MR Arthrography Update

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MR arthrography has emerged as an important technique in the assessment of selected musculoskeletal disorders. A plethora of studies have assessed this technique for the evaluation of shoulder, knee, wrist, elbow, ankle, and hip pathology. The most widespread technique, direct MR arthrography utilizing dilute gadolinium contrast agent, has the obvious disadvantages of increased costs, invasiveness, and inconvenience. The advantages of this technique include: consistent joint distention with contrast medium; markedly improved delineation of key intra-articular structures and consequently improved detection of surgically correctable pathology; more invasive and expensive procedures such as diagnostic arthroscopy maybe obviated; and there are no direct contrast costs. Gadolinium contrast agents, however, have not been approved for intra-articular injection by the Food and Drug Administration. Intra-articular administration of gadolinium contrast agents, therefore, represents an unapproved use of an approved drug. Intra-articular administration of gadolinium contrast agents is currently considered safe and FDA approval is not required for use on an individual patient. Future contrast agents for MR arthrography may incorporate paramagnetic contrast agents entrapped in liposomes to prevent diffusion into articular cartilage. Intraarticular injection of these liposome-entrapped contrast agents may improve the detection of early osteoarthritic cartilage changes.

THE SHOULDER

The shoulder is the joint most often evaluated by MR arthrography. Techniques for MR arthrography of the shoulder can be characterized as direct and indirect. Direct MR arthrography techniques involve intra-articular injection of either dilute gadolinium contrast agent followed by a fat suppressed T1 weighted imaging or intra-articular injection of normal saline followed by intermediate and T2 weight spin echo imaging. An easy method for constituting the dilute gadolinium contrast agent employs 0.1 ml standard gadolinium contrast agent administered from a tuberculin syringe into a standard 20 ml vile of sterile saline. Approximately 15 ml dilute gadolinium contrast agent is intra-articularly injected using fluoroscopic guidance after confirming intra-articular needle placement by injecting a drop of iodinated contrast. The patient´s arm and shoulder are placed through the full range of motion, and the patient is returned to the MRI unit where post-injection images are obtained. Direct MR arthrography of the shoulder may tolerate imaging delays of 1 hour following injection of the shoulder. Frequency-selective fat saturation is of benefit on the T1 weighted images because the signal intensity of fat is decreased while the signal intensity of the dilute gadolinium contrast agent remains high. Non-fat-suppressed images show high signal in the subacromial-subdeltoid fat plane, which can be confused with dilute gadolinium contrast agent in the subacromial-subdeltoid bursa, leading to a false-positive diagnosis of a full-thickness rotator cuff tear. Direct gadolinium MR arthrography has certain advantages compared with direct saline MR arthrography. First of all, the image quality and signal-to-noise ratio of T1 weighted images is superior to that of the T2 weighted images utilized for the saline MR arthrogram. Secondly, in the shoulder, injected saline has signal characteristics identical to effusion within the subacromial-subdeltoid bursa. In other words, fluid that is confined to the subacromial-subdeltoid bursa in a patient with bursitis has the same appearance as saline that has leaked from the glenohumeral joint in a patient with a full-thickness rotator cuff tear. Following saline MR arthrography, therefore, there are no specific diagnostic criteria for differentiating partial- from full-thickness tears of the rotator cuff.

Several investigators are currently exploring the role of indirect arthrography for the diagnosis of rotator cuff and labral abnormalities. This technique involves a standard intravenous dose of gadolinium contrast agent followed by ten minutes of exercise of the involved shoulder. T1 weight spin echo images are then obtained in all three routine planes using frequency-selected fat saturation. A T2 weighted fast spin echo sequence with fat suppression is also obtained in the oblique coronal plane to assess the bone marrow and extra-articular soft tissues. Winalski et al. were able to produce an arthrographic effect of contrast enhancement of joint effusion in the knee fifteen minutes after intravenous gadolinium administration, and this effect persisted for up to one hour. There is potential for this technique to outline and show tears of the rotator cuff and labrum that may be difficult to identify on conventional MR images. This technique is also less invasive and less cumbersome than the direct arthrography technique, however, there is the additional cost of the dose of gadolinium contrast agent. Also, with indirect MR arthrography, there is no control over joint distention. The usefulness of this method needs to be more completely evaluated.

The major contribution of MR arthrography in the shoulder is the demonstration of the glenoid labrum and glenohumeral ligaments in patients with suspected glenohumeral instability. It is now well documented that conventional MRI has yielded disappointing or inconsistent results in the evaluation of shoulder instability. Anterior labral lesions have been diagnosed with sensitivities from 44-95% and specificities ranging from 67-86%. Unless a joint effusion is present, the glenohumeral ligaments and labrum cannot be accurately assessed. Studies with MR arthrography, however, report accurate diagnosis of labral and glenohumeral ligament abnormalities with sensitivities and specificities ranging from 90-95%. MR arthrography is also helpful in the evaluation of the superior labrum and labral-bicipital anchor. The diagnosis and characterization of SLAP lesions is more reliably made with MR arthrography.

A major benefit of MR arthrography is direct visualization of the primary passive stabilizer preventing anterior instability in the shoulder, the inferior glenohumeral ligamentous-labral complex. Arthrographic MR abnormalities of the inferior glenohumeral ligament and especially its labral attachment site correlate closely with anterior instability. Specifically, if a torn labral segment extends into the attachment of the anterior band of the inferior glenohumeral ligament, there is a high likelihood of anterior shoulder instability.

MR arthrography can also be a valuable tool in the evaluation of rotator cuff pathology. It has been well shown that MR arthrography is more sensitive and specific than conventional MRI for the diagnosis of partial thickness tears involving the under surface of the rotator cuff. MR arthrography can also improve the accuracy for distinguishing partial thickness tears from full thickness tears. Arthrographic MR images also show anatomical features that are useful in the prediction of cuff reparability and post-operative prognosis. This includes depiction of the location and size of the cuff tear, the degree of tendon retraction, and the quality of the remaining tendon tissue as indicated by the presence of imbibition. Tendons that imbibe contrast material are swollen and friable at surgery. They typically require debridement to expose suitable tissue for suturing, increasing the technical difficulty of the procedure and decreasing the prognosis for operative success. Finally, MR arthrography may be helpful in the assessment of the post-operative rotator cuff for recurrent tear. There appear to be no useful MR

arthrographic signs of adhesive capsulitis, however.

Published studies demonstrate that specialized positioning of the shoulder during MR arthrography may facilitate evaluation of certain specific shoulder disorders. For example, oblique axial images of the glenohumeral joint can be obtained with the patient's palm resting under his/her head, resulting in the so-called dislocation position of abduction and external rotation (ABER). This position places traction on the inferior glenohumeral ligament-labral complex and may cause distraction of an otherwise unrecognized tear involving the insertion of the anterior band of the inferior glenohumeral ligament on the anterior-inferior labrum, that is, a Bankart lesion. This position has also been shown to be of value in the evaluation of patients with posterosuperior glenoid impingement and patients with partial thickness tears of the humeral surface of the rotator cuff.

THE KNEE

For direct arthrography of the knee, 1 ml of gadolinium contrast agent is diluted in a 250 ml normal saline IV bag. A 21 gauge needle is inserted into the patellofemoral joint via the lateral approach with the patient on the MR table. No fluoroscopic guidance is necessary. Any knee effusion present is aspirated first. 40-50 ml of the dilute gadolinium contrast agent is than injected intra-articularly. Direct MR arthrography of the knee may tolerate imaging delays of 3.5 hours following injection of the knee. T1 weighted images are than obtained in the coronal, sagittal, and axial planes utilizing frequency-selective fat suppression. A T2 weighted fast spin echo sequence is also obtained in the coronal plane utilizing frequency-selective fat suppression. Indirect MR arthrography of the knee consists of a standard intravenous dose of gadolinium contrast agent. The knee is than exercised for fifteen minutes by placing the patient on an exercise bicycle. The patient is than returned to the MRI suite where the same pulse sequences are utilized as for direct MR arthrography. In the absence of a significant knee effusion, there is generally suboptimal distention of the joint utilizing the indirect arthrography technique.

Until recently, the standard treatment for most symptomatic meniscal tears was partial or complete meniscectomy. Currently, however, meniscal preservation and arthroscopic repair are the standard of practice. The detection of residual or recurrent meniscal tear following prior meniscectomy or meniscal repair is difficult with conventional MRI due to the varied appearance of the post-surgical meniscus. In fact, grade 3 meniscal signal alteration may persist on MR imaging despite complete healing of a resected or repaired meniscus. Applegate et al. compared direct MR arthrography and conventional MRI with follow-up arthroscopic surgical results in patients who had previously had either a meniscal repair or a resection. The overall accuracy in diagnosing recurrent meniscal tears in the post-operative meniscus was 66% with conventional MR imaging and 88% with direct MR arthrography. Specifically, MR arthrography was substantially more accurate than conventional imaging when more than 25% of the meniscus had been resected. The contrast material within the joint coats the meniscal remnant or repaired meniscus allowing it to be reliably delineated from adjacent cartilage, granulation tissue, or scar tissue. Elevated intra-articular pressure also drives the contrast material into meniscal remnants that are torn reliably distinguishing them from healed meniscal repairs that can produce confusing signal intensity changes on conventional MR imaging.

THE WRIST

As with the knee, direct gadolinium MR arthrography of the wrist can easily be performed on the MR table without fluoroscopic guidance. A 25 gage needle is introduced into the radiocarpal joint space via a standard dorsal approach. Gadolinium contrast agent dilution is performed as with direct MR arthrography of the shoulder. 2-4 ml of the dilute gadolinium contrast agent is then intra-articularly injected. The wrist is then imaged utilizing a dedicated quadrature wrist coil with a FOV of 8-10 cm. T1 weighted images are then obtained in the coronal plane with and without frequency-selective fat suppression. A 3D spoiled gradient recalled sequence is then obtained in the coronal plane which later allows multi-planar reconstructions. A T2 weighted fast spin echo image utilizing frequency-selective fat suppression is also obtained for evaluation of the bone marrow and extra-articular soft tissues.

Evidence suggests that direct MR arthrography of the wrist is more reliable than conventional MR imaging for the evaluation of the triangular fibrocartilage complex (TFCC) and the scapholunate and lunotriquetral ligaments. Scheck et al. compared conventional MR imaging and direct gadolinium MR arthrography in patients with chronic wrist pain. Wrist arthroscopy was utilized as the gold standard. The accuracy of MR arthrography was significantly higher than with conventional MRI for the evaluation of the TFCC, the scapholunate and lunotriquetral ligaments.

Indirect MR arthrography of the wrist has also been shown to be a non-invasive method with a high sensitivity in the evaluation of TFCC lesions. Herold et al compared indirect MR arthrography of the wrist with arthroscopy in the detection and characterization of pathology involving the TFCC. For indirect MR arthrography detection of TFCC lesions the sensitivity was 100%, the specificity was 77% and the accuracy was 93%. For the evaluation of the scapholunate ligament, the sensitivity was 88%, the specificity was 95% and the accuracy was 93%.

THE ELBOW

The technique for direct MR arthrography of the elbow consists of placement of a 23 gage butterfly needle into the medial joint space utilizing fluoroscopic guidance. The gadolinium contrast agent is diluted utilizing the same technique as for direct MR arthrography of the shoulder. Approximately 10 ml of the dilute gadolinium contrast agent is intra-articularly injected after confirming intra-articular needle placement by injecting a drop of iodinated contrast. The patient is then returned to the MRI suite where T1 weighted images are obtained in the coronal, sagittal, and axial planes utilizing frequency-selective fat suppression. A T2 weighted fast spin echo image in the coronal plane is also obtained utilizing frequency-selective fat suppression for evaluation of the bone marrow and extra-articular soft tissues.

Very few studies have been published documenting the utility of MR arthrography in the elbow. Schwartz et al. evaluated a series of college-level and professional throwing athletes utilizing direct saline MR arthrography of the injured elbow. Direct MR arthrography demonstrated an accuracy of 95% for diagnosing complete ulnar collateral ligament tears and 86% for diagnosing partial ulnar collateral ligament tears. Diagnosis of partial tears in the throwing athlete is critical because these individuals will undergo surgical reconstruction of the ulnar collateral

ligament.

Cotten et al demonstrated in cadavers that the collateral ligaments are accurately assessed utilizing either a 20° posterior oblique coronal plane with the elbow fully extended or the coronal plane aligned with the humeral shaft with the elbow flexed 20-30°. MR arthrography improved the delineation of normal and abnormal collateral ligaments in each case.

THE ANKLE

For direct MR arthrography of the ankle, a 23 gage needle is inserted into the ankle joint medial to the tendon of the extensor hallucis longus muscle utilizing fluoroscopic guidance. The gadolinium contrast agent is diluted using the same technique as for direct MR arthrography of the shoulder. Up to 12 ml of the dilute gadolinium contrast agent is than intra-articularly injected after confirming intra-articular needle placement by injecting a drop of iodinated contrast. The patient is then returned to the MRI suite where T1 weighted images are obtained in the axial, sagittal, and coronal plane utilizing frequency-selective fat suppression. A T2 weighted fast spin echo image is also obtained in the axial plane utilizing frequency-selective fat suppression for evaluation of the bone marrow and extra-articular soft tissues.

Inversion injuries of the ankle are the most common sports medicine injury in the United States, accounting for 25,000 visits to the emergency room each day. While most of these inversion injuries heal uneventfully, 10-20% of patients may experience chronic lateral instability of the ankle. This instability is the result of disruption of the lateral collateral ligament. Chandnani et al. demonstrated that direct MR arthrography of the ankle is more sensitive than stress radiography and conventional MR for the detection of lateral collateral ligament tears in the context of chronic ankle instability. MR arthrographic signs of ligament disruption are based on leakage of gadolinium contrast: anterior to the anterior talofibular ligament following disruption of that ligament; into the common peroneal tendon sheath or lateral to the ligament with calcaneofibular ligament disruption; and posterior to the ligament with posterior talofibular ligament disruption. Utilizing these signs, direct MR arthrography was over 90% sensitive for demonstration of lateral collateral ligament disruption.

Over 50 surgical procedures have been described for reconstructing ankle ligaments in the setting of chronic instability. Proper operative treatment planning is facilitated when the presence and extent of ligament injury is well documented. Documentation of the peroneal tendon integrity is also important pre-operatively since tendon transfer is often utilized for treatment of chronic ankle instability.

MR arthrography has also been shown to accurately assess the anterolateral recess of the ankle in patients with chronic ankle pain. Robinson et al demonstrated that MR arthrography assessment of the anterolateral soft tissues had an accuracy of 97%, sensitivity of 96% and specificity of 100%. The accuracy was 100% for the diagnosis of anterolateral impingement.

THE HIP

Direct MR arthrography of the hip also utilizes the same dilution of gadolinium contrast agent as for direct MR arthrography of the shoulder. A 20 gage spinal needle is introduced into the hip joint via the anterior approach utilizing fluoroscopic guidance. Intra-articular positioning of the needle is confirmed with a drop of iodinated contrast material. Approximately 15 ml of the dilute gadolinium contrast agent is then intra-articularly injected. Direct MR arthrography of the hip may tolerate imaging delays of 2 hours following injection of the hip.The patient is then returned to the MRI suite where T1 weighted pulse sequences are performed in the axial, sagittal, and coronal plane utilizing frequency-selective fat suppression. A coronal T2 weighted fast spin echo sequence is also obtained utilizing frequency-selective fat suppression for evaluation of the bone marrow and extra-articular soft tissues.

Acetabular labral tears are increasingly recognized as a cause of intra-articular hip pain. In addition to hip pain, affected patients typically present with decreased range of motion and clicking. These tears can be idiopathic or occur secondary to trauma, athletic activities, or hip dysplasia. Diagnosis of an acetabular labral abnormality, however, has been difficult both clinically and with conventional radiographic techniques. Hip arthroscopy has recently become the standard for establishing this diagnosis; however, this technique is not widely available and it is both relatively expensive and invasive. Early recognition and surgical resection of acetabular labral tears can result in substantial pain relief and may prevent development of degenerative joint disease.

Several studies have demonstrated that the acetabular labrum and intra-articular structures are well seen on direct MR arthrography. On T1 weighted images the normal acetabular labrum is a triangular low signal intensity structure attached to the osseous rim of the acetabulum. The joint capsule inserts at the labral base anteriorly and posteriorly while it inserts several millimeters above the labrum superiorly. There is a normal recess between the labrum and capsule that is lined with synovium and fills with contrast material. On MR arthrography, criteria for labral tears include: absence of the labrum; intra-substance contrast; labral blunting; or irregularity of the labral margins. Frank labral detachments are characterized by the presence of contrast material tracking along the labral-acetabular junction. One must be careful to distinguish a labral detachment from a normal variant sub-labral sulcus.

In summary, preliminary studies suggest that direct MR arthrography enables accurate diagnosis and staging of lesions of the acetabular labrum. This examination may be indicated in the assessment of chronic hip pain in patients with a strong suspicion labral pathology.

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