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Imaging of Femoral Acetabular Impingement Syndrome

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Osteoarthritis of the hip is not limited to the elderly. It can affect both young and middle-aged adults. It is these patients in which early detection and treatment may be particularly beneficial, allowing longer pain-free functionality of the hip and possibly obviating total hip arthroplasty.

Biomechanical factors in development of osteoarthritis (OA) of the hip include concentric or eccentric overload, resulting in cartilage degeneration. This etiology is supported by the example of early development of OA in patients with developmental dysplasia. However, it fails to explain the development of OA in young adults with apparently normal anatomy and intra-articular pressures.

The pathogenesis of such "idiopathic" OA has not been well established. Recently, femoroacetabular impingement (FAI) has been implicated as an etiology of both labral tears and adjacent cartilage damage, and through repetative microtrauma at these sites is felt to be a precursor to OA in young adults [1]. FAI represents impingement of the anterior femoral head-neck junction against the adjacent anterosuperior labrum. It may occasionally be a result of unusual stress placing the femoral neck in contact with the anterosuperior labrum, such as in a football punter or carpet layer. However, more frequently FAI results from subtle morphologic abnormalities in the femoral head-neck junction or in the acetabulum. Less stress is required to develop clinical symptoms of FAI when such abnormalities are present.

Recognition of FAI both clinically and radiographically may be difficult. This review serves to demonstrate both the radiographic findings and imaging work-up of FAI, and relates them to early surgical treatment of this syndrome. It is hoped that early recognition will lead to routine early intervention, delaying the onset of end-stage OA in these young patients [2].

CLINICAL SYMPTOMS OF FAI

The most common feature of FAI is that the clinical symptoms seem disproportionate to the radiographic findings. Patients may present with groin pain or

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pain overlying the greater trochanters [1]. They may complain of grinding or popping. The loss of internal rotation is usually out of proportion to other decreased range of motion. Patients report pain with flexion and internal rotation, such as in a sitting position and getting out of a car; the pain is worse after prolonged sitting. The impingement test, elicited by 90° flexion, adduction, and internal rotation of the hip, is almost always positive [2]. This position results in sheer stress or compression on the labrum or adjacent damaged cartilage. The labrum contains proprioceptive and nociceptive nerve fibers [3] that are sensitive to this provocative movement.

Although anterosuperior impingement is most frequent, posteroinferior impingement may rarely occur. The provocative test for this calls for the patient to lie supine with the legs hanging free (creating hip extension); external rotation results in severe deep-seated groin pain [2].

MORPHOLOGIC DEFINITION OF FAI

Morphologically, FAI is defined as a conflict occurring between the anterior femoral head-neck junction and the adjacent anterosuperior labrum and acetabular rim. This conflict is caused by an abnormality of either the proximal femur or the acetabulum, or occasionally both [4]. The acetabular cartilage may be focally damaged or delaminated. The histologic features of the damaged labrum include hyperplasia with disorganized cystic matrix, and no inflammatory changes. This suggests the mechanism of damage is chronic irritation consistent with repetative microtrauma [5].

There are two types of FAI, the "cam" and "pincer"; combinations of the two may occur. These types are described based on the pattern and characteristics of chondral and labral injuries observed in situ during surgical dislocation of the hip. There are radiographic patterns that follow these descriptions as well.

Cam Type of FAI

In any position of the femoral neck, one normally can see a head/neck offset (or cutback) (Fig. 1A). FAI with a femoral head/neck abnormality occurs when there is an insufficient femoral head/neck offset. Most frequently this occurs when there is a lateral femoral neck "bump" (Fig. 1B). With flexion, adduction, and internal rotation, the nonspherical portion of the femoral head rotates into the acetabular rim (Fig. 1C,D), causing sheer stress on the articular cartilage and a subsequent labral tear or detachment [1,2,4] (Fig. 1E). Because of the offset at the normally rounded femoral head, this has been termed a "cam" mechanism. There is surgical evidence supporting the supposition that the principal initial damage in the cam type of FAI is to the cartilage and that the labrum is uninvolved at first. Additionally, all of the labral tears or detachments occur at the articular (not capsular) margin [2]. This further supports the cartilage rather than labrum being the initial site of damage. The cam type of FAI tends to be seen in young active male patients.

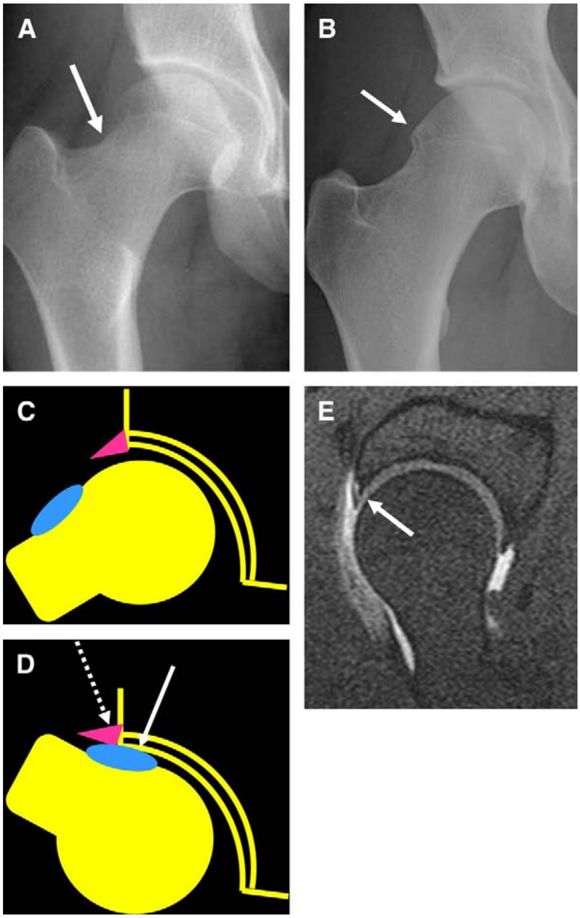

Fig. 1. Cam type of femoroacetabular impingement. (*A*) A normal femoral head/neck offset (*arrow*). (*B*) A case of FAI, with a lateral ''bump'' (*arrow*) resulting in decreased femoral head/neck offset. This corresponds to the diagram in (*C*); with flexion, internal rotation, and adduction (*D*), the abnormal femoral neck contacts the anterosuperior cartilage first (*solid arrow*), and secondarily damages the labrum, most frequently as a detachment (*dotted arrow*). (*E*) An axial oblique image obtained from an MR arthrogram of the patient in (*B*), showing a tear in the anterosuperior labrum (*arrow*).

The etiology of the abnormal femoral head/neck offset (or lateral bump, Fig. 2A) is unclear. Currently it is being discussed as a subclinical slipped capital femoral epiphysis [6,7]. Another theory is that a growth disturbance may result in delayed separation or eccentric closure of the common physis between the femoral head and greater trochanter. This would result in an abnormal extension of the femoral head epiphysis and a consequent decrease in the head/neck offset [6,8].

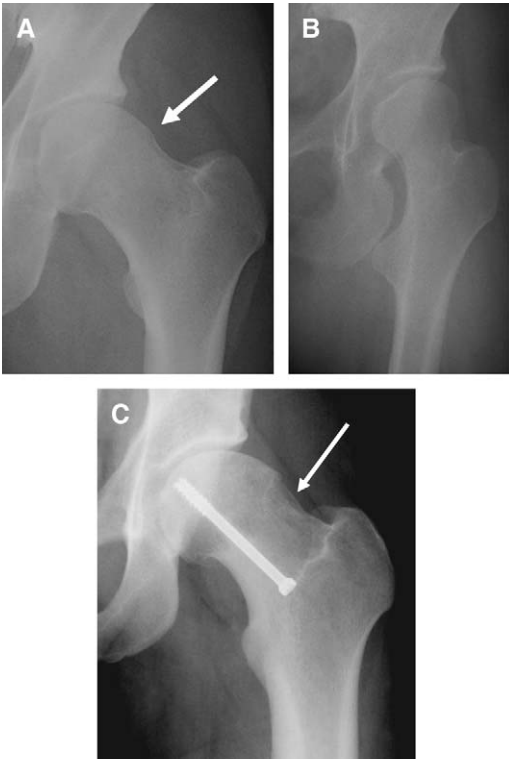

Fig. 2. Cam type of FAI. (*A*) A subtle lateral ''bump'' (*arrow*), of unclear etiology, but the most common type of this disorder. (*B*) A severe coxa valga hip dysplasia; the motion consisting of flexion, internal rotation, and adduction results in abnormal contact between the femoral head/neck with the anterosuperior acetabulum. (*C*) An old slipped capital femoral epiphysis, where the femoral neck has outgrown the stabilizing nail. Because the slip is medial, the lateral femoral head/neck offset is lost (*arrow*), resulting in a Cam-type of morphology.

There are other, more obvious, etiologies of abnormal femoral head/neck offset. These include retrotorsion of the femoral head, malunited femoral neck fracture, prior femoral neck osteotomy, an elliptical femoral head, severe coxa valga deformity (Fig. 2B), and any etiology of a coxa magna deformity [1,9]. The latter may include prior Legg Perthes, adult avascular necrosis with collapse, and prior slipped capital femoral epiphysis (Fig. 2C).

Pincer Type of FAI

The pincer type of impingement results from any abnormality that results in increased coverage of the anterosuperior portion of the femoral head (Fig. 3A,B). This results in a linear contact between the (normal) anterolateral femoral neck on the prominent acetabular rim (Fig. 3C,D) [1,2]. This impingement results primarily in labral tears and bony proliferation at the acetabular

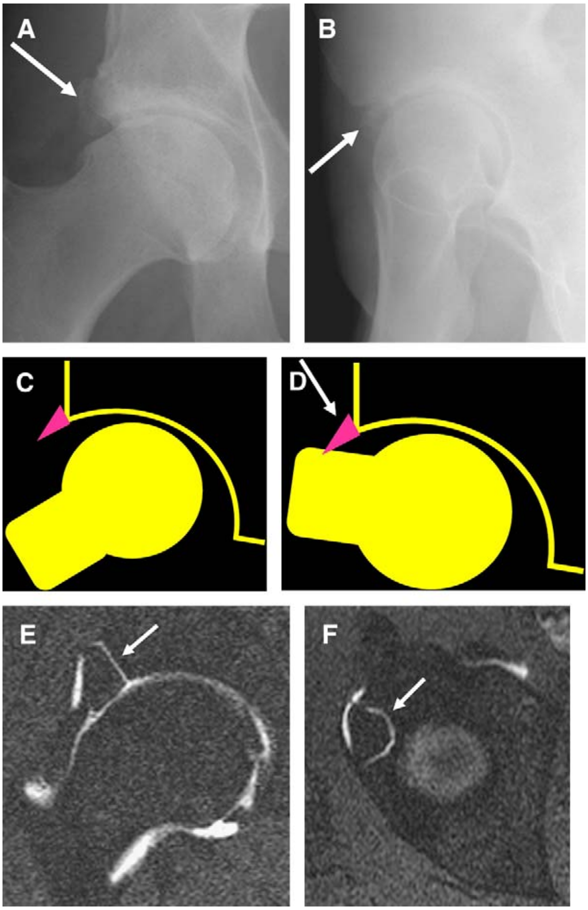

Fig. 3. Pincer type of FAI. (*A*,*B*) An anteroposterior and false profile view, respectively, of a hip with abnormal acetabular bony rim proliferation. Note that there is an abnormal amount of bone at both the anterior and lateral portions of the rim (*arrows*). (*C*) Diagram demonstrating increased acetabular coverage of a normal femoral head and neck. With flexion, internal rotation, and adduction, the normal femoral neck contacts the abnormal acetabular rim and damages the labrum (*D*). (*E*,*F*) Coronal and axial images, respectively, from the MR arthrogram of the patient in (*A*). The labral tear is not shown in these images, but the fragmented hypertrophic acetabular rim is well demonstrated, with fluid tracking around the rim fragments (*arrows in both*).

rim (Fig. 3E,F). With chronicity, a focal chondral injury may result. Continued injury may lead to cyst formation from the labral tear or ossification of the acetabular rim, which in turn worsens the condition. Finally, the pincer type of FAI may result in chondral injury in the "contre-coup" region of the posteroinferior acetabulum [4]. The pincer type of FAI tends to occur more in women and older patient age groups than the cam type.

The acetabular abnormality resulting in the pincer type of FAI may be either local, as in a focal acetabular retroversion (Fig. 4A), or more global (Fig. 4B). Etiologies of the more general abnormal acetabular coverage of the femoral head include coxa profunda (projection of the acetabular fossa medial to the ilioischial line) and protrusio acetabulae (projection of the femoral head medial to the ilioischial line) [7].

Box 1 outlines the major differences between the cam and pincer types of FAI. It is important to note that although these two basic mechanisms of FAI have been described, it is not infrequent to find combined femoral and acetabular abnormalities. It is extremely important to assess all features of FAI, since the corrective surgery might be altered if more than one type coexists. It should also be noted that developmental dysplasia of the hip (DDH) often results in labral and cartilaginous damage, and may be a part of the complex. DDH will be more completely described in a later section.

IMAGING FINDINGS IN FAI: RADIOGRAPHIC, CT, MR, MR ARTHROGRAM

Osseous Abnormalities

The osseous abnormalities found in FAI are similar, whether seen on radiograph, computed tomography (CT), magnetic resonance (MR), or MR arthrogram. They will be demonstrated in all of these types of imaging throughout the remainder of the review.

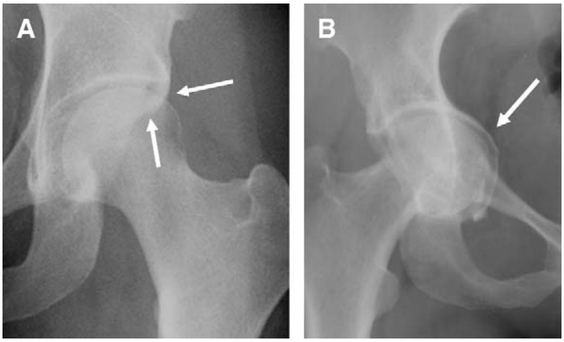

Fig. 4. Other etiologies of Pincer type FAI. (*A*) Anterosuperior acetabular retroversion. Both arrows outline the focal region of the acetabulum where the anterior rim overlaps and lies lateral to the posterior rim, resulting in a focal site of abnormal contact between the femoral head/neck and this acetabulum. (*B*) A case of coxa profunda due to Otto's disease (a hereditary disorder of the acetabulum, possibly related to abnormal fusion at the Y cartilage). The acetabulum projects medial to the ilioischial line (*arrow*), resulting in a relative overcoverage of the femoral head/neck.

Box 1: Cam versus pincer*

Cam

- Abnormality is at femoral head/neck junction
- Cartilage damage occurs first
- Labral injury tends to be detachment
- Treatment is femoral neck osteoplasty

Pincer

- Abnormality is at acetabular rim
- Cartilage damage is secondary
- Labral injury tends to be a tear
- Treatment is to reduce acetabular rim overcoverage

*Remember that these may present as combinations

Abnormal Lateral Femoral Head/Neck Offset

The most frequently used radiograph is the anterioposterior (AP) view. This is supplemented by various lateral views, including the frog lateral (flexion and external rotation), Dunn lateral (90° flexion and 20° abduction) and groin lateral. If there is abnormal femoral head/neck offset, it should be visible on each of these views, usually as a lateral femoral neck "bump." This configuration has been termed the "pistol grip" deformity (Fig. 5A–D) and is typical of cam-type FAI. Although there is usually no difficulty in making this assessment, an abnormal femoral head/neck offset can be measured using the alpha angle. This angle can be measured on any image of the femoral head and neck, but is used most frequently on a lateral radiograph (Fig. 6B) or sagittal oblique (Fig. 6E) or radial MR image. The alpha angle is constructed by the following steps [6]: (a) form a perpendicular line to the femoral neck at its narrowest, (b) bisect the femoral neck, perpendicular to the line described in (a), (c) form a best-fit circle on the femoral head, (d) the alpha angle is formed between the line (b) and a line drawn from the center of the head to the point where the neck intersects the circular head. The alpha angle is normally less than 55°.

Os Acetabulae

An os acetabulum is suggestive (although not diagnostic) of FAI, and is often seen in conjunction with a lateral femoral neck bump (Fig. 6). One study of 42 hips with cam-type FAI showed an abnormal alpha angle in 93% and an os acetabulum in 40% [6]. A double rim sign (rim ossification) has also been described in conjunction with FAI.

Fibrocystic Changes (Synovial Herniation Pits)

The relationship between synovial herniation pits (fibrocystic changes in the anterolateral femoral neck) and FAI is not entirely clear. Before the suggested

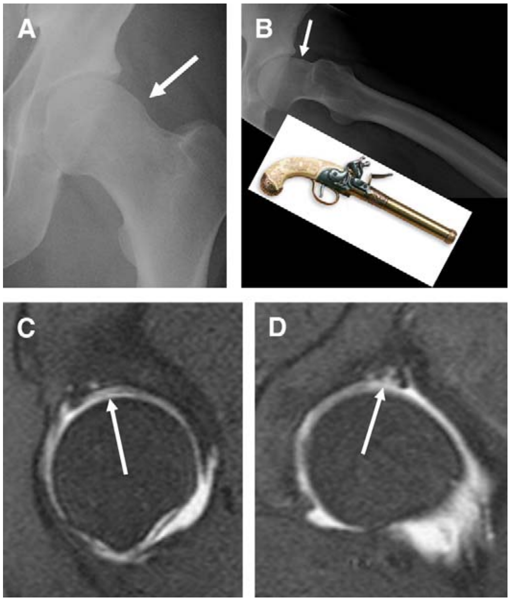

Fig. 5. Abnormal lateral femoral head/neck offset in Cam FAI. (*A*) A subtle lateral ''bump'' (*arrow*), which is also noted on the frog lateral view (*B*, *arrow*). Note that the configuration of the femoral head and neck is reminiscent of an old-fashioned pistol; hence the term ''pistol grip'' deformity. (*C*) Sagittal view from the MR arthrogram, showing extensive cartilage delamination (*arrow*), while the coronal view (*D*) shows the complex labral tear to best advantage (*arrow*).

association with FAI, these pits were thought to be caused by pressure anteriorly by the iliofemoral ligament on the capsule when the hip is held in full extension, and were considered an incidental finding in 5% of the normal population. However, one study of 117 FAI-affected hips showed fibrocystic changes in 33% of their cases [7]. Examinations using dynamic MR as well as intraoperative observations reveal a close spatial relationship between the region of fibrocystic change and the acetabular rim with the hip in flexion. Therefore, these are considered by some investigators to be a result of repetitive mechanical contact between the femoral head/neck region and the acetabular rim (Fig. 7).

Acetabular Overcoverage, Including Retroversion

Generalized overcoverage, as seen with coxa profunda and protrusio acetabulum, is easily diagnosed based on the relationship of the femoral head and acetabulum to the ilioischial line. However, focal anterosuperior acetabular retroversion may be more difficult to note. Retroversion can be a result of trauma or prior surgery, but is usually a focal dysplasia. It is seen when the

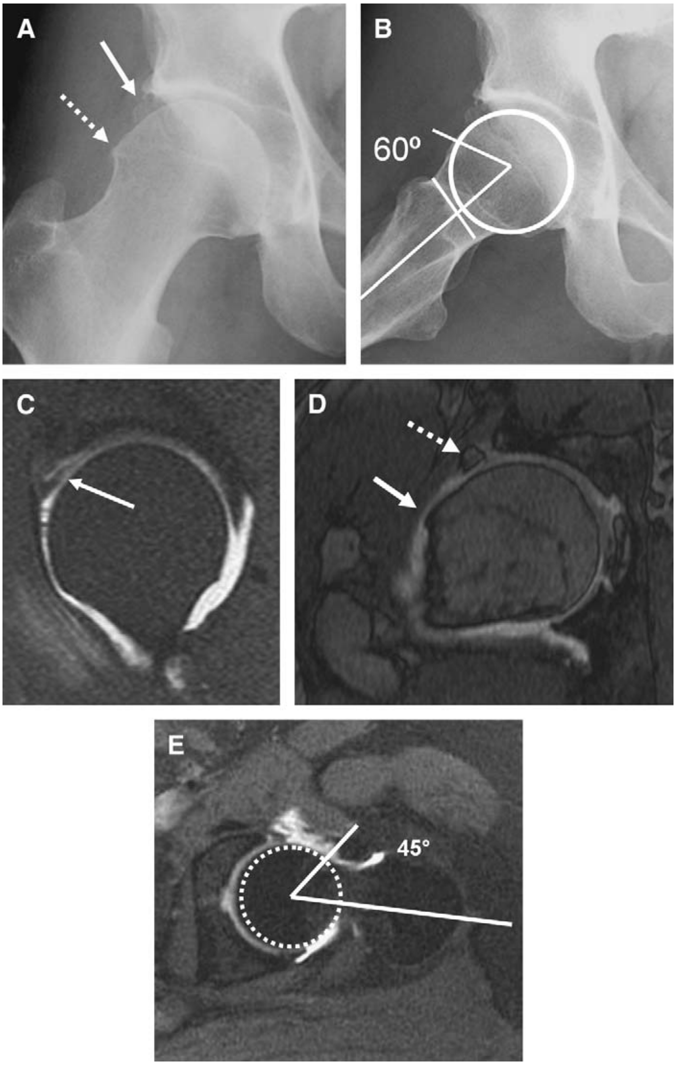

Fig. 6. Cam type FAI. (*A*) An anteroposterior view, showing the lateral femoral neck ''bump'' (*dotted arrow*) as well as an os acetabulum (*solid arrow*). The frog lateral view (*B*) shows an abnormal alpha angle (see text for description of its construction). The MR arthrogram confirms the suspected labral tear and cartilage damage (*C, arrow*). (*D*) A reformatted radial image, showing the lateral bump (*dotted arrow*) and os acetabulum (*solid arrow*). The combination of lateral femoral neck bump, abnormally large alpha angle, labral tear, and cartilage damage is a common theme in cam type FAI. Os acetabulae are frequently seen as well, although less often than these other listed abnormalities. (*E*) Normal alpha angle on an MR arthrogram of a different patient.

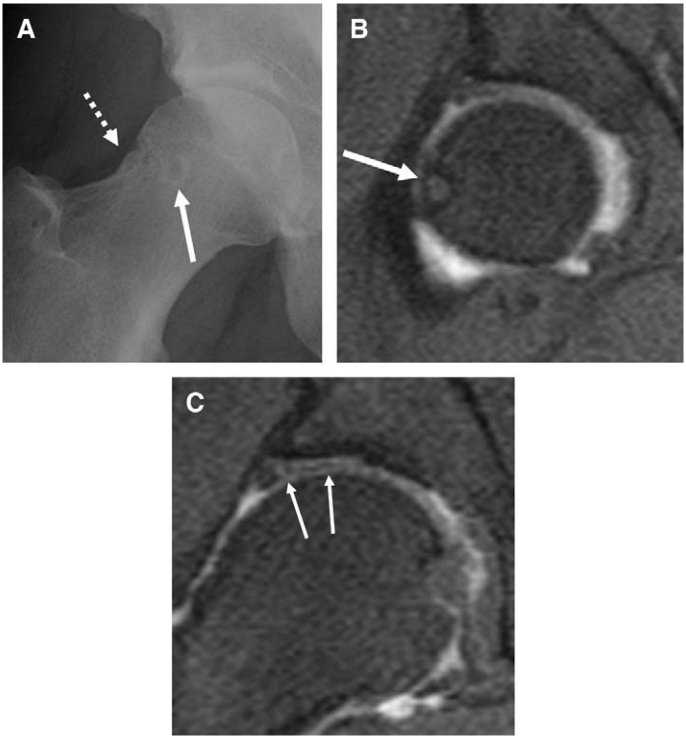

Fig. 7. Synovial herniation pits (fibrocystic changes). (*A*) Anteroposterior radiograph showing a lateral femoral neck ''bump'' (*dotted arrow*), indicating a cam type FAI. There is also a rounded lucency located in the anterolateral femoral neck (*solid arrow*), an appearance known as a synovial herniation pit. The coronal view on the MR arthrogram is located far anteriorly (*B*) and shows the herniation pit to be low in signal (*arrow*). This suggests the fibrous tissue within the pit; they may also contain high signal fluid. These fibrocystic changes are seen more frequently in hips with cam-type FAI than in the asymptomatic patient population. (*C*) Coronal view in the mid portion of the joint, shows irregularity of the cartilage and labrum with imbibation of contrast (*arrows*); this represents injury to these soft tissue structures.

anterior rim of the acetabulum projects more laterally than the posterior rim, resulting in a focal posterior orientation of the acetabulum in relation to the sagittal plane.

The normal anterior and posterior acetabular rims are seen on an AP radiograph as an inverted V, with the anterior rim entirely medial to the posterior rim (Fig. 8A,B). With focal retroversion, the superior portion of the anterior rim projects laterally to the posterior rim. This results in the ''crossover'' or ''figure-8'' sign (Fig. 8C,D). The prominent anterolateral edge of the acetabulum is an obstacle to flexion and internal rotation, and results in a pincer mechanism that causes labral injury (Fig. 8E,F) [10].

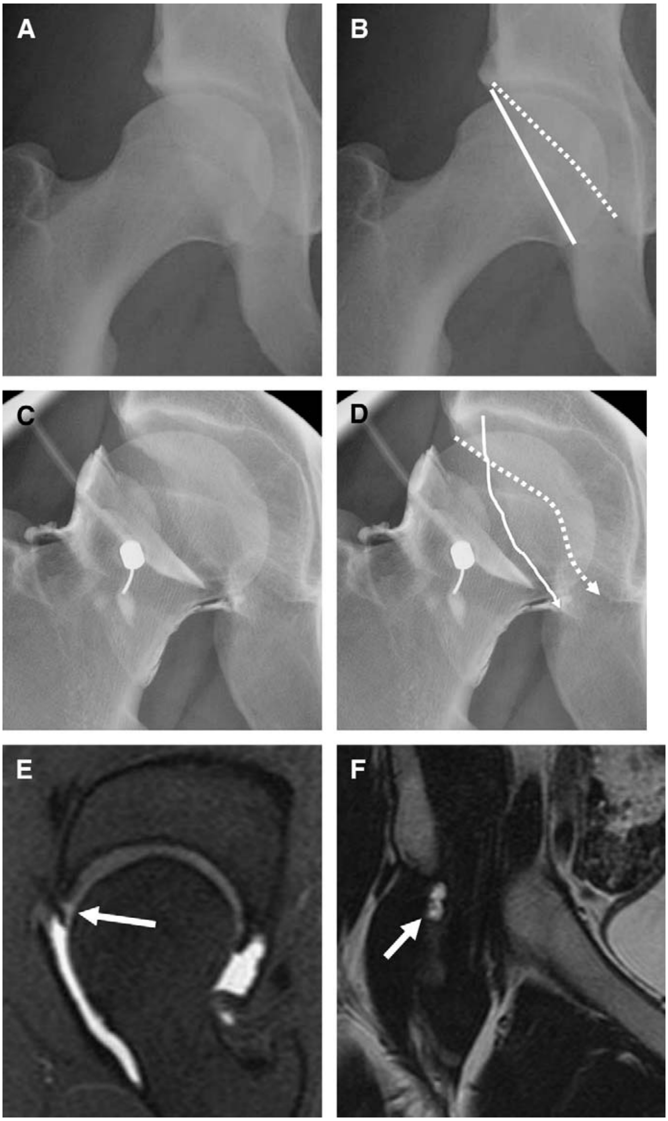

Fig. 8. Explanation of focal acetabular retroversion. Normal (*A*) anteroposterior view of a hip; (*B*) Anterior rim of the acetabulum outlined (*dotted line*) and posterior rim of the acetabulum (*solid line*). In the normal configuration, these rims form an inverted V and do not overlap; the posterior rim is lateral to the anterior rim throughout. (*C,D*) A case of focal superior acetabular retroversion in a 22-year-old Olympic kayak qualifier. (*D*) The acetabular rims are outlined, showing the superior crossover of the anterior (*dotted line*) rim so that it lies lateral to the posterior rim (*solid line*). (*E*) The MR arthrogram of this patient shows an anterosuperior labrum tear on the oblique axial (*arrow*). (*F*) There is a related paralabral cyst seen far anteriorly on the coronal T2 image (*arrow*).

Hyaline Cartilage Abnormalities

As already discussed, there is a very strong association between FAI and hyaline cartilage abnormalities. One study showed 95% of 42 hips with cam-type FAI had significant cartilage damage [6]. It is felt that cartilage damage is the primary etiology of early development of OA in these patients. It can be difficult to detect cartilage damage by means of imaging. The hip joint is small, and even with arthrography it is difficult to force contrast around the femoral head to demonstrate filling defects in the cartilage. Nonetheless, these defects must be carefully sought. They are usually found in the anterosuperior portion of the acetabulum, adjacent to an associated labral injury. The cartilage injury may be focal or may be extensive, with delamination.

In one study, two readers of MR arthrography showed a variable sensitivity (50% to 79%) and specificity (77% to 84%) in detecting cartilage lesions; 88% of the anterosuperior cartilage lesions were detected [11]. Another study of 102 hips undergoing MR arthrography showed limited sensitivity (47%) for articular cartilage pathology, but high specificity (89%), yielding a positive predictive value of 84% and accuracy of 67% for cartilage damage [12].

There is a classification system for osteochondral lesions of the hip [13]. Grade 1 shows intact cartilage with signal changes in the subchondral bone. Grade 2 shows a partial detachment of the cartilage with signal changes in the subchondral bone. Grade 3 shows complete detachment of a nondisplaced fragment. Grade 4 shows the fragment to be both detached and displaced. MR arthrography demonstrates grades 3 and 4 osteochondral injury with substantially more accuracy than grades 1 and 2.

Labral Tears

In one study of 42 hips with cam-type FAI, 100% of the patients had an anterosuperior labral tear. This completes the triad of findings that this study demonstrated: an abnormal alpha angle, anterosuperior cartilage abnormality, and anterosuperior labral tear were shown in 88% of the cases [6]. It is clear that labral abnormalities are an important part of this syndrome, and must accordingly be understood and sought aggressively.

Labral Morphology

The labrum merges with articular hyaline cartilage through a transition zone of 1 to 2 mm. A tongue of bone extends from the edge of the bony acetabulum into the substance of the labrum. The labrum is firmly attached to the articular side of this bony extension by a zone of calcified cartilage [14]. On the capsular side, a narrow synovial lined recess separates the labrum from the capsule.

The shape of the labrum can be variable. Based on an MR study of 200 asymptomatic patients, 66% of labra were triangular in shape, 14% were absent (this significantly increased with age), 11% were rounded, and 9% were flat [15]. The authors also noted that intralabral signal increases with patient age.

Another investigator, studying MR of 382 asymptomatic patients, showed a triangular shape in 80% of labra [16]. This author also noted that both high signal and the frequency of labral irregularity or absence are more likely both with increasing patient age and anterior location within the joint.

Sublabral sulci occur, but only far anteriorinferiorly and posteroinferiorly. A retrospective study of 58 MR exams with arthroscopic correlation showed a normal posteriorinferior sublabral groove in 22% and a normal cleft at the low anterior junction of the anterior labrum with the transverse ligament in 33% [17]. It is notable that in the anteriorsuperior region, where labral tears are most frequently found, no normal sublabral sulcus was demonstrated.

Imaging Recommendations

Imaging of the labrum can be performed with MR alone, but it is much more accurate with MR arthrography, as demonstrated by several investigators [18]. In one paper directly comparing MR with MR arthrography in 40 patients, there were 42% false negative MR exams as opposed to 8% false negative MR arthrograms for labral tears [19]. Many investigators have shown MR arthrography to be promising [20], including one showing 91% accuracy for MR arthrography as opposed to 36% accuracy for MR alone [21], and another showing 88% accuracy for MR arthrography in 46 individuals [22]. Finally, one study reported less spectacular success in identifying labral pathology in 102 patients undergoing MR arthrography: 71% sensitivity, 44% specificity, yielding a positive predictive value of 93% and accuracy of 69% [12].

It must be concluded that although MR arthrography is somewhat limited in sensitivity for diagnosis of both cartilage and labral lesions, it is a valuable preoperative staging exam. However, a negative MR arthrogram does not necessarily exclude important labral pathology.

Types and Locations of Labral Tears

Labral tears are almost exclusively found in the anterosuperior location, at the site of impingement (Figs. 1, 5–8). However, some Japanese researchers report more posterior than anterior labral tears in their population [17]. This may relate to repetitive posterior stress in the squatting position that is frequently used at rest. It is important to carefully examine the entire labrum for any abnormities (Fig. 9).

There is an arthroscopic classification (Lage) for acetabular labral tears [23]. Type 1 is the most common type, comprising 57% of tears. It is a radial flap tear, with disruption of the free margin of the labrum and formation of a discrete flap. Type 2 is a radial fibrillated tear due to chronic degeneration; it appears brush-like and occurs in 22%. Type 3 is a longitudinal peripheral tear at the junction of the labrum and acetabular rim (16%). Type 4 is an unstable, abnormally mobile tear. With MR arthrography, we can often distinguish between these types. However, preoperative classification may not be necessary at the present time since partial labrectomy is the treatment of choice regardless

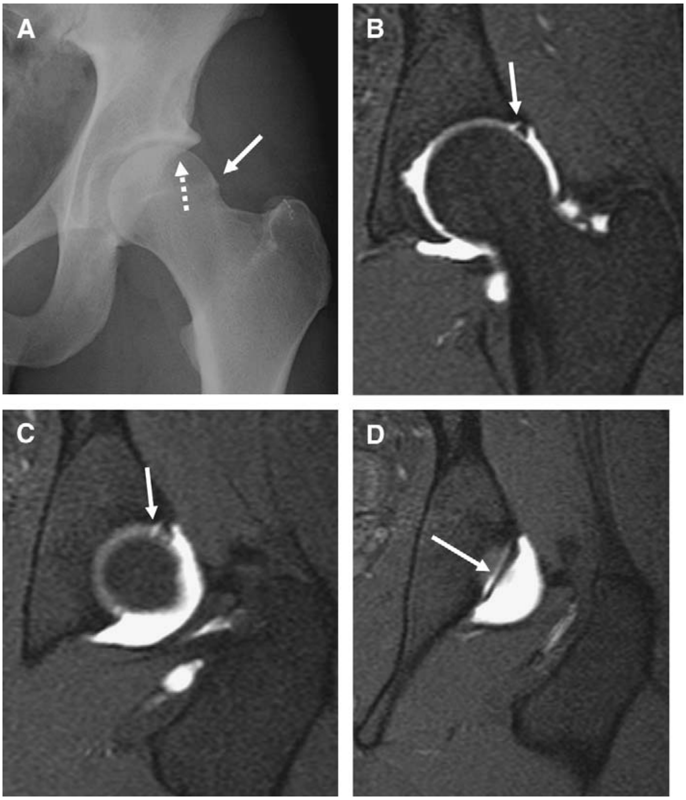

Fig. 9. Posterior labral tear. This is a 23-year-old male with debilitating left hip pain. The anteroposterior view (*A*) shows a lateral femoral bump (*solid arrow*) suggesting cam-type impingement as well as superior acetabular retroversion (*dotted arrow*) suggesting that the impingement may be related to a pincer mechanism as well. (*B–D*) The MR arthrogram shows progressively more posterior views in the coronal plane with a large circumferential labral tear (*arrows*). This is an unusual case in which the tear is posterior in location.

of the tear's morphology. It is much more important to preoperatively identify the extent of the tear.

Finally, the presence of a paralabral cyst on MR is a useful indirect sign of a labral abnormality (Fig. 8) [24,25].

Hints for MR Arthrography

Successful MR arthrography relies on a proper concentration of gadolinium (2 mmol) for optimization of the paramagnetic effect on T1-weighted sequences [13], as well as a small field of view and thin slices. The authors would like to offer two additional hints that the readers may find useful.

First, in preparing the gadolinium mixture, we find it useful to fill the syringe with bacteriostatic saline, gadolinium, and epinephrine (if desired); mix the solution; rid it of all air bubbles; and then attach and fill the tubing with this solution. We do not add radiographic contrast to the syringe. We then pull radiographic contrast back into the same tubing. This leaves a column of radiographic contrast in the tubing, but none of the gadolinium solution in it. The needle is placed in the hip and a test injection has the advantage of routine concentration of radiographic contrast, making it easy to determine if the needle is placed properly within the joint. Furthermore, if the test injection shows an extra-articular position, you have only injected radiographic contrast into that site; since there is no gadolinium, the extra-articular injection will not be seen on the T1 fat-saturated imaging, which constitutes the majority of the sequences. This makes an easier and cleaner injection.

Second, it is mandatory to include a T2-weighted (or equivalent) sequence. There are two reasons for this. The first relates to the fact that the injected contrast in an MR arthrogram does not usually fully fill paralabral cysts or subchondral cysts that already contain synovial fluid. Therefore, to fully visualize these cystic structures, a T2 type of sequence is mandatory (Fig. 10). The second reason relates to the fact that the T1 fat-saturated sequences performed for the MR arthrogram completely mask any marrow abnormality. To be certain to visualize an occult fracture, malignancy, or other marrow disorder, a non–fat-saturated sequence is required (Fig. 11).

Radial images of the MR arthrogram are required for planning by many surgeons. These are reformatted from a 3-dimensional gradient echo sequence. The reformats are based first on a true axial (coronal oblique) orthogonal to the axial plane and then on a sagittal oblique parallel to the acetabular plane (Fig. 6). The imaging findings are those of the routine sequences; the advantage

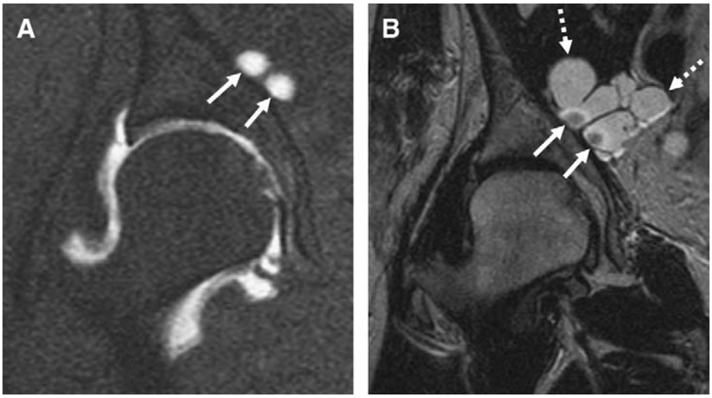

Fig. 10. MR arthrogram indicating the need for T2 imaging. (*A*) The T1 fat-saturated coronal image shows small intrapelvic cysts (*arrows*) that arise from a labral tear (not shown). However, the T2 image (*B*) shows the small cysts (*solid arrows*) are only a small part of the very large intrapelvic cyst. Cysts that already contain synovial fluid often do not fill initially with injected contrast. Dotted arrows outline the full extent of the cyst.

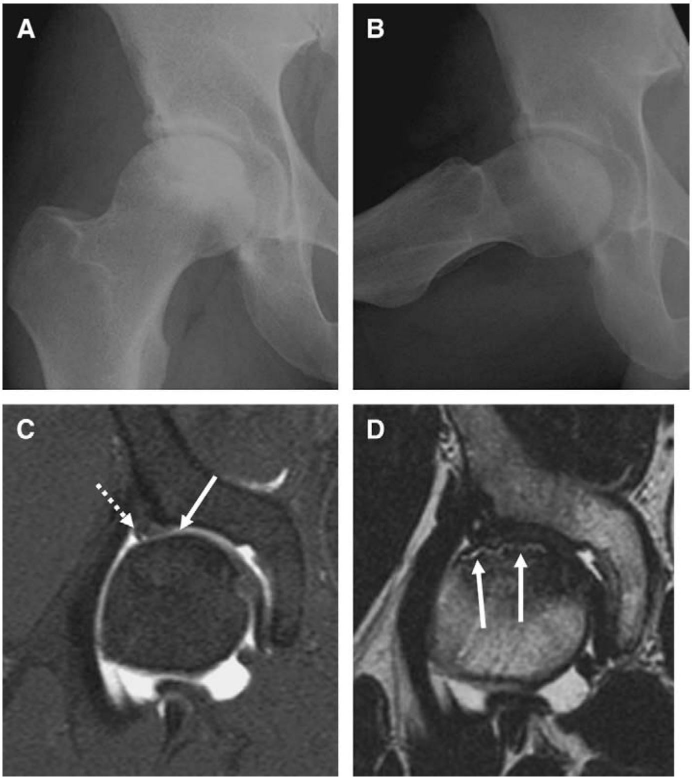

Fig. 11. Exam demonstrating the need for T2 imaging as a part of the MR arthrogram. The anteroposterior (*A*) and frog lateral (*B*) views appear normal in this 35-year-old male with hip pain. (*C*) The coronal image from the MR arthrogram (T1 fat saturated) shows a small focal labral tear (*dotted arrow*) and subtle flattening of the femoral head (*solid arrow*). The diagnosis is clear on the T2 coronal image (*D*), which shows avascular necrosis (*arrows*). This diagnosis was previously unsuspected; the patient admitted to using alcohol freely in his job as a salesman.

to the surgeon is in planning: the radial reformats are designed such that all slices are orthogonal to the acetabular rim and labrum [7,9].

DDH AND FAI

DDH shares many clinical similarities with FAI. Like patients with FAI, early osteoarthritis is a feature: 25% to 50% of DDH patients will develop OA by age 50. They, like the FAI patient, may be candidates for early conservative therapy. Like FAI, they present with symptoms of overload of the acetabular rim, with groin pain, especially with combined hip flexion, adduction, and internal rotation. Less frequently, they also present with an element of instability [26].

At first glance, one would presume that it would be easy to distinguish DDH from FAI on radiographs, even if the clinical presentation is indistinguishable.

However, we have already seen that radiographic findings in FAI can be subtle. Similarly, DDH may be extremely subtle.

Evaluation for DDH involves measuring acetabular coverage of the femoral head. This is most frequently assessed on the weight-bearing AP radiograph by means of the center-edge angle of Wiberg (the angle formed by a vertical line from the center of the femoral head and line extending from the center of the head to the lateral acetabular margin should be greater than 25°) [26] (Fig. 12A). Anterior coverage of the femoral head by the acetabulum is assessed in a similar manner on Lequesne's false profile view [1,26]. This radiograph is the ipsilateral posterior oblique obtained with the patient standing in a position 25° removed from the true lateral position. The angle consists of a line drawn vertically from the center of the femoral head and another extending from the center of the head to the anterior acetabular rim; the angle should measure at least 25° (Fig. 12B).

Besides anterior and lateral femoral head coverage, the DDH hip is evaluated for sphericity (are the head and acetabulum rounded) and concentricity with one another. Finally, it has been established that a large number of

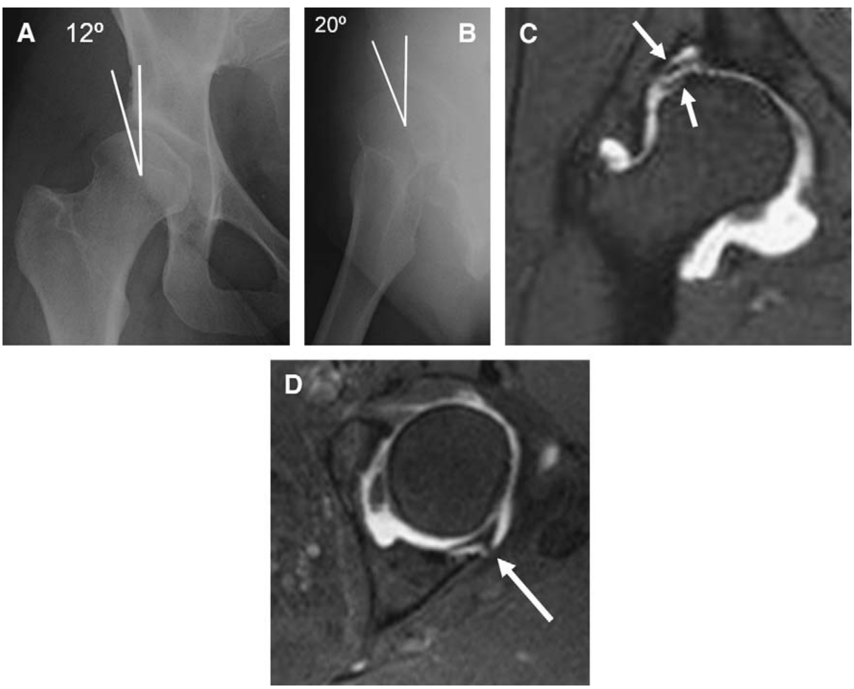

Fig. 12. DDH. (*A*) The anteroposterior view shows an abnormal center-edge angle of Wiberg, indicating inadequate lateral coverage of the femoral head. (*B*) False profile view, showing inadequate anterior coverage of the femoral head. (*C*) The MR arthrogram shows a hypertrophied labrum with a large tear (*arrows*). (*D*) The tear continues posteriorly in a bucket handle pattern (*arrow*).

DDH patients have focal retroversion of the anterosuperior acetabulum; one study of 153 DDH patients showed 37% with acetabular retroversion [27]. Assessment for retroversion is an important part of the overall evaluation since this must be accounted for in the surgical planning.

Deficient acetabular coverage of the femoral head leads to microinstability of the hip in DDH. The anterolateral migration of the femoral head induces shear stress at the acetabular rim. It is notable that there is usually hypertrophy of the labrum in these patients. The enlarged labrum aids in maintaining the head within the joint initially, but eventually fails because of the shear stress, resulting in a labral tear [9] (Figs. 12 and 13).

One recent study emphasized that it is difficult to clinically distinguish FAI from DDH. The study [9] had 14 patients with each diagnosis, based on radiographic exam. All had positive impingement tests and all had disorders of the acetabular rim. The labral abnormality was located in the same anterosuperior site in both groups. However, the labrum itself was different in the two groups.

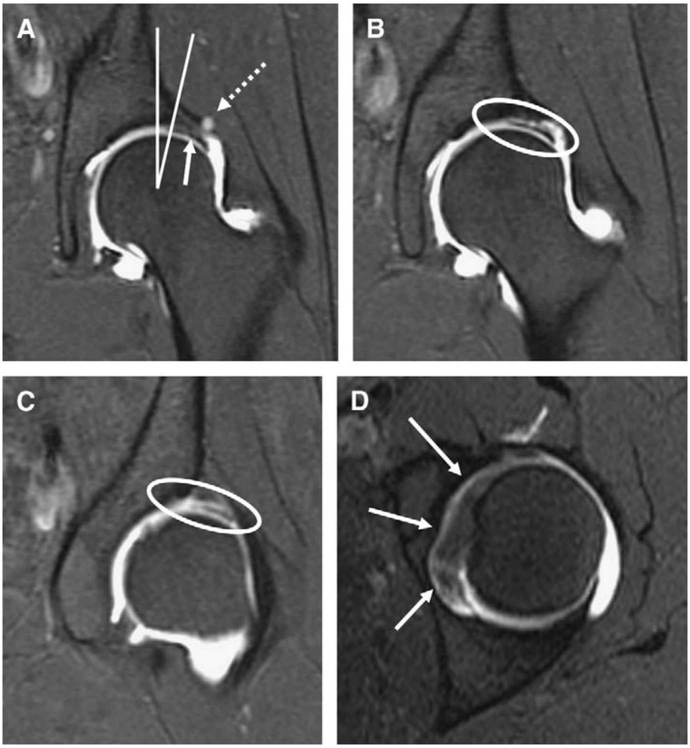

Fig. 13. DDH. The MR arthrogram shows the shallow acetabulum, indicated by a reduced center-edge angle (*A*); there is also a hypertrophied labrum (solid arrow) and paralabral cyst (dotted arrow). (*B,C*) Further posteriorly, one sees extension of a tear throughout the hypertrophied labrum (ovals). (*D*) The axial image demonstrates hypertrophy of the ligamentum teres, typical of DDH (*arrows*).

12 of the 14 DDH patients had myxoid degeneration and increased volume of their labrum; these findings were not present in the FAI group. Paralabral cysts were seen in 10/14 DDH patients but only 3/14 FAI patients. Thus, labral size and cysts can help to distinguish the two on MR arthrography. Additionally, the ligamentum teres and pulvinar are often hypertrophied in DDH (Fig. 13D).

TREATMENT

As discussed earlier, identification of subtle FAI and DDH patients is crucial to ensure early surgical treatment. However, it is also mandatory that the two types of FAI are distinguished from one another, and in turn from DDH. Remember also that an individual patient may have elements of more than one of these disorders. In this section, an introduction to the concepts of surgical

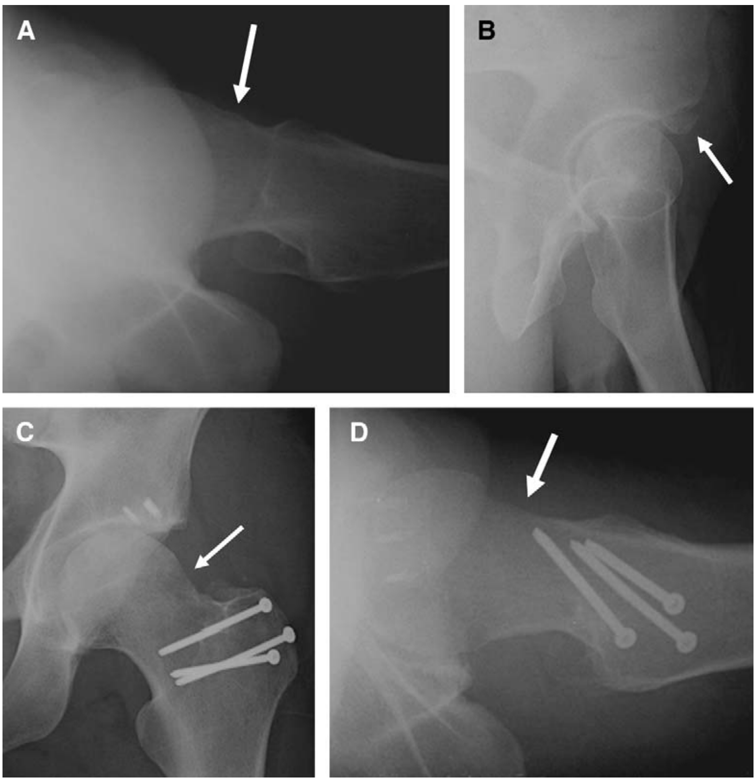

Fig. 14. Treatment of Cam-type FAI. (*A*) A groin lateral showing a ''bump'' at the femoral head-neck junction (*arrow*). The false profile view (*B*) shows a very large os acetabulum (*arrow*). The postoperative anteroposterior (*C*) and groin lateral (*D*) radiographs show the resection osteoplasty at the femoral neck (*arrow in both*). The os acetabulum has been removed, and the labrum repaired (note the suture anchors at the acetabular rim). The screws in the greater trochanter secure the trochanteric osteotomy, which provided the surgical approach.

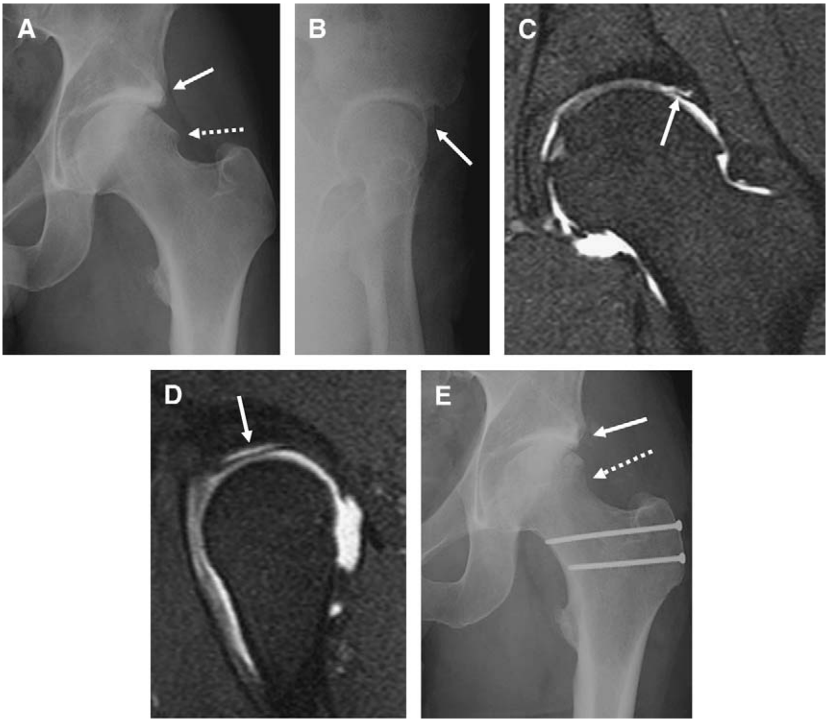

Fig. 15. Treatment of Pincer-type FAI. The anteroposterior view (*A*) shows a lateral femoral bump (*dotted arrow*) as well as overcoverage of the femoral head by a hypertrophied acetabulum (*arrow*). The false profile (*B*) confirms the osseous hypertrophy of the anterior acetabulum (*arrow*). This represents a combination of pincer and cam type FAI. (*C*) The MR arthrogram shows the lateral bump and overcoverage by the acetabulum, as well as both cartilage damage and a torn labrum (*arrow*). (*D*) The extensive labral tear is confirmed on the sagittal plane (*arrow*). (*E*) The postoperative radiograph shows the treatment: the surgical approach was through the greater trochanter, which is secured by screws. The patient had a femoral neck osteoplasty (*dotted arrow*) as well as local resection of the hypertrophied acetabulum (*solid arrow*).

treatment is given, which will serve to demonstrate that the treatment for the different morphologic abnormalities is quite distinct. Incorrect or incomplete treatment may only aggravate the problem, while overtreatment increases morbidity and delays return to functionality.

Although occasionally surgical treatment may be accomplished entirely arthroscopically, the hip is such a tight joint that more frequently the approach is in part arthroscopic and in part a partial hip disarticulation. The surgical exposure for the latter procedure is through a greater trochanteric osteotomy. Therefore, most of these patients will show a reattachment of the greater trochanter at the osteotomy site on their postsurgical films (Figs. 14 and 15).

Treatment for the isolated cam-type FAI appears straightforward. A resection osteoplasty is performed at the impinging site of the femoral head/neck junction [1,28]. This may be followed by resection of anterior soft tissues that may be impinging as well. The labrum is trimmed or reattached (Fig. 14).

Treatment of the pincer-type FAI may be more complicated. The same surgical approach is taken. The anterior overcoverage is reduced by excising the bony prominence either regionally or globally. The global acetabular surgery may involve reorientation by means of a periacetabular osteotomy. The torn labrum is excised and the remainder is reattached (Fig. 15). The surgeon will often also perform a femoral neck osteoplasty to increase the femoral head/neck offset [2,7].

It is important to identify retroversion of the acetabulum since some acetabular reorienting procedures do not allow full freedom of movement of the acetabulum in all three planes (Salter, triple, or Steele osteotomies). Additionally, some of the periacetabular osteotomies actually tend to produce retroversion and in turn impingement if care is not taken [27]. Surgical treatment of retroversion may require a periacetabular osteotomy to decrease the anterolateral acetabular coverage; this also addresses any lack of posterior femoral head coverage. Resection osteoplasty at the femoral head/neck junction often supplements this approach. In other patients, trimming of the anterior rim alone may be an alternative treatment of acetabular retroversion if posterior coverage is adequate [10].

Treatment of DDH generally requires a periacetabular osteotomy to address both lateral and anterior coverage (Fig. 16). The labrum is trimmed or repaired. If it will significantly increase femoral head coverage, a varus-producing osteotomy of the femoral neck may be performed (Fig. 17).

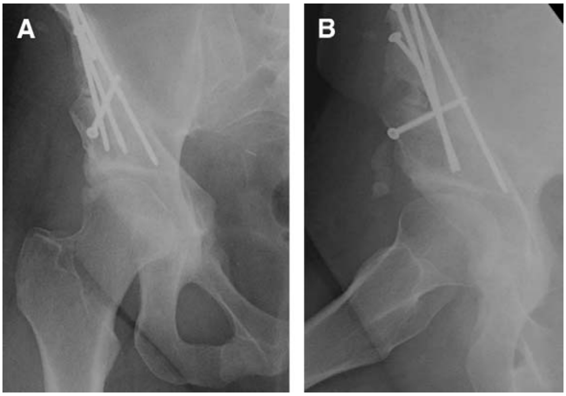

Fig. 16. Periacetabular osteotomy treatment of DDH. (*A*,*B*) This postoperative set of radiographs anteroposterior and lateral, respectively) shows a periacetabular osteotomy that results in appropriate coverage of the femoral head both laterally and anteriorly. This is the patient whose preoperative images are shown in Fig. 12.

Fig. 17. Varus-producing osteotomy may be used to improve femoral head coverage in DDH. This is the patient whose preoperative image is seen in Fig. 2B.

SUMMARY

Evidence is accumulating from several different sources that relates the subtle osseous abnormalities found in FAI and DDH to early development of osteoarthritis [29]. It is incumbent on the radiologist to be vigilant in making these diagnoses and bringing them to the attention of the referring clinician. Early detection on radiographs, followed by MR arthrogram to fully evaluate the pathology, can result in early surgical intervention. Accurate preoperative analysis can assist in developing the optimal surgical plan for the individual patient. New imaging manipulation is being developed that may allow for smaller surgical approaches. Three-dimensional CT is being used in conjunction with range of motion modeling to identify a specific small osseous focus that is the cause of impingement. This may allow for osteoplasty of this small focus by means of a purely arthroscopic approach in some cases. Avoiding the partial surgical hip dislocation whenever possible is important in reducing postoperative morbidity.

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