Acetabular Labral Tears and Cartilage Lesions of the Hip: Indirect MR Arthrographic Correlation With Arthroscopy—A Preliminary Study

Michael B. Zlatkin[1]
Deborah Pevsner[1,2]
Timothy G. Sanders[1]
Chris R. Hancock[1,2]
Cesar E. Ceballos[3]
Mauricio F. Herrera[4]

OBJECTIVE. The purpose of this study was to assess the diagnostic correlation between indirect MR arthrography, conventional MRI, and arthroscopy in acetabular labral and cartilage lesions of the hip.

MATERIALS AND METHODS. Fourteen patients who underwent conventional and indirect MR arthrography with arthroscopic correlation were studied over the course of 18 months. MR studies were performed on a 1.5-T magnet. Sequences consisted of unilateral sagittal turbo spin-echo proton density fat-suppressed, axial turbo spin-echo T2 fat-saturated, and coronal turbo spin-echo proton density fat-saturated images. Whole-pelvis coronal T1 and STIR sequences were also performed. Patients received IV gadolinium contrast material and exercised for 15 minutes. Gadolinium-enhanced fat-saturated T1 sequences were obtained in three planes. Arthroscopy was performed by two orthopedic surgeons who specialize in treating hip disorders. Cases were then retrospectively reviewed by two experienced musculoskeletal radiologists who were blinded to the arthroscopic findings. Cases were examined for acetabular labral tears and chondral lesions. Extraarticular findings of femoral acetabular impingement were recorded. Unenhanced and gadolinium-enhanced images of the labrum were compared for differences and changes in diagnosis. Comparison was made between the arthroscopic and MR findings for analysis of the results.

RESULTS. Of the 13 labral tears found at arthroscopy, 85% were detected by conventional MRI, whereas 100% were identified via indirect MR arthrography. Seventy percent of the labral tears identified on conventional MRI were better delineated by indirect MR arthrography. Identification of chondral abnormalities was not improved via indirect MR arthrography over conventional MRI.

CONCLUSION. IV contrast-enhanced indirect MR arthrography appears to be an effective means of hip evaluation for labral tears. It does not appear to improve detection of cartilage abnormalities when compared with conventional MRI.

Keywords: acetabular cartilage defects, acetabular labrum, femoral acetabular impingement, hip, indirect MR arthrography

DOI:10.2214/AJR.07.3669

Received January 12, 2008; accepted after revision August 12, 2009.

[1]National Musculoskeletal Imaging, 1930 N Commerce Pkwy, Ste. 5, Weston, FL 33326. Address correspondence to M. B. Zlatkin (mzlatkin@nationalrad.com).

[2]Department of Radiology, University of Miami, Jackson Memorial Hospital, Miami, FL.

[3]Center for Orthopedics and Rehabilitation Excellence, Miami, FL.

[4]Miami Institute for Joint Reconstruction, Miami, FL.

AJR 2010; 194:709–714

0361–803X/10/1943–709

Intraarticular abnormalities of the hip are being diagnosed with increased frequency by diagnostic methods such as conventional MRI, conventional MR arthrography, and hip arthroscopy. These intraarticular abnormalities include acetabular labral tears, loose bodies, mild osteoarthritis, osteochondral defects, chondral lesions and flaps, and synovitis [1–12]. More recently, many of these lesions have been shown to be due to underlying femoral acetabular impingement. Many patients with hip pain who undergo MR examination have symptoms often associated with femoral acetabular impingement [13–15].

Although diagnostic arthroscopy may be the most definitive means of diagnosing these disorders and is considered the reference standard, compared with less invasive means, it is costly and invasive. Thus, there has long been a search for alternative, less invasive methods to establish a diagnosis [3]. Several authors have assessed the diagnostic performance of labral tears with conventional MRI and direct MR arthrography in comparison with the reference standard of arthroscopic evaluation. In general, conventional MRI has proven to be useful in the diagnosis of bone and bone marrow disorders and of other extraarticular disorders but has been shown to be less effective in the detection of intraarticular disorders, particularly labral tears and articular cartilage lesions. MR arthrography with the direct intraarticular injection of diluted gadolinium in saline has improved the ability to detect a spectrum of intraarticular disorders of the hip, particularly acetabular labral tears. Many reports in the literature indicate favorable sensitivity and specificity values with MR arthrography and, to a lesser degree, the detection of articular cartilage disorders [3, 9, 11, 12, 16–19].

There are few data on the diagnostic accuracy of indirect MR arthrography of the hip in correlation with arthroscopy. Indirect MR arthrography has been shown to be useful in treating shoulder disorders and postoperative knees [20–28]. The impetus to use indirect MR arthrography is that it is less invasive than the direct technique, does not require fluoroscopy or a physician to perform the injection, is relatively easy to schedule, has improved contrast resolution relative to conventional MRI, and is able to visualize synovitis and extraarticular enhancement. Some disadvantages of indirect MR arthrography, compared with direct MR arthrography, include the lack of capsular distention relative to direct MR arthrography (although this is less of an issue in the hip than in the shoulder), enhancement of normal vascularized structures, higher contrast load than that used in direct MR arthrography, exercise requirements, and less reliable joint opacification.

The purpose of this study was to determine the diagnostic performance of indirect MR arthrography in the diagnosis of acetabular labral tears and articular cartilage disorders in comparison with both arthroscopy and conventional MRI and also to compare those results to the published results of direct MR arthrography. Because many patients with labral tears and chondral lesions have underlying femoral acetabular impingement as the etiologic factor in these pathologic lesions, one additional purpose of this study was to assess the frequency with which lesions of femoral acetabular impingement were present in these patients.

Materials and Methods

Sixty-three patients underwent IV contrast-enhanced indirect MR arthrography during an 18-month period. Of these patients, 14 had arthroscopic follow-up and intervention and, thus, formed the population of patients for this study. Informed consent was obtained from all patients for the injection of contrast material. Institutional review board approval was obtained for the performance of this retrospective study.

The unenhanced MR imaging and indirect MR arthrography imaging with IV gadolinium were performed on a 1.5-T magnet (Symphony, Siemens Healthcare). An initial series of unenhanced images was obtained before indirect MR arthrography. Whole-pelvis coronal T1 and STIR sequences were performed, followed by unilateral sagittal turbo spin-echo proton density fat-saturated, axial turbo spin-echo T2 fat-saturated, and coronal turbo spin-echo proton density fat-saturated sequences. The imaging time for the unenhanced images of the left hip was, on average, approximately 22 minutes.

The patient was then removed from the magnet and taken to a separate room. The patient then received IV gadolinium contrast medium (0.2 mL/kg) and was instructed to exercise for 15 minutes. The patient was then told to move the affected side "vigorously" in circular motion of abduction, flexion, and extension while holding on to a wall or a chair nonstop for a minimum of 15 minutes. Patients tolerated the exercise regimen well. If they were unable to perform the exercise regimen, then they were asked to walk around the room for the requisite amount of time. As the patient was taken from the scanner, the patient had to be repositioned and another scout image had to be obtained before the contrast-enhanced images (localizer, 19 seconds; 3–5 minutes to reposition).

Gadolinium-enhanced fat-saturated T1-weighted sequences were performed in the coronal, sagittal, and axial planes (Fig. 1). The IV contrast-enhanced unilateral MR arthrogram imaging time was, on average, approximately 20 minutes 44 seconds.

A combined four-channel phased-array body flex coil and spine coil were used in a Helmholtz configuration for all unilateral pulse sequences. We tried to minimize the wraparound artifact by positioning the four-channel phased-array body flex coil over the affected side only, having it draped around laterally over the greater trochanter. This was purposely done to minimize the signal from the opposite side. In addition, three saturation pulses of 50-mm thickness were placed on the opposite side to avoid signal from this side and to prevent aliasing.

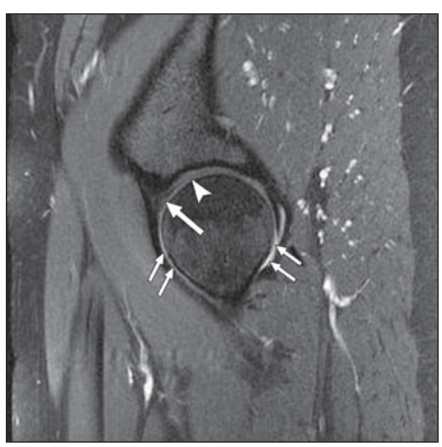


Fig. 1—Sagittal oblique T1-weighted image, with fat suppression, after IV gadolinium injection with exercise and delay in 52-year-old man depicts low-signal anterior superior labrum (*large arrow*) and subjacent intermediate signal hyaline articular cartilage (*arrowhead*). Note enhanced joint fluid (*small arrows*) resulting in an "arthrographic effect."

The slice thickness was 4 mm for all the unenhanced unilateral imaging sequences and 3 mm for the contrast-enhanced portion of the study. The matrix size was 320 × 192 for the unenhanced and 256 × 192 for the contrast-enhanced unilateral sequences. The field of view was 12 cm for all the unilateral sequences and 38 cm for all the whole-body bilateral sequences.

The arthroscopic procedures were performed by two orthopedic surgeons experienced in hip arthroscopy. The 14 IV enhanced MR arthrogram studies were then retrospectively reviewed by two musculoskeletal radiologists, each with more than 15 years' experience, both of whom were blinded to the arthroscopic findings. A standard form was used for evaluation and review.

Patients were examined for labral tears, articular cartilage lesions, and bony changes suggestive of femoral acetabular impingement syndrome. Unenhanced and gadolinium-enhanced images of the labrum were each reviewed and scored separately for the presence or absence of labral tears and their extent and the presence and extent of any cartilage lesions. The location of the labral tears and cartilage lesions was categorized as anterior superior, superolateral, posterosuperior, and multiregional on both the unenhanced and contrast-enhanced studies.

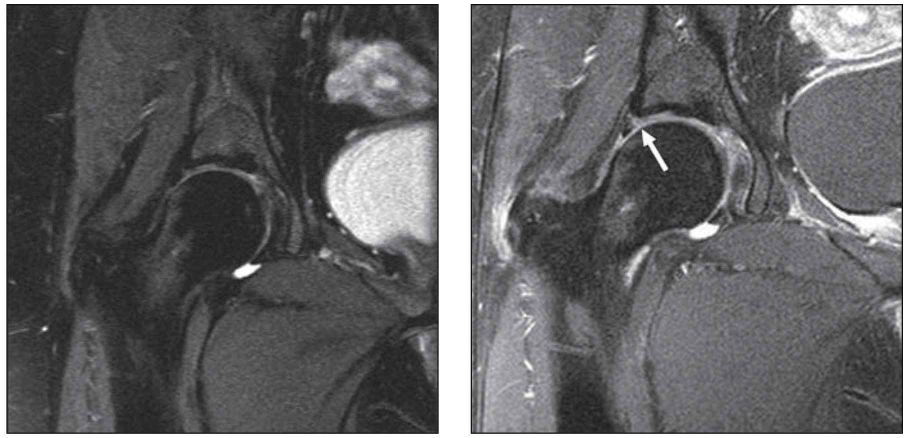
The presence of any femoral head cartilage lesions was also recorded. The labral tears were categorized as normal, frayed or fibrillated, focally torn (fluid signal on T2 or contrast imbibition on indirect MR arthrography), or detached. The cartilage was evaluated using a grading method based on the modified Outerbridge classification system used extensively in the knee, as follows: 0, normal cartilage; I, partial thickness chondral thinning, and surface irregularity; II, full thickness without subchondral change; and III, full thickness with subchondral change [29]. The unenhanced MR images were reviewed separately from the IV contrast-enhanced MR arthrography images to avoid bias in interpretation. All of the unenhanced images were reviewed first, the findings were tabulated, and then the contrast-enhanced images were reviewed in a separate session. These sessions were separated by a period of 24–48 hours. Once this review was completed, all the examinations were reviewed again with the operative reports, and comparison was made between the arthroscopic, MRI, and indirect MRI arthrographic findings using arthroscopy as the standard.

Results

There were 14 arthroscopically confirmed cases. Of the 14 patients, the age range was from 19 to 68 years, with an average age of 39 years. Five patients were male, and nine were female; there were no significant age differences between the male and female distributions. One of the 14 patients had previously undergone surgical repair of the labrum but presented with the suspicion of a recurrent labral tear. Thirteen of the 14 patients had labral tears found at arthroscopy. All 13 of the labral tears visualized at arthroscopy were identified on the contrast-enhanced portion of the examination (100%). Of these 13 patients, 11 (85%) had a labral tear that could also be visualized in the unenhanced portion of the study. Of the 11 patients for whom labral tears could be seen on the unenhanced portion of the study, nine had tears that were more extensive or more prominently visualized on the gadolinium-enhanced sequences (Figs. 2 and 3). For the 13 cases with labral tears at arthroscopy, the extent and character of the labral tears described on the indirect MR arthrograms correlated well with arthroscopic findings while allowing slight differences in language with regard to extent and position. The extent and character of the gadolinium-enhanced imaging findings were thought to more closely correlate to the findings described at arthroscopy than the unenhanced images.

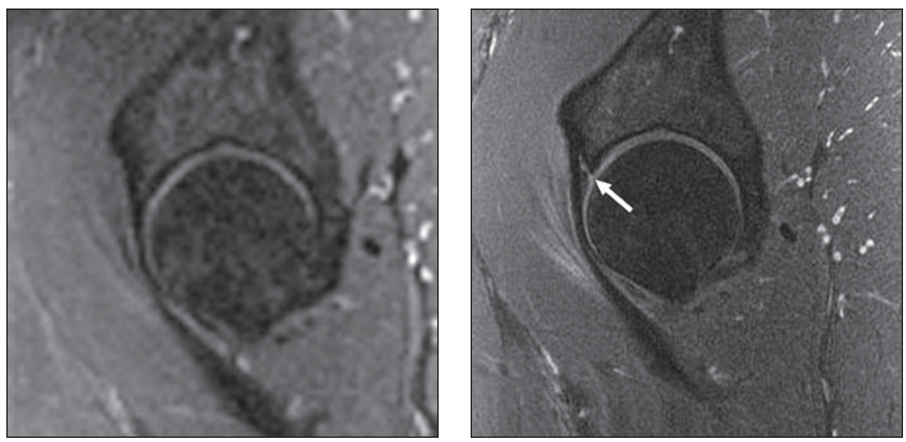
There was one false-positive result (Fig. 4). One of the patients had a tear seen on indirect MR arthrography that was not detected by arthroscopy. The case was reviewed a second time after knowledge of the operative report, and in retrospect, the reviewer thought that the criteria for a labral tear were still present in this patient.

In evaluation of the cartilage, 11 of 14 patients had chondral lesions or chondral flaps revealed by arthroscopy. Nine of 11 lesions (82%) were found to be correlative within one grade between the findings seen on MRI, as well as indirect MR arthrography, and those found at the time of arthroscopy (Fig. 5). Conventional MRI evaluation was qualitatively equal to or better than indirect MR arthrography in this evaluation. In two of the examinations, the findings were better seen on the coronal and sagittal proton density fat-saturated unenhanced images. Both femoral head chondral lesions found at arthroscopy were visible on both the unenhanced MRI and indirect MR arthrography portions of the examination.



A B

Fig. 2—Images of a tear of the acetabular labrum in a 23-year-old woman.
A, Coronal proton density fast spin-echo fat-suppressed unenhanced image obtained without exercise.
B, Coronal T1-weighted image with fat suppression after IV gadolinium enhancement performed after exercise and delay. The acetabular labrum tear (*arrow*) is more clearly depicted on the contrast-enhanced portion of the study.



A B

Fig. 3—Images of a tear and detachment in the anterior superior quadrant of the labrum in a 42-year-old man.
A, Sagittal proton density fast spin-echo fat-suppressed unenhanced image taken before exercise.
B, Sagittal T1-weighted image with fat suppression after IV gadolinium enhancement performed after exercise and delay shows that the tear and detachment in the anterior superior quadrant of the labrum (*arrow*) is better depicted and visualized on the contrast-enhanced image.

Bone changes associated with femoral acetabular impingement syndrome were seen in all 14 patients on MRI. One case of femoral acetabular impingement was the pincer type (from osteophytes), whereas two were a combination of the pincer and cam types. The remaining patients had cam-type femoral acetabular impingement with prominent anterior and lateral bony bumps, along with cystic changes along the femoral head and neck junction (Fig. 6). Of the patients with cam type detected by MRI, seven had cam-type changes detected by arthroscopy. One patient had previously undergone removal of a cam-type femoral acetabular impingement dysplastic bony bump and now had scarring and had developed rim osteophytes. Four of the patients were not evaluated for femoral acetabular impingement changes during arthroscopy, whereas two did not show any evidence of femoral acetabular impingement–associated changes at arthroscopy. Of these two cases, one appeared as a pincer type and the other as a cam type on MRI examination.

Discussion

Acetabular labral tears and chondral lesions of the hip are not rare causes of hip pain in the population and may often be caused by or seen in association with femoral acetabular impingement. Direct MR arthrography has been found to be useful in the evaluation

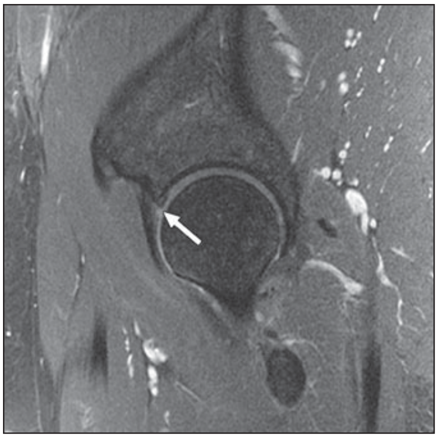
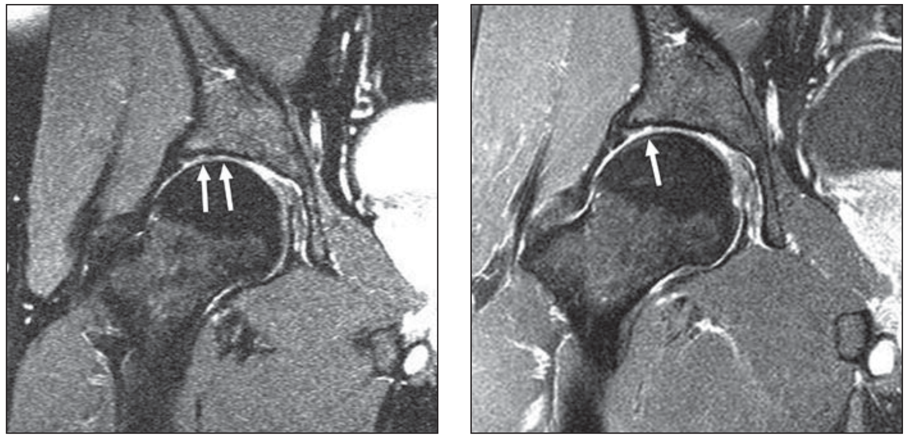
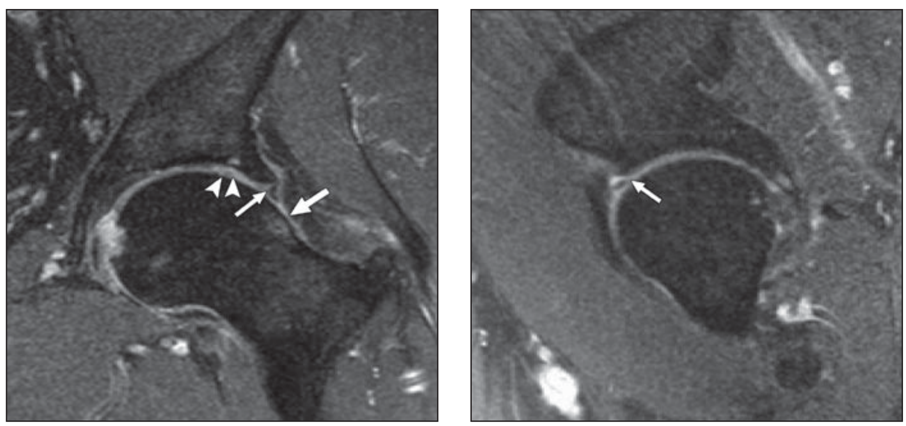


Fig. 4—Sagittal fat-suppressed T1-weighted image with IV gadolinium enhancement performed after exercise and delay in a 54-year-old woman. Contrast outlines what was interpreted as partial separation of anterior superior labrum, with some fraying (*arrow*). Arthroscopy did not reveal a labral tear; hence, this was a false-positive result.



A B

Fig. 5—Images of chondral loss along the acetabular margin in a 35-year-old man.
A, Coronal proton density fast spin-echo fat-suppressed image obtained without contrast enhancement and without exercise shows areas of chondral loss along the acetabular margin (*arrows*).
B, Coronal T1-weighted image with fat suppression after IV gadolinium enhancement performed after exercise and delay shows areas of chondral loss along the acetabular margin (*arrow*).



A B

Fig. 6—Images of a labral tear, cartilage loss, and cystic change along the margin of the acetabulum in a 56-year-old man.
A, Coronal fat-suppressed T1-weighted image with IV gadolinium enhancement performed after exercise and delay, shows a labral tear (*thin arrow*) as well as cartilage loss (*arrowheads*) and cystic change along the margin of the acetabulum. On the femoral side of the joint, there is edema and bony prominence along the lateral femoral neck region (*thick arrow*).
B, Sagittal fat-suppressed T1-weighted image with fat suppression and IV gadolinium enhancement performed after exercise and delay, shows a labral tear (*arrow*) and cystic change along the margin of the acetabulum. These findings are similar to those described in patients with cam-type femoral acetabular impingement.

of these lesions and to have a relatively high diagnostic performance in the assessment of such abnormalities [3, 5, 9, 11, 12, 16, 17, 19, 30]. However, there are many instances in which direct MR arthrography may not be feasible in clinical musculoskeletal MRI practice. This includes examinations performed at remote sites and situations when a musculoskeletal or other radiologist skilled in the performance of arthrogram injections may not be available to perform the intraarticular injection, as was the case in our series of patients. The purpose of our study was to determine whether indirect MR arthrography could provide information similar to that provided by conventional MR arthrography in the evaluation of these patients. If that were the case, then indirect MR arthrography could thus be reasonably used as an alternative to direct MR arthrography when the referring clinicians thought that such a study was necessary and indicated.

The results of this preliminary study reveal that indirect MR arthrography shows significant potential in the assessment of chronic hip pain in patients suspected of having labral abnormalities, and appears to provide information similar to that provided by direct MR arthrography. Indirect MR arthrography was able to clearly show acetabular labral lesions, including their site of involvement and their extent, in all 13 patients who were found to have such lesions at arthroscopy. In this regard, indirect MR arthrography showed some increased sensitivity over the unenhanced MR images, which documented only 11 of the 13 arthroscopically confirmed labral tears.

Qualitatively, the labral lesions and their extent were better visualized on the contrast-enhanced injection images in at least nine of these patients. There was one false-positive result of an indirect MR arthrography examination of a labral tear. Even in retrospect, this case was thought to fulfill the criteria for a labral tear on the basis of the indirect MR arthrography findings.

With respect to the chondral lesions, the results were not as precise as those for the labral pathologic lesions. Qualitatively, the cartilage lesions were less easily visualized than the labral lesions on both the unenhanced portion of the study and the indirect MRI arthrogram portion of the study. Some promise was shown in this evaluation as well, however, because chondral lesions within one grade of that found at arthroscopy were visible in nine (82%) of 11 patients who had such lesions detected by arthroscopy. In this evaluation, the chondral lesions were seen at least equally well on the unenhanced portion of the study.

All 14 of the patients in this study were shown to have additional extraarticular findings, besides the labral and chondral alterations, associated with the clinical syndrome of femoral acetabular impingement. Thus, femoral acetabular impingement appears to be the predominant etiologic factor in the development of the labral and chondral lesions in our patient population. Labral and chondral lesions form an important part of the spectrum of disease in patients with femoral acetabular impingement [13–15, 31, 32]. Femoral acetabular impingement is considered to play a significant role in the development of premature degenerative arthritis, especially in patients who are athletically active [13, 31]. Operative treatment, both open and arthroscopic, may prevent further progression when performed early in the course of disease. Operative treatment includes débridement or repair of any identified labral lesions as well as addressing the associated chondral pathologic disorder [33–35]. Careful delineation of these lesions is important preoperatively, and on the basis of the results of this study, indirect MR arthrography may be able to provide useful information in this assessment.

The use of indirect MR arthrography for other joints has been reported since Vahlensieck et al. [36] described the technique. Indirect MR arthrography may be of benefit in diagnosing tears of the glenoid labrum in the shoulder [37, 38]. Using indirect MR arthrography, Dinauer et al. [28] evaluated a series of patients and noted improvement in the sensitivity, but not the specificity, in the diagnosis of superior labral anteroposterior lesions. They believed that specificity did not improve because they did not use delay and exercise, which led to an increased number of false-positive results. Thus, enhancement of surrounding vessels and fibrovascular tissue led not only to increased detection of labral lesions but also to diminished specificity, which they believed might have been mitigated if they had obtained their images after exercise and delay and if they had used unenhanced MRI for correlation and comparison at the time of their review [28].

We believe that assessment of labral tears with indirect MR arthrography in the hip may be less problematic than assessment in the shoulder because there seems to be a less complex anatomy around the labrum and cartilaginous structures of the hip, with a relative paucity of anatomic variants. There is also a relative absence of the complex labroligamentous anatomy in the hip than in the shoulder, which may more often be better seen in the shoulder with the joint distention offered by direct MR arthrography. In addition, there is less problematic enhancement of vascularized soft-tissue structures in the hip than is present in the shoulder, thus leading to less uncertainty in diagnosis.

Allmann et al. [20] and Yagci et al. [27] found improvement in the detection of rotator cuff tears with indirect MR arthrography over conventional MRI. Haims et al. [39] compared indirect MR arthrography to unenhanced MR imaging to assess wrist derangement and found that indirect MR arthrography had better sensitivity than unenhanced MRI examination in the diagnosis of scapholunate ligament tears. White et al. [40] assessed a large population of postoperative menisci with indirect MR arthrography, compared with direct MR arthrography, conventional MRI, and surgery, and found all three methods to be equal in their assessment of these patients.

One issue of note concerning indirect MR arthrography is the overall imaging time required to perform these studies. The scan time required to fully perform these studies is long, with approximately 20 minutes devoted to the preinjection portion, 15 minutes of exercise, time to reposition the patient and obtain another scout image of the patient, and then 20 minutes of scan time after the injection. Overall, the amount of time on the magnet for the patient may be slightly longer than that required for a typical direct MR arthrogram protocol performed only after intraarticular injection without any prescan imaging. The advantage of this procedure is that it is not invasive, and, although the injection is supervised by a radiologist, it does not require a radiologist skilled in performing intraarticular injections be present to perform the injection. This potentially results in a total patient time in the MRI facility less than that required for a direct MR arthrogram.

Another technical issue that arises when small fields of view are used in large joints such as the hip without dedicated hip coils is one of wraparound artifact. When imaging with a small field of view, we used full-phase oversampling. In addition, we minimized the wraparound artifact by positioning the four-channel phased-array flexible body coil over the affected side only, draping it around laterally over the greater trochanter. This was purposely done to minimize the signal from the opposite side. In addition to this, three saturation pulses of 50-mm thickness were placed on the opposite side to avoid signal from that side, further preventing aliasing. This technique provided us with images that were relatively free of wraparound artifact.

There were some differences in the matrix and slice thicknesses that we used in the contrast-enhanced and unenhanced portions of the study. On the contrast-enhanced imaging sequences, we used thinner sections of 3 mm, versus 4 mm on the unenhanced images. We took advantage of the shorter time for T1-weighted sequences to obtain thinner sections, which thus resulted in somewhat higher spatial resolution from this parameter. We did not think that the longer imaging time required to obtain 3-mm slice thicknesses on the contrast-unenhanced T2-weighted images was warranted or tolerable by the patients. In addition, the diminished signal-to-noise ratio would also have resulted in poorer quality unenhanced images. We do not believe that the small variation in the frequency matrix from the contrast-enhanced to unenhanced portion of the study is sufficiently different to result in significant differences in the interpretation of the scans and is typical of standard imaging matrices used in imaging these joints with long TR/TE and short TR/TE sequences.

Thus, we believe that indirect MR arthrography shows promise in the evaluation of acetabular labral tears when direct MR arthrography is not feasible. The technique appears to reveal some qualitative and quantitative improvements in the detection of these lesions over conventional MRI. Although the detection of cartilage lesions revealed some promise as well and was similar to published reports of this diagnosis for direct MR arthrography, indirect MR arthrography did not appear to improve the detection of chondral lesions over conventional MRI in this study.

The results of our study, however, have several important limitations. Because this study has a small sample size and the analysis was done in a retrospective manner, the results should be considered a preliminary study; the findings will need to be confirmed in a larger population of patients before our conclusions can be considered fully valid. In addition, we did not have a control population of patients with intact acetabular labral and cartilage surfaces. Thus, a true statistical analysis of its diagnostic performance could not be performed. Our study was also performed in a retrospective manner, with consensus review. There is also likely selection bias, owing to the fact that the orthopedic surgeons were unlikely to operate on patients without a significant clinical finding of a suspected labral pathologic disorder and a positive MRI examination result. A larger follow-up study is therefore needed with these biases better controlled to further confirm and validate these initial findings.

We believe that this study is valuable, however, because to our knowledge there are no other published studies of indirect MR arthrography specifically addressing patients with hip pain and suspected labral pathologic abnormalities. Second, this study does appear to show the benefit of indirect MR arthrography over conventional MRI in this assessment and indirect MR arthrography does appear to be a viable alternative to direct MR arthrography when it is not feasible to perform the latter. Owing to the possibility of diminished specificity of indirect MR arthrography when not used in combination with exercise, delay, and contrast-unenhanced conventional MRI sequences, as outlined by Dinauer et al. [28] in their study of superior labral anteroposterior lesions in the shoulder, it is suggested that indirect MR arthrography be performed in this manner. Thus, indirect MR arthrography in combination with exercise, delay, and contrast-enhanced imaging sequences may prove to be a useful study in the evaluation of labral and cartilage lesions in patients with hip pain and with suspected femoral acetabular impingement.

Acknowledgment

We thank Bill Leon for his technical assistance in this study.

References

1. Bencardino JT, Kassarjian A, Palmer WE. Magnetic resonance imaging of the hip: sports-related injuries. *Top Magn Reson Imaging* 2003; 14:145–160
2. Chan YS, Lien LC, Hsu HL, et al. Evaluating hip labral tears using magnetic resonance arthrography: a prospective study comparing hip arthroscopy and magnetic resonance arthrography diagnosis. *Arthroscopy* 2005; 21:1250
3. Keeney JA, Peelle MW, Jackson J, Rubin D, Maloney WJ, Clohisy JC. Magnetic resonance arthrography versus arthroscopy in the evaluation of articular hip pathology. *Clin Orthop Relat Res* 2004; Dec:163–169
4. Kelly BT, Williams RJ 3rd, Philippon MJ. Hip arthroscopy: current indications, treatment options, and management issues. *Am J Sports Med* 2003; 31:1020–1037
5. Leunig M, Podeszwa D, Beck M, Werlen S, Ganz R. Magnetic resonance arthrography of labral disorders in hips with dysplasia and impingement. *Clin Orthop Relat Res* 2004; Jan:74–80
6. Mason JB. Acetabular labral tears in the athlete. *Clin Sports Med* 2001; 20:779–790
7. McCarthy J, Noble P, Aluisio FV, Schuck M, Wright J, Lee JA. Anatomy, pathologic features, and treatment of acetabular labral tears. *Clin Orthop Relat Res* 2003; Jan:38–47
8. McCarthy JC. The diagnosis and treatment of labral and chondral injuries. *Instr Course Lect* 2004; 53:573–577
9. Petersilge CA. MR arthrography for evaluation of the acetabular labrum. *Skeletal Radiol* 2001; 30: 423–430
10. Newman JS, Newberg AH. MRI of the painful hip in athletes. *Clin Sports Med* 2006; 25:613–633
11. Palmer WE. MR arthrography of the hip. *Semin Musculoskelet Radiol* 1998; 2:349–362
12. Toomayan GA, Holman WR, Major NM, Kozlowicz SM, Vail TP. Sensitivity of MR arthrography in the evaluation of acetabular labral tears. *AJR* 2006; 186:449–453
13. Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res* 2003; Dec:112–120
14. Pfirrmann CW, Mengiardi B, Dora C, Kalberer F, Zanetti M, Hodler J. Cam and pincer femoroacetabular impingement: characteristic MR arthrographic findings in 50 patients. *Radiology* 2006; 240:778–785
15. Bredella MA, Stoller DW. MR imaging of femoroacetabular impingement. *Magn Reson Imaging Clin N Am* 2005; 13:653–664
16. Plötz GM, Brossmann J, von Knoch M, Muhle C, Heller M, Hassenpflug J. Magnetic resonance arthrography of the acetabular labrum: value of radial reconstructions. *Arch Orthop Trauma Surg* 2001; 121:450–457
17. Czerny C, Hofmann S, Urban M, et al. MR arthrography of the adult acetabular capsular-labral complex: correlation with surgery and anatomy. *AJR* 1999; 173:345–349
18. Kassarjian A. Hip MR arthrography and femoroacetabular impingement. *Semin Musculoskelet Radiol* 2006; 10:208–219
19. Leunig M, Werlen S, Ungersbock A, Ito K, Ganz R. Evaluation of the acetabular labrum by MR arthrography. *J Bone Joint Surg Br* 1997; 79:230–234
20. Allmann KH, Schafer O, Hauer M, et al. Indirect MR arthrography of the unexercised glenohumeral joint in patients with rotator cuff tears. *Invest Radiol* 1999; 34:435–440
21. Bergin D, Schweitzer ME. Indirect magnetic resonance arthrography. *Skeletal Radiol* 2003; 32: 551–558
22. Hirano Y, Sashi R, Izumi J, Itoi E, Watarai J. Comparison of the MR findings on indirect MR arthrography in patients with rotator cuff tears with and without symptoms. *Radiat Med* 2006; 24:23–27
23. Morrison WB. Indirect MR arthrography: concepts and controversies. *Semin Musculoskelet Radiol* 2005; 9:125–134
24. Schweitzer ME, Natale P, Winalski CS, Culp R. Indirect wrist MR arthrography: the effects of passive motion versus active exercise. *Skeletal Radiol* 2000; 29:10–14
25. Vahlensieck M, Lang P, Sommer T, Genant HK, Schild HH. Indirect MR arthrography: techniques and applications. *Semin Ultrasound CT MR* 1997; 18:302–306
26. Vives MJ, Homesley D, Ciccotti MG, Schweitzer ME. Evaluation of recurring meniscal tears with gadolinium-enhanced magnetic resonance imaging: a randomized, prospective study. *Am J Sports Med* 2003; 31:868–873
27. Yagci B, Manisali M, Yilmaz E, et al. Indirect MR arthrography of the shoulder in detection of rotator cuff ruptures. *Eur Radiol* 2001; 11:258–262
28. Dinauer PA, Flemming DJ, Murphy KP, Doukas WC. Diagnosis of superior labral lesions: comparison of noncontrast MRI with indirect MR arthrography in unexercised shoulders. *Skeletal Radiol* 2007; 36:195–202
29. Outerbridge RE. The etiology of chondromalacia patellae. *J Bone Joint Surg Br* 1961; 43-B:752–775
30. Czerny C, Hofmann S, Neuhold A, et al. Lesions of the acetabular labrum: accuracy of MR imaging and MR arthrography in detection and staging. *Radiology* 1996; 200:225–230
31. Kassarjian A, Brisson M, Palmer WE. Femoroacetabular impingement. *Eur J Radiol* 2007; 63:29–35
32. Wagner S, Hofstetter W, Chiquet M, et al. Early osteoarthritic changes of human femoral head cartilage subsequent to femoro-acetabular impingement. *Osteoarthritis Cartilage* 2003; 11: 508–518
33. Espinosa N, Rothenfluh DA, Beck M, Ganz R, Leunig M. Treatment of femoro-acetabular impingement: preliminary results of labral refixation. *J Bone Joint Surg Am* 2006; 88:925–935
34. Guanche CA, Bare AA. Arthroscopic treatment of femoroacetabular impingement. *Arthroscopy* 2006; 22:95–106
35. Murphy S, Tannast M, Kim YJ, Buly R, Millis MB. Débridement of the adult hip for femoroacetabular impingement: indications and preliminary clinical results. *Clin Orthop Relat Res* 2004; Dec:178–181
36. Vahlensieck M, Peterfy CG, Wischer T, et al. Indirect MR arthrography: optimization and clinical applications. *Radiology* 1996; 200:249–254
37. Maurer J, Rudolph J, Lorenz M, et al. A prospective study on the detection of lesions of the labrum glenoidale by indirect MR arthrography of the shoulder [in German]. *Rofo* 1999; 171:307–312
38. Sommer T, Vahlensieck M, Wallny T, et al. Indirect MR arthrography in the diagnosis of lesions of the labrum glenoidale [in German]. *Rofo* 1997; 167:46–51
39. Haims AH, Schweitzer ME, Morrison WB, et al. Internal derangement of the wrist: indirect MR arthrography versus unenhanced MR imaging. *Radiology* 2003; 227:701–707
40. White LM, Schweitzer ME, Weishaupt D, Kramer J, Davis A, Marks PH. Diagnosis of recurrent meniscal tears: prospective evaluation of conventional MR imaging, indirect MR arthrography, and direct MR arthrography. *Radiology* 2002; 222:421–429