Clin Orthop Relat Res (2013) 471:554–561
DOI 10.1007/s11999-012-2494-1

Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

CLINICAL RESEARCH

Rotator Cuff Integrity Correlates With Clinical and Functional Results at a Minimum 16 Years After Open Repair

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Received: 24 February 2012 / Accepted: 6 July 2012 / Published online: 16 August 2012

Abstract

Background Recurrent or persistent defects in the rotator cuff after its repair are common. Short- and medium-term surveys have revealed, after open repair, patients with an intact rotator cuff have increased function and ROM. However, no long-term studies have verified cuff integrity on MR arthrography or correlated it with clinical and functional outcomes.

Questions/purposes We evaluated long-term cuff integrity and fatty infiltration after open repair using MR arthrography and determined whether these findings correlated with clinical and functional results.

Methods Using MR arthrography, we retrospectively evaluated 67 patients (48 men, 19 women) who underwent open rotator cuff repair between 1980 and 1989. Their mean age at surgery was 52 years. Minimum followup was 16 years (mean, 20 years; range, 16–25 years).

Results The retear rate was 94%, and mean size of rerupture was 3.5 × 3.6 cm (ranges, 0.5–5.0 cm × 0.5–5.2 cm; median, 4 × 4 cm). The remaining four patients had a partial supraspinatus tendon tear. Fatty infiltration was marked in the supraspinatus and infraspinatus tendons. Cuff integrity correlated with clinical results: active external rotation and forward flexion, and flexion, abduction, and external rotation strengths, were better in patients with an intact rotator cuff or a small retear of 4 cm^2 or less than in patients with larger tears. Cuff integrity also correlated with functional results.

Conclusions Rotator cuff integrity was lost in 94% of patients after a minimum followup of 16 years. Cuff integrity correlates well with clinical and functional results even several years postoperatively. A large retear seems to be the most important factor in deteriorating long-term clinical and functional results after open rotator cuff repair.

Level of Evidence Level IV, therapeutic study. See Instructions for Authors for a complete description of levels of evidence.

The institution of one or more of the authors (MV) has received, during the study period, funding from the Helsinki and Uusimaa Hospital District (HUS EVO).
All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request.
Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
This work was performed at ORTON Orthopaedic Hospital, Helsinki, Finland.

Electronic supplementary material The online version of this article (doi:10.1007/s11999-012-2494-1) contains supplementary material, which is available to authorized users.

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Introduction

Recurrent or persistent defects in the rotator cuff after open rotator cuff repair (RCR) are common. Retears have been documented in 13% to 57% of patients after open repair [3, 10, 12, 13, 17, 18, 21, 24, 26, 32]. Increased function and

ROM appear in patients who have an intact rotator cuff after open repair [19]. Goutallier et al. [16] stated, if the fatty degeneration index is 2 or less, open tension-free tendon-to-bone suture is effective functionally and structurally, if the repair is intact after 1 year. After repair of tears smaller than 3 cm, open and arthroscopic RCR reliably provided satisfactory clinical results, with a high rate of rotator cuff integrity evident after both types of repair at a minimum of 1 year postoperatively [3]. In tears larger than 3 cm, cuff integrity was greater after open than arthroscopic repair [3]. We reported our very long-term clinical and functional results after open RCR [4] and now are ready to correlate those results with cuff integrity estimated by MR arthrography.

Many authors have found chronic and massive rotator cuff tears have a high likelihood for retear after either open or arthroscopic repairs [1–3, 6, 7, 10–13, 17, 19, 20, 23, 25, 27, 32] (Table 1). There is no apparent correlation between MRI findings and clinical outcomes at 1 year [23] or 2 years [24]. However, tears that are more retracted on MRI correlate with lower abduction strength [26]. Gerber et al. [14] stated the ability of the rotator cuff muscles to develop tension correlates closely with their degree of fatty infiltration at 1-year followup. No long-term studies on cuff integrity are verified by MR arthrography or show its correlation with clinical and functional outcomes.

Because we found no long-term surveys including MRI evaluation ranging more than 10 years after RCR, our aim was to study long-term cuff integrity after open RCR. In a previous review of patients undergoing open RCR, we found pain and function deteriorated with long-term followup [4]. We therefore performed this analysis to determine whether MRI results provided a reason for this deterioration.

Our assumption was that cuff integrity might deteriorate with time. According to our clinical experience, we also presumed cuff integrity might correlate with long-term clinical and functional results. We therefore evaluated findings in MR arthrography including long-term evaluation specifically to document rotator cuff integrity and fatty infiltration and correlated these findings with those from patients' reporting of shoulder pain, the Simple Shoulder Test Questionnaire, and functional results assessed by the Constant-Murley score in a series of 67 patients 16 to 25 years after surgery.

Patients and Methods

We performed MR arthrography in 67 shoulders in 67 patients (48 men, 19 women) selected from among 282 patients with a surgically treated primary rotator cuff tear from 1980 to 1989 [4, 5]. We identified 282 patients who had a primary rotator cuff tear treated surgically between January 1980 and May 1989. Of these, 137 (49%) had undergone preoperative ROM and strength measurements with a spring balance [31]. For the other patients, strength testing had been performed only manually. Of these 137, 36 had died and one lived abroad.

The remaining 100 were asked to participate in the study, and 75 agreed to participate. MR arthrography was performed in 67 patients (24% of the total; 48 men, 19 women). The mean age of the patients at time of surgery was 52 years (range, 30–65 years). The time from onset of symptoms to surgery was 0.2 to 19 years (mean, 2.4 years; median, 1.1 years). Operative delay was less than 6 months in 14 patients, 6 to 12 months in 17, and greater than 12 months in 36. Tears involved the supraspinatus only (53%), the supraspinatus and infraspinatus (36%), the supraspinatus, infraspinatus, and subscapularis (6%), and the supraspinatus and subscapularis (4%). Tear size at surgery was measured in two directions in 43 patients: 23 tears measured 9 cm^2 or less and 20 tears measured greater than 9 cm^2. Minimum followup was 16 years (mean, 20 years; range, 16–25 years). The mean age of the patients at latest followup was 72 years (range, 52–84 years). Preoperative and postoperative data were obtained from the patients' medical records. All patients gave informed consent, and permission to perform this study was obtained from the ethics committee of the hospital district where the study was conducted.

All patients had open RCR and thorough preoperative evaluation, including preoperative strength measurements with a spring balance. Surgical methods and postoperative treatment have been documented [4]. We repaired 15 tears directly with nonabsorbable suture (Mersilene®; Ethicon Inc, Somerville, NJ, USA) and 52 reconstructions using free tendon grafts (long plantaris tendon in 40 and long extensor tendon of the second and third toes in 12) [4, 29, 31]. A tendon graft was used mostly as strong suture material to reattach the torn tendon to the bone more accurately. We believed, especially in old retracted rotator cuff tears, a free tendon graft would hold better than rather thin suture material. For better observation, anterior acromioplasty or acromial osteotomy was performed, and 20 patients had biceps tenodesis. Postoperatively, the arm was immobilized in an abduction splint for an average of 6 weeks. The elbow was mobilized on the first postoperative day. Passive mobilization of the arm was started at 2 weeks on the splinted arm; ie, the patient used the other hand or another person lifted the arm 10 to 20 cm upward to prevent adhesions. After immobilization, all patients visited the hospital for 2 to 4 days of intensive supervised physiotherapy including pool exercises. Physiotherapy continued for 1 to 3 months as an outpatient and in some cases even longer.

Table 1. Literature on cuff integrity at followup after open rotator cuff repair

Study	Number of patients	Imaging method	Number of tendons involved	Followup (years)	Retear rate (%)	Intact/retear						
						Absolute Constant-Murley score (points)	Relative Constant-Murley score (points)	Pain VAS	Flexion strength (kg)	Abduction strength (kg)	External rotation strength (kg)	Fatty degeneration index
Fuchs et al. [10]	32	MRI	1	3	13	83/71		0.7/1.8			5.4/4.3	
Klepps et al. [23]	32	MRI		1	31	83/74		0.7/1.8	6.5/4.1	8.5/7.5		
Gerber et al. [13]	29	MRI	Massive	3	41		96/70					SS 1.3/2.8 IS 1.5/2.0 SSC 0.5/1.2
Goutallier et al. [16]	30	CT arthrography	FDI $\leq$ 2 at surgery	9	3	77						SS 1.2 IS 1.6 SSC 0.9
Harryman et al. [19]	89	Ultrasound		5	35 (30 after primary repair)	Satisfied 96%/70%			132°			
Jost et al. [20]	65	MRI	5	3	31							
Zumstein et al. [32]	23	MRI		9	57	81/64	95/77			5.5/2.6		
Knudsen et al. [24]	31	MRI	1	2	31	76/62						
Gazielly et al. [12]	98	Ultrasound	4	24								
Bartl et al. [1]	25	MRI	Massive	6	44	73		2.1				
Liem et al. [26]	19	MRI	1 mini-open	1.5	37							
Current study	67	MR arthrography	4	19	94	71/58	83/66	1.0/1.9	5.3/3.1	5.0/2.7	6.8/4.2	SS 2.1/4.6 IS 1.8/3.9 SSC 1.2/2.4

SS = supraspinatus; IS = infraspinatus; SSC = subscapularis.

Questionnaires were mailed to the patients along with the invitation to participate in the study. One questionnaire comprised questions concerning demographics, subjective satisfaction measured on a 5-point Likert scale (1 = very satisfied and 5 = very unsatisfied), and symptoms of the surgically treated shoulder, including pain evaluation on a VAS range, 0–10; 0 = no pain and 10 = maximal, intensive pain) (Appendix 1; supplemental materials are available with the online version of CORR). In addition, patients received the Simple Shoulder Test questionnaire [28]. The patients completed these questionnaires at home and returned them at the followup visit. Their answers were checked during the visit.

All 67 patients underwent a physical examination preoperatively, postoperatively, and at latest followup. ROM of both shoulders was measured with a goniometer, and muscle strength was measured with the same Salter spring balance used preoperatively [4, 29, 31]. During these measurements, the patient was seated, although abduction strength measurement with the arm at a 30° angle was performed standing.

The last postoperative routine clinical followup was done approximately 6 months after surgery. At the latest followup, an independent observer (NB) performed the physical examination. Presence of a painful arc sign was indicated by yes or no. Shoulder function was assessed by the Constant-Murley score [8]; absolute and age- and sex-related scores were calculated [22].

All patients had an MR arthrogram of the surgically treated shoulder before the clinical evaluation. Under ultrasound guidance, 10 mL diluted gadoterate meglumine (0.0025 mmol/mL; Artirem®, Guerbet, Villepinte, France) was injected into the shoulder by the anterior injection technique described by Valls and Melloni [30]. All MR studies were performed with the same Siemens Magnetom® Symphony 1.5-T MRI system (Siemens AG, Erlangen, Germany) and a local small-sized flexible coil. The following sequences were obtained: with fat saturation: oblique coronal T1-weighted spin echo (TR, 651 ms; TE, 12 ms; slice thickness, 4 mm), oblique coronal T2-weighted fast spin echo (TR, 4000 ms; TE, 70 ms; slice thickness, 4 mm), and angled axial (perpendicular to the glenoid joint surface) T1-weighted spin echo sequence (TR, 738 ms; TE, 12 ms; slice thickness, 4 mm); without fat saturation: oblique sagittal T1-weighted spin echo sequence (TR, 545 ms; TE, 12 ms; slice thickness, 5 mm). The field of view was 16 cm in all sequences.

Two of three senior radiologists (ML, PT, MK), familiar with musculoskeletal MR and blinded to the patient data and clinical findings, analyzed each MR study for various parameters (Appendix 2; supplemental materials are available with the online version of CORR). The evaluation was based on a consensus decision.

ANOVA served for analysis of long-term cuff integrity and fatty infiltration. Differences in categorical variables were tested with Pearson's chi-square test. We performed all statistical analyses with PASW® (Version 18.0; SPSS Inc, Chicago, IL, USA).

Results

A full-thickness tear in the supraspinatus tendon was detectable in 63 patients (94%), with a mean size of 3.5 × 3.6 cm (ranges, 0.5–5.0 cm × 0.5–5.2 cm; median, 4 × 4 cm) (Table 2). The remaining four patients had a partial supraspinatus tendon tear. In three of those four patients, the primary tear sizes were 25, 25, and 15 cm^2, operative delays were 7.3, 0.4, and 0.4 months, and ages at surgery were 50, 50, and 56 years. The retear measured 12.0 cm^2 in patients with a primary tear of 9 cm^2 or smaller and 15.5 cm^2 in the others ($p = 0.251$). Thus, primary tear size did not influence the retear size.

In one 66-year-old patient with an operative delay of 0.2 month, primary tear size was not estimated. Fatty infiltration was marked in the supraspinatus and infraspinatus tendons but not in the subscapular and teres minor (Table 2). In 27% of the patients, glenohumeral osteoarthrosis was severe, and the acromiohumeral space was narrow (Table 3). However, glenohumeral arthrosis estimated in MRI (moderate in 25 shoulders, severe in 18 shoulders) did not correlate with functional outcome (Constant-Murley score, $p = 0.060$; adjusted Constant-Murley score, $p = 0.073$; Simple Shoulder Test, $p = 0.360$). Only 9% of the patients had a normal labrum, and in ½ of the patients, a labrum tear was detected by MR

Table 2. Fatty degeneration and cuff integrity at minimum 16 years after open rotator cuff repair

Variable	Number of patients			
	Subscapularis	Supraspinatus	Infraspinatus	Teres minor
Goutallier stage				
0	6	1	2	15
1	35 (54%)	7	14	33 (49%)
2	4	10	9	7
3	4	5	10	3
4	3	3	5	3
5	14	41 (61%)	27 (40%)	6
Tendon integrity				
Normal	6	0	9	50 (75%)
Partial tear	27	4	16	8
Complete tear	34 (51%)	63 (94%)	42 (63%)	9

arthrography. The biceps tendon was normal in only 6% and dislocated in 58%.

Clinical and functional results were reported earlier [3] (Table 4). Cuff integrity correlated with clinical results. Twenty patients having an intact rotator cuff or a retear with a maximum size of 4 cm^2 achieved mean abduction strength of 5.0 kg, whereas abduction strength in the others was only 2.7 kg ($p < 0.001$). The active external rotation was 65° versus 42° ($p < 0.001$, and forward flexion was 155° versus 137° ($p = 0.031$), respectively. However, cuff integrity did not correlate with shoulder pain (Table 5).

Table 3. MRI findings at minimum 16 years after open rotator cuff repair

Variable	Value
Glenohumeral arthrosis*	
No	4
Mild	45
Severe	18
Acromiohumeral interval	
1–2 mm	33
3–4 mm	8
5–6 mm	20
7–9 mm	6
Labral lesion	
No	6
Yes	61
Biceps	
Normal	4
Partial tear	32
Complete tear	31
Full-thickness rotator cuff tear	
No	4
Yes	63
Tear size (cm)	
Mean	3.4 × 3.5
Median	4.0 × 4.0

* Values are expressed as number of patients.

Cuff integrity also correlated with functional results. Twenty patients having an intact rotator cuff or a retear with a maximum size of 4 cm^2 achieved a mean Constant-Murley score of 71, whereas the others achieved only 58 ($p = 0.004$). The Simple Shoulder Test scores were 9.1 versus 7.6 ($p = 0.069$), respectively. Cuff integrity correlated similarly with the fatty degeneration index (Table 6). However, tear size at surgery, measured in 43 patients, did not correlate with long-term outcome (23 tears $\leq$ 9 cm^2 versus 20 tears $>$ 9 cm^2) (Constant-Murley score, $p = 0.148$; adjusted Constant-Murley score, $p = 0.230$; Simple Shoulder Test, $p = 0.115$). The 15 patients treated using a free tendon graft had functional results similar to those of the others ($p = 0.259$, 0.215, and 0.560, respectively).

Discussion

Recurrent or persistent defects in the rotator cuff after its repair are common. Short- and medium-term surveys have revealed, after open repair, patients with an intact rotator cuff have increased function and ROM. However, no long-term studies have verified cuff integrity on MR arthrography or correlated it with clinical and functional outcomes. We therefore evaluated long-term cuff integrity and fatty infiltration as documented by MRI and correlated these findings with the clinical and functional results in 67 patients 16 to 25 years after open RCR.

We acknowledge several limitations. First, many of the patients in this series initially had quite large and complicated rotator cuff tears. The time from onset of symptoms to surgery, approximately 30 years ago, was on average 2.4 years (median, 1.1 year), making the ruptures difficult to repair. Free tendon grafts therefore were used in as many as 52 of the total 67 patients. Our patients therefore may not represent a typical patient population in the current clinical setting with widespread awareness of this condition and the demand for accurate diagnosis and treatment without delay. However, we believe our patients represent, from the era before common use of MRI and early diagnosis, typical patients with rotator cuff ruptures and with

Table 4. Clinical and functional results mean 20 years after open rotator cuff repair

Time	Flexion (°)	Abduction (°)	External rotation (°)	Flexion strength (kg)	Abduction strength (kg)	External rotation strength (kg)	Constant-Murley score (points) (male/female)	Adjusted Constant-Murley score (points) (male/female)	Simple Shoulder Test (points)
Preoperatively	140	148	60	4.9	4.4	6.4			
Mean 20 years after open rotator cuff repair	144	139	49	4.1	3.7	5.2	66/60	81/82	8

Table 5. Cuff integrity and clinical results at minimum 16 years after rotator cuff repair

Patient group	Number of patients	Mean active ROM (°)				Mean strength (kg)			Pain VAS		
		Flexion	Abduction	External rotation	Internal rotation	Flexion	Abduction	External rotation	At rest	On exertion	At night
Intact cuff or retear ≤ 4 cm^2	20	155	148	65	L5	5.3	5.0	6.8	1.0	3.5	1.7
Retear > 4 cm^2	47	137	130	42	S1	3.1	2.7	4.2	1.9	4.0	2.4
p value		0.031	0.074	< 0.001	0.048	< 0.001	< 0.001	0.001	0.155	0.630	0.471

Table 6. Cuff integrity, functional results, and fatty degeneration index at minimum 16 years after rotator cuff repair

Patient group	Number of patients	Constant-Murley score	Adjusted Constant-Murley score	Simple Shoulder Test	Fatty degeneration index			
					Subscapularis	Supraspinatus	Infraspinatus	Teres minor
Intact cuff or retear ≤ 4 cm^2	20	71	83	9.1	1.2	2.1	1.8	1.1
Retear > 4 cm^2	47	58	66	7.6	2.4	4.6	3.9	1.6
p value		0.004	0.001	0.069	0.004	< 0.001	< 0.001	0.099

distinct clinical findings and functional disorders. Second, the patients were selected to include only those with preoperative ROM and strength measurements performed with a spring balance. We could include only ½ of the patients who had had surgery, and only ½ of those fulfilled our requirements owing to death or other reasons. Third, the Constant-Murley score and Simple Shoulder Test were not in use at the time of these surgeries. Although we place great value on longitudinal assessment of outcome measures, only ROM and strength measurements were available preoperatively and postoperatively.

Cuff integrity appeared to be poor 16 years after open repair: 94% had a full-thickness retear, whereas 69% of repairs were intact at 1 year [3, 23], 68% at 2 years [24], and 69% at 7 years [21], but only 56% after repair of massive tears at 6 years [1]. A retear rate of only 13% [10] was found 3 years after open repair of an isolated one-tendon tear of the rotator cuff and 41% after repair of massive tears [13], but this reached 57% at 9 years [32]. The retear rate was reported to be increased with shorter operative delay [13]. We could not confirm this finding. In addition, Fuchs et al. reported reruptures of the supraspinatus that had been smaller than 4 cm^2 had the potential to heal [10]. We also considered retears smaller than 4 cm^2 as benign retears when comparing clinical and functional results. Gladstone et al. [15] stated the most influential effect on repair integrity appeared to be from tear size. However, in the current series, tear size did not influence repair integrity. After all-arthroscopic RCR, the healing rates estimated by ultrasonography were 64% at 1 year, 75% at 2 years, and 81% at 5 years [17]. Arthroscopic RCR of massive rotator cuff tears with advanced mobilization techniques led to reversal of preoperative pseudoparalysis in 90% of patients who did not have previous surgery, but only 43% of patients regained flexion greater than 90° after revision arthroscopic RCR [9].

Fatty degeneration was severe in the supraspinatus and infraspinatus tendons in 61% and 40%, respectively, whereas the subscapularis and teres minor tendons remained in better condition, with only 19% and 9%, respectively, having severe fatty degeneration. Fatty infiltration increased in all muscles [13] and in the supraspinatus and infraspinatus muscles during 3 years after open RCR although the cuff was intact [11]. Fatty infiltration progressed during the first year after RCR [15].

Concerning the current study, the lack of MRI data regarding the preoperative fatty infiltration does not allow interpretation of the progression of fatty infiltration from the time of repair. This is particularly critical given the substantial delay in treatment in the current patient population. There is no way to confirm the fatty infiltration identified in our patients is different from that present preoperatively. There also is no way to confirm fatty infiltration greater than 50% was not present preoperatively in the current population.

Regarding correlations between cuff integrity and clinical or functional results, Harryman et al. [19] reported increased functional ROM in patients who had an intact rotator cuff after open repair. Goutallier et al. [16] reported open tension-free tendon-to-bone suture with a fatty degeneration index of 2 or less is effective functionally and structurally if the repair is intact after 1 year [16]. Smaller

retears had no influence on the clinical result, but more retracted retears correlated with lower abduction strength [26]. We found the same when comparing retears of 4 cm^2 or smaller and larger 4 cm^2. Klepps et al. [23] did not find postoperative cuff integrity to have any effect on outcome 1 year after surgery, nor did Knudsen et al. [24] 2 years after surgery, but we found a strong effect after 16 years. Recent data have suggested radiographic healing (ultrasonography) after all-arthroscopic repair may occur after 1 year, despite no evidence of healing at 1 year [18].

Goutallier et al. [16] stated fatty degeneration increased during the first year after RCR but remained stable thereafter [14]. Gladstone et al. [15] found it correlated with poor functional outcomes but did not improve after RCR. In our study, fatty infiltration also correlated with poor functional outcomes.

In determining long-term cuff integrity and fatty infiltration correlated with clinical and functional results up to 16 years after surgery, we noticed a surprisingly high retear rate of 94%. However, this finding may be in accordance with earlier findings with a shorter followup: 13% after 3 years [10], 35% after 5 years [19], and 57% after 9 years [32]. We found cuff integrity also correlated with clinical and functional results after open repair in the long run. A high retear rate might lead us to reconsider the role of operative treatment of rotator cuff rupture. However, taking into account the good short- and medium-term clinical results, the fairly good long-term clinical results, and the long operative delay in this study, operative treatment of rotator cuff tears is still the preferred method in appropriate cases. We need long-term followup on smaller tears that we treat earlier during their clinical course.

Acknowledgments We thank Pekka Tervahartiala MD, PhD and Martti Kiuru MD, PhD for MRI evaluation; Leena Ristolainen PT, PhD for statistical help; and Carol Norris PhD for language revision.

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