J Shoulder Elbow Surg (2019) 28, 706–714

JOURNAL OF SHOULDER AND ELBOW SURGERY

www.elsevier.com/locate/ymse

Long-term results after arthroscopic transosseous rotator cuff repair

Fabian Plachel, MD[a,b,c,*], Andreas Traweger, PhD[c], Imre Vasvary, MD[d], Jakob E. Schanda, MD[e], Herbert Resch, MD[a], Philipp Moroder, MD[a,b]

[a]*Department of Orthopedics and Traumatology, Paracelsus Medical University, Salzburg, Austria*
[b]*Center for Musculoskeletal Surgery, Campus Virchow, Charité–Universitaetsmedizin Berlin, Berlin, Germany*
[c]*Institute of Tendon and Bone Regeneration, Spinal Cord Injury and Tissue Regeneration Center, Paracelsus Medical University, Salzburg, Austria*
[d]*Department of Radiology, Paracelsus Medical University, Salzburg, Austria*
[e]*Department of Trauma Surgery, AUVA Trauma Center Meidling, Vienna, Austria*

Background: The purpose of this study was to evaluate the long-term clinical and radiologic results after arthroscopic transosseous rotator cuff repair (TORCR).
Methods: A total of 69 patients with full-thickness supraspinatus tendon tears with or without infraspinatus tendon tears treated with arthroscopic TORCR by a single surgeon between 1998 and 2003 were included. Among them, 56 patients (81%) with a mean age of 58 ± 5 years (range, 42-70 years) were available for final follow-up examination after an average of 15 ± 2 years (range, 12-18 years). The Subjective Shoulder Value, Constant score (CS), University of California at Los Angeles score, and American Shoulder and Elbow Surgeons score were recorded. Magnetic resonance imaging (MRI) was performed to visualize tendon integrity in 66% of patients.
Results: At final follow-up, the mean CS was 84 ± 8 points; mean University of California at Los Angeles score, 33 ± 2 points; mean American Shoulder and Elbow Surgeons score, 92 ± 10 points; and mean Subjective Shoulder Value, 89% ± 17%. MRI revealed asymptomatic repair failure in 9 patients (27%). Moreover, 4 patients (7%) underwent revision surgery because of a symptomatic rerupture, resulting in an overall retear rate of 33%. Patients with intact repairs at final follow-up showed a significantly higher CS ($P = .019$) and abduction strength ($P = .016$) than patients with retears.
Conclusion: Arthroscopic TORCR for the treatment of full-thickness rotator cuff tears provided good clinical results 12 to 18 years after surgery. Cuff integrity on follow-up MRI scans had a positive effect on the clinical outcome.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Rotator cuff tear; arthroscopy; transosseous fixation technique; long-term follow-up; cuff integrity; magnetic resonance imaging

The prevalence of a rotator cuff tear (RCT) significantly increases with age, posing one of the most common causes of shoulder pain and restricted movement.[28] In the presence of a symptomatic RCT, surgical reconstruction of the rotator

This retrospective investigation was approved by the local ethical committee (Ethikkommission Land Salzburg, 415-EP/73/594-2015).

*Reprint requests: Fabian Plachel, MD, Center for Musculoskeletal Surgery, Campus Virchow, Charité–Universitaetsmedizin Berlin, Augustenburger Platz 1, Berlin 13353, Germany.

E-mail address: fabian.plachel@charite.de (F. Plachel).

1058-2746/$ - see front matter © 2018 Journal of Shoulder and Elbow Surgery Board of Trustees. All rights reserved.
https://doi.org/10.1016/j.jse.2018.09.003

cuff is the preferred treatment to reduce pain and restore function. Despite the achievement of satisfactory clinical outcomes, a high failure rate has been reported, regardless of which technique is used.[18,19,30] With technical innovations and surgical modifications, there has been a shift from mini-open to arthroscopic approaches in rotator cuff surgery.[31] Along with the rise in arthroscopic procedures, suture anchor repair techniques have replaced the former fixation techniques using transosseous sutures.

Nevertheless, several studies have reported consistently high retear rates ranging from 12% to 40% at short-term to midterm follow-up despite technical innovations.[6,17] This fact, together with the increasingly cost-conscious environment, led to an upward trend for some surgeons to prefer the traditional fixation techniques using the concept of transosseous rotator cuff repair (TORCR).[1,7,8,15,21,22] Although various arthroscopic techniques using transosseous sutures have proved to achieve equivalent clinical and radiologic outcomes without affecting surgical time at short-term to midterm follow-up, no long-term outcome studies of arthroscopic transosseous repair techniques are present in the current literature.[5,22,25]

The purpose of this retrospective study was to evaluate the long-term clinical and radiologic results of arthroscopic TORCR. We hypothesized that arthroscopic TORCR would provide durable clinical results along with a high patient satisfaction rate at long-term follow-up.

Methods

Patient selection

All patients treated with arthroscopic TORCR for symptomatic full-thickness tears of the supraspinatus tendon (SSP) with or without infraspinatus tendon (ISP) tears by a single surgeon (H.R.) between January 1998 and December 2003 were identified from our institutional shoulder database and included in this retrospective analysis. The exclusion criteria for this study were (1) involvement of the subscapularis tendon (SSC) at the time of surgery, (2) concomitant glenohumeral pathologies except for lesions of the long head of the biceps tendon (LHB), and (3) previous surgical procedures on the affected shoulder. All previously identified patients were then asked to return for clinical and radiologic evaluation in 2015.

Preoperative assessment

Recorded patient demographic characteristics included age at the time of surgery, sex, hand dominance, and subjective shoulder history including the time interval from symptom onset to surgery. Preoperative magnetic resonance imaging (MRI) was performed to confirm the diagnosis of a RCT. Operative reports were reviewed to determine tear size, as well as biceps procedure, acromioplasty, and suture configuration applied during rotator cuff repair. The anteroposterior (AP) tear size was classified intraoperatively according to Bayne and Bateman,[3] indicating a small (<1 cm), medium (1 to <3 cm), large (3 to <5 cm), or massive (>5 cm) cuff tear.

Surgical technique

The indication for arthroscopic TORCR was a RCT with sufficient mobility to allow for anatomic attachment of the tendon stump to the insertion site at the greater tuberosity (Fig. 1). The surgical procedures were performed by a single surgeon (H.R.) in all patients.

Under general anesthesia, the patient was placed in the beach-chair position with the affected arm prepared and draped in a sterile fashion. After diagnostic arthroscopy, a lesion of the LHB was directly addressed by performing a tenotomy next to the origin on the superior labrum. An acromioplasty limited to the anterolateral aspect of the acromion was performed to improve the overall view while proceeding with the tendon repair. A full-radius shaver was then used to lightly decorticate the footprint on the greater tuberosity. Small pilot holes at an interval of 5 mm at the insertion area were created to prepare the cuff repair.

A "simple tunnel repair" was performed in RCTs with an AP diameter of less than 2 cm. Therefore, a high anterosuperior portal was established percutaneously. A sharp-hooked cannulated needle (Rotator Cuff Bone Stitcher; Smith & Nephew, London, UK) was then introduced to primarily thread the rotator cuff tendon approximately 1 cm medial to the lateral edge of the tear and to subsequently perforate the greater tuberosity, subsequently coming through on the lateral side (Fig. 1, *A*). A thin eyelet wire loaded with a nonabsorbable suture (either No. 2 Ethibond Excel suture [Ethicon, Somerville, NJ, USA] or No. 2 FiberWire suture [Arthrex, Naples, FL, USA]) was pulled through the cannulated needle, perforating the skin on the lateral side approximately 1.5 cm distal to the apex of the greater tuberosity. Once the cannulated needle was removed in a proximal direction, the eyelet wire together with the suture was pulled out laterally through the tendon and the bone channel (Fig. 1, *B*). A suture grasper was used to guide the caudal strand of the suture out through the working cannula placed in the lateral portal. The cranial strand of the suture was then shuttled above the rotator cuff and passed out through the same working cannula for suture management. This procedure was replicated from anterior to posterior. The number of simple transosseous tunnels was dependent on the tear size.

If the AP tear diameter was greater than 2 cm, a "combined medial and lateral tunnel repair" was performed. This configuration is composed of a medial transosseous mattress suture and simple transosseous tunnels laterally. Therefore, the first bone tunnel was created at the cartilage-bone interface in the same manner as mentioned earlier. Then, the cannulated needle was inserted through the same anterosuperior skin incision to perforate the tendon and greater tuberosity approximately 1 cm posterior to the first bone channel by internally rotating the affected arm (Fig. 1, *B*). The cranial end of the suture was subsequently passed through the tendon and greater tuberosity via an eyelet wire. To complete the medial mattress suture configuration, both strands were retrieved through the lateral working portal (Fig. 1, *C*). The repair configuration was finalized by creating lateral simple transosseous tunnels as mentioned earlier (Fig. 1, *D*). All sutures were finally tied under direct arthroscopic visualization.

Postoperatively, the affected arm was placed in a shoulder sling for 6 weeks. Pain-free passive range of motion including pendulum exercises was permitted immediately after surgery. After 6 weeks, the immobilization device was removed, and active exercises of increasing intensity were commenced.

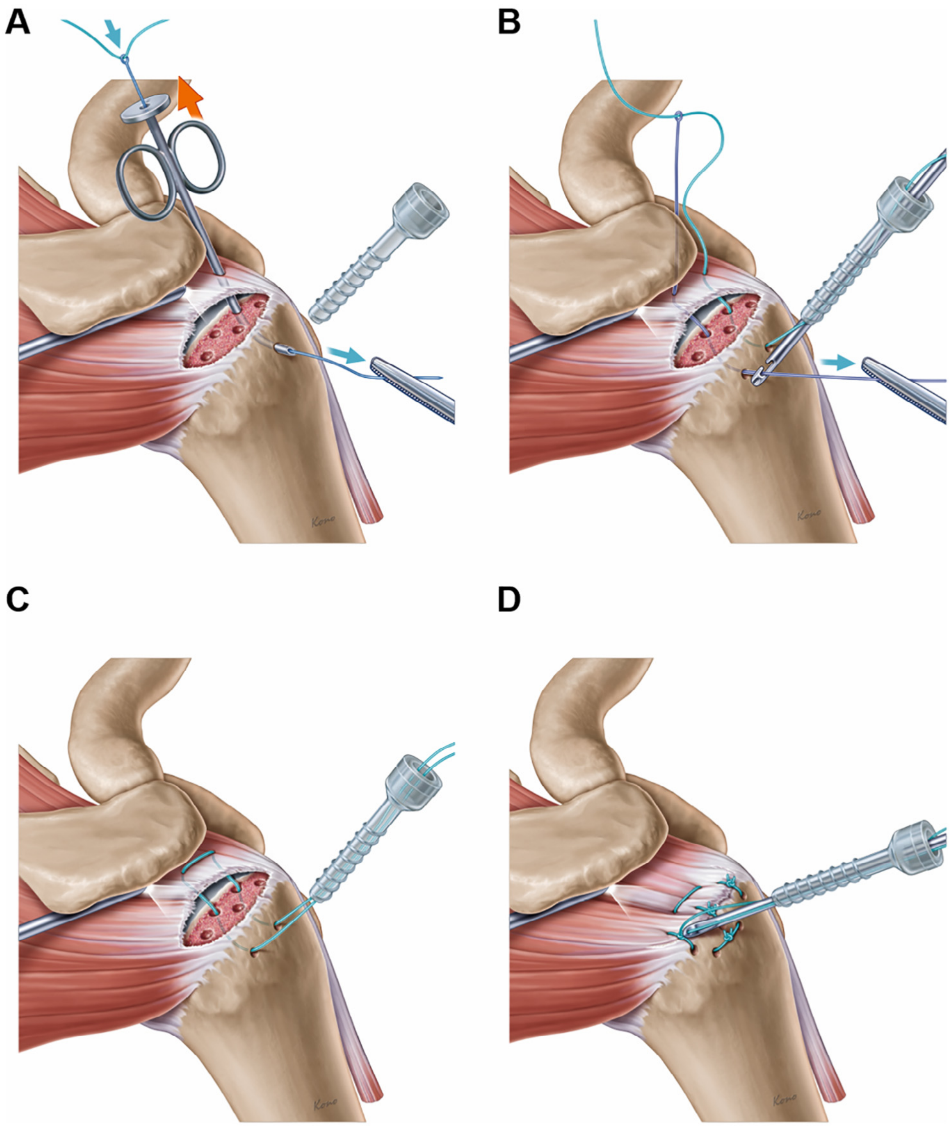

Figure 1 **(A-D)** Step-by-step illustration of arthroscopic transosseous rotator cuff repair including medial mattress suture and simple tunnels laterally. (**A**), the eyelet wire loaded with a nonabsorbable suture is pulled out latteraly (*blue arrow*) while removing the cannulated needle in a proximal direction (*orange arrow*). (**B**), the eyelet wire is pulled out latterly (*blue arrow*).

Postoperative assessment

The final follow-up examination was conducted in our outpatient clinic by the principal investigator (F.P.). Before clinical examination, all patients completed a questionnaire to record satisfaction with the outcome of surgery (very satisfied, satisfied, rather satisfied, rather unsatisfied, or unsatisfied), history of injury to the contralateral shoulder, and any complications encountered or revision surgical procedures required since the index procedure. Patients who underwent revision surgery were requested to specify the cause, date, and type of revision surgery and were subsequently excluded from final clinical and radiologic outcome evaluation but were included in the analysis of failure.

The Constant score (CS),[12] University of California at Los Angeles shoulder score,[2] American Shoulder and Elbow Surgeons (ASES) score,[23] and Subjective Shoulder Value[16] were used to objectively and subjectively determine the clinical outcome. The primary outcome measure for functional assessment was the CS at final follow-up, with a final score of 90 to 100 points considered excellent; 80 to 89 points, good; 70 to 79 points, fair; and less than 70 points, poor. Current pain intensity was assessed using a 10-point visual analog scale (VAS) for pain. Shoulder function including active range of motion (flexion, abduction, and external and internal rotation) measured with a goniometer and strength in 90° of abduction measured with an isometer (IDO, Worcestershire, UK) was assessed for both the affected and unaffected shoulders. To evaluate the relationship between individual preoperative factors and clinical outcomes, correlation analysis was applied, considering the age at the time of surgery, time interval from symptom onset to surgery, and tear size.

MRI of the affected shoulder using a 1.5-T MRI system (Ingenia; Philips, Amsterdam, The Netherlands) was performed to evaluate tendon integrity at final follow-up. The repaired rotator cuff was assessed according to the classification system of Sugaya et al.[26] Stages

1, 2, and 3 were considered intact repairs, whereas stages 4 and 5 were categorized as reruptures. Analysis of cuff integrity on MRI was performed by a specialized musculoskeletal radiologist who was blinded to the clinical results.

Statistics

Statistical analyses were performed using SPSS Statistics software (version 21.0; IBM, Armonk, NY, USA). Descriptive statistics (mean, standard deviation, minimum, and maximum) were applied for all values. The Kolmogorov-Smirnov test was used to assess the distribution of data. Comparison of the clinical variables was performed using the dependent-samples t test for normally distributed data and the Wilcoxon signed rank test for non-normally distributed data. Either the unpaired Student t test for normally distributed data or the Mann-Whitney U test for non-normally distributed data was used to compare continuous variables between cases with intact tendons and cases either with rerupture or without MRI. Correlation was assessed by the Pearson or Spearman correlation coefficient. Multivariate analysis of variance was used to test for differences in retear rates according to tear size. The level of significance was set at $P < .05$ (2-sided).

Results

Patient data

Among 91 consecutive patients with a reparable, full-thickness posterosuperior RCT identified by review of the institutional database who received arthroscopic TORCR between 1998 and 2003, a cohort of 69 patients fulfilled the inclusion criteria and were included in the analysis. Of the 22 patients who were excluded, 12 had undergone previous surgery on the affected shoulder, 7 had an anterosuperior RCT involving the upper part of the SSC, and 3 underwent concomitant labral repair after traumatic anterior shoulder dislocation. In addition, 2 patients (3%) died of an unrelated cause and 11 patients (16%) were lost to follow-up because current contact information was lacking. Thus, 56 patients (81%) were available for final follow-up examination after an average of 15 ± 2 years (range, 12-18 years) (Fig. 2). The mean patient age at surgery was 58 ± 5 years (range, 42-70 years). There were 26 women (46%) and 30 men (54%). The dominant arm was affected in 44 patients (79%). The average duration from initial contact in our shoulder department to surgery was 11 months (range, 7-36 months).

The SSP was involved in all patients (100%). A concomitant tear of the ISP was confirmed in 17 patients (30%). There were 2 small RCTs (4%), 36 medium RCTs (64%), and 18 large RCTs (32%), with a mean AP tear diameter of 2.4 cm (range, 0.8-4.0 cm). An acromioplasty was performed in all patients (100%). In 21 patients (38%), a tenotomy of the LHB was performed. Overall, 32 patients (57%) underwent TORCR with the simple tunnel repair (mean, 3 ± 1 tunnels; range, 1-5 tunnels), whereas in 24 patients (43%), a combined medial and lateral tunnel repair was performed with a mean of 3 ± 1 simple tunnels laterally (range, 2-4 tunnels). Within the follow-up period, 21 patients (42%) received either conservative or surgical treatment of the unaffected shoulder for unspecified complaints.

Failures and revision surgical procedures

At the time of final follow-up, 6 patients (11%) had undergone revision surgery. Of these patients, 4 had undergone revision surgery because of a symptomatic rerupture of the rotator cuff. The mean period from index to revision rotator cuff surgery was 8 ± 3 years (range, 1-11 years). The mean tear size was 2.8 ± 1.0 cm (range, 1.5-4.0 cm), which was revealed during the initial surgical procedure. The first patient (a woman aged 51 years at the time of initial surgery) had persistent pain and weakness despite adequate physiotherapy, which were related to nonhealing of the repair and required open transosseous repair 7 months after index surgery. The second patient (a man aged 48 years at the time of initial surgery) sustained a traumatic rerupture of the SSP and ISP 9 years after primary reconstruction and underwent revision arthroscopically by a double-row suture anchor technique. In the third patient (a man aged 65 years at the time of initial surgery), a rerupture of the rotator cuff with tear progression was detected 10 years after arthroscopic TORCR and was treated with arthroscopic partial repair. The fourth patient (a man aged 46 years at the time of initial surgery) had a traumatic rerupture 11 years after index surgery after falling from a ladder and underwent revision with a biodegradable subacromial balloon spacer owing to the irreparability of the torn rotator cuff shown intraoperatively. The remaining 2 patients (both of whom were women aged 61 years at the time of index surgery) underwent revision arthroscopic subacromial decompression because of persistent pain and restricted range of motion 12 years after initial arthroscopic TORCR, whereby the rotator cuff was confirmed as intact.

Overall clinical outcomes

At final follow-up, all 50 patients without revision surgery were either very satisfied (n = 48, 96%) or satisfied (n = 2, 4%) with the clinical outcome of the procedure. A significant improvement in active range of motion from preoperatively to postoperatively was observed (Table I). Detailed consideration of active range of motion and abduction strength at final follow-up comparing the affected shoulder with the contralateral shoulder is outlined in Table I. The mean CS of the affected shoulder was 84 ± 8 points (range, 56-98 points); mean ASES score, 92 ± 10 points (range, 62-100 point); mean University of California at Los Angeles score, 33 ± 2 (range, 26-35 points); mean VAS score, 0.8 ± 1.3 points (range, 0.0-5.0 points); and mean Subjective Shoulder Value, 89% ± 17% (range, 30%-100%). Neither age at the time of surgery, time interval from symptom onset to cuff repair, nor tear size showed a significant influence on the clinical outcome scores at long-term follow-up (Table II).

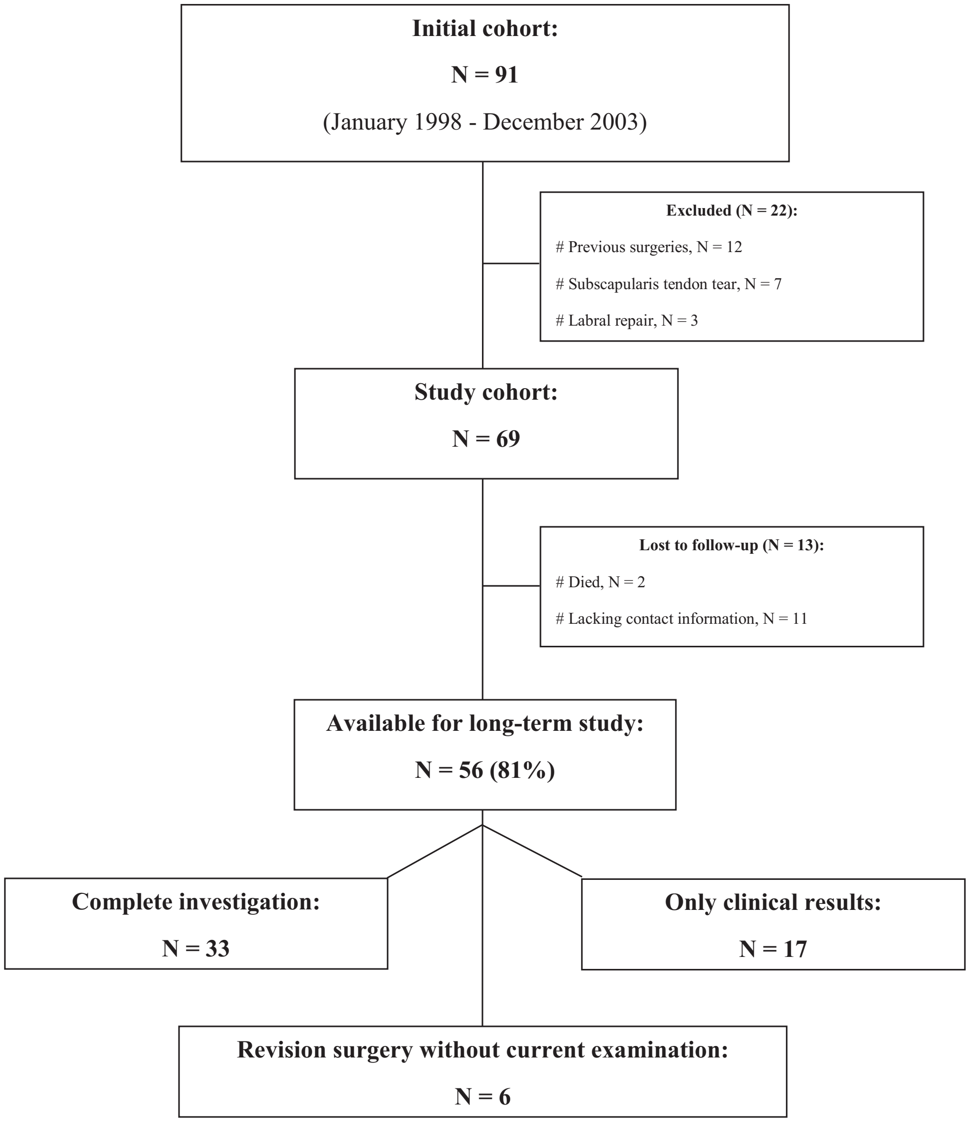

Figure 2 Flowchart of study.

Table I Preoperative and postoperative range of motion and strength

Variable	Affected arm at baseline (n = 50)	Follow-up		*P* value	
		Affected arm (n = 50)	Unaffected arm (n = 50)	Comparison of outcome of affected arm between baseline and final follow-up	Comparison between affected and unaffected arms at final follow-up
Flexion, °	130 ± 44	170 ± 11	161 ± 31	<.001	.19
Abduction, °	121 ± 48	166 ± 16	155 ± 27	<.001	.13
Constant score for internal rotation, points	7 ± 2	9 ± 1	9 ± 2	<.001	.37
External rotation, °	50 ± 12	64 ± 8	60 ± 19	<.001	.23
Constant score for external rotation, points	6 ± 3	10 ± 1	9 ± 3	<.001	.22
Abduction strength, kg	3 ± 2	7 ± 3	6 ± 3	<.001	.09

Data are reported as mean ± standard deviation.

Table II Correlations of preoperative individual factors with clinical outcome scores at final follow-up

	CS		UCLA shoulder score		ASES score		SSV	
	CC (*R*)	*P* value	CC (*R*)	*P* value	CC (*R*)	*P* value	CC (*R*)	*P* value
Age at time of surgery	−0.112	.471	−0.122	.420	−0.245	.094	−0.161	.272
Time interval from symptom onset to surgery	0.120	.431	0.008	.957	−0.021	.889	−0.187	.219
Tear size	0.031	.831	0.042	.793	−0.020	.922	0.011	.990

CS, Constant score; *UCLA*, University of California at Los Angeles; *ASES*, American Shoulder and Elbow Surgeons; *SSV*, Subjective Shoulder Value; *CC*, correlation coefficient.

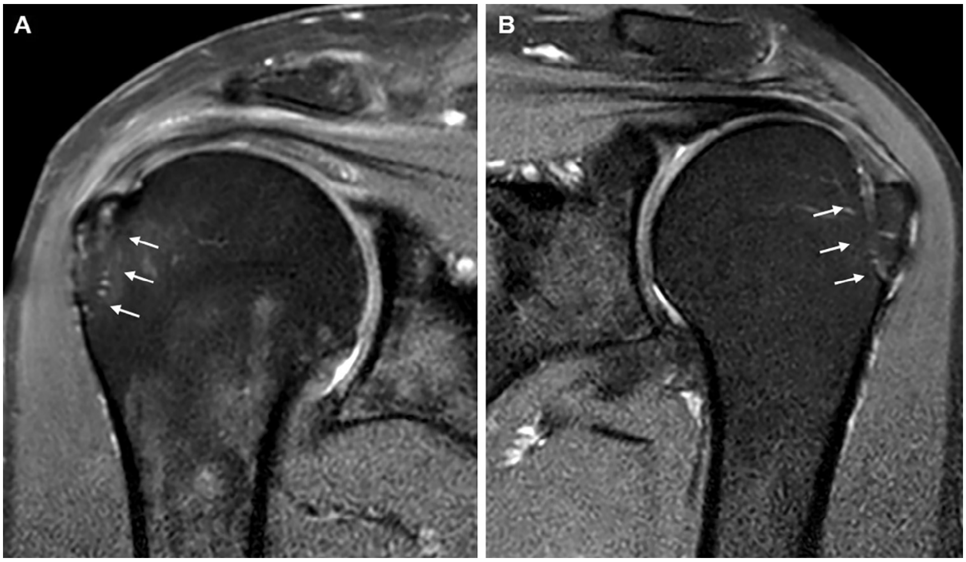

Figure 3 Postoperative magnetic resonance imaging of a right shoulder in a 75-year-old male patient with a follow-up of 14 years **(A)** and a left shoulder in a 77-year-old female patient 17 years after arthroscopic transosseous rotator cuff repair **(B)** revealed an intact cuff classified as stage 2 according to the Sugaya classification. A bone channel (*arrows*) was still visible at the greater tuberosity in both cases.

Radiologic outcomes

At final follow-up, MRI could not be performed because of a relative or absolute contraindication (eg, pacemaker or claustrophobia) in 12 patients (24%), and 5 patients (10%) refused MRI without a specific reason. Thus, radiographic assessment was conducted in 33 of 50 patients (66%) at final follow-up. On the basis of MRI findings, an asymptomatic rerupture of the rotator cuff was revealed in 9 of 33 patients (27%). Of these reruptures, 3 (9%) were graded as stage 4 and 6 (18%) were graded as stage 5 according to the Sugaya classification. Furthermore, of the intact repairs (Fig. 3), 0 (0%) were classified as stage 1, 16 (49%) were stage 2, and 8 (24%) were stage 3. Regarding tear size, the incidence of structural failure was 0% (0 of 2) for small cuff tears, 14% (5 of 36) for medium cuff tears, and 22% (4 of 18) for large cuff tears ($P = .079$). Age at the time of surgery did not significantly influence retear rate ($R = 0.104$, $P = .471$). The overall retear rate after arthroscopic TORCR was 33%, composed of 13 of 39 patients in whom either MRI or revision diagnostic arthroscopy was performed evaluating tendon integrity.

Further analyses were performed according to repair integrity at final follow-up. Among the 33 patients who underwent the entire follow-up clinical and radiologic assessment, a significant difference was found in clinical results by means of the total CS ($P = .019$) and its strength subgroup ($P = .016$) between patients with intact repairs and patients with reruptures. No further statistically significant differences in baseline patient characteristics, tear characteristics, and clinical results were detected at final follow-up (Table III). Poor clinical results in terms of the total CS (n = 2, 4%) were exclusively found in patients with MRI-proven reruptures.

Discussion

To our knowledge, this is the first study demonstrating long-term clinical and radiologic outcomes after arthroscopic TORCR. The most important finding was that this technique resulted in good functional results combined with a high satisfaction rate at an average of 15 years' follow-up and, therefore, the hypothesis was proved. Moreover, MRI-proven intact

Table III Comparison of demographic characteristics, tear size configuration, and clinical outcomes at final follow-up regarding tendon integrity

Variable	Follow-up			*P* value	
	Intact tendon (n = 24)	Rerupture (n = 9)	No MRI (n = 17)	Comparison between cases with intact tendon and rerupture at final follow-up	Comparison between cases with intact tendon and those without MRI at final follow-up
Age at time of surgery, yr	58 ± 5	56 ± 6	58 ± 6	.361	.372
SSP/SSP + ISP, %	79/21	56/44	71/29		
Tear size, cm	2.3 ± 0.6	2.4 ± 1.2	2.3 ± 1.0	.930	.611
Constant score, points	86 ± 6	79 ± 17	85 ± 7	.019	.565
Pain, points	14 ± 2	13 ± 2	14 ± 1	.241	.491
ADL, points	20 ± 1	18 ± 3	20 ± 1	.102	.865
ROM, points	38 ± 2	36 ± 4	39 ± 1	.191	.311
Strength, points	15 ± 5	10 ± 4	13 ± 6	.016	.161
UCLA shoulder score, points	33 ± 2	32 ± 3	34 ± 2	.077	.128
ASES score, points	92 ± 9	86 ± 13	95 ± 7	.201	.271
VAS score, points	0.7 ± 1.2	1.6 ± 1.9	0.4 ± 0.9	.255	.433
SSV, %	89 ± 17	76 ± 26	94 ± 8	.110	.405

MRI, magnetic resonance imaging; *SSP*, supraspinatus tendon; *ISP*, infraspinatus tendon; *ADL*, activities of daily living; *ROM*, range of motion; *UCLA*, University of California at Los Angeles; *ASES*, American Shoulder and Elbow Surgeons; *VAS*, visual analog scale; *SSV*, Subjective Shoulder Value.
Data are reported as mean ± standard deviation.

repairs yielded statistically better clinical results than reruptures in terms of overall CS and abduction strength. Nevertheless, differences in all functional outcome scores did not reach the minimal clinically important difference threshold values of approximately 10 points for the CS, 21 points for the ASES score, and 1.4 points for the VAS score.[20,27]

Transosseous suture techniques have been described as viable and reproducible fixation methods in open, mini-open, and arthroscopic repair procedures for the treatment of RCTs.[8,15,25] The surgical technique used in this study has been routinely performed at our institution for approximately 2 decades, as previously described with good clinical results at short-term follow-up.[22] To date, comparative studies of transosseous sutures and suture anchor–based fixation techniques have revealed that short-term results are comparable by means of shoulder function and retear rates.[25]

A further claim regarding this anchorless technique is that it reduces costs. Recently, Black et al[5] reported substantially reduced implant-related costs associated with the use of arthroscopic TORCR. Furthermore, Urita et al[29] demonstrated an increased blood supply after transosseous repairs compared with after suture anchor repair. This might contribute to biological healing with potential enhancement in tendon integrity in the long term.[29]

Although short-term results after arthroscopic TORCR are promising, there are no long-term studies demonstrating results after arthroscopic repairs using transosseous sutures. Available outcome studies focusing on both functional results and imaging evaluations with a minimum follow-up of 10 years have included open transosseous as well as arthroscopic suture anchor–based fixation techniques. However, these studies varied significantly based on methodologic factors, including patient demographic characteristics, repair techniques, and follow-up investigations[11,14,18,24,30] (Table IV). The studies by Vastamäki et al[30] and Paxton et al[24] reported long-term results after either rotator cuff repair combined with the use of tendon grafts or treatment of reruptures. Thus, 3 of 5 studies were regarded to be appropriate for comparison with our study, reporting on 30 to 288 patients with a mean age at surgery of 57 to 59 years.[11,14,18]

The CS was most frequently used to assess shoulder function postoperatively, and tendon integrity was evaluated by MRI at follow-up in all studies. The average CS ranged from 75 to 78 points, comparable with the final score in our study. It seems plausible that the slightly lower score of 75 points demonstrated by Elia et al[14] may be attributed either to the additional involvement of the SSC in 4 patients or to the implemented partial repair in 8 patients. Radiologic evaluation revealed a retear rate between 16% and 50% after arthroscopic suture anchor–based single-row repair and between 25% and 42% following open transosseous techniques. In our study, we found a structural failure rate of 33%, falling within the aforementioned ranges.

Contrary to the studies reporting no effect of tendon integrity on functional results at short-term to midterm follow-up,[4,10] most of the reported studies highlighted the positive clinical impact of intact repairs at long-term follow-up.[11,18] In the study by Heuberer et al,[18] differences in total CS (change of 13.3 points) reached the minimal clinically important difference (10.4 points),[20] whereas Collin et al[11] found a decrease of 5.9 points in patients with a structural failure, similar to our findings (change of 7.0 points). Therefore, it seems that

Table IV Long-term outcomes in series of rotator cuff repair

Study	No. of patients	Mean age	Mean follow-up, mo	RCT	Surgical technique	Radiologic follow-up	% rerupture	Clinical outcome
Collin et al,[11] 2017	288	57	120	SSP	Arthroscopic SR Open TO or SR	MRI	16 25	CS: 78 points SST: 10 points SSV: 85%
Heuberer et al,[18] 2017	30	57	129	SSP ± ISP	Arthroscopic SR	MRI	50	CS: 78 points UCLA: 32 points
Elia et al,[14] 2017	53	59	137	SSP ± ISP	Open TO	MRI	42	CS: 75 points SST: 10 points SSV: 83%
Paxton et al,[24] 2013	18	61	127	SSP + ISP ± SSC	Arthroscopic SR	Ultrasound	100	CS: 65 points ASES: 79 points SST: 9 points
Vastamäki et al,[30] 2013	67	52	240	SSP ± ISP ± SSC	Open TO with tendon graft	MRA	94	CS: 63 points SST: 8 points
Present study	56	58	183	SSP ± ISP	Arthroscopic TO	MRI	33	CS: 84 points ASES: 92 points UCLA: 33 points SSV: 89%

RCT, rotator cuff tear; *SSP*, supraspinatus tendon; *SR*, single-row repair; *TO*, transosseous repair; *MRI*, magnetic resonance imaging; *CS*, Constant score; *SST*, Simple Shoulder Test; *SSV*, Subjective Shoulder Value; *ISP*, infraspinatus tendon; *UCLA*, University of California at Los Angeles; *SSC*, subscapularis tendon; *ASES*, American Shoulder and Elbow Surgeons; *MRA*, magnetic resonance arthrography.

healing of the rotator cuff is beneficial to achieve good clinical results in the long-term follow-up.

Several studies have found the clinical and radiologic outcomes were negatively related to age at the time of surgery, as well as tear size.[9,11] Diebold et al[13] demonstrated that reruptures after arthroscopic rotator cuff repair increased linearly in patients aged 50 to 70 years, with maximization from age 70 years onward. On the basis of our study results, we could not confirm patient age as a significant determinant of outcomes. This could be explained by our study cohort's lack of patients older than 70 years. There was a trend toward RCT size being associated with reruptures at final follow-up, although this did not reach significance. Although no reruptures were found in patients treated for small RCTs, reruptures occurred in 14% of medium tears and 22% of large tears.

This study was limited by the retrospective design and the lack of complete preoperative clinical and radiologic data. Thus, multiple regression analysis could not be performed. Another limitation is the incomplete radiologic follow-up, which can lead to an underestimation of the true rerupture rate.

The main strength of this study is that this is the first long-term assessment of both clinical and MRI-based radiologic outcomes after TORCR. Moreover, all patients were treated by a single surgeon, thus reducing both indication and treatment bias. Further comparative studies demonstrating the differences between arthroscopic transosseous and arthroscopic anchor-based rotator cuff repair techniques will be necessary.

Conclusion

Arthroscopic TORCR for the treatment of full-thickness RCTs involving the SSP with or without ISP tears provided good clinical results 12 to 18 years after surgery. Cuff integrity on follow-up MRI scans had a positive effect on the clinical outcome.

Disclaimer

This study was funded by a non-industry related fund (Lorenz Böhler Fund, Vienna, Austria, Project Number 1.15).

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Adla DN, Rowsell M, Pandey R. Cost-effectiveness of open versus arthroscopic rotator cuff repair. J Shoulder Elbow Surg 2010;19:258-61. http://dx.doi.org/10.1016/j.jse.2009.05.004
2. Amstutz HC, Sew Hoy AL, Clarke IC. UCLA anatomic total shoulder arthroplasty. Clin Orthop Relat Res 1981;(155):7-20.
3. Bayne O, Bateman JE. Long-term results of surgical repair of full-thickness rotator cuff tears. In: Bateman JE, Welsch RP, editors. Surgery of the shoulder. Philadelphia: CV Mosby; 1984. p. 167-71.

4. Bennett WF. Arthroscopic repair of full-thickness supraspinatus tears (small-to-medium): a prospective study with 2- to 4-year follow-up. Arthroscopy 2003;19:249-56. http://dx.doi.org/10.1053/jars.2003.50083
5. Black EM, Austin LS, Narzikul A, Seidl AJ, Martens K, Lazarus MD. Comparison of implant cost and surgical time in arthroscopic transosseous and transosseous equivalent rotator cuff repair. J Shoulder Elbow Surg 2016;25:1449-56. http://dx.doi.org/10.1016/j.jse.2016.01.003
6. Boileau P, Brassart N, Watkinson DJ, Carles M, Hatzidakis AM, Krishnan SG. Arthroscopic repair of full-thickness tears of the supraspinatus: does the tendon really heal? J Bone Joint Surg Am 2005;87:1229-40. http://dx.doi.org/10.2106/jbjs.d.02035
7. Churchill RS, Ghorai JK. Total cost and operating room time comparison of rotator cuff repair techniques at low, intermediate, and high volume centers: mini-open versus all-arthroscopic. J Shoulder Elbow Surg 2010;19:716-21. http://dx.doi.org/10.1016/j.jse.2009.10.011
8. Cicak N, Klobucar H, Bicanic G, Trsek D. Arthroscopic transosseous suture anchor technique for rotator cuff repairs. Arthroscopy 2006;22:565.e1-6. http://dx.doi.org/10.1016/j.arthro.2005.07.029
9. Cofield RH, Parvizi J, Hoffmeyer PJ, Lanzer WL, Ilstrup DM, Rowland CM. Surgical repair of chronic rotator cuff tears. A prospective long-term study. J Bone Joint Surg Am 2001;83:71-7.
10. Cole BJ, McCarty LP III, Kang RW, Alford W, Lewis PB, Hayden JK. Arthroscopic rotator cuff repair: prospective functional outcome and repair integrity at minimum 2-year follow-up. J Shoulder Elbow Surg 2007;16:579-85. http://dx.doi.org/10.1016/j.jse.2006.12.011
11. Collin P, Kempf JF, Molé D, Meyer N, Agout C, Saffarini M, et al. Ten-year multicenter clinical and MRI evaluation of isolated supraspinatus repairs. J Bone Joint Surg Am 2017;99:1355-64. http://dx.doi.org/10.2106/jbjs.16.01267
12. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res 1987;(214):160-4.
13. Diebold G, Lam P, Walton J, Murrell GAC. Relationship between age and rotator cuff retear: a study of 1,600 consecutive rotator cuff repairs. J Bone Joint Surg Am 2017;99:1198-205. http://dx.doi.org/10.2106/jbjs.16.00770
14. Elia F, Azoulay V, Lebon J, Faraud A, Bonnevialle N, Mansat P. Clinical and anatomic results of surgical repair of chronic rotator cuff tears at ten-year minimum follow-up. Int Orthop 2017;41:1219-26. http://dx.doi.org/10.1007/s00264-017-3456-8
15. Garofalo R, Castagna A, Borroni M, Krishnan SG. Arthroscopic transosseous (anchorless) rotator cuff repair. Knee Surg Sports Traumatol Arthroscopy 2012;20:1031-5. http://dx.doi.org/10.1007/s00167-011-1725-4
16. Gilbart MK, Gerber C. Comparison of the subjective shoulder value and the Constant score. J Shoulder Elbow Surg 2007;16:717-21. http://dx.doi.org/10.1016/j.jse.2007.02.123
17. Hein J, Reilly JM, Chae J, Maerz T, Anderson K. Retear rates after arthroscopic single-row, double-row, and suture bridge rotator cuff repair at a minimum of 1 year of imaging follow-up: a systematic review. Arthroscopy 2015;31:2274-81. http://dx.doi.org/10.1016/j.arthro.2015.06.004
18. Heuberer PR, Smolen D, Pauzenberger L, Plachel F, Salem S, Laky B, et al. Longitudinal long-term magnetic resonance imaging and clinical follow-up after single-row arthroscopic rotator cuff repair: clinical superiority of structural tendon integrity. Am J Sports Med 2017;45:1283-8. http://dx.doi.org/10.1177/0363546517689873
19. Kluger R, Bock P, Mittlbock M, Krampla W, Engel A. Long-term survivorship of rotator cuff repairs using ultrasound and magnetic resonance imaging analysis. Am J Sports Med 2011;39:2071-81. http://dx.doi.org/10.1177/0363546511406395
20. Kukkonen J, Kauko T, Vahlberg T, Joukainen A, Aarimaa V. Investigating minimal clinically important difference for Constant score in patients undergoing rotator cuff surgery. J Shoulder Elbow Surg 2013;22:1650-5. http://dx.doi.org/10.1016/j.jse.2013.05.002
21. Kuroda S, Ishige N, Mikasa M. Advantages of arthroscopic transosseous suture repair of the rotator cuff without the use of anchors. Clin Orthop Relat Res 2013;471:3514-22. http://dx.doi.org/10.1007/s11999-013-3148-7
22. Matis N, Hübner C, Aschauer E, Resch H. Arthroscopic transosseous reinsertion of the rotator cuff. Oper Orthop Traumatol 2006;18:1-18. http://dx.doi.org/10.1007/s00064-006-1159-1
23. Michener LA, McClure PW, Sennett BJ. American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form, patient self-report section: reliability, validity, and responsiveness. J Shoulder Elbow Surg 2002;11:587-94. http://dx.doi.org/10.1067/mse.2002.127096
24. Paxton ES, Teefey SA, Dahiya N, Keener JD, Yamaguchi K, Galatz LM. Clinical and radiographic outcomes of failed repairs of large or massive rotator cuff tears: minimum ten-year follow-up. J Bone Joint Surg Am 2013;95:627-32. http://dx.doi.org/10.2106/jbjs.l.00255
25. Randelli P, Stoppani CA, Zaolino C, Menon A, Randelli F, Cabitza P. Advantages of arthroscopic rotator cuff repair with a transosseous suture technique: a prospective randomized controlled trial. Am J Sports Med 2017;45:2000-9. http://dx.doi.org/10.1177/0363546517695789
26. Sugaya H, Maeda K, Matsuki K, Moriishi J. Functional and structural outcome after arthroscopic full-thickness rotator cuff repair: single-row versus dual-row fixation. Arthroscopy 2005;21:1307-16. http://dx.doi.org/10.1016/j.arthro.2005.08.011
27. Tashjian RZ, Hung M, Keener JD, Bowen RC, McAllister J, Chen W, et al. Determining the minimal clinically important difference for the American Shoulder and Elbow Surgeons score, Simple Shoulder Test, and visual analog scale (VAS) measuring pain after shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:144-8. http://dx.doi.org/10.1016/j.jse.2016.06.007
28. Tempelhof S, Rupp S, Seil R. Age-related prevalence of rotator cuff tears in asymptomatic shoulders. J Shoulder Elbow Surg 1999;8:296-9.
29. Urita A, Funakoshi T, Horie T, Nishida M, Iwasaki N. Difference in vascular patterns between transosseous-equivalent and transosseous rotator cuff repair. J Shoulder Elbow Surg 2017;26:149-56. http://dx.doi.org/10.1016/j.jse.2016.06.010
30. Vastamäki M, Lohman M, Borgmastars N. Rotator cuff integrity correlates with clinical and functional results at a minimum 16 years after open repair. Clin Orthop Relat Res 2013;471:554-61. http://dx.doi.org/10.1007/s11999-012-2494-1
31. Zhang AL, Montgomery SR, Ngo SS, Hame SL, Wang JC, Gamradt SC. Analysis of rotator cuff repair trends in a large private insurance population. Arthroscopy 2013;29:623-9. http://dx.doi.org/10.1016/j.arthro.2012.11.004