Arthroscopic Double-Layer Lasso Loop Technique to Repair Delaminated Rotator Cuff Tears

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Purpose: To evaluate the arthroscopic double-layer lasso loop repair technique for delaminated posterosuperior rotator cuff tears. **Methods:** Forty-one patients underwent arthroscopic rotator cuff repair of a delaminated posterosuperior rotator cuff tear by the double-layer lasso loop technique. Their preoperative and postoperative clinical and functional scores were compared to evaluate surgical outcomes. The prerequisite for inclusion was a minimum follow-up period of 2 years. We excluded patients with a history of shoulder surgery before the double-layer lasso loop repair. **Results:** Statistically significant improvements ($P < .001$) were found in the Constant score (54 vs 83) and University of California, Los Angeles functional score (6.4 vs 9.5). Pain and strength improved according to the Jobe test, bear-hug test, belly-press test, Gerber lift-off test, and external rotation test ($P < .001$). No significant difference in strength was noted between the operated and nonoperated sides. There was only 1 complete rerupture (3.1%), whereas 5 patients (15.6%) had partial ruptures. **Conclusions:** The arthroscopic double-layer lasso loop repair technique for delaminated posterosuperior rotator cuff tears is an effective procedure. Our series showed a low rerupture rate. At a mean follow-up of 44 months, postoperative recovery with resultant functional, pain, and patient satisfaction scores was good to excellent and was comparable with the nonoperated side. **Level of Evidence:** Level IV, case series.

See commentary on page 2952

Arthroscopic repair of the rotator cuff is a safe, reproducible, and minimally invasive surgical procedure. Repair outcomes depend on patient factors such as age, tear size, tissue quality, fatty infiltration of muscle, and tendon retraction. Surgical factors that can influence repairs include suture and/or anchor configurations.[1] Fibrous interconnections between the supraspinatus and infraspinatus mask the cleavage plane between the 2 tendons, making individual footprints anatomically difficult to delineate.[2] This may lead to supraspinatus lesions erroneously labeled as isolated deficits even with partial to equal involvement of the infraspinatus.

The delamination of the posterosuperior cuff has been described as a horizontal lesion between the superficial and deep fiber layers.[3,4] Posterosuperior cuff delamination is considered a negative prognostic factor for cuff healing and is associated with a high retear rate.[5-8]

Double-layer cuff repair techniques have resulted in satisfactory restoration of the cuff footprint anatomy.[9,10] Numerous techniques are used for repair based on surgeon preference and training.[1,9,11-14] Arthroscopic posterosuperior cuff repair has reported retear rates of 11% to 94%, and this correlates with a poor surgical outcome.[15,16]

The aim of our study was to evaluate the arthroscopic double-layer lasso loop repair technique for delaminated posterosuperior rotator cuff tears. We hypothesized that the double-layer lasso loop stitch would provide improved tissue grip, resulting in anatomic reduction of the deep and superficial layers of the cuff, leading to a lower rerupture rate.[17,18]

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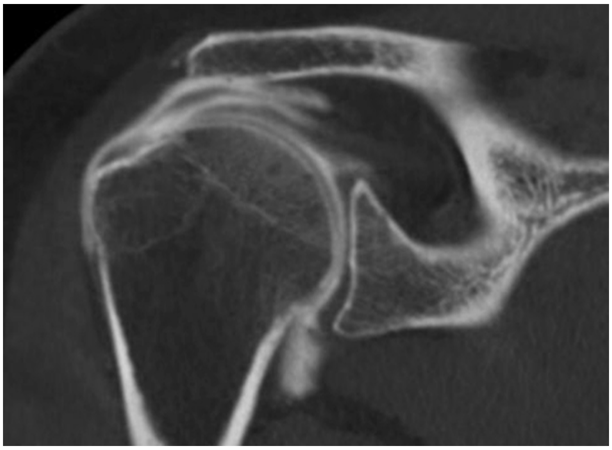

Fig 1. Arthro—computed tomography scan in a right shoulder (coronal view), showing a delaminated posterosuperior cuff tear.

Methods

Our retrospective study included 54 patients with a unilateral delaminated posterosuperior rotator cuff tear confirmed by computed tomography (CT) arthrogram and/or magnetic resonance imaging (MRI) between January 2010 and November 2013. The prerequisite for inclusion was a minimum follow-up period of 2 years. Patients with a history of shoulder surgery before the double-layer lasso loop repair were excluded. Ethics approval was received from the institutional review board (approval No. CERC-VS-2017-06-1, Vivalto Santé Institutional Review Board).

Preoperatively, a detailed clinical examination was performed evaluating active and passive joint mobility. Rotator cuff strength was evaluated by performing the Jobe test, palm-up test, bear-hug test, belly-press test, Gerber lift-off test, and external rotation test (external rotation with the arm in maximal adduction [ER1]). Functional assessment was carried out by recording the Constant score and University of California, Los Angeles (UCLA) function score.[19-22]

Cuff tears were evaluated with standard radiographs plus either a CT arthrogram or MRI arthrogram (Fig 1). Patients with unilateral delaminated cuff tears were included in the study. Final confirmation of the delamination was made intraoperatively. The presence of delamination between the layers of the supraspinatus or between the layers of the supraspinatus and infraspinatus was a prerequisite for study inclusion. Posterosuperior rotator cuff tears were further categorized according to the Patte classification.[22,23]

All the procedures were carried out with patients in the beach-chair position with inline traction applied to the arm in 45° of flexion. Standard arthroscopy was commenced through the posterior portal. A systematic intra-articular examination was performed, and any underlying biceps pathology was addressed. Subacromial decompression and bursectomy were performed, and tear morphology was confirmed.

With the arthroscope in the lateral portal, the cuff was mobilized, starting posteriorly and moving progressively anteriorly. Detailed, systematic cuff release was commenced with excision of the superior adhesions between the supraspinatus and the bursa. The undersurface of the supraspinatus and infraspinatus was debrided free of its capsular adhesions to the glenoid, and any adhesions between the 2 layers of the delaminated tear were debrided. The rotator interval was opened to dissect the superior surface of the subscapularis, and the coracohumeral ligament was excised. At the end of this release, the surgeon was able to clearly delineate the articular and bursal layers of the tendon tear (Fig 2).

The deep layer was freely mobilized to the osteochondral junction of the humeral head without excessive traction. Traction was applied to the superficial tendon to ensure tension-free excursion up to the lateral aspect of the cuff footprint. We acknowledge that the direction of the reduction of each layer may be individually variable and optimal muscle relaxation during cuff mobilization allowed for accurate assessment in a tension-free excursion of the tendon-muscle complex.

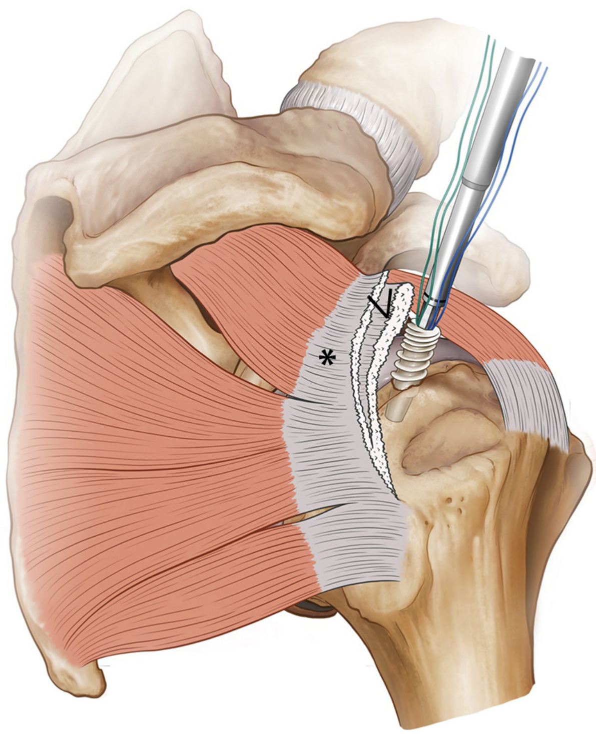

Fig 2. Delaminated posterosuperior cuff tear in a right shoulder (posterior view). The arrowhead indicates the deep layer, and the asterisk indicates the superficial layer. The double-loaded juxta-chondral medial-row anchors are fixated onto the greater tuberosity.

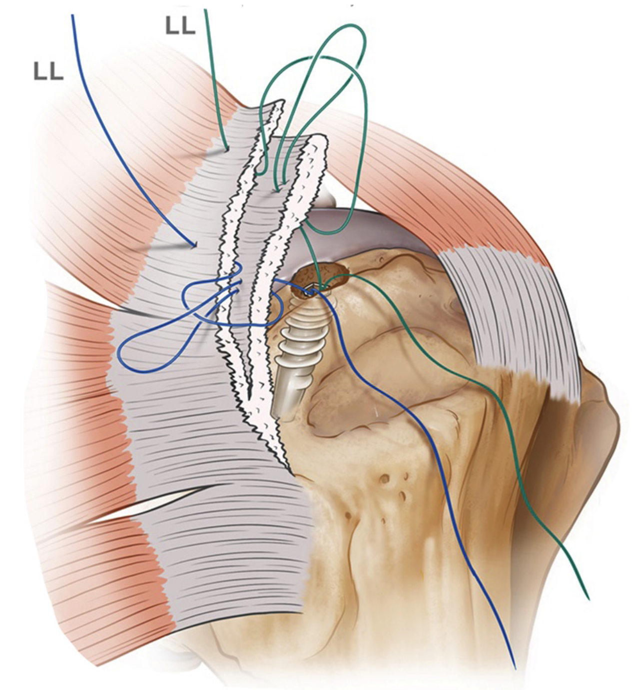

Fig 3. Placement of the lasso loop (LL) is performed around the free edge of the deep layer, as shown in a right shoulder (posterior view). The free end of this lasso loop suture is then passed at the muscle-tendon junction through the superficial layer. The same steps are repeated with the second suture.

Excessive decortication of the footprint was avoided to allow for optimal anchor stability. Depending on the tear size, 1 or 2 double-loaded juxta-chondral medial-row anchors were fixated onto the greater tuberosity (Fig 2). The anchors were placed from posterior to anterior through additional medial inline portals. Placement of a lasso loop (Fig 3) was performed around the free edge of the deep layer.[17,24] The free end of this lasso loop suture was then passed at the muscle-tendon junction through the superficial layer (Fig 3). The second free end of the suture was subsequently passed through both the deep and superficial layers of the cuff (Fig 4). It was imperative that the second suture passed medially to the first. The same steps were repeated for the remaining sutures. Usually 2 to 4 lasso loop stitches were required to reduce the deep layer (Fig 5). Knots were tied sequentially from posterior to anterior with the free suture limb acting as the post, pulling the lasso and deep layer toward the anchor (Fig 6).

Satisfactory anatomic reduction of the deep layer was attained. A suture-bridge fixation of the superficial layer was then performed with 1 or 2 Healix knotless anchors (DePuy Mitek, Raynham, MA), completing the double-row repair (Fig 7).

The arm was positioned in a broad arm sling with an abduction pillow for daytime wear for 3 weeks after surgery. The patient was encouraged to commence active range of movement of the elbow and wrist from day 1, with physiotherapy started from day 45.

At the last follow-up, a postoperative clinical examination was performed, with reassessment of the Constant score, UCLA function score, Subjective Shoulder Value, and Simple Shoulder Test score and evaluation of range of motion including abduction, forward elevation, external rotation in abduction at 90°, and ER1.[19,21,25] Focused clinical tests to evaluate the postoperative rotator cuff were repeated. Power was graded on the Medical Research Council scale from 0 to 5, and pain was subjectively graded from 0 to 15 using a modification of the Constant score pain analysis (0, severe; 5, moderate; 10, mild; 15, no pain).[19,26] Maximum and mean isometric strength was measured for 5 seconds in abduction, elevation, and external rotation (ER1) with an electronic dynamometer (EZ-Force; TAG Medical, Ga'aton, Israel).

All patients underwent radiography and an ultrasound examination of the cuff repair at the time of last follow-up. According to Guerini et al.,[27] ultrasonography is efficient to show an interstitial tendon tear and a partial-thickness (deep or superficial) or full-thickness tendon tear.[28] In addition, ultrasonography is less expensive than MRI and less invasive than arthro-CT or arthro-MRI.[29,30] Shoulder radiographs comprised anteroposterior views in neutral, internal, and external

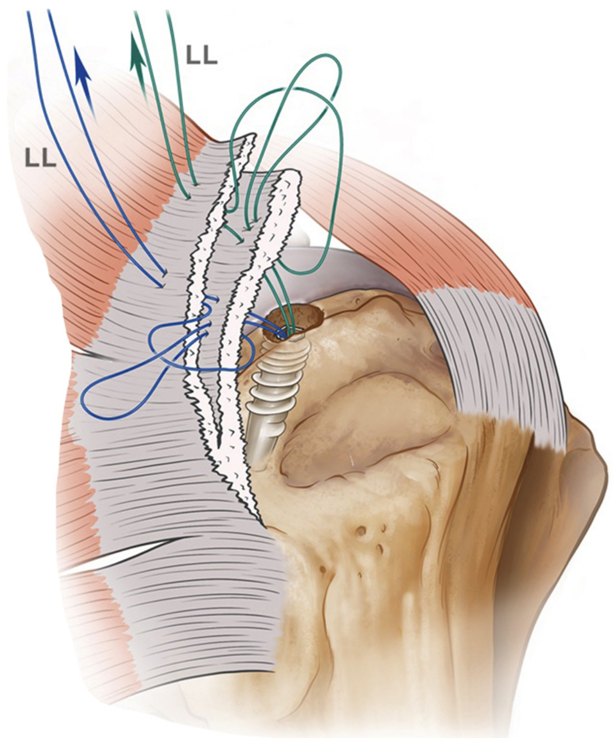

Fig 4. The second free end of the sutures is passed through both the deep and superficial layers of the cuff, medially to the first, as shown in a right shoulder (posterior view). (LL, lasso loop.)

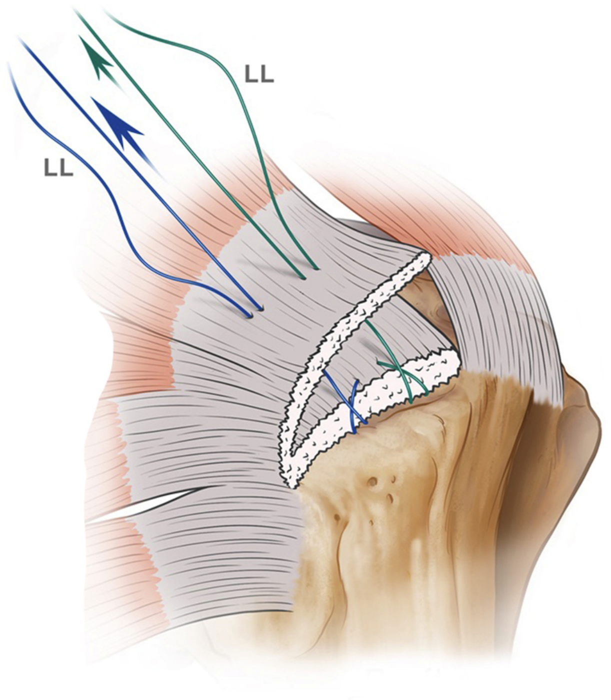

Fig 5. When the second free end is pulled, the deep layer is anatomically reduced thanks to the lasso loop (LL), as shown in a right shoulder (posterior view).

rotation; a lateral view; and a Y view. The presence of any osteoarthritic changes was assessed with the Hamada-Fukuda classification.[31,32]

Postoperative ultrasonography was performed by an experienced musculoskeletal radiologist reporting on the state of the repaired tendon to be evaluated as either no tear (full coverage of the footprint), partial tear (lack of coverage of <20 mm of the footprint), or full tear (lack of coverage of >20 mm). The presence or absence of delamination was also evaluated. Supraspinatus and infraspinatus tendon thickness was recorded, and partial tears were reported by the presence of hypo-echogenic regions within either layer.[27]

Statistical analysis was carried out using PASW Statistics 18 software (IBM, Armonk, NY) with numerical results expressed as mean ± standard deviation. The nonparametric Kolmogorov-Smirnov test was used to evaluate the normal value distribution, whereas the paired t test was performed to verify significant differences before and after treatment. If the values were not normal, the Wilcoxon test was used and the correlations were assessed with the Pearson test. $P < .05$ was considered significant.

Results

We recruited 54 consecutive patients with delaminated posterosuperior rotator cuff tears into the study. Of these, 13 were excluded on the basis of previous shoulder surgery. Thus 41 patients underwent arthroscopic double-layer lasso loop repair for cuff tears. Of these patients, 7 (17%) were lost to follow-up whereas a further 2 required shoulder arthroplasty for arthritis and were excluded.

The remaining 32 patients were assessed by 2 of the coauthors (G.J.O. and K.P.). The examiners were not blinded to the surgical technique. We performed a post

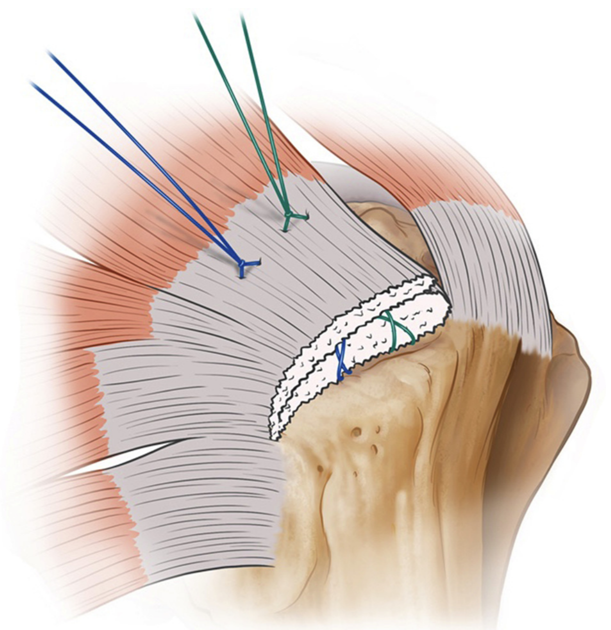

Fig 6. The knots are tied from posterior to anterior, as shown in a right shoulder (posterior view).

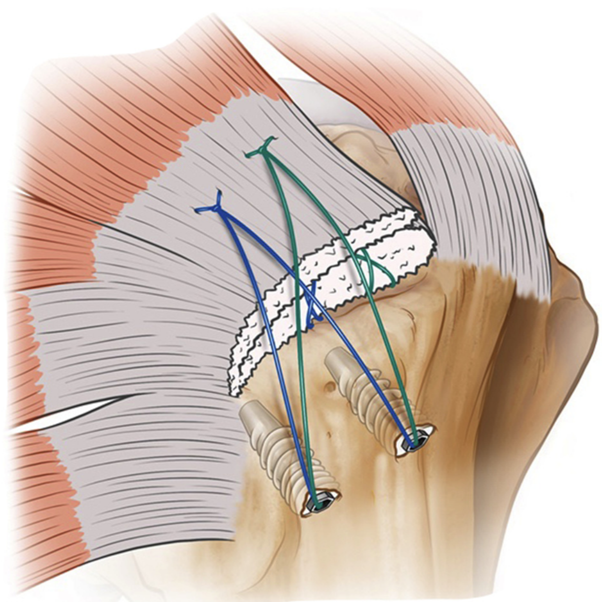

Fig 7. A suture-bridge fixation of the superficial layer is performed with 1 or 2 knotless anchors, completing the double-row repair, as shown in a right shoulder (posterior view). Anatomic reduction of the superficial layer is achieved.

Table 1. Study Group Demographic Data

	Data
No. of patients	32
Sex	
Men	15 (47%)
Women	17 (53%)
Age at surgery, yr	64 ± 6
Follow-up, mo	44 ± 8
SFA activity classification	
I: sedentary	4
II: active occasionally	5
III: active	9
IV: very active	14
Cause	
Spontaneous	18
Work accident	3
Sporting accident	11
Suture anchors	
1 medial plus 1 lateral	14 (44%)
2 medial plus 1 lateral	18 (56%)

NOTE. Data are presented as mean ± standard deviation or number.
SFA, Société Francophone d'Arthroscopie.

hoc power calculation on this subgroup that showed a study power of 88% for an effect size of 0.5 at an α threshold of .05.

The sex distribution of patients was approximately equal, and the mean surgical age was 64 years. Of the sample, 72% had active to very active lifestyles based on the Société Francophone d'Arthroscopie classification (Table 1). No preceding trauma was noted for 56% of the cuff tears, whereas 9% of ruptures were due to a work-related injury and the remaining 35% had a history of a sporting accident.

During arthroscopy, the cuff was reassessed and tears were graded according to the classification proposed by Patte[23] (Table 2). The tear size and number of anchors used (1 medial plus 1 lateral or 2 medial plus 1 lateral) are described in Table 3.

Table 2. Patte Classification of Cuff Tear

	n
Supraspinatus retraction	
1	7 (22%)
2	14 (44%)
3	11 (34%)
Infraspinatus retraction	
0	8 (25%)
1	7 (22%)
2	14 (44%)
3	3 (9%)
Subscapularis retraction	
0	22 (69%)
1	3 (9%)
2	6 (19%)
3	1 (3%)

Table 3. Suture Anchor Placement With Patte Classification

Tear Size (Patte Classification)	No. of Suture Anchors
SSP 3 and ISP 3	3 (9.4% of cases)
SSP 3 and ISP 2	3 (18.7% of cases)
SSP 3 and ISP 1	3 (3.1% of cases)
SSP 3 and ISP 0	2 (3.1% of cases)
SSP 2 and ISP 2	3 (25% of cases)
SSP 2 and ISP 1	2 (9.4% of cases)
SSP 2 and ISP 0	2 (9.4% of cases)
SSP 1 and ISP 1	2 (9.4% of cases)
SSP 1 and ISP 0	2 (12.5% of cases)

ISP, infraspinatus; SSP, supraspinatus.

Postoperative ultrasound evaluation of rotator cuffs indicated sealed repairs (full coverage of the footprint) in 81% of patients. Five patients had a partial retear (lack of coverage of <20 mm). The complete retear rate (lack of coverage of >20 mm of the footprint) was 3% (Table 4). To evaluate cuff healing, we divided the ultrasound results into 2 subgroups: sealed and nonsealed (partial or complete retear). Cuff healing significantly influenced the Constant score.

We found statistically significant improvements in the Constant score in the 2 groups, from 54 (preoperatively) to 83 (postoperatively) ($P < .001$) in the sealed cuff group and from 58.7 to 74.6 ($P = .04$) in the nonsealed cuff group. In the sealed cuff group, a statistically significant improvement also occurred in the UCLA function score ($P < .001$), from 6.4 of 10 (preoperatively) to 9.5 of 10 (postoperatively). In the nonsealed cuff group, a weakly significant improvement ($P = .06$) was noted, from 6.7 to 8.7.

Patient satisfaction scores were high, with a mean value of 97.5% ± 5.7% in the sealed cuff group and 89.2% ± 11.1% in the nonsealed cuff group. All patients improved after surgery, and 100% reported that they would undergo the operation again if needed. At final follow-up, we noted a mean Subjective

Table 4. Ultrasound Evaluation of Rotator Cuff

	Data
Ultrasound evaluation of rotator cuff	
Sealed	26
Partial tear	5
Full tear	1
SSP thickness, mm	5.4 ± 2.4
ISP thickness, mm	5.1 ± 1.2
Delamination	
Yes	1
No	31
Hamada-Fukuda classification	
Stage 1	15 (47%)
Stage 2	12 (38%)
Stage 3	3 (9%)
Stage 4a	2 (6%)

NOTE. Data are presented as mean ± standard deviation or number.
ISP, infraspinatus; SSP, supraspinatus.

Table 5. Preoperative and Postoperative Comparison of Jobe, Palm-up, Belly-Press, Bear-Hug, Gerber Lift-off, and External Rotation Tests in Sealed Cuff Group

	Sealed Cuff Group (n = 25)					
	Pain (0-15)			Strength (0-5)		
Test	Preoperative	Postoperative	*P* Value	Preoperative	Postoperative	*P* Value
Jobe	6.6 ± 2.8	14.4 ± 1.6	<.001	3.4 ± 0.7	4.8 ± 0.4	<.001
Palm up	9.3 ± 1.9	14.6 ± 1.6	.02	3.6 ± 0.5	4.9 ± 0.3	.014
Belly press	11.7 ± 3.1	14.4 ± 1.6	.001	4.4 ± 0.6	4.9 ± 0.4	.003
Bear hug	9.8 ± 3.2	14.6 ± 1.4	<.001	4.2 ± 0.5	4.9 ± 0.2	<.001
Gerber lift off	11.1 ± 3.2	15 ± 0	.002	4.2 ± 0.7	5 ± 0	.002
ER1	9.8 ± 3	14.8 ± 1	<.001	3.7 ± 0.7	4.9 ± 0.2	<.001

NOTE. Data are presented as mean ± standard deviation.
ER1, external rotation with arm in maximal adduction.

Shoulder Value of 93.1 ± 13.2 in the sealed cuff group and 85 ± 13.4 in the nonsealed cuff group. In addition, we recorded a mean Simple Shoulder Test score of 10.1 ± 1.9 in the sealed cuff group and 9 ± 2.5 in the nonsealed cuff group.

In the sealed cuff group, we found statistically significant improvements in the postoperative pain and strength measures while assessing the rotator cuff by performing the Jobe, palm-up, bear-hug, belly-press, Gerber lift-off, and ER1 tests (Table 5). Results from the nonsealed cuff group regarding these parameters are described in Table 6.

We compared force in abduction, elevation, and external rotation (ER1) between the operated and contralateral sides. In the sealed cuff group, no significant difference was observed in mean strength of abduction (6.9 kg ± 3.5 kg vs 6.8 kg ± 2.5 kg, $P = .73$) despite patients recovering normal abduction. There was no observable statistically significant difference in mean elevation (6.7 kg ± 3.3 kg vs 7.1 kg ± 3.7 kg, $P = .26$). We found a significant difference in mean external rotation (7.7 kg ± 3.5 kg vs 6.7 kg ± 3.2 kg, $P = .018$).

In the nonsealed cuff group, there was no significant difference between the operated and contralateral sides in mean strength of abduction (4.9 kg ± 2.1 kg vs 7 kg ± 2.1 kg, $P = .083$), elevation (5.6 kg ± 2 kg vs 9 kg ± 5 kg, $P = .11$), or external rotation (7.9 kg ± 3.1 kg vs 7.5 kg ± 2.7 kg, $P = .5$). Only 1 adverse event was recorded: the development of complex regional pain syndrome in a patient that fully resolved.

Discussion

In our study with a minimum 2-year follow-up, we found the arthroscopic double-layer lasso loop technique to be an effective repair technique for delaminated posterosuperior cuff tears. We report good postoperative functional results and a low retear rate.

For delaminated tears, the deep layer is more retracted; thus the use of the lasso loop suture configuration allows for better tendon fixation.[17,18,33] In a biomechanical study, Ponce et al.[18] reported enhanced ultimate load strengths of the lasso loop configuration when compared with a simple stitch, which they attributed to the self-cinching design leading to enhanced tissue-holding strength. The deep layer pulls the superficial layer with it, helping to reduce traction on the superficial layer. Both layers are reattached anatomically at the footprint, permitting anatomic cuff healing.[10,13,34,35] The absence of a knot between the 2 layers promotes increased interlayer contact between the fibers, enhancing the healing process.[9]

Arthroscopic cuff repair studies have shown varied retear rates between 11.4% and 94%.[5,14,24,33,36-42] A multitude of factors affect the occurrence of retears, including patient age, tear size, fatty infiltration of cuff

Table 6. Preoperative and Postoperative Comparison of Jobe, Palm-up, Belly-Press, Bear-Hug, Gerber Lift-off, and External Rotation Tests in Nonsealed Cuff Group

	Nonsealed Cuff Group (n = 6)					
	Pain (0-15)			Strength (0-5)		
Test	Preoperative	Postoperative	*P* Value	Preoperative	Postoperative	*P* Value
Jobe	8 ± 2.7	12.5 ± 2.7	.059	3.6 ± 1.1	4.5 ± 0.5	.059
Palm up	3 ± 1.4	13.3 ± 2.6	NS	4.5 ± 0.7	4.6 ± 0.5	NS
Belly press	12.5 ± 2.7	15 ± 0	NS	4.7 ± 0.5	5 ± 0	NS
Bear hug	10.8 ± 2	15 ± 0	.025	3.7 ± 0.6	5 ± 0	.034
Gerber lift off	10 ± 4	15 ± 0	NS	3.75 ± 0.9	5 ± 0	NS
ER1	9.2 ± 3.8	14.2 ± 2	NS	3.5 ± 1	4.7 ± 0.5	NS

NOTE. Data are presented as mean ± standard deviation.
ER1, external rotation with arm in maximal adduction; NS, not significant.

tissue, tendon retraction, repair construct, rehabilitation, and other medical comorbidities.[1,34,36]

Hepp et al.[9] explained that an overlapping posterosuperior cuff insertion into the greater tuberosity is necessary for the appropriate force couple balance required in the glenohumeral fulcrum. The deep layer inserts at the cartilage-bone junction, whereas the superficial layer inserts farther laterally.[9,43] Different techniques have been described to reattach double-layer cuff tears.[1,5,35,36,38,44] In theory, the large tendon-bone contact area created by the double-row repair technique and the insertional stability should allow better healing.[1,35]

Hepp et al.[12] showed that the double-row double-layer mattress suture reattachment technique for cuff tears offered stronger postoperative biomechanical resistance than the classic double-row technique, as well as the double-row double-layer technique compared with a simple suture configuration. Our technique offers an anatomic reduction of the deep and superficial layers on the footprint, resulting in a similar advantage to the double-row double-layer mattress suture technique.[12,17] In addition, in our case series, the double-layer lasso loop did not have any medial retears at follow-up, which we attribute to the reduction in traction on the superficial layer as also shown by Galatz et al.[37]

Biomechanical displacement controlled studies have shown the fibers of the superficial layer to have maximum tension at 90° of glenohumeral abduction whereas the deep layer has maximum tension at 22° of glenohumeral abduction.[20,22,45] This differential strain creates a shearing force between the 2 layers, which results in delaminating tears.[12]

Huang et al.[22] also showed in a biomechanical study that the deep layer of the posterosuperior cuff disrupts first and then involves the superficial layer and, finally, the infraspinatus. This is attributed to the tendon fiber alignments of the superficial layer being parallel and thus more resistant to tears.[46]

In our series all patients reported an improvement in pain and shoulder function, including patients with partial retears. The patient-reported satisfaction rate of 97% in our series was also comparable to the findings of Tashjian et al.,[47] who reported patient satisfaction at 95%.

There was 1 case of complex regional pain syndrome with full resolution after 1 year. In the follow-up of patients, our reported rate of complete retears was 3.1% whereas only 5 patients had partial retears. Hein et al.[48] similarly showed lower retear rates associated with double-row repair than with single-row repair in most tear categories in their systematic review. Two patients with intact repairs but progressive osteoarthritis required shoulder arthroplasty. In view of their debility, pain, and dysfunction, a medically and ethically based decision was made by the senior author (L.L.) to perform total shoulder arthroplasty. These patients were subsequently excluded from the study before meeting the minimum criteria.

The improvement in the Constant score in our study is similar to that in the literature.[5,6,25,36,37,49] Our study showed a correlation between healing from the double-layer lasso loop repair technique and improvement in the Constant score. Boileau et al.[5] reported similar improvements in UCLA functional scores in a similar study.

In the sealed cuff group, the Jobe test improved significantly with respect to pain and force. In our study group, 10 patients presented with concomitant subscapularis tears that were repaired. This may explain the observed significant improvements in the belly-press test, Gerber lift-off test, and bear-hug test.[50] These improvements were also reported by Longo et al.[51]

In the sealed cuff group, external rotation on the operated side showed greater strength. We attribute this to the fact that not all patients had associated infraspinatus lesions and the affected side was most often the dominant side. Cole et al.[36] evaluated forward elevation strength and external rotation strength, obtaining similar results to our series (5.3 kg vs 6.7 kg of forward elevation and 7.1 kg vs 7.7 kg of external rotation).

Limitations

Our study has several limitations. First, the low number of enrolled patients and the number lost to follow-up (17%) may impact the findings, and further evaluation is warranted. Second, the absence of a control group restricts us to comparisons within the literature. Third, there was a lack of blinding for postoperative evaluation. Finally, the lack of advanced imaging such as CT arthrogram or MRI arthrogram to document healing was a constraint.[52,53] We countered this by having a single highly experienced musculoskeletal radiologist perform all postoperative radiologic and ultrasonographic assessments.[28-30] The results indicate our clinical experience, and further biomechanical testing is suggested.

Conclusions

The arthroscopic double-layer lasso loop repair technique for delaminated posterosuperior rotator cuff tears is an effective procedure. Our series showed a low rerupture rate. At a mean follow-up of 44 months, postoperative recovery with resultant functional, pain, and patient satisfaction scores was good to excellent and was comparable with the nonoperated side.

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