Surface-holding repair: an original arthroscopic rotator cuff repair technique

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Background: Arthroscopic rotator cuff repair provides satisfactory results; however, there is still a high rate of re-tear. The objective of this study was to present a surface-holding technique that we recently developed for arthroscopic rotator cuff repair in detail and to evaluate the clinical outcome as well as cuff repair integrity with this new method.

Materials and methods: A consecutive series of 116 patients with full-thickness rotator cuff tears underwent arthroscopic surface-holding repair and were monitored with the Japanese Orthopaedic Association, Constant-Murley, and University of California–Los Angeles scores to assess the clinical outcome. The mean follow-up period was 17.9 months (range, 12-40 months). Cuff repair integrity was evaluated by magnetic resonance imaging.

Results: All 3 rating systems at the time of final follow-up reflected a significant improvement in functional recovery of the shoulder compared with the preoperative scores. The overall rate of rotator cuff retear was 19.0% (22 of 116 shoulders), and the rates were 13.6% (9 of 66 shoulders) for small and medium-sized tears and 26% (13 of 50 shoulders) for large and massive tears. The rate for large and massive tears was much higher in patients older than 70 years (58.3%) compared with those younger than 70 years (36.3%), whereas the retear rates were similar in these 2 groups (22.2% and 17.5%, respectively).

Conclusions: Arthroscopic surface-holding repair technique with medial suture and transosseous fixation improved rotator cuff healing. This method may be useful both for young patients and for elderly patients, who frequently have chronic large and massive tears, including osteoporotic bones.

Level of evidence: Level III, Retrospective Comparative Study.
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Keywords: Arthroscopic rotator cuff repair; surface-holding technique; arthroscopic medial advanced footprint fixation; wide contact area; stress dispersion; retear; elderly

IRB: Not applicable. This study and data collection were performed from 2006 to 2010, during which time an Investigational Review Board was not present at our institution. A detailed explanation of the study was provided to the patients before the investigation, and consent to participate was obtained.

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Rotator cuff tear is a common cause of pain and functional limitation in adults. Arthroscopic repair of full-thickness tears of the rotator cuff typically provides satisfactory results, including decreased shoulder pain and improved shoulder motion.\(^2\) In some cases, results are not entirely satisfactory in the sense that repair does not result in either complete tendon healing or return to full function, and a relatively high percentage of re-rupture has still been reported after standard rotator cuff repair.

Healing rates differ among the various surgical procedures used for rotator cuff repair. Imaging studies have demonstrated a retear rate of 30% to 94% after arthroscopic single-row repair.\(^2\)\(^,\)\(^3\)\(^,\)\(^1\)\(^5\)\(^,\)\(^3\)\(^6\) with a higher failure rate among patients with a massive tear. After the single-row or transosseous fixation techniques, a double-row fixation technique was developed that provides strong fixation of tendon to bone as well as “footprint” coverage.\(^2\)\(^5\)\(^,\)\(^3\)\(^4\), however, the repair integrity assessed by magnetic resonance imaging (MRI) showed that the retear rate for large and massive tears was 40%, whereas it was 5% for small to medium-size tears.\(^3\)\(^2\)

Recent biomechanical studies indicated that an increased number of failures occurred at the musculotendinous junction or where the medial suture anchors had been placed.\(^3\)\(^1\) Sano et al reported that higher stress concentrations inside the tendon exist in both single-row and double-row fixations compared with the stress concentrations in transosseous suture fixations, and the stress concentration of the medial suture may cause retear around the medial suture, particularly in double-row fixations.

To advance the biomechanical properties for rotator cuff repair, we have developed a modified transosseous-equivalent technique using medial anchors and lateral transosseous fixation, called the surface-holding repair procedure.\(^3\)\(^7\) Our biomechanical testing showed that this technique provides strong fixation of tendon to bone that is greater than that in the double-row repair.\(^1\)\(^4\) More important, a finite element analysis proved that the surface-holding repair model disperses the stress pattern much better compared with that of the double-row repair model.\(^1\)\(^4\)

The objective of this study was to present the surface-holding technique we recently developed for arthroscopic rotator cuff repair in detail and to evaluate the clinical outcome as well as cuff repair integrity with this method. We hypothesized that this method might be useful for young patients and for elderly patients, who frequently have chronic large and massive tears with muscle atrophy and fatty degeneration in addition to osteoporotic bones.

Materials and methods

Patient inclusion

This is a retrospective case series of 116 patients treated by the arthroscopic surface-holding repair method. Between January 2006 and December 2010, the senior author (N.S.), who has experience of more than 200 arthroscopic rotator cuff repairs, performed consecutive primary arthroscopic repairs for full-thickness rotator cuff tears using this method. The patients had a mean age of 64.0 years (range, 43-83 years) at the time of surgery. There was no selection bias for surgical indications in any of the patients. A total of 41 women and 75 men were treated. The mean follow-up period was 17.9 months (range, 12-40 months).

The criteria for surgical repair included patients who (1) had a full-thickness rotator cuff tear and complained of subjectively unacceptable pain or disability after failed nonoperative treatment for at least 6 months, (2) were eager to elevate the arm at or above the level of the head, (3) understood the need to follow the postoperative treatment regimen, and (4) agreed to have a clinical and functional evaluation of tendon healing at 12 months or later after surgery.

We examined all of the patients by MRI to evaluate rotator cuff tendon integrity before surgery and at 12 months or later after surgery. However, when patients complained of sudden shoulder pain, felt something wrong in the affected shoulder, or were concerned about retear and asked for an examination, MRI was performed immediately to examine rotator cuff retear. Retear occurred in 3 patients at 3 months, 3 patients at 6 months, and 3 patients at 10 months, and they were all included in the retear group. For another 13 cases, retear was found at 12 months or later. Patients were excluded if there was a history of dislocation or fracture of the shoulder, degenerative or inflammatory arthritis, infection, neuropathic changes, prior surgical procedures to the shoulder, or less than 12 months of postoperative follow-up.

The size of the tear was measured intraoperatively according to the system of DeOrio and Cofield: small (<1 cm), medium (1-3 cm), large (3-5 cm), and massive (>5 cm or if 2 tendons were involved). The preoperative cuff tear size was small in 11 cases (9.5%), medium in 55 (47.4%), large in 26 (22.4%), and massive in 24 (20.7%).

Evaluation

The Japanese Orthopaedic Association (JOA) shoulder score (100-point scoring system),\(^3\)\(^2\) Constant-Murley score (100-point scoring system),\(^4\) and University of California–Los Angeles (UCLA) rating scale (35-point scoring system)\(^3\)\(^1\) were recorded before the surgery and at 1 year or later after the surgery.

All patients received a standard postoperative assessment by MRI scans. Oblique coronal, oblique sagittal, and axial T2-weighted spin-echo MRI scans were obtained in all patients. Cuff repair integrity was classified into 5 types based on oblique coronal and oblique sagittal views of T2-weighted MRI according to Sugaya’s system\(^3\)\(^2\): type I, repaired cuff of sufficient thickness with a homogeneously low intensity in each image; type II, sufficient thickness associated with a partial high-intensity area; type III, insufficient thickness without discontinuity; type IV, minor discontinuity in more than one slice, suggestive of a small tear; and type V, major discontinuity in each image, suggestive of a medium to large tear. Types IV and V were defined as retears.

Surgical technique

All the patients received a preoperative interscalene block. All the procedures were done with patients in the beach chair position. After careful arthroscopic evaluation of the full-thickness rotator
cuff tear through standard posterior and anterior portals, bursectomy and acromioplasty were performed with resection of the coracoacromial ligament by Ellman's method, followed by extra-articular and intra-articular soft tissue release to obtain sufficient tendon mobility.

**Surface-holding repair technique**

After newly establishing midlateral and anterolateral portals that were used as a view portal and working portal, respectively, we performed the surface-holding repair technique. This procedure modified the anatomic double-layer repair with use of medial row anchors and transosseous fixation (Fig. 1 and online Video Supplement).

First, rotator cuff tear size was determined after bursectomy of the subacromial space, and deep débridement around the ruptured tendons was done not only on the bursal side but also on the articular side by use of a soft tissue excision shaver. If the mobility of the tendon was insufficient in larger tears, a tendon mobilization procedure, including either a partial or entire capsulotomy and coracohumeral ligament release, was done before the repair. The footprint was then identified on the greater tuberosity, and approximately 5 to 15 mm of the medial site of the footprint was abraded with a shaver through the anterolateral portal until cancellous bone was exposed (Fig. 2, A). This technique, which was named arthroscopic medial advanced footprint fixation (AMAFF), took advantage of enlarging the contact area of the tendon in the footprint.

Next, 1 to 3 suture anchors were placed through the anterior portal in an optimal anchor orientation at 45° to the plane of the footprint, and the distance between each anchor was approximately 10 mm. Then, 6 to 16 threads were passed through the tendon without tying (Fig. 2, B), and 2 to 4 tunnels separated by 15 mm were created in the cancellous bone at the lateral edge of the footprint and extended to the lateral cortex with use of a giant needle (Mutoh, Sapporo, Japan) (Fig. 2, C, D). Finally, the threads were pulled out through the skin with this needle (Fig. 2, E, F) and collected in the anterolateral portal and tied below the greater tuberosity as a lateral transosseous fixation (Fig. 2, G, H). The numbers of anchors, sutures, and bone tunnels and anchor number ratios by tear size are shown in Table I.

**Postoperative treatment**

An abduction pillow was used for 6 to 8 weeks postoperatively. A systematic postoperative rehabilitation program was carried out with self-assisted range of motion exercise at either 2 days or 2 weeks after the surgery. Active elevation in a sitting position from the adducted position of the shoulders was permitted after 8 to 10 weeks, and isometric cuff exercises were initiated at 10 to 12 weeks. The patients were allowed to resume heavy work or sports after an assessment of sufficient muscle strength as well as range of motion recovery at 6 months or more postoperatively.

**Statistical analysis**

Results are expressed as mean ± standard deviation. Statistical comparison between 2 groups was performed with a Mann-Whitney U test. P values < .05 were considered statistically significant.
All 3 rating systems reflected a significant improvement in functional recovery of the shoulders when the preoperative scores were compared with the scores at the time of final follow-up ($P < .001$). The average total score had increased from 69.2 points (range, 39-94 points) preoperatively to 92.4 points (range, 73-100 points) in the JOA score, from 59.3 points (range, 16-91 points) to 86.4 points (range, 71-100 points) in the Constant-Murley score, and from 18.5 points (range, 7-27 points) to 29.3 points (range, 20-35 points) in the UCLA rating scale (Fig. 3, A).
The shoulder range of motion improved significantly after rotator cuff repair; flexion improved from 125 ± 38° to 158 ± 11° (P < .001), abduction improved from 113 ± 46° to 147 ± 38° (P < .001), and internal rotation by the Constant-Murley system improved from 6.1 ± 2.7 points to 7.7 ± 1.7 points (P = .003). External rotation was not significantly changed between the preoperative (50 ± 16°) and final follow-up (50 ± 17°) groups (P = .782) (Fig. 3, B).

**Repair integrity**

Repair integrity was assessed by MRI scans at a mean of 16.0 months postoperatively and was found to be 56.0% (65 shoulders) with a type I repair, 16.4% (19 shoulders) with a type II repair, 8.6% (10 shoulders) with a type III repair, 6.9% (8 shoulders) with a type IV repair, and 12.1% (14 shoulders) with a type V repair (Fig. 4, A). The overall rate of rotator cuff retear categorized in types IV and V was 19.0% (22 of 116 shoulders), whereas 94 shoulders (81.0%) had a continuous cuff with sufficient thickness. The retear rate by size was as follows: 9.1% (1 of 11 shoulders) in small size, 14.5% (8 of 55 shoulders) in medium size, 19.2% (5 of 26 shoulders) in large size, and 33.3% (8 of 24 shoulders) in massive size at the final follow-up (Fig. 4, B).

The postoperative clinical scores of the retear group were significantly lower than those of the non-terar group (P = .008), although both groups had significant improvement compared with the preoperative scores (non-terar, P < .001; retear, P = .001) (Fig. 4, C).

**Arthroscopic surface-holding repair for the elderly**

We hypothesized that the surface-holding technique, which features a broad tendon contact area as well as stress dispersion, may exert a positive effect on rotator cuff healing, particularly in the elderly, who frequently have chronic large and massive tears, including muscle atrophy and fatty degeneration. Therefore, we compared the outcomes in 36 patients 70 years of age and older (≥70 group; mean age, 73.3 years; 23 men, 13 women) with a control group of 80 patients younger than 70 years (<70 group; mean age, 59.7 years; 52 men, 28 women) who underwent arthroscopic surface-holding repair. As we expected, the ratio of large and massive tears was higher in the ≥70 group (58.3%) compared with the <70 group (36.3%) (Fig. 5, A). On the other hand, the retear rate was comparable between the two groups: 22.2% in the ≥70 group and 17.5% in the <70 group (Fig. 5, B). The clinical outcome assessed by the JOA system also supports this result, showing that the postoperative scores are similar between the two groups without significant difference (P = .273) (Fig. 5, C), although statistically significant differences were found between the preoperative score and postoperative score (P < .001). Similar results were obtained with the Constant-Murley and UCLA scoring systems (data not shown).

**Complications**

There were no intraoperative or perioperative complications. No patient had a neural injury, wound infection, or suture anchor problem.

**Discussion**

Successful repair of a rotator cuff tear requires strong fixation, high interface pressure, wide interface area between the tendon and the bone, and minimization of the stress concentration inside the tendon. Recent biomechanical studies demonstrated that the mean intersurface pressure of a transosseous-equivalent suture bridge is greater than that of the simple suture anchor and the suture anchor mattress techniques. Our surface-holding repair technique is a modification of Waltrip’s method with medial suture and lateral transosseous fixation. This procedure is similar to the transosseous-equivalent suture bridge technique, but it differs in that the threads are not tied on the tendon and the medial advanced footprint fixation is employed. This knotless repair on the surface of cuff tendon at the medial site may help diminish retear because in arthroscopic suture bridge repair of full-thickness rotator cuff tears, the knotless group had a significantly lower retear rate compared with the conventional knot-tying group.

There are additional advantages of this technique. We already reported that the surface-holding procedure provided 87.9% more stiffness than the double-row repair and that the number of tendon-suture site failures of the surface-holding technique was smaller than that of the double-row repair. In a finite element analysis, the stress concentration on the tendon stump was barely detectable in a transosseous suture bridge repair of full-thickness rotator cuff tears, the knotless group had a significantly lower retear rate compared with that of the double-row repair.

A micro–computed tomographic assessment showed that the bone distribution in the humeral head is highly inhomogeneous and that cancellous bone density is low in the greater tuberosity. This is consistent with reports showing that suture anchors may be difficult to anchor securely within the greater tuberosity region because of variable bone quality. Therefore, it is beneficial to place suture anchors underneat the articular

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surface with medialized rotator cuff tendon insertion to obtain appropriate holding power. Following these findings, we made a bone trough proximal to the greater tuberosity to enlarge the tendon contact area. This AMAFF method may be useful, particularly in osteoporotic bones, which occur more commonly in the elderly. Because a medial advancement of 17 mm or more reduces the “moment arm” of the shoulder, we made an approximately 5- to 15-mm bone trough at the medial site of the footprint.

In addition, cell-mediated tissue healing and regeneration might be expected in our technique. Mesenchymal stem cells derived from the bone marrow through the bone tunnel and drilled anchor holes have the potential to differentiate into tendon tissues. Our contrast-enhanced ultrasonography analysis for the repaired cuff showed that the longitudinal blood flow in intratendinous tissue was augmented even at 3 months after rotator cuff repair. Thus, our surgical procedures providing multiple bone tunnels and drilled anchor holes may facilitate the healing process of rotator cuff tissues by bone marrow–derived cells released from the humeral bone.

It has been reported that osteolysis appears in the inferior surface of the acromion because of the suture thread knots. In our method, this “knot impingement” resulting in failed rotator cuff repair should never occur because our suture thread knots are usually created under the greater tuberosity. Furthermore, before knot tying, we can demonstrate how the repaired rotator cuff overlies the footprint by pulling the suture thread as shown in Figure 2, G. Thus, using this approach, we can insert additional anchors when we assess that the rotator cuff coverage is incomplete.

Finally, this procedure is less complicated than the double-row method, in which multiple sutures are required. Once a rotator cuff tear is determined by arthroscopic observation, we can complete the cuff repair in 30 to 60 minutes, and only 1 to 3 anchors and a giant needle are needed. Therefore, this is a cost-effective procedure compared with the arthroscopic double-row rotator cuff repair that incurs higher costs and a prolonged surgery time.

Nevertheless, some concerns are raised with our method. One is that partial cartilage loss will occur in the humeral head because the AMAFF technique requires sufficient abrasion in the medial site of the footprint to enlarge the tendon contact area. Second, if the bone density is low in osteoporotic bones, which is often observed in the elderly, bone cutout by the suture thread may occur in the greater tuberosity, leading to failure of rotator cuff fixation. When this is determined during the surgery, we can generate new holes in the footprint more medially with a giant needle to make a deeper tunnel to avoid this risk. Third, when the suture threads are pulled out with a giant needle for lateral transosseous fixation, this procedure might damage the axillary and radial nerve. Thus far, however, we have never experienced such problems, but the possibility should be kept in mind.

Rotator cuff failure is attributed to age and to intrinsic overloading rather than to extrinsic impingement. Boileau et al. observed retears in up to 25% of full-thickness supraspinatus tears, and the rate was more than twice as high (57%) in older patients (>65 years), suggesting that increasing age is negatively associated with tendon healing. In this study, we compared the clinical results and cuff integrity of an age group older than 70 years with those of an age group younger than 70 years and found that similar results appeared in those 2 groups. As the surface-holding repair has a broad contact area for tendon and provides stress dispersion in addition to the AMAFF technique for

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**Figure 3**  (A) Average total Japanese Orthopaedic Association (JOA) score, Constant-Murley score, and University of California–Los Angeles (UCLA) rating scale. (B) Shoulder range of motion improvement after rotator cuff repair. Statistically significant differences between the preoperative (pre-op) score and the postoperative (post-op) score are indicated (*P < .001; †P = .003). ER, external rotation; IR, internal rotation.
osteoporotic bone, we assume that this technique leads to favorable results, particularly in the elderly, who often have chronic large and massive tears.

For large and massive rotator cuff tears, however, a higher retear rate was still observed with this method (26.0%; 13 of 50 shoulders), and this is consistent with previous reports showing that the retear rate remains remarkably high for large and massive tears after arthroscopic rotator cuff repair surgery: 76% to 94% in the single-row method,13,15 17% to 40% in the double-row method,18,23,32 and 22% to 51% in the suture bridge method.6,7,22 Long-term follow-up of patients with retears has provided significant improvements in both pain and function,20 although fatty degeneration and atrophy of the supraspinatus muscle as well as glenohumeral osteoarthritis progressed significantly from the preoperative state.19 To improve cuff integrity for massive rotator cuff tears by arthroscopic rotator cuff repair, our surface-holding repair technique could be developed. In this regard, endogenous regenerative healing by bone marrow–derived cells may be helpful, and our method features a wide contact area for the tendon. Further modification, such as a bone marrow stimulation technique, might further improve healing in severe cuff rupture.

**Conclusion**

The arthroscopic surface-holding repair technique using medial suture and transosseous fixation without a complicated suture procedure improved rotator cuff healing. This method may be useful in young patients and for elderly patients, who frequently have chronic large and massive tears, including osteoporotic bones.

**Disclaimer**

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