Arthroscopic Repair of Isolated Partial- and Full-Thickness Upper Third Subscapularis Tendon Tears: Minimum 2-Year Outcomes After Single-Anchor Repair and Biceps Tenodesis

J. Christoph Katthagen, M.D., Alexander R. Vap, M.D., Dimitri S. Tahal, M.Sc., Marilee P. Horan, M.P.H., and Peter J. Millett, M.D., M.Sc.

Purpose: To investigate outcomes of arthroscopic single-anchor repair and biceps tenodesis of partial- and full-thickness tears of the upper third subscapularis (SSC). **Methods:** Thirty-three patients with arthroscopically confirmed isolated SSC tears, Lafosse type I (>50% of the tendon thickness involved), or type II were included. All patients underwent arthroscopic subcoracoid decompression, coracoplasty if the coracohumeral distance was narrowed, biceps tenodesis, and a single-anchor repair of the upper third SSC. No other reconstructive procedures were performed. Subjective evaluations included American Shoulder and Elbow Surgeons, Short-Form 12, Quick Disabilities of the Arm, Shoulder and Hand, Single Assessment Numeric Evaluation, and visual analog scale pain scores preoperatively and at minimum 2 years postoperatively. **Results:** Thirty-one patients (n = 25 male, n = 6 female) were included in the final collective, because 2 patients refused participation. Minimum 2-year follow-up data were available for 28 of the 31 patients (90.3%). The mean age at the time of surgery was 54.8 (range, 36-71) years. The mean follow-up was 4.1 (range, 2.0-8.0) years. The results of all outcome measures improved significantly postoperatively compared with preoperative scores ($P < .05$). Patients with single-anchor repair of type II SSC tears (n = 17) had a significantly higher mean postoperative American Shoulder and Elbow Surgeons score (93.7 ± 10.8) than patients with single-anchor repair of type I SSC tears (n = 11; 86.7 ± 10.9; $P = .027$). **Conclusions:** Arthroscopic single-anchor repair of upper third SSC tendon tears led to improved function and decreased pain with high patient satisfaction. Outcomes of full-thickness upper third SSC tears were more favorable compared with outcomes of high grade partial-thickness upper third SSC tears. **Level of Evidence:** Level IV, retrospective therapeutic case series.

Symptomatic rotator cuff tears (RCTs) are common and a major contributor to shoulder dysfunction.[1,2] The subscapularis (SSC) is the only anterior, and the most powerful rotator cuff muscle, making its integrity crucial to balance the forces of the posterior rotator cuff.[3] Often overlooked and underdiagnosed with open rotator cuff surgery, SSC lesions became more recognized with the emergence of arthroscopic shoulder surgery.[4,5] In fact, the SSC was found to be involved in up to 50% of arthroscopically repaired RCTs.[6] SSC tears most commonly occur in conjunction with supraspinatus tears as anterosuperior RCTs or as massive RCTs.[7-11] Isolated tears of the SSC are less common, accounting for 3% to 5% of all arthroscopically repaired RCTs.[6,12-14]

Outcomes of arthroscopic treatment of isolated SSC tears in the literature are limited. Most outcomes studies have focused on large SSC tears with only a few studies evaluating treatment of the more commonly

From the Center for Outcomes-Based Orthopaedic Research at the Steadman Philippon Research Institute (J.C.K., A.R.V., D.S.T., M.P.H., P.J.M.), Vail, Colorado, U.S.A.; The Steadman Clinic (A.R.V., P.J.M.), Vail, Colorado, U.S.A.; and the Department of Trauma, Hand and Reconstructive Surgery, University Hospital Münster (J.C.K.), Münster, Germany.

The authors report the following potential conflicts of interest or sources of funding: Steadman Philippon Research Institute corporate sponsors are Smith & Nephew, Arthrex, Siemens, Ossur, and Vail Valley Medical Center. P.J.M. receives support from Arthrex (paid consultant), Arthrex and Springer Publishing (royalties), GameReady (stock options), and VuMedi (stock in). J.C.K.'s position was sponsored for the year by Arthrex.

Received May 11, 2016; accepted January 3, 2017.

Address correspondence to Peter J. Millett, M.D., M.Sc., Center for Outcomes-Based Orthopaedic Research, Steadman Philippon Research Institute, 181 West Meadow Drive, Suite 1000, Vail, CO 81657, U.S.A. E-mail: drmillett@thesteadmanclinic.com

0749-8063/16414/$36.00

http://dx.doi.org/10.1016/j.arthro.2017.01.027

encountered tears of the upper third of the SSC tendon.[9-25] Because the upper third of the SSC has the broadest footprint insertion, it has been suggested that the integrity of the upper third SSC is crucial for the SSC function and that these lesions should be repaired rather than debrided.[5,26] However, little is known about the results of arthroscopic single-anchor repair of partial-thickness and full-thickness tears of the upper third SSC.[9,16,18,25]

The purpose of this study was to investigate outcomes of arthroscopic single-anchor repair and biceps tenodesis of partial- and full-thickness tears of the upper third SSC. It was hypothesized that single-anchor repair of the upper third SSC would result in excellent outcomes, with improved function, decreased pain, and high satisfaction without significant differences between patient-reported outcomes of partial- and full-thickness tears.

Methods

This was an institutional review board approved Level IV, retrospective outcomes study with prospectively collected data. Between November 2005 and March 2014, the senior surgeon (P.J.M.) performed 1,082 arthroscopic rotator cuff repairs. These cases were reviewed to identify patients with arthroscopic repair of isolated SSC tendon tears without concomitant repair of the supraspinatus and/or infraspinatus tendon. The term "isolated" was defined as repair of the SSC tendon only with no other reconstructive procedures than biceps tenodesis. Patients with concomitant pathologies that were addressed with debridement and/or decompression were included. To pursue the purpose of the study, only patients with single-anchor repair of partial- (Fig 1A) or full-thickness tears of the upper third SSC (Fig 1B) were included. With regard to the anatomic extensions of the SSC footprint,[27,28] the upper third of the SSC tendon was defined as the superior 1 cm of the tendon. Partial-thickness tears were repaired if they involved more than 50% of the tendon thickness and 5 mm or more of the tendon's upper third. Patients with a grade IV cartilage lesion of the glenohumeral joint were excluded. All patients failed a minimum 3-month period of nonoperative treatment with anti-inflammatory pain medications, physiotherapy, and, in most cases, corticosteroid injections. All patients had significant pain and dysfunction of the shoulder with intraoperatively confirmed SSC tears according to the prementioned criteria.

Surgical Technique

Operations were performed using general anesthesia with additional interscalene nerve blocks with the patients positioned in the beach-chair position. Diagnostic arthroscopy was performed using standard posterior and anterior portals and a 70° arthroscope to allow for better visualization of the SSC tendon and the lesser tuberosity over the top of the humeral head. The size of the SSC tear was arthroscopically confirmed with a scaled probe. All patients underwent subcoracoid soft-tissue decompression. If the coracohumeral distance was narrowed (<10 mm in men; <8 mm in women) on preoperative magnetic resonance imaging scans, an additional coracoplasty was performed.[26] A knotted technique was performed early in the study period followed by a transition to a knotless technique later in the study period.

Knotted Repair Technique

For the knotted repair technique, a double-loaded bioabsorbable anchor (5.5 Bio Corkscrew anchor, Arthrex, Naples, FL) was placed in the region of the exposed footprint (Fig 2A). The 2 high-strength No. 2 sutures were shuttled independently through the upper portion of the SSC with a spinal needle and No. 1 polydioxanone suture (PDS; Ethicon US, Somerville, NJ) a shuttle (Fig 2B). Sliding locking Weston knots were used to secure the rotator cuff back down onto its footprint (Fig 2C). The arm was then placed through a range of motion to confirm that the SSC was secure and stable.

Knotless Repair Technique

For the knotless repair technique, a spinal needle was placed percutaneously through the tear portion and a

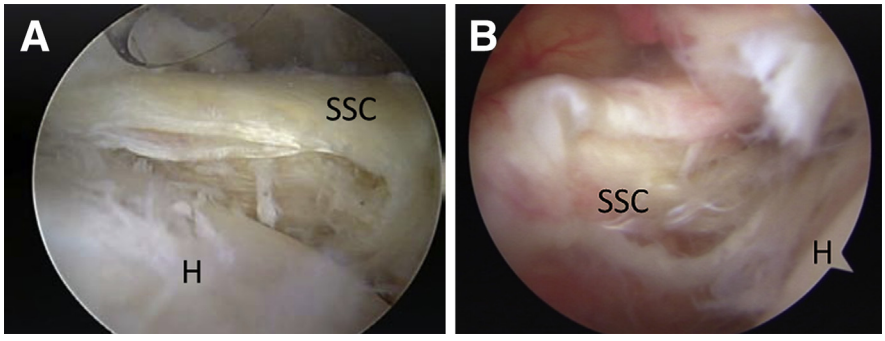

Fig 1. Intraoperative, arthroscopic views of subscapularis tears involving the upper third of the tendon, posterior viewing portal: (A) left shoulder, partial-thickness tear; (B) right shoulder, full-thickness tear. (H, humeral head; SSC, subscapularis.)

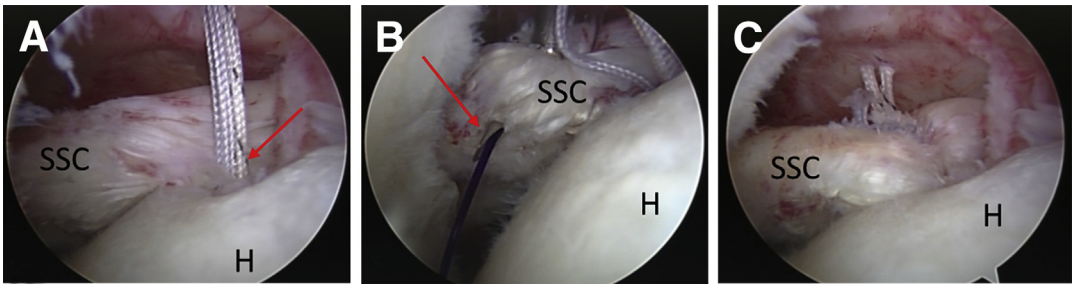

Fig 2. Right shoulder with partial-thickness upper third subscapularis (SSC) tear, posterior viewing portal. (A) After placement of a double-loaded 5.5 BioCorkscrew (Arthex, Naples, FL) (red arrow). (B) Perforation of the upper portion of the SSC with a spinal needle and a polydioxanone suture (PDS; Ethicon US, Somerville, NJ) (red arrow) using a passing technique to shuttle the sutures. (C) After securing the upper subscapularis back to its footprint on the lesser tuberosity. (H, humeral head.)

PDS was shuttled out through the anterior-superior portal.[29] Suture tape (FiberTape, Arthrex) was then passed through the upper portion of the SSC. Next, a 4.75-mm tamp was used to create a hole in the exposed anatomic SSC footprint (Fig 3A). The suture tape was passed through a bioabsorbable anchor (4.75 Bio SwiveLock, Arthrex). This was placed into the premade tamped hole and the SSC was repaired (Fig 3 B and C).

Concomitant pathologies were addressed with debridement and/or decompression as indicated. All patients had an open subpectoral biceps tenodesis, in most cases due to medial instability of the biceps tendon. None of the patients had other associated reconstructive procedures.

Outcome Measures

Subjective evaluations were obtained via a mailed questionnaire with the American Shoulder and Elbow Surgeons (ASES), Quick Disabilities of the Arm, Shoulder and Hand, Single Assessment Numeric Evaluation, Short-Form 12 Physical Component Summary, and visual analog scale "pain today" and "pain with activities of daily living" scores preoperatively and at minimum 2 years postoperatively. Pre- and postoperative outcome scores were compared for the whole group. Postoperative outcomes of type I tears were compared with those of type II tears.

Statistical Analysis

Pre- and postoperative outcome scores of the entire collective were compared with the Wilcoxon signed-rank test. The postoperative outcomes of patients with type I and type II tears were compared with the Mann-Whitney *U*-test. The difference of the Pseudo-Median between both groups was given along with the 95% confidence interval to report the similarity of outcomes. To investigate if the repair technique would influence postoperative outcomes, results of patients treated with the knotted technique were compared with those treated with the knotless technique. All statistical analyses and graphics were produced using the statistical programming language R version 3.2.3 (R Development Core Team, Vienna, Austria). The level of significance was set at $P < .05$.

Results

Thirty-eight rotator cuff repairs involved only the upper third of the SSC tendon. Five patients had to be excluded (n = 4 with 2 anchors, n = 1 with grade IV cartilage lesions), leaving 33 patients eligible for inclusion (Fig 4). Two patients refused participation. Minimum 2-year follow-up data were available for 28 of the remaining 31 patients (90.3%; n = 25 male, n = 6 female; n = 11 of 12 type I, n = 17 of 19 type II).

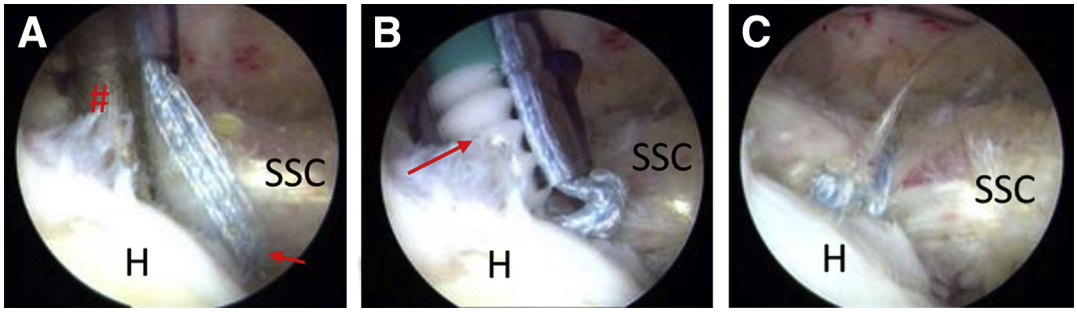

Fig 3. Left shoulder with partial-thickness upper third subscapularis (SSC) tear, posterior viewing portal. (A) Creating a hole in the anatomic SSC footprint with a tamp (#). The FiberTape has been passed through the upper SSC tendon (red arrow). (B) Repairing the SSC by securing the FiberTape with a 4.75 Bio SwiveLock (Arthrex, Naples, FL) (red arrow) to the premade hole. (C) After securing the upper SSC back to its footprint on the lesser tuberosity. (H, humeral head.)

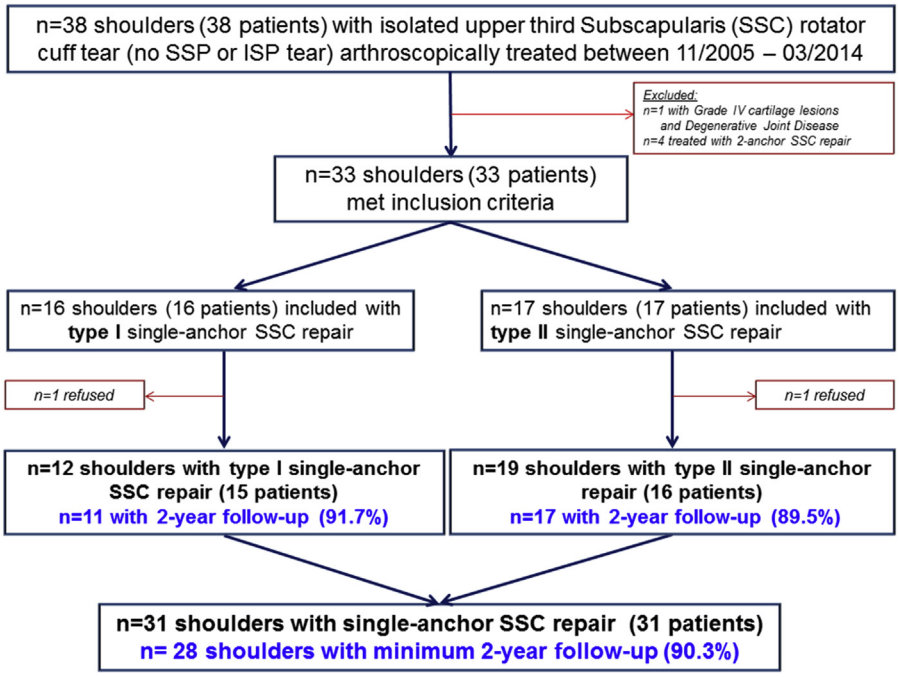

Fig 4. Patient flowchart showing initial patient collective, excluded patients, and final groups. (ISP, infraspinatus; SSP, supraspinatus.)

The mean age at the time of surgery was 54.8 (range, 36-71) years and the mean follow-up was 4.1 (range, 2.0-8.0) years. The results of all outcome measures improved significantly postoperatively (Table 1). The median postoperative patient satisfaction was 10 of 10 (range, 1-10).

Type I Versus Type II SSC Tears

Patients with single-anchor repair of a type II SSC tear (knotted or knotless repair) were found to a have significantly higher mean postoperative ASES score (93.7 ± 10.8) than patients with single-anchor repair of a type I SSC tear (86.7 ± 10.9; $P = .033$). All other scores were also in favor of type II tear repair; however, they were not significantly different ($P > .05$; Table 2).

Table 1. Comparison of Pre- and Postoperative Outcome Parameters (Mean ± Standard Deviation) of the Entire Patient Group

Outcome Measure	Preoperative	Postoperative	Significance (P Value)
ASES score	54.1 ± 19.7	90.8 ± 11.2	<.001*
SANE	56.4 ± 19.2	86.3 ± 17.9	.003*
QuickDASH	44.9 ± 13.9	12.7 ± 14.5	.002*
SF-12 PCS	42.2 ± 7.2	52.4 ± 6.0	<.001*
VAS "pain today"	4.2 ± 2.8	0.8 ± 1.2	<.001*
VAS "pain with activities of daily living"	2.1 ± 0.7	0.4 ± 0.7	<.001*

ASES, American Shoulder and Elbow Surgeons; QuickDASH, Quick Disabilities of the Arm, Shoulder and Hand; SANE, Single Assessment Numeric Evaluation; SF-12 PCS, Short-Form 12 Physical Component Summary; VAS, visual analog scale.
*Indicates a significant difference.

The distribution of concomitant procedures performed along with the SSC repair was similar between groups (Table 3).

Knotted Versus Knotless Repair

The mean follow-up of patients with knotted SSC repair (n = 13) was significantly longer (mean 5.7 years; range, 2.0-8.0 years) than that of patients with knotless SSC repair (n = 15; mean 2.8 years; range, 2.0-4.9 years; $P < .001$). Outcomes of the knotless SSC repair technique were similar to outcomes of the knotted SSC repair technique (Table 4).

Discussion

The most important finding of this study was that arthroscopic single-anchor repair of upper third SSC tendon tears resulted in excellent outcomes, with improved function, decreased pain, and high satisfaction. Arthroscopic single-anchor repair resulted in more favorable results for complete tears of the upper third SSC (Lafosse type II) than for partial tears involving more than 50% of the upper third SSC tendon thickness (Lafosse type I).

Although several other studies have included patients with debridement or anchor repair of partial- and full-thickness tears of the upper third SSC, the outcomes of their treatment have not been reported separately from those of larger tears.[6,8,10-13,15] A comparison of the results of this study with pre-existing results was not possible with regard to single-anchor repair of Lafosse type II tears, because no comparable data were found in the published literature.

Table 2. Comparison of Postoperative Outcome Scores (Mean ± Standard Deviation) of Patients With Type I and Type II Subscapularis Tears

Outcome Measure	Type I Tear (n = 11)	Type II Tear (n = 17)	Significance (*P* Value)	Pseudo-Median Difference	Confidence Interval (LB; UB)
ASES score	86.7 ± 10.9	93.7 ± 10.8	.027*	−6.1	−13.4; 0.0
SANE	81.5 ± 22.3	89.9 ± 13.6	.11	−5.0	−12.0; 1.0
QuickDASH	18.4 ± 17.9	8.8 ± 10.4	.15	6.8	−2.2; 22.8
SF-12 PCS	50.3 ± 7.7	53.6 ± 4.5	.59	−1.3	−9.1; 2.0
VAS "pain today"	1.1 ± 1.2	0.5 ± 1.2	.11	0.0	0.0; 2.0
VAS "pain with activities of daily living"	0.6 ± 0.8	0.3 ± 0.6	.26	0.0	0.0; 1.0

ASES, American Shoulder and Elbow Surgeons; LB, lower boundary of the 95% confidence interval; QuickDASH, Quick Disabilities of the Arm, Shoulder and Hand; SANE, Single Assessment Numeric Evaluation; SF-12 PCS, Short-Form 12 Physical Component Summary; UB, upper boundary of the 95% confidence interval; VAS, visual analog scale.
*Indicates a significant difference.

The ideal treatment of type I SSC tears according to Lafosse (partial tears of the upper third) SSC remains a matter of debate. Some authors advocate an arthroscopic repair of these tears.[5,18] Kim et al.[18] reported excellent outcomes of 31 patients with arthroscopic anchor repair of isolated partial articular-sided SSC tears. Sixteen of these tears could be classified as type I tears. At a mean follow-up of 27 months postoperatively, the mean ASES was 96 ± 7 for the entire group and mean visual analog scale pain was 0.3 ± 0.7. Randelli et al.[25] conducted a prospective randomized study with comparison of shaving (debridement) and repair for partial-thickness articular-sided tears of the upper SSC in association with posterosuperior supraspinatus tears and long head of the biceps tendon treatment. Of the initially included 28 patients, follow-up data were available for 20 patients (n = 11 with repair and n = 9 with debridement). Because no significant differences were found between the groups, the authors concluded that either simple shaving or a tendon-to-bone repair of a partial-thickness articular-sided tear of the upper SSC tendon, when limited to the superior centimeter of the SSC tendon, shows comparable performance in terms of strength in internal rotation.[25] The Constant Score and Disabilities of the Arm, Shoulder and Hand score were in favor of the debridement group, without reaching statistical significance. It has to be noted that 11 of 20 included patients had a limited partial-thickness tear of the upper third with involvement of less than 30% of the tendon thickness. Gerhardt et al.[9] reported outcomes of 68 prospectively enrolled patients with 2-year follow-up after arthroscopic treatment of isolated anterior and combined anterosuperior rotator cuff lesions. The authors reported that patients with small SSC partial tears treated with debridement alone reached full SSC function postoperatively without residual SSC deficiency. In this study, patients with arthroscopic single-anchor repair of high-grade partial-thickness tears of the upper third SSC had a significantly lower mean ASES score and statistically nonsignificant lower outcomes in the Single Assessment Numeric Evaluation, Short-Form 12 Physical Component Summary, and Quick Disabilities of the Arm, Shoulder and Hand scores when compared with patients with repair of type II tears. Findings reported in the literature and findings in this study suggest that debridement seems to be the ideal treatment for low-grade partial-thickness upper third SSC tears. Findings in this study and those by Randelli et al.[25] suggest that this may apply for high-grade partial-thickness tears too; however, further research is warranted to determine the ideal treatment for these tears.

Unexpectedly, the postoperative ASES score of patients with type I SSC tear was significantly lower than of patients with type II SSC tear. A possible explanation

Table 3. Concomitant Procedures Performed With Single-Anchor Repair of Type I and Type II Upper Third Subscapularis Tendon Tears

Concomitant Procedures	Type I (n = 12 Patients)	Type II (n = 19 Patients)
Subacromial decompression ± acromioplasty	11	18
Coracoplasty	9	17
Debridement ± healing response of supraspinatus partial tear	3	9
Debridement of SLAP 1	6	5
Debridement of anterior/posterior labrum	7	16
Chondroplasty	2	2
Distal clavicle resection	1	2
Total number of concomitant procedures	n = 39 (mean of 3.3 per patient)	n = 69 (mean of 3.6 per patient)

NOTE. All patients received subpectoral biceps tenodesis or had a prior biceps tenodesis.

Table 4. Comparison of Postoperative Outcome Scores (Mean ± Standard Deviation) of Patients With Knotted and Knotless Repair Techniques

Outcome Measure	Knotted Repair Group (n = 13)	Knotless Repair Group (n = 15)	Significance (*P* Value)	Pseudomedian Difference	Confidence Interval (LB; UB)
ASES score	90.6 ± 11.8	91.0 ± 11.2	>.99	0.0	−6.6; 8.4
SANE	84.2 ± 23.3	87.3 ± 13.5	.98	0.0	−7.0; 9.0
QuickDASH	12.9 ± 17.6	12.5 ± 12.0	.46	2.2	−6.8; 9.1
SF-12 PCS	51.3 ± 6.5	53.4 ± 5.5	.41	1.3	−2.1; 7.6
VAS "pain today"	0.8 ± 1.3	0.7 ± 1.2	>.99	0.0	0.0; 0.0
VAS "pain with activities of daily living"	0.1 ± 0.8	0.4 ± 0.6	.88	0.0	0.0; 0.0

ASES, American Shoulder and Elbow Surgeons; LB, lower boundary of the 95% confidence interval; QuickDASH, Quick Disabilities of the Arm, Shoulder and Hand; SANE, Single Assessment Numeric Evaluation; SF-12 PCS, Short-Form 12 Physical Component Summary; UB, upper boundary of the 95% confidence interval; VAS, visual analog scale.

for this rather paradoxical finding may be related to the fact that the intact portion of the upper SSC tendon is incorporated into the repair of type I SSC tears. As possible consequence, this intact portion of the SSC tendon may be exposed to overtensioning, resulting in a distorted length-tension relationship. Further research is warranted to answer this question. The minimal clinically important difference has not been defined specifically for SSC tears yet. Regarding a minimal clinically important difference of 12 to 17 points for nonoperative treatment of RCTs in general, it has to be called into question if the statistically significant difference that was found between the postoperative ASES score of type I and type II SSC tears is clinically relevant.[30]

Regarding the ideal number of anchors for repair of SSC tears, no clear, validated guidelines are available in the literature. It has been suggested that for each centimeter of SSC tendon tear, in proximal to distal direction, one suture anchor should be used.[8] Subsequently, a single anchor repair would be indicated and sufficient to repair tears of the upper third SSC. This principle is supported by a recent biomechanical evaluation of fixation strength of SSC repair, which showed that SSC tears involving up to 50% of the tendon footprint (Fox and Romeo and Lafosse types I-III) can reliably be repaired with a single anchor.[31]

Outcomes of the classic knotted and the newer knotless technique were equivalent in this study. In consequence, surgeons can be assured that either technique can provide equally excellent outcomes. However, the knotless technique may have some practical advantages over knotted techniques. Knotless repair techniques do not require knot-tying that limits the amount of work necessary in the tight subcoracoid space. The technique is potentially easier to perform than a knotted SSC repair and may reduce the surgical time needed, which is already limited due to rapid and progressive anterior soft tissue swelling.[5,24] Knotless repair techniques furthermore offer the option to use wider tape sutures that may provide a stronger fixation with improved cut-through resistance in degenerative tissue.[23] Finally, because of the lower profile of the knotless repair, there is less risk of irritation in the joint or subcoracoid space. The comparison of knotted and knotless techniques has been moved out of the main focus of the study. The change in technique was a decision made by the senior author based on biomechanical findings with regard to knotless tape-bridging techniques used for the supraspinatus.

With regard to current knowledge, arthroscopic treatment of symptomatic upper third SSC tears with failed nonoperative treatment results in significant improvement of postoperative outcomes. Therefore, patients with persistent, refractory anterior shoulder pain benefit from diagnosis and arthroscopic treatment of upper third SSC tears. The diagnosis of upper third SSC tears, however, is more difficult than that of SSC tears involving larger parts of the tendon because of the limited sensitivity of magnetic resonance imaging and physical findings.[14] Tears of the upper third are less commonly caused by traumatic events, are often associated with subcoracoid impingement, and are less commonly associated with other pathologies seen with larger SSC tears.[5,14,26] Many of these tears are partial-thickness, articular-sided tears and appear as "hidden lesions."[23,32-35] Visualization of the SCC with both 30° and 70° arthroscopes from both posterior and anterior portals, and use of shoulder elevation and internal rotation, can help to avoid missing such SSC tears intraoperatively in patients with persistent, refractory anterior shoulder pain.[4,36]

Limitations

This study has several limitations that should be respected when interpreting the results. First, no imaging was used to investigate and compare structural outcomes. Second, no examination of the patients with SSC specific tests (such as the Belly-press test, Bear-hug test, or Lift-off test) was conducted to assess the specific SSC function at the final follow-up. Third, no control group with debridement or nonoperative treatment was available to validate the benefit of arthroscopic single-anchor repair over other treatments. Although

only "isolated" SSC repairs without additional reconstructive procedures other than biceps tenodesis were included, the influence of debridement and decompression of other concomitant pathologies remains unknown. However, treatment of concomitant lesions, which are frequently reported in association with "isolated" SSC tears, is inevitable.[6,15,16,19] Because more patients we not eligible for inclusion in this study, a prehoc power analysis was not appropriate. The fact that comparison between the groups' outcome scores did not reach statistically significant differences was likely related to a type II(β) error.

Conclusions

Arthroscopic single-anchor repair of upper third SSC tendon tears led to improved function and decreased pain with high patient satisfaction. Outcomes of full-thickness upper third SSC tears were more favorable compared with outcomes of high grade partial-thickness upper third SSC tears.

Acknowledgment

The authors thank Grant J. Dornan, M.Sc., for his assistance with statistical analysis.

References

1. Clayton RA, Court-Brown CM. The epidemiology of musculoskeletal tendinous and ligamentous injuries. *Injury* 2008;39:1338-1341.
2. Minagawa H, Yamamoto N, Abe H, et al. Prevalence of symptomatic and asymptomatic rotator cuff tears in the general population: From mass-screening in one village. *J Orthop* 2013;10:8-12.
3. Keating JF, Waterworth P, Shaw-Dunn J, Crossan J. The relative strengths of the rotator cuff muscles. A cadaver study. *J Bone Joint Surg Br* 1993;75:137-140.
4. Bennett WF. Arthroscopic subscapularis repair: A look at primacy from a historical perspective. *Arthroscopy* 2014;30:661-664.
5. Denard PJ, Burkhart SS. Arthroscopic recognition and repair of the torn subscapularis tendon. *Arthrosc Tech* 2013;2:e373-e379.
6. Lafosse L, Jost B, Reiland Y, Audebert S, Toussaint B, Gobezie R. Structural integrity and clinical outcomes after arthroscopic repair of isolated subscapularis tears. *J Bone Joint Surg Am* 2007;89:1184-1193.
7. Denard PJ, Jiwani AZ, Lädermann A, Burkhart SS. Long-term outcome of a consecutive series of subscapularis tendon tears repaired arthroscopically. *Arthroscopy* 2012;28:1587-1591.
8. Van der Zwaal P, Schuller L, Urlings TAJ, Coerkamp EG, van Arkel ERA, van der List MPJ. Clinical outcome and structural integrity of all-arthroscopic repair of degenerative subscapularis tendon tears. *Knee Surg Sports Traumatol Arthrosc* 2013;21:1620-1625.
9. Gerhardt C, Bartl C, Voigt C, et al. Recovery of subscapularis and shoulder function following arthroscopic treatment of isolated anterior and combined anterosuperior rotator cuff lesions. *Arch Orthop Trauma Surg* 2016;136:75-81.
10. Toussaint B, Audebert S, Barth J, et al. Arthroscopic repair of subscapularis tears: Preliminary data from a prospective multicenter study. *Orthop Trauma Surg Res* 2012;98:S193-S200 (suppl).
11. Adams CR, Schoolfield JD, Burkhart SS. The results of arthroscopic subscapularis tendon repairs. *Arthroscopy* 2008;24:1381-1389.
12. Nove-Josserand L, Hardy MB, Ogassawara RLN, Carrillon Y, Godeneche A. Clinical and structural results of arthroscopic repair of isolated subscapularis tear. *J Bone Joint Surg Am* 2012;94:e125.
13. Heikenfeld R, Gigis I, Chytas A, Listringhaus R, Godolias G. Arthroscopic reconstruction of isolated subscapularis tears: Clinical results and structural integrity after 24 months. *Arthroscopy* 2012;28:1805-1811.
14. Naimark M, Zhang AL, Leon I, Trivellas A, Feeley BT, Ma CB. Clinical, radiographic, and surgical presentation of subscapularis tendon tears: A retrospective analysis of 139 patients. *Arthroscopy* 2016;32:747-752.
15. Bartl C, Salzmann GM, Seppel G, et al. Subscapularis function and structural integrity after arthroscopic repair of isolated subscapularis tears. *Am J Sports Med* 2011;39:1255-1262.
16. Mancuso F, Di Benedetto P, Beltrame A, Cainero V, Causero A. Arthroscopic treatment of isolated subscapularis lesions: Our experience. *Acta Biomed* 2014;85:20-24 (suppl 2).
17. Osti L, Soldati F, Buono AD, Buda M. Arthroscopic repair of the subscapularis tendon: Indications, limits and technical features. *Muscles Ligaments Tendons J* 2013;3:213-239.
18. Kim SH, Oh I, Park JS, Shin SK, Jeong WK. Intra-articular repair of an isolated partial articular-surface tear of the subscapularis tendon. *Am J Sports Med* 2005;33:1825-1830.
19. Bennett WF. Arthroscopic repair of isolated subscapularis tears: A prospective cohort with 2- to 4-year follow-up. *Arthroscopy* 2003;19:131-143.
20. Grueninger P, Nikolic N, Scheider J, et al. Arthroscopic repair of traumatic isolated subscapularis tendon lesions (Lafosse type III or IV): A prospective magnetic resonance imaging-controlled case series with 1 year of follow-up. *Arthroscopy* 2014;30:665-672.
21. Mall NA, Chahal J, Heard WM, et al. Outcomes of arthroscopic and open surgical repair of isolated subscapularis tendon tears. *Arthroscopy* 2012;28:1306-1314.
22. Burkhart SS, Tehrany AM. Arthroscopic subscapularis tendon repair: Technique and preliminary results. *Arthroscopy* 2002;18:454-463.
23. Denard PJ, Burkhart SS. A new method for knotless fixation of an upper subscapularis tear. *Arthroscopy* 2011;27:861-866.
24. Gilmer BB, Crall TS, Guttmann D. Knotless arthroscopic repair of subscapularis tendon tears using looped suture. *Arthrosc Tech* 2015;4:e267-e271.
25. Randelli P, Arrigoni P, Aliprandi A, et al. Repair versus shaving of partial-thickness articular sided tears of the upper subscapularis tendon. A prospective randomized controlled trial. *Joints* 2015;3:109-115.

26. Burkhart SS, Brady PC. Arthroscopic subscapularis repair: Surgical tips and pearls A to Z. *Arthroscopy* 2006;22:1014-1027.
27. Richards DP, Burkhart SS, Tehrany AM, Wirth MA. The subscapularis footprint: An anatomic description of its insertion site. *Arthroscopy* 2007;23:251-254.
28. Ide J, Tokiyoshi A, Hirose J, Mizuta H. An anatomic study of the subscapularis insertion to the humerus: The subscapularis footprint. *Arthroscopy* 2008;24:749-753.
29. Vaishnav S, Millett PJ. Arthroscopic rotator cuff repair: Scientific rational, surgical technique, and early clinical and functional results of a knotless self-reinforcing double-row rotator cuff repair system. *J Shoulder Elbow Surg* 2010;19:83-90.
30. Tashjian RZ, Deloach J, Green A, Porucznik CA, Powell AP. Minimal clinically important differences in ASES and simple shoulder test scores after nonoperative treatment of rotator cuff disease. *J Bone Joint Surg Am* 2010;92:296-303.
31. Lorbach O, Trennheuser C, Kieb M, Efe T, Kohn D, Anagnostakos K. Reconstruction of 25 and 50 % subscapularis tears: A single anchor with a double-mattress suture is sufficient for the reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2016;24:3855-3862.
32. Walch G, Nove-Josserand L, Levigne C, Renaud E. Tears of the supraspinatus tendon associated with "hidden" lesions of the rotator interval. *J Shoulder Elbow Surg* 1994;3:353-360.
33. Braun S, Millett PJ, Yongpravat C, et al. Biomechanical evaluation of shear force vectors leading to injury of the biceps reflection pulley: A biplane fluoroscopy study on cadaveric shoulders. *Am J Sports Med* 2010;38:1015-1024.
34. Gaskill TR, Braun S, Millett PJ. Multimedia article. The rotator interval: Pathology and management. *Arthroscopy* 2011;27:556-567.
35. Braun S, Horan MP, Elser F, Millett PJ. Lesions of the biceps pulley. *Am J Sports Med* 2011;39:790-795.
36. Bennett WF. Visualization of the anatomy of the rotator interval and bicipital sheath. *Arthroscopy* 2001;17:107-111.