Correlations of isokinetic measurements with tendon healing following open repair of rotator cuff tears

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Abstract The aim of this study was to investigate the correlation of tendon integrity following open cuff repairs with functional and isokinetic strength measurements. Twenty-six shoulders of 25 patients were included in this study. At the final follow-up, 14 repairs (53.8%) were intact and 12 repairs (46.2%) had failed on magnetic resonance imaging (MRI). Mean UCLA score at latest follow-up was 28.5 and mean Constant score was 80.3. Constant scores were found to be significantly low for the failed group. Age was found to be significantly related to failed repair. Fatty infiltration stage in the failed repair group was significantly high,

and a strong positive correlation for both groups existed pre and postoperatively. When both groups were compared, the failed group was found to have significantly low measurements at extension and internal rotation. Despite high failure rates, functional results were satisfactory. Increased age and fatty infiltration stage decrease success.

Introduction

Tears of the rotator cuff are a common cause of shoulder pain and disability. The frequency of partial or complete rotator cuff tears increases with age and can be asymptomatic. Several clinical and autopsy studies have documented that asymptomatic, age-related partial or complete rotator cuff tears occur in 10–90% of all individuals [15, 20].

Despite the ubiquity of rotator cuff tears, there is substantial debate concerning their management. Management of full-thickness rotator cuff tears can be either by conservative measures (such as nonsteroidal anti-inflammatory drugs, steroid injections, and physical therapy) or by limited surgical interventions like debridement. However, these techniques are not effective for the patient with significant functional limitations. Thus, several surgical techniques to repair these tears have been developed in an attempt to improve functional outcomes [11]. Even though rerupture of the cuff occurs 20–65% of the time, clinical results show success for rotator cuff repair in symptomatic patients who have been followed up for more than ten years [6].

Recent data on the natural history of unrepaired rotator cuff tears has shown that tears may progress and become irreparable [27]. Also, open cuff repairs for massive cuff tears can result in deltoid detachment,

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which negatively affects the functional results [9]. Animal studies demonstrate that a detached cuff has a substantial decrease in muscle twitch strength as well as fatty infiltration of the muscle [5]. Goutallier et al. report that fatty infiltration is a time-dependent process that increases as the tear is left untreated. The authors also reported that rates of recurrent tears are reduced when there is minimal fatty degeneration of muscle at the time of surgical intervention [7, 8]. This study sought to define the relationship between cuff integrity following open rotator cuff repair with functional results and isokinetic muscle strength measurements and to elucidate possible factors leading to failure.

Materials and methods

Patient selection

Twenty-six shoulders of 25 patients who had open rotator cuff repair were available for isokinetic and radiological evaluation with at least one year of follow-up. Bilateral staged cuff repair was performed in only one patient. Mean age at the time of surgery was 58.3 years (range, 39–82). Eight percent of the patients were female.

The dominant arm was involved in 17 shoulders (65.4%). Surgical treatment was indicated for patients who remained symptomatic following adequate conservative management. Home exercise programs, local injections, and physical therapy were tried for at least three months. Patients with symptomatic cervical spine disease, degenerative joint disease, and frozen shoulder were excluded and managed accordingly. The mean time from first symptom to repair was 24.4 months (range, 6–120). Average follow-up was 32.2 months (range, 12–122 months). Mean body mass index (BMI) was 30.6 kg/m² (range, 23.1–38.6 kg/m²).

Surgical technique

Surgery was performed with patients in the beach chair position using a deltoid split approach. Transosseous no. 5 sutures were used for rotator cuff repair. Transosseous sutures alone were used in 17 shoulders (65.4%), and suture anchors alone were used in seven shoulders (26.9%). Both a transosseous suture and a suture anchor were used in two patients (7.7%). Additionally, in shoulders with transosseous sutures, 12 subacromial decompressions were performed; and in shoulders with suture anchors, six subacromial decompressions were performed. Following repair, if the cuff had no undue tension when the arm was in contact with the body, no abduction splint was used.

Functional evaluation

The functional outcome at latest follow-up was rated according to the Constant and University of California at Los Angeles (UCLA) shoulder rating scores. Constant scores included four parameters: pain, activities of daily living, range of pain-free motion, and strength. Patients could achieve a maximum of 100 points [4]. The UCLA score included five parameters: pain, function, active forward flexion, strength of forward flexion, and overall satisfaction, with a maximum score of 35 points [1].

Strength testing

A computerised isokinetic dynamometer (Cybex 770 Norm, Lumex Inc., Ronkoma NY, USA) was used to test isokinetic strength of the shoulder muscles at constant angular velocities of 60°/s, 120°/s, and 180°/s on the repaired side. Five repetitions were performed at each velocity. A 90-second rest period was allowed after each measurement with a five-minute rest between the two shoulders. One examiner performed all isokinetic dynamometer measurements using the same test protocol for all measurements. To standardise the measurements, we created a new test protocol for the isokinetic mode menu of the machine. Subjects were seated in the isokinetic dynamometer chair in 80° of hip flexion, 90° knee flexion, and with the ankle unrestricted. The trunk and legs were stabilised using straps across the chest, waist, and upper thigh. The axis of the lever of the isokinetic dynamometer was aligned with the axis of the shoulder joint. Range of motion was measured while the patient grasped the lever doing maximal possible passive movement in the three motions (i.e. abduction–adduction, flexion–extension, external and internal rotation). One patient who had bilateral rotator cuff repair and two patients who were unable to complete the isokinetic tests were excluded from the statistical analyses.

Radiological evaluation

To compare tear size, retraction, and fatty infiltration of the muscle level, preoperative and postoperative MRIs were evaluated by the same radiologist. The imaging protocol included the following sequences for cuff integrity: oblique coronal fast proton-density weighted with fat saturation and fast STIR (short TI inversion recovery) sequence, and sagittal T2-weighted images with fat saturation. Both preoperative and postoperative cuff integrity according to the supraspinatus tendon were determined with MRI and were classified into five categories: type 1 (sufficient thickness with homogeneously low intensity), type 2 (sufficient thickness with partial high intensity), type 3 (insufficient thickness without discontinuity), type 4-A

(presence of a partial-thickness focal discontinuity), type 4-B (presence of a full-thickness focal discontinuity), and type 5 (presence of a major discontinuity with retraction) [21]. In type 5, length of supraspinatus tendon retraction (in millimeters) was also determined. Supraspinatus tendon retraction in the coronal plane was classified according to the location of the medial edge of the tear in reference to the surrounding anatomy. If the diameter of the tear over the greater tuberosity was <10 mm, it was classified as minimal. If the tear measured 10–30 mm and exposed the humeral head but did not retract to the glenoid articular surface, then the tear was considered moderate. If the tear measured 30–50 mm and retracted to the glenoid, it was considered severe. Tears >50 mm that were retracted medial to the glenoid were classified as massive. Postoperative MRI types 1, 2, and 3 were accepted as intact repairs, and types 4A, 4B, and 5 were considered failed repairs [2, 23].

Preoperative MRIs of five patients were missing, and those patients were thus excluded from the radiological evaluations. Preoperative MRIs of 21 shoulders were evaluated. All patients had supraspinatus tendon tears, one shoulder had an additional subscapularis tendon tear, one shoulder had an additional infraspinatus tendon tear and one shoulder had additional tears of both subscapularis and infraspinatus tendons. All cuff tendons were carefully repaired during index surgery.

Muscle fatty degeneration was evaluated using an oblique sagittal T1-weighted MRI image in which the scapular spine in contact with the scapular body (the so-called Y-shaped view) was examined. A five-stage grading system was used to reach subjective consensus about fatty degeneration of the supraspinatus muscles. This grading system focuses on the amount of fatty deposition within the supraspinatus muscle. Stage 0 corresponds to a muscle with no fat; in stage 1, the muscle contains some fatty streaks; in stage 2, the fatty infiltration is prominent (but there is still more muscle than fat); in stage 3, there is as much fat as muscle; and in stage 4, there is more fat than muscle [17].

Statistical analyses

Demographic features of the patients are presented as percentages, ranges, means, and standard deviations for both groups. The chi-square and Mann-Whitney U tests were used to evaluate the significance of the demographic characteristics of the two groups. The effect of surgery on cuff integrity was analysed with the Mann-Whitney U test. Also, the Kendall tau rank correlation coefficient (r) was used to assess the relationship of postoperative MRI cuff types and isokinetic strength measurements and fatty degeneration stages. Values of $P < 0.05$ were considered statistically significant. The study data were analysed with SPSS software (Statistical Package for the Social Sciences, version 13.0; SPSS Inc., Chicago, IL, USA).

Results

At last follow-up, mean UCLA score was 28.5 (range, 10–35) and mean Constant score was 80.3 (range, 40–100).

According to postoperative MRI evaluation, patients were divided into two groups. Twelve patients with type 4 (5) and type 5 (7) cuffs were classified as the failed repair group and 14 patients with type 1 (5), type 2 (3) and type 3 (6) cuffs were classified as the intact cuff repair group. The type 5 failed repair group had one massive, four severe and two moderate retractions of the supraspinatus tendon.

The demographic features of the two groups were compared with regard to age, sex, involved side, dominant extremity, follow-up duration, BMI, and functional scores (Table 1). Only age was significantly related to failed repair ($P < 0.05$). Although the mean UCLA and Constant scores were higher in the cuff intact group, statistically significant differences were found only for Constant scores ($P < 0.05$) and not for UCLA scores ($P > 0.05$). No statistically significant differences were found between the different surgical techniques with regard to repair failure ($P > 0.05$).

Table 1 Patient demographics

Demographic	Intact repair	Failed repair
Number of shoulders	14	12
Age $\pm$ SD (years)	53.7 $\pm$ 6.1	63.7 $\pm$ 11.1
Gender (female:male)	10:3	10:2
Side (right:left)	7:7	10:2
Number of dominant arm injury	7	10
BMI $\pm$ SD (kg/m ²)	30.7 $\pm$ 4.3	30.3 $\pm$ 3.3
Follow-up duration $\pm$ SD (months)	30.5 $\pm$ 25.1	34.1 $\pm$ 29.7
UCLA score	30.7 (range 27–35)	25.8 (range 10–35)
Constant score	89.4 (range 90–100)	69.7 (range 40–95)

SD standard deviation,
BMI body mass index

Table 2 Cuff integrity gradings

Outcome	MRI	Type 1	Type 2	Type 3	Type 4-A	Type 4-B	Type 5
Intact repair	Preoperative	-	-	-	27.30%	63.60%	9.10%
	Postoperative	35.70%	21.40%	42.90%	-	-	-
Failed repair	Preoperative	-	-	-	-	60%	40%
	Postoperative	-	-	-	-	41.70%	58.30%

The preoperative cuff status of shoulders in both groups was assessed by MRI. Five patients were excluded because of missing preoperative MRI. In the intact group, 27.3% were type 4-A, 63.6% were type 4-B, and 9.1% were type 5 cuff tears. In the failed repair group, 60% were type 4-B and 40% were type 5 cuff tears preoperatively (Table 2). No significant differences were found with regard to preoperative cuff status between the intact and failed repair groups ($P>0.05$).

Retraction of the type 5 failed group was re-evaluated. When compared with preoperative measures, MRI demonstrated that the tear was smaller than the initial tear in two patients, the same in two, and larger in three shoulders.

Shoulders which had failed repair were also re-evaluated for other associated tendon tears. One shoulder had an additional infraspinatus tear, two had additional subscapularis tears and two had additional tears of both subscapularis and infraspinatus tendons. Additional tears of cuff tendons other than supraspinatus which were not noted on preoperative MRIs were only seen in two shoulders at postoperative MRI.

Table 3 shows the preoperative and postoperative stages of fatty infiltration of the muscle as assessed by MRI in both groups. Stage of fatty infiltration in the failed repair group was significantly high postoperatively ($P<0.05$). A strong correlation was found between preoperative and postoperative muscle fatty infiltration stage for both groups ($P<0.05$; $r=0.65$).

On preoperative MRIs one patient had additional subscapularis fatty degeneration and three patients had additional infraspinatus fatty degeneration. One of these patients who had infraspinatus fatty degeneration also had an infraspinatus tear on preoperative MRI, but on postoperative MRI no fatty degeneration was found and the tendon was intact. Fatty degenerations of any muscle group persisted in seven patients and progressed in all the remaining 12 patients.

Shoulder strength of the repaired side was evaluated with an isokinetic dynamometer. Kendall tau rank correlation coefficients (r) were calculated for postoperative MRI tear types (Table 4). Significant negative correlations were found at extension strength (60°/s, 120°/s, and 180°/s) and at internal rotation strength (120°/s) ($P<0.05$). The isokinetic measurements of the involved shoulder in the intact and failed groups were also compared. The failed repair group had significantly low measurements at extension (60°/s and 180°/s) and at internal rotation (120°/s) ($P<0.05$).

Patients were divided into two groups (stages 1–2 and stages 3–4) regarding the fatty degeneration of supraspinatus muscle on postoperative MRI. Statistical analyses revealed that stage 3–4 patients had significantly low internal rotation strength (60°/s and 120°/s) when compared with stage 1–2 patients ($P<0.05$).

Discussion

The prognosis following rotator cuff repair is unpredictable and depends on many factors. Causes of failure may depend on preoperative factors including tear size, retraction, conjoined lesions, muscle atrophy, and fatty infiltration [24]. In addition, it has been suggested that an absence of healing after rotator cuff repair may be secondary to mechanical factors such as pullout of anchors, broken sutures, or inappropriate rehabilitation, and also to biological factors such as osteoporotic bone, weak degenerative tendons, and decreased healing potential with age [19, 22].

Our study demonstrated that age was a significant factor influencing tendon healing. The rate of tendon integrity at postoperative follow-up decreased as patient age increased. The average age of patients in the intact tendon repair group was ten years younger than those in the failed tendon repair group. Recently, Boileau et al. reported similar results [3].

Table 3 Stages of fatty infiltration of the muscle

Outcome	MRI	Stage 0	Stage 1	Stage 2	Stage 3	Stage 4
Intact repair	Preoperative	36.40%	54.50%	9.10%	-	-
	Postoperative	-	78.60%	21.40%	-	-
Failed repair	Preoperative	-	60%	20%	10%	10%
	Postoperative	-	-	41.70%	33.30%	25%

Table 4 Shoulder strength measurements

Strength measurements	Angular velocity					
	60°/s		120°/s		180°/s	
	<i>r</i>	<i>P</i> values	<i>r</i>	<i>P</i> values	<i>r</i>	<i>P</i> values
Internal rotation	−0.28	0.06	−0.32	0.031*	−0.27	0.07
External rotation	−0.07	0.63	−0.11	0.45	−0.11	0.46
Extension	−0.42	0.004*	−0.34	0.023*	−0.36	0.014*
Flexion	−0.26	0.08	−0.01	0.95	−0.1	0.49
Abduction	−0.2	0.18	−0.09	0.58	−0.13	0.38
Adduction	−0.18	0.21	−0.2	0.19	−0.11	0.48

* Significant correlations

They reported that patients older than 65 years had only a 43% chance of tendon healing after open rotator cuff repair.

In this study, significantly better functional outcomes were found in the intact repair group only with Constant score. Although no significant differences were revealed according to UCLA score between the groups, a high rate of patient satisfaction (85%) was observed during follow-up. As a result, it is concluded that patients with appropriate indications (e.g. pain and loss of function) can benefit from rotator cuff surgery. Osti et al. revealed that there was no difference in terms of subjective and objective outcomes between the open and arthroscopic surgical technique if patients had rotator cuff tears of less than 3 cm. We preferred open cuff repair because our patients had chronic tears [18].

Function and appearance of a torn rotator cuff have been shown to deteriorate with time [10]. Recent animal studies have shown that a detached cuff showed fatty infiltration and decreased muscle twitch strength. A cuff tear was created and a subsequent repair was performed at six and 18 weeks. Animals in the six-week group had a partial reversal of fatty infiltration, but this reversal was not observed in the 18-week group [5]. These results may imply that better results can be expected with an earlier repair of the rotator cuff. All patients in our study had chronic tears; repair was delayed more than six months following initial symptoms. In our study, fatty infiltration of the muscle on MRI decreased in one patient, it was stable in seven patients and progressed in all the remaining patients. Although Fabis et al. demonstrated decreased fatty infiltration after repair in an animal study, previous reports have failed to show improvement [5, 7, 8]. We recommend that future studies examine early rotator cuff repair results with respect to fatty infiltration. Following cuff repair, all patients functional results were markedly improved regardless of postoperative cuff status. Therefore, we consider repair for both acute and chronic tears when symptomatic.

Postoperative MRI demonstrated more extensive fatty infiltration of the muscle in the failed repair group. Our results support the hypothesis that failed repair is associated with extensive fatty infiltration of the muscle. In addition, the stage

of fatty infiltration on preoperative MRI was found to be an important factor leading to failure. Our results also demonstrate a strong positive correlation between preoperative and postoperative stages of fatty infiltration of the muscle. In summary, the stage of preoperative fatty infiltration is an important factor determining the success of tendon repair. We conclude that aging of the tendon and duration of the established tear which resulted in fatty degeneration of the muscle group are important factors leading to repeat tears.

The relationship between shoulder strength and preoperative tear size has been previously reported. This relationship is logical because when compared with larger tears, small tears are easier to repair, have less fatty infiltration, surgical exposure is not as extensive, and adhesions are less likely to occur. On the other hand, some researchers have found no relationship between preoperative tear size and shoulder strength [12, 14, 25]. Our results demonstrated a negative correlation between postoperative tear type and shoulder strength at the repair side at extension (60°/s, 120°/s and 180°/s) and at internal rotation (120°/s). We were surprised by our data because failed cuff repairs had not been expected to function better in abduction and external rotation; however, our data show that these two measurements were not related to postoperative tear type. It is well known that external rotators are the weakest group of rotator cuff muscles [13], and our findings may be explained by the overtightening of the external rotators during repair, which may limit internal rotation and decrease its contribution to extension. Two subsequent studies performed on cadavers demonstrated that neither shoulder movement nor glenohumeral kinematics are significantly affected by a simulated paralysis of the supraspinatus [16, 26]. These results suggest that loss of supraspinatus activity is compensated by increased deltoid function. Patient activity level and successful rehabilitation have a positive effect on functional outcome. In instances of failed repair at follow-up, although seemingly contradictory, patient satisfaction and functional scores were satisfactory.

In conclusion, with regard to cuff status on MRI following repair, high failure rates can be expected. Fatty

infiltration of the cuff and aging of the patient significantly increase failure. But this failure only effects extension and internal rotation strengths without compromising functional results. We suggest that if functional improvement is the goal of treatment, then the potential for structural failure should not limit the indications for rotator cuff repair. Further clinical studies are needed to clarify our results.

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