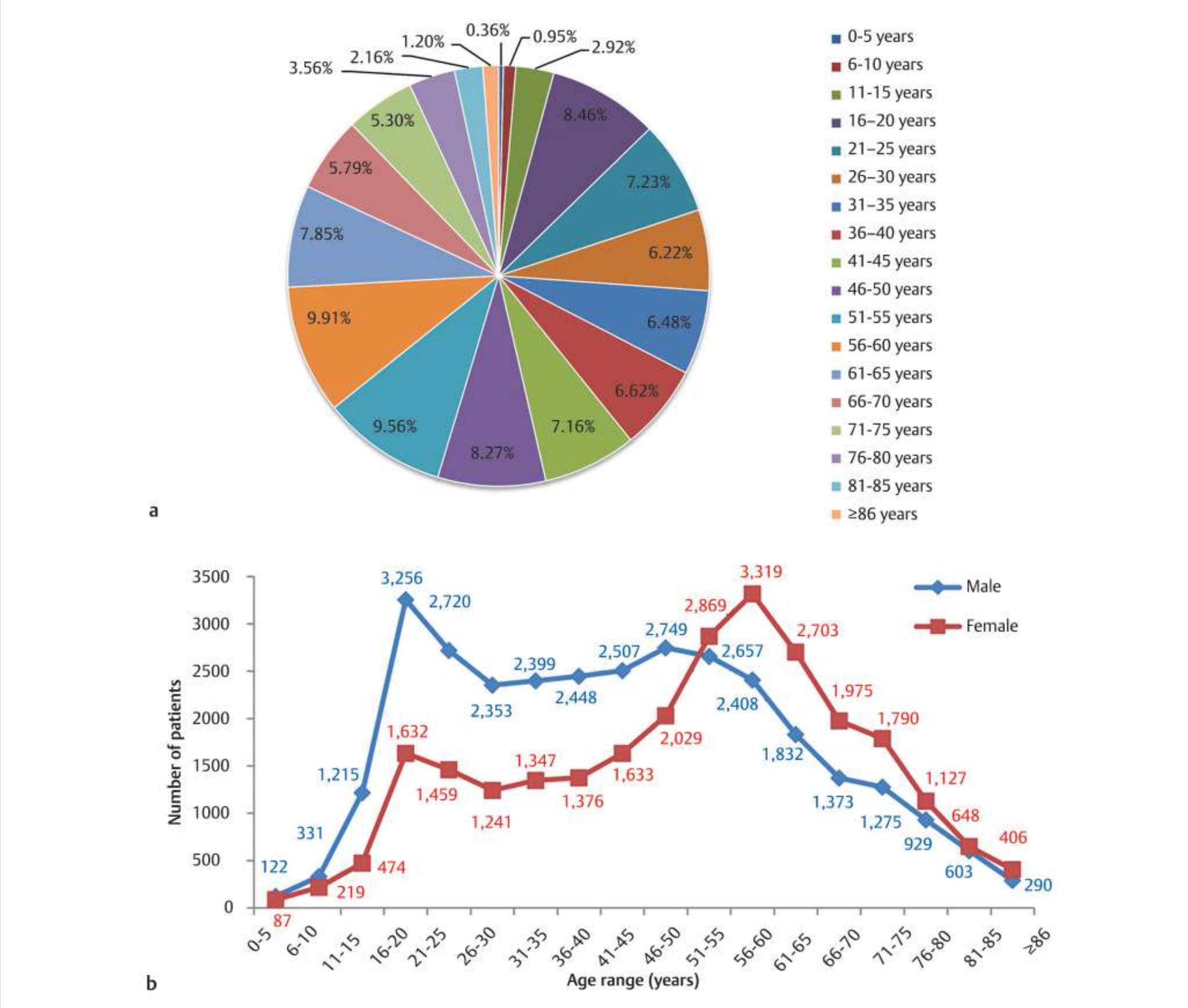

Fig. 11.6 (a) Age distribution of 57,801 patients with tibia and fibula fractures. (b) Age and sex distribution of 57,801 patients with tibia and fibula fractures.

Patients with Spinal Fractures

A total of 40,696 patients with spinal column fractures were treated in Taiwan over a 3-year period from 2011 to 2013. The fractures accounted for 10.43% of all patients with fractures. In general, there were more females than males (▶ Table 11.7; ▶ Fig. 11.7). There were more males in the patients below 55 years and more females in the subjects aged older than 55 years.

Table 11.7 Age and sex distribution of 40,696 patients with spinal fractures

Age group (years)	Male	Female	Total	Percentage
0–5	6	8	14	0.03
6–10	11	9	20	0.05
11–15	60	35	95	0.23
16–20	535	241	776	1.91
21–25	696	275	971	2.39
26–30	730	323	1,053	2.59
31–35	973	406	1,379	3.39
36–40	955	385	1,340	3.29
41–45	1,083	468	1,551	3.81
46–50	1,356	623	1,979	4.86
51–55	1,451	1,091	2,542	6.25
56–60	1,525	1,555	3,080	7.57
61–65	1,272	1,850	3,122	7.67
66–70	1,039	2,326	3,365	8.27
71–75	1,326	3,624	4,950	12.16
76–80	1,407	3,967	5,374	13.21
81–85	1,838	3,312	5,150	12.65
≥ 86	1,460	2,475	3,935	9.67
Total	17,723	22,973	40,696	100.00

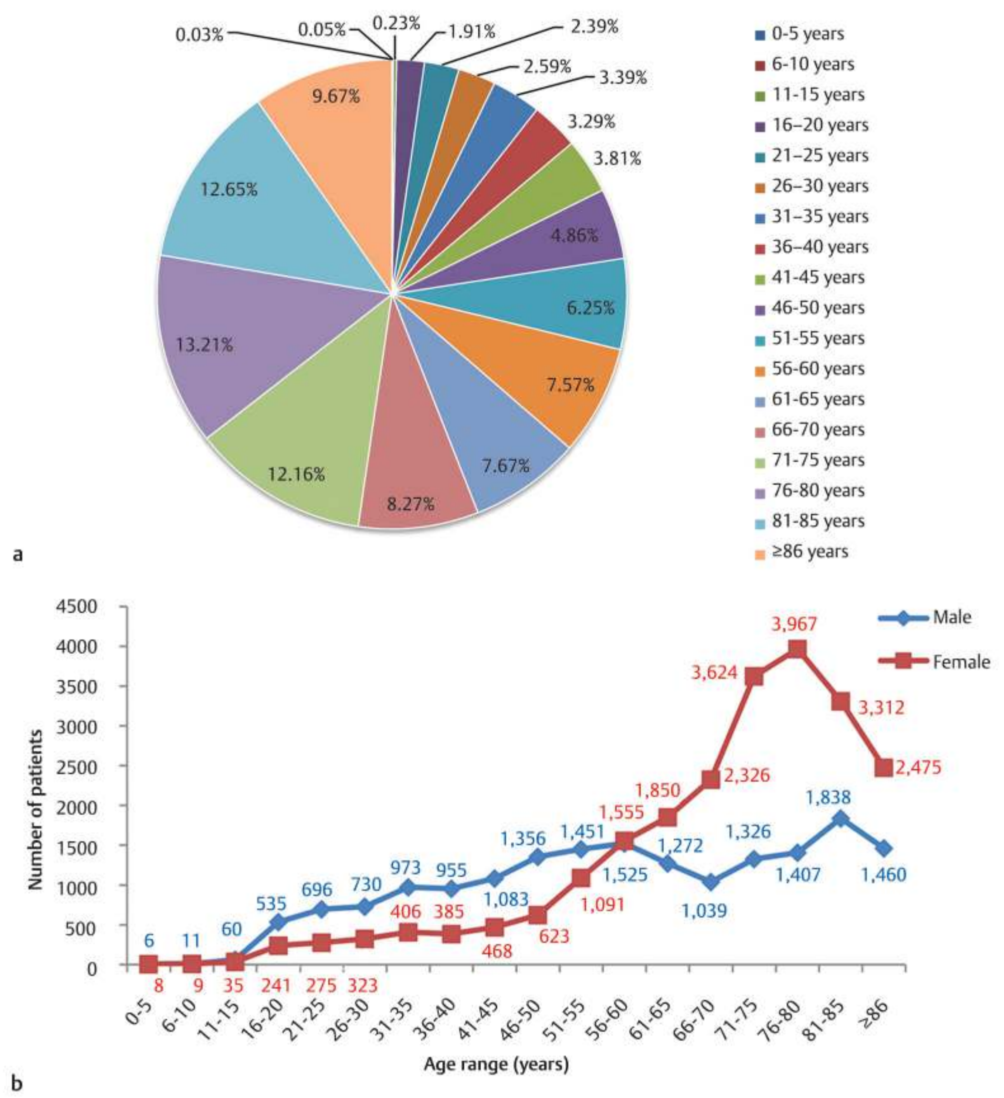

Fig. 11.7 (**a**) Age distribution of 40,696 patients with spinal fractures. (**b**) Age and sex distribution of 40,696 patients with spinal fractures.

Patients with Fractures of the Pelvic Ring and Acetabulum

A total of 13,206 patients with fractures of the pelvic ring and acetabulum were treated in Taiwan over a 3-year period from 2011 to 2013. The fractures accounted for 3.38% of all patients with fractures. In general, there were more females than males (▶ Table 11.8; ▶ Fig. 11.8). There were more males in the patients below 55 years and more females in the subjects aged older than 55 years.

Table 11.8 Age and sex distribution of 13,206 patients with pelvic ring and acetabular fractures

Age group (years)	Male	Female	Total	Percentage
0–5	7	2	9	0.07
6–10	10	6	16	0.12
11–15	146	58	204	1.54
16–20	529	394	923	6.99
21–25	484	468	952	7.21
26–30	460	387	847	6.41
31–35	441	393	834	6.32
36–40	408	323	731	5.54
41–45	448	350	798	6.04
46–50	482	476	958	7.25
51–55	482	568	1,050	7.95
56–60	410	611	1,021	7.73
61–65	361	549	910	6.89
66–70	253	474	727	5.51
71–75	267	640	907	6.87
76–80	248	620	868	6.57
81–85	241	561	802	6.07
≥ 86	164	485	649	4.91
Total	5,841	7,365	13,206	100.00

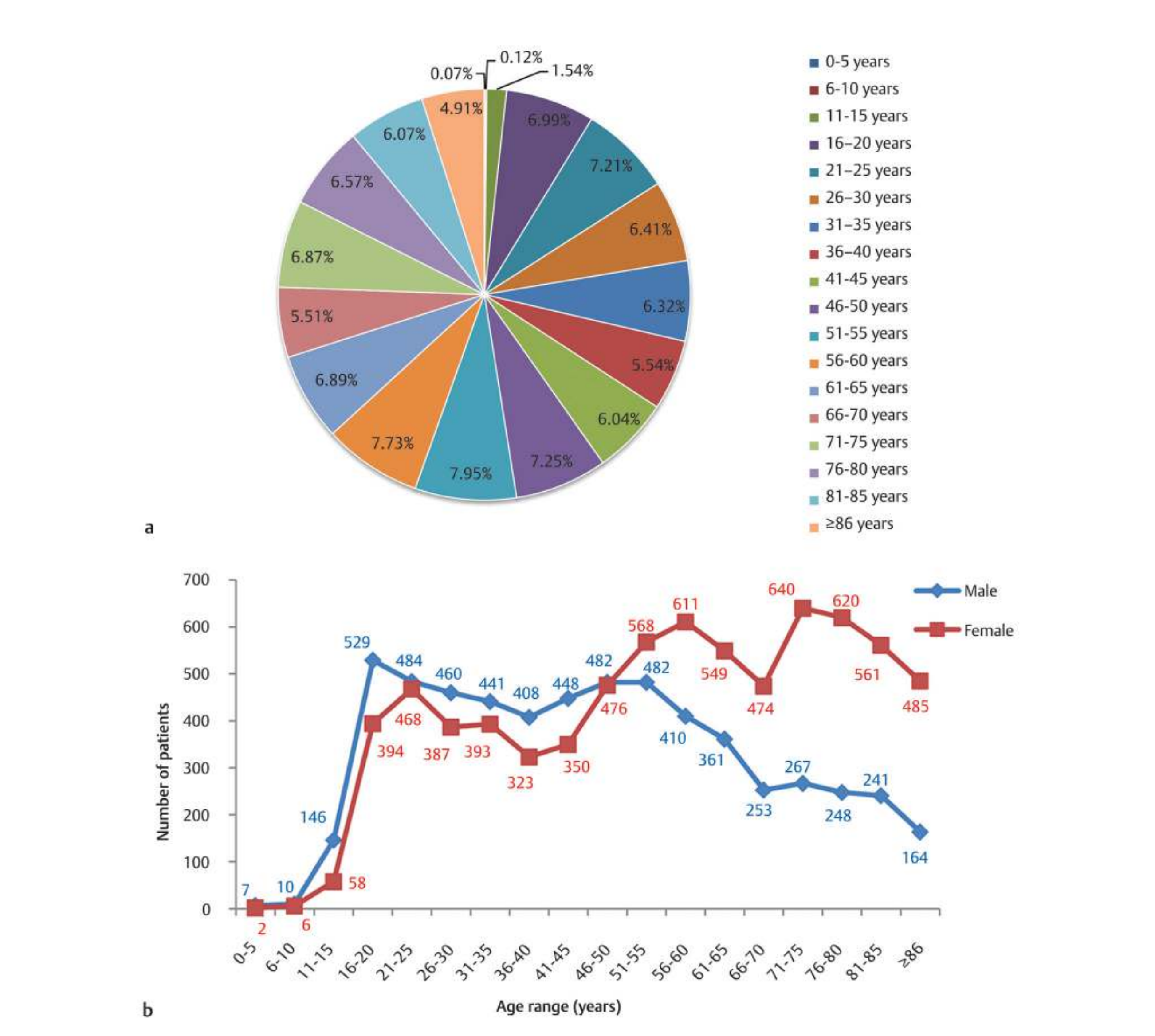

Fig. 11.8 (**a**) Age distribution of 13,206 patients with pelvic ring and acetabular fractures. (**b**) Age and sex distribution of 13,206 patients with pelvic ring and acetabular fractures.

Patients with Hand Fractures

A total of 39,028 patients with hand fractures were treated in Taiwan over a 3-year period from 2011 to 2013. The fractures accounted for 10.0% of all patients with fractures. In general, there were more males than females (▶ Table 11.9; ▶ Fig. 11.9). There were more females in the age group of 66–70 years and 71–75 years, and more males in the rest of the age groups.

Table 11.9 Age and sex distribution of 39,028 patients with hand fractures

Age group (years)	Male	Female	Total	Percentage
0–5	72	43	115	0.29
6–10	149	99	248	0.64
11–15	1,025	228	1,253	3.21
16–20	3,335	752	4,087	10.47
21–25	3,541	784	4,325	11.08
26–30	3,419	718	4,137	10.60
31–35	3,149	662	3,811	9.76
36–40	2,502	644	3,146	8.06
41–45	2,279	575	2,854	7.31
46–50	2,250	800	3,050	7.81
51–55	2,026	1,082	3,108	7.96
56–60	1,609	1,260	2,869	7.35
61–65	1,151	992	2,143	5.49
66–70	602	667	1,269	3.25
71–75	542	571	1,113	2.85
76–80	397	354	751	1.92
81–85	291	181	472	1.21
≥ 86	161	116	277	0.71
Total	28,500	10,528	39,028	100.00

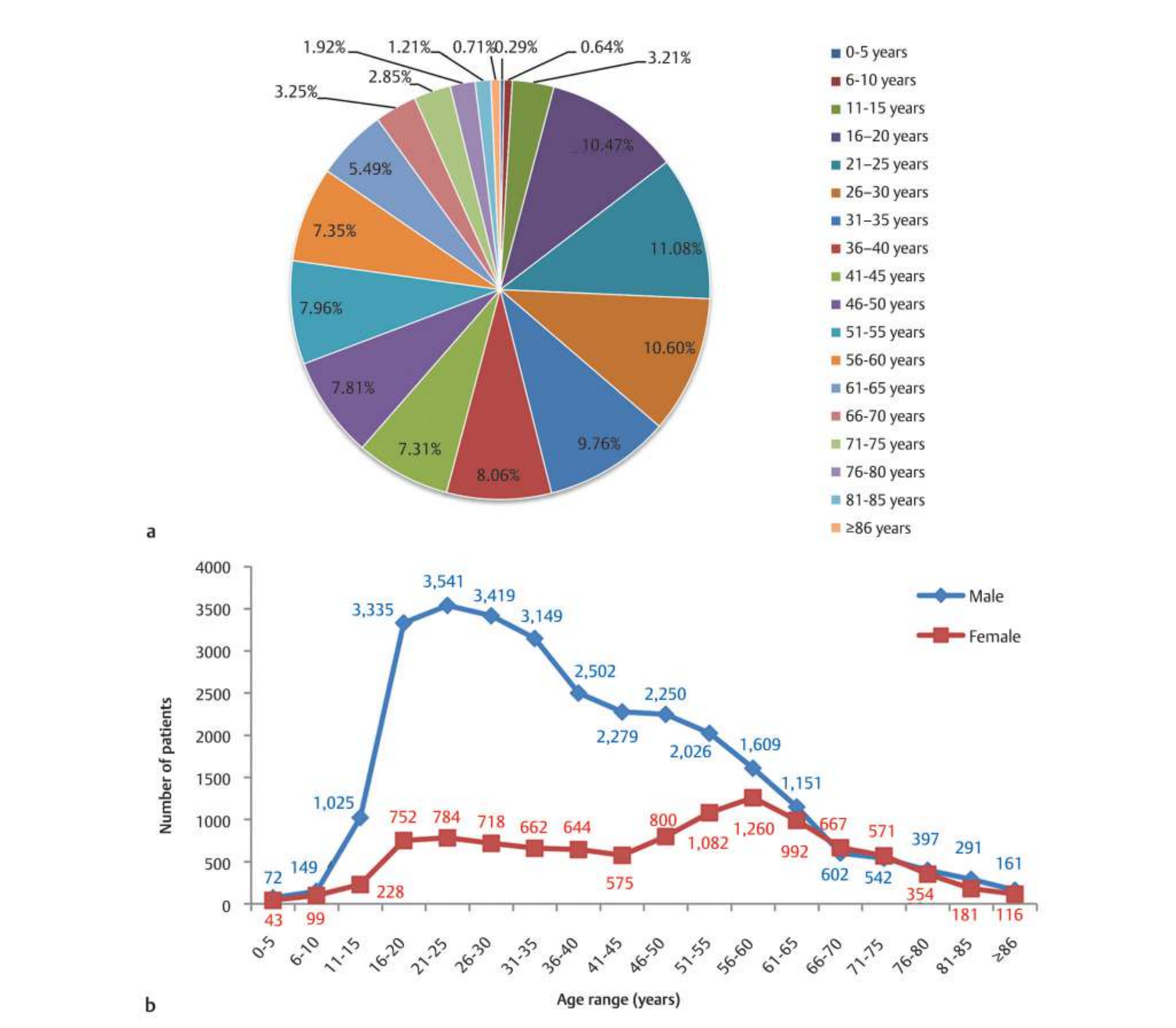

Fig. 11.9 (**a**) Age distribution of 39,028 patients with hand fractures. (**b**) Age and sex distribution of 39,028 patients with hand fractures.

Patients with Foot Fractures

A total of 26,049 patients with foot fractures were treated in Taiwan over a 3-year period from 2011 to 2013. The fractures accounted for 6.68% of all patients with fractures. In general, there were more males than females (▶ Table 11.10; ▶ Fig. 11.10). There were more females in the age group of 61–80 years, and more males in the other age groups.

Table 11.10 Age and sex distribution of 26,049 patients with foot fractures

Age group (years)	Male	Female	Total	Percentage
0–5	30	24	54	0.21
6–10	84	50	134	0.51
11–15	280	168	448	1.72
16–20	1,211	602	1,813	6.96
21–25	1,103	591	1,694	6.50
26–30	1,186	532	1,718	6.60
31–35	1,491	655	2,146	8.24
36–40	1,543	614	2,157	8.28
41–45	1,703	663	2,366	9.08
46–50	1,765	914	2,679	10.28
51–55	1,670	1,180	2,850	10.94
56–60	1,344	1,245	2,589	9.94
61–65	893	967	1,860	7.14
66–70	565	646	1,211	4.65
71–75	496	545	1,041	4.00
76–80	317	349	666	2.56
81–85	243	190	433	1.66
≥ 86	98	92	190	0.73
Total	16,022	10,027	26,049	100.00

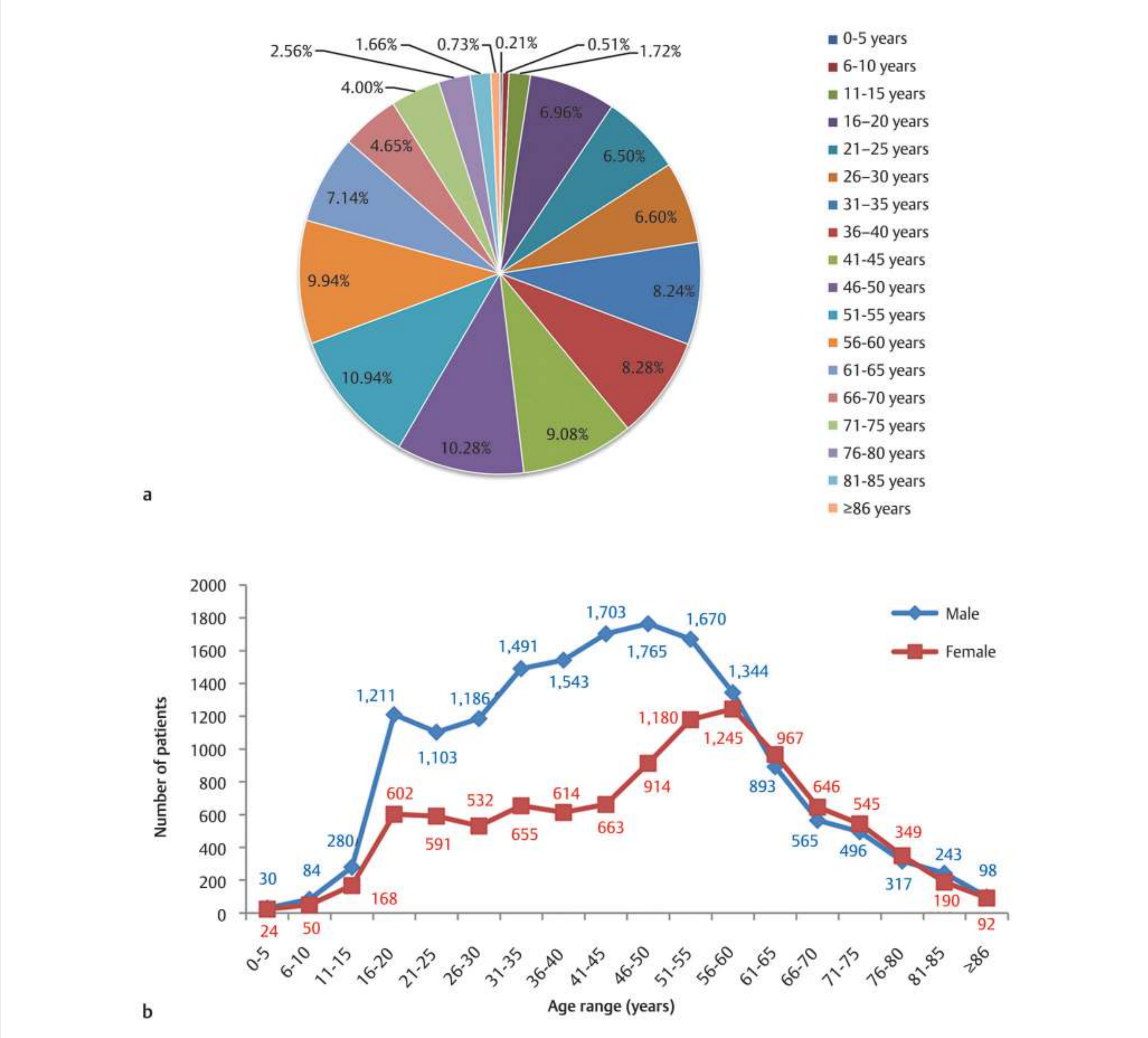

Fig. 11.10 (**a**) Age distribution of 26,049 patients with foot fractures. (**b**) Age and sex distribution of 26,049 patients with foot fractures.

Patients with Patellar Fractures

A total of 12,491 patients with patellar fractures were treated in Taiwan over a 3-year period from 2011 to 2013. The fractures accounted for 3.20% of all patients with fractures. In general, there were more males than females (▶ Table 11.11; ▶ Fig. 11.11). There were more females in the age group of 51–85 years, and more males in the other age group.

Table 11.11 Age and sex distribution of 12,491 patients with patellar fractures

Age group (years)	Male	Female	Total	Percentage
0–5	1	0	1	0.01
6–10	13	2	15	0.12
11–15	88	36	124	0.99
16–20	725	230	955	7.65
21–25	586	151	737	5.90
26–30	423	165	588	4.71
31–35	464	195	659	5.28
36–40	443	197	640	5.12
41–45	508	247	755	6.04
46–50	544	363	907	7.26
51–55	544	643	1,187	9.50
56–60	524	883	1,407	11.26
61–65	393	819	1,212	9.70
66–70	325	582	907	7.26
71–75	331	577	908	7.27
76–80	317	427	744	5.96
81–85	230	264	494	3.95
≥ 86	131	120	251	2.01
Total	6,590	5,901	12,491	100.00

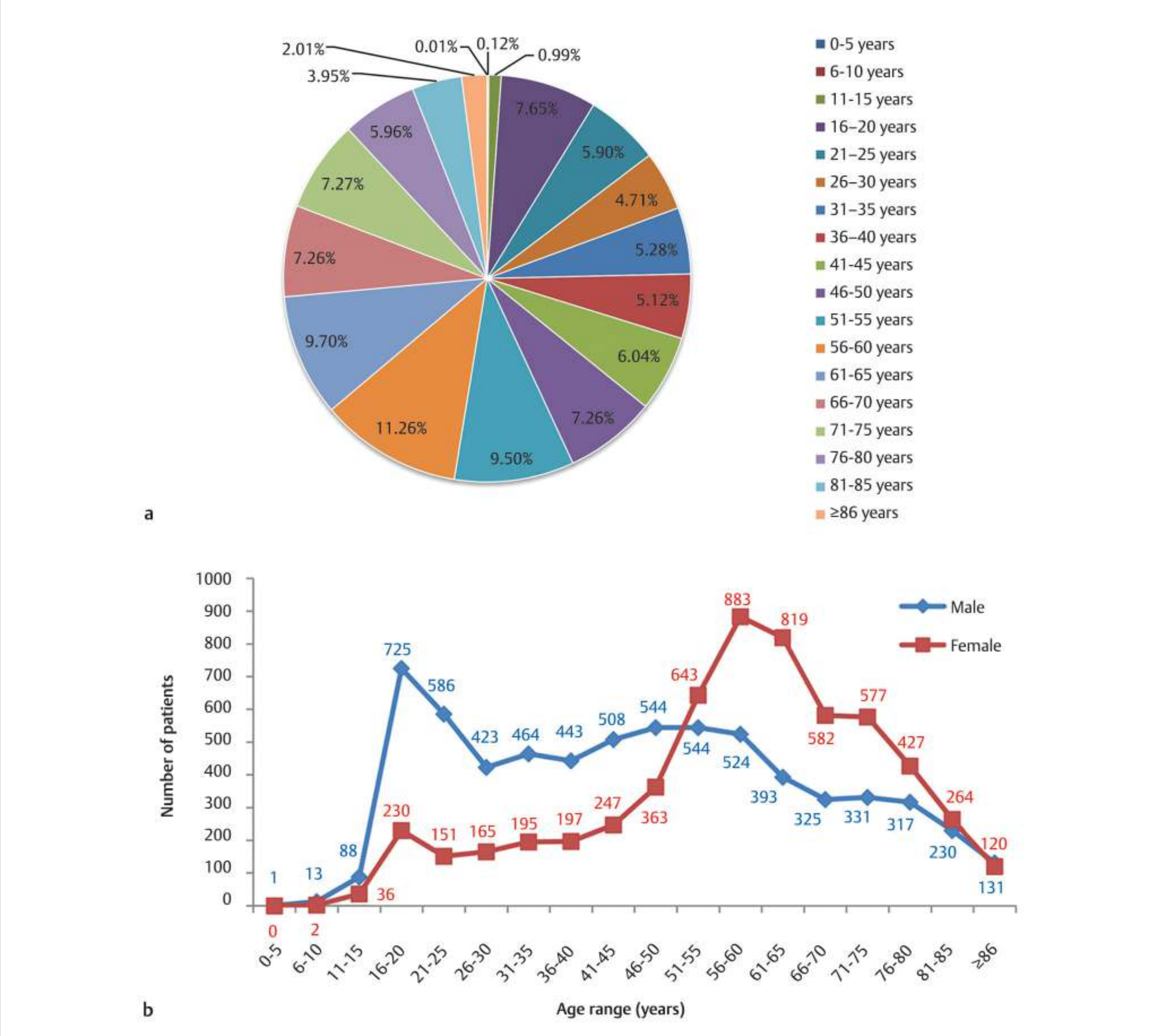

Fig. 11.11 (**a**) Age distribution of 12,491 patients with patellar fractures. (**b**) Age and sex distribution of 12,491 patients with patellar fractures.

Patients with Clavicle Fractures

A total of 34,143 patients with clavicle fractures were treated in Taiwan over a 3-year period from 2011 to 2013. The fractures accounted for 8.75% of all patients with fractures. In general, there were more males than females (▶ Table 11.12; ▶ Fig. 11.12). There were more females in the age group of 61–65 years, and more males in the other age group.

Table 11.12 Age and sex distribution of 34,143 patients with clavicle fractures

Age group (years)	Male	Female	Total	Percentage
0–5	41	29	70	0.21
6–10	68	35	103	0.30
11–15	342	163	505	1.48
16–20	1,883	870	2,753	8.06
21–25	1,759	811	2,570	7.53
26–30	1,719	677	2,396	7.02
31–35	1,904	608	2,512	7.36
36–40	1,900	679	2,579	7.55
41–45	2,149	753	2,902	8.50
46–50	2,221	973	3,194	9.35
51–55	1,988	1,428	3,416	10.00
56–60	1,776	1,713	3,489	10.22
61–65	1,338	1,417	2,755	8.07
66–70	854	830	1,684	4.93
71–75	684	679	1,363	3.99
76–80	541	392	933	2.73
81–85	443	178	621	1.82
≥ 86	182	116	298	0.87
Total	21,792	12,351	34,143	100.00

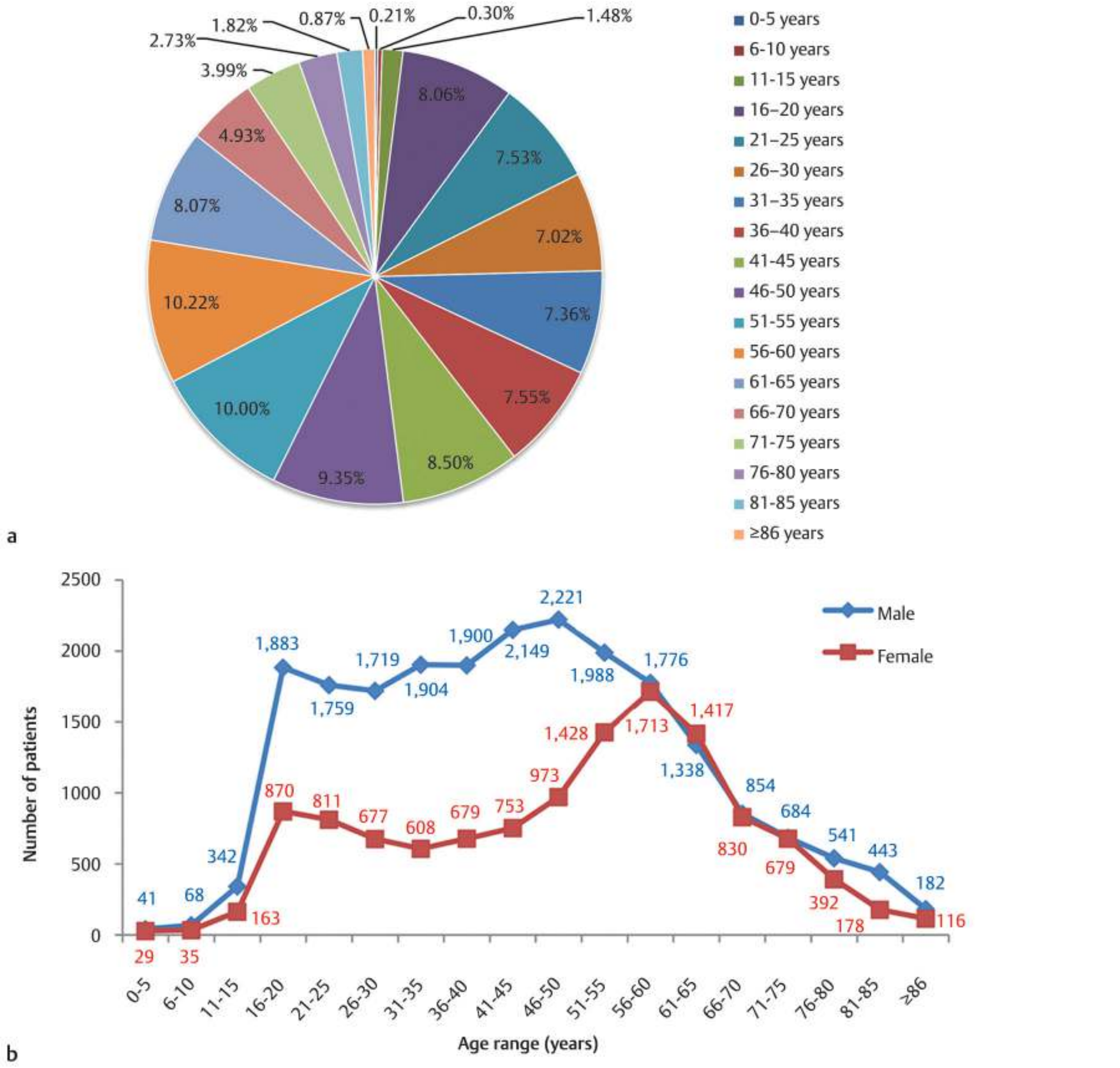

Fig. 11.12 (**a**) Age distribution of 34,143 patients with clavicle fractures. (**b**) Age and sex distribution of 34,143 patients with clavicle fractures.

Patients with Scapular Fractures

A total of 4,436 patients with scapular fractures were treated in Taiwan over a 3-year period from 2011 to 2013. The fractures accounted for 1.14% of all patients with fractures. In general, there were more males than females (▶ Table 11.13; ▶ Fig. 11.13). There were no patients in the age group of 0–5 years, and more males in the other age group.

Table 11.13 Age and sex distribution of 4,436 patients with scapular fractures

Age group (years)	Male	Female	Total	Percentage
0–5	0	0	0	0.00
6–10	2	1	3	0.07
11–15	13	3	16	0.36
16–20	139	37	176	3.97
21–25	157	39	196	4.42
26–30	193	53	246	5.55
31–35	226	49	275	6.20
36–40	247	74	321	7.24
41–45	269	70	339	7.64
46–50	335	123	458	10.32
51–55	378	94	472	10.64
56–60	378	159	537	12.11
61–65	305	133	438	9.87
66–70	207	99	306	6.90
71–75	183	104	287	6.47
76–80	145	50	195	4.40
81–85	85	30	115	2.59
≥ 86	32	24	56	1.26
Total	3,294	1,142	4,436	100.00

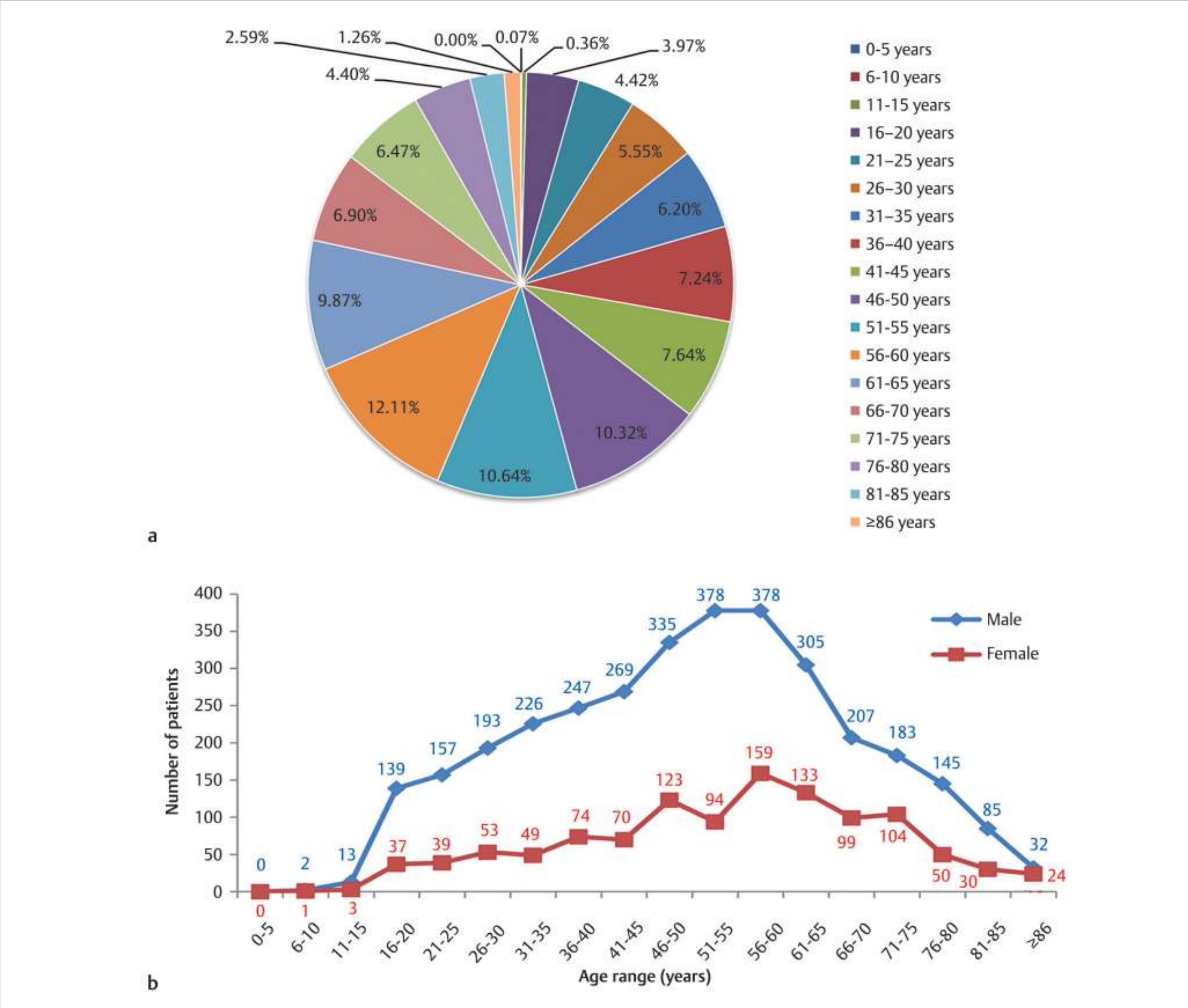

Fig. 11.13 (**a**) Age distribution of 4,436 patients with scapular fractures. (**b**) Age and sex distribution of 4,436 patients with scapular fractures.

Fracture Location

Fractures more frequently occur in femur, ulna/radius, and tibia/fibula (▶ Table 11.14; ▶ Fig. 11.14).

Table 11.14 Fracture location distribution

Fracture location	Humerus	Ulna and radius	Femur	Tibia and fibula	Spine	Foot	Hand	Pelvic ring and acetabulum	Clavicle	Scapula	Patella	Total
Male	12,657	36,178	38,119	31,467	17,723	16,022	28,500	5,841	21,792	3,294	6,590	218,183
Female	16,963	41,560	48,893	26,334	22,973	10,027	10,528	7,365	12,351	1,142	5,901	204,037
Total	29,620	77,738	87,012	57,801	40,696	26,049	39,028	13,206	34,143	4,436	12,491	422,220
Percentage	7.02	18.41	20.61	13.69	9.64	6.17	9.24	3.13	8.09	1.05	2.96	100.00

Note: The number of patients calculated by fracture location is larger than the patients investigated because some patients have multiple fractures.

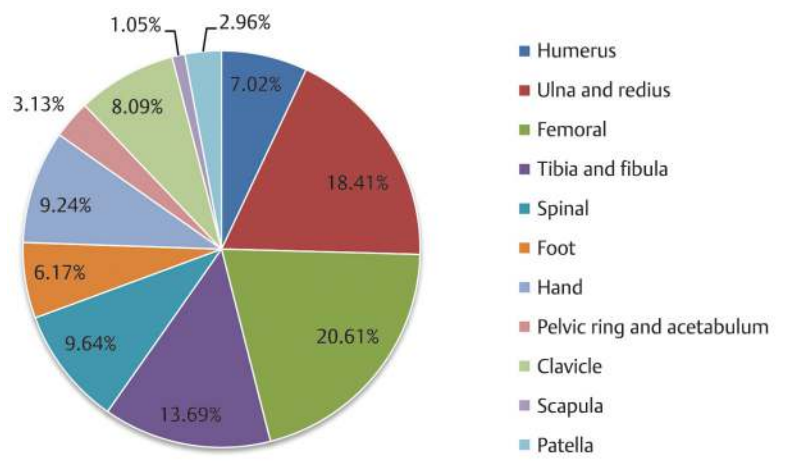

Fig. 11.14 Fracture location distribution.

Fractures in Children

Fracture characteristics in children are different from adults, with ulna/radius, humerus, and tibia/fibula being the particular bones with the highest fracture incidence (▶ Table 11.15).

Table 11.15 Children and adult fracture location distribution

Fracture location	Humerus	Ulna and radius	Femur	Tibia and fibula	Spine	Foot	Hand	Pelvic ring and acetabulum	Clavicle	Scapula	Patella	Total
Children	4,413	8,846	1,224	2,503	130	654	1,623	229	678	19	140	20,459
Adult	25,245	69,259	86,138	56,024	40,575	26,001	37,628	12,978	33,537	4,437	12,364	404,186
Total	29,658	78,105	87,362	58,527	40,705	26,655	39,251	13,207	34,215	4,456	12,504	424,645

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Index

Note: Page numbers set **bold** or *italic* indicate headings or figures, respectively.

A

age and sex distribution
- Barton fractures 191
- Barton fractures *192*
- capitellum fractures of humerus *109*
- capitellum fractures of humerus 108
- colles fractures *183*
- colles fractures 182
- femoral fractures 204, *205*
- fractures of segment 11 37, *38*
- fractures of segment 12 54
- fractures of segment 12 *54*
- fractures of segment 13 70, *70*
- fractures of segment 21 *123*, 124
- fractures of segment 22 *141*
- fractures of segment 22 140
- fractures of segment 23 156, *157*
- fractures of segment 31 209, *210*
- fractures of segment 32 226, *227*
- Galeazzi fractures 178
- Galeazzi fractures *179*
- humeral fractures 31, *32*
- intercondylar fractures of humerus 92, *93*
- lateral condylar fractures of humerus 95
- lateral epicondyle fractures of humerus 102
- lateral epicondyle fractures of humerus *103*
- medial condylar fractures of humerus 98, *99*
- medial epicondyle fractures of humerus 105
- medial epicondyle fractures of humerus *105*
- Monteggia fractures 173
- radial/ulnar fractures 119, *120*
- supracondylar fractures of humerus 88, *89*
- lateral condylar fractures of humerus *96*

age and sex distribution
- fractures of segment 61, 417, *417*
- Pilon fractures, *355*
- with calcaneal fractures, 581
- with clavicle fractures, 776
- with foot fractures, 772
- with fractures of the pelvic ring and acetabulum, 410, *411*
- with patellar fractures, 774
- acromion fractures, 736
- acromion ractures, *737*
- adult patients with foot fractures by individual foot bone, *559*
- coracoid fractures, 729, *730*
- fractures of segment 33, 243
- fractures of segment 41, 283, *284*
- fractures of segment 42, *300*
- fractures of segment 43, 316, *316*
- fractures of segment 44, *332*
- fractures of segment 51.03–51.07 in adults, 379, *380*
- fractures of segment 62, 433, *433*
- fractures of segments 52 and 53 in adults, 390, *391*
- glenoid fractures, 750, *750*
- patients with carpal fractures, *480*
- patients with fractures of the carpal bones (segments 71–76), 479
- pediatric patients with foot fractures by individual foot bone, *559*
- Pilon fractures, 354
- scapular fractures, *779*
- scapular neck fractures, 743
- tibial plateau fractures, *349*
- upper cervical spine fractures in adults, 372, *373*
- with calcaneal fractures, *582*
- with clavicle fractures in CNFS, 686, *686*
- with clavicle fractures, 689, *690*, *777*
- with cuboid fractures, 606, *607*
- with cuneiform fractures, 613, *614*
- with femoral fractures, 762, *763*
- with foot fractures by individual foot bone, *559*
- with foot fractures in CNFS, 552, *552*
- with foot fractures, 556, *557*, *773*
- with fractures of metacarpal bone (segment 77), 503
- with fractures of metacarpal bones (segment 77), *504*
- with fractures of the base of the first metacarpal bone, *521*
- with fractures of the phalanx of the foot, 641
- with fractures of the, phalanx of the foot, *642*
- with fractures, 756, *757*
- with hand fractures in the CNFS, *470*
- with hand fractures, 474, *475*, 770, *771*
- with humeral fractures in CNFS, 664
- with humeral fractures, 758, *759*
- with metatarsal fractures, 622, *623*
- with multiple fractures (segment 79), 544, *545*
- with patellar fractures *775*
- with patellar fractures in CNFS, *664*
- with patellar fractures, 667, *668*
- with pelvic ring and acetabular fractures in the CNFS, *406*
- with pelvic ring and acetabular fractures, 768, *769*
- with phalanx fractures (segment 78), 527
- with scaphoid fractures, 495, *496*
- with scapular fracture, 778
- with scapular fractures in CNFS, 711, *711*
- with scapular fractures, 714, *715*
- with spinal column fractures, 366, *367*
- with spinal fractures in the CNFS, *362*
- with spinal fractures, 766, *767*
- with talar fractures, 562, *562*
- with tarsal navicular fractures, 599, *600*
- with tibia and fibula fractures, 764, *765*
- with tibial/fibular fractures, 276, *277*
- with ulnar and radial fractures, 760, *761*
- Young–Burgess fractures, 452, *452*

age and sex distributions , fractures of segment 33, *244*

age distribution
- Barton fractures *192*
- capitellum fractures of humerus *109*
- femoral fractures *205*
- fractures of segment 11 *38*
- fractures of segment 12 *54*
- fractures of segment 13 *70*
- fractures of segment 21 *125*
- fractures of segment 22 *141*
- fractures of segment 23 *157*
- fractures of segment 31 *210*
- fractures of segment 32 *227*
- Galeazzi fractures *179*
- humeral fractures *32*
- intercondylar fractures of humerus *93*
- lateral condylar fractures of humerus *96*
- lateral epicondyle fractures of humerus *103*
- Monteggia fractures *174*
- radial/ulnar fractures *120*
- supracondylar fractures of humerus *89*
- medial condylar fractures of humerus *99*
- radial/ulnar fractures in CNFS *114*

age distribution
- fractures of segment 61 *417*
- with calcaneal fractures, *582*
- with carpal fractures, *480*
- with clavicle fractures, *777*
- with foot fractures, *773*
- with fractures of the pelvic ring and acetabulum, 409
- with patellar fractures, *775*
- with spinal fractures in the China National Fracture Study (CNFS), *362*
- with spinal fractures in the China National Fracture Study, 362
- acromion fractures, *737*
- coracoid fractures, *730*
- fractures of segment 41, *284*
- fractures of segment 42, *300*
- fractures of segment 43, *316*
- fractures of segment 44, *332*
- fractures of segment 51.03–51.07 in adults, *380*
- fractures of segment 62 *433*
- fractures of segments 52 and 53 in adults, *391*
- glenoid fractures, *750*
- Pilon fractures, *355*
- scapular neck fractures, *744*
- upper cervical spine fractures in adults, 371
- with clavicle fractures, *690*
- with cuboid fractures, *607*
- with cuneiform fractures, *614*
- with femoral fractures, *763*
- with foot fractures in China National Fracture Study (CNFS), *552*
- with foot fractures, *557*
- with fractures of metacarpal bones (segment 77), *504*
- with fractures of the base of the first metacarpal bone, *521*
- with fractures of the phalanx of the foot, *642*
- with fractures, 755
- with hand fractures in the China National Fracture Study (CNFS), *470*
- with hand fractures in the China National Fracture Study, 470
- with hand fractures, *475*, *771*
- with humeral fractures, *759*
- with metatarsal fractures, *623*
- with multiple fractures (segment 79), *545*
- with patellar fractures in China National Fracture Study (CNFS) , *664*
- with patellar fractures, *668*
- with pelvic ring and acetabular fractures in the China National Fracture Study (CNFS), *406*
- with pelvic ring and acetabular fractures in the China National Fracture Study, 406
- with pelvic ring and acetabular fractures, *769*
- with scaphoid fracture *496*
- with scapular fractures, *715*, *779*
- with spinal column fractures, *367*
- with spinal fractures, *767*
- with talar fractures, *562*
- with tarsal navicular fractures, *600*
- with tibia and fibula fractures, *765*
- with tibial/fibular fractures, *277*
- with ulnar and radial fractures, *761*
- Young–Burgess fractures *452*

age distribution of
- colles fractures *183*
- medial epicondyle fractures of humerus *106*

age distributions , fractures of segment 33, *244*

age group and sex distribution
- femoral fractures in CNFS *199*
- femoral fractures in CNFS 199

age group and sex distribution , with tibial/fibular fractures in the China National Fracture Study, 271

age group and sex distribution of 417 patients with tibial/fibular fractures in the CNFS, *271*

age group distribution, femoral fractures in CNFS *199*
age group distribution , patients with tibial/fibular fractures in the China National Fracture Study (CNFS), *271*
algorithm
– acetabular fracture *459*
– acetabular fractures (segment 62) *431*
– Allman classification of clavicle fractures *696*
– calcaneal fractures (segment 82) *579*
– clavicle fractures (segment 15) *684*
– cuboid fractures *604*
– cuneiform fractures (segment 85) *611*
– distal femoral fractures (segment 33) *241*
– distal humeral fractures *68*
– foot fracture *550*
– fractures of humerus *24*
– fractures of radial/ulnar shaft *138*
– letournel classification of pelvic ring fracture *458*
– malleolar injury (segment 44) *329*
– metacarpal fractures *502*
– metatarsal fractures (segment 87) *620*
– multiple fractures of foot (segment 89) *657*
– Patellar fracture *662*
– pelvic ring and acetabulum fracture *404*
– pelvic ring fracture *446*
– pelvic ring fractures (segment 61) *415*
– phalangeal fractures (segment 88) *639*
– phalanx fractures *525*
– proximal humeral fractures *35*
– proximal tibial fractures (segment 41) *281*
– robinson classification of clavicle fractures *703*
– scapular fractures (segment 14) *709*
– Talus fracture *574*
– tarsal navicular (segment 83) *597*
– tibia/fibula fracture *268*
– tibial diaphyseal fractures (segment 42) *298*
– Young–Burgess classification of pelvic ring fracture *450*
– carpal fractures *477*
– cervical column fracture *370*
– diaphyseal femoral fractures *224*
– displaced acetabular fracture *464*
– distal fractures of radius/ulna *154*
– distal tibial fractures (segment 43) *314*
– femur fracture *196*
– fractures of ulna and radius *112*
– hand fracture *468*
– humeral shaft fractures *52*
– proximal femoral fractures *207*
– proximal radial/ulnar fractures *122*
– spine column fracture *361*
– Talar fractures (segment 81) *561*
– thoracolumbar spinal fracture *398*
– thoracolumbar spine fracture *388*
anatomical neck, and tuberosities, 41
anatomical neck, 41
AO classification, of fractures *3*
AO classification system 2
AO code
– for femur *196*
– for humeral fractures *24*
– for shaft of ulna and radius *138*
AO code
– distal tibia, *314*
– malleolus, *329*
AO codes
– pelvic ring, *414*
– pelvis, *404*
– spine, *360*
– tibial diaphysis, *297*
AO Type-A Avulsion fracture of tubercle, 499
AO Type-B Waist fractures Type-C, 499
AO Type-C Multiple fragments or comminuted fractures, 499
articular surface of head 23

B

bifocal multifragmentary, 128
bifocal simple fracture, 128
bone extra-articular fracture, 128
bone fractures 1
bone multifragmentary fracture, 128
bone multifragmentary, 128

C

causal mechanism 7
causal mechanisms , with spinal fractures in the China National Fracture Study, 364
causal mechanisms distribution
– femoral fractures in CNFS *201*
– femoral fractures in CNFS 201
– humeral fractures in CNFS 28
– radial/ulnar fractures in CNFS *116*
causal mechanisms distribution
– tibial/fibular fractures in the China National Fracture Study, 273
– with clavicle fractures in China National Fracture Study (CNFS), *687*
– with foot fractures in CNFS, 554
– with hand fractures in the China National Fracture Study (CNFS), *472*
– with humeral fractures in China National Fracture Study (CNFS), *554*
– with humeral fractures in CNFS, 665
– with humeral, *665*
– with pelvic ring and acetabular fractures in the China National Fracture Study (CNFS), *408*
– with pelvic ring and acetabular fractures in the China National Fracture Study, 408
– with scapular fractures in China National Fracture Study (CNFS), *712*
– with scapular fractures in CNFS, 712
– with tibial/fibular fractures in the China National Fracture Study (CNFS), *273*
cephalotubercular
– with valgus malalignment, 41
– with varus malalignment, 41
cephalotubercular fragmentation, 41
children and adult fracture location distribution, 780
children, fractures in **22**
China National Fracture Study (CNFS)
– age and sex distribution of 106 patients with humeral fractures in 26, *26*
– age and sex distribution of patients with radial/ ulnar fractures in 114
– age and sex distribution of patients with radial/ulnar fractures in the *114*
– age distribution with humeral fractures in *26*
China National Fracture Study (CNFS) 24
China National Fracture Study (CNFS) profile *6*
coding system for humeral fractures **24**
colles fracture, *180*
complete articular fracture (type C) 4
complex fracture (type C) 4
coronoid process and radial head, 128
coronoid process simple, radial head multifragmentary, 128

D

data statistics/analysis **6**
Denis classification of thoracolumbar spinal fractures, 398
design-based multiple logistic regression models 7
diaphyseal fractures of long bone 4
diaphyseal fractures of long bones *4*
distal end of humerus *67*
distal segments of long bone *3*
distal segments, fractures of 4

E

eight quality control teams 5
elbow joint
– anterior view of *67*
– anteroposterior and lateral views of *170*
– lateral view of *67*
– radiographic anatomy of *68*
epidemiological survey of fracture, gender and age distribution of patients in 7
epiphyseal fragment
– with rotatory displacement of 41
– without rotatory displacement of 41
establish supervision system of quality control 6
Evans Type
– I: nondisplaced 2-fragment fracture, stable fracture, 259
– II: lesser trochanter fracture with slight displacement, stable fracture, 259
– III: lesser trochanter multifragmentary without posterolateral support, 259
– IV: type III + greater trochanter fracture, unstable fracture, 259
– V: reversed obliquity fracture with fracture line running upward and inward, extends above the lesser trochanter, unstable fracture, 259
extension type supracondylar humeral fractures *86*
extra-articular fractures (type A) 4

F

femoral shaft, *224*
femur, head of *207*
femur, proximal, extra-articular, trochanteric fractures
– greater trochanter, 213
– intertrochanteric line, 213
– lesser trochanter, 213
– multifragmentary, fracture line extending into the diaphysis, 213
– simple oblique, 213
– simple transverse, 213
– with one intermediate fragment, 213
– with several intermediate fragments, 213
femur, proximal, extra-articular, trochanteric fractures, 213
femur, proximal, intra-articular, head fractures
– head compressed and neck fractured, 213
– head split and neck fractured in subcapital region, 213
– head split and neck fractured in transcervical region, 213
femur, proximal, intra-articular, head fractures, 213
femur, proximal, intra-articular, neck fractures
– anterior and superior, 213
– avulsion of the round ligament, 213
– basicervical, 213
– cervical shear, 213
– impacted with valgus displacement degrees, 213
– marked displacement in varus or vertical translation, 213
– midcervical adduction, 213
– moderate displacement in varus and external rotation, 213
– moderate displacement in vertical translation and external rotation, 213
– nonimpacted, 213
– posterior and superior, 213
– split and compressed, 213
femur, proximal, intra-articular, neck fractures, 213
fixation 1
flexion type supracondylar humeral fractures *87*
fracture group and sex distribution
– adult patellar fractures, 670
– avulsion, 671
– body fractures simple: axial view of patella, 671
– comminuted, 671
– distal, 671
– middle, 671

– patella, complete articular fractures, nonvertical, 671
– patella, extra-articular fractures, 671
– patella, partial articular fractures, vertical, 671
– proximal, 671
– simple: axial view of patella, 671
fracture group distribution
– fractures of segment 11 *40*
– fractures of segment 13 *72*
– fractures of segment 21 *127*
– fractures of segment 22 *143*
– fractures of segment 23 *159*
– fractures of segment 31 *212*
fracture group distribution
– fractures of the phalanx of the foot, *645*
– acetabular fractures by the Letournel classification, *460*
– adult patellar fractures by orthopaedic trauma association (OTA) classification, *670*
– calcaneal fractures, *585*
– cuneiform fractures, *616*
– fractures of carpal bones (segments 71–76), *483*
– fractures of metacarpal bones (segment 77), *506*
– fractures of phalanx (segment 78), *531*
– fractures of segment 32, *230*
– fractures of segment 33, *247*
– fractures of segment 41, *286*
– fractures of segment 42, *303*
– fractures of segment 43, *318*
– fractures of segment 44, *335*
– fractures of segment 62, *435*
– metatarsal fractures, *626*
– talar fractures, *565*
– Young–Burgess fractures, *454*
fracture group distributions, fractures of segment 12 *56*
fracture line extending from articulation into diaphysis 160
fracture line extending from articulation into diaphysis, 160
fracture location distribution
– fractures of pelvic ring and acetabulum in children, *412*
– fractures of the pelvic ring and acetabulum in children, 412
– hand fractures in adults, 476, *476*
– hand fractures in children, 476, *476*
– talar fractures, *575*
fracture location distribution, 780, *780*
fracture pattern distribution, supracondylar fractures of humerus *90*
fracture pattern distribution , scaphoid fractures by Russe classification, 498
fracture segment distribution, femoral fractures in adults based on AO classification 206
fracture segment distribution
– fractures of the phalanx of the foot, *647*
– metatarsal fractures, *628*
fracture side distribution
– with clavicle fractures, 688, *688*
– with foot fractures, 555, *555*
– with fractures of segment 62, 432
– with hand fractures, 473, *473*
– with patellar fractures, 666, *666*
– with scapular fractures, 713, *713*
fracture side distribution o, with fractures of segment 62, *432*
fracture subtype distribution , clavicle fractures by Allman classification, *698*
fracture type distribution
– Barton fractures *193*
– Barton fractures *193*
– fractures of segment 11 *39*
– fractures of segment 12 *55*
– fractures of segment 13 *72*
– fractures of segment 21 *126*
– fractures of segment 22 *142*
– fractures of segment 23 *158*
– fractures of segment 31 *211*
– Monteggia fractures *175*
– proximal humeral fractures by Neer classification *85*
– Smith fractures *188*
fracture type distribution
– fractures of the base of the first metacarpal bone, 523
– fractures of the phalanx of the foot, *644*
– Pilon fractures by Ruedi and Allgower classification, *356*
– type i, 523
– type ii, 523
– type iii, 523
– type iv, 523
– acromion fractures, 738, *738*
– acromion zone I type IA, 739
– acromion zone I type IB, 739
– acromion zone I type II, 739
– acromion zone I Type III, 739
– acromion zone II, 739
– adult patellar fractures by orthopaedic trauma association (OTA) classification, *669*
– adult patellar fractures by Regazzoni classification, *678*
– adult patellar fractures, 669
– adult scapular fractures, 716
– anterior, 566
– calcaneal fractures, *584*
– classification of acromion fractures, 739
– clavicle fractures by Allman classification, *697*
– clavicle fractures by Orthopaedic Trauma Association (OTA) classification, *691*
– clavicle fractures by Robinson classification, *704*
– comminuted, 566
– coracoid fractures, *731*
– cuboid fractures, *608*
– cuneiform fractures, *615*
– femoral head fractures by Pipkin classification, *264*
– femoral neck fractures by Garden classification, *261*
– fractures of carpal bones (segments 71–76), *482*
– fractures of metacarpal bones (segment 77), *506*
– fractures of phalanx (segment 78), *530*
– fractures of segment 32, *228*
– fractures of segment 33, *245*
– fractures of segment 41, *286*
– fractures of segment 42, *302*
– fractures of segment 43, *318*
– fractures of segment 44, *334*
– fractures of segment 51.01 in adults, *374*
– fractures of segment 51.02 in adults, *375*
– fractures of segment 51.03–51.07 in adults, *381*
– fractures of segment 62, *435*
– fractures of segments 52 and 53 in adults, *392–393*
– fractures of the base of the first metacarpal bone, 522, *522*
– involves talar head, 566
– lateral, 566
– metatarsal fractures, *625*
– multiple foot fractures, *658*
– multiple hand fractures (segment 79), *546*
– noncomminuted, 566
– nondisplaced, 566
– posterior, 566
– scaphoid fractures based on AO classification, *497*
– scapular fractures, *717*
– scapular neck fractures, *745–746*
– talar fractures, 563, *564*
– talus, neck fractures, 566
– tarsal navicular fractures, *601*
– tibial plateau fractures by Schatzker classification, *350*
– trochanteric fractures by Evans' classification, *258*
– type IA avulsion fractures, 739
– type IB nondisplaced fractures, 739
– type II displaced fractures with no reduction of subacrominal space, 739
– type III displaced fractures with reduction of the subacrominal space, 739
– types of scapular neck fractures, *741*
– zone II Basal fractures of the acromion, 739
fracture type distributions , fractures of segment 61 *419*
fractures, reduction 1
fractures classification
– bones **3**
– group and subgroup **4**
– segments **3**
– types **4**

G

Galeazzi fracture *176*
Garden Type
– I: incomplete fracture, 262
– II: complete fracture without displacement, 262
– III: complete fracture with displacement, 262
– IV: complete fracture, multifragmentary, 262
greater tuberosity, intact 41
greater tuberosity fracture
– with displacement, 41
– with valgus malalignment, 41
– with varus malalignment, 41
– without displacement, 41
greater tuberosity fracture 41
greater tuberosity fracture with frontal malalignment 41
Greater tuberosity fracture without displacement, 41

H

Heimb's square *3*
humeral capitellum fractures, type I *106*
humeral capitellum fractures, type II *107*
humeral fractures
– by age group and sex in CNFS **26**
– by causal mechanisms in CNFS **28**
– by injured side **30**
– by injury side in CNFS **25**
– by location in CNFS **27**
– by sex **29**
– clinical epidemiologic features of **29**
– coding system for **24**
– epidemiologic features of **24**
humeral shaft *52*
– fractures *66*
humerus
– anterior and posterior aspects of *23*
– proximal part of *34*
humerus, diaphysis, complex fractures
– with one intermediate segment and additional wedge fragment, 57
– with one intermediate segment, 57
– with three intermediate fragments, 57
– with two intermediate fragments, 57
humerus, diaphysis, complex fractures, 57
humerus, diaphysis, simple fractures
– distal third 57
– distal third, 57
– middle third, 57
– proximal third 57
– proximal third, 57
– with limited shattering, 57
– with more than three intermediate fragments, 57
– with two intermediate segments, 57
humerus, diaphysis, simple fractures 57
humerus, diaphysis, wedge fracture, middle third, 57
humerus, diaphysis, wedge fracture, 57
humerus, diaphysis, wedge fractures
– middle third, 57
– proximal third, 57
humerus, diaphysis, wedge fractures, 57
humerus, distal, complete articular fractures
– metaphyseal multifragmentary, 73
– metaphyseal simple, 73

– metaphyseal wedge , 73
– T-shaped epiphyseal 73
– with marked displacement 73
– with slight displacement, 73
humerus, distal, complete articular fractures 73
humerus, distal, extra-articular fractures
– complex, 73
– lateral epicondyle, 73
– medial epicondyle with incarcerated fragment, 73
– medial epicondyle with no incarcerated fragment, 73
– oblique downward and inward, 73
– oblique downward and outward, 73
– transverse, 73
– with fragmented wedge, 73
– with intact wedge, 73
humerus, distal, extra-articular fractures, 73
humerus, distal, partial articular fractures, single condyle
– capitellum and trochlea, 73
– capitellum, 73
– transtrochlear multifragmentary, 73
humerus, fractures of **23**
humerus, proximal, articular fractures, 41
humerus, proximal, extra-articular fractures, bifocal, 41
humerus, proximal, extra-articular fractures, unifocal multiple fragments, 41
humerus, proximal, extra-articular fractures, unifocal with translation, 41
humerus, proximal, extra-articular fractures, unifocal, 41

I

injury side distribution
– femoral fractures 203, *203*
– femoral fractures in CNFS 198, *198*
– humeral fractures in CNFS 25
– humeral fractures in CNFS *25*
– patients with humeral fractures 30
– radial/ ulnar fractures 118
– radial/ ulnar fractures in CNFS 113
– radial/ulnar fractures *118*
– radial/ulnar fractures in CNFS *113*
– with humeral fractures *30*
injury side distribution
– patients with tibial/fibular fractures in China National Fracture Study (CNFS), *270*
– tibial/fibular fractures, 275
– with clavicle fractures in China National Fracture Study (CNFS), *685*
– with clavicle fractures in CNFS, 685
– with foot fractures in China National Fracture Study (CNFS), *551*
– with foot fractures in CNFS, 551
– with hand fractures in the China National Fracture Study (CNFS), *469*
– with hand fractures in the China National Fracture Study, 469
– with patellar fractures in China National Fracture Study (CNFS), *663*
– with patellar fractures in CNFS, 663
– with scapular fractures in China National Fracture Study (CNFS), *710*
– with scapular fractures in CNFS, 710
– with tibial/fibular fractures in the China National Fracture Study, 270
– with tibial/fibular fractures, *275*
intercondylar humeral fractures
– rise type II *91*
– rise type III *91*
– rise type IV *91*
– rise type I *91*
– rise type IV *91*
intertubercular groove 23
investigator training 5

L

lateral humeral condylar fractures
– type I *94*
– type II *94*
– type III *94*
– type IV *94*
lateral humeral epicondyle fractures, *100*
lesser tuberosity fractured, 41

M

M
– ller AO classification *3*
– ller, Maurice E. 1
medial humeral condylar fractures
– type I *96*
– type III *97*
medial humeral epicondyle fractures
– type I *104*
– type II *104*
– type III *104*
– type IV *104*
metaphyseal simple fracture, 128
multifragmentary with depression, 128
multifragmentary without depression, 128
multiple fragments, with fracture of one tuberosity, 41
muscle insertion, areas of 23

N

national incidence
– of traumatic fractures in China (2014) 8
– rate 2014, demographic characteristics and urbanization 8
– rate 2014, traumatic fractures in China by body site in 9
national quality control team 5
Neer Type I humeral fractures *83*
Neer Type II humeral fractures *83*
non-articular fractures (type A) 4
non-traumatic fractures 1

O

olecranon multifragmentary, radial head simple split, 128
olecranon simple, radial head multifragmentary, 128
one bone articular multifragmentary, 128
one bone segmental, the other complex, 144
one bone simple fracture, 128
Orthopaedic Trauma Association (OTA) system 1
orthopaedic trauma, clinical epidemiology of **1**
OTA classification of fractures *3*

P

partial articular fracture (type B) 4
picture archiving and communication systems (PACS) 14
Pipkin Type
– I: fracture inferior to the fovea centralis, 265
– II: fracture superior to the fovea centralis, 265
– III: type I or II associated with fracture of femoral neck, 265
– IV: type I or II associated with fracture of acetabular rim, 265
poststratification weight 7
probability-proportional-to-size sampling method (PPS) 5
proximal humerus 23
proximal segments of long bone *3*
proximal segments, fractures of 4

R

radial neck multifragmentary fracture, 128
radial neck simple fracture 21, 128
radial/ulnar shaft complex fractures, 144
radial/ulnar shaft simple fractures
– oblique, 144
– transvers, 144
– with distal radioulnar joint dislocation (Galeazzi), 144
– with radial head dislocation (Monteggia), 144
radial/ulnar shaft simple fractures, 144
radial/ulnar shaft wedge fractures
– fragmented wedge, 144
– intact wedge, 144
– with distal radioulnar joint dislocation (Galeazzi), 144
– with radial head dislocation (Monteggia), 144
radial/ulnar shaft wedge fractures, 144
radius articular simple, ulna extra-articular fracture, 128
radius more than three fragments, ulna three or more fragments, 128
radius segmental, simple or wedge ulna fracture, 144
radius segmental, ulna intact without dislocation or with dislocation of distal radioulnar (Galeazzi), 144
radius wedge, ulna simple, 144
radius, distal section, 144
radius, middle section, 144
radius, proximal section, 144
radius/ulna, distal, complete articular fractures
– metaphyseal multifragmentary 23, 160
– metaphyseal simple, 160
– posteromedial articular fragment, 160
– with frontal articular fracture line 23, 160
– with frontal articular fracture line, 160
– with sagittal articular fracture line, 160
radius/ulna, distal, complete articular fractures, 160
radius/ulna, distal, extra-articular fractures
– complex, 160
– impacted with axial shortening, 160
– impacted with wedge fragments, 160
– metaphyseal multifragmentary, 160
– metaphyseal simple, 160
– Monteggia Type I, **170**
– Monteggia Type II, **170**
– Monteggia Type III, **170**
– Monteggia Type IV, **170**
– styloid process, 160
– with dorsal displacement (Colles fracture), 160
– with volar displacement (Smith fracture), 160
– without displacement, 160
radius/ulna, distal, extra-articular fractures, 160
radius/ulna, distal, partial articular fractures
– lateral multifragmentary, 160
– lateral simple, 160
– medial, 160
– multifragmentary, 160
– simple with large fragment, 160
– simple with small fragment, 160
– with dorsal displacement of carpus, 160
– with lateral sagittal fracture line, 160
radius/ulna, distal, partial articular fractures, 160
radius/ulna, proximal, complete articular fractures, 128
radius/ulna, proximal, extra-articular fractures, 128
radius/ulna, proximal, partial articular fractures, 128
repeated program demonstration 5
Russe classification of scaphoid fractures, 499
Russe–Horizontal, 499
Russe–Transverse, 499
Russe–Vertical, 499

S

sampling weight 7
scapula
– anteroposterior view of *50*
– axillary view of *51*
– outlet view of *50*
scapular fractures distribution , scapular fractures, *718*
segment distribution
– femoral fractures in adults based on AO classification *206*
– femoral fractures in children 206, *206*
– femoral fractures in CNFS based on AO classification 200, *200*
– humeral fractures in adults based on AO classification 33, *33*
– humeral fractures in children 33, *33*
– humeral fractures in CNFS based on AO classification 27, *27*
– radial/ ulnar fractures in adults based on AO classification *121*
– radial/ ulnar fractures in children *121*
– radial/ ulnar fractures in CNFS based on AO classification 115
– radial/ulnar fractures in adults based on AO classification 121
– radial/ulnar fractures in children 121
– radial/ulnar fractures in CNFS based on AO classification *115*
segment distribution
– fractures of the pelvic ring and acetabulum in adults, 412, *412*
– with spinal fractures in the China National Fracture Study, 363
– AO code of proximal tibia, *281*
– superior view of tibia, *280*
– tibial/fibular fractures based on AO classification, *278*
– tibial/fibular fractures in adults based on AO classification, 278
– tibial/fibular fractures in children, 279, *279*
– with foot fractures in China National Fracture Study (CNFS), *553*
– with foot fractures in CNFS based on AO classification, 553
– with hand fractures in the China National Fracture Study, 471
– with pelvic ring and acetabular fractures in the China National Fracture Study (CNFS), *407*
– with pelvic ring and acetabular fractures in the China National Fracture Study, 407
– with spinal fractures in the China National Fracture Study (CNFS), *363*
– with tibial/fibular fractures in the China National Fracture Study (CNFS) based on AO classification, *272*
– with tibial/fibular fractures in the China National Fracture Study based on AO classification, 272
sex and age distribution
– fractures of segment 42, 300
– fractures of segment 44, 331
– scapular neck fractures, *744*
– tibial plateau fractures, 349
sex and fractre group distribution , transverse fracture, lateral malleolus, 336
sex and fracture distribution
– fractures of segment 11 *40*
– fractures of segment 13 71
sex and fracture group distribution
– distal end of the femur, *240*
– fractures of segment 11 39
– fractures of segment 12 56, *56*
– fractures of segment 13 *72*
– fractures of segment 13 71
– fractures of segment 21 126, *127*
– fractures of segment 22 142, *143*
– fractures of segment 23 158, *159*
– fractures of segment 31 212, *212*
– subtrochanteric section, 231
sex and fracture group distribution
– fractures of segment 61, 418, *419*
– fractures of the phalanx of the foot by individual foot digit, 646, *646*
– fractures of the phalanx of the foot, 643, *645*
– ischium, 436
– a2 split fracture, 394
– acetabular fractures by the Letournel classification, 460, *460*
– acetabular, complete articular fracture, both columns, both columns simple, 436
– acetabular, complete articular fracture, both columns
–– posterior column and posterior wall, 436
–– posterior column simple, anterior column multifragmentary, 436
– acetabular, complete articular fracture, both columns (floating acetabulum), 436
– acetabular, partial articular fracture, one column involved, 436
– acetabular, partial articular fracture, one column sex and fracture group distribution , involved, 436
– acetabular, partial articular fracture, transverse
–– transtectal, 436
–– uxtatectal, 436
– acetabular, partial articular fracture, transverse
–– anterior column high, 436
–– anterior column low, 436
–– anterior wall, 436
–– both columns simple, 436
–– posterior column and posterior wall, 436
–– posterior column simple, anterior column multifragmentary, 436
– acetabular, partial articular fracture, transverse, 436
– adult patellar fractures by OTA classification, *670*
– anterior and lateral flake fracture, 248
– anterior column fracture, high fracture to iliac crest, sex and fracture group distribution , with one or more fragments, 436
– anterior column fracture, low fracture to anterior border, with one or more fragments, 436
– anterior sacroiliac joint disruption + A injury, , 420
– anterior wall (anterior column high/ low, simple; high/low multifragmentary), 436
– anterior wall fracture, with one or more fragments, 436
– anteromedial wedge, 319
– anteroposterior and lateral views, 484
– AP and lateral views, 484
– apophyseal avulsion, 248
– avulsion of the tip of the lateral malleolus, 336
– B1 or B2 injury + A injury, 420
– bicondylar posterior, 248
– bilateral pubic rami fracture, 420
– bilateral type B1 injury, 420
– bilateral type B2 injury, 420
– Bohler angle, *592*
– bones of the metatarsus, *619*
– both plateaus displaced, 287
– Broden views of the foot, *592*
– Burst fracture, 394
– calcaneal fractures, 583, *585*
– calcaneus, articular fractures involving posterior facet, 586
– calcaneus, avulsion, process, or tuberosity, 586
– calcaneus, extra-articular body fractures, 586
– capitate fractures, 484
– comminuted, 586
– complex, 287
– complex, through the load-bearing surface, 248
– contralateral, partial sacroiliac joint fracture/subluxation (buckethandle) + A injury, , 420
– cuneiform fractures by individual cuneiform, 616, *616*
– cuneiform fractures, 615, *616*
– cuneiform, comminuted fractures, 617
– cuneiform, noncomminuted fractures, 617
– dislocation, pure dislocation, transsacral fracture dislocation), contralateral B1 or B2 injury + A injury, , 420
– displaced sacral fracture, 420
– distal pole, 484
– epiphyseal +metaphyseal, 319
– epiphyseal, 319
– epiphyseal, metaphyseal, and diaphyseal, 319
– extrasacral on both sides (ilium, transiliac SI joint fracture/dislocation, transsacral SI joint fracture/dislocation, SI joint dislocation), 420
– facet, 592
– fibular multifragmentary, 336
– fibular multifragmentary, with medial lesion, 336
– fibular multifragmentary, with sex and fracture group distribution , fracture of medial malleolus + a sex and fracture group distribution , Volkmann fracture, 336
– fibular simple, 336
– fibular simple, with fracture of medial malleolus + a Volkmann Fracture, 336
– fibular simple, with rupture of anterior syndesmosis + fracture of medial malleolus, 336
– fibular simple, with rupture of anterior syndesmosis +medial collateral ligament, 336
– fibular simple, with rupture of sex and fracture group distribution , medial collateral ligament + a sex and fracture group distribution , Volkmann fracture, 336
– fibular simple, with rupture of the sex and fracture group distribution , anterior syndesmosis, 336
– four or more parts, 586
– fracture involving anterior superior iliac spine, anterior sex and fracture group distribution , inferior iliac spine, or pubic spine, 420
– fracture line extending into the diaphysis, 319
– fracture line extending into the sex and fracture group distribution , diaphysis, 319
– fracture of ilium + A injury, , 420
– fracture-dislocation, with marginal impaction in posterior, posterosuperior, or posteroinferior, 436
– fractures of carpal bones (segments 71–76), 481, *483*
– fractures of metacarpal bones (segment 77), 505, *507*
– fractures of phalanx (segment 78), *531*
– fractures of segment 32, *230*
– fractures of segment 33, 246, *247*
– fractures of segment 41, 285, *286*
– fractures of segment 42, *303*
– fractures of segment 43, 317, *318*
– fractures of segment 44, 333
– fractures of segment 62, 434, *435*
– fractures of segments 52 and 53 in adults, 393
– fragmented wedge, 287
– frontal, 319
– Gissane angle, *592*
– hamate fractures, 484
– iliac crest, 420
– iliac wing fracture, with one or more fragments, 420
– impaction fracture, 394
– incomplete posterior iliac fracture + A injury, , 420
– infratectal fracture (stem posterior, stem through obturator foramen, stem anterior), 436
– intact wedge, 287
– intact, 248
– intermediate, 617
– ipsilateral C1 lesion through the ilium, contralateral B1 or B2 injury + A injury, , 420
– ipsilateral C1 lesion through the sacrum (lateral, medial, or through the

sacral foramina) contralateral B1 or B2 injury + A injury, , 420
– ipsilateral, anterior sacral buckle fracture + A injury, , 420
– irregular, extending into the diaphysis, 248
– irregular, limited to the metaphysis, 248
– ischial tuberosity, 420
– juxtatectal fracture (stem posterior, stem through obturator foramen, stem anterior), 436
– lateral fragmented, 248
– lateral limited 287
– lateral total, 287
– lateral+medial, 287
– lateral, 287, 617
– letournel-1 posterior wall fractures, 461
– letournel-2 posterior column fractures, 461
– letournel-3 anterior wall fractures, 461
– letournel-4 anterior column fractures, 461
– letournel-5 transverse acetabular fractures, 461
– letournel-6 posterior wall + posterior column Letournel-6 posterior wall + posterior column 88 fractures, 461
– letournel-7 transverse + posterior wall, 461
– letournel-8 T-type fractures, 461
– letournel-9 anterior column + posterior hemitransverse fractures, 461
– letournel-10 both column fractures, 461
– medial fragmented, 248
– medial, 287, 617
– metaphyseal complex, 248
– metaphyseal simple, articular multifragmentary, 248
– metaphysealmultifragmentary, 319
– metaphysealmultifragmentary, articular multifragmentary, 248
– metaphysio-diaphysealmultifragmentary, 248
– metatarsal fractures, 624, *626*
– multifragmentary, 287
– noncomminuted, 586
– nondisplaced sacral fracture, 420
– nondisplaced, 586
– oblique in the frontal plane, 287
– oblique in the sagittal plane, 287
– oblique or spiral, 248
– oblique, 319
– oblique, involving the tibial spine and one of the plateaus, 287
– oblique, involving the tibial spines and one of the plateaus, 287
– obturator foramen (preserving tear drop or involving tear drop), 436
– of cruciate insertion, 287
– of fibular head, 287
– of lateral surface, 287
– of medial surface, 287
– of tibial tuberosity, 287
– one plateau displaced, 287
– one side C1 lesion through the sacrum (lateral, medial, or through the sacral foramina), the other side extra sacral lesion + A injury, , 420
– one side type B1 injury, the other side type B2 injury, 420
– pelvic ring, complete posterior arch disruption, unstable fracture, 420
– pelvic ring, complete posterior arch disruption, unstable fractures, 420
– pelvic ring, incomplete posterior arch disruption, partial stable fractures, 420
– pelvic ring, posterior arch intact, stable fractures, 420
– pisiform, 484
– posterior column multifragmentary, anterior column high, 436
– posterior column multifragmentary, anterior column low, 436
– posterolateral wedge, 319
– proximal pole, 484
– pure fracture dislocation, multifragmentary in posterior, sex and fracture group distribution , posterosuperior, or posteroinferior, 436
– pure fracture dislocation, one fragment in the posterior, sex and fracture group distribution , posterosuperior, or posteroinferior, 436
– radial carpal fractures (trapezium, trapezoid), 484
– rupture of the lateral collateral ligament, 336
– sacral fracture + A injury, , 420
– sacral lesion on both sides (lateral, medial, or through the sacral foramina) + A injury, , 420
– sacrococcygeal dislocation, 420
– sacroiliac dislocation or fracture dislocation + A injury, , 420
– sagittal, 319
– Sanders classification (intra-articular calcaneal fractures), 592
– Sanders IIa, 592
– Sanders IIb, 592
– Sanders IIc, 592
– Sanders IIIab, 592
– Sanders IIIac, 592
– Sanders IV, 592
– Sanders Type I Nondisplaced, 592
– Sanders Type IV Highly comminuted fractures with four or more fragments of the posterior facet, 592
– scaphoid fractures, 484
– scapular fractures, 716
– simple, through the load-bearing surface, 248
– simple, through the notch, 248
– skeleton of hand, *467*
– spiral, 319
– T- or Y-shaped fracture with slight displacement, 248
– T-shaped fracture, 248
– talar fractures, *565*
– three-part fractures, 586
– transtectal fracture (stem posterior, stem through obturator foramen, stem anterior), 436
– transverse fracture, lateral malleolus, 336
– transverse, 248, 319
– trapezium, 484
– trapezium: AP and lateral views, 484
– trapezoid, 484
– triquetrum, 484
– triquetrum: AP and lateral views, 484
– two-part fractures, 586
– unicondylar posterior, 248
– unilateral pubic rami fracture, 420
– waist, 484
– with a fragmented wedge, 248
– with an intact wedge fragment, 248
– with an intermediate split fragment, 248
– with asymmetric impaction, 319
– with central fragment, 319
– with depression, 319
– with dislocation of proximal fibula, + fracture of medial malleolus + a Volkmann fracture, 336
– with fracture of medial malleolus + a Volkman fracture, 336
– with fracture of medial malleolus 44, 336
– with fracture of medial malleolus, 336
– with more than three intermediate fragments, 319
– with rupture of medial collateral ligament, 336
– with shortening, without Volkmann fracture, 336
– with three intermediate fragments, 319
– without asymmetric impaction, 319
– without depression, 319
– without shortening, without sex and fracture group distribution , Volkmann fracture, 336
– Y-shaped fracture with marked displacement, 248
sex and fracture group distribution acromion, 719
sex and fracture group distribution articular comminuted, , 719
sex and fracture group distribution body, 719
sex and fracture group distribution comminuted, 719
sex and fracture group distribution comminuted, , 719
sex and fracture group distribution coracoid, 719
sex and fracture group distribution extra-articular glenoid neck, , 719
sex and fracture group distribution inferior rim, 719
sex and fracture group distribution intra-articular simple, neck comminuted, , 719
sex and fracture group distribution intra-articular simple, neck simple, , 719
sex and fracture group distribution intra-articular with body, , 719
sex and fracture group distribution intra-articular with neck, , 719
sex and fracture group distribution posterior rim, 719
sex and fracture group distribution scapula, complete-articular fractures, , 719
sex and fracture group distribution scapula, extra-articular fractures, 719
sex and fracture group distribution scapula, partial-articular fractures, 719
sex and fracture group distribution simple, 719
sex and fracture group distribution types of Ogawa fractures of the coracoids, *728*
sex and fracture location distribution
– Hawkins Type I, 576
– Hawkins Type II, 576
– Hawkins Type III, 576
– Hawkins Type IV, 576
– Talar body fracture, 576
– Talar fractures, 575, *575*
– Talar head fracture, 576
– Talar neck fracture, 576
– Talar neck fractures (Hawkins classification), 576
– Talar process fracture, 576
– type I Nondisplaced, 576
– type II Displaced, with subluxation and dislocation of the subtalar joint, 576
– type III Displaced, with subluxation and dislocation of the subtalar and talotibial joints, 576
– type IV Displaced, with subluxation and dislocation of the talotibial, subtalar, and talonavicular joints, 576
sex and fracture pattern distribution, supracondylar fractures of humerus 90, *90*
sex and fracture segment distribution
– avulsion or split, 648
– bending, 648
– comminuted articular and metaphysic, 648
– comminuted articular, 648
– comminuted, 648
– complex comminuted, 648
– depression, 648
– fractures of the phalanx of the foot, 647, *647*
– fragmented, 648
– noncomminuted articular comminuted metaphysic, 648
– noncomminuted articular/comminuted metaphysic, 648
– noncomminuted articular/metaphysic, 648
– noncomminuted, 648
– oblique, 648
– phalanx proximal and distal complete articular, and sex and fracture segment distribution , diaphysis comminuted, 648
– phalanx proximal and distal extra-articular, and sex and fracture segment distribution , diaphysis noncomminuted, 648
– phalanx proximal and distal partial articular, and diaphysis wedge comminuted, 648

– phalanx proximal and distal partial articular, and sex and fracture segment distribution , diaphysis wedge comminuted, 648
– segmental, 648
– spiral, 648
– split/depression, 648
– transverse, 648
– avulsion or split, 629
– bending, 629
– comminuted articular, 629
– comminuted wedge, 629
– comminuted, 629
– complex comminuted, 629
– depression, 629
– distal articular, 629
– metatarsal fractures, 628, *628*
– metatarsal proximal, distal complete articular, and sex and fracture segment distribution , diaphysis comminuted, 629
– Metatarsal proximal, distal extra-articular, and sex and fracture segment distribution
–– diaphysis noncomminuted , 629
–– diaphysis noncomminuted, 629
– metatarsal proximal, distal partial articular, and diaphysis wedge comminuted, 629
– metatarsal proximal, distal partial articular, and sex and fracture segment distribution , diaphysis wedge comminuted, 629
– noncomminuted articular and metaphysic, 629
– noncomminuted articular, comminuted metaphysic, 629
– noncomminuted, 629
– oblique, 629
– phalanges of the foot, *639*
– segmental, 629
– simple articular/comminuted metaphysic, 629
– simple articular/metaphysic, 629
– spiral, 629
– split/depression, 629
– transverse, 629
sex and fracture subsegment distribution
– oblique posterior–superior views of atlas, *369*
– spinal column fractures, 368
– superior view of atlantoaxial ligaments, *369*
sex and fracture subtype distribution
– Allman classification of clavicle fractures, 699
– Allman Ib with displacement, 699
– Allman Ic comminuted, 699
– Allman IIa with no displacement, 699
– Allman IIb with displacement, 699
– Allman IIIa with no displacement, 699
– Allman IIIb with displacement, 699
– clavicle fractures by Allman classification, 697, *698*
– type I middle third, 699
– type II lateral third, 699
– type III medial third, 699
sex and fracture type distribution
– Barton fractures 192, *193*
– fractures of segment 11 38
– fractures of segment 11 *39*
– fractures of segment 12 55, *55*
– fractures of segment 13 *72*
– fractures of segment 21 126, *126*
– fractures of segment 22 142, *142*
– fractures of segment 23 158, *158*
– fractures of segment 31 211, *211*
– Monteggia fractures 175
– proximal, humeral fractures by Neer classification *85*
– Smith fractures 188, *188*
– anatomic neck fractures, 747
– classification of scapular neck fractures, 747
– coracoid fractures , coracoid fractures, *731*
– inferior neck fractures, 747
– scapular anatomic neck fractures, 747
– scapular inferior neck fractures, 747
– scapular neck fractures by degree of fracture displacement, 745
– scapular surgical neck fractures, 747
– surgical neck fractures, 747
sex and fracture type distribution
– fractures of segment 61, 418, *419*
– fractures of the phalanx of the foot, 643, *644*
– glenoid fractures, *751*
– acromion fractures, *738*
– adult clavicle fractures by OTA classification, *691*
– adult patellar fractures by OTA classification, *669*
– adult patellar fractures by Regazzoni classification, 678, *678*
– Allman classification of clavicle fractures, *695*
– bones of the foot, *549*
– burst fracture, 376
– calcaneal fractures, 583, *584*
– clavicle fractures by Allman classification, 696, *697*
– clavicle fractures by OTA classification, 691
– clavicle fractures by Robinson classification, 704, *704*
– clavicle, *682*
– comminuted, 602, 609, 692
– compression fracture of vertebral body, 382
– coracoid fractures, 731
– coracoid process fractures Types IV, 732
– coracoid type I, 732
– coracoid Type II, 732
– coracoid Type III , 732
– coracoid Type IV, 732
– Coracoid Type V, 732
– cuboid fractures, 608, *608*, 609
– cuneiform bones in the foot, *611*
– cuneiform fractures, 615, *615*
– Delineation illustration of three-column spine concept, *359*
– Delineation illustration of two-column spine concept, *359*
– diaphysis, 692
– dislocation of atlas–axis, 376
– distal, 692
– distraction injuries of the anterior and posterior elements, 382
– extra-articular, 692
– femoral head fractures by Pipkin classification, 264, *264*
– femoral neck fractures by Garden classification, 261, *261*
– fibula intact, 304
– forefoot, 659
– fracture displacement of the clavicle, *683*
– fractures of carpal bones (segments 71–76), 481, *482*
– fractures of metacarpal bones (segment 77), 505, *506*
– fractures of phalanx (segment 78), *530*
– fractures of segment 32, 228, *228*
– fractures of segment 33, 245, *245*
– fractures of segment 41, 285, *286*
– fractures of segment 42, 301, *302*
– fractures of segment 43, 317, *318*
– fractures of segment 44, 333
– fractures of segment 51.01 in adults, *374*
– fractures of segment 51.01 in adults, 374
– fractures of segment 51.02 in adults, 375
– fractures of segment 51.03–51.07 in adults, 381, *381*
– fractures of segment 62, 434, *435*
– fractures of segment, 51.02 in adults, *375*
– fractures of segments 52 and 53 in adults, 392, *392–393*
– fractures through isthmus, 376
– glenoid fractures, 751, *751*
– hindfoot, 659
– Ideberg classification of glenoid fractures, 752
– Ideberg Type I, 752
– Ideberg Type II, 752
– Ideberg type III, 752
– Ideberg type IV, 752
– Ideberg type V, 752
– Ideberg type VI, 752
– intra-articular, 692
– joint and ligaments of the clavicle, *683*
– LC-I Ipsilateral sacral buckle fracture, horizontal pubic rami fractures stable, 455
– metatarsal fractures by the number of the metatarsal bones, 627, *627*
– metatarsal fractures, 624, *625*
– midfoot, 659
– multiple foot fractures, 658, *658*
– multiple fractures of metacarpals, 547
– multiple fractures of the foot, 659
– multiple fractures of the hand, 547
– multiple fractures of the phalanx, 547
– multiple hand fractures (segment 79), *546*
– muscle attachments of the clavicle, *682*
– noncomminuted, 602, 609
– odontoid fracture plus fractures through isthmus, 376
– odontoid fracture, 376
– Ogawa classification of coracoid fractures, 732
– Ogawa Type I, 732
– Ogawa Type II, 732
– OTA classification of clavicle fractures, 692
– patella, *661*
– patellar fractures, *661*
– Pilon fractures by Ruedi and Allgower classification, 356, *356*
– proximal, 692
– radiograph of the clavicle, *684*
– Regazzoni A1 Without displacement, 679
– Regazzoni A2 With displacement, 679
– Regazzoni A3 Comminuted, 679
– Regazzoni B2 Simple, 679
– Regazzoni B3 Comminuted, 679
– Regazzoni C1 Without marked displacement, 679
– Regazzoni C2 With displacement of, 679
– Regazzoni C3 Combined with burst fractures with displacement, 679
– Regazzoni classification of patellar fractures, 679
– Robinson 1B displaced fractures, 705
– Robinson 2A cortical alignment fractures, 705
– Robinson 2B displaced fractures, 705
– Robinson 3A cortical alignment fractures, 705
– Robinson 3B displaced fractures, 705
– Robinson classification of clavicle fractures, 705
– rotation injuries with translation affecting the anterior and posterior elements, 382
– scaphoid fractures based on AO classification, 497
– scapula: anterior (a) and posterior (b) views, *708*
– scapular fractures, *717*
– scapular neck fractures by fracture line direction, 745
– scapular neck fractures, *745–746*
– simple, 692
– talar fractures, *564*
– tarsal navicular fracture, 602
– tarsal navicular fractures, 601, *601*, 602
– thoracolumbar spine *388*
– tibia and fibula fractures at different level, 304
– tibia and fibula fractures at the same level, 304
– tibial and fibular fractures at different levels, 304
– tibial and fibular fractures at the same level, 304
– tibial plateau fractures by Schatzker classification, 350, *350*
– trochanteric fractures by Evans' classification, *258*

– trochanteric fractures of the femur by Evans' classification, 258
– two zones of acromion fractures, *735*
– type 1 medial fifth, 705
– type 2 intermediate three-fifths of diaphysis, 705
– type 3 lateral fifth, 705
– Type A Vertical, 679
– Type C Comminuted fractures, 679
– type I Basal fracture, 732
– type I Glenoid rim, 752
– type I: coracoid tip or epiphyseal fracture, 732
– type II avulsion fracture, 732
– type II Fracture line exiting inferior part of glenoid fossa, 752
– type II: mid process, 732
– type III Fracture line exiting superior part of glenoid sex and fracture type distribution , fossa, 752
– type III: Basal fracture coracoid Type III, 732
– type IV Transverse fracture from the glenoid fossa to the medial border of the scapula, 752
– type V Combination of fractures of the glenoid fossa and the body of the scapula, 752
– type V: extension into the glenoid fossa, 732
– type VI Severe comminution of the glenoid fossa, 752
– Type-B Transverse, 679
– unilateral neural arch fracture, 376
– wedge, 692
– with extensive shattering (b %4 cm), 304
– with limited shattering, 304
– with more than three intermediate fragments, 304
– with one intermediate fragment and an additional wedge Fragment, 304
– with one intermediate fragment, 304
– with three intermediate fragments, 304
– with two intermediate fragments, 304
– with two or three intermediate fragments, 304
– Young-Burgess CM-I Anterolateral force, 455
– Young-Burgess CM-II Anterovertical force, 455
– Young-Burgess VS-I Pubic diastasis, 455
– Young-Burgess VS-II Vertical pubic rami fractures, vertical displacement, and an iliac fracture , 455
– Young-Burgess VS-III Vertical pubic rami fractures, vertical displacement, SI joint disruption, and a sacral fracture, 455
– Young–Burgess fractures, 453, *454*
sex and fracture type distribution of 28,279 fractures of segment 44, *334*
sex and frature group distribution , simple, through the load-bearing surface, 248
sex distribution
– Barton fractures 190, *190*
– capitellum fractures of humerus 107, *107*
– Colles fractures 181, *181*
– femoral fractures *202*
– femoral fractures in CNFS 197, *197*
– fractures of segment 11 36, *36*
– fractures of segment 12 53, *53*
– fractures of segment 13 69, *69*
– fractures of segment 21 *123*
– fractures of segment 21 123
– fractures of segment 22 139
– fractures of segment 22 *139*
– fractures of segment 23 155, *155*
– fractures of segment 31 *208*
– fractures of segment 31 208
– fractures of segment 32 225, *225*
– Galeazzi fractures 177, *177*
– humeral fractures in CNFS 25, *25*
– intercondylar fractures of humerus *92*
– lateral condylar fractures of humerus sex 95
– lateral epicondyle fractures of humerus 101, *101*
– medial condylar fractures of humerus 97, *97*
– medial epicondyle *105*
– medial epicondyle fractures of humerus 105, *105*
– Monteggia fractures 172, *172*
– radial/ulnar fractures 117, *117*
– radial/ulnar fractures in CNFS 39, *112*
– Smith fractures 185, *185*
– supracondylar fractures of humerus 88, *88*
– phalanx fractures by individual finger, *532*
sex distribution
– another anterior view of the pelvis, *414*
– fractures of segment 61, 416, *416*
– intercondylar fractures of humerus sex 92
– pediatric patients with acetabular fractures 413
– pediatric patients with acetabular fractures, *413*
– pediatric patients with pelvic ring fractures, 413, *413*
– Pilon fractures, 353, *353*
– tibial plateau fractures, 348
– with fractures of carpal bones (segments 71–76), 478
– with fractures of the pelvic ring and acetabulum, 409, *409*
– with spinal column fractures, *365*
– with spinal fractures in the China National Fracture Study, 361
– acromion fractures, 735, *735*
– adult fractures of segments 52 and 53 in adults, *389*
– avulsion or split, 509, 533
– bending wedge, 509
– bending, 533
– comminuted articular, 509, 533
– comminuted, 509, 533
– complex comminuted, 509, 533
– coracoid fractures, 728, *728*
– depression, 509, 533
– distal section, 231
– extra-articular, comminuted, 533
– extra-articular, simple, 533
– fractures of metacarpal bones by individual metacarpal bone, *508*
– fractures of segment 33, 242
– fractures of segment 41, 282, *282*
– fractures of segment 42, 299, *299*
– fractures of segment 43, 315, *315*
– fractures of segment 44, 330, *330*
– fractures of segment 51.03–51.07 in adults, 378, *378*
– fractures of segment 62, *432*
– fractures of segment, 432
– fractures of segments 52 and 53 in adults, 389
– fragmented, 533
– glenoid fractures, 749, *749*
– metacarpal fractures by individual metacarpal bo noncomminuted ne, 508
– metacarpal proximal and distal complete articular and diaphysis comminuted, 509
– metacarpal proximal and distal nonarticular and diaphysis noncomminuted, 509
– metacarpal proximal and distal partial articular and diaphysis wedge comminution, 509
– middle section, 231
– noncomminuted articular and metaphysic, 509
– noncomminuted articular metaphysic, 533
– noncomminuted articular, comminuted metaphysic, 509
– noncomminuted articular/comminuted metaphysic, 533
– noncomminuted articular/metaphysic, 533
– oblique, 509, 533
– patients with tibial/fibular fractures in China National Fracture Study (CNFS), *269*
– patients with tibial/fibular fractures in China National Fracture Study, 269
– phalanx fractures by individual finger, 532, *532*
– phalanx proximal and distal complete articular and diaphysis comminuted, 533
– phalanx proximal and distal extraarticular and diaphysis noncomminuted, 533
– phalanx proximal and distal partial articular and diaphysis wedge comminution, 533
– scapular neck fractures, 742, *742*
– segmental, 509, 533
– simple articular/comminuted metaphysic, 509
– simple articular/metaphysic, 509
– simple, 509
– spiral wedge, 509
– spiral, 509, 533
– spiral, simple, 533
– split/depression, 509, 533
– subtrochanteric section, 231
– tibial plateau fractures, *348*
– tibial/fibular fractures, 274, *274*
– transverse, 509, 533
– upper cervical spine fractures in adults, 371, *371*
– wedge or comminuted, 509
– with calcaneal fractures, 580, *580*
– with carpal fractures, *478*
– with clavicle fractures in China National Fracture Study (CNFS), *685*
– with clavicle fractures in CNFS, 685
– with clavicle fractures, 688, *688*
– with cuboid fractures, 605, *605*
– with cuneiform fractures, 612, *612*
– with extensive shattering, 231
– with foot fractures in China National Fracture Study (CNFS), *551*
– with foot fractures in CNFS, 551
– with foot fractures, 555, *555*
– with fractures of the base of the first metacarpal bone, 519, *519*
– with fractures of the phalanx of the foot, 640, *640*
– with fractures, 755, *755*
– with hand fractures in the China National Fracture Study (CNFS), *469*
– with hand fractures in the China National Fracture Study, 469
– with hand fractures, 473, *473*
– with limited shattering, 231
– with metacarpal bone (segment 77) fractures, 502, *502*
– with metatarsal fractures, 621, *621*
– with more than three intermediate fragments, 231
– with multiple fractures (segment 79), 543, *543*
– with one intermediate segmental fragment with an sex distribution , additional wedge fragment, 231
– with one intermediate segmental fragment, 231
– with patellar fractures in China National Fracture Study (CNFS), *662*
– with patellar fractures in CNFS, 662
– with patellar fractures, *666*
– with patellar fracturesc, 666
– with pelvic ring and acetabular fractures in the China National Fracture Study (CNFS), *405*
– with pelvic ring and acetabular fractures in the China National Fracture Study, 405
– with phalanx fractures (segment 78), 526, *526*
– with scaphoid fractures, 494, *494*
– with scapular fractures in CNFS, 710
– with scapular fractures, 713, *713*
– with spinal column fractures, 365
– with talar fractures, 561, *561*
– with tarsal navicular fractures, 598, *598*
– with three intermediate fragments, 231
– with two intermediate fragments, 231
– with two or more intermediate segmental fragments, 231
– with two or three intermediate fragments, 231
– Young–Burgess fractures, *451*

sex-specific fractures **15**
shoulder, radiographic anatomy of *35*
simple fracture (type A) 4
Smith fractures
– age and sex distribution of *187*
– age and sex distribution of 186
– age distribution of *187*
– type I, II, III *184*

T

thoracolumbar spine, anterior and posterior element injury with rotation, 394
thoracolumbar spine, anterior and posterior injuries with flexion-distraction
– anterior disruption through disk, 394
– anterior view of the pelvis, *403*
– composition of the pelvis, *403*
– lateral view of the sacrum, *404*
– posterior disruption predominantly ligamentous fractures, 394
– rotational shear injury, 394
– transmission of load through the pelvis, *404*
– type A injury with rotation, 394
– type B injury with rotation, 394
thoracolumbar spine, anterior and posterior injuries with flexion-distraction, 394
tile classification
– Type B, 447
– Type C, 447
– bilateral injury, ipsilateral vertically unstable, contralateral rotationally unstable, 447
– bilateral Type C injury, involving an acetabular fracture, 447
– tile A2 Pure iliac wing fracture with minimal displacement, 447
– tile A3 Transverse sacral or coccygeal fracture, 447
– tile B2 Lateral compression; ipsilateral, 447
– tile B3 Lateral compression; contralateral (Buckle handle type), 447
– type A, Tile A1 Avulsion fracture, without disruption of the pelvic ring, 447
– unilateral injury, 447
transcephalic and tubercular, with varus malalignment, 41
transthoracic lateral projection of shoulder *51*
traumatic fractures 1
traumatic fractures incidence in China **4**
tuberosity fractures
– lateral and greater 41
– medial and lesser 41
– posterior and greater 41

U

ulna complex, radius intact, simple or wedge, 144
ulna more than three fragments, radius three or more fragments, 128
ulna segmental, radius simple or wedge, 144
ulna wedge, radius simple, 144
unified classification system *3*

V

vertical cervical line 41

W

wedge fracture (type B) 4