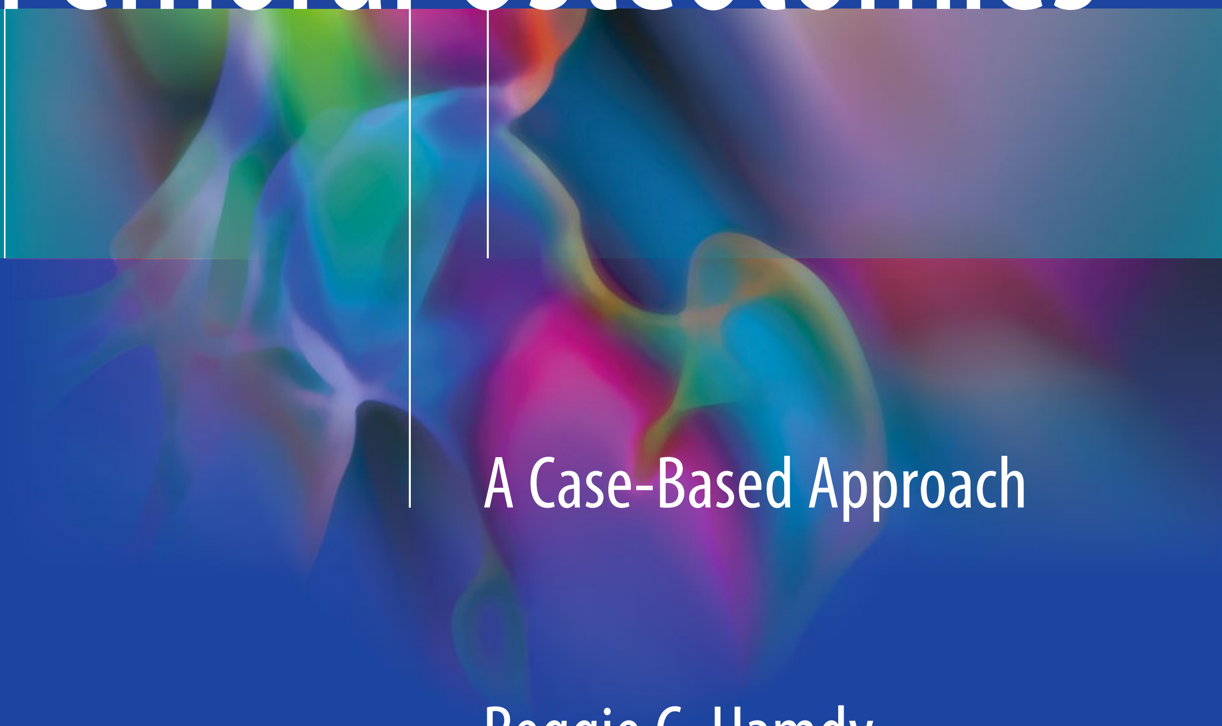
Pediatric Pelvic and Proximal Femoral Osteotomies



A Case-Based Approach

Reggie C. Hamdy
Neil Saran
Editors

Springer

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Editors
Reggie C. Hamdy
Shriners Hospital for Children
Montreal
Québec
Canada

Neil Saran
Shriners Hospital for Children
Montreal
Québec
Canada

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We dedicate this book to all the children and adolescents with hip problems hoping that it will help improve their quality of life; to our teachers and mentors for everything they taught us, to our wives, Sylvie and Pascale, for their unconditional love and continuous support and our sons-Sebastien, Nicolas and Charles-who will always inspire and motivate us.

Foreword

Reggie C. Hamdy and Neil Saran have produced a superb and comprehensive textbook of current practice of pediatric hip surgery, focusing on contemporary pelvic and proximal femoral osteotomies. The book contains information essential to all orthopedic trainees and those responsible for care of children and adolescents with these complex and disabling conditions. The editors have assembled a stellar cast of pediatric hip surgeons, each a respected expert, to describe the technique for 37 different or closely related variations of osteotomies about the hip.

The case-based and common format for all chapters creates a consistency of approach that will be appreciated by the reader, as it makes navigation through each chapter simple and convenient. This book has beautiful illustrations, both line drawings and intraoperative photographs, which precisely detail the operative technique for each osteotomy. The Pearls and Pitfalls section in each chapter offers advice and wisdom that may only be gained through extensive experience and will serve to reduce major and common errors in the application of a particular operative technique. The Indications and Contraindications section permits the reader to compare the preoperative imaging with the indications for each clinical scenario and thus be able to contrast and compare between chapters to learn how to select the appropriate osteotomy for a particular clinical problem or presentation. In this respect, this book is unique in that all conceivable operative solutions that involve osteotomies have been included, making it a one-stop reference source for the latest information on the subject.

A skeptic may ask two questions. The first is why so much emphasis on osteotomies when there is a universal solution at skeletal maturity in hip replacement arthroplasty? I believe that the value of osteotomies has been discounted because they are more technically demanding, require adaptation for many variations in deformities, and are not applied in situations where they may be more appropriate because of the lack of familiarity with them by most surgeons. The failure of an arthroplasty in a young person following a precipitous decision for this particular intervention is an all too common phenomenon that is exceedingly difficult to salvage for the long term. Familiarity with osteotomies and their thoughtful application may lead to better results over a lifetime, reserving arthroplasty to an age where it may be expected to last in active individuals.

The second question is why a book when almost all "information" is available online? The answer is that this book provides comprehensive "knowledge" in a systematic manner where the reader is able to compare and contrast clinical presentations with their potential solutions in a structured manner, something that is not readily available online.

In summary, I believe that this book is an essential reference source that should be available, in hard copy or electronically, to all surgeons taking care of children with hip disease or deformity. It is best described as an operative manual embedded in extensive knowledge to guide the surgeon in applying the proper osteotomy for any given clinical application that may benefit from surgical intervention.

Toronto, ON, Canada John H. Wedge

Preface

The hip is a complex joint with several important functions including weight bearing and ambulation. Various congenital, developmental and acquired conditions may affect the anatomy and biomechanics of the hip joint during childhood and adolescence and may have a significant impact on ambulation, overall function and quality of life.

In most of these hip pathologies, the anatomy and biomechanics of the hip joint can be restored to normal or near-normal states by various osteotomies of the proximal femur, acetabulum or both.

In this clinical casebook, commonly performed proximal femoral and pelvic osteotomies in the child and adolescent are described in 39 chapters. We enlisted the help of surgeons from around the world for their expertise in order to have each chapter written by a content expert. All of these chapters are written in a systematic format that will allow the reader to easily navigate between chapters.

The book is divided into three parts. The first part includes two chapters on the clinical and radiological examination of the paediatric and adolescent hip. These chapters outline the general approach and management of any hip problem in the paediatric population and the radiologic evaluation of the adolescent or young adult hip. The second part describes various pelvic osteotomies including redirectional osteotomies (Salter, triple, Ganz), acetabuloplasties (Dega, Pemberton) and salvage procedures (Shelf and Chiari). As a specific osteotomy may be indicated in more than one pathology, the same osteotomy may be discussed in more than one chapter depending on the pathology. The third part describes proximal femoral osteotomies in various conditions (Perthes, slipped capital femoral epiphysis, neuromuscular hips, etc.). The last part includes miscellaneous procedures involving combined pelvic and femoral osteotomies and other surgical procedures such as articulated hip distraction.

We believe that this book will be a valuable reference for all orthopaedic surgeons as well as all personnel (medical and paramedical) involved in the management of children and adolescents with hip disorders requiring surgical intervention. We sincerely hope that this book will ultimately help the care of these children and adolescents and improve their quality of life.

Montreal, Québec, Canada Reggie C. Hamdy
Montreal, Québec, Canada Neil Saran

Acknowledgements

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Contents

Contributors

Franck Accadbled, MD, PhD Pediatric Orthopaedics, Hôpital des Enfants, CHU de Toulouse, Toulouse, France

Fahad S. Alhuzaimi, MD, MBBS Division of Paediatric Orthopaedic Surgery, Department of Paediatric Surgery, Montreal Children's Hospital, McGill University Health Centre, Montréal, QC, Canada

Department of Orthopaedic Surgery, Shriners Hospital for Children Canada, Montreal, QC, Canada

Elizabeth Ashby, MB BChir FRCS (Orth) Department of Orthopaedics, Evelina Children's Hospital, London, UK

Yaroslav Basyuk, MD Orthopaedics, University Hospital, Newark, NJ, USA

Paul E. Beaulé, MD, FRCS(C) Division of Orthopaedic Surgery, University of Ottawa, The Ottawa Hospital, Ottawa, ON, Canada

Étienne L. Belzile, MD, FRCS(C) Department of Orthopaedic Surgery, CHU de Québec-Université Laval, Quebec City, QC, Canada

Thierry E. Benaroch, MD, FRCS(C) Division of Paediatric Orthopaedic Surgery, Department of Paediatric Surgery, Montreal Children's Hospital, McGill University Health Centre, Montréal, QC, Canada

Department of Orthopaedic Surgery, Shriners Hospital for Children-Canada, Montréal, QC, Canada

John G. Birch, MD, FRCS(C) Department of Pediatric Orthopedics, Texas Scottish Rite Hospital for Children, Dallas, TX, USA

Ayşegül Bursalı, MD Private Practice, Istanbul, Turkey

Alexander M. Cherkashin, MD Department of Pediatric Orthopedics, Division of Clinical Implementation and Data Management, Center of Excellence for Limb Lengthening and Reconstruction, Texas Scottish Rite Hospital for Children, Dallas, TX, USA

John C. Clohisy, MD Shriners Hospitals for Children, St. Louis, MO, USA

St. Louis Children's Hospital, St. Louis, MO, USA

Barnes-Jewish Hospital, St. Louis, MO, USA

Department of Orthopaedic Surgery, Washington University School of Medicine, St. Louis, MO, USA

John P. Dormans, MD Division of Orthopaedic Surgery, University of Ottawa, The Ottawa Hospital, Ottawa, ON, Canada

Christopher Dowding, MD, FRCS(C) Division of Orthopaedic Surgery, University of Ottawa, The Ottawa Hospital, Ottawa, ON, Canada

Deborah M. Eastwood, MB ChB Department of Orthopaedic Surgery, Great Ormond Street Hospital for Children, London, UK

Mark Eidelman, MD Pediatric Orthopedics, Ruth Children's Hospital, Technion Faculty of Medicine, Haifa, Israel

Dan S. Epstein, MD McGill University, Montreal, QC, Canada

Shriners Hospital for Children – Canada, Montreal, QC, Canada

David S. Feldman, MD Paley Orthopedic and Spine Institute, St. Mary's Medical Center, West Palm Beach, FL, USA

Panagiotis Peter Glavas, MD Sainte-Justine University Hospital Center, University of Montreal, Montreal, QC, Canada

H. Kerr Graham, MD, FRCS (Ed), FRACS Department of Orthopaedic Surgery (NHMRC CP-CRE), Royal Children's Hospital, Parkville, VIC, Australia

Reggie C. Hamdy, MB, MSc (Ortho), FRCS(C) Division of Orthopaedic Surgery, McGill University Health Centre, Montreal, QC, Canada

The Montreal Children's Hospital, Montreal, QC, Canada

Shriners Hospital for Children – Canada, Montreal, QC, Canada

Lee S. Haruno, BS Division of Orthopedic Surgery, Baylor College of Medicine, Texas Children's Hospital, Houston, TX, USA

Simon P. Kelley, MBChB,PhD,FRCS(C)(Tr and Orth) Department of Surgery, University of Toronto, Toronto, ON, Canada

The Hospital for Sick Children, Toronto, ON, Canada

Young-Jo Kim, MD, PhD Department of Orthopedic Surgery, Boston Children's Hospital, Boston, MA, USA

David J. Kirby, BS Division of Pediatric Orthopaedic Surgery, Department of Orthopaedic Surgery, The Johns Hopkins Hospital, Baltimore, MD, USA

Ken N. Kuo, MD Department of Orthopaedic Surgery, Taipei Medical University, Taipei, Taiwan

Department of Orthopaedic Surgery, National Taiwan University Hospital, Taipei, Taiwan

Jill E. Larson, MD Department of Orthopedic Surgery, Harvard University, Boston Children's Hospital, Boston, MA, USA

Michael Leunig, MD Orthopedic Surgery, University of Rochester Medical Center, Rochester, NY, USA

William G. Mackenzie, MD Orthopedic Department, Nemours/Alfred I. duPont Hospital for Children, Wilmington, DE, USA

M. Chad Mahan, MD Henry Ford Health System, Detroit, MI, USA

Hannes M. Manner, MD Department of Orthopedic Surgery, Schulthess Clinic, Zurich, Switzerland

Benjamin D. Martin, MD Division of Orthopaedic Surgery and Sports Medicine, Children's National Health System, Washington, DC, USA

Travis Matheney, MD, MLA Department of Orthopaedic Surgery, Harvard Medical School, Boston Children's Hospital, Boston, MA, USA

Michael B. Millis, MD Department of Orthopedic Surgery, Boston Children's Hospital, Child and Adult Hip Program, Boston, MA, USA

Nicole I. Montgomery, MD Orthopaedic Oncology, University of Texas MD Anderson Cancer Center, Clinical Care Center, Houston, TX, USA

Kishore Mulpuri, MBBS, MS (Ortho), MHSc (Epi) Orthopaedic Surgery, British Columbia Children's Hospital, Vancouver, BC, Canada

Unni G. Narayanan, MBBS, MSc, FRCS(C) The Hospital for Sick Children, University of Toronto, Toronto, ON, Canada

Eduardo N. Novais, MD Department of Orthopedic Surgery, Boston Children's Hospital, Boston, MA, USA

Ryan M. O'Shea, MD Department of Orthopaedic Surgery, Kaiser Permanente San Diego, San Diego, CA, USA

Matthew E. Oetgen, MD, MBA Division of Orthopaedic Surgery and Sports Medicine, Children's National Health System, Washington, DC, USA

The George Washington University School of Medicine and Health Sciences, Washington, DC, USA

Dror Paley, MD, FRCS(C) Paley Orthopedic and Spine Institute, St. Mary's Medical Center, West Palm Beach, FL, USA

Stefan Parent, MD, PhD Sainte-Justine University Hospital Center, University of Montreal, Montreal, QC, Canada

Thierry Pauyo, MD, FRCSC Department of Orthopaedic Surgery, Shriners Hospital for Children Canada, Montreal, QC, Canada

Department of Paediatric Surgery, The Montreal Children's Hospital, Montreal, QC, Canada

Division of Orthopaedic Surgery, Department of Surgery McGill University, Montreal, QC, Canada

Karl E. Rathjen, MD Department of Pediatric Orthopedics, Texas Scottish Rite Hospital for Children, Dallas, TX, USA

Benjamin F. Ricciardi, MD Orthopedic Surgery, University of Rochester Medical Center, Rochester, NY, USA

Sanjeev Sabharwal, MD, MPH Department of Orthopedics, University of California, San Francisco, CA, USA

Division of Pediatric Orthopedics, University Hospital, Newark, NJ, USA

Jérôme Sales de Gauzy, MD, PhD Pediatric Orthopaedics, Hôpital des Enfants, CHU de Toulouse, Toulouse, France

Mikhail L. Samchukov, MD Department of Pediatric Orthopedics, Center of Excellence for Limb Lengthening and Reconstruction, Texas Scottish Rite Hospital for Children, Dallas, TX, USA

Adolfredo Santana, MD Orthopedic Department, Nemours/Alfred I. duPont Hospital for Children, Wilmington, DE, USA

Neil Saran, MD, MHSc (Clin. Epi.), FRCS(C) Department of Orthopaedic Surgery, Shriners Hospital for Children Canada, Montreal, QC, Canada

Department of Paediatric Surgery, The Montreal Children's Hospital, Montreal, QC, Canada

Division of Orthopaedic Surgery, Department of Surgery McGill University, Montreal, QC, Canada

Emily K. Schaeffer, PhD Orthopaedic Surgery, British Columbia Children's Hospital, Vancouver, BC, Canada

Perry L. Schoenecker, MD Shriners Hospitals for Children, St. Louis, MO, USA

St. Louis Children's Hospital, St. Louis, MO, USA

Barnes-Jewish Hospital, St. Louis, MO, USA

Department of Orthopaedic Surgery, Washington University School of Medicine, St. Louis, MO, USA

Mehmet Serhan Er, MD Orthopedic Department, Nemours/Alfred I. duPont Hospital for Children, Wilmington, DE, USA

Claire E. Shannon, MD Division of Orthopaedics, Department of Orthopaedic Surgery, The Hospital for Sick Children, Toronto, ON, Canada

Benjamin J. Shore, MD, MPH, FRCS(C) Department of Orthopaedic Surgery, Harvard Medical School, Boston Children's Hospital, Boston, MA, USA

Paul D. Sponseller, MD, MBA Division of Pediatric Orthopaedic Surgery, Department of Orthopaedic Surgery, The Johns Hopkins Hospital, Baltimore, MD, USA

Daniel J. Sucato, MD, MS Department of Orthopaedic Surgery, Texas Scottish Rite Hospital, University of Texas at Southwestern Medical School, Dallas, TX, USA

Magdalena Tarchala Department of Orthopaedic Surgery, Shriners Hospital for Children Canada, Montreal, QC, Canada

Department of Paediatric Surgery, The Montreal Children's Hospital, Montreal, QC, Canada

Division of Orthopaedic Surgery, Department of Surgery McGill University, Montreal, QC, Canada

Andrew D. W. Tice, MD Department of Orthopaedic Surgery, Texas Scottish Rite Hospital for Children, Dallas, TX, USA

Vidyadhar V. Upasani, MD Rady Children's Hospital San Diego, University of California San Diego, San Diego, CA, USA

Harold J. P. van Bosse, MD Shriners Hospital for Children, Philadelphia, PA, USA

Ting-Ming Wang, MD, PhD Department of Orthopaedic Surgery, National Taiwan University Hospital, Taipei, Taiwan

Dennis R. Wenger, MD Department of Orthopedic Surgery, Pediatric Orthopedic Training Program, Rady Children's Hospital San Diego, University of California, San Diego, San Diego, CA, USA

Timur Yıldırım, MD Orthopaedic and Traumatology Department, Baltalimani Bone Diseases Training and Research Hospital, Istanbul, Turkey

Ira Zaltz, MD Pediatric Orthopaedic Surgery, Beaumont Hospital, Royal Oak, MI, USA

Stephan T. Zmugg, MD Department of Orthopaedic Surgery, Texas Scottish Rite Hospital, University of Texas at Southwestern Medical School, Dallas, TX, USA

1 Preoperative Planning for Pelvic and/or Proximal Femoral Osteotomies

Reggie C. Hamdy and Dan S. Epstein

Introduction

The hip joint is the largest joint in the human body after the knee joint and the most mobile after the shoulder joint. It is a complex joint that plays a major role in daily activities and has a major impact on the quality of life. In this introductory chapter, some specific aspects of its anatomy and biomechanics that are pertinent to pelvic and proximal femoral osteotomies are discussed.

The hip joint serves several important *functions*. First, it supports the weight of the human body, and second, it permits a wide range of movements that are necessary for ambulation and for carrying out various sports and daily activities (walking, running, sitting, squatting, jumping, etc.).

To fulfill these important functions, the hip joint has to be very *mobile*, very *stable*, and at the same time able to withstand various amounts of stresses across its articulating surfaces. During running and jumping, for instance, the force of the body's movements multiplies the forces on the hip joint to many times the force exerted by the body's weight. Normally, the hip joint can accommodate these extreme forces repeatedly during intense physical activities.

Stability of the Hip Joint

Hyaline cartilage lines both the acetabulum and the head of the femur, providing a smooth surface for the moving bones to glide past each other. Hyaline cartilage also acts as a flexible shock absorber to prevent collision of the bones during movement. The acetabulum is formed by the confluence of the three pelvic bones at the triradiate cartilage: the ilium, pubis, and ischium (Fig. 1.1). The hip joint is a very *stable* joint, due to the depth of the bony acetabular socket, which is slightly less than a hemisphere. The tough fibrocartilaginous labrum, lining the rim of the acetabulum, increases its functional depth and like a suction cup helps maintain the negative pressure in the hip joint (Fig. 1.2). The very strong ligaments surrounding the joint capsule (the iliofemoral ligament anteriorly, ischiofemoral ligament posteriorly, and pubofemoral ligament medially) (Fig. 1.3), combined with the powerful muscles surrounding the joint, ensure the stability of the hip joint and prevent it from dislocating, unless subjected to high energy forces.

R. C. Hamdy (✉)
Division of Orthopaedic Surgery, McGill University Health Centre, Montreal, QC, Canada

The Montreal Children's Hospital, Montreal, QC, Canada

Shriners Hospital for Children – Canada, Montreal, QC, Canada
e-mail: rhamdy@shriners.mcgill.ca

D. S. Epstein
McGill University, Montreal, QC, Canada

Shriners Hospital for Children – Canada, Montreal, QC, Canada

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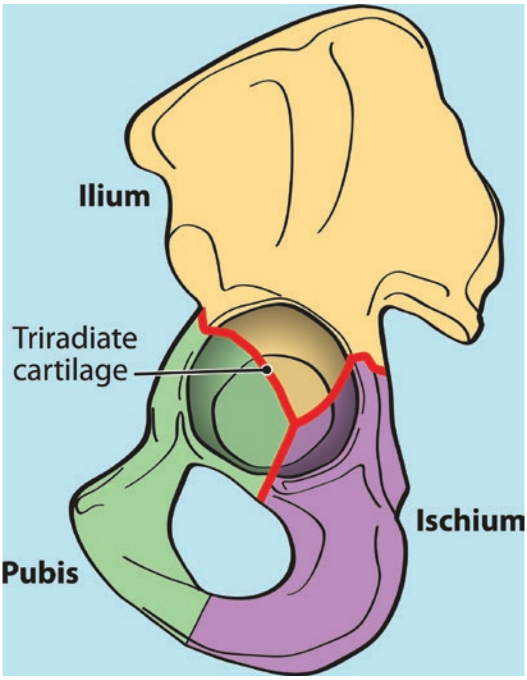

Fig. 1.1 Fusion of the three bones in the pelvis, ilium, ischium, and pubis, forms a cup-shaped socket known as the acetabulum, shown here in lateral view

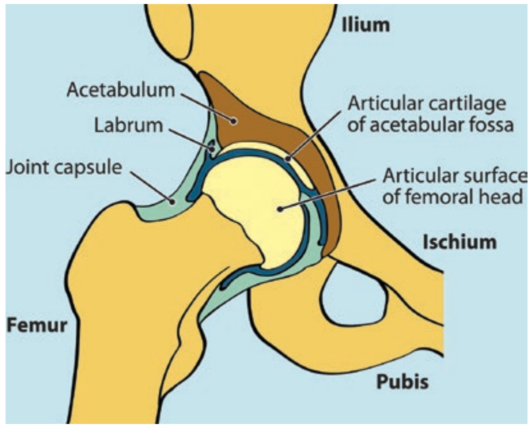

Fig. 1.2 The head of the femur and the acetabulum are in a ball-and-socket configuration. The labrum deepens the socket and allows a negative pressure inside the joint. A thick capsule surrounds the joint

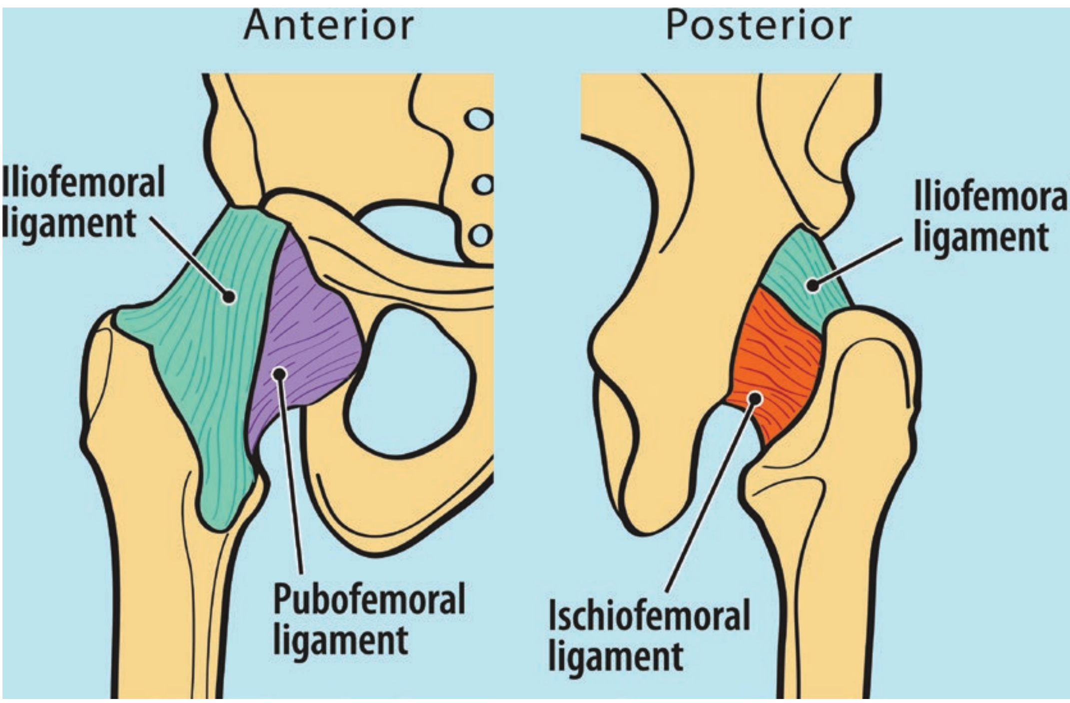

Fig. 1.3 The ligaments surrounding the joint capsule: the iliofemoral anteriorly, ischiofemoral ligament posteriorly, and pubofemoral ligament medially

Mobility of the Hip Joint

Functionally, the hip joint enjoys a very *high range of motion* (*ROM*). Two factors are responsible for this large ROM. First, the ball-and-socket structure of the joint allows the femur to circumduct almost freely through a 360° circle. The second factor that contributes to this large ROM is the shape of the femoral neck. Besides its length, its diameter is smaller than that of the femoral head and that allows this large ROM. A normal hip joint allows about 120° flexion, 20° extension, 60° abduction, 30° adduction, and about 40° of each internal/external rotation. Only the shoulder joint provides as high a level of mobility as the hip joint. Thus any cause leading to a short femoral neck (coxa breva) inevitably leads to a decrease in the hip ROM. In such cases, a femoral neck lengthening procedure may then be indicated (Morsher or Wagner types of proximal femoral osteotomies).

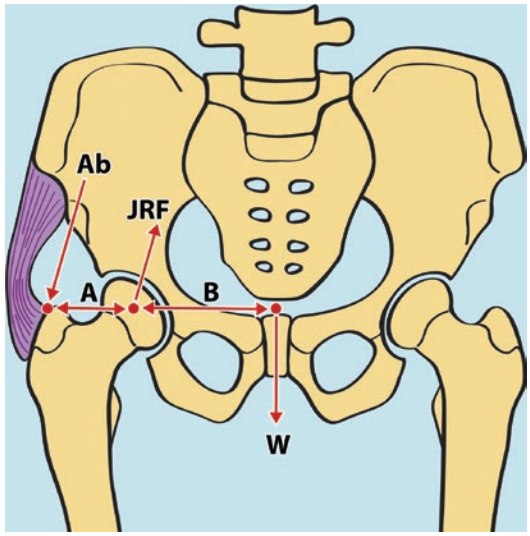

Fig. 1.4 A vector diagram of the joint reaction forces (JRF) generated within the hip joint. *Ab* abductor force, *A* abductor moment arm, *B* moment arm of body weight, *W* body weight

Joint Reaction Forces, Abductor Mechanism, and Role of the Greater Trochanter

The joint reaction forces (JRF) are the forces generated within the hip joint in response to forces acting on the joint and are the result of the need to balance the moment arms of the body weight and abductor tension. This balance is important in order to maintain the pelvis leveled. The JRF equal the combined values of the body weight and the abductor force (Fig. 1.4). During two-leg stance phase, little or no muscular forces are required to maintain equilibrium. However, during walking and running, the JRF are increased several times the body weight. The *greater trochanter* plays a significant role in maintaining the normal biomechanics of the hip joint. The powerful hip abductors (gluteus medius and minimus) are attached to the tip of the greater trochanter, and the abductor muscle length is an important factor in maintaining an adequate abductor force (Fig. 1.5).

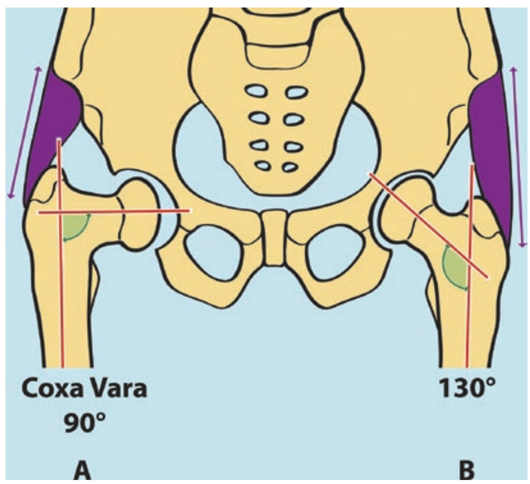

Fig. 1.5 The powerful hip abductors (gluteus medius and minimus) are attached to the tip of the greater trochanter. The abductor muscle length is an important factor in maintaining an adequate abductor force. *A* Coxa vara with decreased neck-shaft angle and decreased abductor muscle length. *B* Normal neck-shaft angle with normal abductor muscle length

Causes of Hip Dysplasia

Numerous causes—congenital, developmental, and acquired—may lead to dysplasia of the hip joint, either by altering the normal anatomy of the hip joint (acetabulum, proximal femur, or both) or by altering the biomechanics of the joint [1, 2]. The implications may be minimal or severe and may affect the daily activities and quality of life of the patient.

Management of Hip Dysplasia in the Pediatric Age

It is generally agreed that hip dysplasia in children should be treated to prevent or delay the onset of degenerative arthritis. The management of various hip pathologies in pediatric patients can be very challenging due to the multitude of causes that can lead to hip dysplasia as well as the complexity of the anatomy and biomechanics of the hip joint. The clinical effects of these conditions may range from mild discomfort to severe debilitation and loss of quality of life. The first step is to identify what is the problem and put forward a "problem list" that includes the presenting complaints, physical examination, and radiological evaluation. Then the expectations of the patient and family, the various treatment options, and, finally, the "surgical approach" should be discussed with the patient and family.

Problem List

What Is the Problem?

The problem is based on the presenting complaint and the findings of the physical examination. It is extremely important to clearly define the reason for the visit. Why did the parents or caregivers bring the child to the clinic? What is their concern? Is there any history of pain? If pain is present, then more details about the pain should be obtained. Is there any limping or stiffness? What is the impact on mobility, daily activities, and quality of life? Is the problem localized to the hip, or is it part of a more generalized systemic problem (such as skeletal dysplasia or metabolic disorder)? Is there any family history of similar problems, previous history of trauma or infection, and similar episodes of pain? In cases of neuromuscular conditions, are there any difficulties with positioning (in wheelchair) or hygiene care (abducting the legs)?

Following a thorough history taking, a complete physical should be performed. The gait of the child is analyzed, specifically, for the presence of a Trendelenburg gait that may point to abductor mechanism pathology (Fig. 1.6). The spine is examined in the standing position. If the pelvis is not horizontal, this may be due to limb length discrepancy (LLD). Wooden blocks under the short leg may be used to determine the amount of LLD. Next, the patient is examined on the bed. The ROM is determined in both the supine and prone position. Assessing rotation in the supine position with the hips flexed 90° relaxes the anterior joint capsule and should eliminate the effects of any hip flexion contractures, thus giving an exaggerated value for hip rotation.

Assessing rotation of the hips is, therefore, more accurate in the prone position, as this is the normal position of the hips during standing and walking. That said, rotational range of motion in the 90° flexed position is useful in cases of suspected femoroacetabular impingement (FAI) as internal rotation is typically decreased on the affected side. The presence of any muscular atrophy and contractures is documented. Pain elicited by any movements—passive or active—should be carefully noted. Anterior and posterior impingement tests should also be performed to detect the presence of any femoroacetabular impingement. A complete neuromuscular examination is a must. In cases of any suspicion of a neuromuscular condition, a neurological consultation and a complete muscular assessment are recommended. A gait laboratory analysis may also be considered.

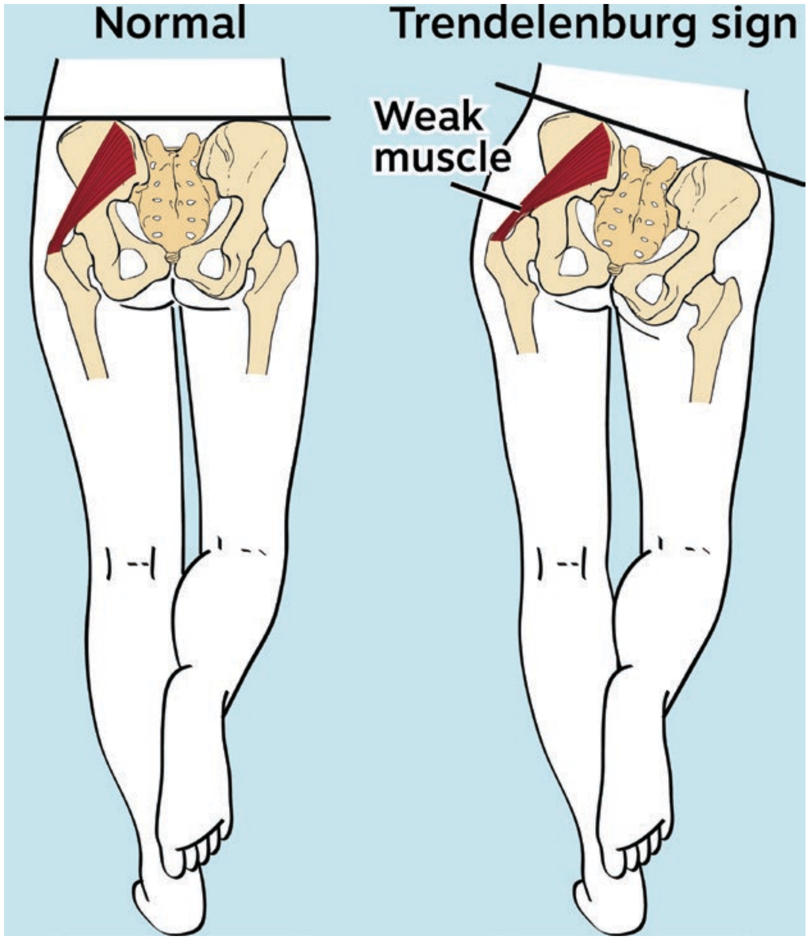

Fig. 1.6 Trendelenburg sign. While standing on one leg, the abductors contract to maintain a leveled pelvis. In case of abductor muscle weakness, the contralateral pelvis "drops"

Where Is the Problem?

This is answered by a careful radiological assessment of the hip joint, as detailed below.

Radiological Assessment of Hip Problems Many modalities can be used for the initial diagnosis and further workup, including ultrasonography in the first 6 months of life, plain radiography, arthrography, computerized tomography with or without three-dimensional (3D) imaging, and magnetic resonance imaging (MRI). Most recently, 3D printing is used in the evaluation and preoperative planning of complex deformities. However, most hip problems could be evaluated on a plain anteroposterior (AP) radiograph, and much can be learned from this simple study. Radiological analysis of the hip joint should include assessment of the acetabulum, the proximal femur, and the relation between the acetabulum and proximal femur.

The most commonly used angles and parameters to assess hip dysplasia include:

1. *To assess acetabular dysplasia*:
   (a) Acetabular index [3]
   (b) Acetabular index of Sharp [4]
   (c) Acetabular depth
   (d) The sourcil
   (e) The teardrop
2. *To assess proximal femoral dysplasia*:
   (a) Neck-shaft angle
   (b) Hilgenreiner epiphyseal angle [5]
   (c) Femoral neck changes: coxa vara and coxa valga
   (d) Changes in the femoral head: coxa breva and coxa magna
   (e) Relation between the greater trochanter and the femoral head

3. *To assess the relationship between the acetabulum and proximal femur*:
   (a) Shenton's line [6]
   (b) Center-edge angle for lateral coverage of the femoral head [7]
   (c) False-profile view for anterior coverage of the femoral head
   (d) AP of the pelvis in neutral and in maximum abduction/internal rotation
   (e) Migration index of Reimers [8]
   (f) Acetabular protrusion

The Hilgenreiner [9] and Perkins Lines [10] (Fig. 1.7) These are the standard lines used in many angular measurements.

Acetabular Index (Fig. 1.8) This is the angle between the Hilgenreiner line—the horizontal line running through the triradiate cartilage of both sides of the pelvis—and a line connecting the deepest part of the triradiate cartilage with the bony edge of the lateral acetabulum. Values more than 20° after the age of 2 years represent acetabular dysplasia.

Sharp Acetabular Index (Fig. 1.9) This angle measures the degree of acetabular dysplasia after the closure of the triradiate cartilage. It is measured on the AP view of the pelvis and represents the angle between the lateral margin of the acetabular roof or lateral sourcil and inferior aspect of the teardrop and the horizontal line between the inferior aspects of both pelvic teardrops. Values more than 42° represent acetabular dysplasia.

Sourcil (Fig. 1.10) The *sourcil* (eyebrow in French) is an area of subchondral osseous condensation in the acetabular roof and represents a response to the articular portion of the ileum to the stress provoked by the compressive forces acting on it. The length of the sourcil is usually about 80% of the width of the femoral head. The lateral extent of the sourcil may appear—in some cases—different than the lateral edge of the extra-articular ileum. This is important as it may give a false estimate of femoral head coverage.

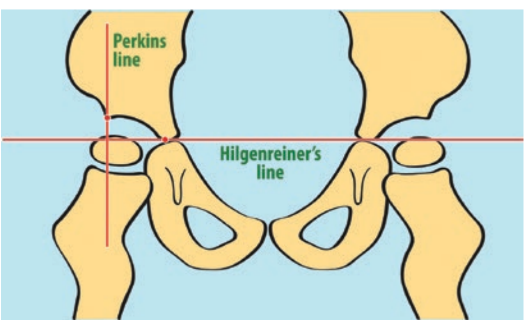

Fig. 1.7 The Hilgenreiner and Perkins lines. The *Hilgenreiner line* is the horizontal line running through the triradiate cartilage of both sides of the pelvis. The *Perkins line* is the vertical line running from the lateral edge of the acetabulum and perpendicular to the Hilgenreiner line

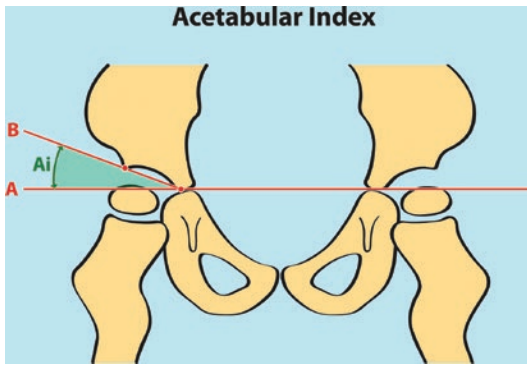

Fig. 1.8 Acetabular index is used to measure acetabular dysplasia in young children prior to the ossification of the triradiate cartilage. It is the angle between the Hilgenreiner line and a line connecting the lateral edge of the acetabulum and the triradiate cartilage. Values more than 20° after the age of 2 years represent acetabular dysplasia

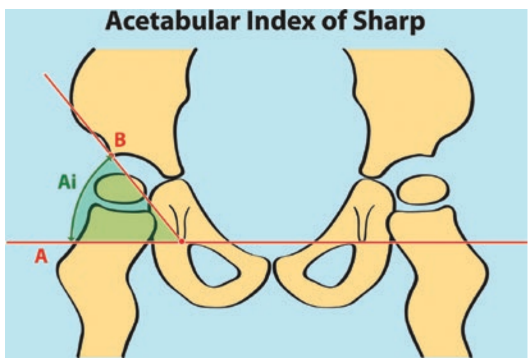

Fig. 1.9 Acetabular index of Sharp is used to measure acetabular dysplasia after ossification of the triradiate cartilage. It is the angle between Hilgenreiner and a line connecting the lateral edge of the acetabulum and the inferior part of the teardrop. Values greater than 42° represent acetabular dysplasia

Tönnis angle is the slope of the sourcil and is normal between 0° and 10°. It measures the inclination or angle of the weight-bearing area of the acetabulum. Tönnis angle is formed between a line joining the medial and lateral ends of the sourcil and a horizontal line. An increase in the slope of the sourcil may be associated with lateral subluxation of the femoral head and represents acetabular dysplasia.

Teardrop (See Fig. 1.10) The acetabular teardrop consists of two vertical lines connected distally. The teardrop is a radiographic condensation of the innominate bone at the inferior end of the acetabulum. A normal teardrop is U-shaped. The medial border of the teardrop is continuous with the ilio-ischial line (named the Kohler line), and the lateral wall is continuous superiorly with the floor of the acetabulum. The width of the teardrop varies with rotation of the pelvis. A wide teardrop is associated with a shallow acetabulum. A very narrow teardrop where the medial and lateral wall touch each other at the floor of the acetabulum or crossover is a sign of a deeper than normal acetabulum causing over coverage of the head called coxa profunda.

The Shenton Line (See Fig. 1.10) The Shenton line is an imaginary line joining the inferior border of the superior pubic ramus to the inferomedial border of the proximal femur. It should be a smooth line. In cases of subluxation, this line is "broken."

Neck-Shaft Angle (Fig. 1.11) The neck-shaft angle represents the angle between the intersection of the femoral neck axis and the long axis of the femoral shaft. The value in adults ranges between 120° and 135°. Values >135° represent

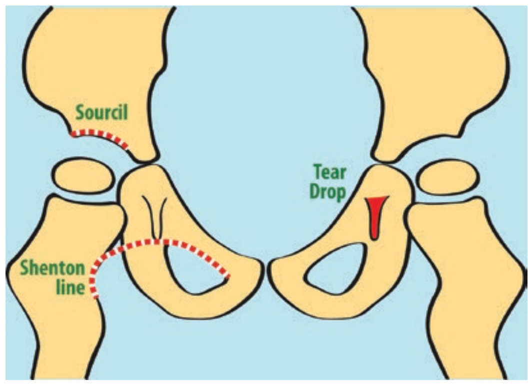

Fig. 1.10 The acetabular teardrop (*marked in red*). The sourcil in the acetabular roof and the Shenton line—the imaginary line joining the inferior border of the superior pubic ramus to the inferomedial border of the proximal femur

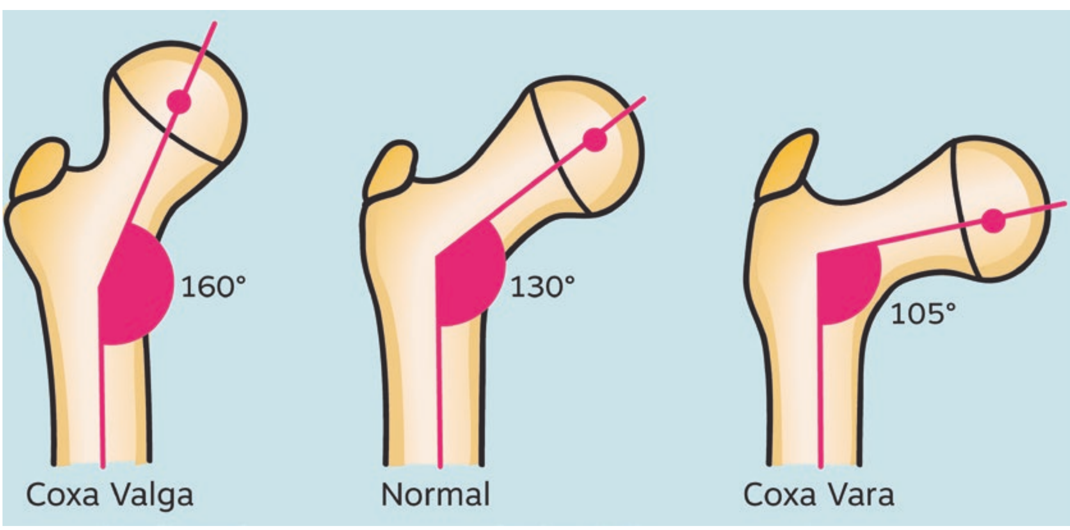

Fig. 1.11 A normal neck-shaft angle ranges between 120° and 135°. Values >135° represent coxa valga. Values of <110–120° represent coxa vara

coxa valga, and values <110–120° represent coxa vara. Internally rotating the hips until the neck is horizontal to the floor shows the true angle, while any external rotation of the femur will increase this value.

Hilgenreiner Epiphyseal Angle (Fig. 1.12) This is an angle used specifically in cases of coxa vara. It is the angle formed between the Hilgenreiner line and a line along the upper femoral physis. Values of more than 60° signify coxa vara.

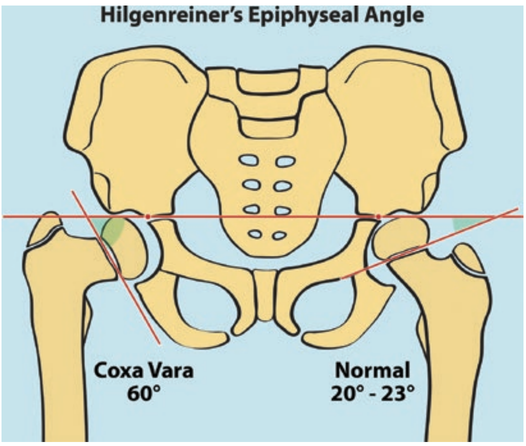

Fig. 1.12 The Hilgenreiner epiphyseal angle is between the Hilgenreiner line and a line along the upper femoral epiphysis. Values >60° signify coxa vara

Shape of the Femoral Head (Fig. 1.13) The femoral head is close to a sphere. Loss of sphericity by flattening (coxa plana) or overgrowth of the epiphysis on to the neck produces a misshapen head that may not be congruous within the acetabulum, and this may lead to degenerative changes in the articular cartilage of both the femoral head and acetabulum. *Coxa magna* (large head) may not be problematic if it is well contained and is congruous in the acetabulum (in certain cases of Perthes disease). However, it may lead to femoroacetabular impingement, labral damage, and degenerative changes. *Coxa breva* (short neck) decreases the abductor resting length and lever arm, increases joint reaction forces, and causes abductor fatigue and Trendelenburg gait.

Articulo-trochanteric Height (Fig. 1.14) The tip of the trochanter lies at the level of the center of the femoral head. In coxa vara, it is superior to the center of the head and in coxa valga; it is inferior to the center of the head (Fig.1.14A). This relation is minimally affected by any rotation of the hips. The articulo-trochanteric height is another measurement used to describe the height of the greater trochanter. It is a line drawn between the tip of the greater trochanter and the superior aspect of the femoral head (Fig.1.14B).

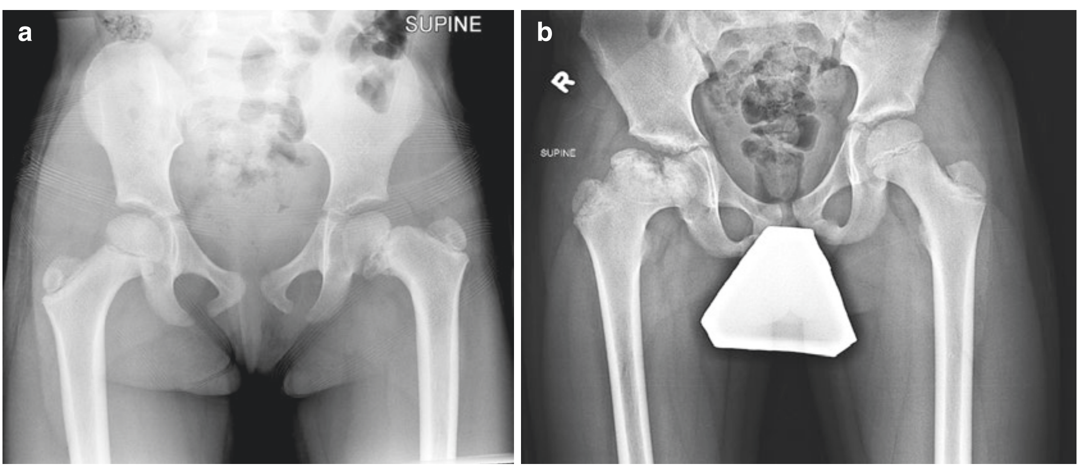

Fig. 1.13 (**a**) The left hip demonstrates coxa breva with varus and high-riding greater trochanter. (**b**) The right hip demonstrates coxa magna coxa breva and coxa irregularis