Radiology

Lesions of the Biceps Pulley: Diagnostic Accuracy of MR Arthrography of the Shoulder and Evaluation of Previously Described and New Diagnostic Signs[1]

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Purpose: To retrospectively determine the diagnostic accuracy of magnetic resonance (MR) arthrography of the shoulder in the evaluation of lesions of the biceps pulley and to evaluate previously described and new diagnostic signs.

Materials and Methods: Institutional review board approval was obtained; the requirement for informed consent was waived. MR arthrograms of 80 consecutive patients (mean age, 34.2 years; 53 male, 27 female) with arthroscopically proved intact or torn pulley systems were assessed for the presence of a pulley lesion by three radiologists who were blinded to arthroscopic results. Criteria evaluated were displacement of the long head of the biceps tendon (LHBT) relative to the subscapularis tendon on oblique sagittal images (displacement sign), medial subluxation of the LHBT on transverse images, nonvisibility or discontinuity of the superior glenohumeral ligament (SGHL), presence of biceps tendinopathy, and rotator cuff tears adjacent to the rotator interval.

Results: There were 28 pulley lesions noted at arthroscopy. For observers 1, 2, and 3, respectively: MR arthrography showed a sensitivity of 89%, 86%, and 82% and a specificity of 96%, 98%, and 87% in the detection of pulley lesions. Nonvisibility or discontinuity of the SGHL was sensitive (79%, 89%, and 79%) and specific (83%, 79%, and 75%). With the displacement sign, sensitivity was 86%, 82%, and 75% and specificity was 96%, 98%, 90%. Tendinopathy of the LHBT on oblique sagittal images showed a sensitivity of 93%, 82%, 64%; specificity was 81%, 96%, and 85%. Subluxation of the LHBT was insensitive (36%, 50%, and 64%) but specific (100%, 98%, and 96%).

Conclusion: MR arthrography is accurate in the detection of pulley lesions; the displacement sign, nonvisibility or discontinuity of the SGHL, and tendinopathy of the LHBT on oblique sagittal images are the most accurate criteria for the detection of pulley lesions.

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The superior border of the subscapularis (SSC) tendon and the biceps pulley are considered to be the major soft tissue restraints of the intraarticular course of the long head of the biceps tendon (LHBT) that prevent the tendon from medial and inferior dislocation (1–3). The pulley sling is formed by the coracohumeral ligament (CHL) and predominantly by the superior glenohumeral ligament (SGHL) at the apex of the rotator interval (4–7). Acute trauma, repetitive microtrauma, or degeneration can lead to damage of the biceps pulley and adjacent structures (8–10). This may result in instability of the LHBT with impairment of function and anterior shoulder pain. With an arthroscopic prevalence of 7%, pulley lesions are not a rare disorder and represent a considerable source of morbidity (10). Since clinical tests are often equivocal, further diagnostic workup is usually needed to avoid unnecessary diagnostic arthroscopy, and magnetic resonance (MR) arthrography is often suggested (10–12).

At MR imaging, previously described criteria of a pulley lesion are subluxation and dislocation of the LHBT in relation to the intertubercular groove (4,13–15). However, a recent arthroscopic study has shown that the LHBT was centered within the intertubercular groove with the shoulder in neutral position in about two-thirds of patients with pulley lesions (16). Because the shoulder is usually examined in the neutral position at MR imaging as well, this means that by following the usual MR imaging criteria, the majority of pulley lesions might be missed.

Furthermore, partial tearing of the superior SSC tendon was reported to be associated with pulley lesions (14). Since the frequency of isolated pulley lesions ranges from 29% to 74%, an unremarkable superior border of the SSC tendon cannot safely exclude a pulley lesion (5,10,16). In addition, isolated pulley lesions indicate an earlier and more readily treatable stage of this disorder and should not be missed on MR images (10). This means that by relying on these criteria only a more severe and less common stage of this disorder would be detected, which results in underreporting of pulley lesions. Therefore, the MR imaging criteria for pulley lesions have to be reconsidered.

The purpose of the study was to retrospectively determine the diagnostic accuracy of MR arthrography of the shoulder in the evaluation of lesions of the biceps pulley and to evaluate previously described and new diagnostic signs.

Advances in Knowledge

- With a sensitivity of 82%–89% and a specificity of 87%–98%, MR arthrography is accurate in the detection of lesions of the biceps pulley and shows substantial interobserver and excellent intraobserver agreement.
- Caudal and/or anterior displacement of the long head of the biceps tendon relative to the subscapularis tendon on oblique sagittal MR arthrograms (displacement sign) provides high sensitivity (75%–86%) and specificity (90%–96%) for the diagnosis of a pulley lesion.
- Previously described criteria for the presence of a pulley lesion, such as subluxation or dislocation patterns of the long head of the biceps tendon relative to the intertubercular groove, are highly specific (96%–100% and 100%, respectively), but insensitive (36%–64% and 4%–7%, respectively).

Implications for Patient Care

- The rotator interval, and in particular the biceps pulley, should preferably be evaluated on oblique sagittal T1-weighted MR arthrograms.
- Considering the displacement sign, MR arthrography is of substantial value in the evaluation of the biceps pulley; on the other hand, the exclusion of a pulley lesion at MR imaging might avoid unnecessary diagnostic arthroscopy.

Materials and Methods

Study Population

The study was approved by our institutional review board. The requirement for informed consent was waived. The clinical data of patients referred for MR arthrography of the shoulder between January 1, 2006, and September 30, 2010, were retrospectively evaluated. Inclusion criteria were as follows: *(a)* MR arthrography performed at our institution with a standardized protocol, and *(b)* subsequent arthroscopy performed, with availability of a detailed report regarding the pulley sling. Exclusion criteria were previous shoulder surgery, age younger than 16 years, clinical signs of multidirectional instability, and signs of adhesive capsulitis (reduced range of motion at clinical examination). Patients with an arthroscopically proved pulley lesion were considered the study group. The control group comprised patients with arthroscopically intact pulley systems.

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Abbreviations:
CHL = coracohumeral ligament
LHBT = long head of the biceps tendon
SGHL = superior glenohumeral ligament
SSC = subscapularis
SSP = supraspinatus

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Guarantors of integrity of entire study, C.S., M.S., E.J.R., K.W.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; literature research, C.S., K.H., C.K.; clinical studies, C.S., S.W., K.H., C.K., P.M.J., M.S., E.J.R., A.B.I., K.W.; statistical analysis, C.S., C.K., P.W.; and manuscript editing, C.S., K.H., C.K., P.W., M.S., E.J.R., A.B.I., K.W.

Potential conflicts of interest are listed at the end of this article.

Arthroscopy

All arthroscopy examinations were performed by one of four orthopedic surgeons, with 9, 15, 18 (M.S.), and 23 (A.B.I.) years of experience in shoulder surgery. The surgeons were aware of the results of the MR examination. The arthroscopic reports were retrospectively evaluated for the presence of a pulley lesion, signs of tendinopathy of the LHBT, and for the integrity of the rotator cuff tendons adjacent to the rotator interval. On the basis of the arthroscopic diagnoses, pulley lesions were retrospectively classified according to the criteria of Habermeyer et al (Table 1) (5). Therapeutic procedures performed at arthroscopy were documented.

Table 1

Classification of Pulley Lesions

Group	Pathologic Finding
I	Isolated tear of the SGHL
II	Tear of the SGHL and tear of the adjacent SSP tendon
III	Tear of the SGHL and tear of the adjacent SSC tendon
IV	Tear of the SGHL and tears of the adjacent SSC and SSP tendons

Note.—According to the classification of Habermeyer et al (5). SSP = supraspinatus.

MR Arthrography

MR arthrography was performed with a 1.5-T (Espree/Avanto; Siemens Medical Solutions, Erlangen, Germany) or a 3-T (Verio; Siemens Medical Solutions) MR imaging system with use of a dedicated shoulder coil (Invivo, Gainesville, Fla). All examinations were commenced after intraarticular injection of 8–12 mL of gadopentetate dimeglumine (Magnevist; Bayer Healthcare, Berlin, Germany) at a concentration of 2.5 mmol/L by means of an anterior (rotator interval) approach, and with fluoroscopic guidance. MR imaging was performed within 15 minutes after contrast agent injection.

The patients underwent imaging with the shoulder in neutral position. The standard protocol comprised T1-weighted images in the oblique coronal plane (parallel to the long axis of the SSP tendon) with fat suppression, oblique sagittal plane (parallel to the glenohumeral joint), and transverse plane, as well as intermediate-weighted images with fat suppression in the oblique coronal plane. Parameters for all sequences are presented in Table 2.

Image Interpretation

MR arthrograms were retrospectively and independently reviewed by three radiologists (K.H., S.W., and K.W., with 2, 10, and 17 years of experience in musculoskeletal radiology, respectively). The observers were unfamiliar with the cases and unaware of the arthroscopic results. The image material was presented in random order and did not contain any patient information. Image quality was assessed by one observer by using a four-point Likert scale (score of 1, excellent; 2, good; 3, moderate; 4, poor). The observers had to decide whether a pulley lesion was present. The confidence of the decision was additionally evaluated with a five-point Likert scale (score of 1: certainly not; 2, probably not; 3, equivocal; 4, probably yes; 5, certainly yes).

In addition, several signs that were hypothesized to be helpful in diagnosing pulley lesions were evaluated:

1. Nonvisibility or discontinuity of the SGHL was assessed on oblique sagittal T1-weighted arthrograms.

2. Displacement sign: The observers had to evaluate if there was caudad and/or anterior displacement of the LHBT relative to the SSC tendon on a midsection through the lesser tuberosity of the humerus on oblique sagittal T1-weighted arthrograms (Fig 1).

3. Tendinopathy of the LHBT was diagnosed if changes in diameter, increased signal intensity, or irregular margins of the tendon were seen on oblique sagittal T1-weighted arthrograms on a midsection through the lesser tuberosity and on transverse T1-weighted arthrograms (17,18).

Table 2

MR Arthrography Parameters

	T1-weighted Transverse MR		T1-weighted Oblique Coronal MR		T1-weighted Oblique Sagittal MR		Intermediate-weighted Oblique Sagittal MR	
Parameter	1.5 T	3 T	1.5 T	3 T	1.5 T	3 T	1.5 T	3 T
Sequence	SE	TSE	SE	TSE	SE	TSE	SE	TSE
Repetition time (msec)	537–790	873	537–790	1100	537–790	1140	2620–3370	2570
Echo time (msec)	10–14	12	10–14	13	10–14	12	33–45	39
Field of view (mm)	160	160	160	160	160	160	160	160
In-plane resolution (mm)	0.5 × 0.4	0.5 × 0.4	0.5 × 0.4	0.5 × 0.4	0.5 × 0.4	0.5 × 0.4	0.5 × 0.4	0.5 × 0.4
Gap (%)	10	10	10	10	10	10	10	10
Bandwidth (Hz/pixel)	70	161	100	161	70	161	109	161
No. of acquisitions	2	1	1	1	2	1	2	1
Echo train length		2		2		2	7	5

Note.—SE = spin echo, TSE = turbo spin echo.

4. The position of the LHBT relative to the entire course of the intertubercular groove was assessed on transverse T1-weighted images. Subluxation of the LHBT was defined as displacement over the inner rim of the intertubercular groove with remaining partial contact to the groove. Dislocation of the LHBT was defined as total loss of contact with the intertubercular groove (13).

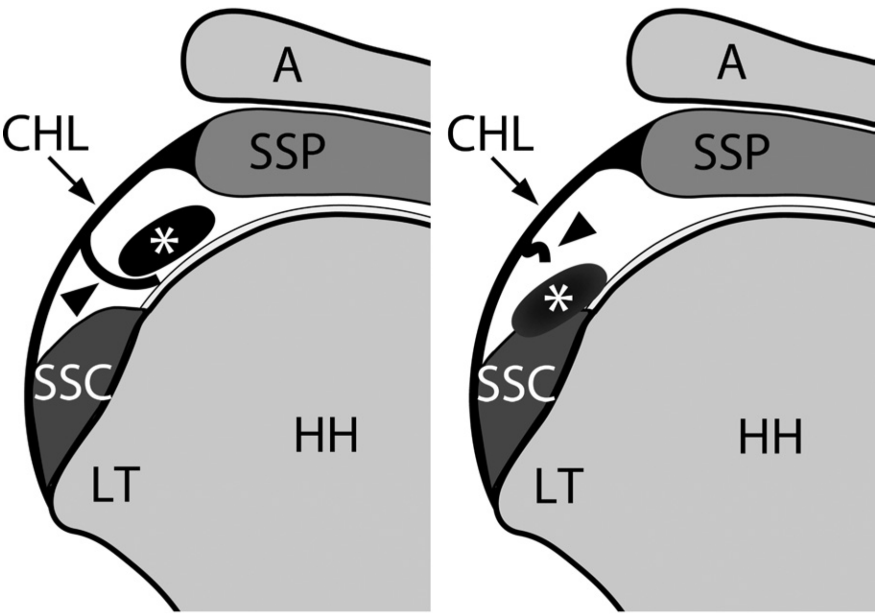
5. The tendons of the SSC and SSP were evaluated for tears adjacent to the rotator interval. A partial tear was diagnosed if there was discontinuity of tendon fibers with contrast agent extending into the defect on T1-weighted arthrograms. A full-thickness tear of the SSP tendon was diagnosed if contrast material extended through the entire articular-to-bursal thickness of the tendon on T1-weighted images. Complete tearing of the SSC tendon was defined as complete detachment of the tendon from the lesser tuberosity.

To assess intraobserver variability, all MR images were re-evaluated by one observer 3 months after the first assessment.

Statistical Analysis

The data were analyzed by an experienced statistician (P.W.) by using R 2.13.11 (R Foundation for Statistical Computing, Vienna, Austria) and Stata statistical software (release 8; Stata, College Station, Tex). The diagnostic performance of different signs in the diagnosis of arthroscopically proved pulley lesions is expressed by sensitivity, specificity, and accuracy. For the evaluation of the detection of lesions of the biceps pulley, predictive values are also reported. To account for the dependence of predictive values on the prevalence, we calculated predictive values taking into consideration the general prevalence of lesions of the biceps pulley, which did not meet the prevalence in our study. Confidence intervals for predictive values were calculated by using the standard logit method of Mercaldo et al (19). As for all other criteria the prevalence is not known, we therefore only present sensitivity and specificity. The confidence of the decision to discriminate present from absent pulley lesions was evaluated by using receiver operating characteristic curve analysis. To compare the diagnostic accuracy between the three observers, the area under the receiver operating characteristic curve was used. The Fleiss κ was used as an index of interrater agreement. Intra-observer agreement was determined by using the Cohen κ coefficient. For all measures, 95% confidence intervals were calculated.

Figure 1



a. b.

Figure 1: Drawings of oblique sagittal sections illustrate normal anatomy of the rotator interval and the displacement sign in a pulley lesion. **(a)** Normal anatomy of shoulder at rotator interval on a midsection through the lesser tuberosity. The SGHL (arrowhead) and CHL (arrow) form a sling that prevents the LHBT (*) from medial and caudal dislocation. **(b)** If the SGHL (arrowhead) is torn, the LHBT (*) dislocates caudad onto the superior border of the SSC tendon. The displacement sign represents direct contact of the displaced LHBT and the SSC tendon on a midsection through the lesser tuberosity *(LT)*. *A* = acromion, *HH* = humeral head.

Results

Study Population

Recruitment of patients and the reasons for and numbers of exclusions are displayed in a flowchart in Figure 2. Twenty-eight patients were included in the study group. Twenty-three were male (mean age, 42.0 years; age range, 25–67 years; 17 right and six left shoulders) and five were female (mean age, 48.2 years; age range, 43–60 years; three right and two left shoulders). The control group comprised 52 patients. Thirty were male (mean age, 27.6 years; age range, 16–49 years; 18 right and 12 left shoulders) and 22 were female (mean age, 31.3 years; age range, 17–48; 12 right and 10 left shoulders).

MR arthrography examinations of included patients were predominantly performed at 1.5 T. Only five of 80 patients underwent MR arthrography with the 3-T system.

The indications for MR arthrography were as follows: instability or labral pathologic finding (*n* = 34), superior labral anterior posterior (or SLAP) lesions (*n* = 29), rotator cuff tear (*n* = 10), injury to the pulley system (*n* = 4), and clinically

Figure 2

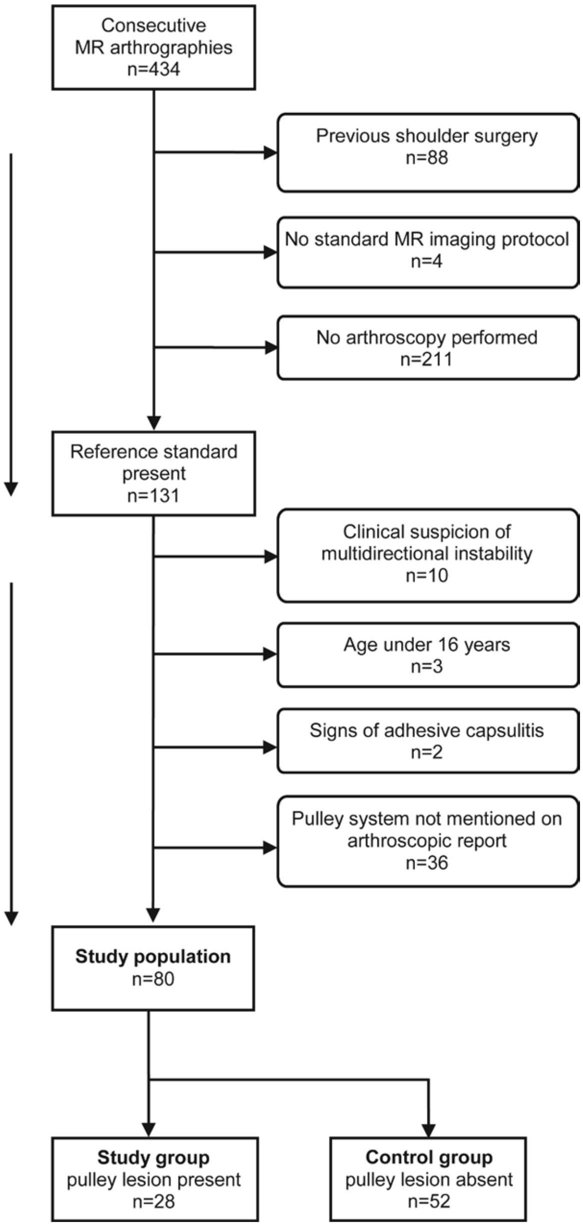


Figure 2: Flowchart of study population and patient recruitment.

suspected posterosuperior glenoid impingement (n = 3).

Arthroscopy

The mean interval between MR imaging and arthroscopy was 67 days (standard deviation, 104 days).

Of the patients with arthroscopically proved pulley lesions, eight of 28 (28.6%) had isolated pulley lesions (Habermeyer group I). Five of 28 (17.9%) lesions were classified as group II or group III, respectively. The remaining 10 of 28 lesions (35.7%) were diagnosed as group IV lesions. Twenty-four of 28 (85.7%) patients showed signs of tendinopathy of the LHBT. Tenotomy and/or subsequent tenodesis of the LHBT were performed in all 28 (100%) patients in the study group.

In the control group, the arthroscopic diagnoses were as follows: lesions of the labral-ligamentous-complex in 30 of 52 (58%), superior labral anterior posterior lesions in 13 of 52 (25%), SSP tendon tear in four of 52 (8%), posterosuperior glenoid impingement in three of 52 (62%), tear of the middle glenohumeral ligament in one of 52 (2%), and acromioclavicular joint injury in one of 34 (2%).

Image Interpretation

Image quality was assessed as excellent in 21of 80 cases (26.3%), good in 38 (38.8%), moderate in 19 (23.8%), and poor in two (2.5%). Moderate or poor image quality was secondary either to movement artifacts or to low signal intensity of intraarticular contrast material.

The results of the overall diagnostic efficacy of MR arthrography in the detection of pulley lesions are shown in Table 3. For all three observers, high sensitivity, specificity, and accuracy for the diagnosis of pulley lesions at MR arthrography were found (Fig 3). The areas under the receiver operating characteristic curves regarding the confidence of the decision for each observer were 0.976, 0.936, and 0.872. These areas were not significantly different (P = .053). For the detection of pulley lesions, interobserver agreement was substantial (multirater κ = 0.74 [95% confidence interval: 0.62, 0.86]) among all three observers and intraobserver agreement for observer 1 was excellent (κ = 1.00).

The performance of evaluated signs for biceps pulley lesions is presented in Table 4. The results for interrater agreement among the observers and intraobserver agreement for observer 1 are also shown in Table 4. The displacement sign, nonvisibility or discontinuity of the SGHL, and signs of tendinopathy of the LHBT on

Table 3

Efficacy of MR Arthrography in the Diagnosis of Biceps Pulley Lesions

Value	Observer 1 (%)	Observer 2 (%)	Observer 3 (%)
Sensitivity	89 (25/28) [72, 98]	86 (24/28) [67, 96]	82 (23/28) [63, 93]
Specificity	96 (50/52) [87, 100]	98 (51/52) [90, 100]	87 (45/52) [74, 94]
PPV	64 [31, 87]	77 [32, 96]	31 [18, 48]
NPV	99 [98, 100]	99 [97, 100]	98 [97, 99]
Accuracy	94 (75/80) [86, 98]	94 (75/80) [86, 98]	85 (68/80) [75, 92]

Note.—Data in parentheses are raw numbers used to calculate percentages, and data in brackets are 95% confidence intervals. NPV = negative predictive value, PPV = positive predictive value.

Figure 3

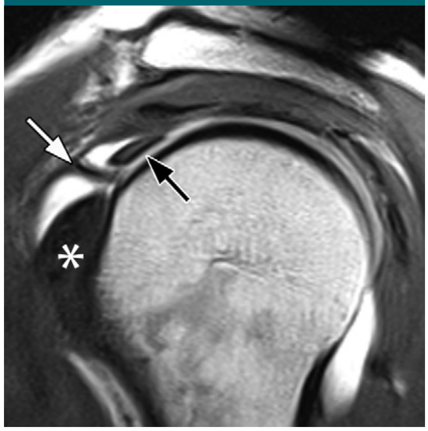


Figure 3: Oblique sagittal T1-weighted MR arthrogram of right shoulder in a 24-year-old woman with chronic instability of the shoulder after anteroinferior dislocation. SGHL and pulley system were assessed as intact by all three observers, which was confirmed at arthroscopy. Image shows the normal anatomic appearance of the pulley sling. The SGHL (white arrow) wraps around the horizontal portion of LHBT (black arrow), which at a distance from the SSC tendon (*). The LHBT shows normal diameter and signal intensity.

oblique sagittal T1-weighted arthrograms showed high sensitivity, specificity, and accuracy in the diagnosis of a pulley lesion for all three observers (Figs 4–6). The three criteria were objective, with substantial interrater agreement and excellent intraobserver agreement.

Signs of tendinopathy on transverse images were insensitive but highly specific, and interrater agreement was only moderate. Subluxation or dislocation of the LHBT relative to the intertubercular groove were highly specific for the diagnosis of a pulley lesion and showed substantial agreement among the observers, but sensitivities proved to be inappropriate. The presence of tears of the SSC and/or the SSP tendon were not sensitive in the diagnosis of a pulley lesion for all three observers. There was only moderate agreement in the diagnosis of lesions to the SSP tendon in the evaluation of the biceps pulley, as the specificity in the detection of pulley lesions for this sign was low for observer 1 but high for observers 2 and 3. On the other hand, tears of the SSC tendon were highly specific for the presence of a pulley lesion among all three observers (Fig 7).

Discussion

In the present study, we demonstrated that MR arthrography of the shoulder is accurate in the evaluation of the biceps pulley, with arthroscopy serving as reference standard. The displacement sign, nonvisibility or discontinuity of the SGHL, and signs of tendinopathy of the LHBT observed on oblique sagittal MR arthrograms were accurate diagnostic criteria. Other previously described criteria, such as subluxation and dislocation patterns of the LHBT and the presence of lesions of the rotator cuff tendons adjacent to the rotator interval, were highly specific but insensitive. These findings are important, because relying on the previously described MR imaging criteria might cause a considerable number of pulley lesions to be missed. The preferred therapies for pulley lesions are tenotomy or tenodesis (2,8,20). Therefore, the correct diagnosis of a pulley lesion on MR images would not only enable a more accurate planning of treatment and time duration of surgery but also provide an adequate means for preoperative patient education.

The theory of the displacement sign is that, in the absence of the supporting SGHL, the LHBT displaces caudad onto the SSC tendon, where the tendinous slip at the superior border serves as an additional restraint (3,21). This leads to abnormal and more medial contact of the horizontal portion of the LHBT with the SSC tendon. Thus, neither a bandlike structure (SGHL) nor intraarticular contrast material should be seen between the LHBT and the SSC tendon.

Our results are in concordance with those of Weishaupt et al (14), who found sensitivity of 86% and 93% (observer 1 and observer 2) and specificity of 100% and 80% for MR arthrography in the evaluation of the biceps pulley. However, their study group was much smaller and, in contrast to our results, they found an irregularity of the superior border of the SSC tendon to be strongly associated with pulley lesions. Our study population included a considerable number of Habermeyer group I and II lesions, which, by definition, show an unremarkable SSC tendon (5). Furthermore, in the literature the prevalence of isolated SGHL tears is reported as 29%–74%, with 29% in the present study (5,10,16). Hence, we suggest that isolated pulley lesions are underrepresented in the study of Weishaupt et al and conclude that an unremarkable SSC tendon cannot safely exclude a pulley lesion. As opposed to our results, Weishaupt and coworkers observed that the finding of discontinuity of the SGHL was specific but insensitive. At the lateral rotator interval, the SGHL wraps around the LHBT and forms the pulley sling (3). Although there is variability in the appearance of the glenohumeral

Table 4

Evaluation of Diagnostic Criteria in the Diagnosis of Arthroscopically Proved Pulley Lesions

Variable	Sensitivity (%)	Specificity (%)	Accuracy (%)	Multirater κ	Intraobserver κ
T1-weighted oblique sagittal MR					
SGHL not visible or discontinuous					
Observer 1	79 (22/28) [59, 92]	83 (43/52) [70, 92]	81 (65/80) [71, 89]	0.69 [0.55, 0.81]	0.80 [0.65, 0.92]
Observer 2	89 (25/28) [77, 99]	79 (41/52) [65, 89]	84 (67/80) [74, 91]		
Observer 3	79 (22/28) [59, 92]	75 (39/52) [61, 86]	76 (61/80) [65, 85]		
Displacement sign of the LHBT					
Observer 1	86 (24/28) [67, 96]	96 (50/52) [87, 100]	93 (74/80) [84, 97]	0.71 [0.58, 0.83]	0.97 [0.90, 1.00]
Observer 2	82 (23/28) [63, 94]	98 (51/52) [90, 100]	93 (74/80) [84, 97]		
Observer 3	75 (21/28) [55, 89]	90 (47/52) [79, 97]	85 (68/80) [75, 92]		
Tendinopathy of LHBT					
Observer 1	93 (26/28) [77, 99]	81 (42/52) [68, 90]	85 (68/80) [75, 92]	0.64 [0.49, 0.77]	0.95 [0.87, 1.00]
Observer 2	82 (23/28) [63, 94]	96 (50/52) [87, 100]	91 (73/80) [83, 96]		
Observer 3	64 (18/28) [44, 81]	85 (44/52) [72, 93]	78 (62/80) [67, 86]		
T1-weighted transverse MR					
Subluxation of LHBT					
Observer 1	36 (10/28) [19, 56]	100 (52/52) [90, 100]	78 (62/80) [67, 86]	0.62 [0.43, 0.77]	0.94 [0.76, 1.00]
Observer 2	50 (14/28) [31, 69]	98 (51/52) [90, 100]	81 (65/80) [71, 89]		
Observer 3	64 (18/28) [44, 81]	96 (50/52) [69, 100]	85 (68/80) [75, 92]		
Dislocation of LHBT					
Observer 1	4 (1/28) [0, 18]	100 (52/52) [90, 100]	66 (53/80) [55, 76]	0.80 [0.49, 1.00]	1.00
Observer 2	7 (2/28) [1, 24]	100 (52/52) [90, 100]	68 (54/80) [56, 78]		
Observer 3	7 (2/28) [1, 24]	100 (52/52) [90, 100]	68 (54/80) [56, 78]		
Tendinopathy of LHBT					
Observer 1	75 (21/28) [55, 89]	89 (46/52) [77, 96]	84 (67/80) [74, 92]	0.43 [0.27, 0.59]	0.92 [0.80, 1.00]
Observer 2	43 (12/28) [25, 63]	100 (52/52) [90, 100]	80 (64/80) [70, 88]		
Observer 3	21 (6/28) [8, 41]	98 (51/52) [90, 100]	71 (57/80) [60, 81]		
SSP tendon lesion					
Observer 1	68 (19/28) [48, 84]	58 (30/52) [43, 71]	61 (49/80) [50, 72]	0.43 [0.29, 0.57]	0.77 [0.63, 0.90]
Observer 2	46 (13/28) [28, 66]	83 (43/52) [70, 92]	70 (56/80) [59, 80]		
Observer 3	57 (16/28) [37, 76]	87 (45/52) [74, 94]	76 (61/80) [65, 85]		
SSC tendon lesion					
Observer 1	54 (15/28) [34, 73]	100 (52/52) [90, 100]	84 (67/80) [74, 91]	0.54 [0.36, 0.69]	0.84 [0.67, 0.96]
Observer 2	50 (14/28) [31, 69]	98 (51/52) [90, 100]	81 (65/80) [71, 89]		
Observer 3	68 (19/28) [48, 84]	92 (48/52) [82, 98]	84 (67/80) [74, 91]		

Note.—Data in parentheses are raw numbers used to calculate percentages, and data in brackets are 95% confidence intervals; multirater κ is presented for all three observers, and intraobserver κ is presented for observer 1.

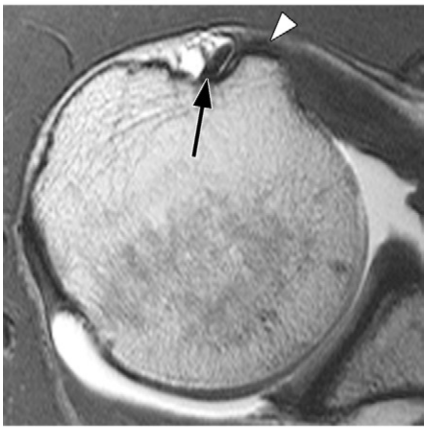
ligaments, the SGHL is considered to be a constant structure (22). We conjecture that a better understanding of the anatomy of the SGHL and improvement of the MR imaging technique in the past 10 years may have improved the better visualization of the SGHL in our series.

In contrast to the small number of original research studies, several review-type articles on MR imaging of the rotator interval have been published (23–26). Most of the authors describe typical subluxation and dislocation patterns of the LHBT, which were originally established by Walch et al (13) and Bennett (27). Bennett's arthroscopic classification of pulley lesions in particular is not applicable for MR arthrography as the detailed anatomy at the apex of the rotator interval cannot be visualized. We agree that with a medially dislocated LHBT the diagnosis of a pulley lesion is straightforward. However, recently published data showed that in the majority of pulley lesions the LHBT is centered within the intertubercular groove (16). This illustrates the considerable limitation of such sub-and dislocation patterns on transverse images and emphasizes our diagnostic observations.

Since a pulley lesion causes chronic instability of the LHBT, the LHBT often demonstrates signs of tendinopathy (17,18,28). In our study, the finding of associated tendinopathy of the LHBT on oblique sagittal images was accurate

Figure 4

a.



b.

Figure 4: Arthroscopically confirmed isolated (Habermeyer group I) SGHL rupture in right shoulder in a 31-year-old man who complained of chronic anterior shoulder pain after a bicycle accident. All three observers made the correct diagnosis of a pulley lesion. **(a)** T1-weighted oblique sagittal MR arthrogram illustrates the displacement sign. LHBT (arrow) shows contact with the superior border of the intact SSC tendon (*) on a midsection through the lesser tuberosity. The SGHL is invisible. Owing to chronic instability, there is increased signal intensity of the LHBT, representing tendinopathy. **(b)** T1-weighted MR arthrogram in the transverse plane shows the centered LHBT (arrow) within the intertubercular groove and an unremarkable SSC tendon (arrowhead).

Figure 5

a.

b.

Figure 5: Arthroscopically confirmed Habermeyer group I lesion in right shoulder of a 25-year-old man with chronic shoulder pain intensified through overhead activities. **(a)** T1-weighted MR arthrogram in the oblique sagittal plane through the medial rotator interval shows irregular thickened and discontinuous SGHL (arrow). **(b)** Corresponding displacement sign can be found. LHBT (arrow) shows caudad displacement onto the SSC tendon (*), which was considered to be intact. Additionally, increased signal intensity and irregular margins of the LHBT owing to tendinopathy are shown.

Figure 6

Figure 6: Oblique sagittal T1-weighted MR arthrogram of right shoulder in a 42-year-old woman with chronic shoulder pain. Evaluation revealed false-positive finding of a pulley lesion by all three observers. Image shows increased signal intensity and diameter of the LHBT (arrow), which seems to be in contact with the SSC tendon (*). A pulley lesion was ruled out at arthroscopy, however, tendinopathy was confirmed.

and seems to be of additional value for the diagnosis of a pulley lesion. On the other hand, we found high specificity of this finding and conclude that the absence of tendinopathy makes a pulley lesion unlikely.

The classification of pulley lesions by Habermeyer et al (5) refers to SGHL tears. In accordance with Walch et al (4), the Habermeyer classification considers the importance of the SGHL at the lateral rotator interval. However, the CHL is also a part of the pulley system and forms the roof of the rotator interval. Since in our study we applied to the classification of Habermeyer the evaluation of the CHL was not included to our study.

Several limitations of our study have to be considered. First, the study design is retrospective. Second, arthroscopy is an operator-dependant examination with considerable variability in the interpretation of shoulder pathologies. Third, the surgeons were aware of the imaging reports. Hence, their focus on certain pathologies might have been influenced. Fourth, the sample size in our study is relatively small. Fifth, to use T1-weighted MR images in the assessment of increased signal intensity as a sign of tendinopathy of the LHBT might be prone to magic angle artifacts. However, this phenomenon does not influence the diameter or the appearance of the margins of the tendon. Sixth, only patients with MR arthrography and subsequent arthroscopy were

Figure 7

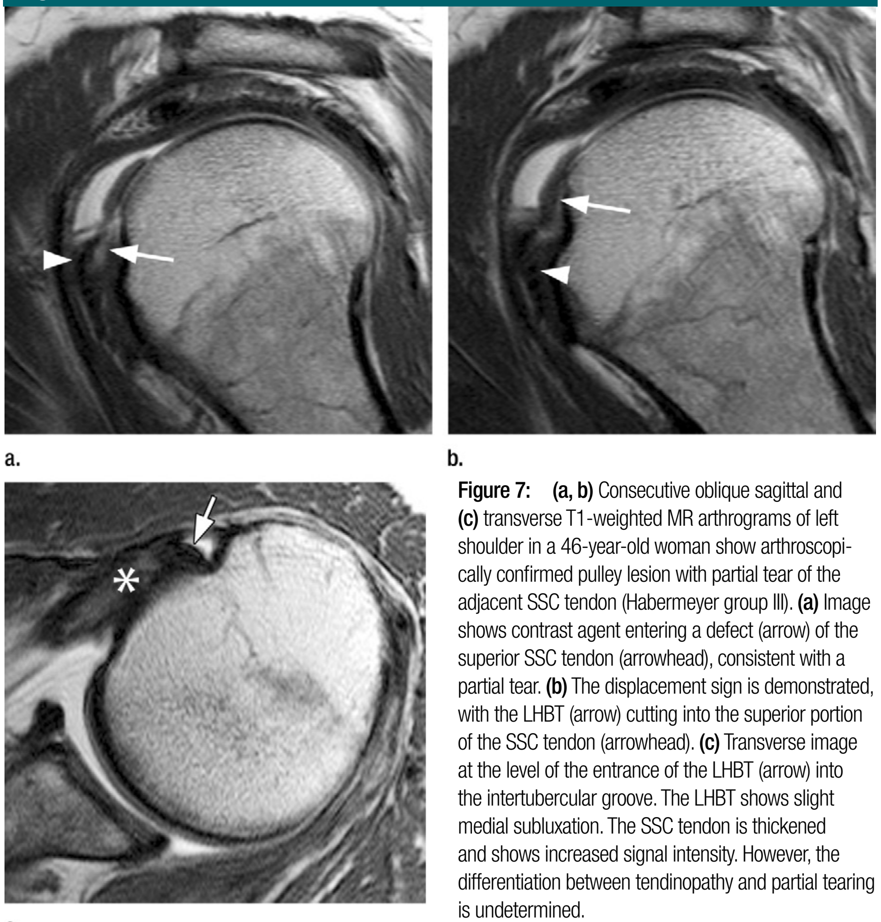


Figure 7: **(a, b)** Consecutive oblique sagittal and **(c)** transverse T1-weighted MR arthrograms of left shoulder in a 46-year-old woman show arthroscopically confirmed pulley lesion with partial tear of the adjacent SSC tendon (Habermeyer group III). **(a)** Image shows contrast agent entering a defect (arrow) of the superior SSC tendon (arrowhead), consistent with a partial tear. **(b)** The displacement sign is demonstrated, with the LHBT (arrow) cutting into the superior portion of the SSC tendon (arrowhead). **(c)** Transverse image at the level of the entrance of the LHBT (arrow) into the intertubercular groove. The LHBT shows slight medial subluxation. The SSC tendon is thickened and shows increased signal intensity. However, the differentiation between tendinopathy and partial tearing is undetermined.

included to the study which might lead to spectrum bias.

In conclusion, MR arthrography of the shoulder provides high accuracy in the evaluation of the biceps pulley, with the displacement sign found to be the most accurate finding for the diagnosis of a pulley lesion. We recommend that the biceps pulley should be preferably assessed on oblique sagittal T1-weighted arthrograms.

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