**Purpose:** The aim of this study was to evaluate the outcome of arthroscopic partial repair and margin convergence of irreparable large to massive rotator cuff tears. **Methods:** Between January 2003 and July 2008, 27 patients who met the inclusion criteria underwent arthroscopic partial repair and margin convergence of irreparable large to massive rotator cuff tears. An irreparable tear was defined as a tear with a minimum anterior-to-posterior width of 3 cm or larger, where it was not feasible to completely cover the humeral head with the cuff at the time of surgery. **Results:** The mean preoperative tear size was 42.1 ± 6.2 mm. The mean size of the postoperative residual defect in the repaired tendon along the medial margin of the greater tuberosity was 12.0 ± 5.5 mm. All shoulder scores showed improvement. The Simple Shoulder Test improved from 5.1 ± 1.2 to 8.8 ± 2.1 (P < .001), the Constant score from 43.6 ± 7.9 to 74.1 ± 10.6 (P < .001), and the University of California, Los Angeles score from 10.5 ± 3.0 to 25.9 ± 5.0 (P < .001). Both Constant and University of California, Los Angeles shoulder scores also showed an inverse correlation with defect size. We compared muscle strength between the affected and contralateral sides and found that the strength of the affected side was not restored to the same level as the contralateral side (P < .001). **Conclusions:** Arthroscopic partial repair and margin convergence showed satisfactory short-term outcomes in irreparable large to massive rotator cuff tears. Thus it is suggested that, even in a large to massive tear that appears irreparable, attempting to repair it as much as possible to possibly convert it into a functional rotator cuff tear by re-creating a balanced forced couple can be helpful in reducing pain, as well as improving functional outcomes. **Level of Evidence:** Level IV, therapeutic case series.

Despite remarkable advances in arthroscopic rotator cuff repair over the past few decades, arthroscopic repair of large to massive rotator cuff tears is still challenging, especially in cases of inelastic and severely retracted torn tendons due to muscle atrophy, fatty degeneration, and adhesion. Although mobilization of the torn tendon can be obtained through the release of adhesion and the interval slide technique, poor tissue quality sometimes precludes complete reattachment of the torn tendon to its anatomic footprint and leaves a residual defect in the cuff. There are several treatment options for irreparable large to massive rotator cuff tears: partial repair, simple debridement, tendon transfer, and biologic augmentation. One should select the most appropriate option by taking into consideration the patient’s age, degree of comorbidities, level of activity, and physical demand. In elderly patients with low physical demands, a simple debridement may be indicated. In selected younger patients, tendon transfer may be feasible. The use of biologic augmentation such as tissue-engineered matrix or allograft patch has shown fair to
poor clinical results. Partial or incomplete repair also seems to have less favorable outcomes than complete repair. However, Burkhart\textsuperscript{11} introduced the concept of “functional rotator cuff tear” and the biomechanical rationale of the “suspension bridge system.” Thus partial rotator cuff repair attempts to re-create the transverse force couple of the rotator cuff and provide a stable fulcrum for the glenohumeral joint. Despite this concept, there have been a few studies regarding partial or incomplete arthroscopic repair of large to massive rotator cuff tear and its results.\textsuperscript{2,3,11}

The aim of our study was to evaluate the outcome of arthroscopic partial repair of irreparable large to massive rotator cuff tears. We hypothesized that although overall functional outcomes would improve after surgery, muscle strength would not be restored to the same level as the contralateral shoulder.

**METHODS**

**Study Population and Demographics**

Between January 2003 and July 2008, 37 patients underwent arthroscopic partial repair and margin convergence of irreparable large to massive rotator cuff tears and their medical reports including radiologic findings were reviewed retrospectively. An irreparable tear was defined as a tear with a minimum anterior-to-posterior width of 3 cm or larger, where it was not feasible to completely cover the humeral head with the cuff at the time of surgery. Of the patients in the initial study population, 27 met the inclusion criteria. The inclusion criteria were (1) irreparable large to massive rotator cuff tear (\(\geq 3\) cm in diameter) accompanied by pain and functional disability refractory to conservative treatment; (2) arthroscopic partial rotator cuff repair (failed attempt to completely cover the humeral head with the cuff at the time of surgery). Of the patients in the initial study population, 27 met the inclusion criteria. The inclusion criteria were (1) irreparable large to massive rotator cuff tear (\(\geq 3\) cm in diameter) accompanied by pain and functional disability refractory to conservative treatment; (2) arthroscopic partial rotator cuff repair (failed attempt to completely cover the humeral head with the cuff, leaving the defect in the repaired rotator cuff); and (3) available for a minimum 2-year follow-up after surgery. Ten patients were excluded according to the exclusion criteria, which were (1) a subscapularis tear requiring repair; (2) near complete fatty replacement of the supraspinatus, infraspinatus, and teres minor tendon; (3) prior surgery on the affected shoulder; (4) moderate to severe rotator cuff arthropathy (Hamada classification III, IV, or V);\textsuperscript{12} (5) existing shoulder pain on the contralateral side; and (6) Workers’ Compensation claim. The mean patient age at the time of the operation was 62.3 years (range, 54 to 72 years), and the mean follow-up period was 41.3 months (range, 36 to 52 months). Approval for this study was obtained from our institutional review board, and informed consent was obtained from all patients.

**Surgical Procedure and Postoperative Rehabilitation**

Under general anesthesia, all patients underwent arthroscopic rotator cuff repair in the lateral decubitus position with 10 lb of longitudinal traction. Typically, the senior author used 4 routine portals: posterior, lateral, posterolateral, and anterior portal. If necessary, additional portals were created to obtain an optimal insertion angle of the anchors, as well as to appropriately release adhesion. By use of the posterolateral or lateral portal as a viewing portal, the status and mobility of the retracted torn tendon were evaluated (Video 1, available at www.arthroscopyjournal.org). After release of adhesions and mobilization of the tendon, it still could not be completely advanced to the greater tuberosity. The surgeon tried to repair it as well as possible and converge the margins to help restore the transverse force couple and reduce the size of the tear (Fig 1). A single-row repair was performed with insertion of the suture anchors within the footprint of the greater tuberosity or less than 1 cm medial to the junction between the articular cartilage and greater tuberosity. After the partial repair and margin convergence had been performed, the residual defect was measured along the junction between the articular cartilage and greater tuberosity. Arthroscopic acromioplasty was performed limited to the impingement site, with preservation of the coracoacromial ligament as much as possible (Fig 2).

With regard to coexisting lesions of the long head of the biceps or SLAP lesions, unless the SLAP lesion had severe degeneration in the superior labrum or long head of the biceps, arthroscopic SLAP repair was performed with suture anchors. In the case of a lesion of the long head of the biceps, if the lesion involved more than one-fourth of the tendon or was subluxated or dislocated, tenotomy was performed in patients aged older than 60 years and tenodesis in patients aged younger than 60 years. If the biceps lesion involved less than one-fourth of the tendon, a simple debridement was performed.

After the operation, the shoulder was kept in an abduction brace for 6 weeks. Every 4 hours, the patient was encouraged to remove the brace and to perform pendulum exercises, starting the day after surgery. Self-assisted passive range-of-motion exercise as tolerated was begun at 4 to 5 weeks postoper-
atively according to pain subsidence, and self-assisted active range-of-motion exercise began at 6 to 8 weeks postoperatively. Isotonic strengthening exercises by use of an elastic band were begun at 3 to 4 months postoperatively.

**Assessment**

As for radiologic evaluation, magnetic resonance imaging was reviewed in addition to the plain radiographs, such as standing shoulder anteroposterior view in neutral, axial view, and supraspinatus outlet view. To evaluate the superior migration of the humeral head, the acromiohumeral distance was measured preoperatively and postoperatively by an independent observer. The observer measured the distance twice, and the mean of these 2 values was used. Muscle atrophy and fatty degeneration were evaluated on the most lateral oblique sagittal T1-weighted magnetic resonance images in which the scapular spine was seen in contact with the scapular body (the so-called Y-shaped view). A 5-stage system was used to evaluate the amount of fatty degeneration in the cuff muscle: stage 0 indicates a completely normal muscle without any fatty streaks; in stage 1 the muscle contains some fatty streaks; in stage 2 fatty infiltration is increased but there is still more muscle than fat; stage 3 contains as much fat as muscle; and stage 4 contains more fat than muscle (Fig 3).
As for functional evaluation, the Simple Shoulder Test, the University of California, Los Angeles (UCLA) shoulder score, and the Constant shoulder score were used preoperatively and postoperatively. With regard to the manual measurement of muscle strength, in the UCLA shoulder score, isometric 90° forward flexion was measured bilaterally with the elbow extended and the forearm in a neutral position and was compared with the strength of the normal contralateral side. If the strength of the affected arm was the same as that of the normal contralateral side, it was graded as normal. If the affected arm was weaker than the contralateral side, it was graded as good. If the patient could barely raise the arm or was unable to resist the examiner’s downward pull at all, it was graded as fair. An independent observer measured arm strength twice, and the mean of these values was used. In the Constant score, isometric 90° abduction strength was measured twice in the scapular plane with the elbow extended and the forearm pronated in the same manner; the mean of these values was used. In the Constant score, isometric 90° abduction strength was measured twice in the scapular plane with the elbow extended and the forearm pronated in the same manner; the mean of these values was used. We acknowledge that in the Constant score, abduction strength was measured using a spring balance and expressed in pounds. In addition, this absolute strength value varies according to age and sex. It is possible to normalize and correct according to age and sex, as was reported by Katolik et al.\textsuperscript{15} However, we chose the strength of the contralateral side as the normal standard of comparison with the affected side. The strength of active forward elevation or abduction was measured manually and graded on a scale of 0 to 5 (5, normal; 4, good; 3, fair; 2, poor; 1, trace; and 0, zero) for the UCLA score and on a scale of 0 to 25 (25, normal; 20, good; 15, fair; 10, poor; 5, trace; and 0, zero) for the Constant score.

Statistical Analysis

To compare preoperative and postoperative outcomes, a paired t test was implemented. A simple linear regression analysis was performed to investigate the correlation between residual defect size in the repaired cuff and muscle strength, as well as the overall shoulder score and fatty infiltration of the supraspinatus and infraspinatus. A level of significance of $P < .05$ was used with a 95% confidence interval.

RESULTS

Arthroscopic Findings

A U-shaped tear was found in 19 of 27 patients (70%), and a V-shaped tear was found in the remaining 8 (30%). The mean tear size was 42.1 ± 6.2 mm (range, 35 to 54 mm). After arthroscopic partial rotator cuff repair with suture anchors, the mean size of the residual defect along the medial margin of the greater tuberosity was 12.0 ± 7.0 mm (range, 5 to 32 mm) and the mean decrease in tear size after repair was 30.4 ± 9.4 mm (range, 24 to 40 mm). The mean number of anchors used was 3.0 (range, 1 to 5), and in all but 4 patients, the surgeon placed side-to-side sutures for margin convergence. However, the number of side-to-side sutures per patient varied.

A coexisting SLAP type II lesion was found in 5 patients (19%). Four of these underwent arthroscopic SLAP repair with a suture anchor, with the exception of one patient who had concomitant severe tendinitis involving greater than 25% of the tendon. Coexisting severe tendinitis of the long head of the biceps was present in 6 patients (22%); arthroscopic biceps tenodesis was performed in 1 patient with a suture anchor, and tenotomy was performed in 2 patients. Two patients underwent arthroscopic debridement for the biceps lesion. In the remaining 1 patient, the long head of the biceps was already ruptured (Table 1). In all cases, arthroscopic acromioplasty was performed limited to the impingement site while preserving the coracoacromial ligament as much as possible.

Functional and Radiologic Assessment

All 3 of the shoulder scores showed significant improvement over the preoperative scores at the most
recent follow-up: the Simple Shoulder Test improved from 5.1 ± 1.2 to 8.8 ± 2.1 (P < .001), the Constant shoulder score from 43.6 ± 7.9 to 74.1 ± 10.6 (P < .001), and the UCLA shoulder score from 10.5 ± 3.0 to 25.9 ± 5.0 (P < .001) (Tables 2 and 3). In the simple linear correlation analysis between the residual defect size in the repaired cuff and muscle strength (active forward elevation), there was an inverse correlation (β = −0.720, P < .001). Both the Constant and UCLA shoulder scores showed an inverse correlation with the defect size (β = −0.751 [P < .001] for Constant shoulder score and β = −0.780 [P < .001] for UCLA shoulder score) and showed an inverse correlation with stage of fatty infiltration (β = −0.558 [P = .003] for supraspinatus and β = −0.668 [P < .001] for infraspinatus for Constant shoulder score and β = −0.534 [P = .004] for supraspinatus and β = −0.524 [P = .005] for infraspinatus for UCLA shoulder score). In addition, the residual defect size showed a correlation with stage of fatty infiltration in the supraspinatus (β = 0.564, P = .002) and infraspinatus (β = 0.507, P = .007).

**TABLE 1. Concomitant Lesions and Related Procedures**

<table>
<thead>
<tr>
<th>Coexisting Lesion</th>
<th>Concomitant Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLAP lesion: 5 (19%)</td>
<td>Repair using anchor: 4</td>
</tr>
<tr>
<td></td>
<td>Tenotomy: 1</td>
</tr>
<tr>
<td>Long head of biceps lesion: 6 (22%)</td>
<td>Debridement: 2</td>
</tr>
<tr>
<td></td>
<td>Tenotomy: 2</td>
</tr>
<tr>
<td></td>
<td>Tenodesis: 1</td>
</tr>
<tr>
<td></td>
<td>Already ruptured: 1</td>
</tr>
</tbody>
</table>

**FIGURE 3.** Different stages of fatty degeneration: (A) stage 0, (B) stage 1, (C) stage 2, (D) stage 3, and (E) stage 4.
cuff tears are reparable and some favorable outcomes have been documented, severe retraction and poor tendon quality combined with fatty infiltration and muscle atrophy have occasionally precluded complete repair of the torn tendon to its native footprint. However, it has been documented that through the concept of margin convergence, the repaired tendon could not only re-create the transverse force couple of the rotator cuff but also reduce the overall tension of the repaired tendon on the bone by distributing it to the anterior and posterior tear leaves. Thus surgeons began to recognize that re-establishment of a stable fulcrum is more important than complete closure of the defect. In addition, several studies have verified favorable clinical outcomes despite partial or incomplete repair.

Early on, Burkhart et al. proposed a “suspension bridge” in the rotator cuff and emphasized the role of the rotator cable. This concept could be applied to margin convergence, in repairing massive rotator cuff tears and reducing tensile strain on repaired tendon and re-creating the rotator cuff cable and balanced force couple. Recently, Halder et al. performed an in vitro biomechanical study that supported this concept and showed that muscle forces could be effectively transmitted through the rotator cuff cable even with small- or medium-sized tears. They proposed that even in irreparable rotator cuff tears, side-to-side repair may be worthwhile to restore the muscle pre-tension and integrity of the rotator cable. Similar to these previous reports, our study indicates that with reduced residual defects in the cuff, there was functional improvement and a relatively strong inverse correlation between the residual defect size and post-

**Table 2. Preoperative and Postoperative Constant Shoulder Score**

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain (0-15)</td>
<td>2.6 ± 2.5</td>
<td>9.6 ± 2.4</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Activities of daily living (0-10)</td>
<td>3.0 ± 1.8</td>
<td>8.0 ± 1.4</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Range of motion (0-50)</td>
<td>25.0 ± 4.5</td>
<td>39.2 ± 5.4</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Strength (manual muscle testing) (0-25)</td>
<td>13.0 ± 2.5</td>
<td>17.2 ± 2.9</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Total (0-100)</td>
<td>43.6 ± 7.9</td>
<td>74.1 ± 10.6</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

**NOTE.** The values are given as the mean ± standard deviation. An isometric 90° abduction strength was measured bilaterally in the scapular plane with the elbow extended and the forearm pronated and was compared with the contralateral side. The strength was graded on a scale of 0 to 25 (25, normal; 20, good; 15, fair; 10, poor; 5, trace; and 0, zero).

In terms of comparing muscle strength (active forward flexion and 90° abduction in the scapular plane by manual test) between the affected and contralateral sides, mean muscle strength was 3.4 ± 0.6 on the affected side (κ value for intraobserver reliability, 0.971) and 4.6 ± 0.5 on the contralateral side (κ value for intraobserver reliability, 0.961) (0 to 5 scale, where 5 indicates normal; 4, good; 3, fair; 2, poor; 1, trace; and 0, zero) in forward flexion (P < .001). Mean muscle strength in 90° of abduction was 17.2 ± 2.9 on the affected side (κ value for intraobserver reliability, 0.939) and 23.1 ± 2.5 on the contralateral side (κ value for intraobserver reliability, 0.917) (0 to 25 scale, where 25 indicates normal; 20, good; 15, fair; 10, poor; 5, trace; and 0, zero) (P < .001). Some patients with a fair motor grade (4 of 13 patients) swung their arm up or bent their elbow first when raising their arm, to decrease the length of the lever arm.

The mean acromiohumeral distance before surgery was 6.5 ± 1.5 mm (range, 3 to 9.5 mm) (κ value for intraobserver reliability, 0.980), and this decreased to 5.9 ± 1.8 mm (range, 2 to 9.5 mm) (κ value for intraobserver reliability, 0.989) at the most recent follow-up. This difference of 0.7 ± 0.6 mm was statistically significant (P < .001). According to the stage system for muscle fatty infiltration on the oblique sagittal image, the mean stage was 3.2 (range, 2 to 4) for the supraspinatus and 2.7 (range, 2 to 4) for the infraspinatus.

**DISCUSSION**

The treatment of massive rotator cuff tear has been a challenging problem. Although most massive rotator cuff tears are reparable and some favorable outcomes have been documented, severe retraction and poor tendon quality combined with fatty infiltration and muscle atrophy have occasionally precluded complete repair of the torn tendon to its native footprint. However, it has been documented that through the concept of margin convergence, the repaired tendon could not only re-create the transverse force couple of the rotator cuff but also reduce the overall tension of the repaired tendon on the bone by distributing it to the anterior and posterior tear leaves. Thus surgeons began to recognize that re-establishment of a stable fulcrum is more important than complete closure of the defect. In addition, several studies have verified favorable clinical outcomes despite partial or incomplete repair.

Early on, Burkhart et al. proposed a “suspension bridge” in the rotator cuff and emphasized the role of the rotator cable. This concept could be applied to margin convergence, in repairing massive rotator cuff tears and reducing tensile strain on repaired tendon and re-creating the rotator cuff cable and balanced force couple. Recently, Halder et al. performed an in vitro biomechanical study that supported this concept and showed that muscle forces could be effectively transmitted through the rotator cuff cable even with small- or medium-sized tears. They proposed that even in irreparable rotator cuff tears, side-to-side repair may be worthwhile to restore the muscle pre-tension and integrity of the rotator cable. Similar to these previous reports, our study indicates that with reduced residual defects in the cuff, there was functional improvement and a relatively strong inverse correlation between the residual defect size and post-

**Table 3. Preoperative and Postoperative UCLA Shoulder Score**

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain (0-10)</td>
<td>2.0 ± 1.2</td>
<td>7.0 ± 1.7</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Function (0-10)</td>
<td>3.3 ± 1.5</td>
<td>7.6 ± 1.2</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Satisfaction (0 or 5)</td>
<td>0</td>
<td>4.1 ± 2.0</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Active forward flexion (0-5) (range of motion)</td>
<td>2.6 ± 0.7</td>
<td>3.8 ± 0.7</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Strength (manual muscle testing) (0-5)</td>
<td>2.6 ± 0.5</td>
<td>3.4 ± 0.6</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Total (0-35)</td>
<td>10.5 ± 3.0</td>
<td>25.9 ± 5.0</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

**NOTE.** The values are given as mean ± standard deviation. An isometric 90° forward flexion was measured bilaterally with the elbow extended and the forearm in neutral position and was compared with the strength of the contralateral side. The strength was graded on a scale of 0 to 5 (5, normal; 4, good; 3, fair; 2, poor; 1, trace; and 0, zero).
operative functional shoulder score. Duralde and Bair\textsuperscript{3} reported in their series regarding partial repair of massive rotator cuff tear that 67\% of patients showed good to excellent results with satisfactory pain relief and increased active elevation and 92\% of patients were satisfied with the results of surgery. In their series the mean size of the residual defect in the repaired cuff was 1.7 cm (range, 0.5 to 3 cm). Burkhart\textsuperscript{11} also reported outstanding outcomes with partial repair of irreparable rotator cuff tears: All patients were satisfied with their results, except for 1, and their mean residual defect was 2.9 cm\textsuperscript{2} in size. Our study also showed satisfactory outcome with a mean residual defect size of 12 mm, with 81\% of patients satisfied with their improvement. Although all of the previously mentioned studies left a residual defect and the outcomes may be inferior to those of complete repair, these partial or incomplete repairs of irreparable large to massive rotator cuff tears may be worthwhile, given the level of preoperative pain and functional disability.

However, we do not deny the effectiveness or promising outcomes of complete closure of the rotator cuff tear and do not insist that partial repair is superior to complete repair, which is beyond the scope of this study.

The acromiohumeral distance was decreased from 6.5 ± 1.5 mm to 5.9 ± 1.8 mm, and this was statistically significant, even though it does not seem to be clinically significant. Other reports showed similar outcomes in change of the acromiohumeral distance\textsuperscript{3-5}: Duralde and Bair\textsuperscript{3} indicated no significant difference after partial repair. Liem et al.\textsuperscript{4} and Boileau et al.\textsuperscript{5} reported a 1-mm decrease or greater in acromiohumeral distance after arthroscopic debridement or biceps tenotomy/tenodesis.

This study had several limitations. First, like previous similar studies, this study indicated a relatively short-term result, and we do not expect that this satisfactory outcome will last for the long-term. We suppose, because there are negative prognostic factors in treating massive rotator cuff tears,\textsuperscript{22} that there will be a possibility of the outcome deteriorating over time. Thus we are not sure that arthroscopic partial or incomplete rotator cuff repair will guarantee satisfactory midterm or long-term outcomes. Second, this study did not have a control group to determine whether this treatment option would be better than other options, such as arthroscopic debridement, in addressing irreparable large to massive rotator cuff tear repair. Third, we did not perform follow-up magnetic resonance imaging to assess the changes in fatty infiltration, muscle atrophy, and structural integrity. If these scans had been done, this study would have been weightier. Fourth, the strength of 90° of abduction in the Constant score was measured manually and compared with the contralateral side. This could make the outcomes appear better than they actually were.

CONCLUSIONS

Arthroscopic partial repair showed satisfactory short-term outcomes in irreparable large to massive rotator cuff tears if the patients did not have severe muscle atrophy and fatty infiltration in all supraspinatus, infraspinatus, or teres minor. This study suggests that in large to massive rotator cuff tears that appear irreparable, a partial repair may provide improvement in pain and functional outcomes; however, additional work is necessary.

Acknowledgment: The authors are grateful to Dong-Su Jang (Medical Illustrator, Medical Research Support Section, Yonsei University College of Medicine, Seoul, South Korea) and Young-Jun Cho for their help with the figures.

REFERENCES


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