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# Subscapularis Tendon Tears: Detection and Grading at MR Arthrography<sup>1</sup>

**PURPOSE:** To assess diagnostic accuracy in the detection and grading of subscapularis tendon lesions at magnetic resonance (MR) arthrography.

**MATERIALS AND METHODS:** MR arthrograms in 50 consecutive patients (29 with normal subscapularis tendons, 11 with a lesion in the cranial quarter, seven with a major tear but not complete detachment, three with complete detachment) with arthroscopic or surgical confirmation were evaluated independently by two radiologists. Diagnosis was established on findings from transverse and/or parasagittal images.

**RESULTS:** With transverse images alone, sensitivity was 95%/100% (reader 1/reader 2); specificity was 55%/62%. With parasagittal images alone, sensitivity was 91%/91%; specificity was 76%/90%. With combined images, sensitivity was 91%/91%; specificity was 86%/79%. Interobserver agreement was substantial ( $\kappa = 0.67$ ). Forty-one of 50 (82%) grades for subscapularis abnormalities matched at MR imaging and surgery; nine mismatches differed by only one degree. Several signs were specific (90%–100%) but insensitive (29%–62%); these included leakage of contrast material onto the lesser tuberosity, fatty degeneration of the subscapularis muscle, and abnormality in the course of the long biceps tendon (luxation, subluxation).

**CONCLUSION:** MR arthrography is accurate in the detection and grading of subscapularis tendon lesions. Specificity of findings on transverse images for this diagnosis can be improved by including indirect signs and findings on parasagittal images.

Tears of the subscapularis tendon have recently received much attention in the orthopedic literature (1–6). The diagnosis can be difficult and may be missed clinically and on imaging studies. Moreover, subscapularis tendon lesions may be missed at arthroscopy or surgery when they are not specifically sought (1,4,7). In patients with suspected rotator cuff tears, the preoperative diagnosis of subscapularis tendon lesions is relevant because it may affect the surgical treatment plan.

Magnetic resonance (MR) imaging is accurate in the detection of abnormalities in the rotator cuff (8–13). However, most investigators have focused on supraspinatus tendon lesions. Little attention has been paid to disorders of the subscapularis tendon in the radiology literature (14,15). To our knowledge, no formal analysis of MR arthrography in the subscapularis tendon has been published. The purpose of this investigation was to assess the diagnostic accuracy of MR arthrography in the detection and grading of subscapularis tendon lesions.

## MATERIALS AND METHODS

### Patients

We retrospectively examined the records of 50 consecutive patients who fulfilled the following criteria: (a) MR arthrography of the shoulder was performed at our institution according to a standardized protocol; (b) all patients underwent surgery performed by a single specialized shoulder surgeon (C.G.); (c) no surgery had been performed previously;

(d) the surgery report provided a precise description of the subscapularis tendon; and (e) surgery was performed within less than 3 months of MR arthrography.

Thirty-five patients were men, and 15 were women. Their ages were between 21 and 76 years (mean age, 50.6 years). Open surgery was performed in 29 patients, and arthroscopic surgery was performed in the remaining 21. The indications for surgery or arthroscopy were rotator cuff tear ( $n = 28$ ), shoulder impingement syndrome ( $n = 7$ ), instability ( $n = 6$ ), or chronic shoulder pain with multiple clinical diagnoses ( $n = 9$ ).

At surgery, the subscapularis tendon was normal (grade 0) in 29 patients. A lesion of the upper margin (tear or tendon degeneration of less than one-quarter of the craniocaudal diameter, grade 1) (16) was observed in 11, major tears (more than one-quarter of the craniocaudal diameter of the tendon, but no complete detachment; grade 2) was observed in seven, and complete detachment of the tendon from the lesser tuberosity (grade 3) was observed in three. Additional intraoperative findings were full-thickness ( $n = 23$ ) or partial-thickness ( $n = 6$ ) tears of the supraspinatus and infraspinatus tendons, lesions of the long biceps tendon ( $n = 24$ ), and labral abnormalities ( $n = 11$ ).

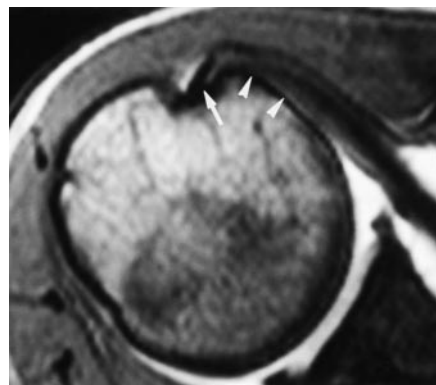
### MR Imaging Protocol

MR imaging was performed with a 1.0-T system (Impact; Siemens Medical Systems, Erlangen, Germany). The shoulder was placed in a dedicated receive-only shoulder coil with the arm in a neutral position and the thumb pointing upward. All patients underwent MR arthrography after an injection of 10 mL of diluted gadopentetate dimeglumine (Magnevist; Schering, Berlin, Germany) with a concentration of 4 mmol/L. Informed consent was obtained from the patients before MR arthrography. This method was approved by the ethics committee of the hospital and by the responsible state agency.

The imaging protocol included the acquisition of parasagittal, transverse, and angled coronal images, which were not further used in this investigation. Parasagittal T1-weighted turbo spin-echo MR images (700/12 [repetition time msec/echo time msec]) were obtained in a plane tangent to the rim of the glenoid. Fifteen sections with a thickness of 5 mm and an intersection gap of 1.5 mm were acquired. The field of view was 16 or 18 cm. The image matrix was  $192 \times 256$ , and the echo train length was three. Four sig-



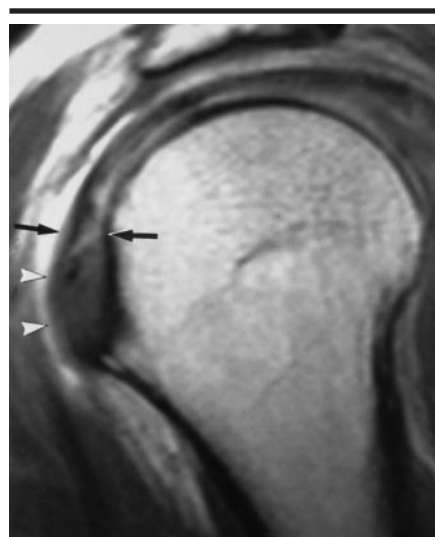
a.



b.

**Figure 1.** Grade 0: arthroscopically proved normal subscapularis tendon in a 19-year-old woman. (a) Parasagittal T1-weighted MR arthrographic image (700/12) shows a well-defined subscapularis tendon (arrowheads) with homogeneously hypointense signal. (b) Transverse gradient-echo MR arthrographic image (32/10, 40° flip angle) reveals an intact tendon (arrowheads). No contrast medium has leaked onto the lesser tuberosity. The long biceps tendon (arrow) is centered.

nals were acquired, which resulted in an imaging time of 3 minutes 20 seconds. To obtain the transverse images, a three-dimensional fast imaging sequence with steady-state precession (32/10), a flip angle of 40°, an 18-cm field of view, a 3.1-mm section thickness, and a  $192 \times 256$  matrix with one signal acquired was used. Imaging time was 1 minute 40 seconds. An angled coronal T2-weighted turbo spin-echo sequence and an angled coronal three-dimensional fast imaging with steady-state precession (FISP; Siemens Medical Systems) sequence were also used, but images obtained with these sequences not evaluated in this investigation.



a.

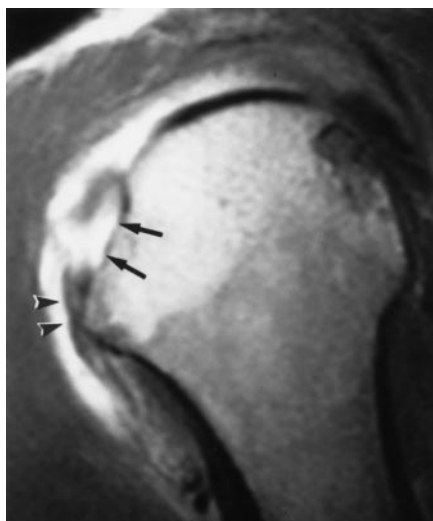


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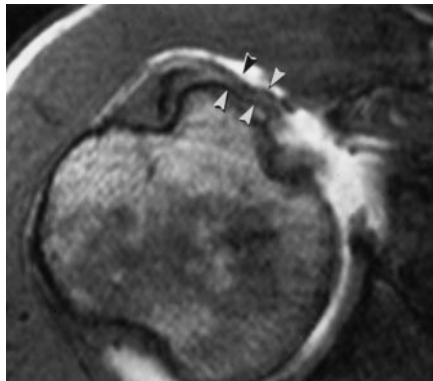
**Figure 2.** Grade 1: surgically proved lesion of the cranial subscapularis tendon in a 57-year-old man. (a) Parasagittal T1-weighted MR arthrographic image (700/12) shows fraying and signal alteration in the cranial part of the tendon (arrows). Other parts of the tendon (arrowheads) have a normal shape, with firm contact with the lesser tuberosity. (b) Transverse gradient-echo MR arthrographic image (32/10, 40° flip angle) shows a localized increase in the signal intensity in the substance at the tendon insertion (arrowheads) and shows a slight subluxation of the long biceps tendon (arrows).

### Analysis of MR Images

MR images were analyzed independently by two radiologists (M.Z., D.W.) who were specialized in musculoskeletal radiology. They were unaware of the surgical diagnosis. Three evaluations separated by 3-week intervals were performed. In the first session, only the parasagittal images were evaluated. In the second, only the transverse images were evaluated. In the third, one image from each imaging plane was made available. The



a.



b.

**Figure 3.** Grade 2: tear of the cranial three-quarters of the subscapularis tendon in a 49-year-old man with a supraspinatus tendon rupture. (a) Parasagittal T1-weighted MR arthrographic image (700/12) shows a large part of the subscapularis tendon (arrows) is missing. Lowest part of the tendon (arrowheads) remains attached. (b) Transverse gradient-echo MR arthrographic image (32/10, 40° flip angle) demonstrates that the lowest part of the subscapularis tendon (arrowheads) remains attached to the lesser tuberosity.

radiologists were asked to classify the subscapularis tendon as normal or abnormal and to grade abnormal tendons according to the system used in the surgery reports (16) (Figs 1–4). Imaging criteria for the classification of the subscapularis tendon as normal or abnormal were the following: discontinuity of the tendon, contrast media entering into the tendon substance, circumscribed signal alteration of the tendon, and caliber changes.

In addition, several signs that were considered to be helpful in diagnosing subscapularis tendon abnormalities were

**TABLE 1**  
Diagnostic Efficacy at MR Arthrography for Subscapularis Tendon Abnormalities

Value	Imaging Plane		
	Transverse	Parasagittal	Both
No. of true-positive cases	20/21	19/19	19/19
No. of true-negative cases	16/18	22/26	25/23
No. of false-positive cases	13/11	7/3	4/6
No. of false-negative cases	1/0	2/2	2/2
Sensitivity (%)	95/100	91/91	91/91
Specificity (%)	55/62	76/90	86/79
Accuracy (%)	72/78	82/90	88/84
Positive predictive value (%)	61/66	73/86	82/76
Negative predictive value (%)	94/100	92/93	92/92

Note.—Data are the number of normal versus abnormal findings for reader 1/findings for reader 2.

**TABLE 2**  
Agreement between Grades at MR Imaging and Surgery

Grade at MR	Grade at Surgery				Total
	0	1	2	3	
0	25	2	0	0	27
1	4	8	2	0	14
2	0	1	5	0	6
3	0	0	0	3	3
Total	29	11	7	3	50

Note.—Data are number of lesions. Grade 0 = normal tendon (Fig 1), grade 1 = tendon degeneration or tear of the cranial margin of the tendon that is less than one-quarter of the craniocaudal diameter (Fig 2), grade 2 = major tear that is more than one-quarter of the craniocaudal diameter of the tendon but not complete detachment (Fig 3), grade 3 = complete detachment of the tendon (Fig 4).

evaluated. This included (a) leakage of intraarticular contrast medium under the insertion of the subscapularis tendon onto the lesser tuberosity (transverse and parasagittal images) (1,6,7) (Fig 5), (b) presence of fatty infiltration in the subscapularis muscle (separate evaluation of the superior and inferior halves) (17–19) (Fig 6), and (c) abnormalities in the course of the long biceps tendon (subluxation, dislocation) (20–22) (Figs 2b, 4b).

### Statistical Analysis

Sensitivities, specificities, accuracies, and negative and positive predictive values were calculated for the ancillary signs and for the diagnosis of subscapularis tendon abnormalities on images in each plane. Interobserver agreement for the grading of subscapularis tendon lesions was calculated with  $\kappa$  statistics (23).

### RESULTS

Results are presented in Tables 1–4. Sensitivity for subscapularis tendon abnormalities was high for each imaging plane and for their combination, as follows: transverse, 95%/100% (reader 1/reader 2); parasagittal, 91%/91%; and combination of planes, 91%/91%. Specificity was moderate in the transverse plane alone (55%/62%). It was higher in the parasagittal planes (76%/90%) and in the combination of both planes (86%/79%).

Perfect agreement between MR arthrographic grading and surgical grading was achieved in 41 of 50 MR arthrographic diagnoses (82%). The nine remaining cases differed by only one degree. (Four were underdiagnosed, five were overdiagnosed.) Interobserver agreement for grading was also substantial ( $\kappa = 0.67$ ). All signs were insensitive (29%–62%) but specific (90%–100%). Fatty atrophy of the upper half of the subscapularis muscle was observed in 10 (reader 1) or six (reader 2) of 21 subscapularis tendon lesions. Sensitivity for fatty infiltration of subscapularis tendon tears was 48%/29%, and specificity was 100%/100%.

No correlation was found between subscapularis tendon abnormalities and fatty infiltration of the caudal part of the muscle ( $n =$  three for both readers). Abnormalities in the course of the long biceps tendon (luxation, subluxation) was observed in seven (reader 1) or eight (reader 2) cases; one case was false-positive for both readers (specificity, 97%/97%). Leakage of intraarticular contrast medium onto the lesser tuberosity was seen in nine (reader 1) or 10 (reader 2) patients on transverse images and in 15 patients (both readers) on parasagittal images. On transverse images, there were three (reader 1) or two (reader 2) false-positive cases (specificity, 90%/93%). On parasagittal images,



**TABLE 3**  
**Interobserver Agreement**

Findings for Observer 2	Findings for Observer 1				Total
	Grade 0	Grade 1	Grade 2	Grade 3	
Grade 0	23	2	0	0	25
Grade 1	4	12	4	0	20
Grade 2	0	0	2	0	2
Grade 3	0	0	0	3	3
Total	27	14	6	3	50

Note.—Data are number of lesions.  $\kappa = 0.67$ .

there were three (reader 1) or two (reader 2) (specificity, 90%/93%).

## DISCUSSION

The subscapularis muscle arises from the anterior surface of the scapula. Four to six thick collagen bundles that originate from the muscle belly insert at the lesser tuberosity. A number of fibers extend laterally and superiorly to form the medial wall of the biceps tendon groove and merge with the supraspinatus tendon (24). At the inferior part, the subscapularis tendon becomes shorter, and at the lowest part, the insertion is almost purely muscular. Tendon degeneration, degenerative tendon tears, and traumatic tears of the subscapularis tendon are most commonly located in the cranial part. The caudal part is usually involved with only extensive lesions. Lesions that are limited to the inferior part are exceptionally rare (16).

The following three types of subscapularis tendon lesions can be discriminated: (a) the isolated subscapularis tendon tear (1,2), (b) the involvement of the subscapularis in large rotator cuff tears (4), and (c) the anterosuperior lesions of the rotator cuff (7,16). The isolated complete tear of the subscapularis tendon is rare. Its pathogenesis is usually traumatic and occurs after forceful external rotation of the adducted arm (1,2). Anterior shoulder dislocation and recurrent anterior instability have also been reported to be associated with isolated subscapularis tendon tears (25). The anterior extension of a large supraspinatus tear to the subscapularis tendon is far more frequent than are the isolated traumatic tears (4). The last type of tear that involves the subscapularis tendon is the anterosuperior lesion of the rotator cuff. It involves the interval structures of the rotator cuff such as the coracohumeral ligament, the superior glenohumeral ligament, and the adjacent borders of the supraspinatus and subscapularis

tendons (7). Anterior extension of a large rotator cuff tear was observed in 16 of our patients. Four subscapularis tendon tears were limited to the anterosuperior complex. Only one patient had an isolated subscapularis tendon tear.

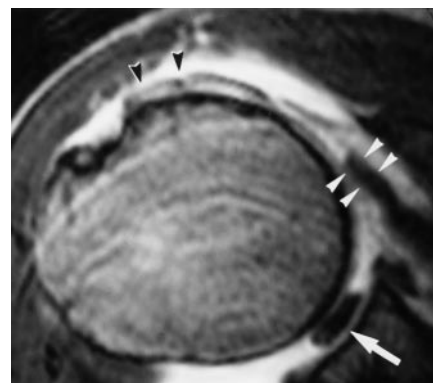
Lesions in the cranial part of the subscapularis tendon may be difficult to diagnose clinically and may even be missed during surgery if they are not specifically sought. Therefore, some authors suggest routine exploration of structures adjacent to the rotator interval in patients with supraspinatus tears during surgery because lesions can be missed without specific inspection (7). Even if a subscapularis tear is recognized, its extent may be difficult to assess during surgery because integrity may be mimicked by a scar that bridges the defect between the torn, medially retracted tendon and the lesser tuberosity. This scar can be mistaken for an intact tendon (1,4). Therefore, preoperative diagnosis of a subscapularis tendon lesion is important for the surgeon. During arthroscopy, the articular surface of the capsule may be visually intact in patients with complete subscapularis tendon tears. On probing, the finding of an unusually soft and elastic capsule may lead to the correct diagnosis (1).

Treatment for subscapularis tendon lesions is variable and depends mainly on the functional demand of the patient and the extent of the lesion. Conservative treatment with physiotherapy, corticosteroid injections, and pain medication is appropriate in patients with little functional demand. Arthroscopic débridement leads to pain relief and is indicated as a palliative treatment for small tears or tendon degeneration and for very large (inoperable) tears (16). Open surgery is performed mainly to restore function in younger patients or patients with high functional demand. Large irreparable tears are treated by transferring the pectoralis major tendon to the lesser tuberosity (5).

The success of surgical treatment is



a.

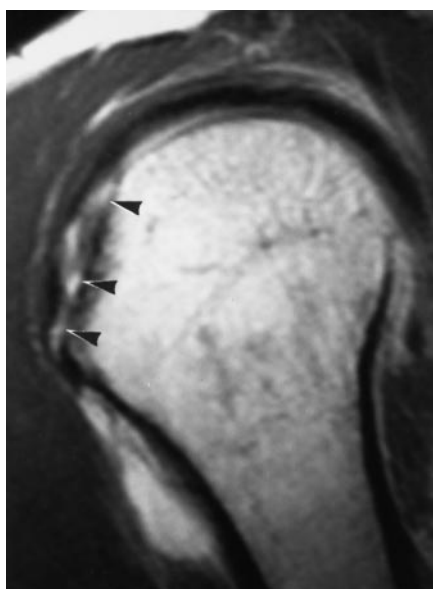


b.

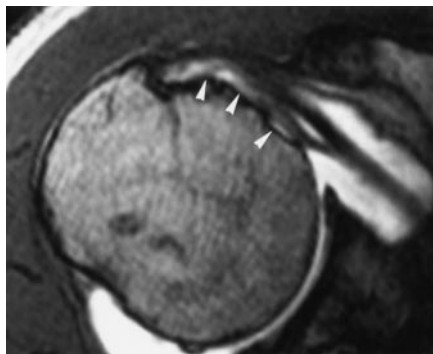
**Figure 4.** Grade 3: complete tear of the subscapularis tendon in a 68-year-old woman. (a) Parasagittal T1-weighted MR arthrographic image (700/12) shows a completely absent subscapularis tendon (arrows). (b) Transverse gradient-echo MR arthrographic image (32/10, 40° flip angle) shows the subscapularis tendon (white arrowheads) is medially retracted. Some fibrous strands (black arrowheads) partially cover the lesser tuberosity. The long head of the biceps tendon (arrow) is dislocated medially and is located between the humeral head and glenoid. Despite standard positioning of the patient, the humerus is externally rotated. (This phenomenon was present in all three patients with complete subscapularis tendon rupture.)

jeopardized by delayed diagnosis. In two series published in the orthopedics literature (1,3), the mean delay to surgery was 9 or 15 months. In one of these series (3), a subscapularis tendon tear was not diagnosed in the shoulders of 12 of 14 patients until MR imaging was performed. Therefore, imaging can reduce the delay in surgical intervention.

MR arthrography is superior to standard MR imaging in the depiction of partial tears in the supraspinatus and



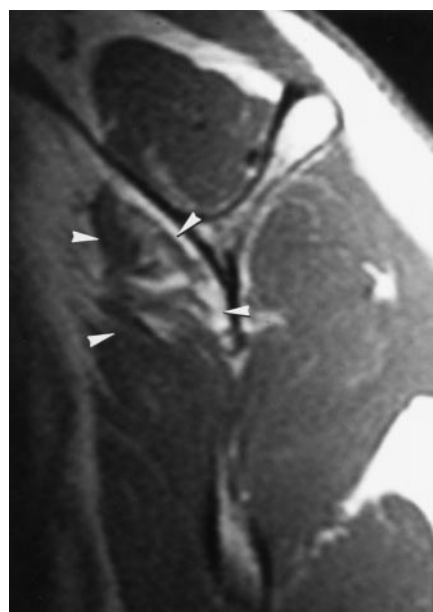
a.



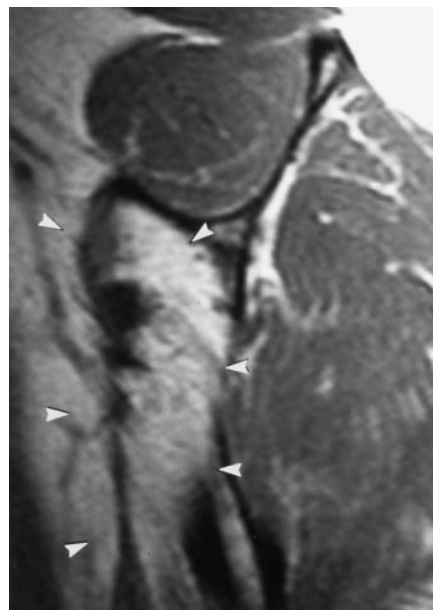
b.

**Figure 5.** Ancillary signs: leakage of contrast material (arrowheads) onto the lesser tuberosity and a grade 2 subscapularis tendon lesion in a 67-year-old man. (a) Parasagittal T1-weighted MR arthrographic image (700/12) shows contrast material has extended under the insertion of the subscapularis tendon onto the lesser tuberosity. (b) Corresponding transverse gradient-echo MR arthrographic image (32/10, 40° flip angle) shows contrast medium has leaked onto the lesser tuberosity.

infraspinatus tendons (11). For this reason, we routinely use MR arthrography in our institution when the differentiation among degeneration, partial tears, and small full-thickness tears in the rotator cuff is of clinical importance. The sensitivity is between 71% and 100%, and specificity is between 84% and 100% (11,12). In our study, sensitivity was 91% and specificity was 86% for the detection of subscapularis tendon lesions; thus, these findings lie within the range of findings for other rotator cuff abnormalities. Because diagnostic accuracy of fat-saturated MR imaging is known to be superior to



a.



b.

**Figure 6.** Ancillary sign: fatty infiltration of the subscapularis muscle. (a) Parasagittal T1-weighted MR image (700/12) obtained 3 cm medial to the glenoid (left side of the image is anterior) in a 68-year-old woman with a complete tear of the subscapularis tendon (same patient as in Fig 4) shows fatty atrophy (arrowheads) in the cranial part of the subscapularis muscle. Inferior parts of the rotator cuff muscles are normal. (b) Parasagittal T1-weighted MR image (700/12) obtained 3 cm medial to the glenohumeral joint (left side of the image is anterior) in a 43-year-old man with a complete subscapularis tendon tear shows almost complete atrophy and fatty replacement of the subscapularis muscle (arrowheads). Supraspinatus and infraspinatus muscles are normal.

scapularis tendon lesions (1,4,7). When using these data, readers must be aware of the small number of patients ( $n = 21$ ) with subscapularis tendon tears. The grading system used in this study reflected the development of subscapularis tendon tears, usually in a craniocaudal direction at the site of the insertion at the lesser tuberosity. It may not be suitable for all subscapularis tendon lesions, such as tears medial to the insertion, at the lesser tuberosity, or tears in the muscular part.

In previous investigations, the transverse images have usually been preferred for the depiction of subscapularis tendon abnormalities (3,14). However, at MR imaging in other tendons and ligaments (in the ankle or occasionally in the knee), images that are oriented perpendicularly to the structure under investigation have been advocated (26,27). Our results indicate that such an imaging strategy may also be useful for depicting the subscapularis tendon. Specificity for subscapularis tendon abnormalities with parasagittal images was higher than that obtained with transverse images (76%/90% vs 55%/62%), although comparable sensitivities were found. With regard to grading, parasagittal images were superior to transverse images ( $\kappa = 0.59/0.73$  vs  $\kappa = 0.33/0.38$ ).

The leakage of contrast material from the joint space onto the lesser tuberosity has been described as a sign for subscapularis tendon tear at standard or computed tomographic arthrography (1,28,29). In our investigation, this sign was specific (90%/93%). However, its sensitivity was poor and varied for observers and imaging planes (29%–62%) (Fig 5). Scar tissue that prevents the leakage of contrast media into defects in the subscapularis tendon could be a cause of false-negative diagnoses at MR arthrography.

Muscle atrophy and fatty degeneration develop after rotator cuff tears occur and

**TABLE 4**  
Diagnostic Value of Ancillary MR Arthrographic Signs for Subscapularis Tendon Abnormality

Ancillary Sign	No. of True-Positive Cases	No. of True-Negative Cases	No. of False-Positive Cases	No. of False-Negative Cases	Sensitivity (%)	Specificity (%)	Accuracy (%)	Positive Predictive Value (%)	Negative Predictive Value (%)
Fatty atrophy of the subscapularis muscle (upper half)	10/6	29/29	0/0	11/15	48/29	100/100	78/70	100/100	73/66
Abnormality in the course of the long biceps tendon	6/7	28/28	1/1	15/14	29/33	97/97	68/70	86/88	65/67
Leakage of contrast material onto the lesser tuberosity (transverse images)	6/8	26/27	3/2	15/13	29/38	90/93	64/70	67/80	63/68
Leakage of contrast material in front of the lesser tuberosity (parasagittal images)	12/13	26/27	3/2	9/8	57/62	90/93	76/80	80/86	74/77

Note.—Data are findings for reader 1/findings for reader 2.

are an important (negative) predictor for the success of surgical interventions (4,16,18). There is a delay of at least 6 weeks for fatty infiltration to develop (18). Fatty infiltration that involves more than half of the cross-sectional area of the muscle has been considered to be a relative contraindication for surgical reconstruction. Therefore, preoperative assessment with imaging studies is important (16). Besides the therapeutic impact, atrophy and fatty infiltration may be helpful for correct diagnosis during MR imaging (Fig 6). Atrophy of the supraspinatus muscle and fatty infiltration has been shown to be specific (97%) for a rotator cuff tear (17). On the basis of our results, the presence of fatty degeneration as diagnosed on MR images is also a specific sign for subscapularis tendon lesions. Fatty atrophy must be evaluated in the cranial part of the subscapularis muscle because the inferior part is rarely involved.

Biceps tendon abnormalities are associated with subscapularis tendon abnormalities because of a close anatomic relationship (14,20,21). Some authors (4,16) consider medial dislocation of the long biceps tendon to be diagnostic for a subscapularis tendon tear. Our results support the importance of this association. In the presence of a biceps tendon subluxation or dislocation, a subscapularis tendon lesion must be suspected (Figs 2b, 4b). Tendinopathy or partial volume effects in the long biceps tendon might influence the assessment of the subscapularis tendon at its cranial border and could be a potential cause of diagnostic error.

In conclusion, MR arthrography is accurate in the detection and grading of lesions in the subscapularis tendon. The specificity of findings on transverse images for this diagnosis can be improved

by including ancillary signs and findings from parasagittal images.

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