Clinical and structural outcome twenty years after repair of isolated supraspinatus tendon tears

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Background: This study evaluated the clinical and structural outcome 20 years after repair of isolated supraspinatus tendon tears. We hypothesized that the results would deteriorate over time.

Materials and Methods: For this retrospective multicenter study, 137 patients were recalled for a clinical and imaging assessment. Six patients (4.3%) had died from unrelated causes, 52 (38.0%) were lost to follow-up, and 13 (9.5%) had undergone reoperations. This left 66 patients for clinical evaluation. Radiographs and magnetic resonance imaging were additionally performed for 45 patients, allowing assessment of osteoarthritis, tendon healing, fatty infiltration (FI), and muscle atrophy.

Results: The Constant Score (CS) improved from 51.5 ± 14.1 points preoperatively to 71 points ($P < .05$) with a mean Subjective Shoulder Value (SSV) of 77.2% ± 22%. Tendon discontinuity (Sugaya IV-V) was present in 19 of 45 patients (42 %), and there was advanced FI (Goutallier III-IV) of the supraspinatus in 12 (27%) and of the infraspinatus muscle in 16 (35%). Supraspinatus atrophy was present in 12 patients (28%), advanced arthritis in 6, and cuff tear arthropathy in 12 (30%). The CS and SSV were significantly inferior for shoulders with FI of stages III to IV ($P < .05$). The CS was lower in cuff tear arthropathy and correlated with infraspinatus FI.

Conclusions: At 20 years after surgical repair of isolated supraspinatus tears, the clinical outcome remains significantly above the preoperative state. FI of the infraspinatus is the most influential factor on long-term clinical outcome.

Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Rotator cuff; tear; long follow-up; MRI; open repair; supraspinatus

Rotator cuff tears are among the most frequent shoulder pathologies causing pain and functional impairment. It is estimated that rotator cuff tears are responsible for 4.5 million annual patient visits in the United States and for nearly 250,000 operative repairs.[6,17] Numerous authors have reported considerable improvement in clinical and radiographic outcomes after repair of isolated supraspinatus tears using various surgical techniques, although most studies have limitations due to small cohort sizes or short follow-up. To date, true long-term clinical and structural results after operative supraspinatus repair have not been reported.

The objective of this study was to report the clinical and structural outcome 20 years after repair of isolated supraspinatus tears in a sizeable cohort. We hypothesized that 20 years

The Medical University of Strasbourg Ethical Committee approved this clinical research (Number IDRCB 2013-AO1788-37).

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after surgery, the benefit of surgery would have substantially decreased or disappeared due to a high tendon failure rate and advanced osteoarthritis, with a need for revision with procedures such a reverse shoulder arthroplasty.

Materials and methods

Study design

We retrospectively studied the records of all patients who underwent surgical repair of isolated supraspinatus tears by 6 surgeons in 6 different centers in 1994. To be included in the study, the patients had to be adults with full-thickness, isolated supraspinatus tears that were treated with an open operative repair. Patients were excluded if they had partial-thickness tears, history of previous shoulder surgery, partial tendon repair, or concomitant lesions of other rotator cuff tendons. A total of 137 patients fulfilled these criteria and were recalled in 2014 for evaluation at a follow-up of 20 years. All patients provided informed consent. For clinical assessment, we used the Constant Score (CS), the Subjective Shoulder Value (SSV), and the Simple Shoulder Test (SST).

We analyzed on standard x-ray images the rate of glenohumeral arthritis with the Samilson-Prieto classification.[21] We considered stage 0, 1, and 2 as nonarthritic and 3 and 4 as arthritic. Cranial head migration was analyzed on true anteroposterior radiographs taken in neutral rotation using the Hamada and Fukuda classification,[9,10] as modified by Walch et al.[26]

The magnetic resonance imaging (MRI) protocol included T2-weighted fat-suppression sequences (nonproton density weighted) in the oblique coronal, oblique sagittal, and transverse planes, including the entire scapula, to analyze tendon healing, and T1-weighted sequences in the transverse and sagittal planes to analyze fatty infiltration (FI) and muscle conditions. FI was analyzed according to Goutallier/Fuchs.[5,8] We grouped stages 0/1 and 2 as functional muscles and stages 3 and 4 as nonfunctional muscles. Supraspinatus tendon healing was analyzed with the Sugaya classification.[23] We defined types I/II and III as healed and types IV and V as retorn tendons. We analyzed muscle atrophy with the tangent sign described by Zanetti et al.[27]

Surgical technique

The repairs were performed with the patient in a beach chair position using an open, anterosuperior approach with the use of nonabsorbable transosseous sutures.[18] All repairs were watertight at the end of the operation. An adjuvant anterior acromioplasty was performed in all shoulders.

Postoperative rehabilitation

After surgery, the arm was supported in a sling at 20° of abduction for 5.6 ± 1.0 weeks (median, 6; range, 1-8 weeks). Passive-motion exercises were initiated on the first postoperative day, and when possible, hydrotherapy was initiated after skin healing. Active shoulder motion was allowed after 8.2 ± 6.8 weeks (median, 6; range, 3-50 weeks). Patients were not allowed to perform any strengthening or strenuous work for 6 months after surgery. Low-demand sports and activities were allowed after 6 months.

Statistical analysis

Statistical analyses were performed using R 3.2.2 software (R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics were used to summarize the data. For non-Gaussian quantitative data, intergroup differences were evaluated using Wilcoxon rank sum tests (Mann-Whitney *U* test). When 3 or more groups were compared, Kruskal-Wallis tests were used. Categoric data were analyzed using Pearson χ^2 tests or Fisher exact tests. Stepwise descending multivariate linear and logistic regression was performed. Model assumptions were checked before the analyses were performed. *P* values of <.05 were considered statistically significant.

Results

Of the original cohort, 6 patients (4.4%) had died from unrelated causes, 52 (38.0%) were lost to follow-up, corresponding to a 1.9% loss per year (Fig. 1), and 13 (9.5%) had undergone reoperations (4 repeat repairs, 4 total shoulder arthroplasties, 3 infections, 1 tenotomy of long biceps, 1 other) before the 20-year follow-up and were not included in the final functional analysis. This left a cohort of 66 patients (35 women [53%]), aged 52 years (range, 25-65 years), for the final analysis (Table I). Of this study cohort, 45 patients (41% women), aged 56.1 ± 7.6 years (range,

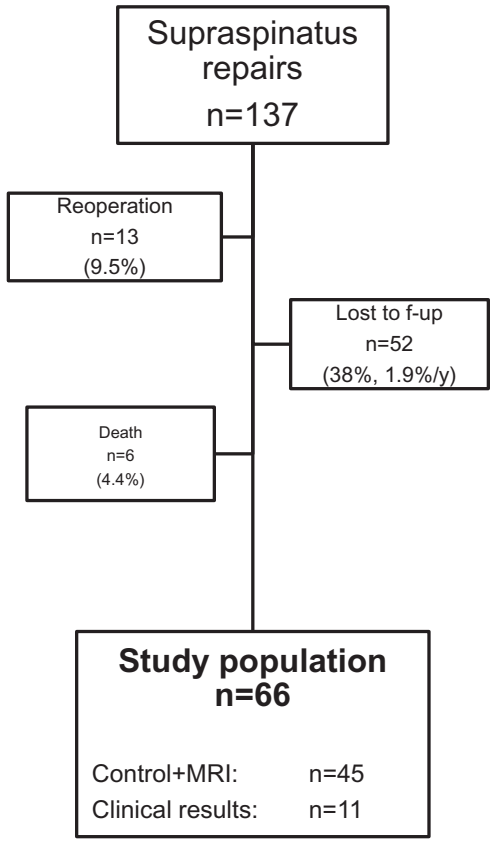

Figure 1 Flowchart detailing inclusion and exclusion of patients from the original cohort. *F-up*, follow-up; *MRI*, magnetic resonance imaging.

Table I Patient demographics

Variables	Patient data (n = 66)
Age at surgery, yr	52 ± 7.8 (25-70)
Sex	
Men	31 (47)
Women	35 (53)
Dominant side	55 (83)
Smokers	12 (22)
Previous trauma	30 (45)
Work-related accidents	12 (18)
Profession	
Sedentary	14 (22)
Light manual	17 (27)
Heavy manual	22 (36)
Repetitive	9 (15)
Disability pension	12 (22)
Return to work, mo	4.5

Data are shown as mean ± standard deviation (range), as number (%), or as indicated.

32-67 years), consented to standard radiographs and MRI at the 20-year follow-up.

In the 66 shoulders evaluated clinically, the CS improved from 52 points (range, 16-83 points) preoperatively to 71 points (range, 16-94 points) at 20 years, from 6 to 13 points for pain (15 points, freedom from pain; 0 , worst imaginable pain), and from 6.5 to 9.2 points for strength (1 point representing 0.5 kg of strength at 90° of scapular plane abduction). The SSV at 20 years was 77% (range, 2%-100%), and the SST was 9.5 (range, 2-12; Table II). A postoperative complication had occurred in 7 patients (11%), consisting of 6 stiff shoulders and 1 infection, which were treated nonoperatively.

Analysis of 53 standard radiographs showed no arthritis in 18 patients (34%), arthritis stage 1 in 16 (30.2%), stage 2 in 7 (13.2%), stage 3 in 5 (9.4%), and stage 4 in 1 (1.9%). Cuff tear arthropathy (Hamada-Fukuda stage 4) was diagnosed in 12 patients (30%).

Of the 45 shoulders evaluated using MRI, repair integrity was Sugaya type I in 4 patients (8.8%), type II in 8 (17.8%), type III in 14 (31.1%), type IV in 8 (17.8%), and type V in 11 (24.4%). Thus, repair integrity (Sugaya I, II, and III) was 58%, and repair failure was 42%. Integrity of the supraspinatus (healed tendon) was associated with an albeit not statistically significant better total CS (75 vs. 68 points, $P = .1$). FI of the supra supinatus was stage 1/2 or 3 (functional muscles) in 33 shoulders (73.3%) and stage 3 or 4 (nonfunctional muscles) in 12 (26.7%). Supraspinatus atrophy, as judged with the tangent sign of Zanetti et al,[27] was absent in 21 patients (48.8%) mild in 10 (23.2%), moderate in 4 (9.3%), and severe in 8 (18.7%).

The influence of supraspinatus repair integrity, supraspinatus muscle functionality, and trophicity on clinical results is summarized in Table III.

Table II Postoperative assessment

Outcome	Preoperative (n = 66)	Postoperative (n = 66)
Complications		
Total		7 (10.6)
Infection		1 (1.5)
Stiffness		6 (9.8)
CS, points		
Pain	6.4 ± 3.1 (0-15)	13.1 ± 2.7 (5-15)
Activity	10.5 ± 3.6 (4-20)	16.4 ± 4.2 (0-20)
Mobility	27.2 ± 8.9 (0-40)	32.2 ± 7.4 (0-40)
Strength	6.5 ± 4.9 (0-19)	9.2 ± 5.3 (0-20.8)
Total CS	51.5 ± 14.1 (16-83)	71.3 ± 15.1 (16-94)
SFA		
Sedentary	1 (2%)	6 (9.8%)
Occasionally active	6 (11.8%)	16 (26.2)
Active	15 (29.4%)	19 (31.1)
Very active	29 (56.9%)	20 (32.8)
SSV		77.2 ± 22.7 (2-100)
SST		9.5 ± 2.6 (2-12)
Sugaya classification		
I		4 (8.9)
II		8 (17.8)
III		14 (31.1)
IV		8 (17.8)
V		11 (24.4)

CS, Constant Score; *SFA*, Shoulder Function Assessment; *SSV*, Subjective Shoulder Value; *SST*, Simple Shoulder Test.
Data are presented as mean ± standard deviation (range) or as number (%).

The association of rotator cuff FI (supraspinatus, infraspinatus, and subscapularis) with CS, SSV, and supraspinatus tendon retear rate is reported in Table IV. Multivariate analysis confirmed significant associations between clinical outcome and FI of any of the rotator cuff muscles. The most predictive parameter for postoperative CS and SSV was postoperative infraspinatus FI (Table IV).

Minor supraspinatus discontinuities (Sugaya type IV) were associated with less infraspinatus FI and better clinical results (CS) compared with major supraspinatus discontinuities (Sugaya type V) at 20 years of follow-up (Table V).

Multivariable regression analysis revealed no additional significant associations between other independent variables of preoperative tear size, chronicity of symptoms, occupational injuries, level of activity, and smoking habits. Surgical procedures on the biceps tendon or acromioclavicular joint resection were not associated with the quality of the clinical outcome (CS, SSV) or tendon healing.

Discussion

The principal findings of this study are, first, that less than 10% of the patients required further surgery, and only

Table III Influence of supraspinatus repair integrity, supraspinatus muscle functionality, and trophicity on clinical results

Result	Tendon in continuity (Sugaya I-III) (n = 26)	Tendon retear (Sugaya IV, V) (n = 19)	*P* value
Total CS, points	75 ± 12.5 (47-94)	68 ± 14.1 (41-94)	.10
SSV	84 ± 15.1 (50-100)	69 ± 21.7 (30-100)	.02
SST	10 ± 2.1 (5-12)	8.7 ± 2.7 (3-12)	.10
	Functional muscle (Goutallier stage 0, 1, 2) (n = 33)	Nonfunctional muscle (Goutallier stage 3, 4) (n = 12)	
Total CS, points	75 ± 12.3 (46-94)	64 ± 12.9 (41-83)	.02
SSV	83 ± 14 (50-100)	68 ± 25 (30-100)	.02
SST	10 ± 1.7 (6-12)	8.1 ± 3.4 (3-12)	.02
	Muscle atrophy SSP (Warner stage 0, 1) (n = 31)	Muscle atrophy SSP (Warner stage 2, 3) (n = 12)	
Total CS, points	75 ± 12.4 (41-94)	63 ± 12.3 (46-83)	
SSV	82 ± 17 (30-100)	68 ± 21 (40-100)	
SST	10 ± 1.5 (7-12)	7.7 ± 3.4 (3-12)	

CS, Constant Score; *SSV*, Subjective Shoulder Value; *SST*, Simple Shoulder Test.
Data are presented as the mean ± standard deviation (range).

Table IV Effect of fatty infiltration of supraspinatus, infraspinatus, and subscapularis on the CS, SSV, and tendon retear

Variable	CS↓	SSV↓	Tendon retear
FI postoperatively			
Supraspinatus	0.02	0.02	NS
Infraspinatus	0.01	0	0
Subscapularis	0.02	0.03	NS

CS, Constant Score; *SSV*, Subjective Shoulder Value; *FI*, fatty infiltration; *NS*, not significant.

Table V Impact of supraspinatus tendon discontinuity on infraspinatus fatty infiltration and Constant Score

Variable	Sugaya type IV (n = 8)	CS Sugaya type IV	Sugaya type V (n = 11)	CS Sugaya type V
FI ISP	5	82	2	67
Grade 2				
Grade 3	2	79	4	60
Grade 4	1	66	4	53

CS, Constant Score; *FI*, fatty infiltration; *ISP*, infraspinatus.

approximately 3% required revision into reverse shoulder replacement. Second the remaining patients have a CS that is a mean of 19 points higher than the preoperative score, a difference that markedly exceeds the minimal clinically important difference established for this scoring system.[12] In addition, two-thirds of the patients subjectively had an excellent or good shoulder (SSV ≥ 80) at 20 years.

Structurally, 58% of all repaired tendons were still in continuity, but only 8.9% of the tendons were "normal" (Sugaya type I). Therefore, the hypotheses that 20 years after surgery, the clinical benefit of supraspinatus tendon repair is lost and revision surgery is very frequently necessary must be refuted.

Our analysis demonstrated that clinical outcome (CS, SSV) at 20 years was significantly associated with postoperative FI of the rotator cuff. The most predictive parameter for postoperative clinical outcome was postoperative infraspinatus FI (Table IV).

Minor supraspinatus discontinuities (Sugaya type IV) were associated with less infraspinatus FI and better clinical results (CS) than major supraspinatus discontinuities (Sugaya type V; Table V). This suggests that complete supraspinatus discontinuities (Sugaya V) progressively extend toward posteriorly, leading to infraspinatus FI (Table V) and less favorable clinical results (CS, SSV, SST) (Table III).

Outcomes after repair of isolated supraspinatus tears have been reported in 13 studies[2,18-25] (Table VI). The respective cohort sizes range from 22 to 67 shoulders, with 1 study reporting 129 shoulders.[11] Follow-up periods are generally between 1.4 and 8.6 years, with the exception of 1 study that extends up to 20 years.[24] The CS is the most frequently reported clinical outcome (11 of 13 studies).[2-7,14-16,18,20,25] It tends to be higher in studies with short follow-up[2,4,7,11,15,16,25] than in studies with longer follow-up.[20,24]

The mean 20-year CS in the present series was 71 points, which is within the range reported in the literature. Considering that postoperative CSs are often correlated with preoperative CSs, our 20-year results indicate a 50% improvement, which compares favorably with most published studies reporting improvement between 32% and

Table VI Literature review

Author	Year	Journal	Approach	Indications/technique	Cohort	Age		FU	Constant Score			SSV			SST		
									Pre-op	Post-op	Impr	Pre-op	Post-op	Impr	Pre-op	Post-op	Impr
					(No.)	(yr)		(mo)			(%)			(%)			(%)
Djahangiri et al[3]	2013	J Shoulder Elbow Surg	A/O	Full-thickness SSP tear O: acromioplasty, Mason-Allen, TOE fixation A: anterolateral acromioplasty, SR mattress suture	58	69		78	49	78	59	42	83				
Liem et al[16]	2007	JBJS Am	A	Isolated SSP tear, subacromial decompression, Mason-Allen, single row	53	60.9		26.4	53.5	83.4	56						
Boileau et al[2]	2005	JBJS Am	A	Chronic full-thickness SSP tear, tension-band	65	Healed tendon 57.8	Partially healed or unhealed 68	29	51.6		83.8	62					
Fucentese et al[4]	2012	JBJS Am	N	Nonoperative treatment	24	52		42	75	74							
Gerhardt et al[7]	2012	Am J Sports Med	A	SSP tear, SR modified Mason-Allen vs. DR	40	SR 61.5 DR 61.2		SR 16.8 DR 23.4		SR 82.2 DR 77			SR 91 DR 92.9				
Ikemoto et al[11]	2012	Rev Bras Ortop	A	Small and medium-sized SSP tear, acromioplasty	129	55		39									
McCormick et al[18]	2014	Int J Shoulder Surg	A	SR, DR, TOE fixation, subacromial decompression	62	SR 62.5 DR 54.3 TOE 61.8		48		SR 72 DR 78 TOE 76				SR 10.1 DR 9.3 TOE 10.2			
Meyer et al[19]	2012	Am J Sports Med	A/O	Complete SSP tear, O: TOE fixation, Mason-Allen stitches	33			24									
Nich et al[20]	2014	Orthop Traumatol Surg Res	O	SSP full thickness tear combined with adjacent ISP tear (A), SSP and adjacent SSC tear (B), SSP and adjacent ISP and SSC tear (C), TOE fixation	22	58		75	A 56.5 B 62 C 55	A 72 B 76 C 84	A 27% B 22% C 53%						
Vastamäki et al[24]	2013	Clin Orthop Relat Res	O	SSP (53%), SSP + ISP (36%), SSP + ISP + SSC (6%), SSP + SSC (4%), (n = 12), reconstruction using free tendon grafts (n = 52), acromioplasty or acromial osteotomy	67	52		240		Intact cuff 71 Cuff retear 58				Intact cuff 9.1 Cuff retear 7.6			
Voigt et al[25]	2010	Am J Sports Med	A	SSP tear, suture-bridging technique	51	62		24	58	88	51			12			
Kukkonen et al[14]	2015	J Bone Joint Surg Am	A/N	SSP tear, group 1 physiotherapy only group 2 acromioplasty and physiotherapy, all operations arthroscopically, subacromial débridement group 3 rotator cuff repair, acromioplasty and physiotherapy, SR technique in smaller tears, DR technique in larger tears, subacromial débridement, acromioplasty	180	Group 1 64 Group 2 65 Group 3 65		24	Group 1 57.8 Group 2 59.6 Group 3 58	Group 1 76.2 Group 2 80.1 Group 3 80.6	Group 1 31% Group 2 34% Group 3 39%						
Liem et al[15]	2007	Arthroscopy	A/O	SSP, A: SR technique, modified Mason-Allen stitches O: Mini-open	38	A 61.9 O 62.1		A 25 O 17.6	A 53.8 O 53.5	A 83.9 O 83.7	A 56% O 56%						

FU, follow-up; *SSV*, Subjective Shoulder Value; *SST*, Simple Shoulder Test; *SSP*, supraspinatus; *TOE*, transosseous; *SR*, single row; *DR*, double-row; *ISP*, infraspinatus; *SSC*, subscapularis.

62%.[2,3,14-16,20,25] This means that the primary benefit of surgery remains over time, even at long follow-up. There is little consensus on the optimal strategy to manage isolated supraspinatus tears due to the lack of literature reporting long-term outcomes[4,13,22] and conflicting results in those studies with the longest follow-up:

- Vastamäki et al[24] reported outcomes of 67 patients at 20 years. The retear rate was 94%. The remaining 4 patients had a partial supraspinatus tendon tear. FI was marked in the supraspinatus and infraspinatus tendons. Cuff integrity correlated with better clinical results.
- Nich et al[20] reported outcomes of 27 patients at 8.6 years. They analyzed 49 shoulders. At a minimum follow-up of 60 months, the age- and sex-adjusted relative CS improved from 67% to 95%. MRI analysis showed a retear rate of 12%. Retear did not negatively influence the functional result.

A major strength of this study is the availability of clinical and imaging results, which were specifically collected and evaluated in a very standardized fashion 20 years after surgery for the purpose of this study. Our data therefore allow for analysis of tendon repair integrity, correlation between structural and clinical results, and information about longevity of the results.

The study has some limitations. First its retrospective design, without a control group, makes it a level 4 observational study. Nonetheless, it provides previously unavailable information on a well-defined patient group with a well-defined pathology treated in a homogenous manner and also analyzed in a highly standardized fashion. It may be said that current arthroscopic techniques are different and that anterior acromioplasty is no longer a routine. Nonetheless at least the clinical results presented document that previous techniques were already valuable and a benchmark for the assessment of alleged improvements is provided. Moreover, Collin and al[1] showed that that there were no differences between open and arthroscopic repair at 10 years of follow-up.

Second, the loss of patients to follow-up is regrettable but at 20 years inevitable in the environment of the 6 centers. We consider that a yearly loss of follow-up of 1.9% over 20 years is reasonably good.

Third, we would certainly have preferred to obtain imaging studies in all patients but had to accept the refusal of the respective patients who declined imaging studies for very various reasons mostly because they felt it would not change anything for them.

Conclusion

At 20 years after open repair of an isolated supraspinatus tear, two-thirds of the patients have an excellent or good subjective result, less than 10% are revised, and only 3% need a reverse total shoulder arthroplasty. Significantly better results can be obtained if the repair remains intact and specifically if fatty infiltration of the infraspinatus muscle can be prevented.

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