Effect of Preoperative Fatty Degeneration of the Rotator Cuff Muscles on the Clinical Outcome of Patients with Intact Tendon after Arthroscopic Rotator Cuff Repair of Large/Massive Cuff Tears

Running Title: Preoperative Fatty Degeneration after ARCR

Abstract

Background: Fatty degeneration of the rotator cuff muscle is associated not only with postoperative retear but also with postoperative muscle weakness; therefore, fatty changes in the muscles may affect the clinical outcome even in patients with these tears who had intact tendon after arthroscopic rotator cuff repair (ARCR).

Purpose: To evaluate the effect of fatty infiltration on the clinical outcome in patients with intact tendons after arthroscopic repair of large/massive cuff tears.

Study Design: Retrospective study

Methods: One hundred fifty-five consecutive patients with large/massive rotator cuff tears underwent ARCR. Of these, 55 patients (average age, 64.4 ± 9.1 years) in whom intact tendon after surgery was confirmed using magnetic resonance imaging at final follow-up (average, 2.5 ± 1.4 years) were included in this study. Depending on their

University of California Los Angeles (UCLA) score at the final follow-up, they were assigned into either the unsatisfactory group (score ≤27; n = 12) or the satisfactory group (score >27; n = 43). Various clinical parameters affecting the clinical outcome were examined using univariate and multivariate analyses.

Results: The UCLA score of all patients significantly improved from 18.1 ± 4.4 points preoperatively to 29.8 ± 4.5 points postoperatively ($p < 0.0001$). The mean preoperative UCLA scores were not significantly different between the satisfactory and unsatisfactory groups ($p = 0.39$). Multivariate analysis showed that the preoperative Goutallier stages of the infraspinatus (odds ratio [OR], 8.87; 95% confidence interval [CI], 1.51-52.0; $p = 0.016$) and/or subscapularis (OR, 7.53; 95% CI, 1.58-35.9; $p = 0.011$) were significantly associated with outcome. ROC curve analysis revealed that the cutoff value is Goutallier stage 1 in both muscles, with area under the curve values of 0.79 (sensitivity: 91% and specificity: 51%) and 0.84 (sensitivity: 100% and specificity: 54%) in the infraspinatus and subscapularis, respectively.

Conclusion: Preoperative fatty degeneration of the infraspinatus and/or subscapularis with Goutallier stage ≥2 was significantly associated with worse outcome in patients

with large/massive tears who had intact tendon after ARCR.

Key Terms: arthroscopic rotator cuff repair, fatty degeneration, factors for clinical outcome

What is known about the subject: Previous studies reported the risk factor for worse clinical outcome in patients with arthroscopic rotator cuff repair (ARCR), including both retear and non-retear cases after surgery. Fatty degeneration of rotator cuff muscles more or less progresses in large/massive cuff tears; therefore, the muscle changes may affect the postoperative function even in these patients with intact tendon after surgery. However, few studies have evaluated the risk factors for worse outcome particularly in patients with large/massive cuff tears who had intact tendon after ARCR.

What this study adds to existing knowledge: Even if arthroscopic repair is achieved with postoperative intact tendon, preoperative fatty degeneration of the infraspinatus and/or subscapularis is significantly associated with worse clinical outcome after surgery.

Introduction

Rotator cuff tear causes pain and functional disorder of the shoulder, accounting for more than 4.5 million physician visits per year in the United States.[28] This disease can be found in 30% to 50% of the population older than 50 years.[31] When individuals with cuff tear become symptomatic, conservative treatment is performed first except in acute or subacute traumatic injury.[2] Once conservative treatment performed for a certain periods fails,[3,12] open or arthroscopic rotator cuff repair (ARCR) is used.

The clinical outcome of ARCR is generally favorable, but postoperative retear is of great concern, especially in large/massive cuff tears. A number of articles have described the risk factors for retear after ARCR.[5,27] Recent review articles suggested that older patients, larger tears, and fatty degeneration were the risk factors of postoperative structural failure.[19,21] Fatty degeneration of the rotator cuff is closely associated with retear after surgery, causing further propagation if untreated.[23]

Reversibility of fatty degeneration in patients with intact tendon after surgery remains unclear. Fatty degeneration is mostly irreversible despite successful repair[8,9]; by contrast, reversal can be observed in patients with lower Goutallier stage without

63 retear.[35] Fatty degeneration of the rotator cuff muscles is also involved in muscle
64 weakness, which affects shoulder function.[9,28] These results raised the hypothesis that
65 fatty degeneration of the rotator cuff muscles might affect the clinical outcome of
66 patients with large/massive tears, even in those with intact tendon after surgery.
67 Therefore, the purpose of the present study was to evaluate the factors affecting clinical
68 outcome in patients with intact tendon after arthroscopic repair of large/massive cuff
69 tears.
70
71 **Material and Methods**
72 This retrospective study was approved by the institutional review board of Kurume
73 University (#12333).
74
75 **Subjects**
76 Between April 2005 and December 2013, 155 patients with large/massive rotator cuff
77 tears underwent ARCR. Patients who had footprint of torn cuff covered completely,
78 patients who did not show retear on magnetic resonance images (MRI) at final

follow-up, patients who were followed up for at least 1 year, and patients whose University of California Los Angeles (UCLA) score before and after surgery had been evaluated were included. Exclusion criteria were advanced glenohumeral arthritis, fractures of the shoulder, or revision surgeries. Consequently, we confirmed 55 patients with healed tendons, 19 with retears and 14 with partial repairs. Five patients med exclusion criteria, and 62 were lost to follow-up; the follow-up rate was 60% (93/155 cases).

Surgical Technique and Postoperative Regimen

ARCR was performed by two surgeons if the patients did not respond to conservative treatment (administrations of anti-inflammatory drugs, physical therapy, and intra-articular injections of corticosteroids or hyaluronic acid) for at least 3 months.

The patients underwent ARCR in the beach position under general anesthesia. The torn cuff was repaired using single-row, double-row, or suture bridge technique depending on tendon mobility and tear configuration. For single-row repairs, one row of anchors was placed on the lateral aspect of the footprint, and the torn cuff was fixed

with interrupted suture. For double-row repairs, one row of anchors was placed on the medial and lateral aspects of the footprint, and the torn cuff was fixed with mattress and interrupted sutures, respectively. For suture bridge repair, one row of anchors was placed on the medial aspect of the footprint with or without tying, and the torn cuff was transosseously fixed with the knotless anchor on the lateral aspect of the footprint. Additional procedures including capsular release, tenotomy/tenodesis of the long head of the biceps (LHB) tendon, and distal clavicle excision were used if needed. Acromioplasty was performed in all cases.

The patients were immobilized in a sling with abduction pillow after surgery, with the shoulder internally rotated at 30° to 40° and abducted at 20°. Passive range of motion (ROM) exercise of the shoulder was commenced at postoperative day 4, and active ROM exercise was allowed at postoperative week 6. Isotonic muscle strengthening exercises were allowed at postoperative week 12.

Functional Assessment

UCLA scores were used as a clinical outcome measure. ROM was assessed using a

111 goniometer, and muscle strength was measured using a hand-held dynamometer (Micro
112 FET2; Hoggan Health Industry, West Jordan, UT, USA). Visual analogue scale (VAS)
113 scores at three states (at rest, at shoulder motion, and at night) were reported as patients'
114 subjective assessments. These measures were evaluated before and after surgery.
115
116 **Structural Assessment**
117 Tear length, tear width, fatty degeneration, muscle atrophy before surgery, and structural
118 integrity after surgery were examined with MRI, according to a previous report.[25]
119 Postoperative "intact tendon" was defined as types I-III in the Sugaya classification.[34]
120 The tear length and width were evaluated as the coronal and sagittal oblique distance on
121 T2-weighted images, respectively.[13] Muscle atrophy was calculated as the
122 cross-sectional area of the rotator cuff muscle belly in relation to the cross-sectional
123 area of the supraspinatus fossa at Y-view on T2-weighted images,[24] using Image J
124 software (NIH, Bethesda, MD, USA). The fatty degeneration of the rotator cuff muscles
125 at the Y view was evaluated according to the Goutallier classification.[7]
126

Assignment of the Satisfactory and Unsatisfactory Groups

According to the UCLA score at final follow-up, patients who had intact tendon after ARCR were divided into two groups: the unsatisfactory group, comprising individuals classified into the "poor or fair" criterion (≤27 points, n = 12), and the satisfactory group, comprising those classified into the "good or excellent" criterion (>27 points, n = 43).[30,6,17]

Various variables were used to analyze the association with the satisfactory or unsatisfactory outcome using univariate and multivariate analyses: patient's age, sex, symptom duration, smoking, comorbidities, hand dominance, traumatic onset, worker's compensation status, repair techniques, treatments of LHB tendon, tear length, tear width, muscle atrophy, fatty degeneration, ROM, muscle strength, VAS score, and preoperative UCLA score.

Statistical Analysis

The JMP11 software (SAS Institute, Cary, NC, USA) was used for statistical analysis. Wilcoxon test was used to compare between the UCLA scores before and after surgery.

Univariate logistic analysis was used to compare the relationship between the clinical parameters of the satisfactory and unsatisfactory groups and to analyze the relationship between Goutallier stage in the rotator cuff muscles and sections in the UCLA score. Multivariate logistic analysis with stepwise technique using the clinical variables ($p < 0.1$) was performed to evaluate the significant parameters affecting "satisfactory" or "unsatisfactory" outcome in the UCLA score, accompanied by the odds ratio (OR) with 95% confidence intervals (CIs). Then, receiver operating characteristic (ROC) curve analysis was performed to obtain the cutoff value of the parameters affecting the clinical outcome. The cutoff value was determined as the maximum value of Youden Index (sensitivity + (1 − specificity)) on the ROC curve. The data are expressed as the mean values with standard deviation. A p value <0.05 was considered significant.

Results

Functional Outcome in the Satisfactory and Unsatisfactory Groups

Fifty-five patients were included in this study. The mean age at surgery was 64.4 ± 9.1 years, with a mean follow-up period of 2.5 ± 1.4 years. The mean duration of symptom

before surgery was 36.9 ± 49.1 weeks.

The UCLA score of all patients significantly improved from 18.1 ± 4.4 points preoperatively to 29.8 ± 4.5 points postoperatively (n = 55) (Fig. 1A). No significant difference was found in the mean preoperative UCLA scores between patients with satisfactory and unsatisfactory outcomes (p = 0.39) (Fig. 1B).

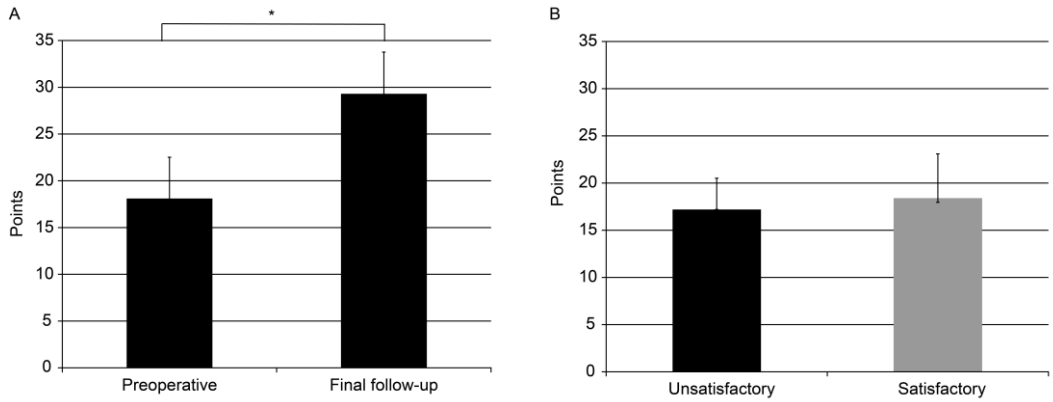

Fig. 1. A Mean preoperative and postoperative UCLA scores of all patients. **B** Mean preoperative UCLA scores of both the satisfactory and unsatisfactory groups. Error bars represent standard deviation. *Statistically significant (p < 0.0001).

Univariate Analysis to Detect the Factors Affecting Clinical Outcome

172 The results of the univariate analysis showed that the preoperative Goutallier stage of
173 the infraspinatus and subscapularis, preoperative muscle abduction strength, and LHB
174 treatment during surgery are significantly associated with postoperative clinical
175 outcome (p = .0021, p = .0024, p = .0051, and p = .0073, respectively) (Table 1).

176 Table 1. Comparison of Various Variables between the Satisfactory and Unsatisfactory
177 Groups

Variables	**Total**	**Satisfactory**	**Unsatisfactory**	**p Value**
Preoperative demographic variables				
Age (years)	64.4	64.6	64.3	0.93
Sex (male/female)	28/27	22/21	6/6	0.94
Diabetes, n (%)	1 (2)	1 (2.5)	0 (0)	0.61
Dominant-side surgery, n (%)	40 (73)	32 (74)	8 (67)	0.59
Traumatic onset, n (%)	30 (58)	30 (73)	8 (54)	0.26
Symptom duration (weeks)	37	19	41	0.11
Hypertension, n (%)	18 (33)	5 (42)	13 (31)	0.49
Smokers, n (%)	13 (26)	9 (23)	4 (36)	0.35
Worker’s compensation, n (%)	4 (8)	3 (6)	1 (10)	0.81
Follow-up (years)	3	3	3	0.98
Preoperative functional variables				
ROM, angle				
Elevation	114	119	95	0.10
Abduction	107	111	89.1	0.18
Internal rotation (vertebrae)	6	6	6	0.76
External rotation	43	44	43	0.9
Muscle strength, %				

Elevation	66.7	0.68	0.617	0.47
Abduction	65.5	0.7	0.489	0.0051*
Internal rotation	67.5	71.1	54.5	0.12
External rotation	74.3	71.3	85.3	0.17
VAS (mm)				
Rest	26.3	24.4	34.2	0.25
Motion	59.8	62.2	50	0.17
Night	52.3	54.8	42.1	0.2
Preoperative structural variables				
Tendon retraction (mm)	25.4	25.4	25.4	0.1
Tear width (mm)	21.8	21.5	23.2	0.6
Muscle atrophy (%)				
Supraspinatus	76	76	76	0.77
Infraspinatus	>100	>100	>100	0.21
Subscapularis	>100	>100	>100	0.21
Preoperative Goutallier classification, n (%)				
Supraspinatus				
Stage 0	11 (23)	9 (25)	2 (18.2)	
Stage 1	13 (28)	12 (33)	1 (9.1)	
Stage 2	20 (43)	14 (39)	6 (54.6)	
Stage 3	2 (4)	1 (3)	1 (9)	
Stage 4	1 (2)	0	1 (9)	0.16
Infraspinatus				
Stage 0	1 (41)	18 (51)	1 (9)	
Stage 1	20 (43)	15 (43)	5 (46)	
Stage 2	7 (15)	2 (6)	5 (46)	
Stages 3 and 4	0	0	0	0.0021*
Subscapularis				
Stage 0	18 (39)	18 (51)	0 (0)	
Stage 1	17 (37)	12 (34)	5 (46)	
Stage 2	9 (20)	5 (14)	4 (37)	

Stage 3	2 (47)	0	2 (187)	
Stage 4	0	0	0	0.0024*
Intraoperative variables				
Treatment of the LHB tendon				
Untreated	27	17	10	
Treated	28	26	2	0.0073*
Repair technique				
Single-row	10	7	3	
Double-row	2	2	0	
Suture bridge	40	32	8	0.595

Statistics were evaluated by logistic analysis. *Statistically significant. ROM, range of motion; VAS, visual analogue scale; LHB, long head of the biceps.

Multivariate Analysis to Detect Factors Affecting Clinical Outcome and Calculation of Cutoff Value

The multivariate logistic regression analysis with stepwise technique showed that the preoperative Goutallier stages of the infraspinatus and subscapularis are significantly associated with clinical outcome (Table 2).

Table 2. Summary of Variables Associated with the Outcome that was Statistically Verified by Multivariate Logistic Analysis

Goutallier Stage	OR	95% CI	p Value
Infraspinatus	8.87	1.51-52.0	0.016*
Subscapularis	7.53	1.58-35.9	0.011*

*Statistically significant. OR, odds ratio; CI, confidence interval.

ROC curve analysis revealed that the cutoff value to predict the "unsatisfactory" outcome is Goutallier stage 1 in both muscles, with area under the curve values of 0.79 (sensitivity: 91% and specificity: 51%) and 0.84 (sensitivity: 100% and specificity: 54%) in the infraspinatus and subscapularis, respectively (Fig. 2). These results indicate that patients with Goutallier stage 2 or more in both muscles are associated with "unsatisfactory" outcome after surgery.

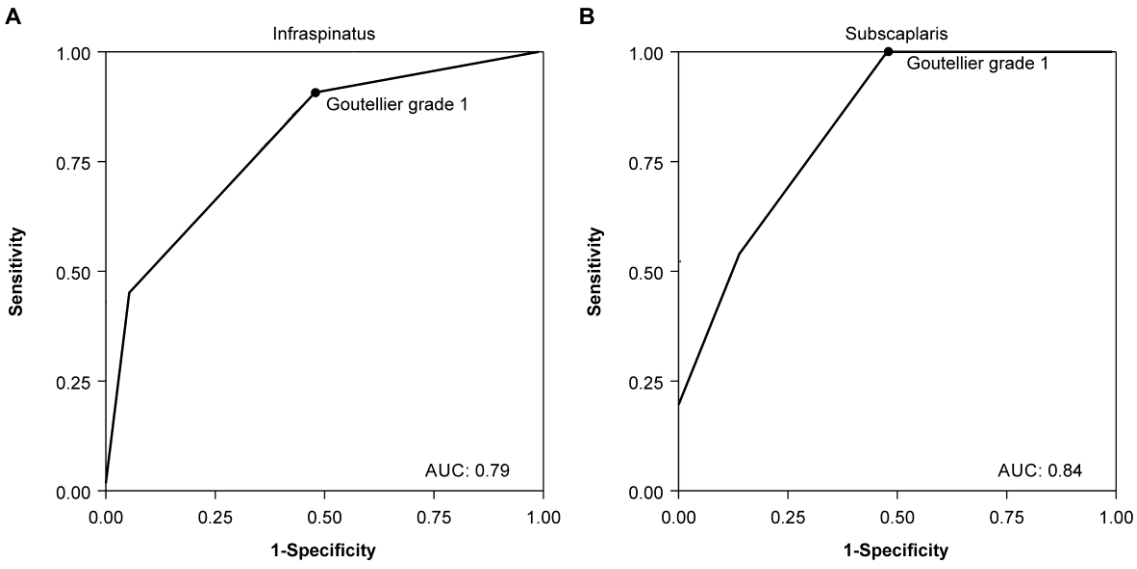

Fig. 2 Receiver operating characteristic curve to determine the predictive cutoff value for the unsatisfactory score in the Goutallier stage of the infraspinatus and subscapularis. Filled circle (●) indicates cutoff value, shown as the point with the maximal Youden index on the ROC curve

Discussion

Fatty degeneration of the rotator cuff muscles is associated not only with postoperative retear but also with muscle weakness affecting shoulder function after surgery.[9] The present study examined the patients with large/massive cuff tears who had intact tendon after ARCR and demonstrated that the infraspinatus and/or subscapularis with fatty degeneration of Goutallier stage 2 or more before surgery were at risk for unsatisfactory outcome in patients with large/massive tears despite having intact tendon after surgery.

Burkhart[4] advocated the importance of "force couple mechanisms" by the infraspinatus and subscapularis in maintaining glenohumeral joint stability. In rotator cuff tears, the joint reaction force is affected by the integrity of the rotator cuff muscles, especially by the transverse force couple formed by the infraspinatus and subscapularis.

213 On the contrary, isolated supraspinatus tears are compensated by the rest of the rotator
214 cuff muscles, thus not contributing to joint instability.[29] Rotator cuff tear progression to
215 half of the infraspinatus tendon was the critical tear size for significant changes in
216 rotational humeral head kinematics, specifically the superior and lateral shift of the
217 humeral head at maximum internal rotation and posterior shift at the midrange of
218 rotational motion.[26] Thus, these reports consistently suggest the importance of the force
219 couple formed by the anterior and posterior aspects of the cuff (i.e., the infraspinatus
220 and subscapularis).

221 Previous studies reported a relationship between fatty degeneration of the rotator cuff
222 muscles and decreased postoperative muscle strength.[9,32,33] Postoperative strength in
223 forward flexion, internal rotation, and external rotation at final follow-up correlated
224 highly with preoperative fatty degeneration, occupation ratio, and tangent sign.[33]
225 Gladstone *et al.*[9] found that fatty degeneration of the infraspinatus or subscapularis
226 independently predicts external rotation strength. Seo *et al.*[32] reported that fatty
227 degeneration of the superior part of the infraspinatus is negatively correlated with the
228 shoulder strength index (SSI) of abduction and that fatty degeneration of the inferior

229 part of the infraspinatus is negatively correlated with both SSIs of abduction and
230 external rotation.

231 The relationship between fatty degeneration of the infraspinatus or subscapularis and
232 worsened clinical outcome is reported. Gladstone *et al.*[9] reported that fatty degeneration
233 and rotator cuff atrophy of the infraspinatus are significant variables associated with
234 poorer clinical scores. Maqdes *et al.*[20] reported that patients with advanced fatty
235 degeneration of the subscapularis shows significantly lower score in anterosuperior
236 rotator cuff tears. They suggested the negative influence of degenerative change of the
237 infraspinatus or the subscapularis on clinical outcome after rotator cuff repair; however,
238 these studies included both retear and non-retear cases. Noteworthy, the present study
239 revealed that preoperative fatty changes in the infraspinatus or subscapularis influenced
240 postoperative clinical outcome, even in those with intact tendon after surgery.

241 Biceps treatment including tenotomy or tenodesis is often used in ARCR.[15] In the
242 present study, the univariate analysis showed that biceps treatment significantly affected
243 the clinical outcome, but the multivariate analysis did not. It is widely accepted that the
244 remaining biceps tendon negatively affects clinical outcome after ARCR.[36] Although no

245 significant association between biceps treatment and clinical outcome was demonstrated
246 in the present study, which has a small sample size, it remains to be elucidated in a
247 larger-scale study.

248 This study has the following limitations. First, because only a relatively small number
249 of cases were assigned especially in the unsatisfactory outcome group, the power of the
250 multivariable analysis is limited. Therefore, it may have missed one or more factors.
251 Second, the present study was a retrospective cohort; therefore, selection bias and a
252 confounding effect might be present. Third, the follow-up period was relatively short
253 (2.5 years). As a majority of retear occurs within 12 months after surgery,[11,14] cases in
254 which the follow-up period was at least 12 months or longer were included. Third, the
255 reversibility of the degenerative change of the rotator cuff muscles was not considered,
256 since the relatively small number of unsatisfactory results limits the power of the
257 multivariable analysis; however, most studies supported the irreversibility of the fatty
258 degeneration in these muscles.[16] Fourth, the symptom duration prior to surgery was
259 relatively long, making it difficult to consider surgery before the progression of fatty
260 infiltration. However, given the data in the present study, early surgical intervention

261 may be encouraged when the surgeon encounters patients with cuff tear who have less
262 progression of fatty changes in the muscles. Fifth, most patients had undergone a variety
263 of treatment including steroid injection, physical therapy, and anti-inflammatories under
264 a local medical doctor before referring them to the hospital; consequently, the treatment
265 details before the referral are unknown. Sixth, various surgical procedures were
266 performed in the present study. Surgical variability influenced the retear rate after
267 ARCR, but did not affect the clinical outcome after surgery.[22] These might have
268 affected the data obtained from the present study.

269 This study has the following strengths. This was the first study to analyze the
270 prognostic factors associated with worsened outcome in patients with intact tendon after
271 surgery for large/massive cuff tears and clearly demonstrated that these patients are at
272 significant risk for fatty degeneration of the infraspinatus and/or subscapularis before
273 surgery. In addition, multivariate analysis excluded the influence of the worker's
274 compensation status on the outcome obtained from the present study because some
275 articles reported independent negative influences of that variable on clinical outcome
276 after surgery.[1,10,18]

In conclusion, preoperative fatty degeneration of the infraspinatus and/or subscapularis with Goutallier stage ≥2 was significantly associated with worse outcome in patients with large/massive tears who had intact tendon after ARCR.

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