Augmentation of Massive Rotator Cuff Repairs Using Biceps Transposition Without Tenotomy Improves Clinical and Patient-Reported Outcomes: The Biological Superior Capsular Reconstruction Technique

Samuel Gray McClatchy, M.D., Douglas E. Parsell, Ph.D., Edward Rhettson Hobgood, M.D., and Larry D. Field, M.D.

Purpose: To evaluate the outcomes of a consecutive series of patients after transposition of the biceps without tenotomy (biological superior capsular reconstruction [bio-SCR] technique) to augment massive rotator cuff repairs. **Methods:** Thirty massive rotator cuff tears repaired and augmented using the bio-SCR technique between June 2018 and July 2021 were identified and retrospectively reviewed. American Shoulder and Elbow Surgeons (ASES) scores, visual analog scale pain scores, supraspinatus and infraspinatus strength, and range of motion were collected preoperatively and postoperatively. **Results:** The average age of patients undergoing bio-SCR augmentation was 67.0 years (range, 28.4-81.9 years), and the mean clinical follow-up period was 2.9 years (range, 1.8-4.5 years). The average ASES score improved from 33.2 preoperatively to 80.8 at 6 months postoperatively, 92.0 at 1 year, and 87.0 at 2 years ($P < .001$). The minimal clinically important difference for the ASES score was exceeded at all postoperative intervals. Active forward flexion improved from 120.6° to 156.8° ($P < .001$). The pain score improved from 7.1 to 0.9 ($P < .001$). Postoperatively, 1 complication (3.3%) occurred: a proximal biceps rupture. **Conclusions:** Incorporating a transposed biceps tendon into the repair of a massive rotator cuff tear using the bio-SCR technique resulted in significant clinical improvements with a low complication rate. **Level of Evidence:** Level IV, case series.

See commentary on page 55

Massive rotator cuff tears are challenging to manage. Operative repair of these tears can be difficult because of tendon retraction, inelasticity, bursal scarring, and atrophy of the rotator cuff.[1-3] Some chronic massive rotator cuff tears are not completely repairable owing to tendon retraction and rotator cuff muscle atrophy. Even when complete or partial repair is possible, poor tissue quality and/or increased repair tension may lead to failure and poor outcomes.[2]

Several procedures have been proposed to surgically manage massive rotator cuff tendon tears, including partial repair, patch augmentation, tendon transfer, superior capsular reconstruction (SCR), reverse total shoulder arthroplasty, and subacromial balloon spacer placement.[1-3] However, no consensus has been reached on how to best treat such tears. A surgical technique coined the biological superior capsular reconstruction (bio-SCR) technique was recently published.[4] This technique uses the biceps tendon to augment partial or complete massive rotator cuff repairs and is carried out by posteriorly transposing and securing the intact long head of the biceps tendon (LHBT) from the bicipital groove to the greater tuberosity. The transposed biceps is then used to augment the rotator cuff tissue and superior capsule. The biceps is otherwise left intact, and a tenotomy is not carried out.

From Mississippi Sports Medicine and Orthopaedic Center, Jackson, Mississippi, U.S.A.

The authors report the following potential conflicts of interest or sources of funding: E.H. is a consultant for Smith & Nephew, outside the submitted work. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received September 21, 2022; accepted June 1, 2023.

Address correspondence to Larry D. Field, M.D., Mississippi Sports Medicine and Orthopaedic Center, 1325 E Fortification St, Jackson, MS 39202, U.S.A. E-mail: larry.field@msmoc.com

0749-8063/221210

https://doi.org/10.1016/j.arthro.2023.06.014

The purpose of this case series was to evaluate the outcomes of a consecutive series of patients after transposition of the biceps without tenotomy (bio-SCR technique) to augment massive rotator cuff repairs. We hypothesized that the outcomes after biceps augmentation would show significant clinical improvement and yield no complications related to biceps transposition.

Methods

All bio-SCR procedures performed by a single surgeon (L.D.F.) from June 2018 to July 2021 were identified. A retrospective chart review was performed under institutional review board approval. The inclusion criteria included all patients who underwent the bio-SCR procedure for massive rotator cuff tears. The only exclusion criterion maintained throughout the study period was reserved for patients with massive rotator cuff tears in which the presence of intact anterior cable tissue was confirmed at the time of arthroscopic assessment. In such instances, we did not believe that releasing the anterior cable from its attachment at the greater tuberosity to accommodate placing the transposed biceps underneath the rotator cuff was advisable. Because we always left the anterior cable connected in these patients, biceps transposition using the bio-SCR technique would have necessitated that the biceps be positioned superior to the anterior rotator cuff cable, and this was not carried out in any patient presented in our case series.

In all patients in this consecutive series, arthroscopic rotator cuff repair was indicated based on history, physical examination findings, magnetic resonance imaging findings, and failure of nonoperative management to yield adequate improvement. Patients were not otherwise excluded based solely on radiographic evidence of some degree of either superior humeral head migration or glenohumeral osteoarthritis if we believed they had a high likelihood of benefitting from arthroscopic rotator cuff repair. In addition, although patients requiring revision arthroscopic rotator cuff repair were not specifically excluded as potential candidates for the bio-SCR procedure, none of the patients in this consecutive series had undergone prior shoulder surgery. Moreover, when we made the intraoperative decision to perform the bio-SCR procedure, the quality and quantity of the available biceps were not considered. We believed that, regardless of the quantity and quality of biceps tissue, incorporation of this biceps tissue was potentially valuable in improving the repair construct, and thus, we transposed the biceps in all cases regardless of the condition of the biceps tendon. The final decision on when to use the bio-SCR technique was made intraoperatively after assessment of rotator cuff repairability and tissue quality. Because the bio-SCR technique was a newly described procedure, we used it sparingly and with discretion during the study period. This technique was generally reserved for the most challenging of our massive rotator cuff repair cases. A review to determine the total number of massive rotator cuff tears repaired by the senior author during the study period was carried out to estimate the percentage of patients who underwent bio-SCR augmentation during this period, but only patients who underwent the bio-SCR technique were included for detailed analysis.

Operative reports, preoperative and postoperative clinical assessment findings, intraoperative arthroscopic photographs, and shoulder radiographs were reviewed. Patient demographic characteristics including sex, age, and handedness were identified and recorded. Preoperative anteroposterior radiographs were used to evaluate for superior humeral head migration using the Hamada classification and acromiohumeral interval measurements.[5] Operative reports were reviewed for type of repair (partial vs complete), residual rotator cuff defect area (measured in square centimeters) that persisted if a partial repair was performed, additional concomitant procedures carried out, and any intraoperative complications that occurred.

Clinical Assessment

The American Shoulder and Elbow Surgeons (ASES) shoulder score[6,7] and visual analog scale (VAS) pain score were collected from all patients preoperatively and at the 6-month, 1-year, and latest follow-up visits. Range of motion, external rotation strength, and supraspinatus strength were documented preoperatively and compared with repeated measurements at the last clinical evaluation. All clinical assessments were conducted by the senior author.

Operative Technique

The surgical procedure was carried out as previously described by Adrian and Field.[4] After induction of general anesthesia, range of motion and stability of the operative shoulder were evaluated and recorded. The patient was positioned in the beach-chair position, and the operative extremity was prepared and draped in standard fashion. A posterior glenohumeral joint portal was created, and a 30° arthroscope was inserted. Under direct visualization, an anterior glenohumeral joint portal was created. Diagnostic arthroscopy of the glenohumeral joint was performed, and the presence of the LHBT was confirmed. After any intra-articular pathology was identified and addressed, the arthroscope was reinserted into the subacromial space through the same posterior portal, and a lateral subacromial portal was created. A subacromial bursectomy was performed, and an acromioplasty and distal clavicle excision were completed if indicated.

The rotator cuff tendon tear size and pattern were assessed and measured in each patient (Fig 1). A rotator cuff tear was classified as massive if it had a width

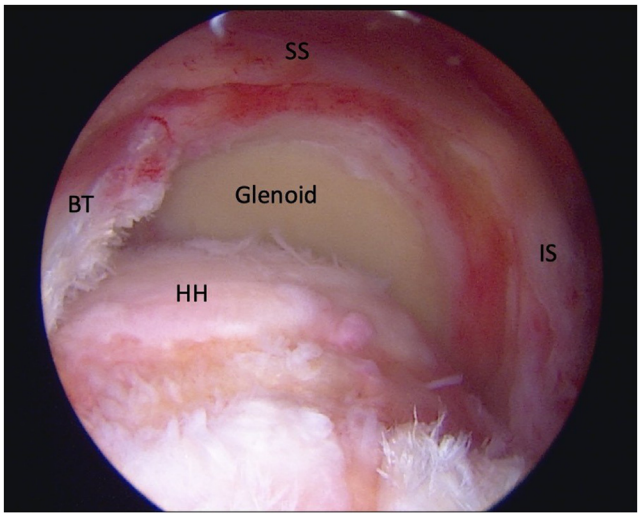

Fig 1. Arthroscopic photograph, as viewed from lateral portal, showing massive, retracted rotator cuff tear with intact long head of biceps tendon (BT) in left shoulder with patient in beach-chair position. (HH, humeral head; IS, infraspinatus; SS, supraspinatus.)

greater than 5 cm, involved 2 or more tendons, and had an area of 30 cm^2 or greater.[8-11] Cuff tear area was measured before and after repair. Measurements were obtained arthroscopically with a calibrated probe oriented anterior-posterior and medial-lateral to the tear.[12] Release of the capsule and adhesions was then performed as necessary to improve lateral mobility of the rotator cuff tissue, and the greater tuberosity was debrided of soft tissue and lightly abraded. By use of an arthroscopic soft-tissue grasper, evaluation of the quality and repairability of the rotator cuff tissue was accomplished by lateralizing the rotator cuff tendon to the greater tuberosity. On the basis of this assessment, the surgeon made an intraoperative decision on whether to transpose the biceps tendon to augment the rotator cuff repair construct. When the decision to transpose the biceps was made, the surgeon then performed the bio-SCR technique regardless of biceps tendon size or quality.

In all patients in this study, the biceps tendon was mobilized thoroughly via a complete release of the transverse humeral ligament with an arthroscopic shaver (Dyonics Incisor Plus Platinum, 4.5 mm; Smith & Nephew, Memphis, TN). A soft-tissue grasper was then used to transpose the biceps tendon from its position within the bicipital groove to a new location at the central aspect of the greater tuberosity. When only a partial repair was possible, we positioned the biceps tendon into the area on the tuberosity that could not be completely covered with rotator cuff tissue. After the biceps tendon was stabilized in its transposed position on the greater tuberosity by use of 1 suture from a triple-loaded anchor, the rotator cuff tissue was also secured to the greater tuberosity by using the additional suture anchor sutures from the same anchor, as well as by using additional suture anchors as needed. It is important to note that sutures were also used to approximate the rotator cuff tissue directly to the repositioned biceps tendon. The transposed, physiologically tensioned biceps serves as a valuable convergence post in this role by providing additional stability to the repair construct and by aiding in offloading repair tension of the rotator cuff tissue (Fig 2). Triple-loaded suture anchors (Healicoil Reginasorb, 5.5 mm; Smith & Nephew) were used in all patients in the study, and suture anchor sutures were retrieved through the rotator cuff and biceps tissue with a retrograde suture retriever (IDEAL Suture Grasper; DePuy Mitek, Raynham, MA). Any residual rotator cuff defects that persisted after rotator cuff repair and biceps transposition were measured arthroscopically using a calibrated probe (Elite Calibrated Probe; Smith & Nephew) and recorded. In patients in whom residual tissue gaps exposed the greater tuberosity surface after rotator cuff repair, the repair was considered a partial repair.

Postoperative Rehabilitation

All surgical procedures were performed on an outpatient basis. Postoperatively, patients were immobilized in a shoulder abduction sling (DonJoy Ultrasling; DJO, Lewisville, TX). Formal physical therapy was initiated at 4 weeks postoperatively and was limited to passive and active-assisted range-of-motion exercises for 2 to 4 weeks. Next, limited strengthening exercises were initiated between 6 and 8 weeks after surgery, with the timing of the introduction of gentle strengthening based on intraoperative assessment of rotator cuff repair security and tissue quality. Strengthening exercises were initiated under low load conditions with minimal biceps recruitment and then progressively increased over 4 to 8 additional weeks under physical therapist oversight. All study patients were allowed to use the operative shoulder without restriction after 3 to 4 months postoperatively. For higher-level athletes or heavy manual laborers, additional recovery time was allocated on a case-by-case basis.

Statistical Analysis

Paired *t* tests were used to compare preoperative and postoperative outcomes in all patients. Statistical analysis software (Excel Analysis ToolPak; Microsoft, Redmond, WA) was used to calculate the mean, standard deviation, and level of significance for all outcome measures. $P < .05$ was considered statistically significant. The primary study measures were ASES score, VAS pain score, range of motion, and supraspinatus and infraspinatus strength. The secondary study measure was the rate of procedural complications.

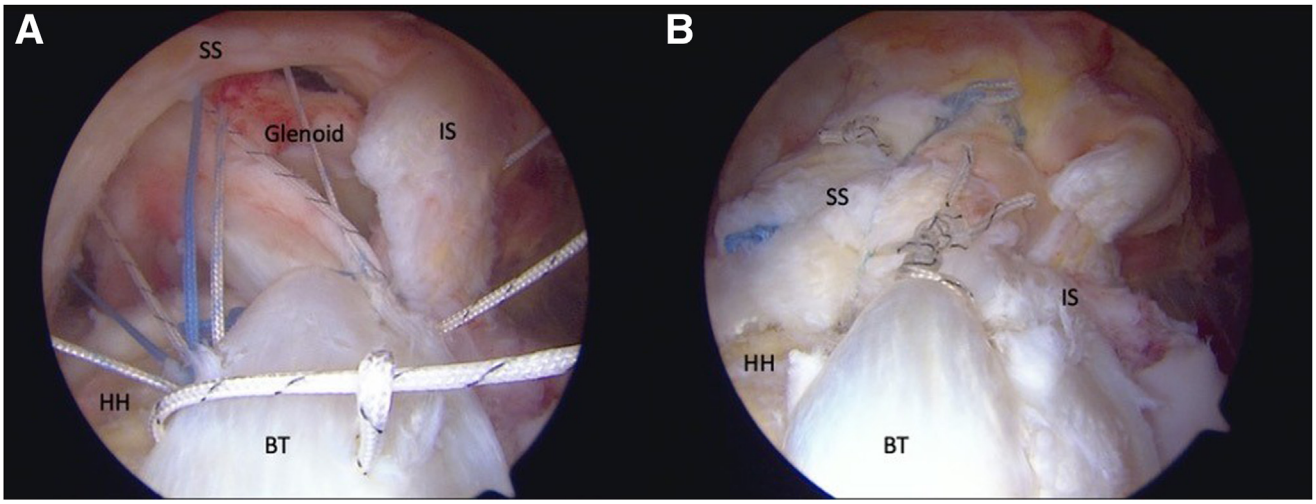

Fig 2. (A) Arthroscopic photograph, as viewed from lateral portal, showing transposition of long head of biceps tendon (BT) with sutures passed through rotator cuff tendon in rip-stop configuration in left shoulder with patient in beach-chair position. (B) Completed repair of massive rotator cuff tendon tear with transposition of biceps tendon (BT) in same patient. (HH, humeral head; IS, infraspinatus; SS, supraspinatus.)

Results

Patients

Thirty consecutive massive rotator cuff repairs in which we carried out the bio-SCR transposition technique were retrospectively evaluated. No bio-SCR cases were excluded from this study. There were 16 male and 14 female patients included. The average age of the patients was 67 years (range, 28-83 years), and the mean period of clinical follow-up was 34 months (range, 22-54 months). The patient-reported onset of symptoms averaged 1.34 years prior to initial evaluation (range, 1 week to 10 years). There were 17 right and 13 left shoulders, with the dominant arm involved in 15 cases. According to the Hamada classification of rotator cuff arthropathy,[5] 9 patients had Hamada stage 1, 10 patients had stage 2, 6 patients had stage 3, and 3 patients had stage 4a. The average preoperative acromiohumeral interval was 5.32 ± 1.83 mm. Patient demographic characteristics and outcomes are listed in Table 1. All patients in this study were classified as having massive rotator cuff tears by satisfying the 3 aforementioned criteria (tear width > 5 cm, involvement of ≥ 2 tendons, and area ≥ 30 cm^2), as described by Iagulli et al.[8] Of the 30 bio-SCR repairs, 12 involved 3-tendon tears. The remaining 18 repairs involved massive supraspinatus-infraspinatus tears. The massive rotator cuff tears in the 30 patients in this consecutive series were completely repairable in 13 and partially repairable in 17. The mean preoperative defect measured 38.1 cm^2 (range, 30-48 cm^2), and the mean residual defect, in partial repair cases, measured 5.9 cm^2 (range, 1-12 cm^2). The average number of triple-loaded suture anchors implanted during repair was 1.53 (range, 1-2). An acromioplasty was performed in 17 shoulders. The final decision to perform an acromioplasty was made intraoperatively in these massive rotator cuff tear patients and was based on acromial morphology and intraoperative evaluation of rotator cuff repairability. The decision not to carry out an acromioplasty was sometimes made when only a partial rotator cuff repair was possible or when intraoperative assessment of the quality of the rotator cuff tissue or security of the partial repair was deemed especially

Table 1. Patient Demographic Characteristics and Outcomes

	Data	*P* Value
Shoulders, n	30	
Mean age (range), yr	67.0 (28.4-81.9)	
Male/female, n	16/14	
Mean follow-up (range), mo	34 (22-54)	
AHI, mean ± SD, mm	5.32 ± 1.83	
Hamada classification, n		
Stage 1	9	
Stage 2	10	
Stage 3	6	
Stage 4a	3	
ASES score, mean ± SD (95% CI)		
Preoperative	33.2 ± 0.8 (27.8-39.0)	
2-yr follow-up	87.0 ± 3.7 (83.3-90.7)	<.001
VAS score, mean ± SD (95% CI)		
Preoperative	7.1 ± 0.2 (6.2-8.1)	
2-yr follow-up	0.9 ± 0.2 (0-1.6)	<.001
Forward flexion, mean ± SD (95% CI), °		
Preoperative	122.4 ± 5.0 (112.5-132.3)	
Final	156.8 ± 11.2 (145.5-168.0)	<.001

AHI, acromiohumeral interval; ASES, American Shoulder and Elbow Surgeons; CI, confidence interval; SD, standard deviation; VAS, visual analog scale.

concerning to us. Distal clavicle resection was carried out in 17 patients and was based on preoperative symptoms and the observation of acromioclavicular joint tenderness on palpation.

A total of 1,658 rotator cuff repairs were carried out by the senior author during the study period. A previous and more detailed review of the senior author's rotator cuff repairs during a similar period revealed that massive tears (>30 cm^2) were present in 18.4% of cases (unpublished internal analysis, D.E.P.). Thus, approximately 305 massive repairs were carried out during the study period. If one assumes that the biceps was intact in approximately two-thirds of these massive tears undergoing repair during the same study period (approximately 200 massive tears), then only about 15% of these massive tears with the biceps present had the bio-SCR augmentation procedure performed during the study period.

Clinical Assessment

No patients were lost to follow-up. The average ASES score of 33.2 (range, 0-56.6) preoperatively improved to 80.8 (range, 76.6-94.9) at the 6-month follow-up evaluation, 92.0 (range, 85.0-100) at 1 year, and 87.0 (range, 63.3-100) at 2 years (Fig 3). Average active forward flexion improved from 122.4° (range, 60°-170°) preoperatively to 156.8° (range, 120°-170°) at latest follow-up ($P < .001$). The average increase in forward flexion from preoperatively to the latest follow-up visit was 34.4°. The range of active forward flexion improvement was 0° to +100°. The average VAS pain score (on a scale of 0-10) improved from 7.1 preoperatively to 1.4 at 6 months postoperatively, 0.6 at 1 year, and 0.9 at 2 years. The average preoperative supraspinatus strength grade (on a scale of 1-5) was 3.4, and the postoperative strength grade improved to 4.2 ($P = .003$). The average preoperative external rotation strength grade (on a scale of 1-5) was 3.4, and the postoperative rotation strength grade improved to 4.6 ($P < .001$) at latest follow-up.

As published by Cvetanovich et al.,[13] the minimal clinically important difference for the ASES score was defined as a change of 11.1 and substantial clinical benefit for the ASES score was defined as a change of 17.5. Substantial clinical benefit for the ASES score was exceeded by all study patients at 2 years postoperatively (range of gains in ASES score, 31.7-81.7). Student *t* test analysis of ASES scores showed significant differences ($P < .01$) for all postoperative time intervals when compared with preoperative measures.

Complications

Among the 30 patients in this study, 1 (3.3%) had a postoperative complication. A 54-year-old male laborer sustained a postoperative rupture of the LHBT that was identified by the physical therapist based on clinically apparent biceps asymmetry at 6 weeks postoperatively. This patient returned for clinical evaluation, and after examination and discussion of management options, he elected to undergo revision open subpectoral biceps tenodesis. This revision surgical procedure gave us the opportunity to additionally perform a concurrent arthroscopic assessment of the shoulder. The biceps rupture was noted arthroscopically to have occurred immediately distal to the rotator cuff repair site on the greater tuberosity. The biceps tendon more proximal to the rupture location was seen to be incorporated into the otherwise healing rotator cuff tissue. There were no other complications, and no additional patients underwent subsequent surgical intervention.

Discussion

The results of this case series support the hypothesis that the bio-SCR technique, when feasible and indicated, is a safe and effective repair construct for cases in which such autograft tissue augmentation is carried

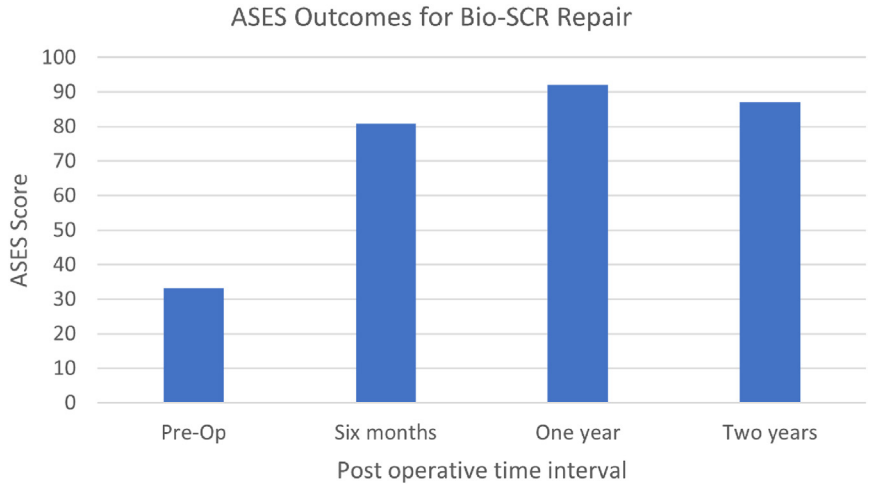

Fig 3. Patient-reported American Shoulder and Elbow Surgeons (ASES) survey outcomes from preoperatively (Pre-Op) to 2-year follow-up in study cohort undergoing biological superior capsular reconstruction (bio-SCR) repair.

out. Complete repair of massive rotator cuff tears is not always possible. Even when complete repair can be accomplished, poor tissue quality can predispose to repair failure. To reduce the rate of repair failure, various structural and biological augmentations have been described.[14-19] However, these supplemental implants and additional techniques often increase the cost and complexity of the repair.

Because of its anatomical location, the LHBT has garnered interest as a graft source for a variety of shoulder procedures, including anterior shoulder instability reconstruction and SCR, and as a biological patch for rotator cuff repairs.[14,20-23] Alternatively, tenotomy or tenodesis of the LHBT is frequently performed at the time of rotator cuff repair as a definitive treatment.[24] Although several reports have described techniques using the LHBT to augment rotator cuff repairs, these techniques differ from our bio-SCR procedure because the LHBT is almost always released from its origin at the superior glenoid or distal to the rotator cuff repair site.[23,25-27]

All biceps tissue is preserved for the bio-SCR technique. The biceps is mobilized from the bicipital groove, but it does not undergo tenotomy at any location along its course. Our intraoperative decision-making process regarding when to use the bio-SCR augmentation technique was based primarily on our intraoperative perception of rotator cuff tear repairability and tissue quality. The bio-SCR technique was used sparingly and with discretion during the study period. Because it was a newly described technique, we generally reserved bio-SCR augmentation for the most challenging massive rotator repair cases, as evidenced, in part, by the fact that more than half of the cases in this series were only partially repairable. Of the approximately 300 massive rotator cuff repairs performed during the study period, only approximately 15% underwent the bio-SCR augmentation technique. On the basis of the results of this retrospective study, however, we do currently apply the bio-SCR augmentation technique more liberally in the repair of massive rotator cuff tears.

We believe that transposition of the LHBT without tenotomy offers significant potential benefits. Leaving the LHBT intact after transposition allows the biceps muscle-tendon unit to theoretically provide a dynamic humeral head depressor force given that some degree of biceps long head contraction is present when the rotator cuff muscles are activated. Likewise, we believe that this transposed position of the biceps as it traverses over the superior humeral head in a more central location, combined with the slightly longer course that the biceps travels in the transposed position, could potentially provide a static humeral head depressive effect, as well as a stabilizing effect. However, whether the transposed biceps actively or statically depresses the humeral head in these patients or stabilizes the humeral head in some other fashion is beyond the scope of this retrospective clinical study.

Some authors have hypothesized that the LHBT may contribute as a stabilizer against proximal humeral head migration.[28-32] Kido et al.[33] showed that in rotator cuff–deficient patients, there was significantly greater proximal humeral head migration with a nonfunctioning biceps but that humeral head depression was noted when the biceps was functioning. Maintaining the LHBT attachments may allow the biceps muscle to provide a depressive force to actively resist proximal humeral head migration. Additionally, a recent biomechanical study in a rabbit model showed that the biceps tendon was progressively remodeled after transposition, that the biceps healed in the newly transposed position, and that the biomechanical strength of the superior capsule after biceps transposition exceeded the strength of the native superior capsule.[34]

SCR is one procedure often used when complete rotator cuff repair cannot be achieved. SCR provides a passive restraint to superior translation of the humeral head and attempts to restore the rotator cuff force couple.[35] SCR was first performed using autologous fascia lata as a graft source. However, owing to donor-site morbidity and increased operative time, human dermal extracellular matrix allograft (HDA) is now frequently used.[36-38] HDA negates the concerns of autograft harvest but carries risks of disease transmission, infection, and rejection, as well as significantly increased costs.

Some studies have suggested that patient outcomes after SCR are similar regardless of the SCR graft material used.[38] SCR graft thickness, however, has been shown to influence patient outcomes. An SCR graft thickness of less than 3 mm carries an increased risk of clinical and radiologic failure.[39] On average, folded fascia lata autograft measures 6 to 8 mm in thickness and acellular dermal allograft measures 3 to 4 mm in thickness.[39] It is interesting to note that the biceps has an average thickness of 6.6 mm at the articular margin of the tendon.[40] A thicker graft source such as the LHBT may provide benefits compared with thinner graft choices. Moreover, similarly to HDA, LHBT graft negates the necessity for a separate incision and consequent donor-site morbidity of fascia lata harvest.

The bio-SCR procedure offers several distinct advantages when compared with traditional SCR using HDA. Bio-SCR can be performed at a much lower cost than SCR because it avoids the expense of an allograft; the bio-SCR technique requires fewer suture anchors as well. Various techniques have been described in the literature for traditional SCR that reported the necessity for between 4 and 9 anchors for graft fixation.[1,4,41] The bio-SCR technique incorporates the biceps tendon into the rotator cuff repair construct using only those suture

anchor sutures that are needed to accomplish the rotator cuff repair. In our study patients, additional anchors were rarely, if ever, required to secure the transposed biceps on the greater tuberosity. In addition, because the transposed biceps tendon is not released either proximal or distal to the greater tuberosity, it maintains its normal physiological tension. This preserved tension creates a valuable convergence post for the rotator cuff tissue. We believed that, owing to the utility of this transposed, normally tensioned biceps, fewer total anchors were needed to accomplish these massive rotator cuff repairs.

A study published by Kim et al.[42] examined the results of rerouting of the intact LHBT combined with rotator cuff repair. They created a new groove for the biceps on the greater tuberosity, and an anchor was placed on both the medial side and lateral side of the footprint to secure the biceps, followed by repair of the rotator cuff tendon in a double-row fashion. Their procedure differs from the bio-SCR technique in that the bio-SCR approach does not create a new biceps groove or routinely include the performance of a double-row repair technique. Despite these differences, the outcomes of the study by Kim et al. and our bio-SCR study were similar, with statistically significant improvements in the ASES score (64.3 to 85.3, $P < .001$), the VAS score (3.7 to 1.6, $P = .019$), and forward flexion (138° to 146°, $P < .001$) in their study.[40] Two patients in their study underwent revision surgery. The results of Kim et al. are consistent with our study findings and further support using a transposed biceps to augment massive rotator cuff repairs.

There was 1 patient with a proximal biceps rupture postoperatively among the 30 patients included in our study population. This complication occurred at 6 weeks postoperatively and was treated with subsequent open biceps tenodesis. The patient was a young, active man who worked as a physical laborer. The quality and condition of the biceps tendon at the time of rotator cuff repair were not documented in the operative record. At the time of revision, the biceps was arthroscopically noted to have ruptured immediately distal to the greater tuberosity. This patient subsequently recovered uneventfully after revision surgery.

In addition, transposing the biceps tendon without performing tenotomy at any location along its anatomic course did not result in demonstrable negative clinical consequences and facilitated massive rotator cuff repair by providing structural support without the necessity for remote-site donor autograft tissue or allograft. The thickness of the LHBT, its viability and immediate proximity to the greater tuberosity, and the ease with which it can be transposed and incorporated into massive rotator cuff repair constructs using the bio-SCR technique create a desirable and effective surgical option for repair of some massive rotator cuff tears.

Limitations

This study has several limitations. The retrospective study design and subjective intraoperative patient selection carry the potential for bias. Additionally, the study was not blinded, and all the procedures and clinical follow-up assessments were performed by the same examiner. The lack of surgical selection blinding and follow-up evaluations process risks implicit bias from the investigator's knowledge of specific study patients, which could have affected the study's results. However, patient-reported outcome scores and objective measures were used postoperatively to limit inherent bias. The lack of a matching control group of cuff repairs performed with an alternative surgical augmentation method or with no augmentation is a further limitation of this study.

Conclusions

Incorporating a transposed biceps tendon into the repair of a massive rotator cuff tear using the bio-SCR technique resulted in significant clinical improvements with a low complication rate.

References

1. El-shaar R, Soin S, Nicandri G, Maloney M, Voloshin I. Superior capsular reconstruction with a long head of the biceps tendon autograft: A cadaveric study. *Orthop J Sports Med* 2018;6:232596711878536.
2. Di Benedetto P, Mancuso F, Tosolini L, Buttironi MM, Beltrame A, Causero A. Treatment options for massive rotator cuff tears: A narrative review. *Acta Biomed* 2021;92:e2021026.
3. Familiari F, Nayar SK, Russo R, et al. Subacromial balloon spacer for massive, irreparable rotator cuff tears is associated with improved shoulder function and high patient satisfaction. *Arthroscopy* 2021;37:480-486.
4. Adrian SC, Field LD. Biceps transposition for biological superior capsular reconstruction. *Arthrosc Tech* 2020;9:e841-e846.
5. Hamada K, Yamanaka K, Uchiyama Y, Mikasa T, Mikasa M. A radiographic classification of massive rotator cuff tear arthritis. *Clin Orthop Relat Res* 2011;469:2452-2460.
6. Kocher MS, Horan MP, Briggs KK, Richardson TR, O'Holleran J, Hawkins RJ. Reliability, validity, and responsiveness of the American Shoulder and Elbow Surgeons subjective shoulder scale in patients with shoulder instability, rotator cuff disease, and glenohumeral arthritis. *J Bone Joint Surg Am* 2005;87:2006-2011.
7. Michener LA, McClure PW, Sennett BJ. American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form, patient self-report section: Reliability, validity, and responsiveness. *J Shoulder Elbow Surg* 2002;11:587-594.
8. Iagulli ND, Field LD, Hobgood ER, Ramsey JR, Savoie FH. Comparison of partial versus complete arthroscopic repair of massive rotator cuff tears. *Am J Sports Med* 2012;40:1022-1026.

9. Burkhart SS, Barth JRH, Richards DP, Zlatkin MB, Larsen M. Arthroscopic repair of massive rotator cuff tears with stage 3 and 4 fatty degeneration. *Arthroscopy* 2007;23:347-354.
10. Cofield RH. Rotator cuff disease of the shoulder. *J Bone Joint Surg Am* 1985;67:974-979.
11. Gerber C, Wirth SH, Farshad M. Treatment options for massive rotator cuff tears. *J Shoulder Elbow Surg* 2011;20: S20-S29 (suppl).
12. Hallock JD, Parsell DE, Field LD. Partial rotator cuff repair for massive tears rarely require revision surgery. *Arthrosc Sports Med Rehabil* 2021;3:e121-e126.
13. Cvetanovich GL, Gowd AK, Liu JN, et al. Establishing clinically significant outcome after arthroscopic rotator cuff repair. *J Shoulder Elbow Surg* 2019;285:939-948.
14. Hohmann E. Editorial commentary: Long head biceps tendon can be used like a split skin graft: Mesh it and augment rotator cuff repairs. *Arthroscopy* 2022;38:49-50.
15. Chalmers PN, Tashjian RZ. Patch augmentation in rotator cuff repair. *Curr Rev Musculoskelet Med* 2020;13:561-571.
16. Thangarajah T, Pendegrass CJ, Shahbazi S, Lambert S, Alexander S, Blunn GW. Augmentation of rotator cuff repair with soft tissue scaffolds. *Orthop J Sports Med* 2015;3: 2325967115587495.
17. Murthi AM, Lankachandra M. Technologies to augment rotator cuff repair. *Orthop Clin North Am* 2019;50:103-108.
18. Jackson GR, Bedi A, Denard PJ. Graft augmentation of repairable rotator cuff tears: An algorithmic approach based on healing rates. *Arthroscopy* 2022;38:2342-2347.
19. Cai YZ, Zhang C, Jin RL, et al. Arthroscopic rotator cuff repair with graft augmentation of 3-dimensional biological collagen for moderate to large tears: A randomized controlled study. *Am J Sports Med* 2018;46:1424-1431.
20. Garcia JC, Belchior RJ, Mello MBD, Cardoso AM. The long head of the biceps Bristow-Bankart procedure for anterior shoulder instability. *Arthrosc Tech* 2019;8:e1185-e1191.
21. Mehl J, Otto A, Imhoff FB, et al. Dynamic anterior shoulder stabilization with the long head of the biceps tendon: A biomechanical study. *Am J Sports Med* 2019;47:1441-1450.
22. Hermanowicz K, Góralczyk A, Malinowski K, Jancewicz P, Domżalski ME. Long head biceps tendon—Natural patch for massive irreparable rotator cuff tears. *Arthrosc Tech* 2018;7:e473-e478.
23. Rhee YG, Cho NS, Lim CT, Yi JW, Vishvanathan T. Bridging the gap in immobile massive rotator cuff tears: Augmentation using the tenotomized biceps. *Am J Sports Med* 2008;36:1511-1518.
24. Zhu XM, Leroux T, Ben-David E, et al. A meta-analysis of level I evidence comparing tenotomy vs tenodesis in the management of long head of biceps pathology. *J Shoulder Elbow Surg* 2021;30:961-968.
25. Sano H, Mineta M, Kita A, Itoi E. Tendon patch grafting using the long head of the biceps for irreparable massive rotator cuff tears. *J Orthop Sci* 2010;15:310-316.
26. Cho NS, Yi JW, Rhee YG. Arthroscopic biceps augmentation for avoiding undue tension in repair of massive rotator cuff tears. *Arthroscopy* 2009;25:183-191.
27. Boutsiadis A, Chen S, Jiang C, Lenoir H, Delsol P, Barth J. Long head of the biceps as a suitable available local tissue autograft for superior capsular reconstruction: "The Chinese way.". *Arthrosc Tech* 2017;6:e1559-e1566.
28. Warner JJ, McMahon PJ. The role of the long head of the biceps brachii in superior stability of the glenohumeral joint. *J Bone Joint Surg Am* 1995;77:366-372.
29. Pagnani MJ, Deng XH, Warren RF, Torzilli PA, O'Brien SJ. Role of the long head of the biceps brachii in glenohumeral stability: A biomechanical study in cadavera. *J Shoulder Elbow Surg* 1996;5:255-262.
30. Rodosky MW, Harner CD, Fu FH. The role of the long head of the biceps muscle and superior glenoid labrum in anterior stability of the shoulder. *Am J Sports Med* 1994;22: 121-130.
31. Alexander S, Southgate DFL, Bull AMJ, Wallace AL. The role of negative intraarticular pressure and the long head of biceps tendon on passive stability of the glenohumeral joint. *J Shoulder Elbow Surg* 2013;22:94-101.
32. Youm T, ElAttrache NS, Tibone JE, McGarry MH, Lee TQ. The effect of the long head of the biceps on glenohumeral kinematics. *J Shoulder Elbow Surg* 2009;18:122-129.
33. Kido T, Itoi E, Konno N, Sano A, Urayama M, Sato K. The depressor function of biceps on the head of the humerus in shoulders with tears of the rotator cuff. *J Bone Joint Surg Br* 2000;82:416-419.
34. Xu J, Li Y, Zhang X, et al. The biomechanical and histological processes of rerouting biceps to treat chronic irreparable rotator cuff tears in a rabbit model. *Am J Sports Med* 2022;50:347-361.
35. Frank RM, Cvetanovich G, Savin D, Romeo AA. Superior capsular reconstruction: indications, techniques, and clinical outcomes. *JBJS Rev* 2018;6:e10-e10.
36. Deprés-tremblay G, Chevrier A, Snow M, Hurtig MB, Rodeo S, Buschmann MD. Rotator cuff repair: a review of surgical techniques, animal models, and new technologies under development. *J Shoulder Elbow Surg* 2016;25: 2078-2085.
37. Ulstrup A, Reinhold M, Falster O. Superior capsular reconstruction: 2-year follow-up results. *JSES Int* 2020;4: 893-899.
38. Abd Elrahman AA, Sobhy MH, Abdelazim H, Omar Haroun HK. Superior capsular reconstruction: Fascia lata versus acellular dermal allograft: A systematic review. *Arthrosc Sports Med Rehabil* 2020;2:e389-e397.
39. Galvin JW, Kenney R, Curry EJ, et al. Superior capsular reconstruction for massive rotator cuff tears: A critical analysis review. *JBJS Rev* 2019;7:e1.
40. Denard PJ, Dai X, Hanypsiak BT, Burkhart SS. Anatomy of the biceps tendon: implications for restoring physiological length-tension relation during biceps tenodesis with interference screw fixation. *Arthroscopy* 2012;28: 1352-1358.
41. Loy BN, Owen MT, Reid JB, Guttmann D. Technique for double row superior capsule reconstruction with dermal allograft. *Arthrosc Tech* 2020;9:e91-e96.
42. Kim JH, Lee HJ, Park TY, Lee JU, Kim YS. Preliminary outcomes of arthroscopic biceps rerouting for the treatment of large to massive rotator cuff tears. *J Shoulder Elbow Surg* 2021;30:1384-1392.