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Diagnostic accuracy of magnetic resonance imaging for partial tears of the long head of the biceps tendon in patients with rotator cuff tears

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A R T I C L E I N F O

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Level of evidence: Level III; Diagnostic Study

Background: Magnetic resonance imaging (MRI) is useful for diagnosing shoulder diseases preoperatively. However, detection of partial tears of the long head of the biceps tendon (LHBT) using current clinical tests and imaging modalities is difficult. We aimed to evaluate the accuracy of radial-slice MRI for diagnosing partial tears of the LHBT. We hypothesized that radial-slice MRI may be a valuable diagnostic tool for assessing diagnosing tears of the LHBT.
Methods: We retrospectively investigated 118 patients who underwent shoulder arthroscopy for rotator cuff tears. Intraoperative LHBT findings were compared with the identification of partial tears of the LHBT on conventional-slice MRI and radial-slice MRI, using a 3.0-T system. We calculated sensitivity, specificity, accuracy, and positive and negative predictive values for the detection of LHBT tears. Inter- and intraobserver reliability for radial-slice MRI was calculated using kappa statistics.
Results: We diagnosed 69 patients (58%) without any LHBT tears and 49 with partial tears (42%), arthroscopically. Sensitivity, specificity, accuracy, and positive and negative predictive values of conventional-slice MRI for detection of partial tears of the LHBT were 52%, 94%, 78%, 92%, and 58%, respectively. Radial-slice MRI had 84% sensitivity, 90% specificity, 86% accuracy, and 92% positive and 80% negative predictive values for partial tears of the LHBT. Inter- and intraobserver reliability for radial-slice MRI was 0.69 and 0.74, respectively, corresponding to high reproducibility and defined as good.
Conclusion: Radial-slice MRI demonstrated significantly higher sensitivity than conventional-slice MRI. These results indicate that radial-slice MRI is useful for diagnosing LHBT partial tears.

Recent developments in shoulder arthroscopy have enabled us to diagnose abnormalities of the shoulder in detail. The long head of the biceps tendon (LHBT) has been considered a common source of shoulder pain.[4,9,22,25] Pathologic changes of the LHBT are frequently accompanied by other shoulder lesions, such as rotator cuff tear,[3,31,32] which make differential diagnosis of LHBT tears by clinical tests difficult.[6,17,18] Recently, LHBT tenotomy and tenodesis have been widely accepted as popular surgical procedures for the treatment of LHBT lesions.[15,34,37] According to the findings from arthroscopy, it is difficult for a shoulder surgeon to visualize a partial tears of the LHBT around the entrance of the biceps groove .[14] Subsequent inappropriate surgical procedures based on the limitation for diagnosis of LHBT lesion could lead to poor postoperative outcomes.[7]

Magnetic resonance imaging (MRI) is the most useful imaging examination for preoperatively diagnosing shoulder lesions .[23,26,29] However, detection of pathologic changes involving the LHBT is difficult by conventional-slice MRI.[10,27,33] We, therefore, believe that another MRI imaging method may be necessary for accurate diagnosis of LHBT lesions. Recently, Furukawa et al[13] reported that radial-slice MRI was useful for the diagnosis of subscapularis tendon tears. Radial-slice MRI provides cross slices perpendicular to the rotator cuff insertions, which might be useful for accurate diagnosis of rotator cuff tears.[35] The purpose of this study was to investigate the diagnostic accuracy rate of partial tears involving the LHBT by conventional-slice MRI and radial-slice MRI. We

This study was approved by the Ethics Committee at Sapporo Medical University (approval number: 282-157).

Informed consent was obtained from patients before enrollment in this study.

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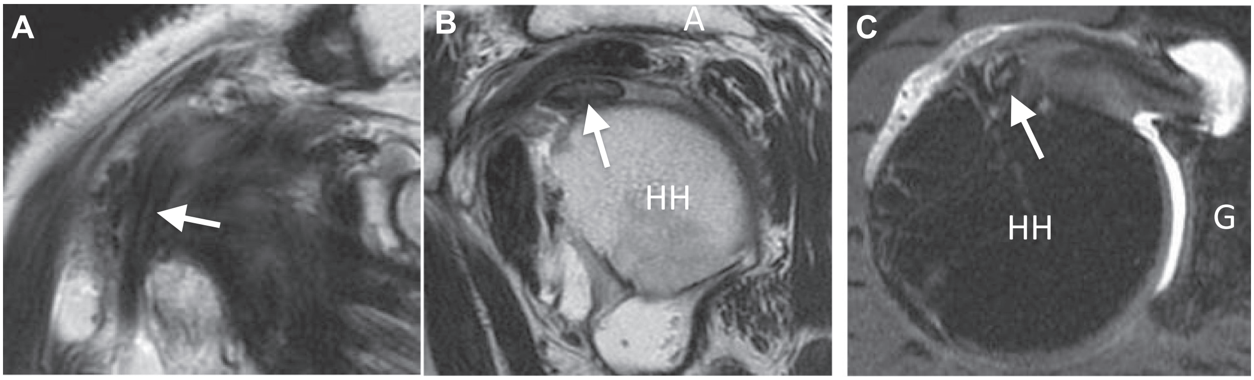

Figure 1 Representative case of partial tears of LHBT in conventional-slice MRI. (A) Oblique coronal image. LHBT increased intratendinous signal (*arrow*). (B) Oblique sagittal image. LHBT was thickening (*arrows*). (C) Axial images. LHBT increased intratendinous signal (*arrow*). *A*, acromion; *G*, glenoid; *HH*, humeral head.

hypothesized that radial-slice MRI may be a valuable diagnostic tool for assessing diagnosing partial tears of the LHBT.

Materials and methods

Patients

Informed consent was obtained from all patients, and this study was approved by the institutional review board of our university hospital. Between June 2010 and September 2019, we investigated patients who underwent shoulder arthroscopy for rotator cuff tears by an orthopedic surgeon with 20 years of experience in shoulder surgery at a particular institution. We acquired preoperative MRI of all patients. We excluded patients from this study if they met the following criteria: (1) no preoperative MRI examination, (2) history of shoulder surgery, (3) age < 20 years, and (4) LHBT lesions as full-thickness tears.

MRI assessment

All preoperative MRIs were performed within 1 month before surgery. We used a 3.0-T MRI unit (Signa HDx 3.0 T, GE Healthcare, Milwaukee, WI, USA). Both conventional and radial slices were acquired in one session using the same MRI system for all images of each patient. All patients underwent imaging with their shoulders in the neutral position. Any tear involving the LHBT was evaluated using oblique coronal and oblique sagittal images, acquired using T2-weighted imaging (repetition time [TR], 4000 ms; echo time [TE], 100 ms; matrix = 320 × 256; slice thickness = 3.0 mm without gap; total scan duration = 3 minutes 20 second), and axial images, acquired using fat saturation T2-weighted imaging (repetition time [TR], 4000 ms; echo time [TE], 60 ms; matrix = 320 × 256; slice thickness = 3.0 mm without gap; total scan duration = 2 minutes 30 seconds). By means of conventional-slice MRI, partial tears of the LHBT were diagnosed based on findings of increased high or heterogeneity signal from intratendinous lesion and/or thickening of the LHBT[33] (Fig. 1). The imaging for radial-slice MRI used T2*-weighted imaging (repetition time [TR], 300 ms; echo time [TE], 8.2 ms; matrix = 352 × 224; slice thickness = 3.0 mm without gap; total scan duration = 4 minutes 34 seconds). First, the rotation axis was defined as the line passing through the center of the humeral head and the center of the glenoid using axial and coronal scans. According to the axis, 18 slices were obtained per 10° rotationally (Fig. 2). By means of radial-slice MRI, partial LHBT tears were diagnosed based on findings of thickening of the LHBT (Fig. 3). MRI evaluations were blindly and independently diagnosed by an orthopedic surgeon with 10 years of experience in shoulder surgery. Conventional-slice MRI and radial-slice MRI evaluations were performed at intervals of more than 1 month.

Arthroscopic findings

All surgical procedures were performed with the patient in the lateral position under general anesthesia. Evaluation of the glenohumeral joint was performed through a posterior portal to confirm the presence of intraarticular injuries, such as the degree of the rotator cuff tears and lesions involving the biceps tendon. The LHBT was directly visualized and probed by pulling the intraarticular portion of the tendon into the joint. The intertubercular portion of the tendon was visually inspected for tendinitis, subluxation, dislocation, and partial- or full-thickness tears. An additional 3-5 cm of the LHBT could be visualized with this maneuver.[11] The size of any rotator cuff tear was measured by a calibrated probe and was classified as either a small tear (<1 cm), medium tear (1–3 cm), large tear (>3–5 cm), or massive tear (≥5 cm).

Interobserver and intraobserver reliability

To evaluate intraobserver reliability, the same shoulder surgeon reevaluated all MRI images at intervals of more than 1 month from the initial evaluation. To investigate interobserver reliability, another orthopedic surgeon with 5 years of experience in shoulder surgery evaluated randomly selected cases.

Data analysis

Arthroscopic findings were considered the standard for assessment. Statistical analysis of the diagnostic accuracy of conventional-slice and radial-slice MRI was performed. Surgical findings were recorded for true and false positives and negatives for biceps lesions, and then 2 × 2 tables were constructed to calculate sensitivity, specificity, accuracy, and positive and negative predictive values. Interobserver and intraobserver agreements were determined by kappa statistics. Agreement by means of kappa values was rated as excellent for values between 0.81-1.0; excellent, 0.61-0.80; good, 0.41-0.60; moderate and poor, ≤0.40. We used a statistical software (IBM SPSS Statistics for Windows, version 25.0, Armonk, NY, USA) to analyze the data.

Results

We treated 130 consecutive patients who underwent shoulder arthroscopic surgeries for rotator cuff tears by the senior shoulder

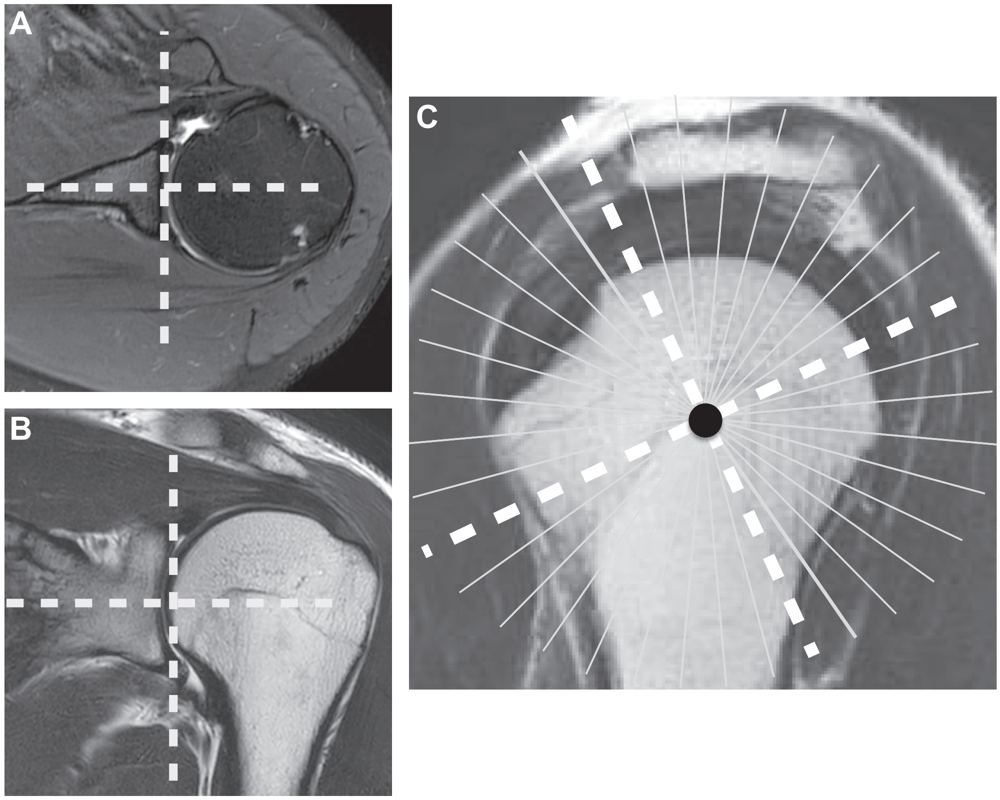

Figure 2 Imaging procedure used for radial slices. (A, B) First, the rotation axis (*dashed line*) was defined by using axial and oblique coronal images. (C) Second, radial slices was obtained per 10° rotationally according to the axis.

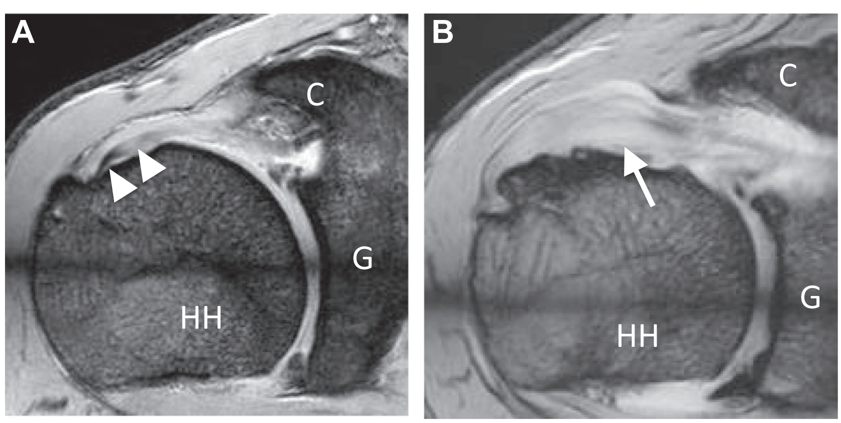

Figure 3 Representative case of normal or partial tears of LHBT in radial-slice MRI. (A) Clear finding in LHBT (*arrowheads*) showing negative findings. (B) Thickening of LHBT showing positive findings (*arrow*). *C*, coracoid; *G*, glenoid; *HH*, humeral head.

surgeons. Sixty-one of 130 patients (46%) had partial- or full-thickness LHBT tears. Because we focused on the evaluation of partial LHBT tears, 12 patients with full-thickness tears were excluded from this study. Finally, 118 patients who underwent shoulder arthroscopy for rotator cuff tears were included. Among these 118 patients, there were 69 patients (58%) without any LHBT tears and 49 patients (42%) with partial tears diagnosed during the arthroscopic evaluation. There were 57 men and 61 women, and the average age of the patients was 67 years (range, 41-86 years).

Regarding the relationship of the size of rotator cuff tear, partial tears involving LHBT were recognized in 4 of 32 small tears (13%), in 23 of 56 medium tears (41%), in 18 of 26 large tears (69%), and in all patients of four massive tears by shoulder arthroscopic findings. Subscapularis tendon tears were found in 33 of 49 patients with partial tears involving the LHBT (67%).

Table I shows the diagnostic values of MRI methods used for the diagnosis of partial LHBT tears. In conventional-slice MRI, sensitivity and specificity were 52% and 94%, and accuracy was 78%, respectively. Positive and negative predictive values were 92% and 58%, respectively. In radial-slice MRI, sensitivity and specificity were 84% and 90%, respectively, and accuracy was 86%. Positive and negative predictive values were 92% and 80%, respectively. Interobserver and intraobserver reliability for radial-slice MRI findings were 0.69 and 0.74, respectively, corresponding to high reproducibility and defined as good.

Table I
Diagnostic rate of magnetic resonance imaging.

Imaging slice	Sensitivity	Specificity	Accuracy	PPV	NPV
Conventional	0.52	0.94	0.78	0.92	0.58
Radial	0.84	0.90	0.86	0.92	0.80

PPV, positive predictive value; *NPV*, negative predictive value.

Discussion

This study demonstrated that the sensitivity of radial-slice MRI was significantly higher than that of conventional-slice MRI for diagnosing partial tears of the LHBT. From this result, radial-slice MRI had a higher diagnostic value regarding preoperative detection of partial tears of the LHBT.

It is well known that shoulder ultrasound is diagnosis tool modality for LHBT.[5,28,36] The findings of previous studies show that shoulder ultrasound can reliably diagnose full-thickness tear of LHBT.[2,36] However, Skelendzel et al reported that ultrasound diagnosis of partial tear versus other findings had sensitivity of 0.27 and specificity of 1.00.[36] They concluded that shoulder ultrasound evaluation of partial tears of the LHBT proved difficult because they were often described as normal or other pathologic conditions. And also, the diagnostic ability of ultrasound is operator dependent, and it takes a long time to master the technique. Belanger et al reviewed that evidence was lacking to recommend its use for the purpose of ruling out LHBT pathology.[5] Further research on ultrasound diagnosis in partial tears of the LHBT may be needed.

Several reports have examined the diagnostic rates of partial tears of the LHBT using MRI.[8,10,24,27,33] Mohtadi et al[27] evaluated the LHBT of 53 shoulders using 1.5-T MRI and reported a sensitivity of 50% and specificity of 70% for partial tears. They concluded that the ability of MRI for diagnosing partial LHBT tears is questionable and that MR arthrography may improve the diagnostic rate for partial tears. Dubrow et al[10] investigated 66 patients who underwent shoulder arthroscopy and evaluated the diagnostic rate of partial tears of the LHBT using 3.0-T MRI. The sensitivity and specificity of MRI for detecting partial tears were 27.7% and 84.2%, respectively. They concluded that conventional-slice MRI was unable to diagnose partial LHBT tears. Therefore, surgeons might encounter partial tears of the LHBT during arthroscopy that were not visualized on preoperative MRI. Razmjou et al,[33] who used 1.5-T MRI, reported similar results and stated that partial tears remain challenging to diagnose by conventional-slice MRI due to several factors. In addition, Lee et al[24] mentioned that partial-volume effect might make it difficult to detect partial tears of the LHBT. The anatomic shape of the LHBT is typically wide and flat at its intra-articular portion[1] and undergoes a rather abrupt angulation of 30 to 40 degrees as it passes through its pulley and into the bicipital groove.[16] These anatomic features may contribute to oblique slices of the LHBT in the anterosuperior region being difficult to visualize on axial slices because of the partial-volume effect[13] and lead to misdiagnosis of LHBT lesions.

Radial-slice MRI was applied to visualize the acetabular labrum of the hip.[20,21] Munk et al first described this for examination of the glenoid labrum of the shoulder joint in 1989.[30] Radial-slice MRI centered on the humeral head provides a cross-slice perpendicular to the insertion in all slices of the rotator cuff. However, cross-talk artifact resulted in impractical quality of labrum and rotator cuff, and this method was subsequently not clinically applied. In recent years, remarkable advances in MRI technology have enabled thinner slices with fewer interactions between adjacent ones.[19] Furukawa et al[13] reported that radial-slice MRI was useful for diagnosing subscapularis tendon tears by achieving a reduction in the partial-volume effect and potentially offering clear visualization of the subscapularis tendon. They suggested that because radial-slice MRI was capable of imaging sections perpendicular to the anterosuperior tendon insertion, early lesions could be more clearly visualized. Similarly, the LHBT passes over the anterosuperior portion of the humeral head near the attachment of subscapularis tendon and contacts the surface of the humeral head. Therefore, radial-slice MRI, which provides a vertical slice toward the LHBT, may have a high ability for capturing partial tears from the intraarticular region to the groove. From our results, the sensitivity of radial-slice MRI was significantly higher than that of conventional-slice MRI for diagnosing partial tears. Furthermore, the radial-slice MRI imaging method was the same as the conventional MRI imaging technique, except for the slice settings. Imaging acquisition time was also approximately the same as that of conventional-slice MRI (approximately 4 minutes), and it is almost the same as oblique coronal slices and axial slices. Moreover, because it was possible to accurately visualize all the rotator cuff attachments orthogonal to each part of the head of the humerus with radial-slice images, it was considered that the oblique coronal and axial images could be covered. Therefore, diagnosis of rotator cuff tears, including supraspinatus tendon, infraspinatus tendon, and subscapularis tendon involvement, may be possible only with radial slices and oblique sagittal slices.

There were several limitations to this study. The arthroscopic diagnosis of LHBT lesions is the gold standard method; however, the extra-articular portion of the LHBT was incompletely visualized,[12] and intrasubstance partial tears discerned on MRI in cross-section may be overlooked. The sample size was also too small to conclude significant superior diagnostic capacity of radial-slice MRI for partial tears of LHBT in comparison with conventional-slice MRI. Future studies with a larger sample size are warranted to examine false-positive and false-negative cases.

Conclusions

This study demonstrated that radial-slice MRI had significantly higher sensitivity than conventional-slice MRI. These results indicate that radial-slice MRI is efficient in capturing partial tears of the LHBT and is a useful tool for diagnosing partial tears of the LHBT.

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Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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