Clinical application of radial magnetic resonance imaging for evaluation of rotator cuff tear

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A B S T R A C T

Background: Magnetic resonance imaging is useful for evaluating the rotator cuff, but some tendinous insertions cannot be assessed using oblique sagittal, oblique coronal, and axial magnetic resonance (MR) images because of the presence of the partial volume effect.

Hypothesis: The purpose of this study was to determine whether radial-slice MR images could reveal normal rotator cuff insertions and rotator cuff tears more clearly than conventional MR images.

Patients and methods: The study included 18 subjects with normal rotator cuffs and 30 with rotator cuff tears. MR images of rotator cuff insertions sliced into radial, oblique coronal, and axial sections were obtained. The extent to which normal rotator cuff insertions and rotator cuff tears were visualized in each of the three MR images was evaluated.

Results: The top to posterior portions of the rotator cuff insertions from 0° to 120° could be visualized in the radial MR images. In comparison, the posterior portions of the rotator cuff insertions could not be visualized around 45° in both the oblique coronal and axial MR images.

Discussion: These findings demonstrate that radial MR images are superior to the oblique coronal and axial MR images regarding their ability to accurately visualize rotator cuff insertions. Radial MR images also revealed greater detail around 45° in the posterior area of the rotator cuff tears than the oblique coronal and axial MR images. Radial MR images are particularly useful for visualizing clinically important posterosuperior rotator cuff tears.

Level of evidence: Level III – Diagnostic study.

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1. Introduction

The rotator cuff (RC) comprises four tendons of the subscapularis, supraspinatus, infraspinatus, and teres minor muscles, which surround the humeral head [1]. These tendons attach to the greater and lesser tuberosities of the humerus. Most RC tears occur at these tendinous insertions to the humeral head, and although the sizes of tears may vary, surgical repair is typically performed when symptoms including pain and restriction of shoulder motion persist [2,3]. Successful RC repair requires a proper understanding of the size of the tear and the condition of the torn tendon preoperatively. Various studies have described the utility of magnetic resonance imaging (MRI) for detecting RC injuries. The sensitivity and specificity of MRI in the diagnosis of RC tears have been shown to be very high, at 90% [4–8].

Oblique sagittal MRI provides the location and size of the tear in the anteroposterior direction, perpendicular to the RC tendons. In addition, MRI parallel to the RC tendons is commonly used for the detection of retracted torn tendons; oblique coronal MRI, for the superior part of the supraspinatus tendon; and axial MRI, for the major part of subscapularis and infraspinatus tendons. These MRI settings also allow for the evaluation of the articular and bursal side tears on the bone-tendon insertion [9]. However, no plane of the oblique coronal or axial MRI provides a proper cross-section of the tendons in their anterosuperior and posterosuperior regions because of the circumferential attachment of the RC tendons to the humeral head, resulting in poor visualization of the tendons due to the artifact of partial volume effect [10]. To avoid this artifact, radial MRI is reported to be useful for the visualization of
the circumferentially attached acetabular labrum of the hip joint [11–13]. Therefore, we hypothesized that a radial MRI centered on the humeral head provides a wider range of visualization of the RC insertions than the conventional combination of oblique coronal and axial MRI (conventional setting MRI).

To confirm this hypothesis, we compared the observable regions in radial and conventional setting MRI in regard to the following: the insertion of the RC tendon in cases without tear and the torn tendon edge of the cases with cuff tear, including the supraspinatus portion. In addition, the detectability of the intratendinous delamination of the torn edge, which required additional arthroscopic suturing besides the usual tendon-to-bone repair, was compared between each MRI setting.

2. Patients and methods

2.1. Patients

Eighteen patients (18 shoulders), comprising 13 men and 5 women (age, 15–38 years; mean, 21.5 years) with a diagnosis of glenoid labrum injury and without tear of the RC, who underwent shoulder arthroscopy between January 2011 and March 2013 were assessed in this study. Cases in which the RC tears were found during the shoulder arthroscopy were excluded.

Thirty patients (30 shoulders), comprising 15 men and 15 women (age, 53–69 years; mean, 63.3 years) with a diagnosis of the RC tear including the supraspinatus portion, who underwent shoulder arthroscopy between January 2011 and March 2013 were assessed in this study.

2.2. Ethical review committee statement

Ethical approval was obtained from the ethics committee of Kyoto Prefectural University of Medicine (ERB-C-163).

2.3. MRI protocol

The MRI system used was a 3.0 T (Achieva 3.0 T X-series; Philips Healthcare, Best, the Netherlands), with a dedicated 4-channel shoulder coil. Subjects were placed in the supine position with their arms on the sides. The elbows were fully extended with the palm upward.

Oblique sagittal, oblique coronal, and axial MRIs were set according to the conventional method: oblique sagittal, perpendicular to the scapula axis; oblique coronal, parallel to the scapula axis; and axial, perpendicular to the body axis. Fat-suppressed T2-weighted images with a 3.0-mm slice thickness and 0.3-mm slice gap [14,15] were used. Oblique coronal and axial MRIs were comprehensively defined as the conventional setting MRIs in this study.

Radial MRI was planned on the oblique sagittal image. The center of radial planes was set at the mid-point of the humeral head on the image in which the lesser tuberosity was best depicted. Twenty-four fat-suppressed T2-weighted images with a slice thickness of 3.0 mm were obtained at 7.5° intervals (Fig. 1).

The image acquisition time was approximately 3.5 min for the oblique sagittal, oblique coronal, and axial MRIs, respectively, and 4 min for radial MRI. The difference of imaging time is reflected by slice numbers. Oblique sagittal MRI was used as reference for the position confirmation on each section of the oblique coronal, axial, and radial MRIs.

2.4. Evaluation of MRIs

The evaluations were focused on the posterior half of the shoulder joint. The evaluated position was recorded as the angle from the uppermost position at 7.5° intervals, such as SP30 (30° from superior to posterior). The uppermost region was expressed as SP0. The position on the oblique coronal and axial images was rounded to the nearest angle at 7.5° intervals (Fig. 2).

For the evaluation of the cuff insertion in the cases without RC tear, detectability of tendon continuity to its bony insertion was evaluated on each section of the radial MRI and conventional setting MRIs.

In the cases with RC tear, the findings of the RC at the tear were judged as “continuous”, “torn”, or “undeterminable” on each slice. The judgment “continuous” meant that the continuity of the RC to its bony insertion was completely observable. The ranges where
the torn tendon edge was well-depicted were compared between the conventional setting MRIs and radial MRI.

To evaluate the detectability of the intratendinous delamination of the torn edge [16], the cuff tear cases that required additional arthroscopic layer-to-layer suturing besides the usual tendon-to-bone repair were submitted. The imaging capability of the delamination was compared between radial MRI and conventional setting MRIs.

2.5. Intra- and inter-rater reliabilities

The evaluations of all MR images were performed twice with a 2-week interval by two independent raters who were certified orthopedic surgeons specialized in shoulder disorders and not informed about the diagnosis or other conditions of the subjects.

3. Results

3.1. Reliability

The inter-class correlation coefficient (ICC) (3,1) was 0.987 (95% confidence interval [CI], 0.974–0.994) for the evaluation of the RC on radial MR images, indicating a good inter-rater reliability. The intra-class correlation coefficient was 0.98 for the evaluation of the RC on MR images, indicating good intra-rater reliability. The ICC of the radial evaluation of the posterior extent of the RC tear (ICC 1.3 = 0.986 [95% CI, 0.970–0.993]) was significantly higher than that of the coronal evaluation (ICC 1.3 = 0.824 [95% CI, 0.699–0.923]) (P < 0.05).

3.2. Evaluation of cuff insertion in cases without RC tear

Typical images of RC insertion on radial, oblique coronal, and axial MRIs are shown in Fig. 3. On conventional setting MRIs, there was an area where no adequate image of the tendon was obtained around the SP45 situs, whereas the areas were clearly visible with radial MRI even in this section (Fig. 4). On the most inferior part, the range of the sections in which continuity of the teres minor tendon was well-delineated to its bony insertion was equivalent between radial MRI and conventional setting MRIs.

3.3. Ranges where the torn tendon edge was observable

Findings of each region were compared between conventional setting MRIs and radial MRI (Fig. 5). From SP0 to SP22.5 and from SP82.5 to SP97.5, the findings of the RC (torn or continuous) were

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**Fig. 3.** Images of insertion in a case without rotator cuff tear. Both radial and oblique coronal images in SP0 were almost the same. Similarly, both radial and axial images in SP90 were almost the same. However, while the rotator cuff insertion was clearly discernible in the radial image in SP45, it was not clearly visible in the oblique coronal image.

**Fig. 4.** Extent to which the normal rotator cuff insertions were clearly discernible in radial and conventional images.
consistent between radial MRI and conventional setting MRIs. At other regions, the findings of the RC were judged as undeterminable on conventional setting MRIs, whereas they were clearly visualized as torn or continuous on radial MRI.

### 3.4. Detectability of the intratendinous delamination of the torn edge

Arthroscopically, there were 11 cases with delamination of the torn edge of the RC, which required layer-to-layer suturing besides the usual tendon-to-bone repair. The anterior part of the delamination was well-detected both with radial MRI and conventional setting MRIs in all cases. On the posterior/inferior parts, however, the lesions were detectable only with radial MRI in 4 cases (Fig. 6).

### 4. Discussion

The potential use of radial MRI for the diagnosis of shoulder abnormality was first advocated by Munk et al. in 1989 [17]. However, little has been reported about its clinical application in this joint. On the other hand, radial MRI has been used for the observation of the acetabular labrum [11–13]. One of the main reasons seems to be that cross-talk artifact caused impractical quality of images of the glenoid labrum and RC under the conventional MRI systems without sufficient performance, because the glenoid is smaller in diameter than the acetabulum.

However, remarkable advances in MRI in recent years have enabled thinner slices with fewer interactions between adjacent ones. In the present study, the status of the cuff, whether it was...
torn or continued, was well-observed throughout the targeted area on radial MRI, in spite of small inter-slice intervals at 7.5°. There was a blind area around the posterosuperior 45° portion in conventional setting MRIs, including combined oblique coronal and axial images. In 87% (26/30) of our cases, the RC tear extended to the posterosuperior blind area. Clear MR images parallel to the tendons are valuable in not only intuitive visualization of the tendon retraction, but also for an accurate grasp of the torn edge, such as in cases of intratendinous delamination, which often requires additional layer-to-layer repair [3,18–20]. A preoperative understanding of the lesion would help simulate the surgical procedures. In four out of 11 patients in the present study who required layer-to-layer repair of horizontal flaps, visualization of the posterior portion of the lesion was possible only by radial MRI (Fig. 6).

Recently, damages of the rotator interval and adjacent subscapularis tendon have been noticed even in cases in which a major lesion exists on the supraspinatus tendon. Additional treatment might be necessary for these abnormalities [21,22]. We previously reported the usefulness of radial MRI for the detection of incomplete or complete subscapularis tendon tear [23]. In a future study, we will also compare incomplete or complete supraspinatus and infraspinatus tendon tears between radial and conventional MRI.

The imaging technique for radial MRI is the same as that for conventional setting MRIs, except for the slice setting. Imaging time is almost the same between radial, oblique coronal imaging, and axial MRI. Therefore, radial MRI provides wider visualization of the RC condition with about half the imaging time compared with conventional setting MRIs. The present study suggests that radial MRI could replace conventional oblique coronal and axial MRIs for RC imaging. Therefore, the rotator cuff lesion could be more accurately detected by the radial and oblique sagittal MRIs than with oblique coronal and axial MRIs.

Radial slice setting might seem troublesome, and indeed, it is, when the individual imaging apparatuses are set for the first time. However, many MRI systems are able to store the radial setting, and afterwards, pointing out the epicenter on the scout image is enough. MRI systems with adequate performance are necessary for practical radial imaging. Using a wider inter-slice angle such as 10° might relieve the required performance of the apparatus. Recorded positions such as SP30 are not always consistent with the same anatomical positions of the RC insertion because of different humeral rotations with each imaging setting. More accurate positioning of the subject is required for radial MRI than conventional setting MRIs.

Despite the limitations mentioned above, our findings suggest that radial MRI would be useful as a substitute for conventional oblique coronal and axial MRIs for RC imaging as long as the system has an adequate performance.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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None.

References