Delaminated Tears of the Rotator Cuff: Prevalence, Characteristics, and Diagnostic Accuracy Using Indirect MR Arthrography

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OBJECTIVE. The purpose of this study was to evaluate the prevalence, radiologic characteristics, and accuracy of diagnosing delaminated tears at the supraspinatus tendon–infraspinatus tendon (SST-IST) on indirect MR arthrography.

MATERIALS AND METHODS. Of 531 consecutive shoulders that underwent indirect MR arthrography, 231 shoulders with tears at the SST-IST were included. On the MR images, delaminated tears at the SST-IST, defined as intratendinous horizontal splitting between the articular and bursal layers of the SST-IST with or without different degrees of retraction between the two layers, were identified and classified into six types. Other radiologic findings of the SST-IST, such as the presence of intramuscular cysts, were evaluated. We used video records of 127 arthroscopic surgeries to determine the diagnostic accuracy of indirect MRI for the detection of the delaminated tears at the SST-IST.

RESULTS. On MRI, 56% (129/231) of shoulders with SST-IST tears had delaminated tears. Articular-delaminated full-thickness tears (n = 58) and articular-delaminated partial-thickness tears (n = 64) were the most common types. Approximately 82% (36/44) of articular-delaminated full-thickness tears occurring at the SST were combined with articular-delaminated partial-thickness tears at the IST. SST-IST footprint tears and intramuscular cysts were significantly more common in the shoulders with delaminated tears. The sensitivity and specificity of indirect MR arthrography for detection of delaminated tears were 92% and 94%, respectively.

CONCLUSION. On indirect MR arthrography, approximately half of the shoulders with SST-IST tears had delaminated tears. The diagnostic accuracy of indirect MR arthrography for detection of delaminated tears was high.

Keywords: arthrography, MRI, rotator cuff, shoulder

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The outcome of rotator cuff repairs is influenced by multiple factors. Several reports concur that the presence of delaminated tears is a negative prognostic factor in functional and morphologic results after rotator cuff repairs [1–3]. Delaminated tears of the rotator cuff have usually been described as a horizontal split of the tendon substance [4, 5]. To improve the outcomes after repair of rotator cuff tears, surgeons have treated delaminated tears differently, such as with interlaminar curettage, layer-to-layer suturing, resection of the flap, and additional suture fixation across the delaminated portion [3, 5–7]. Thus, preoperative detection of delaminated tears is important in planning the appropriate surgical method. However, there are few radiologic reports on delaminated tears of the rotator cuff, and the prevalence of delaminated tears identified on the basis of MRI is low compared with that identified on the basis of surgical findings [1, 2, 5, 6, 8–10]. Moreover, to our knowledge, there is no study in the English language literature of the diagnostic accuracy of MRI for detection of delaminated tears on the basis of surgical results. Therefore, the prevalence, radiologic characteristics, and accuracy of diagnosing delaminated tears at the supraspinatus tendon–infraspinatus tendon (SST-IST) on indirect MR arthrography were evaluated in this study.

Materials and Methods

Subjects

This retrospective study was approved by our institutional review board for human research. Informed consent was waived. A total of 564 consecutive indirect shoulder MR arthrography studies in 531 patients with shoulder discomfort were performed at our institution between January 2011 and December 2013. Of the 564 shoulders, 99 were excluded because of a history of shoulder surgery (n = 18), an infectious condition (n = 34), an acute

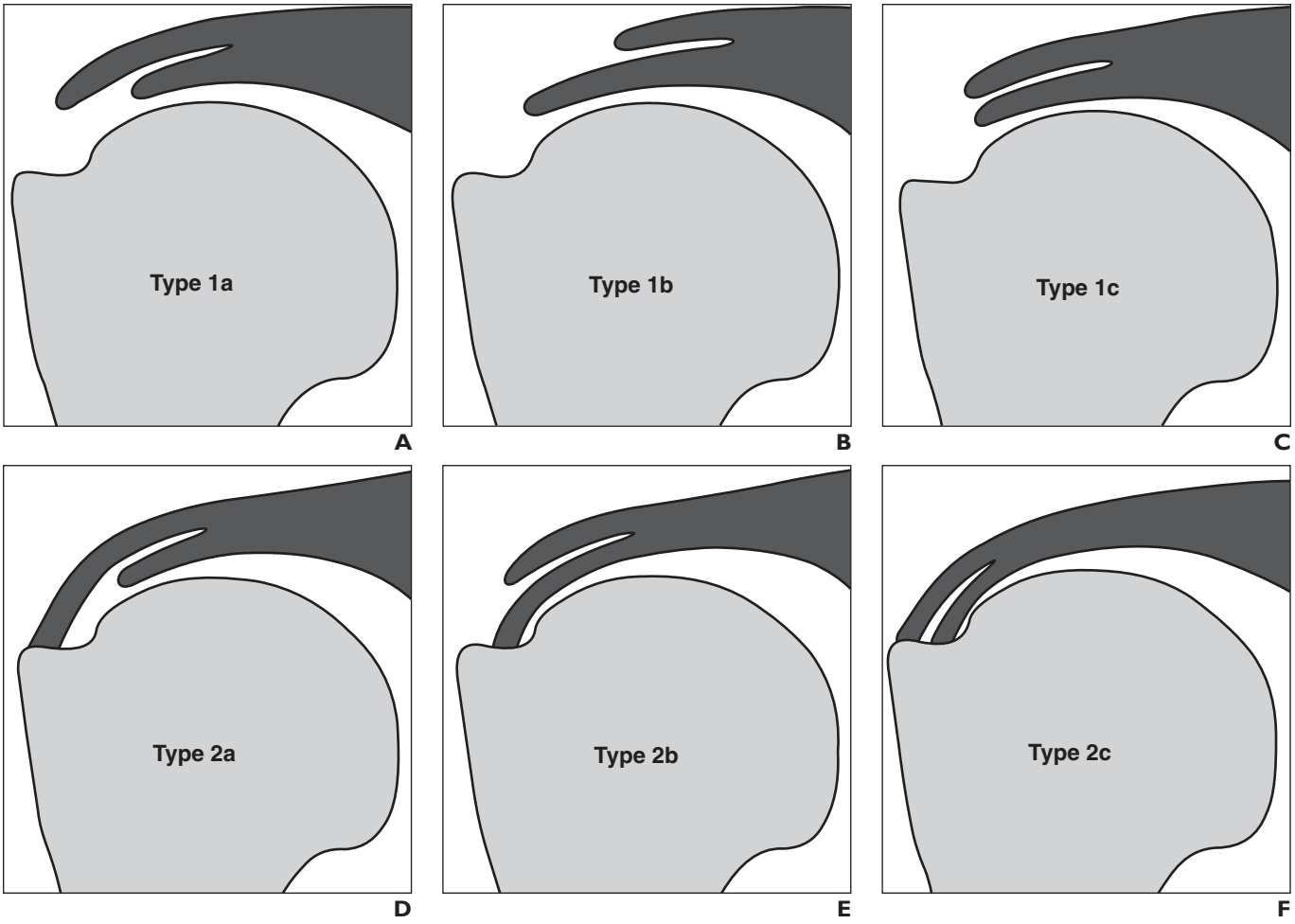

Fig. 1—Drawings of shoulders in oblique coronal plane show six types of delaminated tears at supraspinatus-infraspinatus tendons.
A–F, Drawings show articular-delaminated full-thickness tear (type 1a) (**A**), defined as full-thickness tear in which articular layer is more medially retracted than bursal layer, with or without intratendinous horizontal splitting tear; bursal-delaminated full-thickness tear (type 1b) (**B**), defined as full-thickness tear in which bursal layer is more medially retracted than articular layer, with or without intratendinous horizontal splitting tear; intratendinous-delaminated full-thickness tear (type 1c) (**C**), defined as full-thickness tear in which articular layer is equally retracted to bursal layer, combined with intratendinous horizontal splitting tear; articular-delaminated partial-thickness tear (type 2a) (**D**), defined as articular-surface partial-thickness tear with intratendinous horizontal splitting tear; bursal-delaminated partial-thickness tear (type 2b) (**E**), defined as bursal-surface partial-thickness tear with intratendinous horizontal splitting tear; and intratendinous-delaminated partial-thickness tear (type 2c) (**F**), defined as isolated intratendinous horizontal splitting tear.

fracture (n = 11), calcific tendinitis (n = 29), and poor imaging quality (n = 7). The MR images of the remaining shoulders (n = 465) were evaluated by a musculoskeletal radiologist with 8 years of experience who selected the cases with tears at the SST-IST. Finally, MR images of 231 shoulders with SST-IST tears were included in this study.

MRI

Indirect MR arthrography was performed using a 3-T MR scanner (Achieva 3 T TX, Philips Healthcare) with a 32-element channel coil and with the arm in the neutral position. For the imaging, 0.1 mmol/kg of MR contrast medium (gadobutrol, Gadovist, Bayer Schering Pharma) was administered IV. The patients were instructed to move their shoulders gently for 15 minutes before MRI. The imaging protocol used in this study included T2-weighted fast spin-echo sequences in the oblique coronal and oblique sagittal planes (TR/TE, 2525.2/80; matrix size, 332 × 264; and echo-train length, 16), and fat-suppressed T1-weighted fast spin-echo sequences in the oblique coronal plane (TR/TE, 603.6/10; matrix size, 320 × 258; and echo-train length, 6) and oblique sagittal plane (TR/TE, 603.6/10; matrix size, 320 × 258; and echo-train length, 3). All the sequences had a 3-mm slice thickness with a 0.1-mm interslice gap and 150 × 150 mm FOV and were generated from two averaged signals.

Image Analysis

MR images were retrospectively analyzed in consensus by two musculoskeletal radiologists including the radiologist who reviewed the MR images to select the study population. In this study, a delaminated tear was defined as an intratendinous horizontal splitting between the articular and bursal layers of the SST-IST with or without different degrees of retraction between the two layers, provided that the cleft in the intratendinous horizontal splitting tear was manifested as high signal intensity on fat-suppressed T1-weighted or T2-weighted imaging. The delaminated tears were classified into the following six types (Figs. 1 and 2): Articular-delaminated full-thickness tear (type 1a) was defined as a full-thickness tear in which the articular layer was more medially retracted than the bursal layer, with or without an intratendinous horizontal splitting tear. Bursal-delaminated full-thickness tear (type 1b) was defined as a full-thickness tear in which the bursal layer was more medially retracted than the articular layer, with or without an intratendinous horizontal splitting

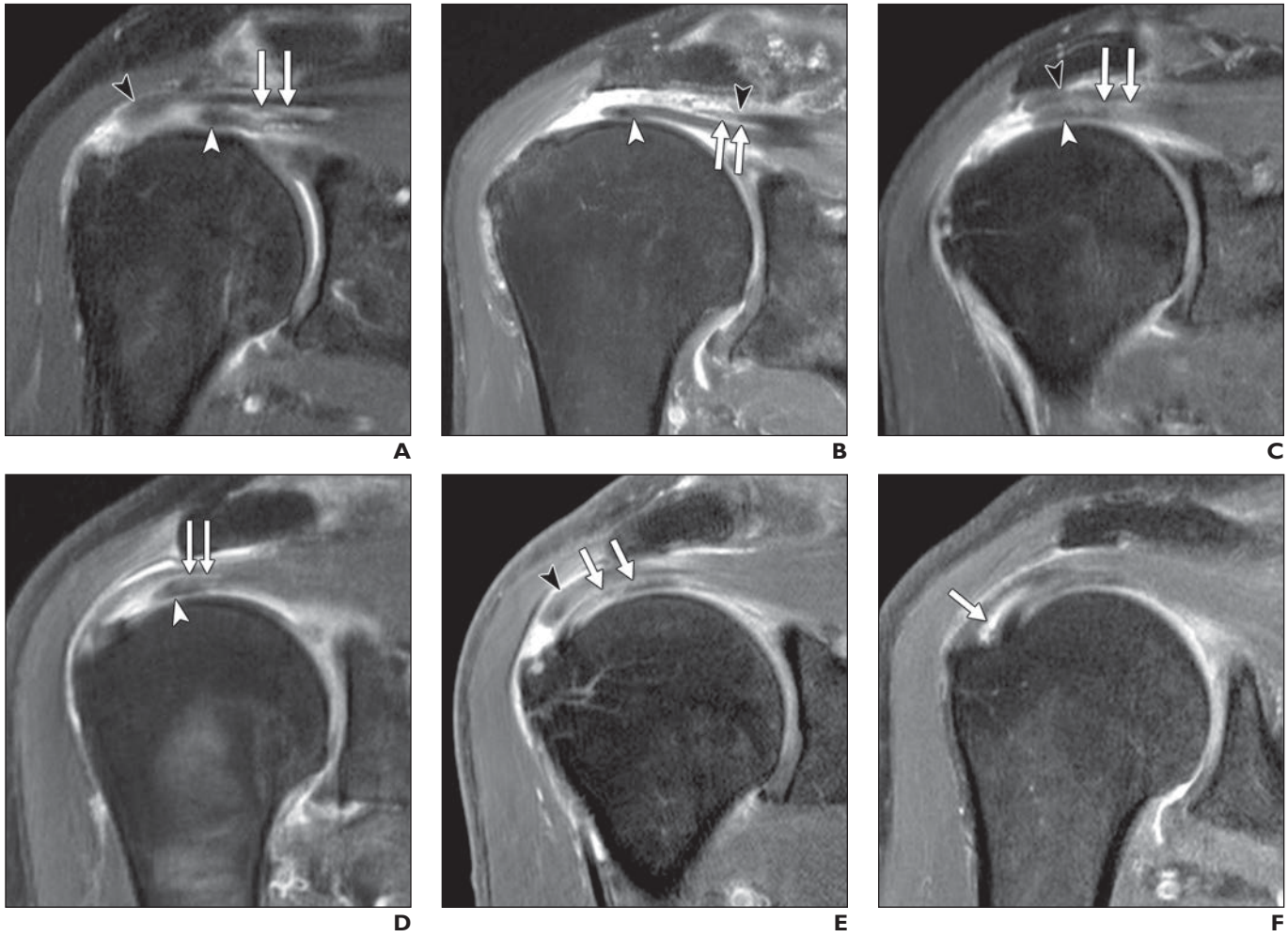

Fig. 2—Fat-suppressed T1-weighted coronal images of indirect MR arthrography of shoulders show six types of delaminated tears at supraspinatus-infraspinatus tendons. **A–F,** Serial MR images show articular-delaminated full-thickness tear in 59-year-old man (type 1a) (**A**), bursal-delaminated full-thickness tear in 58-year-old man (type 1b) (**B**), intratendinous-delaminated full-thickness tear in 64-year-old man (type 1c) (**C**), articular-delaminated partial-thickness tear in 58-year-old man (type 2a) (**D**), bursal-delaminated partial-thickness tear in 69-year-old man (type 2b) (**E**), and intratendinous-delaminated partial-thickness tear in 51-year-old man (type 2c) (**F**). Intratendinous horizontal clefts in each of delaminated tears are shown as high signal intensity on images (*arrows*). White arrowhead indicates articular layer, and black arrowhead indicates bursal layer.

tear. Intratendinous-delaminated full-thickness tear (type 1c) was defined as a full-thickness tear in which the articular layer was equally retracted to the bursal layer, combined with an intratendinous horizontal splitting tear. Articular-delaminated partial-thickness tear (type 2a) was defined as an articular-surface partial-thickness tear with an intratendinous horizontal splitting tear. Bursal-delaminated partial-thickness tear (type 2b) was defined as a bursal-surface partial-thickness tear with an intratendinous horizontal splitting tear. Intratendinous-delaminated partial-thickness tear (type 2c) was defined as an isolated intratendinous horizontal splitting tear.

During the review of the MR images, the presence of the delaminated tears was determined and other radiologic features of the shoulders were evaluated: tear type of the SST-IST (full-thickness tear vs partial-thickness tear); tear size of the SST-IST in the medial-lateral dimension; thickness of the rotator cable; and presence of SST-IST footprint tears, intramuscular cysts, subscapularis tendon tears, biceps tendon tears, and labral detachment. When both partial-thickness and full-thickness tears occurred simultaneously at the SST-IST of a single shoulder, the SST-IST tear type was described as a full-thickness tear and the tear size of the full-thickness tear was regarded as the tear size of the SST-IST tear. The rotator cable was defined as an anteroposteriorly extended hypointense bandlike structure on the undersurface of the SST-IST, anteriorly blended with the coracohumeral ligament. To measure the thickness of the rotator cable, the sagittal T2-weighted image on which the rotator cable was most defined and thickest was selected, and on this slice the thickness of the rotator cable in the 11-o'clock position was measured [11] (Fig. 3). Intramuscular cysts were defined as oval or round fluid collections within the muscles of the SST-IST [12]. SST-IST footprint tears were defined as SST-IST tears involving the humeral insertion of the SST and IST [13].

In each delaminated tear, the specific type, anatomic location, and length were determined. The anatomic location of the delaminated tear was categorized as SST, IST, or SST-IST. The length of the delaminated tear was defined as the sum of the medial-to-lateral extent of the intratendinous horizontal splitting tear and the medial-to-lateral degree of the retraction difference between the articular and bursal layers of the tendon. This tear was measured on coronal fat-suppressed T1-weighted or T2-weighted images.

Review of Arthroscopic Records

Among the 231 shoulders, 131 underwent shoulder arthroscopic surgery by an orthopedic shoulder specialist after shoulder MRI. After discussion regarding the definition of delaminated tears of the SST-IST, video records of the arthroscop-

ic surgeries were reviewed by the orthopedic surgeon who performed the arthroscopic surgery to determine the presence of the delaminated tear and to classify the type of the delaminated tear. During the review of the video records, the surgeons were blinded to the MR findings. Among the 131 arthroscopic video records, four were excluded because of incomplete arthroscopic video records ($n = 3$) and relatively long time interval (4 months) between MRI and shoulder surgery ($n = 1$). In the 127 included cases, the mean time interval between MRI and shoulder arthroscopic surgery was 7.5 days (range, 0–70 days).

Statistical Analysis

Demographic and radiologic characteristics were compared between the shoulders with delaminated tears and nondelaminated tears. The chi-square test was used for categoric data and the Mann-Whitney *U* test for continuous data. The location and degree of the delaminated tears were compared among the six types of delaminated tears using the Fisher exact test and Kruskal-Wallis test. Using the arthroscopic results as the reference standard, the sensitivity, specificity, and accuracy for diagnosis of the delaminated tears on indirect MR arthrography were calculated. A p value of less than 0.05 was considered significant. All statistical analyses were performed using statistical software (SPSS, version 20.0, IBM, and SAS, version 9.3 for Windows, SAS Institute).

Results

Prevalence and Characteristics of Delaminated Tears

Of 231 shoulders, 129 (56%) in 122 patients had delaminated SST-IST tears. Of the 122 patients, 75 were women and 47 were men. The remaining 102 shoulders in 96 patients had nondelaminated SST-IST tears and the 96 patients included 55 women and 41 men. The sex and age of the patients did not differ significantly between shoulders with delaminated tears and those with nondelaminated tears (Table 1).

The distribution of the SST-IST tear type was not significantly different between the shoulders with delaminated tears and those with nondelaminated tears. However, regarding the medial-to-lateral tear size of the SST-IST, in the partial-thickness tears of the SST-IST, the tear size was significantly longer in the shoulders with delaminated tears than in those with nondelaminated tears ($p < 0.001$), whereas in the full-thickness tears of the SST-IST, the tear size was significantly shorter in the shoulders with delaminated tears than in those with nondelaminated tears ($p < 0.001$). The rotator cables were not identified on MR images in three shoulders with delaminated tears and 15 with nondelaminated tears; therefore, these 18 shoulders were excluded for the measurement of the rotator cable. In the remaining shoulders, the thickness of the rotator cable did not differ significantly between the shoulders with delaminated tears and those with nondelaminated tears in subgroups of full-thickness tears and partial-thickness tears. SST-IST footprint tears and intramuscular cysts were significantly more common in the shoulders with delaminated tears than in those with nondelaminated tears ($p = 0.007$ and 0.01, respectively). However, the prevalence of tears at the labrum, subscapularis tendon, and long head of the biceps ten-

TABLE 1: Comparison of Demographic and Radiologic Findings Between Shoulders With Delaminated Tears and Nondelaminated Tears

Characteristic	Shoulders With Delaminated Tears ($n = 129$)	Shoulders With Nondelaminated Tears ($n = 102$)	p
Sex[a]			
Female	77 (60)	57 (56)	0.59
Male	52 (40)	45 (44)	
Age (y)[b]			
Female	62 (43–79)	59 (46–71)	0.88
Male	58 (41–81)	58 (21–74)	0.69
Tear type[a]			
Partial-thickness	61 (47)	58 (57)	0.19
Full-thickness	68 (53)	44 (43)	
Tear size (mm)[b]			
Partial-thickness	8.6 (1.7–26.4)	5.7 (1.0–45.0)	< 0.001
Full-thickness	13.9 (2.8–44.0)	26.0 (1.1–54.0)	< 0.001
Thickness of rotator cable (mm)[b]			
Partial-thickness	1.3 (0.6–2.5)	1.2 (0.4–2.3)	0.24
Full-thickness	1.9 (0.8–4.5)	1.7 (0.6–2.7)	0.12
Footprint tear[a]	103 (78)	65 (64)	0.007
Intramuscular cyst[a]	49 (38)	22 (22)	0.01
Labrum tear[a]	57 (44)	40 (39)	0.42
Subscapular tendon tear[a]	70 (54)	57 (56)	1.00
Biceps tendon tear[a]	49 (38)	43 (42)	0.59

[a]Data are number of cases with percentage in parentheses.
[b]Data are median with range in parentheses.

TABLE 2: Anatomic Location and Length of Delamination Tears According to Six Types of Delaminated Tears

	Anatomic Location of Delamination Tear (No.)			Length of Delamination Tear (mm)	
Type	SST	IST	SST and IST	Median	Range
1a ($n = 57$)	44	1	12	14.81	5.2–32.5
1b ($n = 5$)	4	0	1	16.04	6.3–18.5
1c ($n = 3$)	3	0	0	19.00	15.2–22.0
2a ($n = 63$)	14	43	6	9.02	4.3–20.0
2b ($n = 20$)	20	0	0	12.86	4.2–28.1
2c ($n = 22$)	16	4	2	12.29	3.9–28.0

Note—Type 1a = articular-delaminated full-thickness tear, 1b = bursal-delaminated full-thickness tear, 1c = intratendinous-delaminated full-thickness tear, 2a = articular-delaminated partial-thickness tear, 2b = bursal-delaminated partial-thickness tear, and 2c = intratendinous-delaminated partial-thickness tear, SST = supraspinatus tendon, IST = infraspinatus tendon. All p values < 0.001.

don did not significantly differ between the shoulders with delaminated tears and those with nondelaminated tears (Table 1).

Types of Delaminated Tears

In the 129 shoulders with delaminated tears, 170 were identified because 41 shoulders presented with two types of delaminated tears. Articular-delaminated full-thickness tears (type 1a, $n = 57$) and articular-delaminated partial-thickness tears (type 2a, $n = 63$) accounted for 71% of the total delaminated tears. All types of delaminated tears usually occurred at the SST, except the articular-delaminated partial-thickness tears (type 2a) (Table 2).

The two types of delaminated tears present in a single shoulder were composed of the following combinations: articular-delaminated full-thickness tear (type 1a) at the SST and articular-delaminated partial-thickness tear at the IST (type 2a) ($n = 36$), bursal-delaminated full-thickness tear (type 1b) at the SST and articular-delaminated partial-thickness tear at the IST (type 2a) ($n = 3$), and intratendinous-delaminated full-thickness tear (type 1c) at the SST and articular-delaminated partial-thickness tear (type 2a) at the IST ($n = 2$). In other words, 80% (41/51) of the delaminated full-thickness tears at the SST were combined with delaminated partial-thickness tears at the IST; 82% (36/44) of the articular-delaminated full-thickness tears (type 1a) at the SST, 75% (3/4) of the bursal-delaminated full-thickness tears (type 1b) at the SST, and 67% (2/3) of the interstitial-delaminated full-thickness tears (type 1c) at the SST were combined with articular-delaminated partial-thickness tears (type 2a) at the IST (Fig. 4).

Interestingly, there were three cases of delaminated partial-thickness tear, although the tear types of the SST-IST were full-thickness tears. Two presented with articular-delaminated partial-thickness tears at the IST and nondelaminated full-thickness tears at the SST and one presented with an intratendinous-delaminated partial-thickness tear at the SST and nondelaminated full-thickness tear at the IST.

The median length of the delaminated tear was 12.9 mm (range, 3.9–32.5 mm). Among the six types, the length of the delaminated tear was greatest in the bursal-delaminated full-thickness tear (type 1b) and smallest in the articular-delaminated partial-thickness tear (type 2a) (Table 2).

Diagnostic Accuracy

In the 127 arthroscopic surgeries, 82 full-thickness tears of the SST-IST and 45 partial-thickness tears of the SST-IST were found. In two shoulders, full-thickness tears of the SST-IST confirmed by arthroscopic surgery were interpreted as partial-thickness tears on MRI. However, in the other shoulders, the tear type of SST-IST perfectly corresponded between arthroscopic and MR findings. Thus, the sensitivity and specificity for MRI were 98% (80/82) and 100% (45/45) for diagnosis of full-thickness tears of SST-IST and 100% (45/45) and 98% (80/82) for diagnosis of partial-thickness tears.

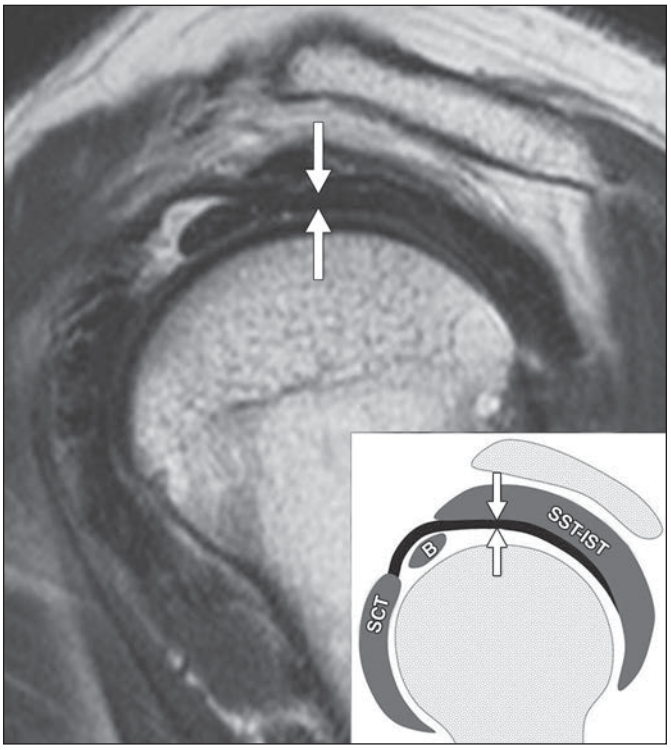

Fig. 3—In T2-weighted sagittal image of indirect MR arthrography of shoulder in 54-year-old woman, rotator cable (*arrows*) is seen as anteroposteriorly extended hypointense bandlike structure under supraspinatus tendon–infraspinatus tendon (SST-IST), which is anteriorly blended with coracohumeral ligament. Thickness of rotator cable is measured in 11-o'clock position. At right lower corner of image, drawing of shoulder on sagittal plane is provided to show rotator cable (*arrows*). SCT = subscapularis tendon, B = biceps tendon.

In the regard to the presence of the delaminated tears in the SST-IST, 78 shoulders had the delaminated tears on the basis of arthroscopic results. In six shoulders, the delaminated tears confirmed by arthroscopic surgery were not detected on MRI, whereas in three shoulders, delaminated tears detected on MRI were not confirmed at arthroscopic surgery. Thus, the sensitivity, specificity, and accuracy of MRI to diagnose the presence of the delaminated tears of the SST-IST were 92% (72/78), 94% (46/49), and 94% (119/127), respectively.

In regard to the types of the delaminated tears of the SST-IST, arthroscopy confirmed 49 articular-delaminated full-thickness tears (type 1a), three bursal-delaminated full-thickness tears (type 1b), two intratendinous-delaminated full-thickness tears (type 1c), 29 articular-delaminated partial-thickness tears (type 2a), 15 bursal-delaminated partial-thickness tears (type 2b), and seven intratendinous-delaminated partial-thickness tears (type 2c). The sensitivity, specificity, and accuracy of indirect MRI to diagnose each type of delaminated tear were good and are listed in Table 3.

Discussion

The cause of delamination tears may be multifactorial. Sonnabend et al. [4] determined that the delamination tear occurred between layers of differing collagen fiber orientation and presumed that delamination was a separation between layers 2 and 3 of the rotator cuff [14]. Dissimilar stress between two layers of the rotator cuff and local ischemia related to hypertrophic changes in the small arteries of the rotator cuff have been postulated as causes of delaminated tears [4, 15].

In the orthopedic literature, the prevalence of delaminated tears of the rotator cuff ranges from 38% to 92%, depending on the method of surgery and definition of delaminated tears [1–3, 5, 6, 8]. There are few reports on delaminated tears in the radiologic literature, and the prevalence of delaminated tears based on MRI is low compared with that in the orthopedic literature. In a study using 548 shoulders that underwent conventional MRI in 2007, only 10 (1.8%) had delaminated tears at the SST-IST [10].

In another study [9] in 2002 in which only delaminated partial-thickness tears at the SST-IST were evaluated, the prevalence of delaminated tears was only 3.9% on direct MR arthrography. However, in our study, the prevalence of delaminated tears at the SST-IST was 23% (129/564) among the shoulders that underwent indirect MR arthrography and 56% (129/231) among the shoulders with SST-IST tears diagnosed on MRI; these results are similar to those in the orthopedic literature. The discrepant prevalence of delaminated tears between the previous imaging studies and the present study may be due to development of MR equipment and different methods of shoulder MRI.

TABLE 3: Sensitivity, Specificity, and Accuracy of MRI to Diagnose Each Type of Delaminated Tear

Type	Sensitivity (%)	Specificity (%)	Accuracy (%)
1a	90 (44/49)	99 (77/78)	95 (121/127)
1b	100 (3/3)	99 (123/124)	99 (126/127)
1c	100 (2/2)	99 (124/125)	99 (126/127)
2a	90 (26/29)	82 (81/98)	84 (107/127)
2b	87 (13/15)	98 (110/112)	97 (123/127)
2c	86 (6/7)	100 (120/120)	99 (126/127)

Note—Data in parentheses are number/total. Type 1a = articular-delaminated full-thickness tear, 1b = bursal-delaminated full-thickness tear, 1c = intratendinous-delaminated full-thickness tear, 2a = articular-delaminated partial-thickness tear, 2b = bursal-delaminated partial-thickness tear, and 2c = intratendinous-delaminated partial-thickness tear.

The definition of the delaminated tear was somewhat ambiguous in the previous articles. Sonnabend and Watson [3] defined delaminated tear as a horizontal partial-thickness split of the tendon substance, and MacDougal and Todhunter [6] defined it as edge fraying or cleavage greater than or equal to 5 mm and also included high-grade partial-thickness tear. Han et al. [5] defined it as a significant horizontal intratendinous tear requiring treatment. In the current study, the delaminated tear was defined as an intratendinous horizontal splitting between the articular and bursal layers of the SST-IST with or without different degrees of retraction between the two layers. Furthermore, according to the morphologic patterns, the delaminated tears were classified into six types. Among the six types of delaminated tears, articular-delaminated full-thickness tears (type 1a) and articular-delaminated partial-thickness tears (type 2a) accounted for approximately 72% of the total delaminated tears. These types of delaminated tears were also frequently found in the previous studies: 100% of the delaminated tears at the SST in the study by Walz et al. [10] and 69% in the study by Matsuki et al. [8] showed more medial retraction of the articular layer of the tendon. In our study, 80% of delaminated full-thickness tears occurring at the SST were combined with delaminated partial-thickness tears at the IST. Therefore, in cases of delaminated full-thickness tears occurring at the SST, careful investigation to determine the presence of a delaminated partial-thickness tear at the IST is required.

In the results of the study by Sonnabend and Watson [3], delaminated tears were more common among tears of less than 5 cm than in massive tears. In our study, the tear size was significantly shorter in the shoulders with delaminated tears than those with nondelaminated tears in the subgroup with full-thickness tears, although it was the opposite in the subgroup with partial-thickness tears. The reason might have been that identification of the intratendinous cleft or separation of the two layers was difficult because of musculotendinous atrophy in the larger SST-IST tears.

In this study, the diagnostic accuracy of indirect MR arthrography to detect delaminated tears was highly satisfactory. The type of delaminated tear on MRI also matched well with that on arthroscopy. Thus, by means of indirect MR arthrography of the shoulders, radiologists can provide accurate information about a delaminated tear to surgeons. Furthermore, we expect that using the classification of delaminated tears would promote clear and effective communication between radiologists and surgeons.

This study has several limitations. First, the design of the study was retrospective. However, all MRI studies included in this study were performed using a standardized protocol. The diagnostic criteria for the delaminated tears were defined precisely, and the arthroscopic video records were reviewed by the orthopedic surgeon after discussion about the definition of delaminated tear. Second, indirect MR arthrography was the only imaging method used in this study because the number of cases using direct MR arthrography in the study setting was insufficient. Indirect MR arthrography cannot detect all clefts between the articular and bursal layers of delaminated tears because the amount of fluid or contrast material is less

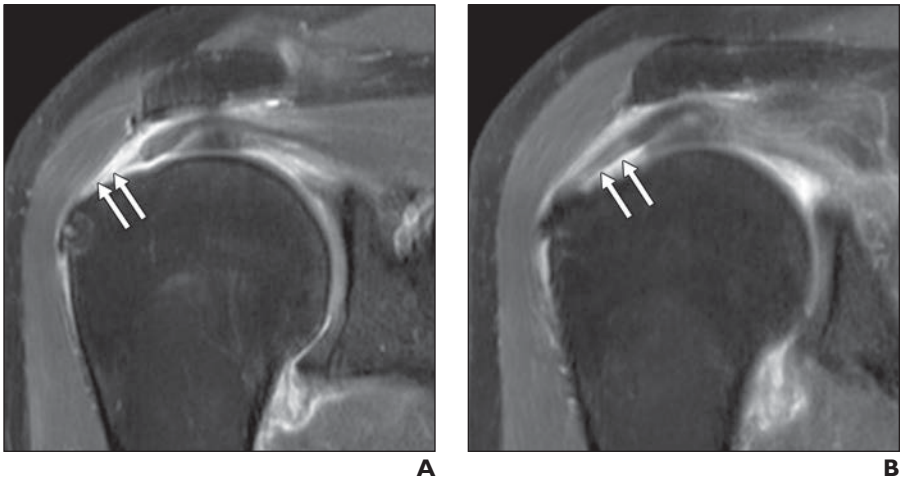

Fig. 4—64-year-old woman with two different types of delaminated tears in right shoulder.
A, Fat-suppressed T1-weighted image from indirect MR arthrography obtained at level of supraspinatus tendon shows more medially retracted articular layer of full-thickness tear (*arrows*) at supraspinatus tendon (articular-delaminated full-thickness tear, type 1a).
B, Fat-suppressed T1-weighted image obtained at level of infraspinatus tendon in shoulder shows horizontal splitting tear in articular partial-thickness tear (*arrows*) at infraspinatus tendon (articular-delaminated partial-thickness tear, type 2a).

than that used in direct MR arthrography. However, indirect MR arthrography can easily detect certain types of delaminated tears, such as bursal-delaminated partial-thickness tears (type 2b) and intratendinous-delaminated partial-thickness tears (type 2c), because the synovium-like lining of the laminated slits is found in these tears histologically [4] and indirect MR arthrography may enhance the synovial or inflamed intraarticular tissue [16]. To determine the superiority of either method in detecting delaminated tears, further evaluation is required. Third, the presence of delaminated tears was evaluated only at the SST and IST but not at the subscapularis tendon. Because the subscapularis tendon has a different anatomy, such as a multipennate structure, detection of delaminated tears in the subscapularis tendons was considered difficult. In most orthopedic studies, detection of delaminated tears was confined to the SST and IST [1, 2, 5, 8]. Fourth, some intratendinous delaminated partial-thickness tears might have been confused with tendinosis.

In conclusion, 56% of SST-IST tears were delaminated tears on indirect MR arthrography. Articular-delaminated full-thickness and articular-delaminated partial-thickness tears (types 1a and 2a) were the most common types of delaminated tears. About 82% of the articular-delaminated full-thickness tears occurring at the SST were combined with articular-delaminated partial-thickness tears at the IST. The diagnostic accuracy of indirect MR arthrography for the detection of delaminated tears was high on the basis of the arthroscopic results.

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