The Accuracy of Magnetic Resonance Imaging and Magnetic Resonance Arthrogram Versus Arthroscopy in the Diagnosis of Subscapularis Tendon Injury

Abdullah Foad, M.D., and Coen A. Wijdicks, Ph.D.

Purpose: The main purpose of this study was to evaluate the accuracy of preoperative magnetic resonance imaging (MRI) in detecting subscapularis tears identified during the gold standard of arthroscopy and determine whether MRI can reliably predict which patients have subscapularis tears. A second purpose was to determine whether magnetic resonance (MR) arthrograms could better identify a subscapularis tear than conventional MRI. **Methods:** This was a retrospective study evaluating 39 consecutive patients (40 shoulders) who had a preoperative 1.5-T MRI study and underwent an arthroscopic subscapularis tendon repair. All cases were performed between December 2007 and November 2010. **Results:** Subscapularis tears were missed on preoperative MR scanning in 25 of 40 shoulders (62.5%). The sensitivity of noncontrast MRI was 40%, the sensitivity of MR arthrography was 36%, and the overall MR sensitivity was 37.5%. **Conclusions:** Preoperative 1.5-T MRI of the shoulder does not reliably predict subscapularis tendon tears, regardless of whether conventional MRI or MR arthrography is used. **Level of Evidence:** Level II, development of diagnostic criteria on basis of consecutive patients with universally applied gold standard.

Advances in magnetic resonance imaging (MRI) have provided a beneficial tool in determining the extent of shoulder pathology. Current MRI technology offers improved diagnostic capabilities. MRI and magnetic resonance (MR) arthrograms have been advocated to diagnose rotator cuff tears and, more specifically, subscapularis tendon tears. Advancements in arthroscopic technique have also allowed a less invasive way to identify subscapularis pathology that has historically been treated with open surgery.[1,2] Use of the 70° arthroscope and special maneuvers have been described.[3,4] However, during arthroscopy, the humeral head can obstruct visualization of the subscapularis tendon footprint, and it has been reported that partial articular-sided tears are often underdiagnosed, which can lead to failed repairs of the more common supraspinatus and/or infraspinatus tears or lead to persistent pain and weakness.[5] Moreover, failed diagnosis of subscapularis tears by conventional MRI or MR arthrograms may also lead to suboptimal postsurgical outcomes (Fig 1).[6] Because most subscapularis tears have been reported to occur on the articular and cephalad aspect of the footprint,[5,7,8] arthroscopic evaluation of the subscapularis tendon has been considered the gold standard for the definitive diagnosis of subscapularis tears.[5]

The main purpose of this study was to evaluate the accuracy of preoperative 1.5-T MRI in detecting subscapularis tears identified during the gold standard of arthroscopy and determine whether MRI can reliably predict which patients have subscapularis tears. A second purpose was to determine whether MR arthrograms could better identify a subscapularis tear than conventional MRI. We hy-

From the Quality Care Clinic and Surgery Center (A.F.), Clinton, Iowa; and the Steadman Philippon Research Institute (C.A.W.), Vail, Colorado, U.S.A.

The authors report that they have no conflicts of interest in the authorship and publication of this article.

Received April 4, 2011; accepted October 13, 2011.

Address correspondence to Abdullah Foad, M.D., Quality Care Clinic and Surgery Center, 2745 Lincoln Way, Clinton, IA 52732, U.S.A. E-mail: foada1@aol.com

0749-8063/11212/$36.00

doi:10.1016/j.arthro.2011.10.006

Figure 1. Direct MR arthrography with axial image at the level of the subscapularis tendon insertion read by a musculoskeletal radiologist as showing that "the subscapularis is intact." The arrow is pointing to the "intact" subscapularis tendon.

pothesized that preoperative imaging of the shoulder would not reliably predict subscapularis tendon tears, regardless of whether conventional MRI or MR arthrography was used.

METHODS

Patients

We performed a retrospective study of 39 consecutive patients (40 shoulders) who had primary arthroscopic subscapularis tendon repairs by the same community-based fellowship-trained sports medicine orthopaedic surgeon. All cases were performed in the same outpatient ambulatory surgical center from December 2007 to November 2010. All patients in this study had a preoperative MRI study. There were no patients who had an MRI study and a clinical diagnosis of subscapularis pathology who were not included in this study. The first author (A.F.) did not differentiate whether the subscapularis repair was an isolated repair or was performed in combination with other rotator cuff repairs or procedures. Age, gender, operative shoulder side, and type of MRI used were determined. The interpretation by a general radiologist versus a musculoskeletal fellowship-trained radiologist, as well as what type of MRI was used (conventional MRI without contrast *v* MR arthrogram), was noted.

The first author ordered 21 of the 40 MRI studies (>50%). These 21 examinations were ordered as MR arthrograms, with a 2-step procedure consisting of a fluoroscopic intra-articular joint injection of a dilute solution (0.2 mmol/L) of gadopentetate dimeglumine (Magnevist; Berlex Laboratories, Wayne, NJ) followed by MRI. The MR arthrogram protocol consisted of 3-plane fat-saturated T1-weighted sequences (axial, oblique-coronal, and oblique-sagittal), a fat-saturated T1-weighted sequence in the abduction–external rotation position, a proton density–weighted oblique coronal sequence, and a T2-weighted fat-saturated oblique-coronal sequence. The 39 patients were imaged on one of four 1.5-T MR image scanners in the community. The radiologists' interpretation was used as entry criteria. The radiologists were blinded to the clinical diagnosis because no communication was made before the MR readings except a written request for all MRI studies to rule out rotator cuff and/or SLAP tears. Tendon quality on MRI was graded on axial T2-weighted and sagittal T2 fat-saturated sequences in accordance with established and widely accepted MRI criteria.[6] An MRI diagnosis of a subscapularis tear was defined as any qualitative interpretation by the radiologists of a complete tear, a partial tear, any signal abnormality such as tendon gap or fluid-equivalent signal in 1 or more sections, or nonvisualization of the subscapularis tendon. Medial subluxation or dislocation of the biceps tendon was also used to qualify the presence of a subscapularis tear. An MRI diagnosis of a "nontear" was defined as the radiologists' interpretation of an "intact subscapularis" or "normal subscapularis."

Clinical Diagnosis

The clinical diagnosis of a subscapularis tear was made by physical examination, including pain and weakness, with a combination of the lift-off, belly-press, and bear-hug tests.[3,9-11] All patients underwent a combination of the 3 tests. Any combination of these clinical tests raised clinical suspicion; however, the patient population in this study also included patients with subacromial and glenohumeral impingement (labral tears) with or without rotator cuff tears. A definitive diagnosis of a subscapularis tear was made during arthroscopy. For the purposes of this study, a subscapularis tendon tear was defined when at least an estimated 30% tendon detachment from the lesser tuberosity footprint was present. All tears that met

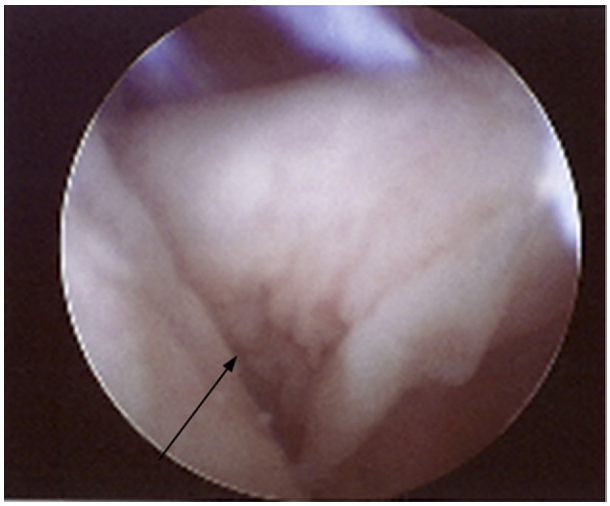

Figure 2. The same right shoulder shown in Fig 1 seen through a posterior portal with a 30° arthroscope viewing the anterior intra-articular anatomy. With a 30° arthroscope, it is difficult to appreciate a subscapularis tendon tear (arrow).

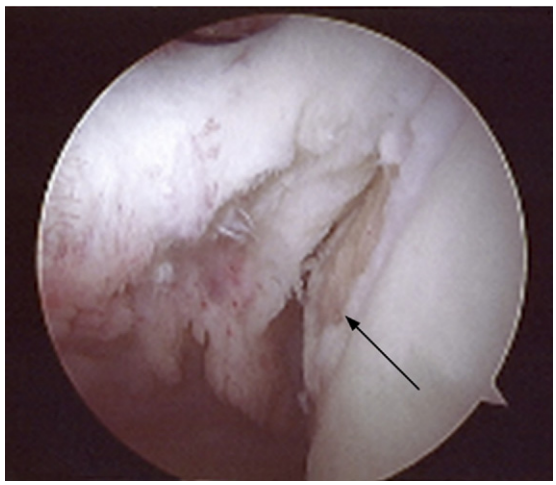

Figure 4. The same right shoulder shown in Fig 1 seen through a posterior portal with a 70° arthroscope viewing the anterior intra-articular anatomy and using the posterior lever push as described by Burkhart and Brady.[13] There is an improved appreciation and diagnosis of a subscapularis tendon tear (arrow).

these criteria were repaired. The arthroscopic linear measurement was made with a calibrated 4-mm arthroscopic probe measuring the cephalad-to-caudal distance, similar to a previously described technique.[5] An anatomic study has reported that the subscapularis footprint was trapezoidal with a mean cephalad-to-caudal footprint length of 25 mm.[12] The widest location (18 mm) was the upper border, and this has been the most commonly reported torn area of the subscapularis tendon.[8,12] The tear length measurement was then divided by 25 mm (total mean cephalad-to-caudal length) to determine the percentage tear of the subscapularis tendon.

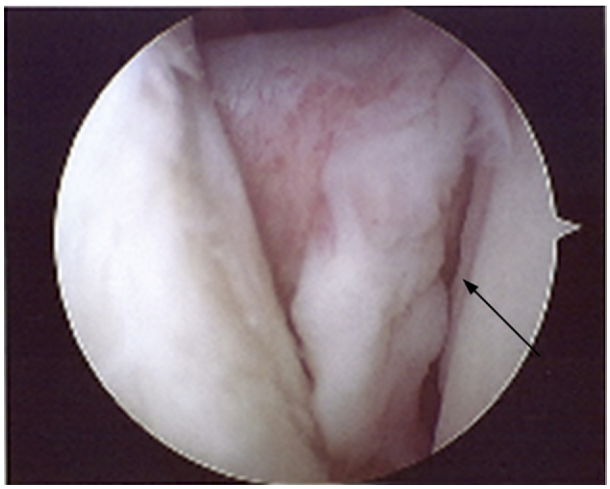

Figure 3. The same right shoulder shown in Fig 1 seen through a posterior portal with a 70° arthroscope viewing the anterior intra-articular anatomy. There is a better appreciation and diagnosis of a subscapularis tendon tear (arrow).

Surgical Technique

All subscapularis repairs were performed arthroscopically with the patient in the beach-chair position under general anesthesia. A comprehensive and systematic diagnostic evaluation of the glenohumeral joint was obtained through a standard posterior portal (in the soft spot) just inferior and medial to the posterolateral corner of the acromion. In addition, an anterior portal was made slightly lateral to the coracoid tip and more medial than the standard anterior portal in anticipation for the need of a subscapularis repair if there were strong clinical signs of a subscapularis tear regardless of the preoperative MRI interpretation. To enlarge the subcoracoid space and help visualize the subscapularis insertion site, a "posterior lever push," as described by Burkhart and Brady,[13] was performed, where the assistant simultaneously pushed posteriorly on the proximal humerus and pulled the distal humerus distally. We used 30° and 70° arthroscopes interchangeably to confirm a tear (Figs 2-4). The 70° arthroscope was usually left in the posterior portal for the subscapularis repair. Use of the 70° arthroscope to repair the subscapularis tendon allowed the surgeon to leave the patient's shoulder in a neutral relaxed position. A third, anterosuperolateral

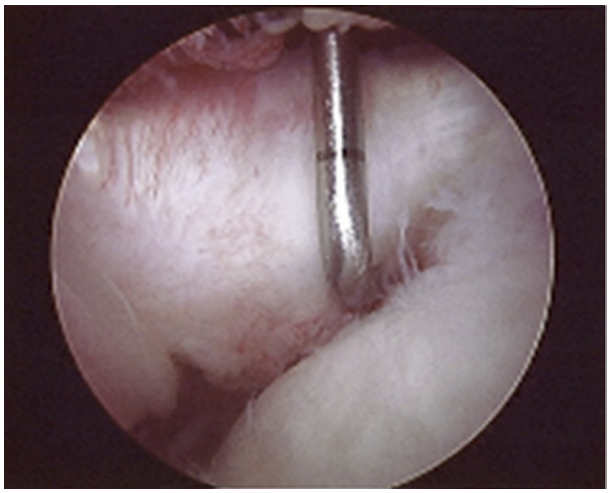

FIGURE 5. The final subscapularis repair of the same right shoulder shown in Fig 1 viewed through a posterior portal with a 70° arthroscope. The subscapularis has been anatomically repaired to its footprint in neutral shoulder rotation and is stable to arthroscopic probing.

portal was made just lateral to the long head of the biceps and anterior to the anterior fibers of the supraspinatus tendon. Once the torn subscapularis tendon and footprint were visualized, we used an arthroscopic shaver to debride the tendon tear and 4-mm high-speed round bur to provide a clean bleeding bone bed at the lesser tuberosity footprint. The shaver also opened up the subcoracoid space and aided in a 3-sided release of the subscapularis if necessary. A coracoplasty was performed when partial or complete subscapularis tears were believed to be degenerative rather than traumatic. Bioabsorbable suture anchors with double-loaded nonabsorbable sutures were placed through the anterior portal at a 45° angle starting inferiorly and working superiorly, depending on whether 1 or 2 anchors were required. Each anchor had 2 sets of sutures that were placed in a horizontal mattress fashion and arthroscopically tied with the shoulder in neutral position (Fig 5).

RESULTS

All 40 shoulders underwent a primary arthroscopic rotator cuff repair by the first author (A.F.). Findings are outlined in Table 1.

Sensitivity was measured to identify the actual positives identified. A sensitivity of 100% is indicative of a test that recognizes all actual positives. For our results, the sensitivity of MRI was 40%, the sensitivity of MR arthrography was 36%, and the overall MR sensitivity was 37.5%. An MRI study never yielded a diagnosis of a subscapularis tear without clinical or arthroscopic findings (no false-positive findings).

Complications included 2 patients with temporary shoulder stiffness that was managed with physical therapy. There were no cases of rerupture, infection, neurovascular injury, hardware failure, or complex regional pain syndrome.

DISCUSSION

There is little information about the accuracy of preoperative MRI in predicting subscapularis tears found on arthroscopy. The principal finding of this study was that preoperative MRI does not reliably predict which patients have isolated or concomitant subscapularis tendon tears. An arthroscopic measurement of at least 30% was used to confirm a positive diagnosis for a subscapularis tendon tear. This number was arbitrary but was comparable to measurements used in other articles.[5,14]

The subscapularis is an important internal rotator for the shoulder, but it also has an important role in dynamic anterior glenohumeral joint stability and in maintaining balanced force couples around the shoulder.[15-18] Despite surgical repair of the supraspinatus and/or infraspinatus, if a subscapularis tendon tear was not identified by MRI or arthroscopy or if specific tests during physical examination were not performed to stimulate a strong suspicion for a torn subscapularis tendon, the tear can go undiagnosed and/or untreated. In such a scenario, there will continue to be an imbalance in the force couples, which can potentially lead to a failed rotator cuff repair.

TABLE 1. *Patient Data*

	Data
Age [mean (range)] (yr)	51 (23-66)
Gender	32 men and 8 women
Shoulder side	29 right and 11 left
Coracoplasty	16 of 40
Failed noncontrast MRI findings of subscapularis tears to intraoperative findings	9 of 15
MRI sensitivity	40%
Failed MR arthrography findings of subscapularis tears to intraoperative findings	16 of 25
MR arthrography sensitivity	36%
Mean time from MR scan to arthroscopy [mean (range)] (d)	67 (7-328)

We found that subscapularis tendon tears are frequently missed on MRI. Few studies have looked at this concept.[19] Tung et al.[19] reported that only 31% of patients with arthroscopy-confirmed subscapularis tears were diagnosed by preoperative MRI. In addition, subscapularis tendon tears may go undiagnosed even during arthroscopy when they are not being specifically looked for.[6] Pfirrmann et al.[6] reported MR arthrography to be a favorable option in comparison with standard MRI when evaluating tears of the supraspinatus and infraspinatus tendons, with sensitivity ranging between 71% and 100%. Adams et al.[5] reported that the radiologists reported 16 of 44 subscapularis tears (36% sensitivity) identified by arthroscopy. Moreover, their results were based on the radiologists reading from conventional MRI scans only. They proposed that perhaps the sensitivity in diagnosing subscapularis tears would increase with MR arthrograms, as described by Pfirrmann et al. We not only had similar findings to Adams et al. (40% *v* 36% sensitivity) but also showed that MR arthrograms did not have any advantage over MRI (36% MR arthrography sensitivity *v* 40% MRI sensitivity) in diagnosing a subscapularis tendon tear.

Although the 3 aforementioned studies have evaluated the accuracy of MRI in predicting subscapularis tears,[5,6,19] they either did not look at a comparison or were not clear on MRI. Our study reviewed a comparison between conventional MRI and MR arthrograms and did not find any improvement for detecting subscapularis tears with the use of MR arthrograms. Furthermore, our study did not find any significant improvement or increase in sensitivity regardless of whether a general radiologist or a musculoskeletal radiologist interpreted the MRI studies. Our results are contrary to the results of Adams et al.,[5] who state that musculoskeletal radiologists "are more adept at identifying subscapularis tendon tears on MRI scans." Nevertheless, the main hypothesis in our study does support the findings/conclusion from their study, in that preoperative MRI of the shoulder does not reliably predict which patients with rotator cuff injury have concomitant subscapularis tears.[5]

It has been proposed that another possible limitation explaining the low sensitivity of MRI in identification of subscapularis tendon tears is the prolonged duration between the time of obtaining the preoperative MRI study and the time of discovery at surgery.[5] In our study the time between obtaining the preoperative MRI study and the time of arthroscopy was a mean of 67 days. This is shorter than that in the study by Adams et al.[5] Therefore we do not believe that the increased time duration (190 days) described by Adams et al. is a significant contributing factor for the low sensitivity of MRI in detecting subscapularis tears.

The prevalence of subscapularis tears in the literature is 3.5% to 29.4%.[9] Many tears occur traumatically with forced external rotation or extension of a partially abducted arm, but most tears are degenerative.[2] Physical findings include increased passive external rotation with the arm at the side or weakness with internal rotation. The lift-off test,[10] belly-press test,[10] Napoleon test,[7] and bear-hug test[4] are all specific clinical tests for the subscapularis. However, the low accuracy and reliability reported for these tests can still present a challenge.[11] Using these tests in combination may increase their diagnostic accuracy. Positive findings on these tests should raise suspicion to actively evaluate the subscapularis footprint for a tear at the time of arthroscopy. Interchangeably using the 30° and 70° arthroscopes through the posterior portal[13] or, if need be, the anterior portal can dramatically improve the visualization of the subscapularis insertion site and aid in the detection of a partial tear. The posterior lever push should also be used to increase the space for visualization.[13] This can be performed with the patient in either the beach-chair or lateral decubitus position.

Limitations of this study include the retrospective approach and a somewhat lacking degree of uniformity with respect to not having all the MRI studies performed at the same facility or perhaps lack of uniformity in the training of the radiologists. Despite this, all 39 patients had scans on 1 of 4 closed 1.5-T MRI scanners in the community. Another weakness of this study is that it does not include any data concerning intraobserver and interobserver reliability. This would have increased the quality of the study, especially in terms of the clinical examination. However, all have been performed in a standardized and consistent manner.

In comparison with the study by Adams et al.,[5] who stated that all procedures were performed with patients in the lateral decubitus position, all of the procedures in our study were conducted with patients in the beach-chair position. We found similar results; therefore we do not believe that patient position for arthroscopy is a substantial contributing limitation.

If one does not specifically look for a subscapularis tendon tear at the time of arthroscopy because of a negative finding on preoperative MRI studies, it can be a potential contributing factor for some failed ro-

tator cuff repairs or persistent limitations with pain and weakness.

We propose that it is not necessarily the type of MRI or the training of the radiologist that is the reason for low sensitivity in detecting subscapularis tears but that further improvement is needed in MRI techniques when examining the subscapularis tendon. New protocols or MR series may need to be developed and/or a change in the shoulder/hand position may be needed to accentuate the ability to detect subscapularis tears and be more concise with intraoperative findings.

CONCLUSIONS

Preoperative 1.5-T MRI of the shoulder does not reliably predict subscapularis tendon tears, regardless of whether conventional MRI or MR arthrography is used.

Acknowledgment: The authors thank Robert F. LaPrade, M.D., Ph.D., for his critical review of this manuscript and his strong support. They also thank Nathan Durick, M.D., Stanislav I. Spiridonov, M.D., Ann Weller, R.N., and Pranav P. Patel, M.D., for their consultation.

REFERENCES

1. Arai R, Sugaya H, Mochizuki T, Nimura A, Moriishi J, Akita K. Subscapularis tendon tear: An anatomic and clinical investigation. *Arthroscopy* 2008;24:997-1004.
2. Deutsch A, Altchek DW, Veltri DM, Potter HG, Warren RF. Traumatic tears of the subscapularis tendon. Clinical diagnosis, magnetic resonance imaging findings, and operative treatment. *Am J Sports Med* 1997;25:13-22.
3. Adams CR, Schoolfield JD, Burkhart SS. The results of arthroscopic subscapularis tendon repairs. *Arthroscopy* 2008;24:1381-1389.
4. Barth JR, Burkhart SS, De Beer JF. The bear-hug test: A new and sensitive test for diagnosing a subscapularis tear. *Arthroscopy* 2006;22:1076-1084.
5. Adams CR, Schoolfield JD, Burkhart SS. Accuracy of preoperative magnetic resonance imaging in predicting a subscapularis tendon tear based on arthroscopy. *Arthroscopy* 2010;26:1427-1433.
6. Pfirrmann CW, Zanetti M, Weishaupt D, Gerber C, Hodler J. Subscapularis tendon tears: Detection and grading at MR arthrography. *Radiology* 1999;213:709-714.
7. Burkhart SS, Tehrany AM. Arthroscopic subscapularis tendon repair: Technique and preliminary results. *Arthroscopy* 2002;18:454-463.
8. Sakurai G, Ozaki J, Tomita Y, Kondo T, Tamai S. Incomplete tears of the subscapularis tendon associated with tears of the supraspinatus tendon: Cadaveric and clinical studies. *J Shoulder Elbow Surg* 1998;7:510-515.
9. Bartsch M, Greiner S, Haas NP, Scheibel M. Diagnostic values of clinical tests for subscapularis lesions. *Knee Surg Sports Traumatol Arthrosc* 2010;18:1712-1717.
10. Gerber C, Krushell RJ. Isolated rupture of the tendon of the subscapularis muscle. Clinical features in 16 cases. *J Bone Joint Surg Br* 1991;73:389-394.
11. Hegedus EJ, Goode A, Campbell S, et al. Physical examination tests of the shoulder: A systematic review with meta-analysis of individual tests. *Br J Sports Med* 2008;42:80-92, discussion 92.
12. Richards DP, Burkhart SS, Tehrany AM, Wirth MA. The subscapularis footprint: An anatomic description of its insertion site. *Arthroscopy* 2007;23:251-254.
13. Burkhart SS, Brady PC. Arthroscopic subscapularis repair: Surgical tips and pearls A to Z. *Arthroscopy* 2006;22:1014-1027.
14. Kim SH, Oh I, Park JS, Shin SK, Jeong WK. Intra-articular repair of an isolated partial articular-surface tear of the subscapularis tendon. *Am J Sports Med* 2005;33:1825-1830.
15. Burkhart SS. Arthroscopic debridement and decompression for selected rotator cuff tears. Clinical results, pathomechanics, and patient selection based on biomechanical parameters. *Orthop Clin North Am* 1993;24:111-123.
16. Burkhart SS. Reconciling the paradox of rotator cuff repair versus debridement: A unified biomechanical rationale for the treatment of rotator cuff tears. *Arthroscopy* 1994;10:4-19.
17. Burkhart SS. Partial repair of massive rotator cuff tears: The evolution of a concept. *Orthop Clin North Am* 1997;28:125-132.
18. Turkel SJ, Panio MW, Marshall JL, Girgis FG. Stabilizing mechanisms preventing anterior dislocation of the glenohumeral joint. *J Bone Joint Surg Am* 1981;63:1208-1217.
19. Tung GA, Yoo DC, Levine SM, Brody JM, Green A. Subscapularis tendon tear: Primary and associated signs on MRI. *J Comput Assist Tomogr* 2001;25:417-424.