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Relationship between postoperative retear and preoperative fatty degeneration in large and massive rotator cuff tears: quantitative analysis using T2 mapping

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Background: Fatty degeneration of the rotator cuff muscles is reported to be associated with retear after rotator cuff repair. The purpose of this study was to assess the relationship between retear and preoperative fatty degeneration, as quantified by T2 mapping.

Methods: This prospective cohort study included 83 large and 24 massive rotator cuff tears (average age, 67 years; range, 46-82 years). All patients preoperatively underwent T2 mapping magnetic resonance imaging, and T2 values of the supraspinatus and infraspinatus muscles were quantified. Cuff integrity was evaluated with magnetic resonance imaging 1 year postoperatively. Preoperative T2 values were compared between the retear and intact groups. The preoperative Goutallier stage, Constant score, and the shoulder score of the University of California at Los Angeles were also compared between the 2 groups.

Results: Retear was found in 32 shoulders (30%). Postoperative Constant and University of California at Los Angeles scores were significantly higher in intact shoulders than in retear shoulders ($P < .001$ for both). Mean preoperative T2 values of supraspinatus and infraspinatus were 77.4 ± 13.2 ms and 73.2 ± 15.3 ms in retear shoulders and 66.5 ± 11.1 ms and 58.6 ± 11.7 ms in intact shoulders, respectively; the differences were significant in both muscles ($P < .001$). Cutoff values for prediction of retear were 71.8 ms in supraspinatus and 63.1 ms in infraspinatus. There were no significant differences in the preoperative Goutallier stages of supraspinatus and infraspinatus between the 2 groups.

Conclusions: Retear shoulders demonstrated significantly higher preoperative T2 values than intact shoulders. T2 mapping can be a useful tool for predicting postoperative retears.

This study was approved by the Institutional Review Board/ERC of Funabashi Orthopaedic Hospital (Proposal IRB/ERC No.: 2014017).

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Cuff integrity after repair of large or massive rotator cuff tears is inferior to that after repair of smaller tears, with the former having retear rates of 25% to 57%.[2-4,21,23] The healing process of repaired tendon is multifactorial, and, in addition to tear size,[22] tendon retraction,[12] duration of symptoms,[13] and patient age[14] are reported factors that negatively affect rotator cuff healing. Moreover, many studies have found that fatty degeneration of the rotator cuff muscles is associated with retear after rotator cuff repair,[2,9] but some have found no such significant relationship.[13,15] It therefore remains controversial whether preoperative fatty degeneration of the rotator cuff muscles affects repair cuff integrity.

Semiquantitative methods such as Goutallier staging are commonly used to evaluate fatty degeneration of the rotator cuff muscles; however, poor reproducibility may be a weakness of such methods.[3] In addition, small changes in fatty degeneration can be overlooked by semiquantitative methods that assess fatty degeneration only in several grades. These weaknesses might account for the controversy surrounding the relationship between fatty degeneration and retear.

Recently, a few quantitative methods using magnetic resonance imaging (MRI) have been proposed for evaluating fatty degeneration of the rotator cuff muscles.[8,17,19] Matsuki et al[16] reported that transverse relaxation time (T2) mapping was potentially useful for quantitatively evaluating fatty degeneration of the rotator cuff muscles by measuring T2 values of the muscles in the presence of very high intraobserver and interobserver variabilities. They also demonstrated that T2 values did not correlate with patient age or symptom duration but with tear size or Goutallier stages. With this technique, we might be able to precisely explore the relationship between preoperative fatty degeneration of the cuff muscles and postoperative cuff retear.

Our aims here were to use T2 mapping to assess the relationship between preoperative fatty degeneration of the cuff muscles and retear after arthroscopic repair of large and massive rotator cuff tears and to determine the cutoff T2 values for prediction of retear. We hypothesized that preoperative fatty degeneration of the cuff muscles would affect postoperative cuff integrity.

Materials and methods

Patients

This study was a prospective cohort study. Between May 2014 and November 2016, we prospectively recruited candidates for this study at our institute. The inclusion criteria were: shoulders (1) with large or massive rotator cuff tears that required surgical treatment, (2) that preoperatively underwent MRI including a T2 mapping sequence, and (3) that underwent arthroscopic rotator cuff repair using the suture-bridge technique.[20] Exclusion criteria were: (1) partial repair, (2) patch augmentation, (3) revision surgery, and (4) trauma within 1 month before preoperative MRI.

MRI acquisition

All patients preoperatively and postoperatively underwent MRI with a 1.5-T system (Intera 1.5T; Philips, Amsterdam, the Netherlands) according to the protocol used in the study by Iijima et al.[11] For preoperative MRI, a T2 mapping sequence was performed in addition to routine, diagnostic T1- and T2-weighted imaging. T2 measurement was performed on a sagittal image 15 mm medial to the Y-view by using the multi–spin-echo sequence.[11] The multi–spin-echo scanning parameters were the same as those used in the study by Iijima et al,[11] namely 8 echo times of 11 to 88 ms; repetition time, 1500 ms; field of view, 200 × 200 mm; matrix size, 320 × 320; and slice thickness, 5.0 mm.[11]

T2 measurement

T2 measurement was performed in accordance with the methods used in the study by Iijima et al.[11] T2 values were measured with a PACS workstation (Doctor PACS; Doctor NET, Tokyo, Japan) by a single experienced shoulder surgeon. Regions of interest were drawn manually around the borders of the supraspinatus (SSP) and infraspinatus (ISP) muscles on T2-calculated images, and mean T2 values were calculated for both muscles (Fig. 1). Muscles with more fatty degeneration were expected to have greater T2 values, reflecting increased fat content.

Radiologic diagnosis

Tear size was determined by preoperative MRI; a large tear was defined as a tear >3 cm in the coronal plane, and a massive tear as >5 cm, according to Cofield's classification.[6] We also assessed fatty degeneration of the rotator cuff muscles with preoperative

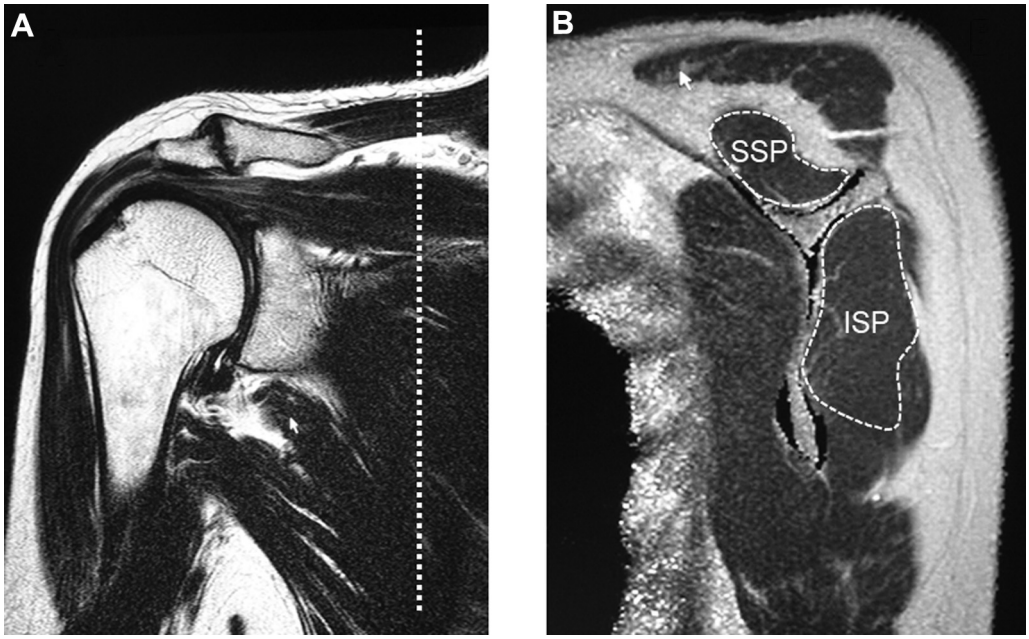

Figure 1 Measurement of T2 values. (**A**) T2-weighted coronal image of a right shoulder. The dotted line represents the site 15 mm medial to the Y-view. (**B**) T2-calculated image. Regions of interest were drawn manually around the borders of the supraspinatus (SSP) and infraspinatus (ISP) muscles.

MRI using Goutallier staging. Repair cuff integrity was evaluated with postoperative MRI at 1 year according to the grading of Sugaya et al;[23] grades IV and V were defined as retear. Two shoulder surgeons, each with more than 15 years' experience, independently made MRI diagnosis. When the diagnosis of retear disagreed, the final grade was determined based on the consensus.

Clinical evaluation

Patients were clinically evaluated by a single surgeon before, and 1 year after, surgery. We evaluated active ranges of motion, including forward flexion, external rotation with the arm at the side, and internal rotation. Shoulder function was also assessed by using the Constant score and the Shoulder Rating Scale of the University of California at Los Angeles (UCLA).

Surgical techniques

All patients underwent arthroscopic rotator cuff repair using suture-bridging techniques. All surgeries were performed in the beach chair position under general anesthesia and interscalene brachial plexus block. After routine diagnostic arthroscopy of the glenohumeral joint and the subacromial bursa, subacromial decompression was performed in all patients. Resection of the coracohumeral ligament and capsular release were performed when mobility of the torn cuff was poor. Two or 3 triple-loaded suture anchors were inserted at the medial border of the greater tuberosity, and 2 suture limbs at a time were passed through the cuff using a suture grasper. We first performed suture-bridging using 2 or 3 knotless suture anchors inserted on the lateral wall of the greater tuberosity; this was followed by medial-row knot-tying to avoid the concentration of stress on the medial-row sutures. Concomitant subscapularis tears were also repaired by using suture-bridging techniques. Tenodesis or tenotomy was performed in all shoulders for the long head of the biceps (LHB), if remained. Generally, we perform tenodesis for males $<$70 years and females $<$65 years.

Postoperative rehabilitation

Shoulders were immobilized for 4 to 6 weeks with an abduction brace, depending on the repair quality. Relaxation of the shoulder girdle muscles was started on postoperative day 1, followed by passive range of motion exercises and isometric cuff exercises. After the immobilization period, active-assisted exercises were initiated followed by active exercises. Patients were allowed to do light work 3 months after surgery and heavy labor 6 months after surgery, depending on their functional recovery.

Statistical analysis

Data were expressed as means $\pm$ standard deviation. Student's *t*-test, the χ^2 test, and Mann-Whitney's *U* test were used for comparison between shoulders with and without retear. Receiver operating characteristic (ROC) curves were used to determine T2 values for prediction of postoperative retear. SPSS Statistics v. 22 (IBM, Armonk, NY, USA) was used for all statistical analyses, and the level of significance was set at $P < .05$.

Results

Consecutive 145 patients (145 shoulders) were recruited for the study; 20 patients were excluded because of partial repair (9 shoulders), patch augmentation (8 shoulders), or

Table I Patient demographic data and clinical results

Data	Intact group	Retear group	*P* value
No. of patients	75	32	
Age (yr)*	66 ± 8	69 ± 7	.21
Gender (M:F)	47:28	16:16	.20
Symptom duration (mo)*	12 ± 11	12 ± 13	.59
Smoking, n (%)	3 (4)	4 (13)	.10
Diabetes, n (%)	9 (12)	6 (19)	.35
SSC tear, n (%)	40 (53)	22 (69)	.12
Preoperative*			
ROM			
FF	134 ± 43	135 ± 48	.81
ER	45 ± 16	39 ± 18	.063
IR	T12 ± 3	L1 ± 3	.73
Constant score	51 ± 15	47 ± 14	.16
UCLA score	18 ± 4	15 ± 4	.004
Postoperative*			
ROM			
FF	165 ± 12	160 ± 16	.24
ER	45 ± 19	41 ± 16	.26
IR	T11 ± 3	T12 ± 4	.71
Constant score	75 ± 10	63 ± 12	<.001
UCLA score	31 ± 4	28 ± 5	<.001

SSC, subscapularis; *ROM*, range of motion; *FF*, forward flexion; *ER*, external rotation; *IR*, internal rotation; *UCLA*, University of California at Los Angeles.
* Data are presented as means ± standard deviation.

revision surgery (3 shoulders). Therefore, 125 shoulders were enrolled in the study, but postoperative MRI at 1 year was not available in 18 shoulders. Consequently, the study included 107 shoulders, and the follow-up rate was 86%. The subjects consisted of 63 males and 44 females with a mean age of 67 ± 8 years (range, 46-82 years), and there were 83 large and 24 massive cuff tears. Based on the operative findings, U-shaped and L-shaped tears were seen in 96 and 11 shoulders, respectively. LHB was torn in 23 shoulders, and tenodesis or tenotomy of LHB was performed in 53 and 31 shoulders, respectively.

Retears were found in 32 shoulders (30%) 1 year after surgery; retear occurred in 20 shoulders with large preoperative tears (24%) and in 12 with massive preoperative tears (50%). Patient demographic data for the intact and retear groups are shown in Table I.

Table II Comparison of preoperative T2 values between the intact and retear groups

Muscle	Intact group	Retear group	*P* value
SSP	66.5 ± 11.1	77.4 ± 13.2	<.001
ISP	58.6 ± 10.7	73.2 ± 15.3	<.001

SSP, supraspinatus; *ISP*, infraspinatus.
Data are represented as means ± standard deviation.

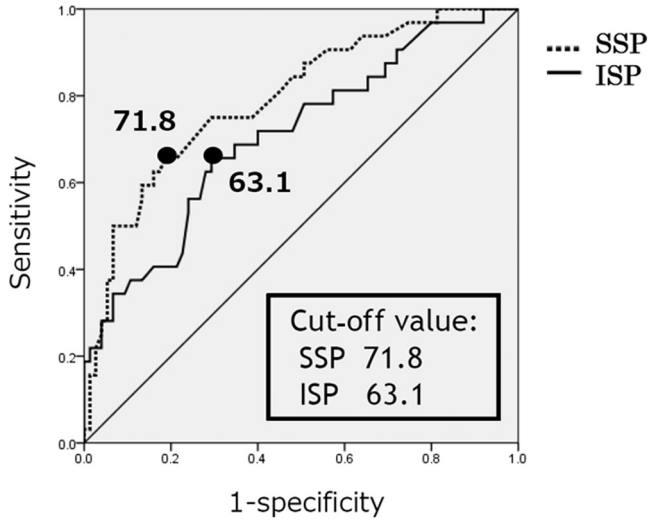

Figure 2 Results of the receiver operating characteristic curve analysis. Cutoff values for retear were 71.8 ms in supraspinatus (SSP) and 63.1 ms in infraspinatus (ISP).

There were no significant differences in the demographic data and preoperative shoulder function between the groups, except in the case of the UCLA score.

The mean preoperative T2 values of SSP and ISP were significantly higher in the retear shoulders than in the intact shoulders (Table II, $P < .001$ for both). ROC curve analysis indicated that the best cutoff values for retear prediction were 71.8 ms for SSP and 63.1 ms for ISP (Fig. 2). There were no significant differences in the preoperative Goutallier stages of SSP and ISP between the retear and intact groups (Table III).

Postoperative UCLA and Constant scores were significantly higher in the intact group than in the retear group (Table I, $P < .001$ for both). There were no significant differences in any of the postoperative active ranges of motion between the intact and intact groups (Table I).

Table III Comparison of preoperative Goutallier stages between the intact and retear groups

Goutallier stage	SSP		ISP	
	Intact (n = 75)	Retear (n = 32)	Intact (n = 75)	Retear (n = 32)
I	12	2	22	7
II	54	26	42	14
III	7	6	11	10
IV	0	0	0	1
P value	.91		.93	

SSP, supraspinatus; *ISP*, infraspinatus.

Discussion

To our knowledge, this is the first study to use quantitative T2 mapping to examine the relationship between postoperative retear and preoperative fatty degeneration in large and massive rotator cuff tears. As we hypothesized, the preoperative T2 values of the retear group were significantly higher than those of the intact group in both SSP and ISP. In addition, ROC curve analysis showed that the best cutoff values were 71.8 ms for SSP and 63.1 ms for ISP. Preoperative T2 mapping evaluation of the cuff muscles can help surgeons to choose their surgical options and to predict the postoperative prognosis.

Many preoperative factors that influence the likelihood of retear after arthroscopic rotator cuff repair have been reported. A recent systematic review showed that patient age, tear size, osteoporosis, acromiohumeral distance, extent of retraction, number of tendons involved, surgical technique, and preoperative fatty degeneration of the cuff muscles were associated with postoperative retears.[22] Many studies have indicated that fatty degeneration of the rotator cuff muscles is a risk factor for retear,[2,12] although a few papers have reported no such significant relationship.[13,15] The use of semiquantitative methods may be the major reason for this controversy. Here, we used a quantitative T2 mapping technique and found significant differences in preoperative fatty degeneration between intact and retear shoulders. Similarly, Nozaki et al[19] quantitatively evaluated fatty degeneration of the rotator cuff muscles by using 2-point Dixon MRI; they reported that the preoperative fat fraction in SSP was higher in retear shoulders than in intact shoulders.

Goutallier staging failed to detect differences in fatty degeneration between our intact and retear groups. This may be because the semiquantitative method overlooked small differences in fatty degeneration. On the other hand, quantitative T2 mapping could detect the differences and determine the cutoff values for retear prediction. Nozaki et al[19] demonstrated, using 2-point Dixon MRI, that the cutoff fat fraction values for prediction of SSP and ISP retear were 26.6% and 31.0%, respectively. Moreover, quantitative MRI methods including T2 mapping and the Dixon technique have shown high reliability.[10,16,17] Quantitative methods may have many advantages over semiquantitative methods in fatty degeneration evaluation.

Functional scores in our retear group were significantly lower than those in the intact group. Many previous studies have reported that cuff integrity after repair can affect clinical results, such as functional improvement and pain relief,[1,7,23,25] although some authors have found no significant differences in clinical outcomes between retear and intact shoulders.[5,24] Repair integrity may be an important factor in better clinical outcomes.

There were some limitations to our research. First, repaired cuff integrity was evaluated 1 year after surgery. This follow-up period could be considered relatively short, although we believe that it was long enough to evaluate cuff integrity, because most retears occur within a year after repair.[4,18] Second, T2 values can be affected by the water content of the muscles. To minimize this effect, we excluded shoulders with recent trauma, which might have increased muscle water content. Third, the T2 values of the subscapularis and teres minor muscles were not measured; the condition of these muscles might have had some influence on the outcomes. Nevertheless, the strengths of our study are that it was prospective, with a good follow-up rate and a sufficient number of patients.

Conclusions

Preoperative T2 values of the SSP and ISP muscles were significantly higher in retear shoulders than in intact shoulders, although Goutallier staging failed to detect the differences in fatty degeneration. T2 mapping can be a useful tool for predicting postoperative retears.

Disclaimer

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