Arthroscopic Repair With Side-to-Side Sutures for Full-Thickness Transtendinous Supraspinatus Tears Versus Traditional Tendon to Bone Fixation

Outcomes and Retear Rates at 4-Year Follow-up

Amin Karimi,* MD, Fritz Steuer,* BS, Sophia McMahon,* BA, Stephen Marcaccio,* MD, Rajiv Reddy,* MD, Confidence Njoku-Austin,* MD, Ryan Gilbert,* BA, Matthew P. Kolevar,* MD, and Albert Lin,*† MD
Investigation performed at UPMC Freddie Fu Sports Medicine Center, Pittsburgh, Pennsylvania, USA

Background: Full-thickness, transtendinous supraspinatus rotator cuff tears involve a significant portion of the remanent tendon attached to the footprint.

Purpose: To compare outcomes and failure rates for arthroscopic side-to-side (STS) suture repair for transtendinous tears versus traditional double-row repair for common tendon-to-bone type tears.

Study Design: Cohort study; Level of evidence, 3.

Methods: A retrospective cohort of 18 patients with full-thickness transtendinous supraspinatus tears who underwent STS suture repair was compared with a group of 36 matched controls with classic tendon avulsion who underwent double-row knotless transosseous-equivalent (TOE) repair. All patients had $\geq$2 years of follow-up. Demographics, postoperative active range of motion, and patient-reported outcomes (PROs) including American Shoulder and Elbow Surgeons (ASES) score, visual analog scale (VAS) for pain, and Subjective Shoulder Value (SSV), were collected.

Results: There were no significant differences between the STS and TOE groups regarding mean follow-up (48.2 $\pm$ 18.5 vs 47.9 $\pm$ 20.5 months; P = .70) or age (64.6 $\pm$ 7.2 vs 64.8 $\pm$ 7.3 years; P = .79). With respect to clinical outcomes and PROs, there were no differences in postoperative VAS pain score (STS vs TOE: 0.94 $\pm$ 1.5 vs 0.89 $\pm$ 1.8; P = .39), SSV score (92.4 $\pm$ 8.9 vs 90.1 $\pm$ 13.0; P = .79), or ASES score (90.8 $\pm$ 9.7 vs 92.6 $\pm$ 12.0; P = .15). No differences were identified for postoperative active forward flexion (STS vs TOE: 154.2° $\pm$ 13.3° vs 159.4° $\pm$ 11.3°; P = .10), external rotation (53.3° $\pm$ 6.2° vs 51.4° $\pm$ 8.7°; P = .47), or internal rotation (P = .69) score. Although there were larger anteroposterior tear sizes in the STS group (21.4 $\pm$ 9.3 vs 16.0 $\pm$ 6.7 for TOE; P = .04), there was no significant group difference in failure rates (11% [STS] vs 8% [TOE]; $P > .99$).

Conclusion: Arthroscopic STS suture repair for transtendinous supraspinatus tears yielded excellent outcomes with low failure rates, comparable with tendon-to-bone double-suture anchor repair for typical tendon avulsion–type cuff tears. Retention of the large tendon stump on the greater tuberosity with STS repair also allows restoration of anatomy without undue tension in this uncommon scenario.

Keywords: rotator cuff; arthroscopy; transtendinous tear; side-to-side repair; supraspinatus

Rotator cuff tears are a common injury, with an incidence reported as high as 50% in individuals aged >65 years.[18,29] Most rotator cuff tears are due to a degenerative process, with only a small portion of the patients' injuries resulting

The Orthopaedic Journal of Sports Medicine, 13(3), 23259671251321470
DOI: 10.1177/23259671251321470
© The Author(s) 2025

This open-access article is published and distributed under the Creative Commons Attribution - NonCommercial - No Derivatives License (https://creativecommons.org/licenses/by-nc-nd/4.0/), which permits the noncommercial use, distribution, and reproduction of the article in any medium, provided the original author and source are credited. You may not alter, transform, or build upon this article without the permission of the Author(s). For article reuse guidelines, please visit SAGE's website at http://www.sagepub.com/journals-permissions.

from traumatic ruptures (2.3%-17.7%).[4,6,7,13] The supraspinatus, infraspinatus, and sometimes teres minor are avulsed from the greater tuberosity in the most common types of rotator cuff ruptures; however, tears may occasionally develop considerably medial to the footprint.[28] These medial transtendinous-to-myotendinous full-thickness rotator cuff ruptures were first reported as the result of a traumatic mechanism by Walcott et al.[28] All transtendinous tears in the Walcott series resulted from a fall on an abducted arm. In another series, Jeon et al[9] reported similar tears, with traumatic tears in 4 out of 5 patients.[9,28] Walcott's case series described 7 patients who had suffered an abduction traumatic injury and had full-thickness transtendinous rotator cuff tears with >1 cm of the remaining tendon at the footprint of the cuff.[28]

This unique pathology is less amenable to traditional surgical repair for typical tears, which focuses on tendon-to-bone repair by pulling the torn tendon edge back to a bare footprint, facilitating bone-to-tendon healing and tension-free anatomic restoration of the footprint. In patients with full-thickness transtendinous rotator cuff tears, a large portion of the tendon remains attached to the footprint. Debridement of the entire footprint stump may leave insufficient tissue available for primary tendon-to-bone repair or generate a nonanatomic medialized footprint repair or higher strains on a primary repair if the entire tendon is pulled laterally to cover the entire footprint, which may predispose traditional repair to early failure.[16,17] In instances of medial tears, anatomic repair may only be achieved through the use of side-to-side (STS) sutures for tendon-to-tendon repair; however, there may be concerns regarding the biomechanical strength of this construct and success of tendon-to-tendon healing.[1,9,10,21,28] There are no studies to our knowledge that compare the clinical outcomes of STS repair in medial transtendinous tears to tendon-to-bone repair in typical tendon to bone tears.

The primary goal of this study was to compare the clinical outcomes of STS repair in patients with medial transtendinous full-thickness rotator cuff tears with standard tendon-to-bone repair via double-row knotless transosseous-equivalent (TOE) repair in patients with bone avulsion type full-thickness rotator cuff tears. The secondary objective was to determine whether STS repairs are more likely to result in failure in comparison with standard tendon-to-bone repair. We hypothesized worse objective and subjective outcomes as well as higher retear rates for STS suture repair.

METHODS

Patient Selection

Institutional review board approval was obtained from the University of Pittsburgh for this retrospective cohort study. Electronic medical records were used to review all patients who underwent rotator cuff repair by a fellowship-trained shoulder surgeon (A.L.) between 2013 and 2021. Included were consecutive patients who underwent primary rotator cuff repair involving STS repair for medial transtendinous supraspinatus tears in the operative note with ≥2 years of clinical follow-up. Only patients with preoperative magnetic resonance imaging (MRI) confirming the characteristics of the tear, the remaining rotator cuff tendon, and the muscle were included in the study. Exclusion criteria were the diagnosis of inflammatory arthropathy, prior surgery to the ipsilateral shoulder, STS repair in any situation other than transverse transtendinous tear, and revisions.

Application of inclusion and exclusion criteria resulted in 18 patients who underwent STS repair (STS group). The control group (TOE group) was a 2:1 cohort comprising 36 patients matched on age, sex, traumatic etiology, and rotator cuff involvement (eg, supraspinatus or supraspinatus and subscapularis) from patients during the same time period with classic tendon avulsion from the rotator cuff footprint on the greater tuberosity, who all underwent double-row knotless TOE repair (555 patients). Matching was performed between the STS cohort and the 555 control patients in STATA (StataCorp) via caliper-based matching with exact matching for sex, traumatic etiology, and rotator cuff involvement, and a ±4-year margin was used for age to ensure sufficient matching numbers.

Clinical and Radiologic Assessment

Patient demographics were collected from the electronic medical records. Complications or the need for revision surgery were recorded. Failure was defined as a symptomatic retear on MRI or need for revision surgery or both. From the latest follow-up, patient-reported outcome (PRO) measures, including the American Shoulder and Elbow Surgeons (ASES) score, Subjective Shoulder Value (SSV), and visual analog scale (VAS) for pain, were collected. Additionally, active range of motion (ROM) for forward elevation and external rotation with the arm at the side were measured and recorded from the preoperative

†Address correspondence to Albert Lin, MD, Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, 3200 S Water Street, Pittsburgh, PA 15203, USA (email: lina2@upmc.edu).

*Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, Pittsburgh, Pennsylvania, USA.

Final revision submitted September 18, 2024; accepted September 26, 2024.

One or more of the authors has declared the following potential conflict of interest or source of funding: S.M. has received education payments from Smith & Nephew and hospitality payments from Stryker. R.R. has received hospitality payments from Abbott Laboratories, Boston Scientific, and Nevro. A.L. has received education payments from Arthrex; consulting fees from Arthrex, Stryker, and Wright Medical; nonconsulting fees from Arthrex; hospitality payments from Linvatec; and honoraria from Wright Medical. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was waived by the University of Pittsburgh (STUDY20030061).

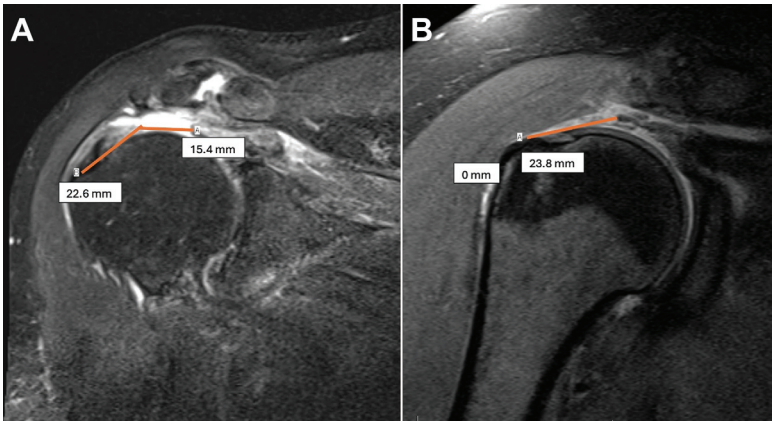

Figure 1. Coronal-oblique magnetic resonance imaging showing the mediolateral tear size (retraction) and remaining stump of the rotator cuff tendon (A) in a transtendinous tear (retraction, 15.4 mm; tendon stump, 22.6 mm) and (B) in a bone avulsion tear (retraction, 23.8 mm; tendon stump, 0 mm).

and last follow-up visit. Internal rotation was reported as a 10-point scale based on the most cephalad midline segment of the back that could be reached by the thumb as described by Levy et al[15]: buttock/greater trochanter (2 points), sacrum to L4 (4 points), L3 to L1 (6 points), T12 to T8 (8 points), and T7 to T1 (10 points).

The tear was categorized as degenerative or acute via preoperative MRI. Muscle edema, a wavelike appearance of the central portion of the torn tendon, and joint effusion were regarded as MRI characteristics of an acute tear.[24] Rotator cuff tear extent including anteroposterior and mediolateral (retraction) tear size at their largest dimension on the sagittal-oblique and coronal-oblique plans, respectively, as well as degree of fatty degeneration of the rotator cuff muscle based on Goutallier classification was evaluated using preoperative MRI.[5,26] Additionally, the size of the remaining tendon stump at its longest length was measured at the rotator cuff footprint in STS patients using coronal-oblique MRI (Figure 1). In the postoperative follow-up, any patient experiencing continued pain or weakness in shoulder ROM or having restricted active ROM compared with passive ROM after completing the rehabilitation protocol was evaluated for a possible rotator cuff retear (loss of tendon continuity) by MRI.

Surgical Technique

Patients were positioned in the beach-chair position, and standard anatomic landmarks were marked. A standard posterior portal was established, and a 30° scope was introduced into the glenohumeral joint. A standard anterior portal was established with direct spinal needle visualization, and diagnostic arthroscopy was performed. If any associated pathology of the labrum, long head of the biceps, or subscapularis tendon was discovered, it was addressed as indicated. A lateral portal was established at the center of supraspinatus cuff tear, and subacromial decompression was performed in almost all patients. The scope was then introduced into a posterolateral viewing portal to view the tear en face. For patients with tendon from bone tears, a double-row knotless TOE technique was utilized using standard techniques. In patients with transtendinous tear patterns with >1 cm of remnant supraspinatus tendon still attached to the footprint, the medial tendon was released and mobilized. The medial and lateral tendon edges were gently debrided to clean edges, and a grasper was used to first confirm that the tendon could not be reduced anatomically to the footprint with undue tension. Next, a grasper was used to determine an appropriate anatomic pattern of STS repair. The transtendinous repair was then commenced by passing the required number of tape sutures (FiberTape; Arthrex Inc) through the lateral tendon remnant and medial tendon in STS fashion with a lasso and scorpion forming a simple suture configuration (Figure 2).

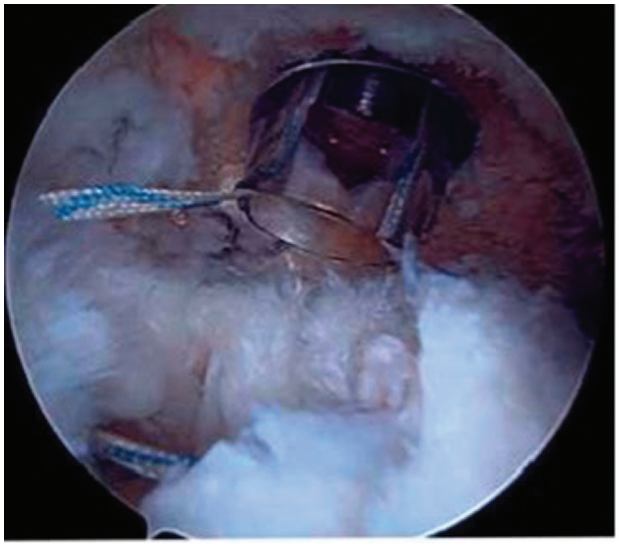

Figure 2. In a transtendinous tear, the suture passes through the medial tendon and the lateral tendon stump.

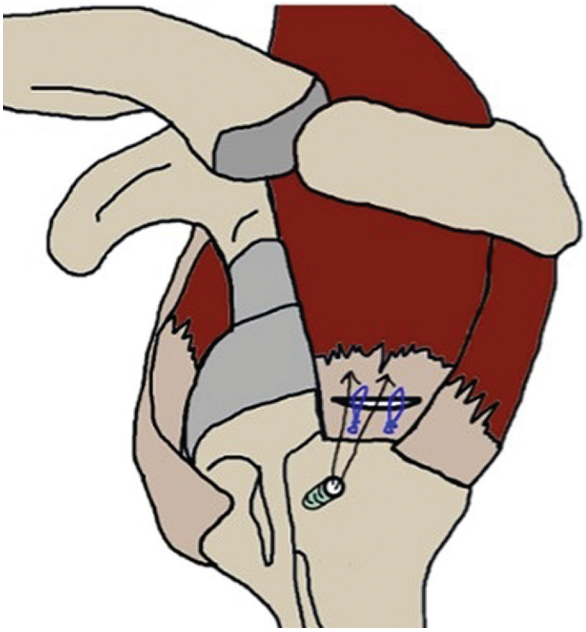

Figure 3. Side-to-side suture repair of transtendinous supraspinatus rotator cuff tear.

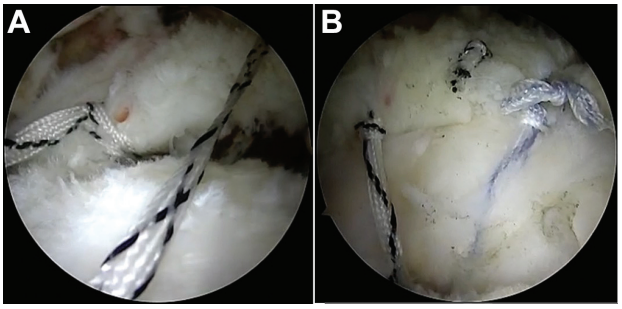

Figure 4. Arthroscopic view of side-to-side suture repair. (A) A partially completed repair with 1 of 2 luggage tag sutures and 1 of 2 side-to-side sutures. (B) The completed construct with the side-to-side sutures tied and luggage tags sutures secured by a lateral row knotless suture anchor.

The scorpion was then utilized to place ≥2 locking looped reduction sutures (FiberLink; Arthrex Inc) between the STS sutures into the leading edge of the medial tendon. The previously passed FiberTape sutures were tied with 6 alternating arthroscopic half-hitches to anatomically reduce the transverse transtendinous tear edges together. The remaining FiberLink sutures were then secured through a lateral row knotless suture anchor (4.75-mm BioComposite SwiveLock; Arthrex Inc) without any significant tension, to augment the STS repair and prevent medial retraction of the myotendinous portion of the tear for a "belt and suspenders" technique. This construct aims to create an anatomic and tension-free repair of the tear (Figures 3 and 4).

Postoperative Rehabilitation

Rehabilitation protocol differed slightly between the STS and TOE groups and was more conservative in patients who underwent STS repair. For the first 6 weeks, the STS repair group was immobilized in a sling except for elbow ROM at the first postoperative visit. At 6 weeks, STS patients began ROM rehabilitation therapy with passive motion, with progression to active-assisted and active ROM by week 10. For the TOE group, sling wearing was 4 weeks, and formal therapy with passive ROM was initiated at 10 days postoperatively. At 6 weeks, the TOE group began active-assisted and active ROM. Both groups began strengthening at 12 weeks postoperatively.

Statistical Analysis

For each group, outcomes and demographic variables were assessed for normality using the Shapiro-Wilk test. When the variables of our independent groups did not follow a normal distribution, a Mann-Whitney *U* test was used for analyzing parametric and nonparametric continuous data. Categorical data analysis was performed using the Pearson chi-square and Fisher exact tests. All statistical analysis was carried out using STATA 18 software (StataCorp). Statistical significance was considered at $P < .05$.

RESULTS

A total of 27 patients were identified who underwent STS repair, after the application of inclusion criteria and matching. Nine patients were excluded for insufficient follow-up or inaccessible preoperative MRI. Ultimately, 18 of the total 54 patients in this study had transtendinous STS repair, while the other 36 underwent double-row knotless TOE repair (Figure 5).

After matching, 100% of STS patients were exact matched based on sex, traumatic etiology status, and rotator cuff involvement with all ages within 4 years of target. There were no significant differences between the STS and TOE groups in mean follow-up (48.2 ± 18.5 vs 47.9 ± 20.5 months; $P = .70$) or age (64.6 ± 7.2 vs 64.8 ± 7.3 years; $P = .79$). Preoperative function scores did not differ between groups (STS vs TOE, respectively) on the SSV (51.9 ± 25.0 vs 58.9 ± 20.0; $P = .44$); VAS pain (6.4 ± 2.6 vs 5.3 ± 2.9; $P = .31$), or ASES (51.4 ± 18.1 vs 56.8 ± 16.6; $P = .42$). Preoperative ROM also did not differ between STS vs TOE groups: forward flexion (137° ± 43° vs 151° ± 30°; $P = .44$), external rotation (43° ± 17° vs 49° ± 10°; $P = .21$), and internal rotation Levy score (6.6 ± 2.0 vs 6.9 ± 1.8; $P = .80$). Regarding preoperative tear characteristics on MRI (Table 1), there were significantly larger anteroposterior tear sizes in the STS group (21.4 ± 9.3 vs 16.0 ± 6.7 mm; $P = .04$).

A total of 15 of 18 patients (83%) in the STS group underwent biceps tenodesis or tenotomy compared with 25 of 36 patients (69%) in the TOE control group ($P =$

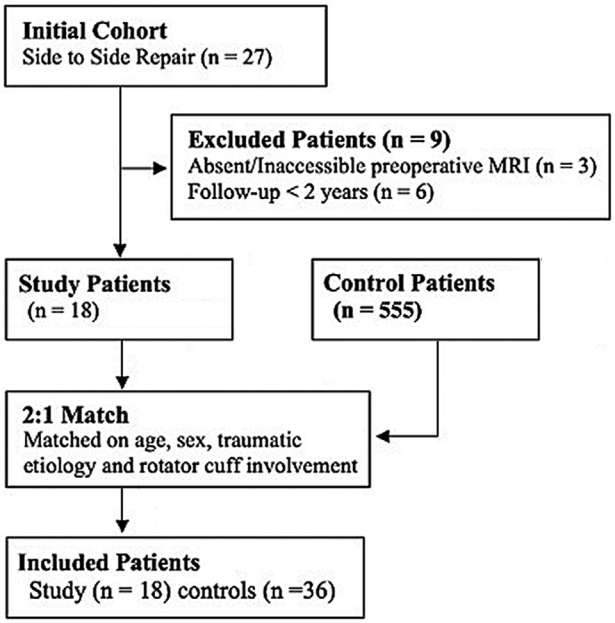

Figure 5. Flowchart of side-to-side repair patient selection and transosseous equivalent matched controls.

TABLE 1
Comparison of Preoperative Rotator Cuff Tear MRI Characteristics Between Patients With Transtendinous Tears and Bone Avulsion Tears[a]

	STS Group	TOE Group	*P*
Anteroposterior tear size	21.4 ± 9.3	16.0 ± 6.7	.04
Mediolateral (retraction) tear size	15.8 ± 6.7	17.0 ± 7.4	.66
Tear type, traumatic/degenerative, n	6/12	12/24	>.99
SS fatty infiltration	1.2 ± 1.0	1.6 ± 0.9	.38
IS fatty infiltration	0.4 ± 0.6	0.5 ± 0.7	.90

[a]Data are presented as mean ± SD unless otherwise indicated. IS, infraspinatus; SS, supraspinatus; STS, side to side; TOE, transosseous equivalent.

.34). All patients underwent acromioplasty, and none underwent distal clavicular excision. There was no significant difference between groups regarding type of tear (traumatic vs degenerative) ($P > .99$) (Table 1). For STS patients, the mean length of lateral tendon that was still attached to the footprint was (17.3 ± 4.5 mm; range, 10.2-25.4 mm) compared with TOE (2.2 ± 3.3 mm; range, 0-9.6 mm; $P < .01$).

With respect to clinical outcomes and PROs, there were no differences in postoperative VAS pain score (STS vs TOE: 0.94 ± 1.5 vs 0.89 ± 1.8; $P = .39$), SSV score (92.4 ± 8.9 vs 90.1 ± 13.0; $P = .79$), or ASES score (90.8 ± 9.7 vs 92.6 ± 12.0; $P = .15$). No differences were identified for postoperative active ROM in forward flexion (STS vs TOE: 154.2° ± 13.3° vs 159.4° ± 11.3°; $P = .10$), external rotation (53.3° ± 6.2° vs 51.4° ± 8.7°; $P = .47$), or internal rotation (6.6 ± 1.7 vs 6.7 ± 1.6; $P = .69$) score. The number of failures (retears) were similar in the STS repair group (2/18 patients; 11%) and the TOE group (3/36 patients; 8%) ($P > .99$); 1 patient with retear in the TOE group underwent revision surgery with reverse total shoulder arthroplasty. The mean time to failure was 5.5 months for STS and 12.5 months for TOE. There was no difference in postoperative imaging, with 3 of 18 (17%) of the STS repair group undergoing postoperative MRI compared with 4 of 36 (11%) of the TOE group ($P = .67$).

DISCUSSION

STS repair for medial transtendinous tears with a significant amount of insertional tendon that remains attached to the greater tuberosity footprint is an anatomic repair technique with excellent clinical outcomes and retear rates comparable with standard double-row knotless TOE repair for tendon-to-bone tears.

In 2017, Walcott et al[28] first described transtendinous rotator cuff tears as traumatic tears primarily found in young patients who had experienced a fall with the arm abducted. The authors hypothesized that the transtendinous tear could result from an axial load forcing the rotator cuff into the acromion. Similarly, Jeon et al[9] reported that trauma was the underlying mechanism in 80% of patients with transtendinous rotator cuff injuries. In our cohort of patients, trauma was identified as the source of tears in only one-third of the patients with transtendinous tears according to our MRI criteria. These findings suggest that trauma may not be the primary mechanism for all transtendinous cuff tears. Additionally, the preoperative function and ROM between the groups was comparable, suggesting that preoperative imaging and mechanism are key to identifying these tears.

If the remnant tissue attached to the tuberosity footprint is completely excised in transtendinous rotator cuff tears, there are 2 potential outcomes if considering a tendon-to-bone repair: first, the medial tendon stump may be pulled laterally and reattached to the entire anatomic footprint, leading to overtensioning; or second, it may be attached to a more medial nonanatomic position with or without excision of the footprint stump. According to research by Meyer et al,[17] the change in the length-tension relationship is a major predictor of retear; if the length of the supraspinatus tendon is <15 mm after arthroscopic repair, the failure rate can reach 92%. One of the most significant variables that predisposes patients to failure is overtension of the repaired tendon.[11,12,23,27] As demonstrated by Miyake et al,[19] even 20 N of tension considerably impairs the microvascular blood flow within the rotator cuff, which is a crucial factor for successful healing. On the other hand, while nonanatomic repair (partial repair or medialized repair) may demonstrate better outcomes than debridement alone,[2,20] worse functional outcomes are observed compared with an anatomic repair.[8,30] Medialized repairs can result in decreased rotator cuff movement in the abducted arm and increased

muscle force for abduction, internal rotation, and external rotation.[14,22] Yamamoto et al[30] reported that significant restriction of ROM occurs with a medial shift of $\geq$10 mm of the supraspinatus repair site.

Regarding all surgical alternatives for transtendinous cuff tears, an ideal repair to obtain an optimal functional result and low failure rate would be a tension-free anatomic repair. To achieve this aim, retention of the residual footprint tendon and its anatomical incorporation into the repair may have significant benefits compared with complete debridement of the footprint. Given that the transtendinous tear patients in this cohort had a mean stump length of 17.3 mm, a substantial amount of insertional footprint tissue remained present in the STS cohort, presenting a significant conundrum for the ability to perform a traditional tendon-to-bone repair.

Few studies have been published in the literature that describes a surgical approach for treating transtendinous rotator cuff injuries while trying to preserve the length-tension relationship via incorporation of the lateral tendon stump in the repair. Following the publication in 2017 of Walcott et al's[28] open repair procedure for transtendinous rotator cuff tears, several authors[1,9,10,21] describe their arthroscopic method of treating this uncommon form of rupture. Despite their attempts to recreate the normal anatomy, all of them used medial row anchors placed medial to the rotator cuff tendon remnant on the anatomic footprint, which medializes the rotator cuff attachment site and ultimately shortens its lever arm. This study is the first to describe the anatomic restoration of transtendinous tears in the rotator cuff using a combination of single lateral row fixation and STS suture repair.

While debate continues regarding rotator cuff repair techniques, several studies comparing single-row fixation and the double-row TOE approach have demonstrated excellent clinical outcomes, particularly with small to medium tears.[3,25,31] In this cohort, patients undergoing transtendinous STS repair with single lateral row augmentation, despite larger anteroposterior tear size, demonstrated excellent and similar clinical and functional outcomes, comparable with those who underwent a knotless TOE equivalent repair.

Tendon-to-tendon healing is necessary for successful repair in the residual tissue preservation approach. Even though the healing mechanism in transtendinous rotator cuff repair is not fully understood, there were no significant differences in failure rates between our STS and tendon-to-bone repair cohorts.

Limitations

This study is subject to several limitations. This was a retrospective cohort study of patients at a single tertiary referral center. As a result, the sample size may be underpowered and lack sufficient external validity. Another limitation of this cohort is the small number of patients, which precludes robust statistical analysis of surgical outcomes. Nonetheless, the number of patients with transtendinous tears represents the largest cohort of this rare tear pattern compared with earlier case series. The retrospective nature of our study is another drawback. Finally, not every patient had imaging used to assess the integrity of the repair; rather, postoperative MRI was only performed on patients who had clinical signs of failure. Some patients may have experienced an asymptomatic retear and, therefore, did not undergo MRI and were not captured with this methodology. The same definition of failure, however, was applied to both case and control cohorts.

CONCLUSION

Arthroscopic STS suture repair for transtendinous supraspinatus rotator cuff tears yields excellent outcomes with low failure rates comparable with tendon-to-bone double suture anchor repair for typical avulsion-type tears. Retention of the large tendon stump on the greater tuberosity with STS repair also allows restoration of anatomy without undue tension in this uncommon scenario.

REFERENCES

1. Anderson S, Trenhaile S. Arthroscopic repair of rare transtendinous rotator cuff tear: utilizing established portals and a posterior superior accessory portal. *Arthroscopy Tech*. 2019;8(4):e419-e422.
2. Berth A, Neumann W, Awiszus F, Pap G. Massive rotator cuff tears: functional outcome after debridement or arthroscopic partial repair. *J Orthop Traumatol*. 2010;11(1):13-20.
3. De Giorgi S, Ottaviani G, Bianchi FP, Delmedico M, Suma M, Moretti B. Single-row versus transosseous technique in the arthroscopic treatment of rotator cuff tears: a meta-analysis. *Eur J Orthop Surg Traumatol*. 2024;34(1):31-38.
4. Fares AB, Scanaliato JP, Dunn JC, Sandler AB, Fink WA, Parnes N. Arthroscopic repair of traumatic rotator cuff tears in patients 70 years and older. *Orthop J Sports Med*. 2022;10(11):23259671221133110.
5. Goutallier D, Bernageau J, Patte D. Assessment of the trophicity of the muscles of the ruptured rotator cuff by CT scan. In: Post M, Morrey BF, Hawkins RF, eds. *Surgery of the Shoulder*. Mosby Year Book; 1990:11-13.
6. Hantes ME, Karidakis GK, Vlychou M, Varitimidis S, Dailiana Z, Malizos KN. A comparison of early versus delayed repair of traumatic rotator cuff tears. *Knee Surg Sports Traumatol Arthrosc*. 2011;19:1766-1770.
7. Hashimoto T, Nobuhara K, Hamada T. Pathologic evidence of degeneration as a primary cause of rotator cuff tear. *Clin Orthop Related Res*. 2003;415:111-120.
8. Holtby R, Razmjou H. Relationship between clinical and surgical findings and reparability of large and massive rotator cuff tears: a longitudinal study. *BMC Musculoskelet Dis*. 2014;15:180.
9. Jeon YS, Kim RG, Shin S-J. A novel remaining tendon preserving repair technique leads to improved outcomes in special rotator cuff tear patterns. *Arch Orthop Trauma Surg*. 2018;138:1135-1141.
10. Kelly BJ, Field LD. Arthroscopic repair of medial transtendinous rotator cuff tears. *Arthrosc Tech*. 2017;6(6):e2217-e2221.
11. Kim DH, Jang YH, Choi YE, Lee H-R, Kim SH. Evaluation of repair tension in arthroscopic rotator cuff repair: does it really matter to the integrity of the rotator cuff? *Am J Sports Med*. 2016;44(11):2807-2812.
12. Kim S-J, Kim S-H, Lee S-K, Seo J-W, Chun Y-M. Arthroscopic repair of massive contracted rotator cuff tears: aggressive release with anterior and posterior interval slides do not improve cuff healing and integrity. *JBJS*. 2013;95(16):1482-1488.
13. Lähteenmäki HE, Virolainen P, Hiltunen A, Heikkilä J, Nelimarkka OI. Results of early operative treatment of rotator cuff tears with acute symptoms. *J Shoulder Elbow Surg*. 2006;15(2):148-153.

14. Leschinger T, Birgel S, Hackl M, Staat M, Müller LP, Wegmann K. A musculoskeletal shoulder simulation of moment arms and joint reaction forces after medialization of the supraspinatus footprint in rotator cuff repair. *Comput Methods Biomech Biomed Engin*. 2019;22(6):595-604.
15. Levy JC, Everding NG, Gil CC Jr, Stephens S, Giveans MR. Speed of recovery after shoulder arthroplasty: a comparison of reverse and anatomic total shoulder arthroplasty. *J Shoulder Elbow Surg*. 2014;23(12):1872-1881.
16. Mandaleson A. Re-tears after rotator cuff repair: current concepts review. *J Clin Orthop Trauma*. 2021;19:168-174.
17. Meyer DC, Wieser K, Farshad M, Gerber C. Retraction of supraspinatus muscle and tendon as predictors of success of rotator cuff repair. *Am J Sports Med*. 2012;40(10):2242-2247.
18. Milgrom C, Schaffler M, Gilbert S, van Holsbeeck M. Rotator-cuff changes in asymptomatic adults. The effect of age, hand dominance and gender. *J Bone Joint Surg Br*. 1995;77(2):296-298.
19. Miyake S, Izaki T, Arashiro Y, et al. Excessively high repair tension decreases microvascular blood flow within the rotator cuff. *Am J Sports Med*. 2022;50(13):3643-3648.
20. Moser M, Jablonski MV, Horodyski M, Wright TW. Functional outcome of surgically treated massive rotator cuff tears: a comparison of complete repair, partial repair, and debridement. *Orthopedics*. 2007;30(6):479.
21. Neff P, Franklin DB 3rd, Jones DL, et al. Transtendinous rotator cuff tear repair with bone marrow aspirate concentrate dermal allograft augmentation. *Arthrosc Tech*. 2021;10(4):e975-e980.
22. Oizumi N, Suenaga N, Fukuda K, Minami A. Massive rotator cuff tears repaired on top of humeral head by McLaughlin's procedure. *J Shoulder Elbow Surg*. 2007;16(3):321-326.
23. Park S-G, Shim B-J, Seok H-G. How much will high tension adversely affect rotator cuff repair integrity? *Arthroscopy*. 2019;35(11):2992-3000.
24. Pogorzelski J, Erber B, Themessl A, et al. Definition of the terms ''acute'' and ''traumatic'' in rotator cuff injuries: a systematic review and call for standardization in nomenclature. *Arch Orthop Trauma Surg*. 2021;141:75-91.
25. Ponugoti N, Raghu A, Colaco HB, Magill H. A comparison of simple and complex single-row versus transosseous-equivalent double-row repair techniques for full-thickness rotator cuff tears: a systematic review and meta-analysis. *JSES Int*. 2022;6(1):70-78.
26. Somerson JS, Hsu JE, Gorbaty JD, Gee AO. Classifications in brief: Goutallier classification of fatty infiltration of the rotator cuff musculature. *Clin Orthop Relat Res*. 2016;474:1328-1332.
27. Uno T, Mura N, Yuki I, Oishi R, Takagi M. Factors correlated with the optimal tension for arthroscopic rotator cuff repair using Grasper Tensioning Attachment. *J Shoulder Elbow Surg*. 2022;31(5):e213-e222.
28. Walcott ME, Daniels SD, Sinz NJ, Field LD, Higgins LD. Traumatic full-thickness transtendinous rotator cuff tears: a case series. *J Shoulder Elbow Surg*. 2017;26(1):62-67.
29. Yamamoto A, Takagishi K, Osawa T, et al. Prevalence and risk factors of a rotator cuff tear in the general population. *J Shoulder Elbow Surg*. 2010;19(1):116-120.
30. Yamamoto N, Itoi E, Tuoheti Y, et al. Glenohumeral joint motion after medial shift of the attachment site of the supraspinatus tendon: a cadaveric study. *J Shoulder Elbow Surg*. 2007;16(3):373-378.
31. Ying ZM, Lin T, Yan SG. Arthroscopic single-row versus double-row technique for repairing rotator cuff tears: a systematic review and meta-analysis. *Orthop Surg*. 2014;6(4):300-312.