MR imaging in femoroacetabular impingement

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Introduction

Femoroacetabular impingement (FAI), sometimes termed acetabular rim syndrome, results from chronic mechanical abutment between the femoral head-neck junction and the acetabulolabral complex. Orthopedists have begun to recognize FAI as a cause of pain, instability and progressive hip dysfunction. Because FAI is implicated in the development of osteoarthritis in young individuals, orthopedists have increasingly utilized imaging to support their clinical diagnoses and treatment decisions. Whereas conservative treatments are considered unsuccessful, many surgical procedures remain controversial. If FAI can be diagnosed in its early stages, surgical procedures may prove to be effective in correcting the anatomical deformities that cause femoroacetabular impingement and, therefore, in limiting the degenerative process and delaying joint replacement.

Pathoetiology

Contemporary hypotheses propose that osteoarthritis is rarely idiopathic (primary) in etiology, instead representing the common final pathway of abnormal mechanical loading of the acetabular rim due to impingement and instability. Both developmental (eg. developmental hip dysplasia) and acquired (eg. Legg-Calve-Perthes disease, slipped capital femoral epiphysis, fracture malunion of femoral neck) deformities are well recognized causes of mechanical impingement. Surgical treatments, such as realignment osteotmy, have been directed at improvement in joint congruence and correction of weight-bearing balance. Other deformity patterns may be subtle in clinical presentation and impossible to confirm on radiographs, but they are now recognized as common causes of pathomechanics in the hip.

In the normal hip, weight-bearing surfaces require adequate but not excessive acetabular coverage of the femoral head. Full range of motion in the hip occurs within a narrow range of normal acetabular and femoral version. The cartilage surfaces must be perfectly congruent due to limited tolerances for excessive peak loads and shear forces. Outside of this narrow physiological range of loading, abnormal hip motion causes mechanical damage to the acetabular rim and adjacent articular cartilage, leading to osteoarthritis.

FAI results from abnormal contact between the anterolateral femur and acetabular rim. The concept was first reported by Ganz et al in 1999 as a complication of periacetabular osteotomy in patients with acetabular dysplasia. The femoral head-neck junction abutted the anterior rim of the acetabulum leading to post-operative pain after repositioning of the acetabulum. Anterior impingement symptoms resolved after repeat surgery to treat the impingement lesion.

Femoroacetabular abutment is now recognized as a primary disorder unto itself. The diagnosis is important because FAI causes early osteoarthritis. It presents in younger, athletic patients involved in activities that require repetitive hip flexion and internal rotation. There are two basic mechanisms of impingement: 1) acetabular-based (pincer) impingement caused by excessive acetabular coverage of the femoral head, or 2) femoral-based (cam) impingement caused by a nonspherical femoral head. In clinical practice, a combination of the two is most common.

In pincer-type impingement, overcoverage usually results from acetabular retroversion, protrusio acetabuli or coxa profunda. The acetabular rim abuts the femur at the head-neck junction during hip flexion and internal rotation. In cam-type impingement, aspherical enlargement of the femoral head results from extension of excessive bone and cartilage from the femoral head onto the femoral neck. This osteochondral contour abnormality decreases the head-neck offset, jamming into the acetabular rim during hip flexion and internal rotation.

In cam impingement, the abnormal head-neck junction of the femur abuts the sublabral articular cartilage, causing abrasion and surface defects with hypertrophic degeneration of the labrum. Eventually, the cartilage along the lateral acetabular rim delaminates with chondral flap formation followed by labral tear due to repetitive compression and shear forces. The articular cartilage of the femoral head remains intact until later in the degenerative process. As the femoral head levers out of the acetabulum due to instability during flexion, a distraction force occurs at the posterior capsule-labral junction and, over time, can lead to posterior labral tear (counter-coup lesion).

Early surgical intervention may avert this cascade of events that result in end-stage osteoarthritis. Corrective surgical treatments include both extra- and intra-articular approaches. In cam-type impingement, the basic principle of surgery is restoration of shpericity of the femoral head, thereby relieving the impinging lesion. Corrective extra-articular procedures include acetabular and proximal femoral osteotomies. Intra-articular procedures include subcapital osteotomy, trimming of the femoral head-neck junction, trimming of the acetabular rim, and combinations of these procedures. Hip arthroscopy is also performed for debridement of unstable cartilage and labral lesions.

MR arthrography

MR arthrography of the hip should be reserved for the preoperative assessment of patients with chronic hip symptoms (eg. painful clicking or mechanical locking) and negative results from conventional imaging studies. The decision to perform MR arthrography depends on the clinical need to identify intra-articular lesions and distinguish them from osseous or periarticular abnormalities. In athletes and younger patients in whom surgery would be performed to repair acetabular labral tears and débride chondral lesions, MR arthrography can improve diagnostic confidence. If the imaging findings are normal or limited to abnormalities that would not be treated surgically, MR arthrography may obviate more expensive, invasive operative procedures. In patients with acetabular dysplasia or FAI, MR arthrography may help to confirm or exclude labral tear before undertaking reconstructive surgery.

MR arthrography of the hip is primarily indicated for assessment of the acetabular labrum but also can help in the detection of intra-articular loose bodies and chondral lesions that are amenable to arthroscopic débridement. Thus, the value of MR arthrography depends on the success of surgical treatments in alleviating symptoms and delaying the progression of degenerative joint disease. Although many patients with acetabular labral tears, chondral flaps or loose bodies experience the resolution of mechanical symptoms following arthroscopic treatment, the long-term benefits of surgery remain unproved.

In patients with labral tears, clinical signs and symptoms are nonspecific and mimic other conditions, including osteoarthritis, osteonecrosis, stress fracture, synovitis, and bursitis. While plain radiography, arthrography, CT, and conventional MR can demonstrate many of these disorders, they have not proven as beneficial in the evaluation of labral tears. Conventional MR is limited by normal variations in labral size and shape, volume-averaging with the joint capsule and pseudotears at the labral junction with articular cartilage. MR arthrography overcomes most of these diagnostic challenges because the contrast solution distends the joint capsule, outlines the labral contour, and fills tears. Pseudotears caused by articular cartilage can be distinguished confidently from true tears because the contrast solution has higher signal intensity and greater contour irregularity compared to cartilage. Czerny and colleagues reported that the sensitivity and accuracy of MR arthrography for diagnosis of labral lesions was 90% and 91%, respectively, whereas the sensitivity and accuracy of conventional MR imaging was 30% and 36%, respectively, when compared with surgical findings.

Technical considerations

Standard arthrographic technique is employed during contrast injection. Under fluoroscopy, the needle is directed towards the junction of femoral head and neck using either an anterior or oblique anterior approach. The femoral vessels should be palpated and marked on the skin prior to needle placement. MR imaging should begin as soon as possible following arthrography to limit absorption of contrast. To improve anatomical detail and signal-to-noise ratio, a single hip is imaging using a surface coil (eg. shoulder or cardiac coil) positioned over the femoral head. In addition to standard T1-weighted sagittal and coronal images, oblique sagittal images are prescribed parallel to the femoral neck using a coronal scout. Oblique sagittal images best depict the anterosuperior acetabular labrum, where labral tears and associated cartilage defects usually occur. Oblique sagittal images also show osseous contour abnormalities that characterize cam-type femoroacetabular impingement. T2-weighted axial images best demonstrate intra-articular loose bodies.

Normal MR arthrographic anatomy of the hip

The acetabular labrum shares common histological and morphological features with the glenoid labrum. In both the hip and shoulder, the labrum creates a fibrocartilaginous rim that effectively deepens the socket of the joint and increases its surface area for articulation. Whereas the labrum of the shoulder lines the rim of the entire glenoid fossa, the labrum of the hip terminates inferiorly and merges with the transverse acetabular ligament. This ligament connects the anterior and posterior horns of the acetabular labrum. The normal labrum is attached partially to bone, and partially to hyaline cartilage. Hyaline cartilage merges with the labral fibrocartilage to form a histological union, but it does not extend as far under the acetabular labrum as under the glenoid labrum.

Both the acetabular and glenoid labra show normal variations in size, shape and signal intensity. The anteroinferior portion of the labrum is smaller and thinner than the posterosuperior portion. The acetabular labrum is usually triangular in shape, but can demonstrate rounding or flattening of the free margin. The labral contour is mostly smooth on both conventional and arthrographic MR images, but can show mild irregularities along its junction with articular cartilage. The labrum is typically low in signal intensity on all pulse sequences.

Normal sulci occur at the interface between labrum and articular cartilage. Since labral tears usually occur at this interface, they can be falsely diagnosed when sulci become filled with contrast solution. In the shoulder, the typical locations and appearances of normal sulci have been reported and distinguished from those of true labral tears. In the hip, the incidence of sulci and their usual locations are less well characterized. Small sublabral sulci have been identified arthroscopically and reported at the superior labral-acetabular junction. Currently, there are no proven MR arthrographic criteria in the differentiation of sulcus from true nondisplaced labral tear.

MR arthrographic abnormalities of the hip

Acetabular labral tears have gained recognition as common and clinically important intra-articular lesions that may cause persistent hip pain or disabling mechanical symptoms, and may limit the daily activities of individuals or the competitive performances of athletes. Labral abnormalities were once associated only with major hip trauma (such as posterior dislocation) or chronic degenerative joint disease. The orthopedic literature now emphasizes that symptomatic tearing of the acetabular labrum can result from mild twisting injury, acetabular dysplasia and femoroacetabular impingement. Acetabular labral tear may be associated with micro-instability of the hip.

Labral tear can be a starting point for degenerative joint disease. As the torn labral fragment becomes separated from the acetabular rim, it loses its capacity for cushioning and protecting the adjacent articular cartilage. Loading forces across the joint are no longer distributed evenly over the entire cartilage surface. Repetitive impaction by the femoral head on the acetabulum eventually results in the development of chondral defects and progressive osteoarthritis. Therefore, labral tears and cartilage flaps often occur together. MR arthrography has not proven reliable in the demonstration of small cartilage defects. Possible explanations include the thinness of cartilage in the hip compared to the knee, the close apposition of cartilage surfaces, and the spherical shape of the femoral head resulting in volume averaging between and cartilage and contrast material.

Acetabular and glenoid labral tears share common MR arthrographic features. The most important diagnostic criteria include extension of contrast material into the labrum or into the interface between labrum and hyaline cartilage. The location of tear depends on its etiology. Sports- and FAI-related tears are usually anterior or anterosuperior on the acetabular rim. In patients with acetabular dysplasia or joint degeneration, labral tears are usually lateral (superior) in location. Whereas coronal images best demonstrate superior labral tears, oblique sagittal images best depict anterosuperior labral tears because the images in this plane are orientated perpendicular to the anterosuperior acetabular rim, showing the labrum in cross-section and its relationships to bone, capsule and cartilage.

Acetabular labral tear may lead to the formation of an extra-articular cyst when the tear passes through the capsule, enabling the leak of joint fluid. A labral cyst sometimes can be differentiated from other extra-articular cysts based on location. The iliopsoas bursa, for example, results from a capsular defect between the pubofemoral and iliofemoral ligaments and lies lateral to the iliopsoas tendon, whereas the labral cyst can be more medial in location and contiguous with the acetabular rim. Acetabular labral cysts communicate with the hip joint and can fill with contrast solution following intra-articular injection, similar to the peri-articular cysts that develop in patients with meniscal tears in the knee and glenoid labral tears in the shoulder. They typically measure 1 cm or less in size, but can enlarge to 3-4 centimeters in transverse dimension. When located adjacent to the acetabular rim, an extra-articular cyst can increase diagnostic confidence in the reporting of a nondisplaced tear.

False positive diagnosis may occur whenever a normal sublabral sulcus is mistaken for a true acetabular labral tear. The posterior and anterior acetabular labra can develop normal sulci near their junctions with the transverse ligament, but labral tears are uncommon in these locations. Small sulci involving the superior acetabular labrum can be more difficult to differentiate from non-displaced, trauma-related labral tearing. In this location, diagnostic specificity for tear is greatly increased if the labrum is displaced from the acetabular rim.

Arthrographic MR images may guide the arthroscopist by showing the lengths of labral abnormalities as well as their locations, which can be described in relationship to four acetabular quadrants (anterior, anterosuperior, posterosuperior, and posterior).

Preoperative classification of tears (ie. radial, longitudinal) is not essential since partial acetabular labrectomy remains the treatment of choice regardless of morphology.

Noncalcified and nonossified loose bodies may not be visible on conventional radiographs or CT, but can produce mechanical symptoms such as pain, locking, and decreased range of motion, leading to premature or progressive osteoarthritis. Because of these imaging limitations and because small loose bodies are difficult to visualize in conventional MR, arthrographic MR may be appropriate for locating and quantifying loose bodies. Potential mimickers of loose bodies on MR arthrography include folds of normal synovium, hypertrophic synovium, fatty fronds, and air bubbles. Single-contrast technique is crucial to avoid introduction of air bubbles during the intra-articular injection of contrast. Several key features of air bubbles help distinguish them from loose bodies: anti-dependent location, spherical configuration, absence of signal on all pulse sequences and associated susceptibility artifact.

Osteochondral defects are less common in the hip than the knee, ankle and elbow. Major sequela include detachment and fragmentation, resulting in loose bodies and accelerated osteoarthritis. Stability of the osteochondral fragment is one of the most important determinants in clinical management. Stable fragments are usually managed conservatively, whereas unstable fragments may undergo arthroscopic debridement or internal fixation. Conventional MR imaging confirms instability when an osteochondral fragment is displaced from its donor site, surrounded by fluid, or associated with bone marrow edema. Since joint fluid may not be sufficient to surround a loose fragment, MR arthrography has been used to help in the staging of osteochondral lesions. Contrast material leaks around an unstable or partially detached fragment. Direct MR arthrography may provide additional information about the integrity of overlying cartilage, but cannot be used to determine the vitality of a stable osteochondral fragment. Vitality is determined by vascularity, and therefore requires intravenous administration of gadolinium.

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Beck paper FAI
Cam, mostly male patients
Notzli alpha and beta angles, JBJS 2002

Movies from Anderson

Plain radiography. Crossover sign (Reynolds JBJS-B 1999)