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Outcomes of arthroscopic rotator cuff repair with muscle advancement for massive rotator cuff tears

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Background: We performed arthroscopic rotator cuff repair (ARCR) combined with miniopen supraspinatus and infraspinatus muscle advancement for massive rotator cuff tears (RCTs) to decrease tension at the repair site with the goal of reduction of the failure rate. We evaluated the clinical outcomes and failure rate after this procedure.
Methods: This study included 47 patients diagnosed with chronic massive RCTs between October 2010 and March 2015. Of these patients, 21 underwent transosseous equivalent (TOE) ARCR only (control group), and 26 underwent TOE ARCR with muscle advancement (study group). We evaluated shoulder clinical outcomes at preoperative and postoperative assessments and also measured muscle strength and the acromiohumeral interval (AHI) at the same time in both groups. Failure rates were calculated in both groups by evaluating the cuff integrity with postoperative magnetic resonance imaging.
Results: Although there was statistically significant improvement for the mean clinical scores in the both groups, there were no significant differences between the 2 groups. The postoperative abduction muscle strength and AHI were significantly higher in the study group (46.3 ± 20.6 N and 9.4 ± 2.9 mm; $P = .04$) than in the control group (34.6 ± 20.0 N and 7.7 ± 3.0 mm; $P = .04$). The failure rates were significantly lower in the study group than in the control group (23.1% and 52.4%; $P = .03$).
Conclusion: The TOE ARCR with muscle advancement can achieve significantly better abduction muscle strength, wider AHI, and lower failure rates for massive RCTs than the normal TOE ARCR.
Level of evidence: Level III; Retrospective Cohort Design; Treatment Study

Keywords: Massive rotator cuff tears; arthroscopic rotator cuff repair; muscle advancement; failure rate; transosseous equivalent; muscle strength; acromiohumeral interval

Good to excellent clinical outcomes and high anatomic healing rates are promising for arthroscopic rotator cuff repair (ARCR) for small- to medium-sized rotator cuff tears (RCTs).[2,31,34,39] However, high failure rates after ARCR in large-to-massive RCTs have been reported.[12,19,37] Whether we should aim for complete repair or partial repair for such massive RCTs is controversial. Some authors have reported that partial repair is enough for such massive RCTs because they do not always

The Hiroshima University Institutional Review Board approved this retrospective study (Permission No.: E-234).

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achieve inferior outcomes, even if failure after ARCR has occurred.[19,33] Other authors have reported that reduction of the failure rate after ARCR might be crucial to achieving excellent functional outcomes for such massive RCTs.[20,37] Many surgeons have designed ingenious procedures to improve the healing rate after ARCR for massive RCTs, but the question whether these techniques produced excellent results depended on the surgeon's skill.[27,38] Surgery that can be performed without high technical demand is needed.

High tension at the repair site is said to be associated with inferior outcomes and the occurrence of failure after ARCR for massive RCTs.[9] Debeyre et al[10] reported a procedure in which the supraspinatus (SSP) muscle was elevated from the supraspinatus fossa and advanced laterally to decrease the tension of the distal SSP tendon with acromial osteotomy. This technique, however, involved very invasive surgery and ran the risk of leading to nonunion at the osteotomy site.[41] In addition, only SSP muscles were advanced, not infraspinatus (ISP) muscles, although massive tears usually involved both SSP and ISP tendons. Moreover, Warner et al[40] pointed out that suprascapular nerve (SSN) palsy may occur with excessive advancement of SSP muscles.

Recently, the technique of arthroscopic SSN release[26] has been presented and often performed to treat SSN entrapment or as a concomitant procedure with massive RCTs to prevent SSN palsy after excessive retraction of rotator cuff muscles. This technique was relatively easy to perform in a short time. We therefore performed ARCR combined with miniopen SSP and ISP muscle advancement with arthroscopic SSN release for such large-to-massive RCTs. This retrospective study was conducted to evaluate the short-term clinical outcomes and cuff integrity after ARCR with muscle advancement.

Materials and methods

Between October 2010 and March 2015, we performed 203 ARCRs, with or without muscle advancement, under the diagnosis of RCTs. The study excluded patients with incomplete RCTs, isolated subscapularis (SSC) or SSP tendon tears, postacute trauma cases, revision cases, RCTs with a neurologic lesion, such as cervical spondylotic myelopathy, osteoarthritis of the glenohumeral joint, rheumatoid arthritis, and postinfection. Finally, 47 patients diagnosed with chronic massive RCTs involving at least 2 tendons were included in the current study (Gerber et al[13]).

These patients were referred to our institution after the failure of several months of conservative treatment. From October 2010 to October 2012, normal transosseous equivalent (TOE) ARCR[32] only was performed for all cases (control group). From November 2012 to March 2015, TOE ARCR with muscle advancement was performed when full coverage of the footprint could not be achieved with the tendon stump at an abduction angle of 30° using 30 N of tension as measured by a tension meter (study group). This tension of 30 N was determined by a previous report described by Reilly et al.[35] The control group included 21 patients (11 men and 10 women) who were a mean age of 66.1 ± 9.0 years. The study group included 26 patients (13 men and women) who were a mean age of 68.6 ± 8.8 years. The demographic data are summarized in Table I.

Table I Demographic data in each group

Variable	Control group (n = 21)	Study group (n = 26)	*P* value
Sex			.87
Male	11	13	
Female	10	13	
Age, yr	66.1 ± 9.0	68.6 ± 8.8	.32
Affected arm			.67
Right	15	20	
Left	6	6	
SSP retraction (Boileau classification)			.04*
Stage III	20	19	
Stage IV	1	7	
SSC lesion (Lafosse classification)			.66
Type 0	6	5	
Type I	1	2	
Type II	11	14	
Type III	1	4	
Type IV	2	1	
Type V	0	0	
LHB lesion (modified Lafosse classification)			.60
Grade I	6	4	
Grade II	4	8	
Grade III	0	1	
Grade IV	8	8	
Grade V	3	5	
Fatty infiltration (Goutallier classification)			.08
SSC	1.5 ± 0.8	1.2 ± 1.0	
SSP	1.8 ± 0.6	1.6 ± 0.6	.31
ISP	1.5 ± 0.8	1.3 ± 0.8	.58
GFDI	1.6 ± 0.5	1.4 ± 0.6	.10
Follow-up period, mo	32.3 ± 10.6	28.3 ± 7.3	.07

SSP, supraspinatus; *SSC*, subscapularis; *ISP*, infraspinatus; *LHB*, long head of biceps; *GFDI*, global fatty degeneration index.
Continuous data are presented as mean ± standard deviation and categorical data as number of patients.
* Statistically significant difference between the control group and the study group ($P < .05$).

RCTs involving the SSC tendon lesion were treated at each SSC stage as described by Lafosse et al.[24] We defined the intact SSC tendon as type 0 and left it as it was. SSC débridement was performed on type I SSC lesions, and type II and III were repaired by TOE ARCR. Irreparable SSC tears were reconstructed by pectoralis major transfer.[36] We defined the long head of the biceps (LHB) lesions as modified Lafosse classification[25]; intact or minor LHB lesion as grade I, major lesion as grade II, positive hourglass sign as grade III, subluxation as grade IV, and rupture as grade V. Shoulders with more LHB lesions than in grade II were treated by tenodesis or tenotomy.

We evaluated the fatty degeneration of each rotator cuff muscle and calculated the global fatty degeneration index assessed by magnetic resonance imaging (MRI).[11] MRI findings, such as SSP retraction and fatty infiltration, were assessed by a blinded radiologist. The intraoperative findings, such as SSC and LHB classification, were assessed by a single surgeon. All parameters of the demographic data from the 2 groups were analyzed statistically.

Surgery

All operations were performed by the same surgeon who assessed the condition of the SSC and LHB. We performed these operations with patients in the beach chair position. The procedure in the study group consisted of 3 main components: arthroscopic SSN release, SSP and ISP muscle elevation, and advancement (Fig. 1), and our original TOE ARCR as described as below. The control group operation consisted of the same components except for the muscle elevation and advancement.

After conventional arthroscopic synovectomy and subacromial decompression, an arthroscopic examination was performed to analyze the cuff tear sizes, quality, and excursion. When a SSC tendon injury or LHB lesion was identified, SSC repair and LHB tenodesis or tenotomy was performed. The extracting tension of the SSP and ISP tendons was measured by a tension meter, by pulling the No. 0 nylon string that penetrated the cuff. If a tension of 30 N was not enough to cover the footprint with the tendon stump, we performed muscle advancement of the SSP or ISP, or both.

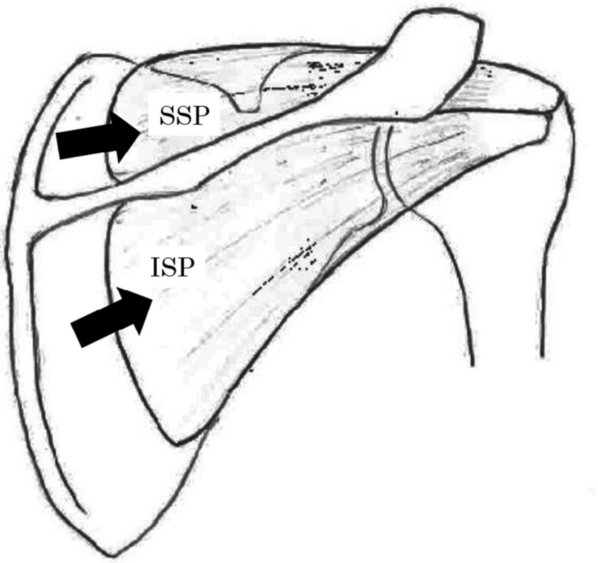

Figure 1 A schema of supraspinatus (*SSP*) and infraspinatus (*ISP*) muscle elevation.

Arthroscopic SSN release

Arthroscopic SSN release was performed as Lafosse reported previously.[26] The electrothermal device or shaver was advanced along the anterior edge of the SSP muscle behind the base of the coracoid process. After the superior transverse scapular ligament running over the scapular notch was detected, the SSN could then be visualized underneath the ligament. SSN release was achieved by cutting the ligament with a blunt rod.

SSP or ISP muscle advancement

For the muscle advancement, a 4-cm transverse skin incision was created along the medial border of the scapular spine (Fig. 2, *A*). The trapezius was detached from the scapular spine, and the SSP and ISP muscle belly was elevated from the scapular body with a blunt elevator (Fig. 2, *B*). The medial border of the cuff muscles was completely peeled off so that the SSP and ISP muscle could be advanced enough laterally. The lateral release of the cuff muscles was performed carefully to avoid injury of the SSN. The SSN could be touched by the surgeon's fingers. After this procedure, the retracted cuff tendon could be shifted laterally about 2 cm. The elevated SSP and ISP muscles were not anchored to the scapular fossa and were left free.

Arthroscopic TOE ARCR

We performed TOE ARCR using our originally modified medial double-pulley technique reported by Lo et al.[28] After the cancellous bone was exposed, 2 or 3 double-loaded anchors (HEALICOIL PK or RG suture anchor; Smith & Nephew Endoscopy, Tokyo, Japan) were inserted at regular intervals, depending on the size of the cuff tears, along the medial edge of the footprint. The torn tendons were penetrated with all 4 sutures from each anchor by a retrograde retrieving device such as the Banana Lasso (Arthrex, Tokyo, Japan).

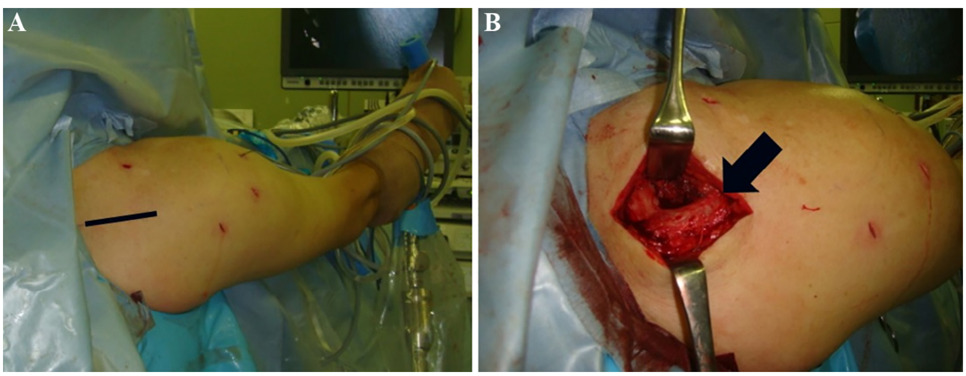

Figure 2 Photographs show the muscle advancement operation site: (**A**) minimal skin incision for the muscle advancement is made along the scapular spine; (**B**) after muscle elevation (*arrow*, scapular spine).

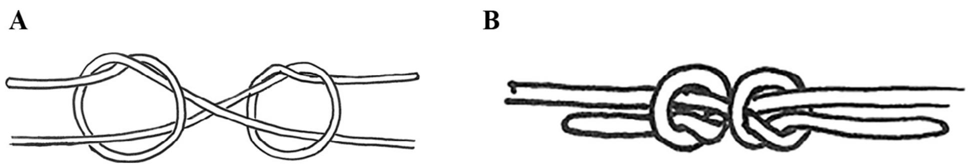

Figure 3 Drawing shows how the medial pulley is created: (**A**) before being tightly fastened and (**B**) after being tightly fastened.

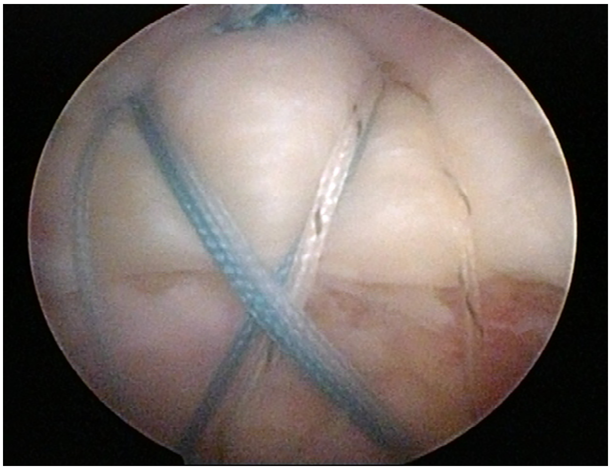

Figure 4 Photograph shows the transosseous equivalent arthroscopic rotator cuff repair.

Two same-colored sutures from each anchor were retrieved from the lateral portal and tied together outside the body using our original technique, as shown in Fig. 3. One loop was made at 1 suture, then the other suture was laced through the loop. Another loop was then made around the proximal part of the first suture (Fig. 3, *A*), and the 2 loops were fastened together tightly. Each suture limb was pulled in a counter direction, so that each suture was locked by a knot (Fig. 3, *B*). After the ends of the sutures were cut short, whole medial mattress sutures were made. By pulling reciprocal suture limbs, the medial knots were introduced into the body.

If 3 medial anchors were inserted, 3 medial double pulleys, between the anterior and middle, middle and posterior, and anterior and posterior, were made. Finally, lateral push-in type anchors (Healix Advance Knotless BR anchor; Johnson & Johnson, Tokyo, Japan) loaded with 3 sutures, 2 from 1 anchor and 1 from the other anchor, which were inserted 1 cm underneath the edge of the greater tuberosity at regular intervals (Fig. 4). When 3 anchors were inserted medially, 3 sutures from each anchor were loaded to the 2 push-in anchors and inserted in a similar fashion.

Wound closure

We had no problems with tissue swelling after the miniopen muscle advancement procedure and arthroscopic TOE repair because irrigation fluid was discharged from the scapular spine incision. We could close the wound at the scapular spine without any difficulty.

Postoperative rehabilitation was as follows: the affected arm was immobilized for 6 weeks in an abduction brace. Passive range of motion (ROM) exercise commenced from 1 week, active ROM exercise commenced from 4 weeks, and rotator cuff and deltoid muscle strengthening exercises commenced from 12 weeks.

Evaluations

The other surgeon (Y.N.), who was blinded to the surgical procedure, evaluated the shoulder clinical outcomes using the Constant score and the University of California, Los Angeles (UCLA) Shoulder Rating Scale score for the preoperative and postoperative status in the control group and the study group. Postoperative clinical scores were assessed 2years after surgery. At the same time, ROM of anterior flexion (AF), external rotation (ER), and internal rotation (IR) were measured using a goniometer in both groups. The value of IR was indicated as the highest vertebral level that a patient's thumb could reach behind the back.

In addition, the quantitative muscle strength of abduction and the preoperative and postoperative status of ER and IR were measured in both groups. The muscle strengths were measured using a hand dynamometer (MicroFet 2; Nihon Medix Co., Ltd., Chiba, Japan). These muscle strengths were measured in seated patients, at a 45° abduction angle in the scapular plane for the abduction strength, and with the upper arm at the side of body and the elbow at the 90° of flexion in ER/IR neutral position for the ER and IR strengths. Each muscle strength was measured 3 times, and the average values were calculated.

The acromiohumeral interval (AHI) in both groups (the superior migration of the humeral head) was measured from the true anteroposterior view of the plain radiograph taken in a standing and ER/IR neutral position. The AHI was defined as the shortest distance between the undersurface of the acromion and the top of the humeral head, measured according to the same method as described by Iannotti et al.[21]

The failure rate was calculated in both groups by evaluating the cuff integrity. We checked the postoperative MRI taken at 2 years after surgery and assessed the cuff integrity[37] according to the Sugaya classification. Types IV and V of the classification were regarded as failures.

Statistical analyses

We performed statistical analyses against the demographic data using the χ^2 test and Fisher exact test on the categorical variables and the Mann-Whitney *U* test on the numeric variables. The comparison of preoperative and postoperative values was performed statistically by the paired *t* test. The comparison between the control group and the study group was assessed statistically using the Mann-Whitney *U* test, except for the comparison of the failure rate. This comparison was performed statistically using the χ^2 test. $P < .05$ was set as a significant difference.

Results

According to the demographic data (Table I), there were no statistically significant differences between the control group

Table II Clinical outcomes, range of motion, muscle strengths, and acromiohumeral interval in each group

Variable	Control group		Study group		*P* value	
	Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op
Clinical outcomes						
Constant score	41.1 ± 8.6	65.8 ± 17.1*	43.0 ± 15.0	71.2 ± 12.7*	.45	.26
UCLA score	12.0 ± 2.8	28.9 ± 6.6*	12.5 ± 3.1	28.5 ± 6.3*	.38	.47
Range of motion						
AF angle,°	124 ± 31	149 ± 22*	120 ± 35	148 ± 18*	.84	.84
ER angle,°	47.9 ± 25.1	53.6 ± 19.2	49.3 ± 23.0	51.7 ± 13.6	.74	.71
IR level, Th spine	12.6 ± 2.6	12.0 ± 2.0	12.4 ± 2.7	11.8 ± 2.4	.75	.36
Muscle strength, N						
Abduction	21.3 ± 10.9	34.6 ± 20.0*	23.7 ± 14.1	46.3 ± 20.6*	.55	.04†
ER	29.2 ± 15.9	41.0 ± 19.5*	29.8 ± 12.5	48.0 ± 18.4*	.91	.24
IR	68.8 ± 31.2	83.5 ± 30.5*	67.0 ± 29.4	87.7 ± 38.8*	.76	.97
AHI, mm	9.0 ± 2.7	7.7 ± 3.0*	7.9 ± 2.2	9.4 ± 2.9*	.06	.04†

UCLA, University of California, Los Angeles Shoulder Rating Scale; *AF*, anterior flexion; *ER*, external rotation; *IR*, internal rotation; *AHI*, acromiohumeral interval.
Data are presented as mean ± standard deviation.
* Statistically significant between preoperative and postoperative values ($P < .05$).
† Statistically significant between the control group and the study group ($P < .05$).

and the study group regarding sex, age, affected arm, SSC lesion, LHB lesion, each of the fatty degeneration values, and follow-up period ($P > .05$). There was, however, a significant difference in the SSP retraction between these 2 groups ($P = .04$); that is, the SSP tendons in the study group were significantly more retracted medially than in the control group.

Short-term shoulder clinical outcomes were as follows: the Constant score improved significantly in both groups, from 41.1 to 65.8 in the control group ($P < .001$) and from 43.0 to 71.2 in the study group ($P < .001$) after surgery. The UCLA score improved significantly in both groups, from 12.0 to 28.9 in the control group ($P < .001$) and from 12.5 to 28.5 in the study group ($P < .001$) after surgery. However, the differences in the preoperative and postoperative scores between these 2 groups were not statistically significant ($P > .05$).

Regarding the postoperative ROM, although the AF improved significantly from 124° to 149° in the control group ($P < .01$) and also significantly improved from 120° to 148° in the study group ($P < .001$), the postoperative ER and IR did not improve significantly: from 47.9° and Th12.6 to 53.6° and Th12.0 in the control group and from 49.3° and Th12.4 to 51.7° and Th11.8 in the study group, respectively ($P > .05$). The postoperative abduction, ER, and IR muscle strength all improved significantly from 21.3 N, 29.2 N, and 68.8 N to 34.6 N, 41.0 N, and 83.5 N in the control group ($P < .01$ for all) and from 23.7 N, 29.8 N, and 67.0 N to 46.3 N, 48.0 N, and 87.7 N in the study group ($P < .001$ for all), respectively. Although there were no significant differences in the ER and IR muscle strength between these 2 groups ($P > .05$), the abduction muscle strength in the study group was significantly higher than that in the control group ($P = .04$).

The postoperative AHI deteriorated significantly after surgery in the control group, from 9.0 mm to 7.7 mm, ($P = .03$) but improved significantly in the study group from 7.9 mm to 9.4 mm ($P < .001$; Table II). Indeed, the postoperative AHI in the study group was significantly higher than that in the control group ($P = .048$). The results of the cuff integrity in both groups are summarized in Table III. The failure rate was significantly lower in the study group than in the control group (23.1% and 52.4%; $P = .03$).

Table III Cuff integrity and failure rate in each group

Variable	Control group (n = 21)	Study group (n = 26)
Sugaya classification		
Type I, No.	0	2
Type II, No.	9	14
Type III, No.	1	4
Type IV, No.	4	1
Type V, No.	7	5
Failure rate, %	52.4	23.1

Discussion

We achieved significant cuff integrity after ARCR with SSP and ISP muscle advancement for such large-to-massive RCTs compared with those after ARCR only, without any additional procedures, although the SSP tendons in the study group significantly retracted medially compared with those in the control group. AF improved significantly after the procedure, but ER and IR did not improve significantly. Although measurements of isometric muscle strength improved significantly after surgery in both groups, the postoperative abduction strength was higher in the study group than in the control group.

The AHI improved significantly after surgery only in the study group but significantly deteriorated in the control group.

One possible reason for this deterioration in the control group is that more failures occurred in the control group than in the study group.

High failure rates after ARCR for large-to-massive RCTs were reported by many authors.[12,13,19,33,37,42] Some authors suggested that complete cuff repair was crucial to achieving good clinical outcomes even for such large tears because the clinical outcomes in the failure cases after cuff repair were inferior to those of complete repairs.[20,37] Surgeons therefore were aiming to repair such tears completely by using several release techniques, such as thorough release around the cuff tendons, margin convergence,[5] and interval slide.[27] The failure rate has the potential to increase, however, because such repairs were not of an anatomic nature and the tension at the repair site caused by these procedures differs from anatomic tension. Kim et al[22] reported that the failure rate after ARCR with margin convergence was relatively high (47.8%) for large RCTs, although the clinical outcomes after surgery were comparable between the groups with or without failure.

Yoo et al[42] recently reported that less-than-optimal coverage of the original footprint during ARCR of massive RCTs correlated with a relatively high failure rate. We think that coverage of the entire footprint by the tendon stamp is important to prevent failure after repair. We therefore performed ARCR with miniopen SSP and ISP muscle advancement for such large-to-massive RCTs to cover the footprint with the torn tendon stump using less tension. Moreover, this technique reduces the failure rate after ARCR. Goutallier et al[15] reported tension-free cuff repairs in the massive RCTs series with limited muscular fatty degeneration of the muscles ≤2 by a similar procedure. Our series in both groups showed lower fatty degeneration, as was the case in Goutallier's reports.

Many surgical options for irreparable tears have been reported, such as partial repair,[20,23] patch graft using fascia lata[30] or artificial biomaterials,[18] and latissimus dorsi transfer.[14] However, the midterm to long-term outcome of partial repair was not acceptable, and muscle weakness may remain after a patch graft because 2 points must be sutured: between the tendon edge and the graft, and between the graft and the footprint. Although our technique is relatively invasive because another incision is needed along the scapular spine, we only repair 1 point between the tendon edge and the footprint, and the repaired tendon can transmit cuff muscle power. Furthermore, poor outcomes or complications, such as glenohumeral osteoarthritis after latissimus dorsi transfer, were also reported.[7,16] Mihata et al[29] recently reported good short-term clinical outcomes after arthroscopic superior capsule reconstruction using the fascia lata, and many surgeons have reviewed this technique. However, the long-term outcomes were doubtful because of deterioration of the free fascia lata graft. Although some kinds of augmentation, such as platelet-rich plasma[6] and the bone marrow-stimulating technique,[43] have been induced during ARCR, effectiveness is still controversial. Good outcomes were reported by reverse shoulder arthroplasty (RSA),[4,17] but restoration of muscle strength cannot be expected, and relatively high complication rates have been reported[1] until now. There is no doubt that repairing cuff tendons using their own tissues produces better results than reconstructive surgery. Furthermore, the repaired results are more enduring than reconstructed results.

To avoid the occurrence of SSN palsy, we added arthroscopic SSN release in the case of all massive tears and not only after SSP and ISP muscle advancement. The SSN runs through the suprascapular notch under the superior transverse scapular ligament and onto the supraspinatus fossa, passing down along the base of the scapular spine and through the spinoglenoid notch onto the infraspinatus fossa.[3] On one hand, some authors have written reports on the relationship between massive RCTs and SSN palsy.[8] On the other hand, Warner et al[40] reported that excessive extraction of the torn rotator cuff tendons may cause SSN palsy, because lateral advancement of the rotator cuff tendons was anatomically limited by the transverse scapular ligament. We therefore released the ligament arthroscopically, and none of our patients have experienced SSN palsy after muscle advancement.

Demographic data showed that the SSP retraction in the study group was significantly more severe than that in the control group. The reason for this is the likelihood that the surgeon can accomplish complete repair of massive RCTs, even for Boileau stage IV, after performing cuff repair with advancement, particularly if the cuff integrity after advancement is very good.

Our study indicated that there were no statistical differences in the clinical outcomes between these 2 groups, although values for abduction strength and AHI were statistically higher in the study group than in the control group. The reason may correlate with reports that show no statistical differences between intact repair and failed repair.[12,22,23,33,42] The long-term outcomes may differ from these short-term outcomes as long as the repaired tendons remain intact. Further follow-up is required. In addition, the significant increase of the AHI after surgery in the study group may be caused by regeneration of the afferent force from completely healed cuff tendons, not only from force couples but also from the alive SSP, because the SSP and ISP muscles can survive by this muscle advancement. Although the increase in the study group may cause subacromial decompression concomitant with cuff repair, the AHI in the control group should also increase. Our technique therefore can prevent the massive RCTs from progressing to cuff tear arthropathy.

Although we achieved good outcomes after ARCR with SSP and IP muscle advancement, our study still has several limitations. Firstly, it has occult problems because it was retrospective and chronological. There were few statistical differences between the 2 groups in our demographic data, so occult bias may exist. However, the bias may decrease minimally because the examiner and radiologist were blinded to the operations and evaluated only the clinical results and postoperative MRI.

Secondly, patient numbers are still small, and we did not perform a power analysis to determine appropriate sample sizes. However, increasing the numbers was difficult because we are improving our procedure aiming to enhance repair ability. Moreover, our sample sizes are sufficient to enable effective assessment of the muscle advancement in massive RCT.

Thirdly, because our follow-up period was short, long-term outcomes may deteriorate compared with our short-term data.

Fourthly, asymptomatic SSN palsy may possibly occur after excessive advancement of the SSP or ISP muscles, although we have never observed clinically obvious nerve lesions in our patients.

Finally, we did not include very severe RCTs, such as shoulders with a global fatty degeneration index of >3. Because the Japanese orthopedic community did not use RSA for severe massive RCTs, such as pseudoparalysis, until 2014, before this year we would have most likely recommended conservative treatment for such patients, without enforcing our technique. Consequently, we may have selection bias for our cohorts. The clinical outcomes may deteriorate if we include such severe massive RCTs. However, there is no doubt that our results are promising, with good outcomes, such as good muscle strength and good cuff integrity, with indications that this revolutionary procedure can prevent superior migration of the humeral head, even for larger RCTs.

Conclusions

We performed ARCR combined with miniopen SSP and ISP muscle advancement for massive RCTs to decrease the tension of the repair site. The results of this study show that ARCR with muscle advancement can achieve significantly better abduction muscle strength, wider AHI, and lower failure rates, even for massive RCTs.

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