MR Imaging and Ultrasound Correlation of Hip Pathologic Conditions

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KEYWORDS
• Ultrasound • MRI • Hip • Arthroplasty • Athletic pubalgia • Effusion • Bursitis

KEY POINTS
• Magnetic resonance imaging and ultrasound are complimentary.
• Ultrasound can dynamically assess structures and can guide interventional procedures.

INTRA-ARTICULAR EVALUATION

A hip joint effusion is one of the most common signs of pathologic conditions in both the native and prosthetic hip, but what constitutes an effusion in terms of capsular distention is debated.1–4 Koski5 defined capsular distention as 7 mm or more, measuring the distance between the femoral neck and the anterior joint capsule, or a difference of 1 mm between both hips as a joint effusion. Bierma and colleagues4 found a higher correlation with clinical symptoms using the criterion of 1-mm difference in capsular distention between hips. This finding was true even when using the higher measure for joint effusion of 9 mm as defined by Sada and colleagues,6 who found 9 mm was the largest measurement in their study of 110 healthy adults. Sada and colleagues found a mean difference of 0.42 mm between hips in their healthy adult population.

Measurements of effusion in symptomatic hips in children have ranged from 4.7 mm7 to 9.9 mm.8 Tien and colleagues9 measured the synovial recesses of both hips in 748 healthy kindergarten-aged children and found that the measurements differed depending on patient positioning and used a standardized extended hip and knee position. In this position, they found a mean difference in the same child of 0.61 ± 0.52 mm. Because 95% of the differences should be 1.46 mm or less in their study, they concluded that if the difference between hips is greater than 1.46 mm, joint effusion should be highly suspected (Fig. 1).

Tarasevicius and colleagues10 studied 27 patients undergoing arthroplasty measuring from the anterior neck of the femoral component to the anterior wall of the joint capsule. At 6 months in patients who had undergone posterior soft tissue repair, the recess measured 1.695 cm (SD 0.25 cm). In patients who had not undergone posterior soft tissue repair, it measured 1.347 cm (SD 0.30 cm). After 12 months, the median capsular distension was 1.406 cm (SD 0.33 cm) and 1.202 cm (SD 0.36 cm), (P = .11), respectively.

Földes and colleagues11 reported a sensitivity of 92.8% and a specificity of 83.3% for ultrasound in the detection of an effusion following hip arthroplasty in 55 patients, 25 of whom had pain (Fig. 2).

The sonographic evaluation of joint effusion can be confounded by hypoechoic synovial thickening, mimicking an effusion, and by a hyperechoic effusion caused by debris, thus mimicking synovial thickening.12 Although color or power Doppler

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sonography may distinguish actively inflamed synovitis from an effusion, the technique does not work for inactive synovitis.\textsuperscript{12,13}

Beyond the presence of an effusion, ultrasound is limited in its ability to diagnose intra-articular pathologic conditions. Connell and colleagues\textsuperscript{14} reported normal hip sonograms in patients in whom magnetic resonance (MR) imaging revealed degenerative arthrosis, labral abnormalities, and avascular necrosis.

Anecdotally, an advanced degenerative change may be detected sonographically by the presence of subcapital osteophytes or loss of normal femoral head sphericity (Fig. 3). Labral tears may be seen sonographically as a hypoechoic cleft through the echogenic fibrocartilaginous labrum or as detachment of the echogenic labrum from the bone (Fig. 4).\textsuperscript{15} Sofka and colleagues\textsuperscript{15} reported that the intra-articular injection of fluid, as during a cortisone injection, had a sono-arthrographic effect, making labral tears more conspicuous, but the sensitivity and specificity of ultrasound for labral tears have not yet been reported. In a meta-analysis of the literature, Smith and colleagues\textsuperscript{16} found that MR imaging had a sensitivity of 66\% and a specificity of 79\% for labral tears, whereas MR arthrography had a sensitivity of 87\% and specificity of 64\%, with less reader variation in

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**Fig. 1.** Pediatric hip effusion. (A) Coronal fat-suppressed fast spin echo T2-weighted magnetic resonance image of the pelvis shows an effusion of the left hip in a child with left-sided pain. (B) Longitudinal sonographic image of the left hip shows an effusion (asterisk). FN, femoral neck; CFE, capital femoral epiphysis. (C) Longitudinal sonographic image of the right hip in this same patient is negative for effusion.

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**Fig. 2.** Sonographic image of total hip arthroplasty with effusion (E). The width of the effusion is measured at the native femoral neck (FN) (double-headed arrow). The joint capsule (asterisks) is thickened. H, prosthetic head; N, prosthetic neck.

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**Fig. 3.** Degenerative arthrosis. Longitudinal sonographic image shows an osteophyte (arrow) and loss of sphericity of the femoral head (H). N, femoral neck.
the sensitivity and specificity of the MR arthrography studies.\textsuperscript{16}

Perilabral cysts are seen sonographically as well-defined anechoic collections adjacent to the labrum, and on MR imaging they are seen as focal T2 hyperintense lesions (Fig. 5). Currently there is a lack of data on the sensitivity and specificity of both ultrasound and MR imaging for the diagnosis of labral cysts.

In addition to the usual disadvantages of MR imaging, such as time and cost, the prosthetic hip has the added disadvantage of artifact arising from the metal. Although advances in MR imaging have made the evaluation of the prosthetic hip possible, some artifact does remain and not all centers have access to these advanced sequences. Although sonography is not hampered by a prosthesis, the modality does not allow for a global assessment of the region and cannot penetrate bone. Osteolysis is difficult to image on ultrasound until it is very advanced.\textsuperscript{17} MR imaging has been shown to be the most sensitive modality for the detection of osteolysis, with a sensitivity of 95% in cadaveric studies.\textsuperscript{18}

Sonography can guide therapeutic injections and diagnostic aspirations of the hip joint (Fig. 6). Smith and colleagues\textsuperscript{19} compared the accuracy of ultrasound-guided hip injection to that of fluoroscopic injection and found that, in 29 of 30 patients, the needle was placed accurately using ultrasound.

**BURSITIS AND EXTRACAPSULAR FLUID COLLECTIONS**

There are 3 major bursae about the hip: the greater trochanteric bursa, the iliopsoas bursa, and the ischial bursa. The greater trochanteric bursa, also called the subgluteus maximus bursa, is located immediately posterior to the posterior facet of the greater trochanter, the lateral insertion of the gluteus medius tendon, and the proximal part of the vastus lateralis.\textsuperscript{20} The iliopsoas bursa is the largest bursa in the body.\textsuperscript{21} It lies between the joint capsule and the medial tendinous portion of the iliacus muscle and extends from the level of the inguinal ligament to just above the lesser tuberosity. Under normal circumstances, it communicates with

![Fig. 4. Acetabular labral tear. (A) Sagittal proton density–weighted MR image shows a high-signal-intensity tear (arrow) through the low-signal-intensity labrum. (B) Longitudinal sonographic image in the same patient shows the hypoechoic tear (arrow) through the echogenic labrum.](image)

![Fig. 5. Perilabral cyst. (A) Axial fat-suppressed T2-weighted MR image shows a bilobed cyst (arrow). (B) Transverse sonographic image of the same patient shows the anechoic bilobed cyst (thin arrows). The labral tear (thick arrow) is better appreciated on this image than the MR image. H, femoral head.](image)
the hip in 15% of the population. The ischial bursa lies deep to the inferior portion of the gluteus maximus muscle and posteroinferiorly to the ischial tuberosity.

In the native hip, bursitis is most often mechanical, although it can occur secondary to infection or arthritis. Trochanteric bursitis is thought to most often occur because of friction during hip flexion and extension. It is most commonly seen in the elderly but can also be seen in athletes and overuse. Ischial bursitis occurs most often from direct trauma but can also occur from prolonged sitting, particularly if there is vibration associated with sitting such as is seen in tractor or machinery operators. Iliopsoas bursitis is most commonly seen in overuse syndromes that require hip flexion, such as in athletes, particularly in uphill runners, or in occupational overuse from heavy lifting. It can also occur in inflammatory arthropathies, such as rheumatoid or from impingement at the hip joint by osteophytes.

In the prosthetic hip, iliopsoas bursitis can be seen in the setting of friction of the tendon over a prominent acetabular cup or decompression from the joint in adverse tissue reactions (Fig. 7). Trochanteric bursitis in the postoperative hip is uncommon but can occur from mechanical causes, such as if the biomechanics of gait are changed, or as an extension of an intra-articular process, such as infection, particle disease, or adverse local tissue reaction (Fig. 8).

Bursitis is seen as a hypoechoic collection on ultrasound and a high signal fluid collection on T2-weighted MR imaging sequences. Septations may be present, and the distended bursa is usually compressible with ultrasound. Other extracapsular collections about the hip, such as abscesses, seromas, hematomas, or adverse local tissue reaction, may have a variable appearance on sonography depending on the amount of debris, organization, wall thickening, or inflammation.

Wunderbaldinger and colleagues found that...
computed tomography, MR imaging, and ultrasound were all equally capable of depicting iliopsoas bursitis, with MR imaging having the slight advantage that the communication of the bursitis with the hip can be demonstrated. With its large field of view, MR imaging may encompass a large bursa better and demonstrate its relationship to the joint, whereas ultrasound has the advantage of providing guidance for treatment with aspiration or steroid injection. Sonographic extended field of view can also be helpful for demonstrating the extent of a collection and its relation to the joint (Fig. 9).

**FRACTURES**

In the skeletally immature pelvis, avulsions of the apophyses of the anterior superior iliac spine, anterior inferior iliac spine, and ischium may occur because of sudden strong contraction of the sartorius muscle, the direct head of the rectus femoris muscle, or the hamstring muscles, respectively, such as in running, kicking, and hurdling. Pisacano and Miller reported acute avulsions of the anterior superior and inferior iliac spines in 4 teenaged boys demonstrated equally well on MR imaging and sonography. On MR imaging, the injury appears as high signal intensity on T2-weighted images in the widened space between the avulsed apophysis and pelvis, with feathery high signal intensity edema and hemorrhage in the avulsed muscle and surrounding soft tissue, whereas on sonography, the avulsed apophysis is echogenic with posterior acoustic shadowing and is displaced from the underlying pelvis, with anechoic edema and hemorrhage in the gap.

**TENDON INJURY**

Tendinopathy can occur from degeneration of the tendon from overuse or aging and by impingement by an external structure. In the case of impingement, ultrasound has an advantage because dynamic imaging can be performed during the provocative motion.

Tendons are comprised of linear, well-organized bundles of collagen, resulting in the normal ultrasound appearance of an echogenic fibrillar...
structure. On MR imaging, the appearance is uniformly low signal intensity on T1- and T2-weighted imaging. As the tendon becomes diseased, it loses its well-organized structure and becomes hypoechoic on ultrasound\textsuperscript{31} and hyper-intense on fluid-sensitive MR imaging.\textsuperscript{32} The tendon may appear thickened, although the abnormal echogenicity or signal of the tendon is a more reliable sign of pathologic conditions than an absolute measurement of diameter.\textsuperscript{31}

An important mimic of tendon pathologic conditions on ultrasound is anisotropy. If the linear transducer is not perpendicular to the collagen fibers, they will artificually appear hypoechoic. This appearance can be corrected in a normal tendon by changing the transducer position; a truly diseased tendon cannot be made to look normal.

Although less common than in other locations, such as the shoulder, calcific tendinosis can occur in the tendons of the hip.\textsuperscript{33} Sonographically, its appearance is that of hyperechoic shadowing foci within the tendon.\textsuperscript{14} The MR imaging appearance is that of a thickened tendon with foci of low signal intensity on all sequences.\textsuperscript{32}

Pathologic conditions of the hip abductors is more common in older patients, particularly elderly women. An analogy has been made between the gluteus medius and minimus tendons, which are abductors of the hip, and the supraspinatus and infraspinatus tendons, which assist in abduction of the shoulder; thus, the gluteus medius and minimus have been termed the rotator cuff of the hip.\textsuperscript{34} Similar to the tendons of the rotator cuff, the gluteus medius and minimus tendons are subject to tendinosis, partial tear, and full-thickness tear, and the greater trochanteric bursa may become inflamed. Peritendinous injection of the gluteal tendons with steroid can be performed as can fenestration with or without injection of plasma-rich protein (PRP) or autologous blood.

Tendinosis and tear of the hip abductors can occur following hip arthroplasty, particularly with the transgluteal approach.\textsuperscript{35} As in the native hip, tendinosis may appear as a hypoechoic thickened tendon on ultrasound. Attrition of the tendon may be seen indicating a tear, and fluid-filled hypoechoic gaps can be seen on ultrasound. On T2- or proton density–weighted MR imaging, tendinosis appears as increased signal intensity within the normally low-signal-intensity tendon and may be accompanied by partial-thickness or full-thickness tears with high-signal fluid-filled gaps (Fig. 10).\textsuperscript{32}

Tendinosis of the gluteal tendons has been described as part of the “greater trochanteric pain syndrome,” which is characterized by pain and focal tenderness in the region of the greater trochanter, exacerbated with weight bearing and hip abduction.\textsuperscript{36} In a review of the literature, Westacott and colleagues\textsuperscript{36} found that in the setting of greater trochanteric pain syndrome in the native hip, MR imaging had sensitivity of 33% to 100%, specificity of 92% to 100%, positive predictive value of 71% to 100%, and negative predictive value of 50%, whereas ultrasonography had a sensitivity of 79% to 100% and positive predictive value of 95% to 100% for diagnosing gluteus medius and minimus tears.

Hamstring injuries often occur in sports that involve sprinting, hurdling, and jumping; the biceps femoris is the most commonly injured tendon.\textsuperscript{37} In the acute setting, in thin patients, ultrasound is as sensitive as MR imaging in the diagnosis hamstring pathologic conditions (Fig. 11).\textsuperscript{37} However, hamstring injuries can be difficult to identify on ultrasound in heavier patients.

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**Fig. 10.** Gluteus minimus tendinosis. (A) Coronal fat-suppressed T2-weighted MR image shows a thickened and heterogeneous gluteus minimus tendon (white arrow) with a focal insertional tear (black arrow) and high-signal-intensity shallow tearing along its deep surface. (B) Longitudinal sonographic image in the same patient shows the thickened tendon (arrows) with loss of the normal echogenic fibrillar appearance. G, greater trochanter.
because of the deep location of the ischial tuberosity. In a review of their experience using MR imaging and sonography to evaluate acute hamstring injuries, Koulouris and Connell found that MR imaging correctly identified avulsion from the ischium in 16 out of 16 cases, whereas sonography only diagnosed 7 out of 12 cases. Percutaneous fenestration of the tendon with or without the use of PRP or autologous blood can also be performed to stimulate healing.

Iliopsoas pathologic conditions can occur in the young and old. Tendinopathy in athletes occurs in sports that involve kicking. Partial tears are more common in acute athletic injuries or falls. Complete tears are more common in the elderly or those with chronic conditions, such as rheumatoid arthritis or diabetes. In the case of arthroplasty, iliopsoas tendinosis and impingement can occur because of chronic friction against the cup. In these cases, the iliopsoas tendon is commonly seen displaced medially and anteriorly (Fig. 12). Rezig and colleagues found that ultrasound could detect the exact site of impingement and the injury to the iliopsoas tendon and muscle, but in many patients no source of impingement can be identified.

Ultrasound-guided peritendinous injection of the iliopsoas tendon with steroids can be performed in the prosthetic and native hip. Adler and colleagues reported that 10 out of 11 patients with arthroplasty and iliopsoas pathologic conditions had immediate relief with peritendinous injection of steroid and cortisone, with 9 out of 11 having at least partial improvement at 1 year; they also reported that 18 out of 28 patients with native hips diagnosed with iliopsoas tendinopathy experienced relief after injection.

Adductor muscle injuries are most often encountered in soccer and hockey players and are a common cause of groin pain in these sports.
athletes. The abnormality may occur at the origin on the pubic symphysis and is included in the spectrum of athletic pubalgia discussed later in this article. It may also occur at the musculotendinous junction or at the distal insertion on the femur (called thigh splints). In addition to the general appearances of tendon injury, MR imaging may demonstrate high-signal-intensity edema and hematoma in the muscle or marrow edema at the enthesis and periosteal reaction, whereas sonography may demonstrate hypoechoic acute hematoma (Fig. 13) and cortical irregularity and hyperemia with color or power Doppler in tendon injury.

The snapping hip syndrome refers to a sudden snapping sensation during hip motion and can be attributable to intra-articular or extra-articular causes. Intra-articular causes include loose bodies (from trauma, degenerative arthritis, or synovial osteochondromatosis), labral tears, and femoroacetabular maltracking, whereas extra-articular causes are attributable to abnormal motion of tendons. As discussed earlier, MR imaging is more sensitive in the detection of intra-articular pathologic conditions.

The extra-articular causes can be further classified as lateral (also called external) snapping attributable to abnormal motion of the iliotibial band or gluteus maximus over the greater trochanter and as medial (also called internal) snapping attributable to abnormal motion of the iliopsoas tendon over the iliopsoicneal eminence of the pelvis, over the anterior inferior iliac spine, or even over the lesser trochanter. Teenagers and young adults are typically affected and may not have any predisposing occupational or athletic activity, although 4 out of the 8 patients with a snapping iliopsoas tendon reported by Janzen and colleagues had a preceding traumatic event of hip abduction and external rotation. Regardless of a medial or lateral cause, the snapping may or may not be painful. Moreover, even patients without demonstrable snapping or visible abnormality of the iliopsoas tendon may get relief from anesthetic and steroid injections.

On static imaging using sonography or MR imaging, the offending tendon most often looks normal, although tendinosis, peritendinous fluid, and iliopsoas bursitis have occasionally been described with both modalities. The advantage of sonography is that it can dynamically evaluate a snap or sudden jerk of the tendon. Wunderbaldinger and colleagues reported that the diagnosis could be made using radiographs and sonography in 83% of the cases. Out of 54 patients, 20 patients were diagnosed with osteoarthritis as the cause of the snapping hip on plain radiographs. The remaining 34 patients then received ultrasound examinations, and the diagnosis of tendon or bursal anomalies was made in 25 patients. Wunderbaldinger and colleagues concluded that MR imaging could be reserved for cases in which ultrasound and plain radiographs did not reveal a diagnosis.

**ATHLETIC PUBALGIA**

The so-called *sports hernia* or *sportsman’s hernia* is not a true hernia because there is no actual herniation of tissue; the misnomer arose because it was initially applied clinically to athletes with groin pain. The preferred term is now athletic pubalgia. The pain of athletic pubalgia is absent at rest, is elicited by exertional activity (especially sudden twisting movements), and may radiate into the thigh or testicles. The diagnosis can be elusive clinically, and the exact pathoanatomy of athletic pubalgia is still being debated. It has been described as a weakness of the posterior wall of the inguinal canal, of either the transversalis fascia or external oblique muscle aponeurosis. Others have proposed that a sports hernia is actually a group of musculoskeletal processes that share similar mechanisms of injury and common clinical manifestations, with the most common

![Fig. 13. Adductor hematoma. (A) Axial proton density-weighted MR image shows a large hematoma (asterisk) in the left adductor muscles. (B) Transverse sonographic image in the same patient shows the hypoechoic hematoma (asterisk).](image-url)
injury involving the common aponeurosis of the rectus abdominis and adductor longus tendons, which are located along the anterior aspect of the pubic symphysis. As proposed by Omar and colleagues, the lesion can extend through the aponeurosis into both the rectus abdominis and the adductor longus. The lesion can cause disruption of the common aponeurosis of the rectus abdominis–adductor longus at its pubic attachment or extend into the adductor tendon origins. In severe injury, complete avulsion can be seen.

In imaging an aponeurosis injury, MR imaging has been the most widely used modality. Findings of aponeurosis injury include edema limited to the anteroinferior pubic ramus and the secondary cleft sign. The primary cleft is that of the pubic symphysis itself, whereas the secondary cleft is a linear high-signal tear in the origin of the adductor longus and gracilis tendons. In their study of 100 soccer players with groin pain in whom 97 the pain was attributed to pubic symphysis pathologic conditions, Cunningham and colleagues found bone marrow edema in 91 patients and a secondary cleft sign in 88. None of the control patients had these findings. Herniation of the fibrocartilaginous disk was found in an equal number of control and affected patients. Frank disruption of the aponeurosis can be seen at the pubic attachment, best appreciated on sagittal images, and has the same appearance as any tendon disruption. Edema or atrophy of the rectus abdominis can also indicate an acute or chronic aponeurosis injury, respectively. Ultrasound of the adductor muscles can be difficult because of their deep location and oblique course. Sonopalpation may be helpful in identifying the site of pain. Sonography can demonstrate the common aponeurosis of the rectus abdominis and adductor longus muscles and can visualize tears as linear hypoechoic foci (Fig. 14). Ultrasound may also demonstrate tendon thickening, hyperemia, and neovascularity and can demonstrate traction spurs of the attachment and osteophytes of the symphysis pubis.

Osteitis pubis is an advanced stage of athletic pubalgia. Although radiographs eventually demonstrate sclerosis, irregularity, and erosions of the pubis and widening of the symphysis, MR imaging and sonography may demonstrate abnormalities sooner, such as fluid in the symphysis and marrow edema in the pubis on MR imaging and distention of the symphysis by effusion, thickening of the joint capsule, and irregularity of the pubis on sonography. In osteitis pubis, the bone marrow edema extends across the anterior posterior dimension of the pubic symphysis, whereas it is confined to the anterior subcortical bone in athletic pubalgia. Additional findings in osteitis pubis include a joint effusion and extensive soft tissue edema, which, in contrast to athletic pubalgia, is symmetric. The secondary cleft sign has also been described in osteitis pubis, suggesting that the cleft sign is an early indicator of symptomatic shear stress injury of the symphysis.

Zoga and colleagues showed MR imaging to have a sensitivity of 68% and a specificity of

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**Fig. 14. Athletic pubalgia.** (A) Axial proton density–weighted MR image shows a thickened and hyperintense rectus abdominis aponeurosis (thin arrow) and extensive cortical erosion (thick arrow) of the anterior aspect of the right superior pubic ramus. Note also the sclerosis of the right superior pubic ramus and the cystic change in the anterior aspect of the left superior pubic ramus. (B) Transverse sonographic image in a different patient during a cortisone injection shows a thickened rectus abdominis aponeurosis (black arrow) with a horizontal tear (secondary cleft sign) (thin solid white arrows). Note the cortical erosion (thick solid white arrow) of the anterior aspect of the right superior pubic ramus and the cortical irregularity of the anterior aspect of the left superior pubic ramus. The reverberation artifact from the needle is present (hollow white arrow).
100% for rectus abdominis tendon injury and a sensitivity of 86% and specificity of 89% for adductor tendon injury.68 Kalebo and colleagues50 examined 36 patients with groin pain and were able to make diagnoses of various tendon tears, including rectus abdominis and adductor tears in 28 patients using ultrasound in comparison with the normal side. The sensitivity and specificity of ultrasound in the diagnosis of adductor and rectus abdominis tears and athletic pubalgia has not been reported. Sonography can guide cortisone injection of the pubic symphysis.

For those who think a weakness of the transversalis fascia is responsible for athletic pubalgia groin pain, dynamic sonography of the inguinal ring is the procedure of choice, demonstrating convex anterior bowing of the transversalis fascia and ballooning of the inguinal canal during the Valsalva maneuver.48,69 The reported MR imaging diagnosis of this entity has had variable results. Albers and colleagues65 found attenuation of the diagnosis of this entity has had variable results.

They most commonly occur in female long-distance and marathon runners66 and military recruits, perhaps related to too long of a stride,70 and more often affect the inferior pubic ramus.71 They are manifested on MR imaging as marrow edema, with or without a discrete fracture line or adjacent soft tissue edema.66 Sonography of this injury has not been reported; the inferior pubic ramus can be difficult to visualize sonographically in its entirety.

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