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

Yuji Shibayama, MD, PhD,*, Toshiaki Hirose, MD, PhDb, Akira Sugi, MD, Emi Mizushima, MD, PhDc, Yuto Watanabe, MDd, Rira Tomii, MDe, Kousuke Iba, MD, PhDe, Toshihiko Yamashita, MD, PhDe

*Department of Orthopedic Surgery, Sapporo Medical University School of Medicine, Sapporo, Hokkaido, Japan  
bAsaba Orthopaedic Hospital, Sapporo, Hokkaido, Japan

cd-Asaba Orthopaedic Hospital, Sapporo, Hokkaido, Japan

dE-mail address: y_shibayama75@yahoo.co.jp (Y. Shibayama).

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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.
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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 (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 gleno-humeral 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. 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
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.
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 a 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.2-6 However, Skelendz 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.3 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 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 al10 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 al34 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 and undergoes a rather abrupt angulation of 30 to 40 degrees as it passes through its pulley and into the bicipital groove.35 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 and lead to misdiagnosis of LHBT lesions.

Radial-slice MRI was applied to visualize the acetabular labrum of the hip.7,9 Munk et al first described this for examination of the glenoid labrum of the shoulder joint in 1989.37 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 al35 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 intra-articular 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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References

1. Ahrens PM, Boileau P. The long head of biceps and associated tendinopathy. J Bone Joint Surg Br 2007;2007:1001-9. https://doi.org/10.1302/0301-620X.89B8.
2. Armstrong A, Terefey SA, Wu T, Clark AM, Middleton WD, Yamaguchi K, et al. The efficacy of ultrasound in the diagnosis of long head of the biceps tendon pathology. J Shoulder Elbow Surg 2006;15:7-11. https://doi.org/10.1016/j.jse.2005.04.009.
3. Beall DP, Williamson EC, Ly QJ, Adkins MC, Emery RL, Jones TP, et al. Association of biceps tendon tears with rotator cuff abnormalities: degree of correlation with tears of the anterior and superior portions of the rotator cuff. AJR Am J Roentgenol 2003;180:613-9. https://doi.org/10.2214/ajr.180.3.1800633.
4. Becker DA, Cofeld RH. Tenodesis of the long head of the biceps brachii for chronic bicipital tendinitis. Long-term results. J Bone Joint Surg 1989;71:376-81.
5. Belanger V, Dupuis F, Leblond J, Roy JS. Accuracy of examination of the long head of the biceps tendon in the clinical setting: a systematic review. J Rehabil Med 2019;51:479-91. https://doi.org/10.2340/16501977-2563.
6. Bennett WF. Specificity of the Speed’s test: arthroscopic technique for evaluating the biceps tendon at the level of the bicipital groove. Arthroscopy 1998:14:789-96.
7. Boileau P, Ahrens PM, Hatzidakis AM. Entrapment of the long head of the biceps tendon: the hourglass biceps—a cause of pain and locking of the shoulder. J Shoulder Elbow Surg 2004;13:249-57. https://doi.org/10.1016/j.jse.2004.01.001.
8. De Maeseneer M, Boulet C, Pouliart N, Kichouh M, Buls N, Verhelle F, et al. Assessment of the long head of the biceps tendon of the shoulder with 3T magnetic resonance arthrography and CT arthrography. Eur J Radiol 2012;81:934-9. https://doi.org/10.1016/j.ejrad.2011.01.121.
9. Denard PJ, Dai X, Hanyspiak BT, Burkhart SS. Anatomy of the biceps tendon: implications for restoring physiological length-tension relation during biceps tenodesis with interference screw fixation. Arthroscopy 2012;28:1352-8. https://doi.org/10.1016/j.arthro.2012.04.143.
10. Dubrow S, Streit J, Shishani Y, Robbin M, Cobezie R. Diagnostic accuracy in detecting tears in the proximal biceps tendon using standard nonenhancing shoulder MRI. Open Access J Sports Med 2014;5:81-4. https://doi.org/10.2147/oajsm.S588255.
11. Favorito PJ, Harding WG III, Heidt RS Jr. Complete arthroscopic examination of the long head of the biceps tendon. Arthroscopy 2001;17:430-2.
12. Festa A, Allert J, Issa K, Tasto JP, Myer JJ. Visualization of the extra-articular portion of the long head of the biceps tendon during intra-articular shoulder arthroscopy. Arthroscopy 2014;30:1413-7. https://doi.org/10.1016/j.arthro.2014.05.044.
13. Furukawa R, Morihara T, Arai Y, Ito H, Kida Y, Sukenari T, et al. Diagnostic accuracy of magnetic resonance imaging for subscapularis tendon tears using radial-slice magnetic resonance images. J Shoulder Elbow Surg 2014;23:e283-90. https://doi.org/10.1016/j.jse.2014.03.011.
14. Gaskin CM, Anderson MW, Choudhri A, Diduch DR. Focal partial tears of the long head of the biceps brachii tendon at the entrance to the bicipital groove: MR imaging findings, surgical correlation, and clinical significance. Skelet Radiol 2009;38:959-65. https://doi.org/10.1007/s00256-009-0720-z.
15. Gill TJ, McIvlin E, Mair SD, Hawkins RJ. Results of biceps tenotomy for treatment of pathologic of the long head of the biceps brachi. J Shoulder Elbow Surg 2001;10:247-9.
16. Habermeyer P, Magosch P, Pritsch M, Scheibel MT, Lichtenberg S. Anterosuperior impingement of the shoulder as a result of pulley lesions: a prospective arthroscopic study. J Shoulder Elbow Surg 2004;13:5-12. https://doi.org/10.1016/j.jse.2003.09.013.
17. Hegedu ES, Goode A, Campbell S, Morin A, Tamadonii M, Moorvan CT III, et al. Physical examination tests of the shoulder: a systematic review with meta-analysis of individual tests. Br J Sports Med 2008;42:80-92. https://doi.org/10.1136/bjsm.2007.038406.
18. Holthay R, Razmjou H. Accuracy of the Speed’s and Yergason’s tests in detecting biceps pathology and SLAP lesions: comparison with arthroscopic findings. Arthroscopy 2004;20:231-6. https://doi.org/10.1016/j.arthro.2004.01.006.
19. Honda H, Morihara T, Arai Y, Horii M, Ito H, Furukawa R, et al. Clinical application of radial magnetic resonance imaging for evaluation of rotator cuff tear. Orthop Traumatol Surg Res 2015;101:715-9. https://doi.org/10.1016/j.otsr.2015.06.007.
20. Horii M, Kubo T, Hachiya Y, Nishimura T, Hirasawa Y. Development of the acetalbum and the acetalbular labrum in the normal child: analysis with radial-sequence magnetic resonance imaging. J Pediatr Orthop 2002;22:222-7.
21. Horii M, Kubo T, Hirasawa Y. Radial MRI of the hip with moderate osteoarthritis. J Bone Joint Surg Br 2000;82:364-8.
22. Kanatli U, Ozturk BY, Esen E, Bolukbasi S. Intra-articular variations of the long head of the biceps tendon. Knee Surg Sports Traumatol Arthrosc 2011;19:1576-81. https://doi.org/10.1007/s00167-010-1384-x.
23. Lee JH, Yoon YC, Jung JY, Yoo JC. Rotator cuff tears noncontrast MRI compared to MR arthrography. Skelet Radiol 2013;44:1745-54. https://doi.org/10.1007/s00256-012-1576-7.
24. Lee RW, Choi SJ, Lee MH, Ahn JH, Shin DR, Kang CH, et al. Diagnostic accuracy of YT conventional shoulder MRI in the detection of the long head of the biceps tendon tears associated with rotator cuff tendon tears. Skelet Radiol 2016;45:1705-15. https://doi.org/10.1007/s00256-016-2501-9.
25. Mazzocca AD, McCarthy MB, Ledgard FA, Chowaniec DM, McKinnon WJ Jr, Delaronde S, et al. Histomorphologic changes of the long head of the biceps tendon in common shoulder pathologies. Arthroscopy 2013;29:972-8. https://doi.org/10.1016/j.arthro.2013.02.002.
26. McGarvey C, Harb Z, Smith C, Houghton R, Corbett S, Ajued J. Diagnosis of rotator cuff tears using 3-Tesla MRI versus 3-Tesla MRA: a systematic review and meta-analysis. Skelet Radiol 2016;45:251-61. https://doi.org/10.1007/s00256-015-2229-x.
27. Mohtadi NC, Vellet AD, Clark ML, Hollinshead RM, Sanyuin TM, Fick GH, et al. A prospective, double-blind comparison of magnetic resonance imaging and arthroscopy in the evaluation of patients presenting with shoulder pain. J Shoulder Elbow Surg 2004;13:258-65. https://doi.org/10.1016/j.jse.2004.01.003.
28. Moosmayer S, Smith HJ. Diagnostic ultrasonography of the shoulder - a method for experts only? Results from an orthopedic surgeon with relative inexpensive compared to operative findings. Acta Orthop 2005;76:503-8. https://doi.org/10.1080/174536705010041484.
29. Morag Y, Jacobson JA, Shields C, Rajani R, Jamadar DA, Miller B, et al. MR arthrography of rotator interval, long head of the biceps brachii, and biceps pulley of the shoulder. Radiology 2005;235:21-30. https://doi.org/10.1148/radiol.2351031455.
30. Munk PL, Holt RG, Helms CA, Gannet HK. Glenoid labrum: preliminary work findings. Acta Orthop 2005;76:503-8. https://doi.org/10.1080/174536705010041484.
31. Murthi AM, Vosburgh CL, Nevisier TJ. The incidence of pathologic changes of the long head of the biceps tendon. J Shoulder Elbow Surg 2000;9:382-5.
32. Post M, Benca P. Primary tendinitis of the long head of the biceps. Clin Orthop Relat Res 1980;246:117-25.
33. Razmjou H, Fournier-Gosselin S, Christakis M, Penninga E, ElMaraghy A, Holthay R. Accuracy of magnetic resonance imaging in detecting biceps pathology in patients with rotator cuff disorders: comparison with arthroscopy. J Shoulder Elbow Surg 2016;25:38-44. https://doi.org/10.1016/j.jse.2015.06.020.
34. Romeo AA, Mazzocca AD, Tauro JC. Arthroscopic biceps tenodesis. Arthroscopy 2004;20:206-13. https://doi.org/10.1016/j.arthro.2003.11.053.
35. Sasaki K, Morihara T, Kida Y, Furukawa R, Arai Y, Fujiwara H, et al. Visualization of rotator cuff tear morphology by radial magnetic resonance imaging. Clin Imaging 2018;50:264-72. https://doi.org/10.1016/j.clinimag.2018.04.005.
36. Skendzel JC, Jacobson JA, Carpenter JE, Miller RS. Long head of biceps brachii tendon evaluation: accuracy of preoperative ultrasound. AJR Am J Roentgenol 2011;197:942-8. https://doi.org/10.2214/AJR.10.5012.
37. Slentker NR, Lawson K, Ciccotti MG, Dodson CC, Cohen SB. Biceps tenotomy versus tenodesis: clinical outcomes. Arthroscopy 2012;28:576-8. https://doi.org/10.1016/j.arthro.2011.10.021.