A Novel Reparability Assessment Scoring System for Full-Thickness Rotator Cuff Tears

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Background: It is difficult to predict the arthroscopic reparability of rotator cuff tears preoperatively when the repair is challenging. This can result in unsatisfactory outcomes and a high retear rate.

Purpose: To develop an assessment score reflecting factors in rotator cuff tears that can predict reparability before surgery.

Study Design: Cohort study; Level of evidence, 3.

Methods: We retrospectively enrolled 170 patients with rotator cuff tears larger than 2 cm who underwent arthroscopic repair. Patients were categorized into "complete repair" and "partial repair" groups based on the area of the exposed footprint after arthroscopic rotator cuff repair. In each group, preoperative magnetic resonance imaging factors (tear size, fatty infiltration, remnant tendon length, atrophy), clinical factors (range of motion, American Shoulder and Elbow Surgeons score, Constant score), and patient demographics were evaluated. Receiver operating characteristic curve analysis was used to choose the optimal cutoff value. A reparability assessment score was formulated through stepwise selection using variables that showed significant between-group differences on univariate analysis. We selected 4 variables and assigned a relative score for each variable based on estimated coefficient values. The sum of the scores for each factor ranged from 0 to 5.

Results: The average rotator cuff tear size was 28 × 26 mm. The torn rotator cuff was repaired completely in 74 patients (43.5%) and partially in 96 patients (56.5%). The following factors were chosen for the reparability assessment score: positive tangent sign (odds ratio [OR], 5.969; $P = .001$), fatty infiltration of the infraspinatus of grade ≤2 (OR, 3.537; $P = .001$), coronal tear size ≥26 mm (OR, 3.315; $P = .002$), and remnant tendon length <15 mm (OR, 2.584; $P = .017$). Complete repair was possible if the sum of the scores was <3 (area under curve, 0.803; 95% CI, 0.739-0.867; sensitivity, 51.0%; specificity, 95.9%).

Conclusion: In patients with a score of <3 on the novel reparability assessment score, complete repair was obtainable, whereas in patients with a score of ≥3, complete repair was difficult and other methods such as biologic grafts or arthroplasty had to be considered for a favorable prognosis.

Keywords: rotator cuff tear; reparability; partial repair; assessment score; arthroscopy

In the surgical treatment of rotator cuff tear, an anatomic restoration of the torn tendon to its original insertion area (ie, complete coverage of the exposed footprint by the rotator cuff) is preferred because partial repair of rotator cuff tear is known to be correlated with a high rate of postoperative retear.[2,8,9] However, surgeons have sometimes encountered unexpected rotator cuff tears that could not be repaired completely in arthroscopic procedures, despite adequate soft tissue release and appropriate surgical techniques. To prevent these situations, many surgeons perform various imaging studies preoperatively, including magnetic resonance imaging (MRI), to assess the arthroscopic reparability of cuff tears. A poorly planned surgery for arthroscopic rotator cuff repair leads to partial repair or complete repair with excessive tension, resulting in unsatisfactory outcomes and a high rate of retear.[1] Therefore, it is important to predict reparability of challenging rotator cuff tears to determine whether partial repair is inevitable. If arthroscopic reparability of challenging rotator cuff tears can be predicted, surgeons could select a procedure that will result in a more favorable prognosis.

Several studies have analyzed individual factors related to reparability of rotator cuff tears.[15,17,21] Positive tangent sign, advanced fatty infiltration, and muscle atrophy of rotator cuff muscles have been reported to be closely related to tear irreparability.[17,21] A previous study introduced a scoring system to predict reparability consistent with coronal and sagittal tear size, the Warner grade, and the modified Goutallier grade.[15] However, these studies evaluated the relationship between reparability and a small number of factors, which limits application of their findings in clinical situations. Surgeons could better predict the reparability of challenging rotator cuff tears preoperatively if a reparability assessment score were

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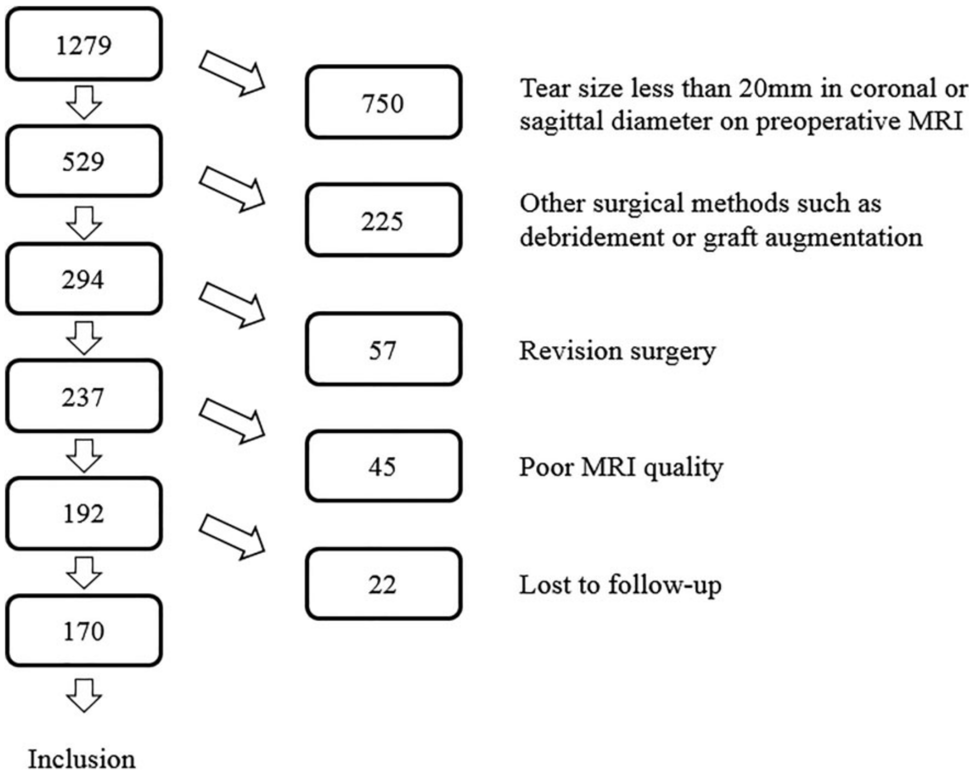

Figure 1. CONSORT (Consolidated Standards of Reporting Trials) flowchart illustrating application of study inclusion and exclusion criteria. MRI, magnetic resonance imaging.

available that included more variable clinical and imaging factors.

The aim of this study was to analyze preoperative clinical and imaging factors affecting rotator cuff tear reparability and to develop a reparability assessment scoring system that reflects various preoperative factors in rotator cuff tears when complete repair is challenging. We hypothesized that there would be differences in preoperative imaging factors between a partial repair group and a complete repair group and that it would be possible to develop an assessment score integrating these factors for reparability in rotator cuff tears.

METHODS

Patient Selection

This study was performed retrospectively with patients who underwent arthroscopic repair of rotator cuff tears from September 2009 to February 2017. The study included patients who had symptomatic full-thickness, posterosuperior rotator cuff tears of 20 mm or larger in both the coronal and sagittal diameters on preoperative MRI; underwent arthroscopic rotator cuff repair at a single institute; and were followed up for more than 2 years. Patients with isolated subscapularis tears, partial-thickness tears, small tears, revision surgeries, other surgical methods such as debridement or graft augmentation, poor MRI quality, and lack of 2-year follow-up results were excluded from the study (Figure 1).

The patients were categorized into 2 groups, complete repair and partial repair, based on the exposed area of the footprint at the conclusion of the arthroscopic repair. *Complete repair* was defined as complete coverage of the footprint or a repair with less than a 1×1–cm^2 residual gap.[6,9] *Partial repair* was defined as a residual defect larger than $1 \times 1\ cm^2$. An institutional review board approved this study, and informed consent was obtained from all participants.

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Ethical approval for this study was obtained from the institutional review board of Ewha Womans University (IRB No. EUMC 2018-06-012-002).

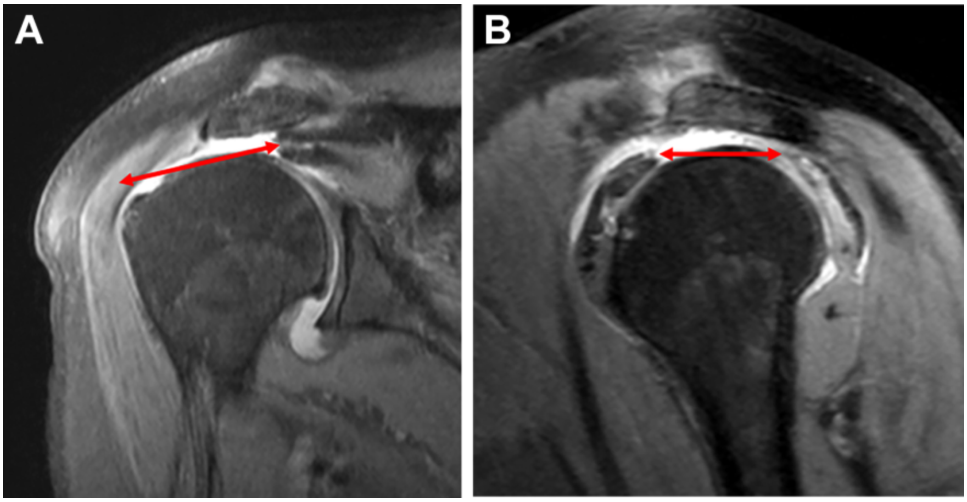

Figure 2. Tear size measurement on T2-weighted image (double-sided red arrows). (A) Coronal tear size on coronal oblique image. (B) Sagittal tear size on sagittal oblique image.

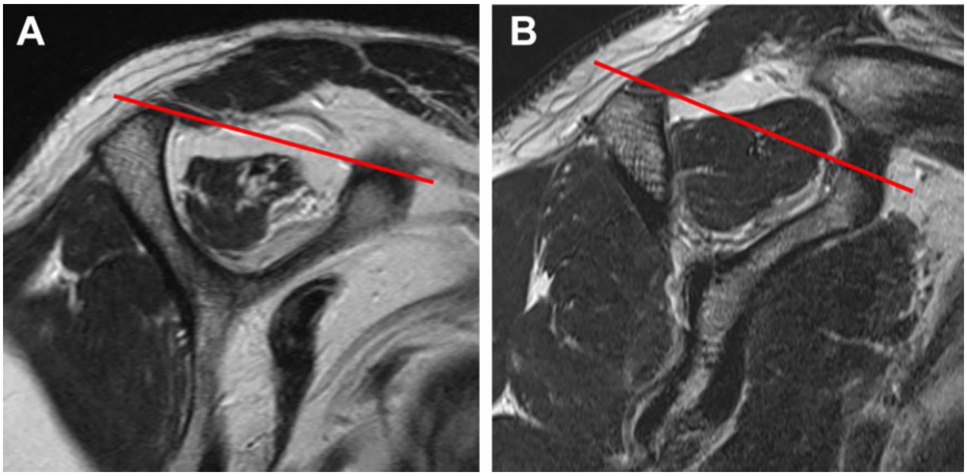

Figure 3. Tangent sign on the lateral oblique sagittal image. (A) Positive tangent sign. (B) Negative tangent sign. A tangent line (red line) was drawn from the superior border of the scapular spine to the superior margin of the coracoid.

Imaging Evaluation

Patients underwent preoperative MRI performed on a 3.0-T (Achieva; Philips) scanner with a shoulder coil. Tear size was measured on T2-weighted coronal oblique and sagittal oblique images. In the coronal view, tear size was measured from the medial edge of the torn tendon to the lateral footprint margin. For the sagittal view, measurements were made from the posterior edge of the torn tendon to the anterior tendon or interval tissue edge (the superior border of the coracoid was used to estimate the location of the rotator interval) (Figure 2).

Fatty infiltration and atrophy of the rotator cuff muscle were assessed on the most lateral oblique sagittal T2-weighted image in which the scapular spine was in contact with the scapular body. The Goutallier grade as modified by Fuchs et al[7] was used to evaluate fatty infiltration of the supraspinatus and infraspinatus muscles. A tangent sign was used to evaluate supraspinatus muscle atrophy. A tangent line was drawn from the superior border of the scapular spine to the superior margin of the coracoid. The tangent sign was negative when the superior border of the supraspinatus muscle extended beyond the line and was positive when the muscle belly of the supraspinatus muscle was inferior to the tangent line (Figure 3).

A T2-weighted coronal oblique image of a slice passing through the center of the supraspinatus tendon was used to assess acromiohumeral distance. The acromiohumeral distance was measured by the distance between the inferior acromion and the superior aspect of the humeral head.[6,11] On the T2-weighted coronal oblique images, the glenoid face line was drawn connecting the supraglenoid and infraglenoid tubercles and was used as a reference line for all vertical measurements.[28] Additionally, the distance

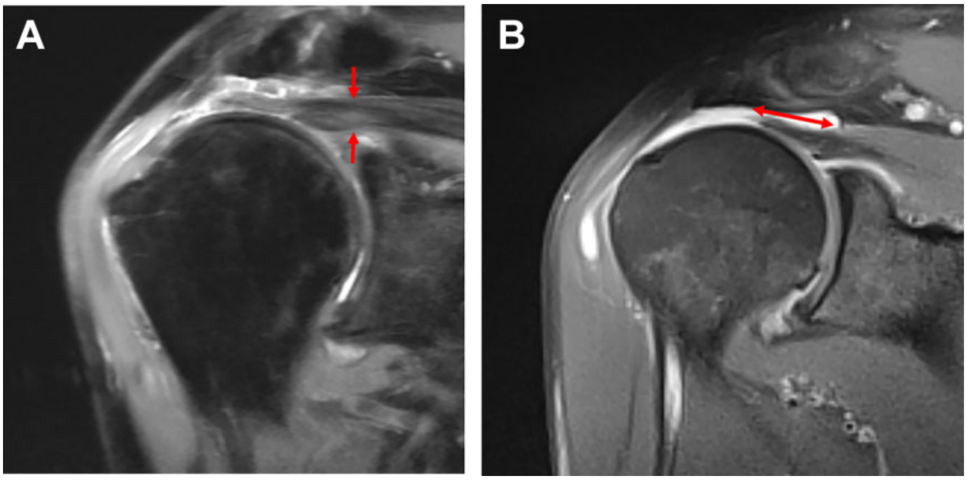

Figure 4. Tendon measurements on T2-weighted coronal oblique images. (A) The distance between the red arrows is the coronal oblique tendon thickness. (B) Remnant tendon length was measured as the distance between the retracted tendon end and the most lateral insertion point of the muscle fibers (double-ended red arrow).

between the glenoid face line and the lateral edge of the greater tuberosity was used to indirectly identify the individual size of the humeral head.

We assessed retraction of the supraspinatus tendon stump on the T2-weighted coronal oblique images using the classification described by Patte.[24] The coronal oblique tendon thickness was assessed as the thickness of the supraspinatus tendon at the superior margin of the glenoid surface on the T2-weighted coronal oblique slice passing through the center of the glenoid.[27] Remnant tendon length was measured by subtracting the musculotendinous junction from the retracted tendon end. The musculotendinous junction was defined as the most lateral point of the junction in which muscle fibers insert on the tendon (Figure 4).

Two surgeons (J.-S.K., Y.-G.J.), each with 7 years of orthopaedic experience, independently made measurements from the preoperative MRI scans to evaluate interobserver reliability, and the averages of these 2 measurements were used in this study. One month after the initial measurement by the 2 surgeons, 1 of the 2 surgeons repeated the preoperative MRI measurements to document intraobserver reliability.

Clinical Evaluation

Preoperative shoulder function was evaluated through use of preoperative range of motion, American Shoulder and Elbow Surgeons (ASES) score, and the Constant score. Demographic factors such as age, sex, symptom duration, involvement of the dominant arm, trauma history, and body mass index were evaluated. Passive forward flexion and external rotation were measured by use of a goniometer. Passive internal rotation was measured by the vertebral spinous process that the patient could reach with his or her thumb and was converted into contiguously numbered groups. Vertebral levels were numbered serially as follows: 1 to 12 for the 1st to 12th thoracic vertebra, 13 to 17 for the 1st to 5th lumbar vertebra, and 18 for any level below the sacral region. A single orthopaedic surgeon who was not involved in this study assessed these evaluations.

Surgical Technique and Rehabilitation

All rotator cuff repairs were performed by a single surgeon (S.-J.S.) at a single institute, with the patient under general anesthesia preceded by a single interscalene block. Manual manipulation of the shoulder under anesthesia before surgery and anterior capsular release during arthroscopic surgery were performed simultaneously in patients with motion limited to less than 90° of forward elevation. All repairs were performed arthroscopically with the patient in the lateral decubitus position. Arthroscopic repair was performed via the double-row suture-bridge technique. Uncovered footprints were measured with a ruler in both the anterior-to-posterior and medial-to-lateral directions.

All patients underwent a standardized rehabilitation program. A shoulder brace with 0° of external rotation and 15° of abduction was applied for 4 weeks. Passive pendulum and passive range of motion exercises were allowed after 4 weeks postoperatively. Muscle strengthening exercises and active motion were allowed after 3 months postoperatively. Return to sports and heavy labor were allowed after 6 months.

Statistical Analysis

Interobserver and intraobserver reliabilities for the MRI measurements were evaluated with weighted kappa for categorical variables and intraclass correlation coefficient (ICC) for continuous variables, respectively. For the weighted kappa, >0.8 indicates very good reliability and 0.6-0.8 indicates good reliability; for ICC, >0.75 indicates excellent reliability and 0.6-0.75 good reliability.

The study results are presented as the mean and standard deviation for continuous variables with normal distribution and as the median and interquartile range for continuous variables with nonnormal distributions. Results for discrete variables are presented as the number and percentages of patients. Demographic, functional, and MRI-measured variables were compared between the complete repair group and the partial repair group, and the *P* value for the mean difference between groups was assessed via the Student *t* test or the Mann-Whitney *U* test, as appropriate. The difference between groups for discrete variables was assessed with the chi-square test. For continuous variables with significant differences between groups, receiver operating characteristic curve analysis was used to choose the optimal cutoff value, and the cutoff value was set based on the Youden index.[25] Continuous variables were then converted into categorical variables based on the identified cutoff values and were used to calculate the odds ratio (OR) with 95% CI for partial repair. Additionally, the OR for partial repair was calculated regarding the presence of atrophy and degree of retraction (with grade 2 set as a reference), which were the 2 factors that showed significant differences between the groups.

Based on the results of a univariate analysis, the final reparability assessment score was formulated through stepwise selection using variables that demonstrated significant differences between the groups. A relative value for each variable selected in the reparability assessment score was assigned based on estimated coefficient values. The area under the curve (AUC) of the reparability assessment score was assessed, and the specificity and sensitivity of the reparability assessment score were calculated. The validity test for the reparability assessment score was conducted by overlapping with the same study group. The patients were divided into 2 groups based on cutoff values of the assessment score, and positive and negative predictive values were calculated. Statistical analyses were performed with IBM SPSS Statistics software (version 24.0; IBM), and a *P* value of less than .05 was considered statistically significant. All analyses were performed by a professional statistician (H.-A.L.).

RESULTS

Of the 1279 patients who underwent arthroscopic rotator cuff repair during the study period, 170 patients met the inclusion criteria. Among the 170 patients, the torn rotator cuff was completely repaired in 74 (43.5%) patients and was partially repaired in 96 (56.5%) patients.

Intraobserver and Interobserver Reliability

Intraobserver reliability as assessed by ICC was 0.9 or higher, and interobserver reliability ranged between 0.72 and 0.99. Intraobserver reliability for coronal tear size was 0.969 (95% CI, 0.946-0.982) and for remnant tendon length it was 0.987 (95% CI, 0.978-0.993); interobserver reliability for coronal tear size was 0.968 (95% CI, 0.944-0.982) and for remnant tendon length it was 0.990 (95% CI, 0.982-0.994). Intraobserver reliability as evaluated by weighted kappa was 0.8 or higher, and interobserver reliability was between 0.62 and 0.92. Intraobserver reliability of fatty infiltration of the infraspinatus was 0.878 (95% CI, 0.774-0.982) and that of the tangent sign was 0.901 (95% CI, 0.767-0.999); interobserver reliability of fatty infiltration of the infraspinatus was 0.829 (95% CI, 0.697-0.961) and that of the tangent sign was 0.811 (95% CI, 0.637-0.985). These results imply a relatively high reliability for the assessments made by the observers.

Demographics and Preoperative Clinical Factors

The current study included 93 men (54.7%) and 77 women (45.3%) with a mean age of 63.5 ± 8.4 years and mean symptom duration of 8.0 months. Preoperative demographic and functional factors demonstrated no significant difference regarding reparability except the ASES score, which was significantly higher in the complete repair group (Table 1). Fatty infiltration of the supraspinatus and infraspinatus muscles, atrophy, retraction, acromiohumeral distance, and coronal oblique tendon thickness demonstrated significant differences between the groups. In addition, tears were larger in the partial repair group ($P < .001$), and remnant tendon length was shorter in the partial repair group than in the complete repair group ($P < .001$).

Reparability Assessment Score

AUC and cutoff values were calculated for 8 continuous variables among 10 variables that showed significant intergroup differences (Table 2). Fatty infiltration of the infraspinatus muscle demonstrated the highest AUC. Among the 10 variables that showed significant intergroup differences, the ASES score was excluded to develop the reparability assessment score. For the other 9 variables, we calculated cutoff values for the 7 continuous variables and ORs for the 2 categorical variables (positive tangent sign and retraction grade 3) to develop the reparability assessment score (Table 3). Among these variables, positive tangent sign, fatty infiltration of the infraspinatus muscle grade 2 or higher, coronal tear size 26 mm or more, and remnant tendon length less than 15 mm were obtained via stepwise selection, and all these variables had independent influence on surgical outcomes. These 4 variables were used to develop the reparability assessment score, and scoring points of each variable were determined based on estimated coefficient values. The reparability assessment score ranged from 0 to a maximum of 5 (Table 4). When the preoperative score was less than 3, complete rotator cuff repair was possible; if 3 or higher, complete repair was not obtainable. The AUC of partial repair calculated by the reparability assessment score was 0.803 (95% CI, 0.739-0.867), and sensitivity of 51.0% and specificity of 95.9% were reached when a score of 3 or higher was set as the cutoff point.

Reparability Assessment Score Validity Test

A test for validity was conducted on all patients in this study. Among the 170 patients, 52 scored 3 or higher on the

TABLE 1
Comparison of Preoperative Factors Related to Reparability Between the Study Groups[a]

	Partial Repair (n = 96)	Complete Repair (n = 74)	*P* Value
Demographic factors			
Sex, male:female, n	53:43	40:34	.99
Age, y	63.9 (43.0-86.0)	63.1 (43.0-82.0)	.56
Body mass index, kg/m^2	24.6 (17.9-35.7)	24.2 (19.3-35.6)	.43
Symptom duration, mo	8.5 (1.0-84.0)	7.3 (1.0-60.0)	.99
Trauma history, n	47	6	.99
Involvement of dominant arm, n	80	64	.73
Imaging factors			
Involvement of IS, n	43	26	.27
Fatty infiltration of SS	2 (1-4)	1 (0-2)	<.001[b]
Fatty infiltration of IS	2 (0-4)	1 (0-2)	<.001[b]
Atrophy, n	42	6	<.001[b]
Retraction, grade 2:3, n	70:26	70:4	<.001[b]
Coronal tear size, mm	30 (20.0-50.0)	25 (20.0-45.0)	<.001[b]
Sagittal tear size, mm	29 (20.0-55.0)	24.5 (20.0-35.0)	<.001[b]
Humeral head size, mm	35.1 (24.3-46.0)	35.5 (26.4-45.7)	.58
Remnant tendon length, mm	15.5 (2.5-31.0)	18.8 (6.4-31.7)	<.001[b]
Acromiohumeral distance, mm	7.3 (2.6-11.7)	8.6 (3.6-13.9)	<.001[b]
Coronal oblique tendon thickness, mm	5.3 (0-13.8)	8.5 (0-19.6)	<.001[b]
Clinical factors			
ASES score	59.7 (32.0-95.0)	65.4 (38.0-95.0)	.002[b]
Constant score	46.9 (17.0-81.0)	52.1 (17.0-100.0)	.06
Passive range of motion			
Internal rotation, vertebral level	13 (7-18)	12 (7-18)	.19
Forward flexion, deg	167.5 (20.0-180.0)	170.2 (20.0-180.0)	.29
External rotation, deg	56.1 (10.0-90.0)	57.9 (10.0-90.0)	.58

[a]Values are expressed as median and interquartile range unless otherwise noted. ASES, American Shoulder and Elbow Surgeons; IS, infraspinatus; SS, supraspinatus.
[b]Statistically significant difference between groups ($P < .05$).

TABLE 2
Receiver Operating Characteristic Curve Analyses for the Significant Continuous Variables[a]

	Area Under the Curve[b]	Cutoff Value
Fatty infiltration of infraspinatus	0.732 (0.658-0.807)	1.5
Fatty infiltration of supraspinatus	0.715 (0.638-0.793)	1.5
Coronal tear size	0.715 (0.638-0.793)	25.5
Sagittal tear size	0.652 (0.571-0.734)	26.5
Remnant tendon length	0.660 (0.579-0.742)	15.12
Acromiohumeral distance	0.657 (0.575-0.739)	9.1
Coronal oblique tendon thickness	0.681 (0.601-0.761)	7.7
ASES score	0.636 (0.553-0.720)	69.0

[a]ASES, American Shoulder and Elbow Surgeons.
[b]Values are expressed as mean (95% CI).

reparability assessment score, whereas 118 patients scored less than 3. Of the 52 patients whose score was 3 or higher, 49 eventually underwent partial rotator cuff repair, and complete repair was obtained in only 3 patients (positive predictive value, 94.2%). Of the 118 patients with a score less than 3, a total of 47 patients underwent partial repair, whereas 71 patients had complete repair (negative predictive value, 60.2%).

DISCUSSION

In the current study, the following factors were chosen for the rotator cuff reparability assessment score: positive tangent sign, fatty infiltration of the infraspinatus muscle with a grade of 2 or higher, coronal cuff tear size 26 mm or larger, and remnant tendon length less than 15 mm. The sum of the scores for each factor ranged from 0 to 5, and complete repair was difficult when this sum was 3 or higher.

To determine the most effective surgical treatment of challenging rotator cuff tears, surgeons should evaluate preoperative clinical and imaging factors that predict surgical reparability. The present study regarding reparability assessment scores has several strong points compared with previous studies that analyzed factors related to reparability. First, the current study evaluated 3-dimensional information on tear patterns, including both coronal and sagittal tear size and coronal oblique tendon thickness. The majority of preexisting reparability studies have used the DeOrio and Cofield classification, categorized according to the greatest tear length, which provides only 1-dimensional assessment.[5,6,9,15] However, 3-dimensional information is more useful to predict reparability, because long but narrow rotator cuff tears could be easily repaired through use of marginal convergence techniques. Davidson and Burkhart[4] introduced a geographic classification considering

TABLE 3
Development of the Reparability Assessment Score Using Stepwise Selection[a]

	Univariate Analysis		Multivariate Analysis	
	Odds Ratio	*P* Value	Odds Ratio	*P* Value
Positive tangent sign	8.815 (3.488-22.274)	<.001	5.969 (2.146-16.608)	.001
Retraction grade 3	6.500 (2.156-19.597)	.001		
Fatty infiltration of infraspinatus grade ≥2	4.900 (2.488-9.651)	<.001	3.537 (1.655-7.559)	.001
Fatty infiltration of supraspinatus grade ≥2	5.319 (2.692-10.508)	<.001		
Coronal tear size ≥26 mm	4.574 (2.304-9.082)	<.001	3.315 (1.540-7.136)	.002
Sagittal tear size ≥27 mm	3.104 (1.640-5.875)	.001		
Remnant tendon length <15 mm	3.216 (1.640-6.307)	.001	2.584 (1.185-5.636)	.017
Acromiohumeral distance <9 mm	3.007 (1.564-5.782)	.001		
Coronal oblique tendon thickness <8 mm	3.017 (1.598-5.696)	.001		

[a]Odds ratios are expressed as mean (95% CI).

TABLE 4
Reparability Assessment Score

	Scoring Point[a]
Positive tangent sign	2
Fatty infiltration of infraspinatus muscle grade ≥2	1
Coronal tear size ≥26 mm	1
Remnant tendon length <15 mm	1

[a]Score <3, reparable; score ≥3, irreparable.

3-dimensional information on tear patterns and repair methods to analyze preoperative reparability. When both coronal and sagittal aspects of tear size were seen preoperative MRI, especially when both were greater than 20 mm, complete repair was reported to be difficult to achieve in 90% of patients.[26] The present study also showed high specificity of reparability assessment scores considering the 3-dimensional information.

A second point of the present study is that we evaluated remnant tendon length as well as rotator cuff tear size. Remnant tendon length has not been widely discussed in previous reparability evaluation studies, despite its importance to reparability assessment.[14,15,18,29] Because the remnant tendon is repaired on the footprint, when the remnant tendon length is short, partial repair or complete repair with excessive tension would be inevitable.[16] Therefore, remnant tendon length plays a major role in reparability and successful clinical outcomes. In addition, the cutoff value of the remnant tendon length yielded in the current study was 15 mm. This finding is relevant given that 12 to 16 mm is known as the mean anatomic coronal length of the supraspinatus and infraspinatus footprint.[3,22] Therefore, a remnant tendon that covers at least the coronal length of the footprint would be necessary to achieve complete repair. Third, in the present study, the size of the patient group was large enough to provide a test power of 98%, which exceeds the minimal standard of 80% required in power analysis. Moreover, all patients had rotator cuff tears 20 mm or larger in both the coronal and sagittal diameters on preoperative MRI scans, which would be expected to be challenging to repair.

Regarding the devised reparability assessment scoring system, rotator cuff muscle conditions showed the strongest relationship with reparability compared with other preoperative factors. Fatty infiltration has been demonstrated to correlate with reparability in many studies.[12-14,29] Recently, fatty infiltration of the infraspinatus muscle was shown to have a stronger relationship with reparability than fatty infiltration of the supraspinatus muscle.[13,14] Hsu et al[10] demonstrated that rats with large supraspinatus and infraspinatus tendon tears showed similar statistically favorable outcomes regardless of whether only the infraspinatus tendon was repaired or both supraspinatus and infraspinatus tendons were repaired, emphasizing the importance of the infraspinatus tendon.[10] Clinically, when fatty infiltration of the infraspinatus muscle was significantly advanced, the tear size was larger and the normal glenohumeral kinematic values were significantly affected, resulting in poor reparability.[11] Therefore, in the present study, the selection of fatty infiltration of the infraspinatus muscle rather than the supraspinatus for reparability assessment scoring is supported by clinical and animal studies.

Atrophy of the rotator cuff muscle is another well-known factor that correlates with reparability.[17,20] In the present study, muscle atrophy was assessed by a tangent sign, which was the strongest factor for assessing reparability. The tangent sign represents not only the degree of atrophy but also the degree of comprehensive muscle degeneration. The tangent sign is easy to use in preoperative evaluation and reproducibility assessments and has relatively high sensitivity and specificity.[17,23] Atrophy progresses as retraction increases or as the number of accompanying rotator cuff tears increases in addition to supraspinatus tears.[19] As a result, reparability decreases as atrophy progresses.

Only 1 previous study has introduced a reparability assessment score for predicting preoperative reparability.[15] In that study, the reparability assessment score was consistent with a coronal tear size 4.2 cm or larger, sagittal tear size 3.7 cm or larger, Warner grade for muscle atrophy, and modified Goutallier grade for fatty infiltration.[15] These results were similar to the findings of the current study, except for sagittal tear size and remnant tendon length. In the present study, both coronal and sagittal tear size were evaluated as factors that correlated with reparability; however, only coronal tear size was used to develop the reparability assessment scoring system, because of the different repair direction between torn supraspinatus and infraspinatus tendon to avoid undue tension. We usually repair torn rotator cuff tendons by pulling the retracted infraspinatus tendon anteriorly and the retracted supraspinatus laterally to cover the footprint and reduce the exposed area. The characteristics of supraspinatus and infraspinatus tendons are different after being torn. The supraspinatus tendon is usually retracted medially with the worn-out edge of the torn tendon, whereas the infraspinatus tendon retracts posteriorly, maintaining its elasticity. Therefore, it is easier to pull the infraspinatus tendon without excessive tension and cover the anterior portion of the footprint. For this reason, only coronal tear size was selected to represent the reparability assessment score, despite the fact that both coronal and sagittal tear size are important to predict reparability. In addition, cutoff values for both coronal and sagittal tear size in the present study were smaller compared with those in the previous study by Kim et al.[15] These results might originate from differences in the enrolled patients. The current study included only patients with both coronal and sagittal tear sizes 20 mm or larger in order to consider tear size 3-dimensionally. Patients with a long but narrow pattern of rotator cuff tears that could be easily repaired were excluded from the current study; therefore, the cutoff values of both coronal and sagittal tear sizes were relatively small.

Limitations

There were several limitations in this study. First, validity was not tested on a new group of patients fulfilling inclusion criteria. In this study, the validity test for the reparability assessment score was conducted by overlapping with the same study group. Prospective validity testing should be conducted for a more reasonable application in clinical settings. Moreover, it would be meaningful to evaluate the correlation between our reparability assessment score and postoperative functional scores in a future study. Second, shoulder function measures such as the ASES and Constant scores were not included in developing the reparability assessment score; this was intended to reduce bias resulting from subjective assessment factors. Instead, we applied a standardized method of measurement with high reproducibility when assessing factors with poor measurement reliability, such as remnant tendon length or supraspinatus thickness, thus leading to higher reliability. Third, a footprint residual gap of 10 mm was set as a standard when distinguishing arthroscopically complete repair from partial repair. We applied the definition of anatomic repair from previous studies, which was a footprint coverage more than 50% or a residual gap less than 10 mm.[6,9] Fourth, we found no significant difference in physical body frame characteristics such as body mass index or indirect humeral head size regarding reparability. However, it should be considered that studies on the correlation between variables and physical body frame have not been carried out.

CONCLUSION

The following factors were chosen for a novel rotator cuff reparability assessment scores: positive tangent sign, fatty infiltration of the infraspinatus muscle grade 2 or higher, coronal cuff tear size 26 mm or larger, and remnant tendon length less than 15 mm. In patients with a reparability assessment score less than 3, complete repair was obtainable, whereas in patients with a score of 3 or higher, complete repair was difficult and other methods such as biologic grafts or arthroplasty had to be considered for a favorable prognosis.

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