Orthopaedics & Traumatology: Surgery & Research (2012) **98S**, S193—S200

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ORIGINAL ARTICLE

Arthroscopic repair of subscapularis tears: Preliminary data from a prospective multicentre study

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Accepted: 25 September 2012

KEYWORDS
Subcapularis;
Arthroscopic repair;
Preliminary results

Summary
Background: Until the introduction of arthroscopic-assisted surgery for rotator cuff repair, the frequency of subscapularis tears was underestimated. These tears remain challenging to treat even with arthroscopy. The absence of a specific classification system has hampered communication about the treatment and outcomes of the various types of subscapularis tears. The objective of this prospective multicentre study was to validate the relevance of arthroscopic subscapularis tendon repair based on an assessment of short-term outcomes according to the initial extent of the anatomic lesions.

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doi:10.1016/j.otsr.2012.10.004

Methods: A prospective multicentre study sponsored by the French Society for Arthroscopy was conducted from March 2010 to January 2011 in 208 patients with subscapularis lesions that were either isolated or associated with limited anterosuperior tears. The Constant and UCLA scores were used to assess clinical outcomes. Anatomic and prognostic results were evaluated based on the physical examination, preoperative and postoperative imaging study findings, and anatomic lesions. Clinical data were available for 103 patients after at least 1 year of follow-up and radiological data for 129 patients after at least 6 months.
Results: The preliminary clinical results in 103 patients with at least 1 year of follow-up showed overall statistically significant improvements in the Constant and UCLA scores, with resolution of the clinical manifestations. The degree of improvement seemed to increase over time. The clinical results varied significantly across patient groups based on a classification system distinguishing four lesion types. Postoperative imaging studies to assess the anatomic results in all patients with at least 6 months of follow-up ($n = 129$) showed tendon healing in 92% of cases but also indicated muscle wasting of the upper subscapularis muscle in 18.6% of cases and increased fatty degeneration of the muscle belly.
Discussion: Our study confirms the good clinical and radiological results reported in the literature. Our classification system distinguishing four lesion patterns was applicable during the imaging workup. The main finding from this classification system was the difference in results between Type 2 and Type 3 lesions. The trend towards improvements over time requires confirmation by longer-term studies, which will also have to establish that the increased wasting of the upper subscapularis muscle and fatty degeneration of the muscle belly have no adverse effects.
Level of evidence: Level 3.

Introduction

Subscapularis tendon tears were long considered uncommon, with an estimated frequency of 3.5 to 8% among all rotator cuff lesions in a study by Deutsch et al. [1]. Challenges with visualising these tears on preoperative imaging studies and during surgery resulted in substantial underestimation [2,3]. The introduction of shoulder arthroscopy improved the diagnosis of subscapularis tendon tears, which accounted for 37% of all rotator cuff tears in a study by Garavaglia et al. [4]. Arthroscopic repair of subscapularis tendon tears was described initially by Burkhart et al. [5,6] and subsequently by Lafosse et al. [7], who also developed the first classification system for these lesions.

The objective of this prospective multicentre study was to validate the relevance of arthroscopic repair of subscapularis lesions based on short-term results, according to the extent of the initial anatomic lesions.

Materials and methods

A prospective multicentre study sponsored by the French Society for Arthroscopy (*Société française d'arthroscopie* [SFA]) was conducted in 11 centres in 10 French cities (Annecy, Cambrai, Dunkerque, Grenoble, Lille, Libourne, Lyon, Nice, Paris, and Strasbourg). Patients were included between March 2010 and January 2011. Inclusion criteria were presence of a subscapularis tendon tear that was isolated or accompanied with either an Ellman grade 1 to 3 partial-thickness supraspinatus tear [8] or a stage 1 full-thickness supraspinatus tear. All other lesions, as well as recurrent rotator cuff tears, were excluded.

In each study patient, the preoperative imaging workup consisted in computed tomography (CT)-arthrography, magnetic resonance imaging (MRI), or MR-arthrography. The preoperative images were compared to a standardised description of the lesions found during arthroscopic exploration.

Healing of the subscapularis tendon was assessed using criteria derived from those developed by Suguya et al. for the supraspinatus tendon [9—11]. Stage 1 was a normal appearance with low signal on T2 images, stage 2 was tendinopathy with high signal on T2 images, stage 3 was an at least 50% decrease in tendon thickness, stage 4 was a tear without extensive separation of the tendon from the lesser tuberosity of the humerus, and stage 5 was extensive separation from the lesser tuberosity. Muscle volume was evaluated on Y views using the criteria of Zannetti et al. [12] and fatty degeneration of the muscles using the criteria of Bernageau et al. [13].

We included 208 patients and arbitrarily divided them into two groups. One group (subscapularis-only group, Sub; $n = 81$) comprised the patients with isolated subscapularis tears ($n = 52$) or with subscapularis tears and Ellman 1 supraspinatus tears ($n = 29$). The other group (subscapularis and supraspinatus group, Sub + Sup; $n = 127$) was composed of patients with subscapularis tears and supraspinatus tears classified as Ellman 2 ($n = 28$), Ellman 3 ($n = 11$), or full-thickness ($n = 88$). Mean patient age was 58.4 years (range, 37—81 years). Males comprised 66% of the population and females 34%. The right shoulder was involved in 72% of cases and the left shoulder in 28%.

The tear was ascribed to a single trauma in 50% of cases, repeated trauma in 9%, and degenerative disease in 41%. Slightly over two-thirds of patients were employed (69 vs.

Table 1 Overall comparison of mean preoperative and postoperative Constant's score values in the group with isolated or very predominant subscapularis tears (Sub group) and in the group with both subscapularis and supraspinatus tears (Sub + Sup group).

$n = 103$	Preoperative Constant score	Postoperative Constant score	% Preoperative Constant score	% Postoperative Constant score	*P* value
Sub group ($n = 35$)	48.3	74.1	51.1	90.8	< 0.001
Sub + Sup group ($n = 68$)	50.7	77.9	63.2	63.2	< 0.001

31% retired) and in 23% of patients the shoulder lesion was recognised as an occupational disorder or workplace injury. Among employed patients, 40% had heavy manual jobs, 40% light manual jobs, and 20% sedentary jobs.

During the preoperative and postoperative physical examinations, patients performed the Gerber lift-off test [14], belly-press test [15], and bear-hug test [16]. The supraspinatus tendon was evaluated using the Jobe manoeuvre and palm-up test. Function was assessed preoperatively and postoperatively based on the Constant score and UCLA score.

Subscapularis lesions were described by examining not only the attachment of the deep aspect of the subscapularis tendon on the lesser tuberosity of the humerus [17,18], but also the bicipital sling and its anterior wall, which is an integral part of the subscapularis attachment site and is shared by the rotator interval and sheath surrounding the long head of biceps tendon (LHBT), as established by several recent anatomic studies [19,20]. The comma sign described by Lo and Burkhart [21] was noted if present, as well as coracoid process impingement [22,23]. We classified the subscapularis lesions into the four types described below.

Type 1 ($n = 18$), isolated and often partial separation of the subscapularis tendon fibres from the lesser tuberosity with a normal bicipital sling, regardless of the appearance of the LHBT.

Type 2 ($n = 93$), separation of the subscapularis tendon fibres from the lesser tuberosity and partial tear in the bicipital sling without involvement of the anterior LHBT pulley or tendinous slip [3]. The probe introduced through the partial sling tear (consisting very often in a cleft in the anterior wall) can lift the superficial subscapularis layer separated from the lesser tuberosity.

Type 3 ($n = 47$), complete separation of the subscapularis tendon fibres from the lesser tuberosity and complete tear in the anterior wall of the bicipital sling. The anterior LHBT pulley is normal, distended or, rarely, completely torn. In this group, tendon retraction is minor because the superficial tendon layer is normally attached to the bicipital sling and connected to the superficial fibres of the supraspinatus (superficial layer of the rotator interval, which produces the comma sign after separation from the bony structures).

Type 4 ($n = 49$), complete separation of the subscapularis tendon fibres from the lesser tuberosity leaving a free edge that can remain continuous with the fibrous scar tissue attached either to the humerus or to the subacromial bursa. The degree of retraction varies but the stump may reach the level of the glenoid labrum. At this stage, the comma sign is readily identified and connects the subscapularis to the supraspinatus if this last is torn.

In a single patient, the lesion could not be classified into one of the four types, despite a review of the video recording by a group of experts. Reducibility and reduction of the subscapularis tendon to the lesser tuberosity were assessed based on individualisation of the free lateral edge of the subscapularis combined with the comma sign. The subscapularis tear was diagnosed preoperatively in 76% of cases and intraoperatively in 24% of cases.

Give the absence in the literature of a consensus regarding the best treatment strategy [24], treatment decisions were left to discretion of the operating surgeon. Abstention or simple debridement was chosen in 17 patients with Type 1 or Type 2 lesions and supraspinatus tears. The remaining 191 (92%) patients underwent surgical repair of the subscapularis tendon.

For the arthroscopic procedure, 196 patients were in the beach chair position and 12 in lateral decubitus. Posterior and anterolateral portals were used for the arthroscope, together with portals for the instruments, which were usually anterior and less often anterolateral. For Type 1 lesions, repair was performed almost entirely with the arthroscope in the posterior portal. Type 4 lesions, in contrast, required changing the arthroscope portal to enable complete release and repair of the lower part of the lesion. Tendon release — a key step of the procedure — involved dissecting the coracoid process and the tendinous connection linking the subscapularis and supraspinatus tendons (the comma sign). This connection must be preserved, as it constitutes a major landmark for cuff repair and a strong structure that serves as an anchor for the repair construct.

A single-row technique was used in 70% of cases [25] and a double-row technique in 30% [26]. Single-row repair was performed for 77% of Type 1 and Type 2 lesions, 72% of Type 3 lesions, and only 44% of Type 4 lesions. Most of the Type 4 lesions were repaired using a double-row technique. The number of anchors varied from 1 to 4 depending on the extent of the lesion and type of repair procedure.

The LHBT was tenotomized in all cases. Tenodesis was performed in 66% of cases.

Strategies for the supraspinatus tears were as follows: abstention, 24% of cases; simple debridement, 5% (Ellman 1 and 2 lesions); and repair in 71% (of which the 62% with Ellman 3 or full-thickness lesions were repaired using a dual-row technique). Acromioplasty was performed in 198 (95%) cases.

We report the 1-year clinical outcomes in the first 103 patients and the imaging study results in 129 patients with follow-up of at least 6 months. Imaging studies consisted of MRI in 112 cases and CT-arthrography in 17 cases. Anatomic results were evaluated using criteria developed by Sugaya et al. [9—11] and clinical results using a thorough clinical

Table 2 Comparison of the preoperative, postoperative pain and activities of daily living Constant score items in the group with isolated or very predominant subscapularis tears (Sub group) and in the group with both subscapularis and supraspinatus tears (Sub + Sup group).

$n = 103$	Pre-operative pain	Post-operative pain	Pre-operative ADL	Post-operative ADL	Pre-operative ROM	Post-operative ROM	Pre-operative strength	Post-operative strength	P value
Sub group ($n = 35$)	4.7	13.1	8.5	17.5	27.6	33.7	7.5	10.9	< 0.001
Sub + Sup group ($n = 68$)	5.3	13.7	9	18.5	29	36.6	6.8	11.7	< 0.001

ADL: activities of daily living; ROM: range-of motion.

Table 3 Comparison of the preoperative and postoperative range-of-motion Constant score items in the group with isolated or very predominant subscapularis tears (Sub group) and in the group with both subscapularis and supraspinatus tears (Sub + Sup group).

$n = 103$	Pre-operative FE (°)	Post-operative FE (°)	Pre-operative Abd (°)	Post-operative Abd (°)	Pre-operative ER (°)	Post-operative ER (°)	Pre-operative IR (°)	Post-operative IR (°)	P value
Sub group	145	164	136.1	149.4	45	54	4	6.2	< 0.001
Sub + Sup group	149.2	170	135.8	164	53.7	48.5	5.3	7.6	< 0.001

FE: forward elevation; Abd: abduction; ER: external rotation; IR: internal rotation.

examination of the shoulder and Constant score determination.

The statistical analysis was performed by a statistician who was not among the clinicians who assessed the results. The Chi^2 test was used to compare qualitative variables and the paired t test to compare quantitative variables. To perform within-patient comparisons, the data analysis included only patients for whom both preoperative and postoperative data were available. P values lower than 0.05 were considered significant.

Results

Overall, 61.8% of patients were re-evaluated, 43% (35/81) in the group with isolated or very predominant subscapularis lesions (Sub group) and 77% (68/88) in the group with subscapularis and supraspinatus lesions (Sub + Sup group). No significant differences were found between these two groups for age, sex, dominant hand, or traumatic versus degenerative aetiology. Occupational disorders and workplace injuries were more common in the Sub + Sup group.

Clinical outcomes

Constant's score improved between the preoperative evaluation and last follow-up in both groups (Table 1), from 48.3 to 74.1 in the Sub group and from 50.7 to 77.9 in the Sub + Sup group ($P < 0.001$). The individual items used in Constant's score also improved significantly ($P < 0.001$). Tables 2 and 3 report the changes in pain, activities of daily living, and range-of motion. Mean Constant's score at last follow-up was significantly better in the Sub + Sup group than in the Sub group (77.9 vs. 74.1) and the difference was particularly noticeable for the range-of-motion score (36.6 vs. 33.7). Comparisons across lesion types showed a significant difference only for Type 2 vs Type 3 in the Sub group (Table 4). No significant differences were found between Type 3 and Type 4 in the Sub group or across any of the types in the Sub + Sup group.

The UCLA score improved postoperatively compared to the preoperative assessment in both groups, from 14.6 to 30.2 in the Sub group and from 14.3 to 32.6 in the Sub + Sup group (Table 5).

The clinical subscapularis tests also improved significantly (Table 6).

Table 4 Comparison of Constant score items between patients with Type 2 and Type 3 lesions in the group with isolated or very predominant subscapularis tears (Sub group).

Sub group	Constant	Pain	ADL	Active ER	Strength	P value
Type 2	80	13	19	61	13	< 0.001
Type 3	70	10	15	48	9	

ADL: activities of daily living; ER: external rotation.

Table 5 Changes in the UCLA score between the preoperative and postoperative evaluations in the group with isolated or very predominant subscapularis tears (Sub group) and in the group with both subscapularis and supraspinatus tears (Sub + Sup group).

n = 103	Preoperative UCLA score	Postoperative UCLA score	*P* value
Sub group (*n* = 35)	14.6	30.2	< 0.001
Sub + Sup group (*n* = 68)	14.3	32.6	< 0.001

Complete separation of the subscapularis was associated with lower Constant scores in both groups ($P < 0.001$). Preoperative fatty degeneration of the subscapularis was not associated with the results in the Sub group, whereas in the Sub + Sup group fatty degeneration stage 2 or higher was associated with poorer results (Table 7). Fatty degeneration of the supraspinatus had no influence on the results. In contrast, after exclusion of recurrent tears the fatty degeneration score worsened, and stage 3 or 4 fatty degeneration was seen in 11 cases postoperatively versus none preoperatively ($P < 0.001$) (Fig. 1). The concomitant presence of a full-thickness supraspinatus tear was significantly associated with the risk of postoperative fatty degeneration of the subscapularis muscle ($P = 0.02269$).

The differences in sample sizes for each surgical technique prevented us from demonstrating that one technique was significantly better than the others. Immobilisation with an abduction pad was associated with better clinical results than keeping the elbow at the side.

Imaging study results

Imaging study results were evaluated in 129 patients with at least 6 months of follow-up, using the five stages described by Sugaya.

Table 7 Influence of fatty degeneration of the subscapularis muscle on Constant score values in the group with both subscapularis and supraspinatus tears (Sub + Sup group).

Fatty degeneration (FD)	Constant	ROM	Strength
FD < 2	84	38	13
FD ≥ 2	76	36	10
P value	0.0027	0.014	0.0018

ROM: range-of motion.

At last follow-up, recurrent tears were seen in 10 (8%) patients, including one with a stage 4 tear and nine with stage 5 tears; initial stages were four in five cases, three in three cases, and one in one case. The subscapularis tendon was normal in 41 (31%) patients and showed stage 2 tears in 52 and stage 3 tears in 26 patients. Table 8 reports Sugaya stages according to initial lesion type and to whether the tear involved all or part of the footprint height. Healing was poorer in patients with more extensive initial lesions (with progression from Type 1 to Type

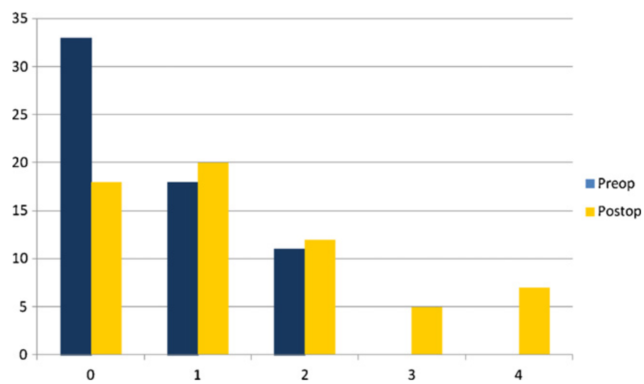

Figure 1 Change in subscapularis fatty degeneration between the preoperative and postoperative evaluations. The X-axis shows the number of patients and the Y-axis the degree of fatty degeneration according to Goutallier et al. [13].

Table 6 Changes in subscapularis clinical test results between the preoperative and postoperative evaluations in the group with isolated or very predominant subscapularis tears (Sub group) and in the group with both subscapularis and supraspinatus tears (Sub + Sup group).

	Not feasible		No strength		Intermediate strength		Normal strength		*P* value
	Pre-operative (%)	Post-operative (%)	Pre-operative (%)	Post-operative (%)	Pre-operative (%)	Post-operative (%)	Pre-operative (%)	Post-operative (%)	
Lift-off test									
Sub group	17	11	9	6	57	29	17	54	< 0.001
Sub + Sup group	19	1	27	3	35	25	19	71	
Bear-hug test									
Sub group	12	0	31	3	40	44	17	53	< 0.001
Sub + Sup group	9	1.5	43	1.5	35	26	17	71	
Belly-press test									
Sub group	0	0	17	3	60	37	23	60	< 0.001
Sub + Sup group	1	0	25	4	50	18	24	78	

Table 8 Healing of the subscapularis tendon according to anatomic lesion type and vertical lesion extent.

Finding at last follow-up	Sugaya 1 Normal				Sugaya 2 Tendinopathy				Sugaya 3 Thin tendon				Sugaya 4 Recurrent tear			
Lesion type	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Partial	4	20	1	0	5	14	2	0	1	4	0	0	0	1	0	0
Complete	0	7	6	3	0	6	12	13	1	4	7	8	0	0	3	6

4, $P = 0.0118$), involvement of the entire footprint height ($P = 0.00374$), preoperative subscapularis fatty degeneration ($P = 0.0175$), and tendon retraction ($P = 0.01639$). No significant effect was found for other factors (age, circumstances of onset, time to treatment, full-thickness supraspinatus tear, type of repair construct, and type and duration of immobilisation).

The presence of muscle wasting was associated with initial lesion type in our classification system ($P = 0.034$) and reducibility prior to surgical release ($P = 0.000022$). The bear-hug test was the only clinical parameter associated with muscle wasting ($P = 0.015$).

Discussion

Our study confirms published epidemiological evidence that isolated and severe subscapularis tears predominantly affect males and that they are more often related to trauma and occur at a younger age than other types of subscapularis tears [1,15,27—31]. We found no significant associations indicating that the natural history of subscapularis tears progresses from one type to the next. In some cases, trauma resulted immediately in Type 4 lesions, in some cases without damage to the bicipital sling. The preoperative imaging studies were effective in predicting the nature of the lesions found during surgery.

The healing rate was 92% overall and ranged across lesion types from 70% to 95%, in keeping with previously published data (Table 9). Despite the predominance in our population of Type 3 and Type 4 lesions, our results confirm the previously reported reliability of arthroscopic treatment [3,5,7,15,30,31,43].

We believe the good postoperative outcomes are ascribable to improved knowledge of rotator cuff anatomy, which allows a more comprehensive exploration and therefore a better evaluation of the lesions. With our classification system, 207 of 208 patients were classifiable, compared to only 71% of patients with the classification system devised by Lafosse et al. [7]. The classification systems developed by Fox et al. [35] and Garvaglia et al. [4] do not allow a complete description, because they fail to take into account the bicipital sling lesions.

Bicipital sling lesions are important to take into account in order to establish the prognosis. Indeed, outcomes differed significantly in our study between Type 2 and Type 3

Table 9 Results in the main published case-series studies.

Author	Year	Number of cases	Mean age	Isolated	Combined lesions	Technique	Results (%)
Gerber, [29,32]	1991/1996	16	51	16	—	Open	92
Nové-Josserand, [33]	1994	21	57.1	21	—	Open	—
Warner, [14]	1994	13	51	13	—	Open	90
Deutsch, [1]	1997	13	39	6	7	Open	95
Walch, [34]	1999	95	57	—	95	Mixed	81
Burkhart, [5]	2002	25	60.7	8	17	Arthros.	92
Fox, [35]	2003	14	56	14	—	Arthros.	80
Bennet, [15]	2003	47	56.8	8	39	Arthros.	90
Edwards, [28]	2005	84	53.2	—	84	Open	74
Kreuz, [36]	2005	29	54	14	15	Arthros.	90
Kreuz, [37]	2005	34	51	16	18	Open	70
Edwards, [24]	2006	11	64	11	—	Tenotomy	82
Flury, [38]	2006	63	60	31	32	Open	87
Lafosse [31]	2007	17	47	17	—	Arthros.	88
Adams, [39]	2008	40	66	7	33	Arthros.	80
Bartl, [40]	2011	30	43.1	30	—	Open	93
Garavaglia, [4]	2011	129	56	5	124	Arthros.	—
Bartl, [41]	2011	21	43	21	—	Arthros.	95
Nové-Josserand, [42]	2012	35	54.7	35	—	Mixed	87.5
Notre série	2011	103	58.4	34	68	Arthros.	92

Arthrosc.: arthroscopic repair; Open: open surgical repair; Mixed: open or arthroscopic surgical repair; Tenotomy: isolated tenotomy of the long head of biceps tendon.

lesions. Another important factor was the vertical extent of the separation, with complete separation along the entire footprint height being associated with a lower rate of anatomical healing. In contrast, the concomitant presence of a supraspinatus tear did not alter the results.

Our results support subscapularis tendon repair in patients with Type 2 to 5 lesions. In contrast, Edwards et al. [24] advocated isolated tenodesis or tenotomy of the LHBT. For Type 1 and Type 2 lesions, the small number of conservatively treated patients prevented us from demonstrating that surgical treatment produced superior results.

The postoperative imaging studies consistently visualised wasting of the upper part of the subscapularis muscle. To our knowledge, this finding has not been described previously. The muscle wasting correlated significantly with lesion type, tendon retraction and reducibility prior to surgical release, and changes in the bear-hug test at the postoperative evaluation. Furthermore, fatty degeneration of the subscapularis muscle belly, independently from the above-described muscle wasting, seemed to progress over time even when tendon healing was achieved. Fatty degeneration did not significantly affect the clinical outcomes.

Our study has two main weaknesses. First, follow-up clinical data were available for only 49.5% of patients and follow-up imaging study data for 59%. These rates are ascribable to the follow-up durations chosen for our study. They limit the general relevance of our data, although our sample size is among the largest to date, together with that of the study by Garvaglia et al. [4]. Second, follow-up was only 6 months for the imaging study outcomes and 1 year for the clinical outcomes. We will continue to monitor the cohort, most notably to verify that no deterioration in the clinical outcomes occurs over time, with or without an increase in the rate of secondary tears in the repaired tendon.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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