Functional Outcome and Healing of Large and Massive Rotator Cuff Tears Repaired With a Load-Sharing Rip-Stop Construct

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Purpose: To prospectively review functional outcomes and healing rates of large and massive rotator cuff tears repaired with a load-sharing rip-stop (LSRS) technique. **Methods:** Twenty-one consecutive patients underwent arthroscopic rotator cuff repair with an LSRS construct between January and December 2014. Seventeen patients with a minimum of 2 years' follow-up were included. Four patients did not complete clinical evaluations and functional outcome scores at a minimum of 2 years' follow-up and were lost to follow-up. Ultrasound imaging was used to assess for rotator cuff healing at a minimum of 6 months postoperatively. Range of motion, strength, and functional outcome scores were evaluated at final follow-up. **Results:** Mean active forward elevation improved from 109° preoperatively to 153° postoperatively, and mean supraspinatus strength improved by 1 strength grade, from 3.5 preoperatively to 4.4 postoperatively. When we compared preoperative and postoperative values, the American Shoulder and Elbow Surgeons score improved from 40.8 to 89.5, the Single Assessment Numeric Evaluation score improved from 32.8 to 83.1, the Simple Shoulder Test score improved from 3.8 to 10.3, and the pain score on a visual analog scale decreased from 4.8 to 0.8 ($P < .001$). Of 17 patients, 13 (82%) were satisfied with their outcomes. Ultrasound evaluation 6 months after surgery showed complete healing in 53%, partial healing in 29%, and no healing in 18%. **Conclusions:** The LSRS construct showed satisfactory functional outcomes with reasonable healing rates in an otherwise challenging subset of rotator cuff tears. This construct may be an alternative for tears not amenable to double-row repair. **Level of Evidence:** Level IV, therapeutic case series.

See commentary on page 1659

Large and massive rotator cuff tears associated with poor tendon quality remain a problematic condition for the orthopaedic surgeon. Achieving tendon-to-bone healing in this setting has proved difficult.[1] The development of double-row suture-bridging repairs has improved biomechanical fixation strength and increased healing rates in tears from the bone-tendon junction. However, a double-row repair is not possible in the setting of medially based tears, lateral tendon loss, or limited tendon mobility.[2] Consequently, single-row (SR) repair has frequently been used for repair of massive rotator cuff tears in these settings. Unfortunately, the healing rate of SR repair is low, with retear rates of up to 94%.[1]

A load-sharing rip-stop (LSRS) suture technique has recently been described that combines the advantages of a rip-stop suture tape and the load-sharing properties of a double-row repair.[3] In a solitary study the authors showed that, biomechanically, an LSRS construct has superior properties to an SR repair.[4] The LSRS construct may be advantageous in cases otherwise only amenable to an SR repair, but the outcomes of the LSRS technique have not been reported.

The purpose of this study was to prospectively evaluate the functional outcome and healing rate of large and massive rotator cuff tears repaired with an LSRS technique. We hypothesized that the LSRS technique would

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show favorable outcomes in patients undergoing arthroscopic repair of large and massive rotator cuff tears.

Methods

We performed a prospective analysis of arthroscopic rotator cuff repairs using the LSRS construct for large and massive posterosuperior tears performed at 2 institutions between January and December 2014. Institutional review board approval was obtained before the study commenced. The inclusion criteria included all large or massive rotator cuff tears repaired with an LSRS technique during this time frame. All tears had decreased tendon length or tendon mobility such that 50% or less of the greater tuberosity footprint from medial to lateral could be covered with a repair. In other words, these tears were not amenable to a suture-bridging double-row repair. A massive rotator cuff tear was defined as a complete tear of 2 tendons[5] or measuring 5 cm or larger in its greatest dimension, and a large tear was 3 cm or larger in its greatest dimension.[6] The exclusion criteria included revision repairs. All repairs during the study period meeting the study criteria were performed with the LSRS construct. The minimum follow-up period for inclusion in the study was 2 years.

Active range of motion in the standing position including forward flexion in the plane of the scapula and external rotation with the arm at the side was measured with a goniometer. Internal rotation was estimated to the nearest spinal level. Rotator cuff strength was graded from 0 to 5 with manual muscle testing. All assessments were performed by the treating surgeons (P.J.D. and A.L.) preoperatively and at 24 months postoperatively. In addition, functional status was determined by review of prospectively collected data preoperatively and at final follow-up. The American Shoulder and Elbow Surgeons (ASES) score,[7] Simple Shoulder Test score, and Single Assessment Numeric Evaluation (SANE) score were recorded. Preoperative and postoperative pain was graded from 0 to 10 on a visual analog scale (VAS). Additional procedures and all complications were reported. Preoperative fatty atrophy of the rotator cuff was assessed with the Goutallier classification system by use of the T1 sagittal view on magnetic resonance imaging.[8] Preoperative supraspinatus (SS) and infraspinatus (IS) fatty atrophy grades are summarized in Table 1. Ultrasound imaging was used to assess for rotator cuff healing at a minimum of 6 months postoperatively and was recorded as complete, partial (≥1 tendon healed), or no healing. Ultrasound was the modality of choice to assess for healing based on its low cost and simple in-office availability and was performed by the senior author (P.J.D. and A.L.) at each institution.

Table 1. Operative Characteristics of Arthroscopic Rotator Cuff Repairs With LSRS Construct

	Data
Age, mean (range), yr	65.3 (54-77)
Male sex, n (%)	14 (82)
Smoking history, n (%)	2 (12)
Mean medial-lateral tear size, cm	4.5
Mean anterior-posterior tear size, cm	4.3
Any interval slide, n (%)	14 (82)
Complete repair, n (%)	17 (100)
No. of anchors used for repair, mean (range)	2.9 (2-4)
Fatty degeneration, n*	
Supraspinatus	8, 5, 1, 3, and 0
Infraspinatus	7, 6, 2, 2, and 0
Subscapularis	10, 4, 3, 0, and 0

LSRS, load-sharing rip-stop.
*Data correspond to Goutallier grade 0, 1, 2, 3, and 4, respectively.

Surgical Technique

The LSRS construct has been described in detail previously by Denard and colleagues.[4] A 2-mm suture tape (FiberTape; Arthrex, Naples, FL) is passed through the rotator cuff as an inverted mattress stitch placed 3 mm lateral to the musculotendinous junction (Fig 1A). Next, 2 double-loaded 5.5-mm anchors (BioComposite Corkscrew FT; Arthrex) are placed anteromedially and posteromedially, along the articular margin. The sutures are passed from the medial anchors as simple stitches that penetrate the rotator cuff medial to the rip-stop suture. Once the medial sutures are passed, the suture tape rip-stop sutures are retrieved and secured laterally with 1 or 2 knotless suture anchors (BioComposite SwiveLock C; Arthrex), with the surgeon making sure they encircle the sutures from the medial anchors (Fig 1B). Finally, simple sutures from the medial anchors are retrieved, and static simple knots are tied with a double-diameter knot pusher (Fig 1C).

Concomitant procedures included 15 acromioplasties (88.2%), 7 arthroscopic biceps tenodeses (41.2%), 5 biceps tenotomies (29.4%), and 4 distal clavicle excisions (23.5%). A total of 13 patients (76%) underwent an anterior interval slide in continuity, in which the coracohumeral ligament was released from the base of the coracoid while the lateral comma tissue was preserved. A posterior interval slide, which separates the SS and IS along the raphe of the spine of the scapula, was performed in 1 patient (5.9%). No marginal convergence (side-to-side) suture repairs were performed. Postoperatively, patients underwent immobilization in a sling for 6 weeks with basic hand, elbow, and wrist exercises started immediately. After 6 weeks, the sling was discontinued and passive forward elevation and table slides were allowed. At 3 months postoperatively, strengthening was initiated (Fig 2).

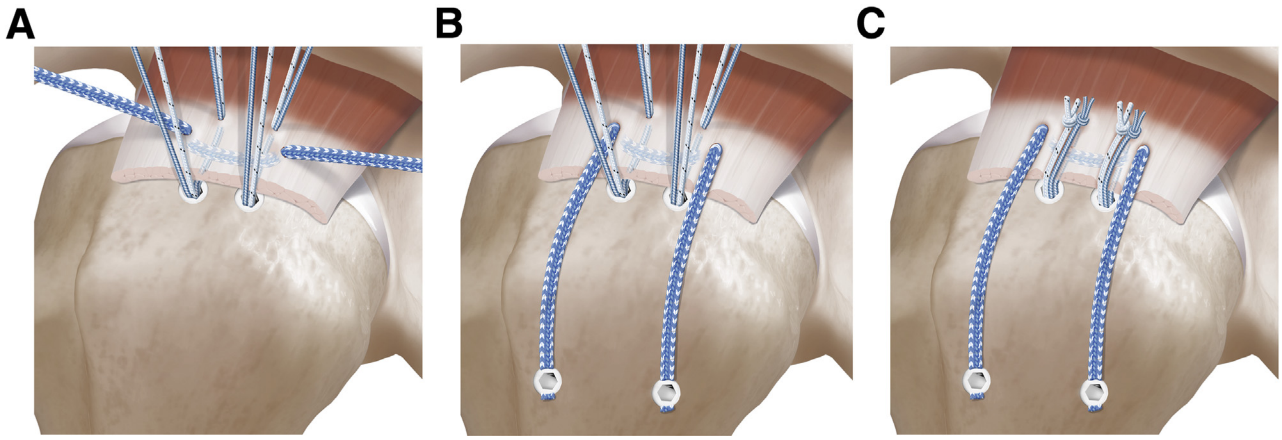

Fig 1. Anchor-based rip-stop rotator cuff repair for rotator cuff tear with lateral tendon loss. (A) A FiberTape suture has been placed as an inverted mattress stitch in the rotator cuff. Two medial anchors (BioComposite Corkscrew FT) have also been placed, and sutures from these anchors are passed medial to the rip-stop stitch. (B) Prior to tying of the sutures from the medial Corkscrew anchors, the rip-stop stitch is secured to bone with 2 lateral BioComposite SwiveLock C anchors. (C) Tying the suture limbs from the Corkscrew anchors completes the repair.

Statistical Analysis

Continuous data were described by mean and standard deviation. A *t* test was used to analyze differences in preoperative and postoperative forward flexion and VAS, ASES, and SANE scores. All statistical analyses were conducted by a trained statistician. A 2-tailed $P < .05$ was considered significant.

Results

A total of 398 rotator cuff repairs were performed during the study period. Twenty-one repairs were performed with an LSRS construct. Four patients were lost to follow-up and did not have 24 months of follow-up, leaving 17 patients available for analysis. The mean age of the study group was 65.3 years at the time of surgery. The mean follow-up period was 25.1 months (range, 24-29 months). Of the patients, 14 (82.3%) were men; 2 patients (11.7%) smoked. The fatty atrophy classification identified 4 patients (23.5%) who had atrophy greater than grade 3 in both the SS and IS muscle bellies preoperatively. These same patients had evidence of pseudoparalysis preoperatively. A complete tear of both the SS and IS tendons was present in the entire study group. Involvement of the teres minor tendon was noted in 3 patients (17.6%). In 11 patients (64.7%), there was an associated subscapularis tear that required repair. The operative characteristics are summarized in Table 1.

Active forward elevation improved from 109° preoperatively to 153° postoperatively (gain, 42° ± 36°; $P = .041$). Mean SS strength improved by 1 strength grade, from 3.5 preoperatively to 4.4 postoperatively (range, 2-5). The mean VAS pain score improved from 4.8 to 0.8 (decrease, 4.0 ± 1.2; $P = .0002$). When we compared preoperative and postoperative values, the ASES score improved from 40.8 to 89.5 (gain, 45.8 ± 21.4; $P < .001$), the SANE score improved from 32.8 to 83.1 (gain, 47.9 ± 28.8; $P < .001$), and the Simple Shoulder Test score improved from 3.8 to 10.3 (gain, 4.7 ± 2.95; $P < .001$). Functional improvement is summarized in Table 2.

Subjectively, 13 patients (76.5%) reported being satisfied with the procedure, and 14 patients (82.4%) were able to return to their previous work or activity level. A complication was sustained in 1 patient who was injured in a motor vehicle accident 12 months after the procedure, in whom an acute loss of 30° of active forward elevation developed. The patient declined revision surgery and ultimately had a poor outcome. No secondary procedures were performed, and there were no instances of deep wound infection or implant failure in the study group. Ultrasound imaging in the clinical setting a minimum of 6 months after surgery showed

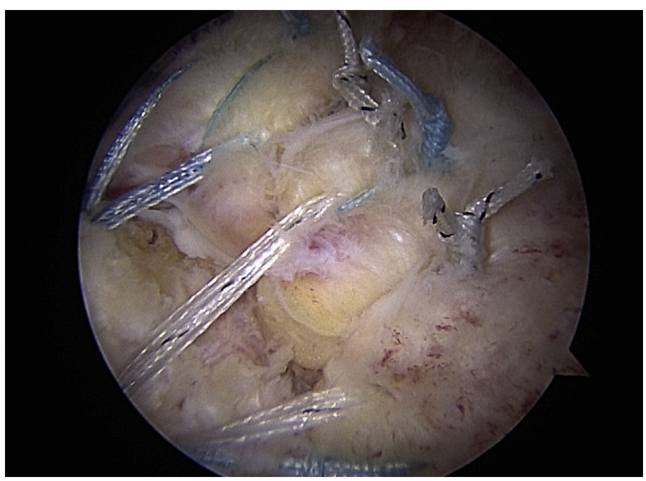

Fig 2. Left shoulder arthroscopy, posterior viewing portal, showing a load-sharing rip-stop construct.

Table 2. Operative Results and Outcomes of Arthroscopic Rotator Cuff Repairs With LSRS Construct

	Preoperative	Postoperative	*P* Value
Forward flexion, °	109 ± 21.3	153 ± 26.6	.0414
External rotation, °	36.1 ± 23.4	36.8 ± 17.2	.2047
Internal rotation (spinal level)	L4	T12	.2047
ASES score	40.8 ± 17.6	89.5 ± 14.3	<.0001
SST score	3.8 ± 2.1	10.3 ± 2.5	<.0001
SANE score	32.8 ± 23.0	83.1 ± 21.5	<.0001
VAS pain score	4.8 ± 3.1	0.8 ± 0.6	.0002

NOTE. Data are presented as mean ± standard deviation.

ASES, American Shoulder and Elbow Surgeons; LSRS, load-sharing rip-stop; SANE, Single Assessment Numeric Evaluation; SST, Simple Shoulder Test; VAS, visual analog scale.

9 patients (52.9%) had complete healing of the SS and IS tendons, 5 patients (29.4%) had partial healing of either the SS or IS tendon, and 3 patients (17.6%) had no healing of either tendon.

Discussion

This study attempted to determine the ability of an LSRS construct for large and massive rotator cuff repairs to improve functional outcomes. The most important findings of this study are the high healing rate and functional improvement of a patient population that is traditionally difficult to manage. The outcomes in our study are favorable when compared with previous reports of SR repair for both large and massive rotator cuff tears.[1] In our study 82.3% of patients obtained complete or partial healing of their posterosuperior rotator cuff tear as determined by ultrasound. Active forward elevation improved by over 40° and mean SS strength improved by 1 strength grade between preoperative assessment and final follow-up.

A variety of suture techniques have been developed to improve fixation strength in poor-quality rotator cuff tendons.[9,10] Gerber et al.[10] reported that the modified Mason-Allen stitch was the strongest of 9 different stitch patterns. However, it is technically demanding to perform an arthroscopic Mason-Allen stitch. In addition, suture patterns such as the modified Mason-Allen stitch may be prone to early failure by gap formation due to loss of loop security.[11] The end result is loss of tendon-to-bone contact and potentially decreased healing rates. Ma et al.[12] showed that a rip-stop suture with a double-loaded anchor had load to failure equivalent to a modified Mason-Allen stitch. In a follow-up study, it was reported that a triple-loaded anchor with a horizontal rip-stop stitch and 2 simple stitches showed maintained loop security and a higher ultimate load to failure compared with the rip-stop configuration with a double-loaded anchor.[13]

The LSRS repair technique previously described combines the advantages of a rip-stop suture with a double-row repair.[3] Burkhart et al.[4] were the first to report a biomechanical study of an LSRS construct for repair of tissue-deficient rotator cuff tears. The mean load to failure for the LSRS construct was nearly twice that for an SR repair construct. In the SR group, 4 of 6 failures occurred at the suture-tendon interface versus only 1 failure in the LSRS group. Unlike previous descriptions of arthroscopic stitches in which the simple and mattress sutures originate from the same anchor, the LSRS technique is independently secured by use of a knotless lateral-row fixation with suture tape, which provides resistance to tissue cutout, along with improving load distribution of the medial-row anchors.

Large and massive rotator cuff tears may be a clinical scenario in which there is an advantage to a double-row repair versus an SR repair. In a retrospective comparison between SR and double-row fixation for massive rotator cuff tears, the double-row repair was 4.9 times more likely to lead to a good or excellent functional outcome.[14] The study's conclusion was that a double-row repair can be expected to have a better long-term outcome than an SR repair in the setting of a massive rotator cuff tear if there is sufficient mobility. Park et al.[15] reported that functional outcomes improved after double-row repair compared with SR repair in tears measuring greater than 3 cm. They concluded that large to massive rotator cuff tears should be repaired with a double-row technique when possible and suggested the advantage is maintained in the long-term. However, in many instances tendon mobility is limited such that a double-row repair cannot be performed.

Reports of SR repair constructs for large and massive rotator cuff tears have shown alarmingly low healing rates, although an improvement in function has been noted in the short-term. Galatz et al.[1] performed arthroscopic SR repair for large and massive rotator cuff tears, and at 12 months' follow-up, ultrasound examination showed 94% recurrence in defects in the cuff tendon. Moreover, they observed a 10° loss of active forward elevation and a nearly 5-point decrease in ASES scores between 1 and 2 years postoperatively. Boileau et al.[16] reported a healing rate of 43% in patients older than 65 years after SR repair performed arthroscopically. Factors that were negatively associated with tendon healing were increasing patient age and poor tendon quality. Recently, a systematic review showed that SR repair of massive rotator cuff tears has led to rerupture in 69% of cases.[17] By comparison, in our study the healing rate for both complete and partial healing was 82.3%. We believe these results are encouraging, particularly given the fact that many of our patients had grade 3 atrophy, which has been shown to be a poor prognostic factor for healing.

Limitations

There are several limitations. First, the procedure is technically challenging and involves more steps with indepth suture management compared with SR repair. In addition, advanced mobilization techniques such as interval slides are commonly performed to increase tendon mobilization to achieve as much footprint coverage on the greater tuberosity as possible. Therefore, these results may not be generalizable to surgeons who do not possess advanced shoulder arthroscopic skills. Second, we did not have a comparative SR repair group. Our goal was simply to evaluate the functional outcomes and healing rates of an LSRS construct in large and massive rotator cuff tears. Further studies are needed to directly compare healing rates and functional outcomes in SR and LSRS repairs. In addition, no ultrasound was performed at 24 months' follow-up, so we do not know if the status of the cuff changed over time. Finally, there is an additional cost associated with LSRS repair because of the additional anchors for the lateral row, along with a potential increase in surgical time.

Conclusions

The LSRS construct showed satisfactory functional outcomes with reasonable healing rates in an otherwise challenging subset of rotator cuff tears. This construct may be an alternative for tears not amenable to double-row repair.

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