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Prognostic indicators for outcome following rotator cuff tear repair

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ABSTRACT

Purpose. To examine the prognostic indicators associated with outcome following rotator cuff surgery.
Methods. A retrospective evaluation of records on 1120 shoulders (1067 patients) with rotator cuff tear treated by surgery was performed. Preoperative, intra-operative and postoperative factors were analysed by Kendall's Tau-b correlation analysis and logistic regression analysis.
Results. Positive correlations were seen between the type of tear and the number of tendons involved, retraction, age, degeneration, subacromial bone spur, surgical technique, preoperative and postoperative muscle power, surgical outcome, and preoperative abduction on Kendall's Tau-b analysis. There was a positive correlation seen between degenerative change and age, number of tendons involved, retraction, preoperative pain, tear type, and preoperative muscle power on logistic regression analysis. Additionally, positive correlations were seen between good surgical postoperative outcome and postoperative activities of daily living, preoperative pain, post-operative muscle power, preoperative activities of daily living, tear type, preoperative external rotation, preoperative muscle power, number of tendons involved, preoperative pain, and duration of symptoms.
Conclusion. Ageing was found to be the major factor in progressive degeneration of the rotator cuff, and should be considered the single most important contributing factor in the pathogenesis of rotator cuff tears. In addition, degenerative tendonopathy appeared the primary pathology in rotator cuff tear, preceding hypertrophic spur formation. Rotator cuff tears are therefore unlikely to be initiated by impingement; rather, they develop as an intrinsic degenerative tendonopathy.

Key words: *orthopedic surgical procedures; outcomes assessment; prognosis; rotator cuff*

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INTRODUCTION

Rotator cuff tear (RCT) is an extremely common and important injury of the shoulder. Smith[1] first reported RCT in the London Medical Gazette in 1834, and Codman[2,3] reported on lesions of the supraspinatus in detail in 1934. In 1972, Neer[4] described the importance of impingement and its association with cuff tears. Potential mechanisms of pathogenesis of rotator cuff tears include supraspinatus outlet impingement, and age-related degeneration of the tendons and microvascular blood supply of the rotator cuff.[5–7] The aim of this study was to explore and analyse factors related to degeneration of the rotator cuff, and their correlation with clinical outcome following surgical management.

METHODS

A retrospective review was performed evaluating 25 factors in 1120 shoulders in 1067 patients who underwent surgical repair of RCT between January 1970 and December 1998. Surgeries were performed by 5 surgeons at the Nobuhara Hospital and Institute of Biomechanics, Hyogo, Japan. All patients were seen for follow-up at Nobuhara Hospital, and the parameters examined are shown in Table 1.

Radiographic studies had been performed on all patients, and the size of subacromial bone spurs and acromioclavicular (AC) joint osteophytes measured and graded. Clinical function, pain, range of motion, muscular power, and activities of daily living (ADL) were rated according to the Nobuhara

Table 1
Variables evaluated in relation to outcome following rotator cuff tear repair

Variable	Parameter coding
Age	age
Sex	male, 1; female, 2
Side	left, 1; right, 2
Occupation	none, 1; manager, 2; business, 3; manual, 4
Duration	months
Trauma	no trauma, 1; trauma, 2
Subacromial bone spur	no spur, 1; spur<5 mm, 2; 5–10 mm, 3; >10 mm, 4
AC* joint spur	no spur, 1; spur<5 mm, 2; 5–10 mm, 3; >10 mm, 4
Calcification	no calcification, 1; calcification, 2
Preoperative pain	no pain, 1; slight pain, 2; severe pain, 3
Preoperative flexion	>90°, 1; <90°, 2
Preoperative abduction	>90°, 1; <90°, 2
Preoperative external rotation	unimpaired, 1; mild reduction, 2; marked reduction, 3
Preoperative muscle power	normal, 1; slight weakness, 2; substantial weakness, 3
Preoperative ADL†	normal, 1; compromised, 2; obstructed, 3
Tear type	superficial, 1; concealed, 2; rim, 3; posterior, 4; anterior, 5; longitudinal, 6; transverse, 7; triangular, 8; massive and global, 9
Number of tendons involved	SSP‡ / ISP§ / SSC‖ / TM¶ / LHB,**1; 2 rotator cuff, 2; 3 rotator cuff (or +LHB), 3; 4 rotator cuff (or +LHB), 4; 4 rotator cuff tear and LHB, 5
Degeneration	no degeneration, 1; degeneration, 2
Retraction	no retraction, 1; retraction, 2
Surgical technique	McLaughlin, 1; side to side, 2; McLaughlin + LHB fixation, 3; side to side + LHB fixation, 4; other methods, 5
Follow-up	months
Postoperative pain	no pain, 1; slight pain, 2; severe pain, 3
Postoperative muscle power	normal, 1; slight weakness, 2; substantial weakness, 3
Postoperative ADL	normal, 1; compromised, 2; obstructed, 3
Surgical outcome	excellent, 1; good, 2; poor, 3

* AC acromioclavicular
† ADL activities of daily living
‡ SSP supraspinatus
§ ISP infraspinatus
‖ SSC subscapularis
¶ TM teres minor
** LHB long head of biceps

Table 2
Tear type and surgical outcome and preoperative, intra-operative, and postoperative factors on Kendall's Tau-b analysis

Variable	Tear type			Surgical outcome		
	Correlation coefficient	p value (one-tailed)	Ranking	Correlation Coefficient	p value (one-tailed)	Ranking
Age	0.222	0.000	3	0.050	0.048	
Sex	–0.018	0.249		0.031	0.154	
Side	0.072	0.004		–0.023	0.216	
Occupation	–0.030	0.123		0.022	0.230	
Duration	–0.041	0.036		0.075	0.006	10
Trauma	0.035	0.094		–0.020	0.251	
Subacromial bony spur	0.168	0.000	5	0.044	0.073	
AC* joint spur	0.045	0.014		0.037	0.106	
Calcification	–0.023	0.197		–0.031	0.149	
Preoperative pain	–0.004	0.443		0.080	0.004	9
Preoperative flexion	–0.044	0.052		0.059	0.024	
Preoperative abduction	–0.081	0.001	10	0.003	0.467	
Preoperative external rotation	–0.048	0.031		0.094	0.001	6
Preoperative muscle power	0.129	0.000	8	0.085	0.002	7
Preoperative ADL†	0.013	0.315		0.101	0.000	4
Tear type	1.000	N/A‡		0.099	0.000	5
Number of tendons involved	0.511	0.000	1	0.083	0.003	8
Degeneration	0.208	0.000	4	0.073	0.007	
Retraction	0.368	0.000	2	0.049	0.051	
Surgical technique	0.162	0.000	6	0.055	0.034	
Postoperative pain	0.012	0.324		0.411	0.000	2
Postoperative muscle power	0.136	0.000	7	0.342	0.000	3
Postoperative ADL	–0.047	0.039		0.489	0.000	1
Surgical outcome	0.089	0.000	9	1.000	N/A	

* AC acromioclavicular
† ADL activities of daily living
‡ N/A Not applicable

hospital rating scale.[8] Factors noted during the operative procedure including the type of tear, tendons involved, and the degree of tendon degeneration and retraction were recorded, along with the operative technique. The tear was classified into 9 types according to the system used at Nobuhara Hospital.[8] Grading of the surgical outcome depended on 3 criteria: pain relief, ADL, and postoperative muscle power. Each patient was evaluated before and after surgery, and the ratings were compared.

Statistical analysis

All the variables assessed were coded as indicated in Table 1. The data were analysed by Kendall's Tau-b correlation analysis and logistic regression using the Statistical Package for the Social Sciences (Windows version 8.0; SPSS Inc., Chicago, US). Kendall's Tau-b is a non-parametric measure of association of ordinal or ranked variables that considers tied ranks. The sign of the coefficient indicates the direction of the relationship, and its absolute value indicates the strength, with larger absolute values indicating stronger relationships. Possible values range from –1 to 1.

To identify preoperative variables, postoperative factors and intra-operative findings that may be associated with a good surgical outcome or a different tear type, a Kendall's Tau-b correlation coefficient analysis was conducted as a preliminary analysis. Variables included age, sex, side of RCT, occupation, history of traumatic event, X-ray findings (subacromial bone spurs, AC joint osteophytes, and calcification), intra-operative findings (tear type, involved tendons, and tendon degeneration), preoperative and postoperative pain, range of motion, muscle power, and ADL, etc. The criterion for entry into the logistic regression analysis equation was a value of $p<0.01$ from the Kendall's Tau-b analysis. A forward stepwise multivariate logistic regression analysis was then performed to derive factors associated with outcome following RCT.

RESULTS

A total of 1120 shoulders with RCTs treated surgically in 1067 patients by 5 surgeons were identified. All patients had received standard postoperative

Table 3
Degeneration and preoperative, intra-operative factor on Kendall's Tau-b analysis

Variable	Correlation coefficient	p value	Ranking
Age	0.2909	0.0000	1
Sex	0.0088	0.1456	
Side	0.0000	0.9466	
Occupation	0.1429	0.0000	5
Duration	0.0000	0.9138	
Trauma	0.0000	0.9847	
Subacromial bony spur	0.0083	0.1470	
AC* joint spur	0.0288	0.0708	
Calcification	0.0163	0.1212	
Preoperative pain	0.0138	0.1303	
Preoperative flexion	0.0000	0.4877	
Preoperative abduction	0.0198	0.1071	
Preoperative external rotation	0.0000	0.5991	
Preoperative muscle power	0.1035	0.0000	6
Preoperative ADL†	0.0000	0.9068	
Tear type	0.1551	0.0000	4
Number of tendons involved	0.2020	0.0000	2
Retraction	0.1819	0.0000	3
Postoperative pain	0.0000	0.4221	
Postoperative muscle power	0.0918	0.0001	7
Postoperative ADL	0.0000	0.2549	
Operative outcome	0.0556	0.0097	

* AC acromioclavicular
† ADL activities of daily living

physiotherapy. The mean age of the patients was 56.9 years (range, 12–87 years). There were 872 male shoulders and 248 female shoulders. Mean follow-up was 7.9 years (range, 1–28 years). The average duration of symptoms was 8.3 months (range, 1–240 months). The left shoulder was involved in 377 patients, the right shoulder in 743 patients, while bilateral involvement was seen in 53 patients. Manual labourers made up 59.6% (n=636) of patients, while 13.5% (n=144) were clerical workers, 2.0% (n=21) were managerial workers, and 24.9% (n=266) were not in employment. The majority (71.4%; n=762) of patients reported a history of injury of varying degree to the shoulder.

Radiographic studies were done in all patients. These included acromial bony spur, acromioclavicular joint osteophyte, and calcified deposits (6.52%). We measured the size of acromial bony spurs and AC joint osteophytes between acromion and the humeral head, and the size of the lesion. Patients were allocated to one of 4 grades namely, no spur (56.6%, 79.6%), spur <5 mm (34.1%, 18.5%), spur 5–10 mm (8.6%, 2.0%), and spur >10 mm (0.7%, 0%).

The tear type was classified into 9 types according to Dr Nobuhara's classification,[8] including superficial (0.4%), concealed (14.0%), rim (6.5%), posterior (1.4%), anterior (2.0%), longitudinal (8.3%), transverse (6.3%), triangular (25.3%), and massive and global tear (35.9%). Operative techniques[9] used by the institution included McLaughlin (45.9%), side-to-side (22.2%), McLaughlin and long head of biceps (LHB) fixation (16.1%), side to side and LHB fixation (5.0%), and others (10.8%).

Relationship between tear type, surgical outcome, and other factors

The relationship between tear type, surgical outcome and other factors were analysed using Kendall's Tau-b correlation analysis. The variables with strongest correlation with the type of tear were number of tendons involved, retraction, age, degeneration, subacromial bony spur, surgical technique, postoperative and preoperative muscle power, surgical outcome, and preoperative abduction. The variables with strongest correlation with surgical outcome were postoperative ADL, postoperative pain and muscle power, preoperative ADL, tear type, preoperative external rotation and muscle power, number of tendons involved, preoperative pain, and duration of symptoms (in descending order of correlation) [Table 2]. Although 5 surgeons performed the operations, the surgeon was not a factor independently associated with outcome.

Table 4
Degeneration and preoperative, intra-operative, and postoperative factors on logistic regression analysis

Variable	Correlation coefficient*	Ranking
Age	0.2298	1
Number of tendons involved	0.1012	2
Retraction	0.0631	3
Preoperative pain	–0.0498	4
Tear type	0.0482	5
Preoperative muscle power	0.0402	6

* $p<0.01$

Correlation of degenerative change with other factors

The degree of degenerative changes were correlated with other factors using Kendall's Tau-b analysis. The order according to strength of correlation were age, number of tendons involved, retraction, tear type, occupation, preoperative muscle power, and postoperative muscle power (Table 3). Factors with a value of $p<0.01$ were selected for logistic regression equation by forward stepwise analysis. For the logistic regression analysis by stepwise analysis, the order by extent of correlation was age, number of tendons involved, retraction, preoperative pain, tear type, and preoperative muscle power (Table 4).

DISCUSSION

Degenerative changes in the rotator cuff tendons in association with RCTs have been widely reported in the literature.[9–12] Intra-operatively, macroscopic findings such as the torn edges of the tendon clearly indicate degenerative changes. However, the relationship between these degenerative changes and preoperative and postoperative factors remains unclear.

Yamanaka et al.[13] observed the histological and pathological changes present in the rotator cuffs of fresh cadavers, and concluded that cuff degeneration was due to hypovascularity related to increasing age. Ageing is well recognised as the single most important contributing factor in the pathogenesis of RCT.[14] It has been demonstrated that ageing induces tendon degeneration that can cause or aggravate RCT. Our results support this, showing that degeneration correlates with age, the number of tendons involved in the tear, and tendon retraction. There was no correlation seen between the presence of subacromial bone spurs, AC joint osteophytes, and degenerative changes in the tendon in this study. Our results did not support the concept that, the slope and length of the acromion and the height of the arch are closely associated with degenerative change in the tendons.[12] Tear type was seen to correlate with degenerative tendon changes, while massive tears were associated with severe degenerative tendon changes. Our observation that degeneration correlated with preoperative muscle power corresponds with the report that degenerative changes reduce the tensile strength of tendons and are a primary factor in the pathogenesis of RCT.[11]

In the clinical setting, RCT classification systems are used for the purpose of identification, diagnosis, treatment and determining prognosis. Codman[3] was the first to classify RCTs and, from a series of 400 painful shoulders and from autopsy findings, divided RCT into 3 types i.e. transverse, triangular, and extensive. Wolfgang[15] classified RCTs according to the pattern they assumed i.e. transverse, triangular, crescentic and massive. Nobuhara et al.[8] offered a more elaborate classification system, based on the morphology, degree of tear, and the tear shape as noted intra-operatively. This system identified 9 types of tear: superficial, concealed, rim, posterior, anterior, longitudinal, transverse, triangular, and massive and global. The classification has since proven useful in determining the best approach to surgery and postoperative physiotherapy at Nobuhara Hospital, Hyogo.

From our analysis, there was a strong correlation between the number of tendons involved and tear type, with the tear type being more severe with increasing numbers of involved tendons. Supraspinatus was more commonly involved than other tendons. There was a strong correlation between tendon retraction and tear type, with massive tears usually having tendon retraction and degeneration. Tear type also strongly correlated with increasing age, and the incidence and severity of cuff tears also increased with age. Together, these results support the concept that ageing is the single most important contributing factor in the pathogenesis of RCT.[14]

Interestingly, the correlation between subacromial bone spurs and tear type was weaker than that between tear type and age. This may relate to the size of the spurs observed. Neer[4] has indicated that abnormalities in the shape and slope of the acromion are the main aetiologic factors in RCT, and that the presence of a subacromial bone spur of 5 mm or greater is of clinical significance. Our study found only a 9.3% incidence of spurs of this size, and a 0.4% incidence of superficial tears. These findings do not support Neer's theory that subacromial bone spurs can cause impingement disease and RCT. It is well-established that joint instability may lead to bone spurs or osteoarthritis in other joints,[16–18] and it has also been reported that RCT may cause shoulder instability.[19,20] This, together with our observation that there is no significant correlation between the presence of subacromial bone spurs and degeneration, lead us to conclude that subacromial bone spurs may arise after the occurrence of RCT. Ozaki et al.[21] and Ogata and Uhthoff[22] also concluded that degenerative tendonopathy precedes hypertrophic spur formation. As rotator cuff tendonopathy and rotator cuff dysfunction lead to secondary changes on the undersurface of the acromion, the RCT may then be further aggravated by friction with the undersurface of the acromion. It is suggested that in order to achieve good long-term results, subacromial bone spurs should be removed when repairing RCT.

As expected, strong correlations were seen between both preoperative and postoperative muscle power and tear type. Therefore, preoperative muscle power may be important in predicting the classification of a RCT before arthrography or magnetic resonance imaging. However, it is interesting that preoperative abduction and external rotation were negatively associated with tear type, indicating that massive tears were not more limiting than small or incomplete tears. In addition, there was no correlation between preoperative pain, flexion and classification of tear, indicating that pain may not be the chief complaint in the early stages of RCT. Moreover, range of motion limitations may not indicate the severity of RCTs.

Grading of the operative results in this study was based on 3 criteria: pain relief, ADL, and postoperative muscle power. Each patient was evaluated before and after surgery, and the ratings were compared. The condition of the tendon and the tear type directly influenced the operative outcome. This finding is in line with other studies showing that patients with small- and medium-sized tears had a significantly better outcome than patients with large and massive tears.[21,22] Preoperative ADL, external rotation, muscle power and pain also correlated with the surgical outcome. Duration and degeneration were both significantly correlated with surgical outcome, with the duration of symptoms before surgery the better predictor of outcome. In the case series reported by Jerosch et al.,[23] patients with symptoms for more than one year had a significantly poorer outcome than patients with symptoms of less than a 1-year duration. Gartsman[24] and Patel et al.[25] also observed that patients with symptoms for less than one year appeared to have better results than patients with prolonged symptoms. It is therefore recommended that patients undergo surgery as soon as possible after definitive diagnosis, if non-surgical management has failed.

There was a weak correlation seen between surgical outcome and surgical technique and age. Various surgical techniques were used for the patients in this study, including McLaughlin's method, and side-to-side suturing, among others.[6] Although suturing methods may differ depending on the degree of tear, results support the use of side-to-side suturing in simple cases, while end-to-end suturing should be avoided. Anchoring the tendon end firmly into a groove made in the humeral head is a yet more reliable method.

CONCLUSION

On the basis of our findings and previous reports, it appears that ageing is the main factor in progressive degeneration of the rotator cuff, and that ageing should be considered the single most important contributing factor in the pathogenesis of RCTs. In addition, degenerative tendonopathy appeared the primary pathology in RCT, preceding hypertrophic spur formation. We therefore concluded that RCTs are unlikely to be initiated by impingement; rather, they develop as an intrinsic degenerative tendinopathy.

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