Chapter 15
Surgical Interventions in Hip and Pelvis Injuries

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Clinical Pearls

- The diagnosis of hip and pelvis pathology can be difficult, and a complete understanding of anatomy and pathology combined with a thorough history and physical examination is essential. Diagnostic injections can be invaluable for pain mapping and clarification of primary versus secondary pain generators.
- Most hip and pelvic pathologies respond favorably to an initial trial of non-operative treatment.
- Femoral neck fractures and traumatic hip dislocations in an athlete require emergent treatment.
- The treating clinician should be comfortable with all available imaging modalities, including radiographs, MRI, and CT, and should be aware of the high rate of asymptomatic hip and pelvic pathology that may be seen in athletic individuals.
- Adolescents with hip pathology may present with knee pain, and there should be a high index of suspicion for hip or pelvic pathology in this setting.

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Fig. 15.1 Anteroposterior (AP) pelvic radiograph demonstrating preserved joint space in the right hip. There is cephalad acetabular retroversion, as demonstrated by a positive "crossover sign" (*arrow*) when comparing the anterior and posterior acetabular walls. The walls of the left hip, which also demonstrates cephalad retroversion, are outlined

15.1 Case Presentation

15.1.1 Chief Complaint

Left hip and anterior pelvic pain.

15.1.2 Patient History

A 20-year-old male hurdler presents with the insidious onset of left hip and anterior pelvic discomfort that worsens with activity, especially when hurdling and lunging. He is minimally symptomatic at rest. The pain has gradually worsened and is unresponsive to conservative treatments including activity modifications.

15.1.3 Physical Examination

The patient is a healthy-appearing young adult. He has tenderness around his pubic symphysis and the left parasymphyseal musculature. Passive hip flexion is 120° and at 90° of flexion, his hip can be internally rotated to 20°. He has pain with passive flexion, adduction, and internal rotation and has mild weakness with active hip flexion.

15.1.4 Imaging

Plain radiographs of the left hip and pelvis (Fig. 15.1) show well-maintained joint space with mild cephalad acetabular retroversion. Magnetic resonance arthrogram (MRA) and computerized tomography (CT) of the hip confirm focal acetabular retroversion as

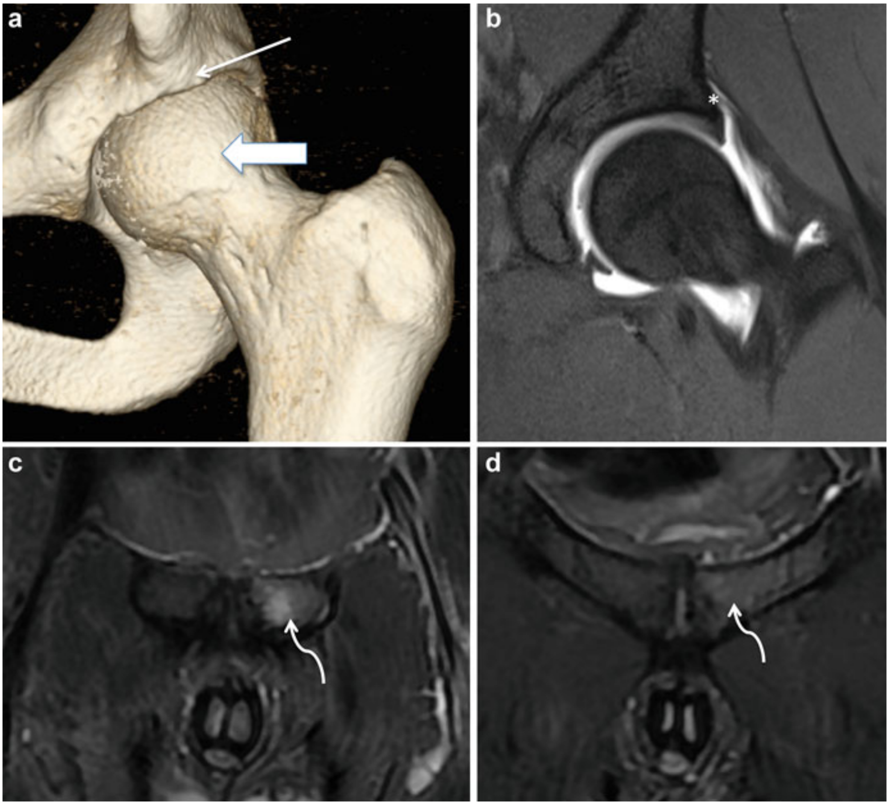

Fig. 15.2 (**a**) 3D CT reconstructions of the left hip demonstrate focal overcoverage from acetabular retroversion (*thin arrow*) at the anterosuperior aspect of the acetabulum as well as decreased femoral head–neck offset (*thick arrow*). (**b**) T2 MRA of the left hip demonstrating an intact chondrolabral junction (*). (**c** and **d**) T2 MRI sequences of the anterior pelvic ring demonstrating increased signal in the left parasymphyseal bone (*curved arrows*)

well as reduced femoral head–neck offset, but no definitive evidence of a discrete labral tear. MRI of the pelvis shows bony edema in the left parasymphyseal bone (Fig. 15.2).

15.2 Introduction

In athletes, hip and pelvic injuries occur less frequently than other lower extremity injuries, but can be a source of considerable impairment and compromised athletic performance. Forces exceeding several times the body's weight are transferred through structures of the hip and pelvis even during routine activities, rendering this area susceptible to injury [1]. The diagnosis and treatment of these disorders can present the treating physician with many challenges. Interrelated body regions and pathologic arthrokinematics can confuse the primary and secondary pain generators. Clarification of primary hip joint pathology from compensatory changes in the adjacent segments of the kinetic chain is vitally important to formulating a strategic treatment plan.

While few surgical emergencies do exist, non-operative modalities with extensive rehabilitation protocols have classically been the mainstay of treatment for most athletic hip and pelvic injuries. Progress in our understanding of the complex pathomechanics and advances in diagnostic imaging have led to increased recognition of these injuries. Technological advances, coupled with a parallel expansion in the application of hip arthroscopy, have enabled physicians to address a wide variety of intra- and extra-articular pathologies through less invasive means [2, 3]. Indications for arthroscopic hip surgery include, but are not limited to, symptomatic femoroacetabular impingement (FAI), loose bodies, labral tears, chondral injuries, synovial pathology, joint sepsis, ligamentum teres injuries, psoas or extra-articular impingement patterns, pathology of the peritrochanteric space, instability, and coxa saltans [3]. Complications are uncommon, and generally stem from traction-related nerve injuries and fluid extravasations [4]. Dysplastic hips may actually undergo accelerated degeneration after arthroscopy due to iatrogenic instability [5]. It is important for the treating clinician to acknowledge the high rate of asymptomatic hip joint and periarticular pathology in athletic individuals when formulating a treatment plan. With advances in the sensitivity of diagnostic imaging, in particular magnetic resonance imaging (MRI), the clinician must use thoughtful clinical judgment and correlate radiographic findings with a focused clinical exam before pursuing surgical management of hip and pelvic pathology [6].

15.3 Skeletal Injuries

15.3.1 Hip Dislocation

Femoroacetabular dislocations are typically associated with high-energy trauma, such as motor vehicle accidents, and are often accompanied by fractures of the acetabulum, femoral head, and femoral neck. While rare, these injuries can occur during routine sporting activity. The majority of hip dislocations occur in a posterior direction (Fig. 15.3). With or without associated fractures, rapid reduction of the dislocation is paramount in order to decrease the risk of osteonecrosis. Mehlman's longitudinal study of pediatric dislocations found a 20-fold increase in the rate of osteonecrosis when reduction was delayed more than 6 h [7]. Osteonecrosis of the femoral head is one of the most feared complications of a hip dislocation as it is difficult to treat, and rates vary widely in the literature [8].

Reduction may first be attempted with appropriate sedation and analgesia through a variety of traction maneuvers. Failure may necessitate reduction under general anesthesia or an open reduction. Dislocations with associated fractures, such as those to the acetabulum or femoral head, should be treated urgently; most commonly, this involves open reduction and internal fixation. If appropriate resources are not available at the initial treating facility, strong consideration should

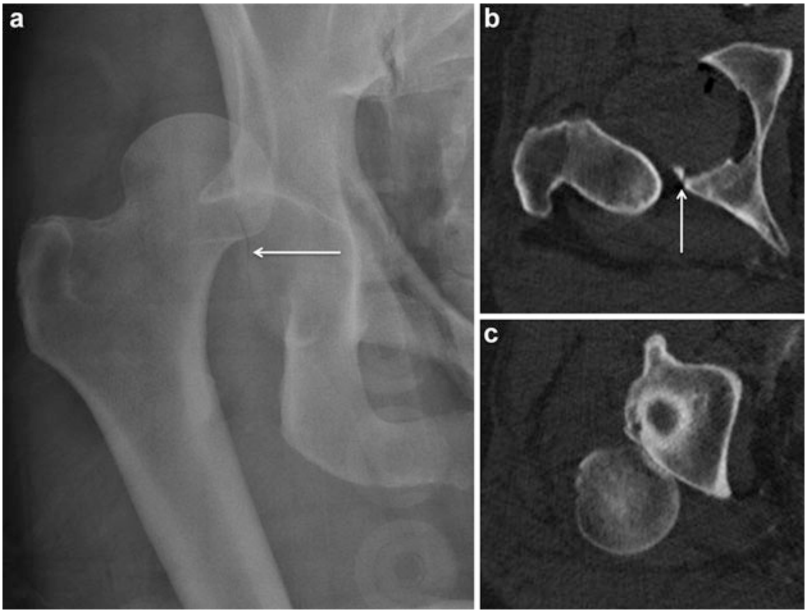

Fig. 15.3 (**a**) AP radiograph of the right hip demonstrating a traumatic hip dislocation in the characteristic posterior and superior location. An *arrow* highlights the associated posterior acetabular wall fracture. (**b**) and (**c**) demonstrate axial CT images of the same hip demonstrating the dislocation and the associated posterior acetabular wall fracture. Because of the small size of the fracture fragment, the fracture was able to be treated non-operatively after concentric reduction of the hip

be given to referral to a facility with experience and personnel to definitively treat both the dislocation and any associated injuries. After reduction, advanced imaging, including magnetic resonance imaging (MRI) and/or CT, should be used to verify a concentric reduction, assess for occult fractures, evaluate for any loose bodies incarcerated within the joint, and define associated chondral or labral injuries. A high rate of intra-articular pathology has been documented after traumatic hip dislocations. Fractures are typically treated with open procedures, while loose bodies and chondral or labral injuries are amenable to arthroscopic treatment [9, 10]. Follow-up MRI at 3 months is recommended by some to detect early signs of osteonecrosis [8].

Reduced hips without associated fractures have typically been treated with immobilization in young children for 3–4 weeks and weight-bearing restrictions in older patients for 6–12 weeks. Good outcomes have been observed in children, however older athletes may have more difficulty returning to high-level sports. Patients with traumatic hip dislocations are more likely to have pre-existing impingement morphology and increased acetabular retroversion, which may predispose them to a posterior dislocation event and could make recovery after a dislocation more difficult [11].

15.3.2 Hip Instability

Recognition of hip instability as a cause of hip pain and dysfunction has grown over the last several years. Instability of the hip can be classified as either traumatic or atraumatic. Traumatic hip instability results from an acute event that damages the osseous or soft-tissue structures of the hip leading to a transient loss of concentric femoroacetabular reduction. An initial traumatic instability event may lead to persistent subacute subluxation or micro-instability episodes due to capsular attenuation or compromise of the dynamic periarticular stabilizers. If a trial of conservative treatment does not resolve instability symptoms, surgical intervention may be necessary to address the offending pathology.

Surgical treatment may be directed at contributions to instability from bony architecture, the hip joint capsule, or other soft-tissue structures in any combination. As arthroscopic hip surgery continues to grow in popularity, it is important to recognize that instability can also be the result of an overzealous capsulotomy performed during prior hip arthroscopy. While some postulate that strategic capsulotomy or capsulectomy may be a therapeutic treatment for hip stiffness, intra-operative capsulotomies disrupt important capsuloligamentous stabilizers. In recent years, a more judicious approach towards capsular management has been adopted and capsular repair has gained support. Various capsular repair methods have been described, but no consensus exists regarding their efficacy or necessity [12].

Atraumatic instability is believed to result from repetitive microtrauma, which eventually leads to capsular attenuation and chondrolabral pathology [12]. Posterior instability in an athlete has also been shown to demonstrate a strong relationship with FAI morphology. According to this proposed mechanism, anatomic conflict between the femoral head/neck junction and the acetabulum may cause the femoral head to lever posteriorly out of the acetabulum [13, 14]. The joint may also be susceptible to atraumatic instability due to acetabular dysplasia (DDH), Legg–Calvé–Perthes disease, or systemic conditions that result in ligamentous laxity such as Marfans or Ehlers–Danlos syndromes, as well as patients who have undergone bariatric surgery [15]. Treatment is highly dependent on the specific pathology, though it is important to understand the limitations and dangers of arthroscopic treatment for patients with dysplastic morphology. Surgical options to address capsular laxity include thermal capsulorraphy or suture plication [16]. Bony abnormalities, such as FAI or DDH, are treated with targeted decompression of the offending structures or rotational osteotomy to provide further structural support. Hip arthroscopy alone is contraindicated in patients with significant DDH.

15.3.3 Hip Fractures

Proximal femoral fractures are rare in sports and usually are associated with high-energy trauma. Femoral neck fractures represent a surgical emergency and may have catastrophic long-term consequences if not treated in a timely manner. Concomitant injury to the tenuous vascular supply increases the risk of femoral head osteonecrosis. The causal relationship between time to reduction and osteonecrosis is less established than what is seen with traumatic hip dislocations. Furthermore, the type of fracture and quality of reduction may also have important prognostic implications for an athlete's long-term outcome. Capsular decompression after reduction and fixation has been advocated to decrease intra-articular pressure on the femoral head vascular supply [17]. Surgical stabilization is the mainstay of treatment for traumatic hip fractures, and a variety of fixation methods can be employed, depending on the specific fracture pattern and associated injuries. Typically, femoral neck fractures are stabilized with either multiple cannulated screws placed from lateral to medial across the fracture site or with a sliding hip screw and side-plate construct [18]. More distally, fractures of the intertrochanteric and subtrochanteric region can be treated with a variety of implants including sliding hip screws, cephalomedullary nails, and plate and screw constructs depending on fracture characteristics and surgeon preference.

15.3.4 Stress Fractures

In contrast to traumatic fractures, stress or fatigue fractures are overuse injuries. These are typically encountered among athletes who increase their training regimen, especially runners. Military personnel are also at risk due to the intensity of their conditioning. Appropriate imaging can be obtained to accurately confirm a suspected diagnosis. While many lesions may not be apparent on plain radiographs, MRI offers high sensitivity for stress fractures or stress reactions in addition to anatomic specificity [19]. MRI findings may include edema within the bone or a distinct fracture line. Certain stress fractures, including tension-sided fractures of the femoral neck, are at a higher risk for progression or displacement and may be treated more aggressively [20]. Lower risk stress fractures, such as those of the pubic ramus, can be treated with activity modifications. The clinician should be aware of and address contributing factors such as leg-length discrepancies or malalignment, femoroacetabular impingement, or acetabular dysplasia, which may alter hip joint arthrokinematics and place excess stress on adjacent structures. It is important to explore and treat any underlying metabolic bone disorders, patterns of nutritional insufficiency, and systemic medical disorders, as these may predispose athletes to stress fractures [21]. The female athlete triad represents a common spectrum of metabolic and nutritional compromise that can occur in the presence of overtraining, placing an athlete at an increased risk for injuries of attrition.

Missed femoral neck fractures can lead to disastrous consequences if not treated appropriately and in a timely fashion. Thus, the index for suspicion for these injuries should be high and the threshold for obtaining advanced diagnostic imaging should be low [22]. Diagnosis typically includes the use of radiographs and MRI. Multiple classification systems have been described, most of which discriminate between compression and tension-sided lesions and displaced fractures. Displaced fractures are generally a surgical emergency. These are treated with anatomic reduction followed by fixation with either cannulated lag screws or a sliding hip screw [23]. Non-displaced compression-sided fractures (found on the medial or inferior aspect of the femoral neck) are more inherently stable and may be treated with limited weight-bearing for 6–12 weeks if they are less than 50 % of the width of the neck. Fracture line extension beyond 50 % of the width of the neck warrants consideration for internal fixation. Most authors advocate fixation of tension-sided injuries, however successful conservative treatment with close follow-up has been reported [24]. Failure of non-operative treatment is an indication for operative intervention (Fig. 15.4). For non-displaced fractures, surgical stabilization often includes percutaneous placement of two or three cannulated lag screws across the femoral neck or a sliding hip screw and side-plate construct followed by a period of restricted weight-bearing. Patients with compression-sided injuries treated operatively may be able to progress weight-bearing earlier or even immediately, depending on their relative stability [25]. Complications after surgical stabilization include those related to hardware irritation and periarticular soft-tissue disruption during fixation, therefore, an attempt at non-operative treatment is preferable when possible.

15.4 Soft-Tissue Injuries

15.4.1 Muscle Strain and Avulsion

Muscle strains of the hip and pelvis are among the most common injuries an athlete can sustain in this anatomic region. They often occur during eccentric contractions and are more common in muscles that cross two joints. They occur most frequently at the myotendinous junction, but are also seen in the muscle belly [1]. In addition to clinical examination, advanced imaging may be helpful in both determination of the diagnosis and the prognosis. Plain radiographs may detect avulsion fractures. MRI can offer further detail regarding the nature of the soft-tissue injury, and the degree of injury seen on MRI has been shown to correlate with time until return to activities [26].

Treatment initially consists of non-steroidal analgesics and local measures to reduce hemorrhage and edema, including ice, elevation, and compression. NSAIDs are also considered to prevent heterotopic ossification or myositis ossificans. Range of motion and then strengthening are progressively introduced as pain improves [1]. Occasionally, however, surgical intervention is required. Following failure of functional rehabilitation, patients with chronic pain from tears of the proximal rectus

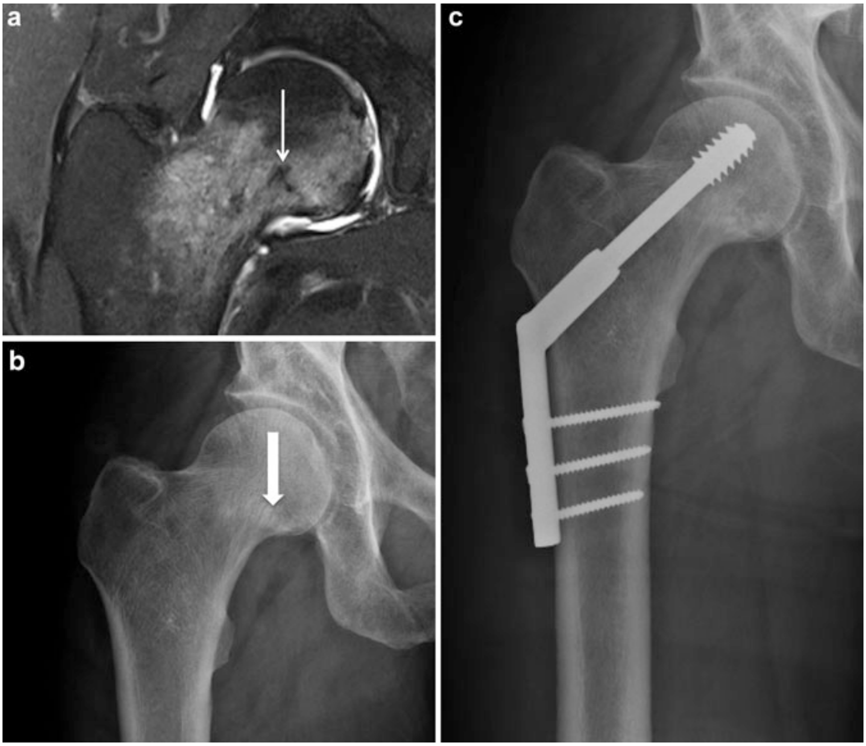

Fig. 15.4 (**a**) Fat-suppressed T1 MRA with contrast reveals bony edema and an incomplete fracture line in the compression side of the right femoral neck (*thin arrow*). (**b**) AP radiograph of the right hip from the same time point demonstrates subtle sclerosis in the femoral neck (*thick arrow*). (**c**) After a course of conservative treatment for the stress fracture failed, surgical fixation was undertaken utilizing a sliding hip screw and side-plate device

femoris musculotendinous junction have been shown to respond favorably to excision of their scar tissue [27]. Others have reported success after unilateral or bilateral adductor tenotomies for chronic groin pain from adductor tendinopathy in athletic populations [28–30]. Recently introduced non-surgical modalities such as instrumented or manual myofascial treatments or Active Release Technique (ART) have gained popularity for the treatment of periarticular myofascial scarring, connective tissue adhesions, or soft-tissue contractures that may develop as sequelae of muscular sprains or strains [31].

Avulsion fractures are less common in skeletally mature athletes. These occur in the same manner as their corresponding soft-tissue injury, and could occur at any muscular attachment with sufficient force. Displacement is limited by periosteum and surrounding fascia. These have been reported to occur with low energy trauma in patients with underlying malignancy, notably around the lesser trochanter [32]. Surgical treatment may be indicated when there is greater than 2 cm of displacement and the fragment is large enough for fixation, or if conservative management fails to allow healing [1].

Injuries to the proximal hamstring tendon complex have gained attention in recent years. These injuries commonly occur suddenly with the leg in a position of hip flexion and knee extension. Partial and full thickness injuries to any one of the three tendons of the proximal hamstring complex have been described. Surgical intervention is generally recommended for patients with an avulsion of at least two tendons, retraction greater than 2 cm, and for those with the desire to resume high-demand physical activity. Failure of conservative treatment may also constitute an appropriate indication for operative repair. A growing body of evidence now supports surgical repair for partial thickness, full thickness, and chronic full thickness tears [33]. The anatomic footprint of the proximal hamstring has been extensively cataloged in recent reports [34]. Advanced imaging, such as MRI, can be an invaluable tool to confirm the diagnosis of a proximal hamstring injury and grade the extent of the pathology. Surgical repair is conducted through an open longitudinal incision for a large retracted tear or chronic tear with nerve entrapment. When the tear is small or partial thickness, surgical repair may be accomplished through a transverse subgluteal incision, which is more cosmetic. Arthroscopic repair techniques have also been described and early reports reflect good and excellent outcomes with minimal soft-tissue morbidity [35]. Limited results reported in the literature have been generally good with regard to return to sport and strength for both full and partial thickness tears [36, 37].

15.5 Structural Pathology

15.5.1 Femoroacetabular Impingement

Femoroacetabular impingement (FAI) is an increasingly recognized source of pain and functional impairment in active individuals. It is believed to result from morphologic alterations of the acetabulum and/or proximal femur (Fig. 15.5), which can lead to pathologic anatomic conflict, labral and chondral injuries, and synovitis. FAI has been causally linked to the progressive development of early onset osteoarthritis (OA) of the hip, though this is somewhat controversial [38].

Imaging is helpful for the diagnosis of FAI and for surgical planning, but it is important to note that FAI is a dynamic phenomenon and may occur in the absence of significant radiographic deformity in positions of extreme hip motions, such as those encountered during martial arts and dancing [39]. The presence of significant OA on weight-bearing radiographs is a poor prognostic indicator of clinical outcomes following arthroscopic hip surgery. While diagnoses can be made provisionally with plain radiographs, MRI and CT are more sensitive for uncovering more subtle abnormalities, gaining a more sound understanding of the global pathomorphology of the joint, and diagnosing associated pathologies prior to surgery [40].

Surgical intervention is indicated when symptomatic FAI does not respond to an appropriate period of rest, activity modifications, and non-steroidal anti-inflammatory medications. Thorough pre-operative workup should be conducted to fully

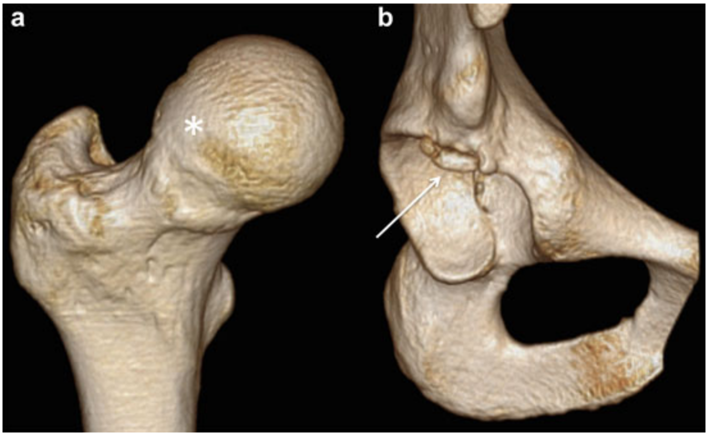

Fig. 15.5 (**a**) 3D CT reconstruction of the proximal femur showing anterosuperior "cam-type deformity" (*) with reduced femoral head–neck offset. (**b**) 3D CT reconstruction of the corresponding acetabulum demonstrating focal retroversion and overcoverage secondary to an acetabular rim fracture (*arrow*)

characterize the bony morphology of the joint as well as the degree of labral and chondral pathology that is present. Initially, open surgical hip dislocation was described to safely access symptomatic pathology within the central and peripheral aspects of the hip joint [41]. More recently, arthroscopic techniques have been increasingly utilized to address symptomatic FAI as well as synovial, labral, and chondral disease [3]. Bozic et al. reported a 600 % increase in the incidence of hip arthroscopies performed by orthopedic surgeons undergoing board certification between 2006 and 2010 [42], while Colvin et al. found an 18-fold increase in the number of hip arthroscopies performed during a study period of 1999 to 2009 [43]. Though preferable to many surgeons, it is important to recognize the limitations of arthroscopy. Cam deformities are typically most severe at the anterosuperior head–neck junction of the proximal femur, which is readily accessible by arthroscopic means. Lesions that extend posteriorly approach the lateral retinacular vessels of the posterolateral neck, and thus they are less accessible and the dissection is more dangerous. Complex lesions, such as deformities from pre-existing Legg–Calvé–Perthes or slipped capital femoral epiphysis (SCFE), may also be difficult to adequately treat arthroscopically. Often these more global pathologies, rotational deformities, or abnormalities of version need to be treated concomitantly and require a more aggressive open approach [44].

Regardless of whether an open or arthroscopic approach is used to access the joint, goals for thorough FAI treatment involve bony decompression and stabilization of associated labral and chondral injuries. Treatment typically involves some combination of a femoral head–neck osteochondroplasty, acetabular rim osteoplasty, labral repair or debridement, and acetabular chondroplasty. Less frequently, an acetabular osteotomy may be indicated for more significant global acetabular retroversion or volume deficiency. Dynamic examination under fluoroscopic or arthroscopic visualization can be used to confirm appropriate resection of bony deformities prior to the conclusion of the procedure [3, 45].

Outcomes following both open and arthroscopic hip surgery are generally favorable [46, 47]. Factors associated with improved outcomes include the absence of significant OA [48], labral repair versus debridement [49], and proper recognition and complete treatment of associated bony pathology [50]. In the absence of significant OA, age should not be a deterrent to arthroscopy [51]. Arthroscopy should be avoided in patients with evidence of dysplasia, as surgery may lead to iatrogenic instability and accelerate degenerative progression in certain cases [52].

15.5.2 Acetabular Labral Injuries

The acetabular labrum is a fibrocartilaginous ring that surrounds the bony acetabulum. It deepens the hip socket, maintains the intra-articular fluid-film layer, and creates a negative pressure seal within the joint. Free nerve endings have been found throughout the labrum, but are most densely located at the anterosuperior aspect [53].

Acetabular labral injuries can occur with or without underlying bony abnormalities, such as FAI. Labral pathology rarely results from acute injuries, including major trauma as well as minor twisting events or falls. More commonly, labral damage occurs as part of a global attritional process, such as OA. Labral injuries tend to result from a shearing mechanism and are typically oriented perpendicular to the articular surface at the chondrolabral junction or within the substance of the labral tissue in cases of degenerative pathology. They are often associated with adjacent acetabular chondral lesions [3], and most pathology is found in the anterosuperior quadrant [54]. When a labral tear is suspected, confirmatory MRI or MRA can be used to verify the diagnosis (Fig. 15.6). The addition of arthrography may enhance visualization of labral or chondral pathology and aid in pre-operative planning [55]. Ultrasonography can be used to detect labral pathology, paralabral cysts, and adjacent injuries within the periarticular soft tissues and may present an alternative imaging modality to aid in formulating an accurate diagnosis.

The natural history of labral pathology is poorly defined, and a course of non-operative treatment is usually initiated before considering more invasive options. A high rate of chondral and labral pathology has been demonstrated in populations of asymptomatic volunteer subjects, strengthening the importance of an appropriate course of non-operative treatment prior to considering surgical intervention [56]. Conservative treatment includes some combination of activity modification, physical therapy, and anti-inflammatory medications. Intra-articular anesthetic or anti-inflammatory injections are commonly used for pain mapping and to improve diagnostic accuracy. A positive response to an intra-articular injection may have prognostic importance when used to predict outcomes following arthroscopic hip surgery [57, 58]. Intra-articular cortisone injections may be limited long-term benefit, however, when employed in a therapeutic role [59].

Fig. 15.6 Axial (**a**), sagittal (**b**), and coronal (**c**) T1 fat-suppressed MR arthrograms of the right hip demonstrate an anterosuperior labral tear with separation of the chondrolabral junction, highlighted by *arrows*

Hip arthroscopy is becoming a popular tool to access the joint and treat labral, chondral, or synovial pathology (Fig. 15.7). After appropriate arthroscopic visualization, the labrum is debrided of any nonviable tissue using arthroscopic shavers, biters, or radiofrequency ablation. Any remaining tissue that can be repaired is reattached to the underlying bone using suture anchors. Prior to suture repair, the acetabular rim is often freshened or trimmed to remove any areas of focal overcoverage and expose a bleeding bone surface, which may optimize the biologic healing response. Sutures may be passed through the labrum in a mattress fashion or around the damaged tissue in a looped configuration [3]. The arthroscopic treatment of labral pathology has been shown to yield favorable and durable results, however the presence of significant OA has been shown to be a poor prognostic factor and increases the chance of conversion to arthroplasty [60].

Labral reconstruction is utilized when severe injury or previous debridement has left the acetabular rim devoid of a functioning labrum. Various graft choices,

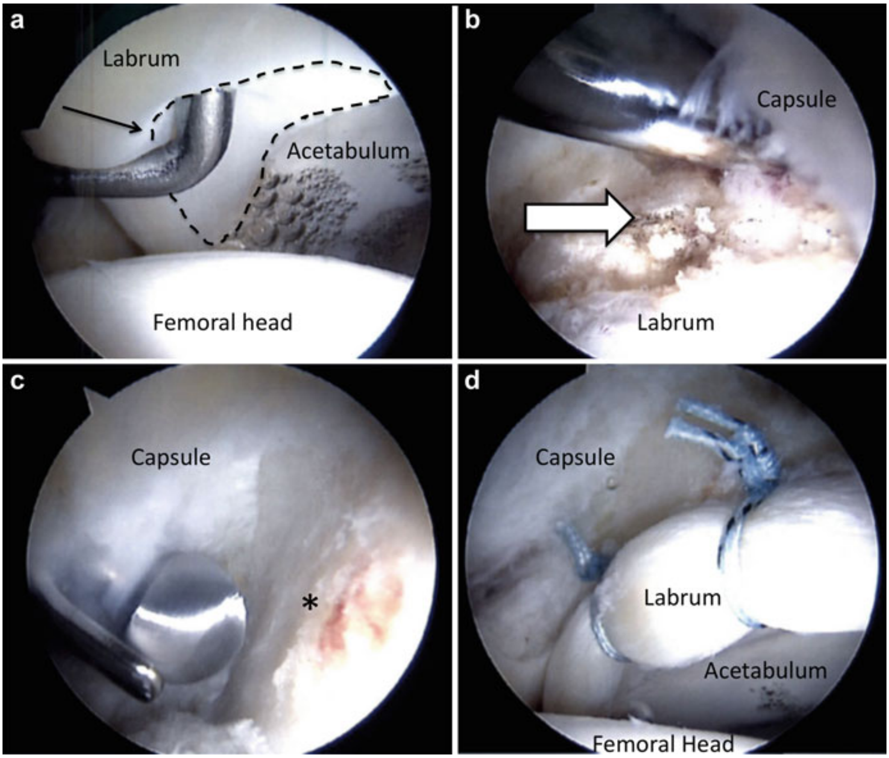

Fig. 15.7 Intra-operative arthroscopic imaging of the left hip demonstrating (**a**) a prominent "wave sign," (*dashed line*) where chondral delamination has occurred, as well as chondral-labral separation of the anterosuperior aspect of the acetabulum (*arrow*). (**b**) Acetabular rim prominence (*thick arrow*), leading to synovitis and labral injury (**c**) Arthroscopic image depicting decompression of the acetabular sided deformity (*) using an arthroscopic burr. (**d**) Decompression is followed by arthroscopic repair of the labral tear using suture anchors. Completed acetabuloplasty is shown superior to the labral repair

including allograft and autograft, have been reported in the literature [61]. Both open and arthroscopic methods are described [62]. Biomechanical [63]. and short-term functional results [61, 64]. show promise, but long-term follow-up has yet to be reported.

15.5.3 *Extra-articular Hip Impingement*

The concept of femoroacetabular impingement has evolved to include patterns of bony impingement that occur between anatomic regions outside the intra-articular space. The so-called extra-articular impingement can cause pain and loss of function in athletes. In contrast to intra-articular impingement, extra-articular pathology encompasses a number of much less common conditions, and treatment strategies are evolving. Abnormal bony contact and soft-tissue compression are responsible for symptoms. Various etiologies include psoas impingement, subspine impingement, ischiofemoral impingement, and greater trochanter/pelvic impingement [65].

Psoas impingement (PI) involves atypical labral wear in the direct anterior position secondary to compression or traction from the adjacent iliopsoas tendon. These distinct labral tears are found anterior and inferior (3 o'clock or 9 o'clock) to the typical location caused by intra-articular impingement. This pattern of impingement may cause anterior hip pain over the iliopsoas at the level of the anterior joint line and pain with hip flexion. Initial treatment may include activity modifications and focused rehabilitation. Refractory symptoms can be treated with image guided iliopsoas injections or arthroscopic fractional lengthening of the iliopsoas tendon along with appropriate labral and chondral treatment [66].

Subspine impingement (SSI) occurs when there is abnormal contact between the distal femoral neck and the undersurface of the anterior inferior iliac spine (AIIS). Prominence of the AIIS can be secondary to prior apophyseal or rectus avulsions, periacetabular osteotomies, acetabular retroversion, or developmental variants. SSI typically manifests as pain with hip flexion, limited hip flexion range of motion, and pain directly over the AIIS. Failure of conservative management, including rest and injections, can be treated with arthroscopic subspine decompression, which has been shown to improve both pain and functional symptoms [67].

Ischiofemoral impingement (IFI) is a less commonly reported form of extra-articular impingement and is caused by static or dynamic narrowing of the area between the ischial tuberosity or posterior acetabular rim laterally and the lesser trochanter or posterior greater trochanter medially. It can be associated with the sequelae of Perthes disease or otherwise morphologically abnormal hips. Surgical treatment involves open resection of the often-prominent lesser trochanter [68].

Greater trochanteric/pelvic impingement (GTPI) results from abnormal contact between the greater trochanter and the ilium, and is also often associated with abnormal hip morphology. Pain occurs with the hip in abduction and extension. Numerous open surgical treatments including osteotomies of the greater trochanter and acetabulum, rotational osteotomy, or arthroscopic decompression have been described [65].

15.5.4 Coxa Saltans

Coxa saltans, or "snapping hip," is an audible and potentially painful snapping about the hip during motion. It has multiple distinct etiologies. External snapping hip is caused by pathologic thickening or contracture of the posterior one-third of the iliotibial (IT) band or from pathologic translation of the gluteus maximus over the posterolateral border of the greater trochanter. Internal snapping hip results from translation of the psoas tendon over the femoral head, iliopectineal eminence, or the AIIS. Intra-articular snapping can be caused by loose bodies or labral pathology [69].

Treatment for coxa saltans depends on the severity and duration of symptoms. Most cases are minimally symptomatic, especially in athletic populations who can develop snapping due to the demands of repetitive training. Activity modification, anti-inflammatory medications, local injections, and focused hip and pelvic rehabilitation are effective strategies for most patients. When these measures fail, surgical intervention is indicated. Mechanical symptoms originating from an intra-articular source are typically due to an unstable labral tear or chondral flap. Arthroscopy is an effective tool used to address the offending pathology, which is typically due to an unstable labral tear or chondral flap [70].

Internal snapping hip can be treated by lengthening or release of the iliopsoas tendon. Traditionally, an open approach was described to lengthen the tendinous portion using multiple transverse incisions. Lengthening can be made at the level of the femoral head or the pelvic brim [69]. Arthroscopic techniques have become more popular with technical evolutions in hip arthroscopy [71]. Arthroscopic fractional lengthening can be performed at the level of the lesser trochanter using fluoroscopic assistance, or through a transcapsular window under direct arthroscopic visualization inside the joint. Arthroscopic lengthening offers the potential advantages of a less invasive approach and fewer complications compared with open techniques [72].

External snapping is typically treated with open or endoscopic trochanteric bursectomy with fractional lengthening of the thickened portion of the IT band or gluteus maximus. Multiple lengthening procedures have been described, including open Z-plasties, transverse releases, cruciate incisions, and tenodesis procedures [73, 74]. Attention should be paid to abnormal morphology or malalignment, such as coxa vara, which may predispose patients to this condition [75]. More recently, endoscopic techniques have emerged in the literature with promising short-term results. Endoscopic options utilize various strategies to relax or release the contracted portion of the IT band or gluteus maximus tendon [76, 77].

15.6 Inflammatory and Compression Syndromes

15.6.1 Greater Trochanteric Pain Syndrome

Reproducible tenderness over the greater trochanter can be due to numerous pathologies of the peritrochanteric space including trochanteric bursitis, abductor tearing, external coxa saltans, or even referred intra-articular pain [78]. The gluteus medius and minimus, which comprise the majority of the hip abductor complex, have been described as the “rotator cuff of the hip.” Inflammation or scarring of the overlying trochanteric bursa can also lead to chronic pain and dysfunction. Much like the shoulder, there is a high prevalence of asymptomatic tendinopathy and tearing that advance with age [3, 79]. Both MRI and musculoskeletal ultrasonography (MSUS) are highly accurate imaging modalities to characterize the extent of abductor disease [80, 81].

Conservative treatment is successful in most cases, but when non-operative measures fail to provide durable symptomatic relief, recalcitrant lateral hip pain may be amenable to operative intervention. Multiple treatment options for trochanteric bursitis exist. Most involve debridement of the bursa with or without IT band lengthening [82]. Arthroscopic bursectomy appears to be effective in the short term as well, though comparative studies are lacking [83]. Refractory lateral hip pain that fails to improve with conservative care or targeted peritrochanteric injections should also raise suspicion for occult intra-articular hip pathology. Because of the variable anatomic presentation of intra-articular pathology, a thorough clinical and diagnostic workup should be conducted before considering surgical intervention in order to clarify any potential contribution of the intra-articular joint space to the overall pain spectrum [84]. The treating clinician should be aware of the potential contribution of structural malalignment of the proximal femur or acetabulum in cases of refractory peritrochanteric pain. Fatigue overload of the abductor complex due to edge loading or abnormal arthrokinematics may manifest as dynamic lateral hip pain that does not respond to traditional conservative interventions.

Both partial and full thickness tears of the abductor complex have been described. Traditionally, an open approach utilizing bone tunnels was favored to achieve a successful repair [79]. More recently, endoscopic suture anchor repair techniques have been adopted and popularized. Good to excellent functional results have been reported for both techniques, but endoscopic repair may offer the advantage of fewer complications [85, 86].

15.6.2 Athletic Pubalgia

Athletic pubalgia, or "sports hernia," has recently been characterized as "central core dysfunction." This pathologic entity is a poorly understood spectrum of conditions affecting the posterior inguinal wall, central pelvic and soft tissues structures, and surrounding sensory nerves. It typically affects athletes who require repetitive overuse of the proximal thigh and lower abdominal musculature, including those who participate in soccer and ice hockey. Injuries to various structures, including the transversalis fascia, conjoined tendon, rectus abdominus insertion, and internal and external oblique musculature result in dilation and weakening of the internal inguinal ring. An insidious onset of deep groin pain with activity and prolonged course are common. There is no clinically detectable hernia, though local tenderness is commonly found. Imaging is nonspecific, but is helpful for ruling out other pathology [87].

If symptomatic athletic pubalgia does not respond favorably to a conservative treatment strategy, surgical intervention may be indicated [88]. After ruling out other associated pathologies, such as abdominal visceral disorders, surgical repair with either a conventional open or laparoscopic approach may be considered. Various open repair techniques have been described with a combination of procedures. Most involve repair of the posterior inguinal canal, often with mesh [89].

Concomitant procedures include repair of the external oblique aponeurosis, Bassini repair, plication of the transversalis fascia [90], pelvic floor repair [91], open external ring repair, and conjoined tendon repair [92]. Successful return to play has been reported in between 77 % and 97 % of athletes, with mostly excellent outcomes [93, 94]. Adductor tenotomy or repair has also been advocated as an adjunctive option and similar positive results have been documented in the literature [93, 95, 96]. When compared with open techniques, laparoscopic groin repair has been shown to demonstrate equivalent functional outcomes with more rapid return to play and durable results [97–99].

Gilmore's groin is a variant of a sports hernia that includes tearing of the external oblique aponeurosis, tearing of the conjoined tendon, dehiscence between the conjoined tendon and inguinal ligament, and a dilated superficial inguinal ring. It is commonly encountered in soccer players. A 97 % success rate has been reported for surgical repair in high-level athletes [100].

Recently, clinicians have begun to recognize a causal link between athletic pubalgia and FAI. Mechanical conflict between the proximal femur and acetabulum is thought to impart mechanical stress on both the hip joint and the surrounding pelvic ring. The demands of functional activity then transfer these stresses to adjacent regions of the pelvis, including the pelvic brim, pubic symphysis, and sacroiliac joint [101]. Treatment of both conditions has been associated with superior outcomes and a higher rate of return to play compared with isolated treatment of either pathology [102, 103].

15.6.3 Osteitis Pubis

Osteitis pubis is a painful condition of the pubic symphysis and parasymphyseal bone. Anterior and medial groin pain is exacerbated by activity, particularly kicking, jumping, twisting, or impact loading. Mechanical overload of the symphysis from the abdominal and adductor muscles is believed to cause a local stress reaction at the pubic symphysis with surrounding soft-tissue inflammation [104]. Osteitis pubis is exacerbated by pregnancy and other conditions that lead to ligamentous laxity, including post-traumatic, post-bariatric surgery, or rheumatologic afflictions [1]. Plain radiographs characteristically demonstrate sclerosis, resorption, and symphyseal widening, while a bone scan often reveals increased activity at the symphysis. MRI may offer more detail or rule out other associated pathology, but has been shown to demonstrate a high rate of incidental parasymphyseal pathology in asymptomatic athletes [105].

Treatment of osteitis pubis includes a period of relative rest, anti-inflammatory medications, and rehabilitation focused on muscles acting across the pelvis. Corticosteroid injections can be helpful, especially if given within several weeks of symptom onset [106]. Several surgical options exist, including curettage of the symphysis [107], preperitoneal polypropylene mesh placement [105], and symphyseal stabilization and fusion [108]. No comparative studies exist, and overall return to play is 80 % in an average of 4–5 months after surgery [109]. Planning treatment for this condition should account for other local factors that may be contributing to increased mechanical stress across the symphysis, such as adjacent FAI.

15.6.4 Nerve Compression

Peripheral nerve entrapment or compression is an uncommon source of pain in athletic populations, but can occur after trauma or local surgical procedures. Obturator neuropathy has been reported as a fascial entrapment of the obturator nerve as it enters the thigh in athletes with over-developed adductors. This exercise-induced medial thigh pain diagnosed on electromyography (EMG) is treated with neurolysis, which results in a return to play within several weeks [110]. Genitofemoral neuropathy causes groin pain and paresthesias in the lower abdomen to medial thigh, including the genitals. Radiofrequency ablation and ultrasound guided cryoablation can be tried before surgical neurectomy [111]. Meralgia paresthetica is characterized by numbness, paresthesias, and pain in the anterolateral thigh from entrapment or a neuroma of the lateral femoral cutaneous nerve. Iatrogenic injury from local procedures or surgical positioning is a common cause. The diagnosis can be made with EMG or diagnostic local anesthetic injections. Treatment options include medial transposition or transection, which is more definitive but does result in permanent anesthesia [112].

Piriformis syndrome is caused by compression of the sciatic nerve as it courses around or through the piriformis muscle, which can lead to hip and buttock pain as well as radiculopathy. No consensus diagnostic criteria or methods exist, and some question its existence despite its presence in the literature. Therapy directed at stretching and injections are the mainstays of treatment. Myofascial techniques can also be effective for deep gluteal contractures and muscular imbalance. Rare refractory cases are treated with surgical exploration of the nerve and release of the piriformis with mixed results [113].

15.7 Pediatrics

15.7.1 Apophyseal Avulsions

Apophyseal avulsions occur in skeletally immature athletes after the appearance of the apophysis but before physeal closure, typically between the ages of 14 and 25. They present in a similar fashion to adult muscle strains or avulsions as a result of forceful muscular contractions. The ischium, anterior inferior iliac spine, and the anterior superior iliac spine are the most frequent sites of injury; less commonly, athletes may sustain avulsion injuries at the adductor tubercle, greater or lesser trochanter, or iliac crest [114]. Plain radiographs are diagnostic in most cases, however

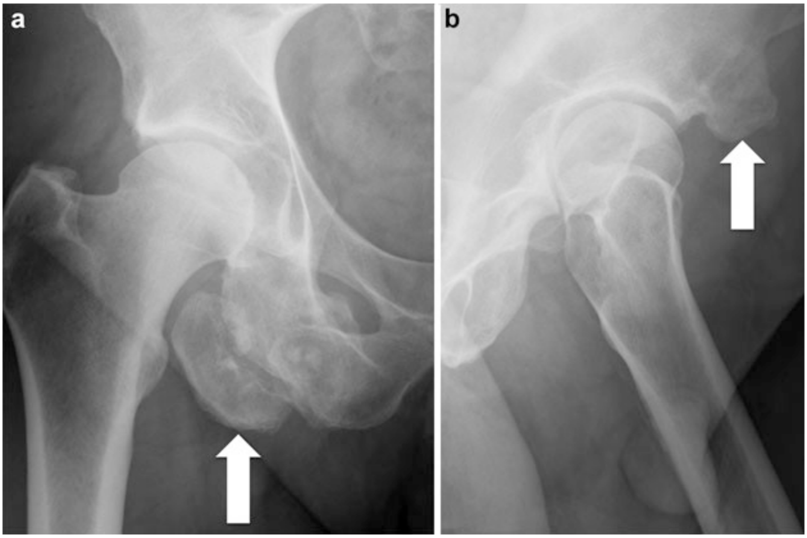

Fig. 15.8 (**a**) AP radiograph of the right hip demonstrating extensive heterotopic ossification at the origin of the hamstring tendon complex (*arrow*), likely from a chronic avulsion injury. (**b**) Lateral false-profile radiograph of the left hip demonstrating prominence of the left anterior inferior iliac spine (AIIS—*arrow*), likely from a remote avulsion injury. This bony prominence may lead to subspine impingement between the proximal femur and the AIIS

CT demonstrates optimal bony detail for more subtle injuries at the cost of increased radiation exposure. MRI may aid in the diagnosis for ossification centers that have yet to ossify [115]. Musculoskeletal ultrasound (MSUS) has also shown promise as a diagnostic option [116].

Treatment generally involves protected weight-bearing followed by functional rehabilitation and resumption of normal activity in 6–8 weeks [117]. Surgery is generally reserved for cases of symptomatic nonunions, painful exostoses, and when displacement is greater than 2 cm in athletes [115]. Fixation of bony ischial avulsions may prevent long-term sequelae of nonunion with painful heterotopic bone formation and "hamstring syndrome" (Fig. 15.8). Some authors advocate fixation of greater trochanteric avulsions, given the importance of the abductor complex [118]. Osteonecrosis of the femoral head has been reported with and without fixation of these injuries [119]. Fixation is generally carried out with screws, and data on rapid to return to play is limited but promising [115].

15.7.2 Slipped Capital Femoral Epiphysis

Slipped capital femoral epiphysis (SCFE) is one of the most severe hip disorders of adolescence. It is characterized by anterosuperior displacement of the metaphysis in relation to the femoral head through the zone of hypertrophy of the proximal femoral

Fig. 15.9 Severe right hip SCFE treated with *in situ* fixation as well as prophylactic fixation on the left side. A residual deformity leads to symptomatic intra and extra-articular impingement in this case

physis. It has been related to obesity, endocrinopathies, and African American race among other factors. It typically presents with groin, thigh, or knee pain, and is diagnosed on plain radiographs. A majority of cases are chronic, though some will present acutely with less than several weeks of symptoms or significant pain. Slips are considered stable if the patient is able to ambulate, and unstable if they are not [120].

Treatment of stable SCFE has traditionally consisted of surgical fixation with a single screw placed percutaneously through the metaphysis perpendicular to the epiphysis (Fig. 15.9). Though there is potential for remodeling after fixation of mild slips, there is increased concern for the resultant deformity from larger slips, which can cause symptomatic impingement [121]. Severe deformities can be corrected after the slip has healed with an intertrochanteric osteotomy that flexes, internally rotates, and abducts the distal fragment to correct for impingement and prevent OA [122]. Open surgical dislocation with femoral neck osteoplasty has also been reported with good results, but is technically demanding [48]. Mild deformities may be amenable to arthroscopic treatment [123].

Recently the modified Dunn procedure has been described as a surgical option for acute SCFE. This procedure involves a careful dissection of the femoral head vascular supply and an acute reduction of an unstable SCFE via an open surgical dislocation. Some studies have shown superior clinical results and more anatomic healing compared with *in situ* pinning [124]. Other series have demonstrated an unacceptably high rate of complications, such as osteonecrosis, using this approach [125]. In experienced hands, this procedure may minimize the long-term sequelae of high-grade SCFE. Further studies, with an emphasis on long-term outcomes and complications, will be necessary prior to widespread endorsement.

Patients with an unstable SCFE are at a much higher risk for developing osteonecrosis compared with patients with stable slips. In a survey of pediatric orthopedists, the majority favored emergent or urgent treatment with an “incidental reduction,” conducted while positioning the patient under anesthesia, followed by fixation with one or two cannulated screws. There is no clear consensus regarding the need for capsular decompression to protect blood flow to the femoral head [126]. Osteonecrosis is a rare but catastrophic complication of SCFE, and has been associated with an unstable SCFE, over-reduction of unstable SCFE, reduction of stable SCFE, and pin placement in the posterosuperior quadrant of the epiphysis [120].

Patients who suffer a unilateral unstable SCFE have a higher incidence of subsequently suffering a contralateral SCFE. The odds are increased in patients who are younger and have endocrinopathies and other risk factors. In the case of high-risk patients, some advocate contralateral prophylactic fixation with a single screw [120].

15.8 Tumor/Other

Bone and soft-tissue tumors that mimic athletic injuries are relatively rare. Pain that occurs at night, is unrelated to physical activity, and is unresponsive to conservative measures should raise suspicion. The presence of a large, fixed mass on exam warrants further workup. Radiographic and advanced imaging modalities are invaluable in detection and classification of neoplasms. Appropriate treatment is highly variable and dependent on treatment, and the ability to make a prompt diagnosis may be life-saving [127].

Autoimmune conditions, rheumatologic disease, and connective tissue disorders also present with an uncharacteristic spectrum of clinical symptoms. Diffuse myalgias or arthralgias, visceral organ involvement, dermatologic manifestations, and/or a positive family history may reflect an underlying systemic pain source. An unusual history or clinical examination should alert the clinician to the possibility of these conditions and a thorough workup should be initiated when indicated.

15.9 Conclusion

Hip and pelvic pathology in the athlete can pose a substantial diagnostic challenge and require a thoughtful approach to optimize treatment. Fortunately, many injuries about the hip involve routine soft-tissue trauma and conservative treatment strategies should be applied when indicated. The treating clinician should exercise caution when interpreting advanced imaging studies in competitive athletes. Clinical suspicion for symptomatic hip and pelvic pathologies should be balanced with caution, as abnormal imaging findings in athletes are common and may not always necessitate intervention. While symptomatic hip and pelvic pathology traditionally required invasive open surgery, technical innovations have led to advances in minimally invasive hip surgery that offer the potential for faster recovery and less soft-tissue morbidity.

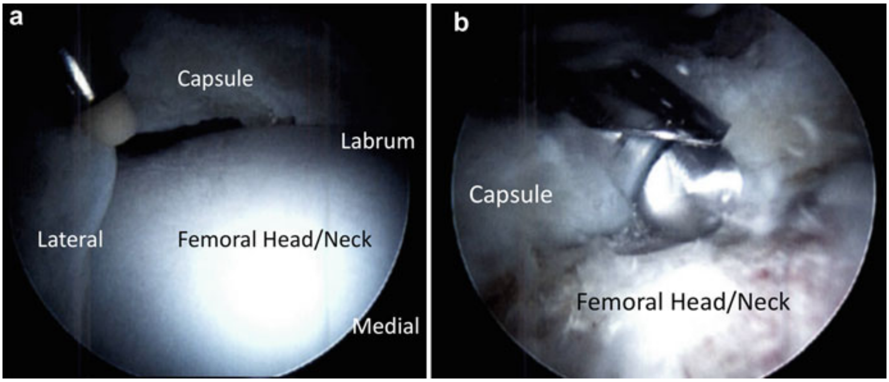

Fig. 15.10 Intra-operative arthroscopic photographs demonstrating a cam deformity of the femoral head/neck junction before (**a**) and during (**b**) decompression using an arthroscopic burr

15.10 Case Presentation (Continued)

15.10.1 Intervention

The patient underwent left hip arthroscopy. Intra-operative findings included mixed-type FAI with a complex intra-substance labral tear in the anterosuperior quadrant. He was treated with acetabuloplasty, femoroplasty, and labral repair (Fig. 15.10).

15.10.2 Follow-up

The patient experienced symptomatic improvement and was able to advance his functional activities under the guidance of a skilled physical therapist. A follow-up MRI completed 5 months post-operatively showed a resolution of his parasymphyseal edema and the patient was able to successfully return to full unrestricted athletic activity.

15.10.3 Decision Making

The patient presented with symptoms of early osteitis pubis. He had failed conservative management consisting of rest and activity modifications. Advanced imaging, including MRI, MRA, and CT demonstrated mixed-type impingement morphology. By addressing his FAI, mechanical stresses on the pelvic ring were rebalanced and the stress reaction in the bone was able to finally heal.

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