© 2022 The Authors. Orthopaedic Surgery published by Tianjin Hospital and John Wiley & Sons Australia, Ltd.

CLINICAL ARTICLE

Factors Associated with Shoulder Range of Motion After Arthroscopic Rotator Cuff Repair: A Hospital-Based Prospective Study

Zhennan Li, BS[1], Gangfeng Hu, MD, PhD[2], Yuan Zhu, MD[2], Fangqi Xu, MD[2], Jiakuan Ye, BS[2], Jie Guan, MD[2], Hong Guan, BS[1]

[1]*The Second Clinical Medicine College, Zhejiang Chinese Medical University, Hangzhou, China and* [2]*Department of Orthopaedics, The First People's Hospital of Xiaoshan District, Hangzhou, Zhejiang, China*

Objective: To assess the factors associated with outcomes of arthroscopic surgical repair of rotator cuff tears (RCTs).

Method: This prospective study recruited patients, at least 18 years old, who underwent arthroscopic rotator cuff repair for full-thickness RCTs at the First People's Hospital of Hangzhou Xiaoshan between July 2019 and October 2020. Patient demographics, lifestyle habits, and medical histories were collected preoperatively; RCT sizes and affected tendons were determined intraoperatively. Outcomes were assessed by shoulder range of motion (ROM) determinations 1.5 and 3 months postoperatively. The factors associated with ROM were determined using a binary logistic regression analysis, and the results were expressed as adjusted relative risks (*RRs*) and 95% confidence intervals (*CIs*).

Results: A total of 132 patients with RCTs underwent arthroscopic surgery. Five were lost to follow-up, leaving 127 patients (mean age, 59 years; 58.3% women) who were included in the study analysis. The majority of the patients (54.5%) had RCTs that were classified as large or massive, and approximately 20% had tears involving multiple tendons; 80.3% of the patients had tears involving only a single tendon. Moreover, 29.9% of the patients had hypertension and 11.0% had diabetes. Among the patients, 23.0% were smokers and 34.6% drank alcohol. According to the multivariate analysis, none of the assessed factors were associated with shoulder ROM at the 1.5-month follow-up. At the 3-month follow-up, RCTs involving a single tendon demonstrated 3-fold better abduction ($RR = 4.00$; 95% *CI*, 1.30–12.33; $P = 0.016$) and 3.15-fold better internal rotation ($RR = 3.15$; 95% *CI*, 1.19–8.36; $P = 0.021$) than did RCTs involving multiple tendons. Patients who did not drink alcohol demonstrated 6.08-fold better anteflexion ($RR = 7.08$; 95% *CI*, 2.11–23.73; $P = 0.002$) and nearly 4-fold better abduction ($RR = 4.97$; 95% *CI*, 1.62–15.23; $P = 0.005$) than patients who drank alcohol.

Conclusion: To improve outcomes, the results indicate that more targeted measures should be directed toward patients with multiple-tendon RCTs and that preoperative alcohol abstinence education is needed for patients with RCTs.

Key words: Arthroscopy; Follow-up study; Range of motion; Risk factors; Rotator cuff; Tendon injuries

Introduction

The rotator cuff, an important structure involved in shoulder movement, consists of the supraspinatus, infraspinatus, subscapularis, and teres minor muscles and tendons. However, the rotator cuff is also a vulnerable structure, and rotator cuff injuries can cause restricted shoulder function. The pathogenesis of rotator cuff injury remains controversial. Two main hypotheses have been formulated to

Address for correspondence Gangfeng Hu, MD, PhD Department of Orthopaedics, The First People's Hospital of Xiaoshan District, Hangzhou, Zhejiang, China. No. 199 Shixin South Rd, Xiaoshan District, Hangzhou, 311201 Zhejiang Province, China. Tel: +86-0571-83807641; Fax: +86-0571-83807019; Email: goodday1112@163.com
Received 9 February 2021; accepted 18 February 2022

Orthopaedic Surgery 2022;14:1309–1316 • DOI: 10.1111/os.13249

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

explain the potential causes of rotator cuff injuries. The "extrinsic" theory, developed by Neer, suggests that hypertrophic changes to the acromion cause impingement of the subacromial-subdeltoid bursa and the rotator cuff, leading to rotator cuff injury. The "intrinsic" theory suggests that rotator cuff tears (RCTs) develop as a result of tendon self-degeneration[1]. Degeneration of rotator cuff tendons drives the superior migration of the humeral head that, in turn, abrades the rotator cuff tendons against the undersurface of the acromion, leading to full-thickness tears[1]. Epidemiologically, the prevalence of rotator cuff disease increases with age; it may affect 15%–30% of individuals, overall, with up to 30% of patients older than 60 years and 50% of patients older than 80 years suffering from this affliction[2–4]. Rotator cuff disease is estimated to result in more than 4.5 million annual visits to physicians and more than 75,000 surgical repairs in the United States, annually[5].

With the development of new surgical techniques, the surgical management of RCTs has evolved over the past decade from formal, open repairs to mini open repairs, to completely arthroscopic techniques. Arthroscopic rotator cuff repair is currently a popular and well-established technique, with well-documented and satisfactory clinical outcomes[6,7]. Previous studies have reported that patient age, sex, smoking status, alcohol intake, hypertension, diabetes, fatty degeneration, tear size, and the number of involved tendons may affect rotator cuff surgical outcomes[8–14]. Nevertheless, these studies remain insufficient, and the results remain controversial.

Identifying the factors that predict slow recovery and poor post-repair shoulder function may help identify patients at risk of poor outcomes and guide therapeutic treatment strategies for improving postoperative shoulder function. Surgeons need to know the risk factors impacting rotator cuff repair prognoses, especially for full-thickness tears. The clinical outcomes associated with full-thickness injury repairs have been documented to be less satisfactory than those for partial-thickness tears[15]. Moreover, published studies have largely focused on Caucasian populations; data from Chinese populations have not been reported. Hence, this study aimed to: (i) assess outcomes of arthroscopic rotator cuff repairs; (ii) determine the factors associated with 1.5-month postoperative outcomes; and (iii) and determine the factors associated with 3-month outcomes in a Chinese population.

Methods

Patient Selection

This prospective hospital-based study recruited consecutive RCT patients who underwent arthroscopic rotator cuff repairs between July 2019 and October 2020 at the First People's Hospital of Xiaoshan District.

Inclusion Criteria

Patients were eligible for inclusion if they: were at least 18 years old and had full-thickness tears diagnosed using preoperative magnetic resonance imaging (MRI); received surgical arthroscopic treatment; and were able to read, understand, and provide signed informed consent.

Exclusion Criteria

Patients were excluded if they had a comorbid shoulder fracture, had previously undergone shoulder surgery on the affected side, were followed for less than 3 months, or had histories of other shoulder problems (e.g., a frozen shoulder).

The ethics committee of the First People's Hospital of Hangzhou Xiaoshan approved this study, and informed consent was obtained for each patient during recruitment.

Surgical Procedures

A single senior orthopedist performed all arthroscopic rotator cuff repairs for the recruited patients.

Surgical Approach

Each surgery was performed under general anesthesia. The patient was placed in the beach chair position, with general disinfection of the shoulder skin and the use of sterile surgical towels. The posterior approach was routinely employed. The glenohumeral joint cavity was entered to establish an anterior channel under arthroscopic monitoring. After routine exploration, the lesions in the articular cavity were cut off. Then, the arthroscope was converted to the subacromial orientation and a lateral channel was established on the extension line of the posterior edge of the clavicle near the lateral 1–2 cm of the acromion.

Pathological Changes, Resection

A planer and radiofrequency ablation knife were used to clean the pathological subacromial synovial sac and perform acromioplasty, according to the condition of the injury. Under arthroscopy, the surgeon determined the type, size, and location of the rotator cuff injury, and cleaned the pathological rotator cuff tissue and the large tubercle bone bed.

Fixation and Reconstruction

The torn rotator cuff was fixed with an anchor after using the repair method that was most appropriate for the specific rotator cuff tendon injury. Single-row sutures and Mason-Allen sutures were used for small–medium tears and for patients with large–massive tears in high-tension areas. Suture bridges were used when the rotator cuff tendon could be reset to the surface of the humerus nodules and covered more than 50% of the bone surface at the point of the tendon.

After suturing was completed, the acromion bursa and shoulder joint cavity were re-explored to confirm the stability of the suture fixation and the integrity of the rotator cuff repair. Finally, the cavity was flushed thoroughly, the skin was sutured and bandaged, and the shoulder joint was restrained using protective equipment.

Postoperative Rehabilitation

After the operation, the affected upper limb was fixed with protective equipment for about 6 weeks. Thereafter, the abduction protective gear was removed and active exercise of the shoulder joint was permitted. Three months after the operation, muscle strengthening exercises were allowed and shoulder activity gradually returned to normal.

General Information Collection

The size of the rotator cuff injury and the involved tendons were determined intraoperatively by the orthopedist. The RCT size was based on Bateman classification, which was categorized as small (<1 cm), medium (1–3 cm), large (3–5 cm), or massive (>5 cm).[16] Subjects were also classified according to the number of involved tendons (single *vs.* multiple).

Patient demographic data (sex, age, occupation [farmer, worker, homemaker], body mass index [BMI]), lifestyle habits (smoking and alcohol consumption [current/ever *vs.* never]), and medical histories were collected during the preoperative assessment. Patients who were current or ever smoking cigarettes and drinking alcohol were categorized as "Yes" and who did not smoke or drink were categorized as "No." The BMI was calculated as the individual's weight (kg) divided by the square of the height (m^2). The collected medical history information included any history of hypertension and/or diabetes. Hypertension was defined as a history of hypertension, systolic blood pressure ≥ 140 mm Hg, and/or diastolic blood pressure ≥ 90 mmHg, or taking antihypertensive drugs[17]. Diabetes was defined as a previous diagnosis of diabetes, fasting plasma glucose levels ≥7.0 mmol/L or 2 h-plasma glucose levels ≥11.1 mmol/L, or taking oral antidiabetic drugs[18].

Outcome Determination

Postoperative follow-up visits were carried out at 1.5 and 3 months. Because 1.5 months after surgery is the brace wearing period and under this period is shoulder joint braking functional training, elbow flexion and stretching training under the premise of stable fixation of the shoulder joint. While at the time of 3 months postoperative, the rotator cuff structure has completed healing, and the rehabilitation training starts with the active lifting. The rehabilitation training should be based on active lifting and other strength training. Hence, we choose this two time points to evaluate the degree of rehabilitation[19]. A trained orthopedist assessed the shoulder function (range of motion [ROM]) and pain condition (visual analogue scale [VAS]); the University of California at Los Angeles scale was also used.

Range of Motion

Shoulder outcomes were assessed by their ROM. The ROM was measured twice, for each shoulder, using a goniometer and the patient in a standing position. Abduction, anteflexion, internal rotation, and external rotation were evaluated. Abduction and anteflexion were classified as <90° or ≥ 90°, and internal rotation and external rotation were classified as <30° or ≥ 30°.

The Visual Analogue Scale

The VAS is the most commonly used questionnaire for pain quantification. Patients self-reported their pain score over a range of 0–10, with 0 indicating no pain and 10 being the worst pain possible.

The University of California at Los Angeles Scale

The University of California at Los Angeles (UCLA)[20] scale is a scale with a maximum score of 35 points, derived from five sections: pain (maximum 10 points), function (10 points), and motion (5 points), strength (5 points), and patient satisfaction (5 points).

TABLE 1 Baseline characteristics for patients with rotator cuff tear

Categories	Men	Women	Total
Cases, *n* (%)	53 (41.7)	74 (58.3)	127 (100)
Age, years, mean (SD)	56.49 (10.46)	61.27 (10.08)	59.28 (10.47)
Age group, *n* (%)			
≤60 years	32 (60.8)	30 (40.8)	62 (48.8)
>60 years	21 (39.2)	44 (59.2)	65 (51.2)
Work type, *n* (%)			
Farmer	25 (48.1)	51 (68.9)	76 (60.3)
Worker	22 (42.3)	12 (16.2)	34 (27.0)
Housework	5 (9.6)	11 (14.9)	16 (12.7)
Rotator cuff tear size, *n* (%)			
Small or medium	20 (40.0)	35 (63.6)	55 (45.5)
Large or massive	30 (45.5)	36 (50.7)	66 (54.5)
Involved tendons, *n* (%)			
Single	40 (75.5)	62 (83.8)	102 (80.3)
Multiple	13 (24.5)	12 (16.2)	25 (19.7)
Hypertension, *n* (%)			
Yes	13 (24.5)	25 (33.8)	38 (29.9)
No	40 (75.5)	49 (66.2)	89 (70.1)
Diabetes, *n* (%)			
Yes	7 (13.2)	7 (9.5)	14 (11.0)
No	46 (86.8)	67 (90.5)	113 (89.0)
Smoking status, *n* (%)			
Yes	27 (50.9)	2 (2.7)	29 (23.0)
No	26 (49.1)	71 (97.3)	97 (77.0)
Drinking status, *n* (%)			
Yes	33 (62.3)	11 (14.9)	44 (34.6)
No	20 (37.7)	63 (85.1)	83 (65.4)
VAS score, median (range)			
Preoperative	5 (2)	5 (2)	5 (2)
Postoperative at 1.5 months	1 (1)	1 (1)	1 (1)
Postoperative at 3 months	1 (2)	0 (1)	1 (1)
UCLA score, median (range)			
Preoperative	17 (4)	17 (4)	17 (4)
Postoperative at 1.5 months	27 (3)	27 (2.5)	27 (3)
Postoperative at 3 months	30 (6)	30 (5)	30 (6)
BMI, mean (SD)	23.59 (3.21)	24.19 (3.06)	23.94 (3.12)

TABLE 2 The association between risk factors and ROM of postoperative at 1.5 months in the univariate analysis

	Anteflexion			Abduction			Internal Rotation			External Rotation		
Risk Factors n (%)	<90°	≥90°	*P* value	<90°	≥90°	*P* value	<30°	≥30°	*P* value	<30°	≥30°	*P* value
Gender:			0.019			0.048			0.316			0.233
Men	31 (60.8)	20 (39.2)		30 (58.8)	21 (41.2)		41 (80.4)	10 (19.6)		43 (84.3)	8 (15.7)	
Women	27 (39.1)	42 (60.9)		28 (40.6)	41 (59.4)		50 (72.5)	19 (27.5)		52 (75.4)	17 (24.6)	
Age group:			0.841			0.841			0.041			0.028
≤60 years	27 (47.4)	30 (52.6)		27 (47.4)	30 (52.6)		48 (84.2)	9 (16.4)		50 (87.7)	7 (12.3)	
> 60 years	31 (49.2)	32 (50.8)		31 (49.2)	32 (50.8)		43 (68.3)	20 (32.8)		45 (71.4)	18 (28.6)	
Rotator cuff tear size:			0.439			0.439			0.633			0.283
Small and medium	23 (45.1)	28 (54.9)		23 (45.1)	28 (54.9)		40 (78.4)	11 (21.6)		43 (84.3)	8 (15.7)	
Large and massive	33 (52.4)	30 (47.6)		33 (52.4)	30 (47.6)		47 (74.6)	16 (25.4)		48 (76.2)	15 (23.8)	
Involved tendons:			0.112			0.112			0.706			0.809
Single	44 (44.9)	54 (55.1)		44 (44.9)	54 (55.1)		75 (75.5)	23 (23.5)		78 (79.6)	20 (20.4)	
Multiple	14 (24.1)	8 (12.9)		14 (24.1)	8 (12.9)		16 (72.7)	6 (27.3)		17 (77.3)	5 (22.7)	
Hypertension:			0.873			0.873			0.545			0.220
No	41 (48.8)	43 (51.2)		41 (48.8)	43 (51.2)		65 (77.4)	19 (22.6)		69 (82.1)	15 (17.9)	
Yes	17 (47.2)	19 (52.8)		17 (47.2)	19 (52.8)		26 (72.2)	10 (27.8)		26 (72.2)	10 (27.8)	
Diabetes:			0.483			0.483			0.082			0.448
No	50 (47.2)	56 (52.8)		50 (47.2)	56 (52.8)		83 (78.3)	23 (21.7)		85 (80.2)	21 (19.8)	
Yes	8 (57.1)	6 (42.9)		8 (57.1)	6 (42.9)		8 (57.1)	6 (42.9)		10 (71.4)	4 (28.6)	
Smoking status:			0.712			0.712			0.973			0.961
No	43 (47.8)	47 (52.2)		43 (47.8)	47 (52.2)		68 (75.6)	22 (24.4)		71 (78.9)	19 (21.1)	
Yes	15 (51.7)	14 (48.3)		15 (51.7)	14 (48.3)		22 (75.9)	7 (24.1)		23 (79.3)	6 (20.7)	
Drinking status:			0.046			0.046			0.683			0.228
No	33 (41.8)	46 (58.2)		33 (41.8)	46 (58.2)		59 (74.7)	20 (25.3)		60 (75.9)	19 (24.1)	
Yes	25 (61.0)	16 (39.0)		25 (61.0)	16 (39.0)		32 (78.0)	9 (22.0)		35 (85.4)	6 (14.6)	

TABLE 3 The association between risk factors and ROM of postoperative at 3 months in the univariate analysis

Risk Factors *n* (%)	Anteflexion			Abduction			Internal Rotation			External Rotation		
	<90°	≥90°	*P* value	<90°	≥90°	*P* value	<30°	≥30°	*P* value	<30°	≥30°	*P* value
Gender:			0.701			0.033			0.006			0.024
Men	9 (17.6)	42 (82.4)		14 (27.5)	37 (72.5)		23 (45.1)	28 (54.9)		24 (47.1)	27 (52.9)	
Women	11 (15.1)	62 (84.9)		9 (12.3)	64 (87.7)		16 (21.9)	57 (78.1)		20 (27.4)	53 (72.6)	
Age group:			0.256			0.687			0.662			0.790
≤60 years	12 (19.0)	48 (81.0)		12 (20.0)	48 (80.0)		20 (33.3)	40 (66.7)		22 (36.7)	38 (63.3)	
>60 years	8 (12.9)	56 (87.1)		11 (17.2)	53 (82.8)		19 (29.7)	45 (70.3)		22 (34.4)	42 (65.6)	
Rotator cuff tear size:			0.325			0.442			0.664			0.369
Small and medium	11 (20.4)	43 (79.6)		12 (22.2)	42 (77.8)		16 (29.6)	38 (70.4)		17 (31.5)	37 (68.5)	
Large and massive	9 (13.6)	57 (86.4)		11 (16.7)	55 (83.3)		22 (33.3)	44 (66.7)		26 (39.4)	40 (60.6)	
Involved tendons:			0.150			0.026			0.018			0.064
Single	14 (13.9)	87 (86.1)		15 (14.9)	86 (85.1)		27 (26.7)	74 (73.3)		32 (31.7)	69 (68.3)	
Multiple	6 (26.1)	17 (73.9)		8 (34.8)	15 (65.2)		12 (52.5)	11 (47.8)		12 (52.2)	11 (47.8)	
Hypertension:			0.550			0.599			0.660			0.537
No	15 (17.4)	71 (82.6)		17 (19.8)	69 (80.2)		26 (30.2)	60 (69.8)		29 (33.7)	57 (66.3)	
Yes	5 (13.2)	33 (86.8)		6 (15.8)	32 (84.2)		13 (34.2)	25 (65.8)		15 (39.5)	23 (60.5)	
Diabetes:			0.332			0.786			0.715			0.985
No	19 (17.3)	91 (82.7)		20 (18.2)	90 (81.8)		34 (30.9)	76 (69.1)		39 (35.5)	71 (64.5)	
Yes	1 (7.1)	13 (92.9)		3 (21.4)	11 (78.6)		5 (35.7)	9 (64.3)		5 (35.7)	9 (64.3)	
Smoking status:			0.399			0.673			0.274			0.585
No	14 (14.7)	81 (85.3)		17 (17.9)	78 (82.1)		21 (0.284)	68 (71.6)		32 (33.7)	63 (66.3)	
Yes	6 (21.4)	22 (78.6)		6 (21.4)	22 (78.6)		11 (39.3)	17 (60.7)		11 (39.3)	17 (60.7)	
Drinking status:			0.001			0.013			0.013			0.012
No	8 (10.0)	72 (90.0)		19 (23.8)	61 (73.6)		19 (23.8)	61 (76.3)		22 (27.5)	58 (72.5)	
Yes	15 (34.1)	29 (65.9)		20 (45.5)	24 (54.5)		20 (45.5)	24 (54.5)		22 (50.0)	22 (50.0)	

Statistical Analysis

All analyses were conducted using SPSS for Windows (version 22.0; SPSS, Chicago, IL, USA). Continuous variables (age, BMI, VAS score, and UCLA scale score) were tested for normal distribution using the Kolmogorov–Smirnov test, and were presented as means and standard deviations (SDs) or as medians with interquartile ranges. Categorical variables (age group, occupation type, RCT size, number of tendons involved, hypertension, diabetes, smoking status, and drinking status) were presented as numbers and percentages. Continuous variables with normal distributions were analyzed using Student's *t*-tests; those with non-normal distributions were analyzed using the Wilcoxon rank-sum test. Categorical variables were compared using chi-squared tests. Binary logistic regression analysis was chosen for the multivariate analysis, with ROM at postoperative 1.5 and 3 months being the dependent variable. The independent variables were those with *P*-values <0.05 (the level of statistical significance) in the chi-squared test or Student's *t*-test analyses; the results were expressed as adjusted relative risks (*RRs*) and 95% confidence intervals (*CIs*).

Results

Demographic and Clinical Characteristics of Patients

A total of 132 patients with RCTs underwent arthroscopic surgery; five were lost to follow-up, leaving 127 patients who were assessed at the 1.5- and 3-month follow-ups. In our study, most (60.3%) of the patients were farmers, and 58.3% of the patients were women; the mean age of the patients was 59 years. Most patients (54.5%) had RCTs that were classified as large or massive. Approximately 20% of the patients had RCTs involving multiple tendons, whereas 80.3% had only a single tendon involved. A minority of the patients had comorbid hypertension (29.9%) or diabetes (11.0%); 23.0% were smokers and 34.6% drank alcohol. The average BMI was 23.94 ± 3.12 kg/m^2 overall, 23.59 ± 3.21 kg/m^2 for men and 24.19 ± 3.06 kg/m^2 for women (Table 1).

The median VAS scores at preoperative, 1.5-month, and 3-month were 5, 1, and 1, respectively. The corresponding median UCLA scale scores were 17, 27, and 37.

Postoperative ROM-Associated Factors (Univariate Analysis)

Table 2 shows the factors correlated with ROM at the 1.5-month postoperative follow-up. Female patients had greater anteflexion and abduction than did male patients ($P = 0.019$ and $P = 0.048$, respectively). Older age was associated with internal rotation and external rotation ($P = 0.041$ and $P = 0.028$, respectively). Moreover, patients who did not drink alcohol had better anteflexion and abduction than did those who drank alcohol (both, $P = 0.046$).

Table 3 shows the factors correlated with ROM at the 3-month follow-up. Again, women were more likely to have

TABLE 4 The association between risk factors and ROM of postoperative at 1.5 and 3 months in the multivariate analysis

Risk Factors	Reference	Anteflexion≥90°	P	Abduction≥90°	P	Internal Rotation≥30°	P	External Rotation≥30°	p
ROM at 1.5 months:									
Men	Women	0.49 (0.20, 1.16)	0.102	0.59 (0.25, 1.40)	0.230	0.70 (0.25, 1.97)	0.498	0.79 (0.27, 2.37)	0.680
Age ≤ 60 years	> 60 years	1.34 (0.63, 2.87)	0.450	1.31 (0.61, 2.78)	0.488	0.42 (0.17, 1.04)	0.061	0.38 (0.14, 1.01)	0.053
Non-drinking	Yes	1.57 (0.64, 3.86)	0.325	1.73 (0.71, 4.24)	0.232	0.87 (0.30, 2.53)	0.790	1.42 (0.44, 4.60)	0.557
ROM at 3 months:									
Men	Women	2.25 (0.68, 7.41)	0.182	0.77 (0.26, 2.29)	0.643	0.52 (0.21, 1.29)	0.156	0.67 (0.28, 1.63)	0.377
Single tendon involved	Multiple	2.70 (0.81, 9.00)	0.106	4.00 (1.30, 12.33)	0.016	3.15 (1.19, 8.36)	0.021	2.49 (0.96, 6.49)	0.062
Non-drinking	Yes	7.08 (2.11, 23.73)	0.002	4.97 (1.62, 15.23)	0.005	2.16 (0.85, 5.48)	0.105	2.32 (0.94, 5.74)	0.069

better ROMs than men in terms of abduction ($P = 0.033$), internal rotation ($P = 0.006$), and external rotation ($P = 0.024$). Patients with a single involved tendon were more likely to have greater abduction and internal rotation than were those with multiple involved tendons ($P = 0.026$ and $P = 0.018$, respectively). Moreover, patients who did not drink alcohol had better anteflexion ($P = 0.001$), abduction ($P = 0.013$), internal rotation ($P = 0.013$), and external rotation ($P = 0.012$) than patients who drank alcohol.

Postoperative ROM-Associated Factors (Multivariate Analysis)

Single-tendon involvement and abstaining from alcohol were independent factors protecting ROM, after adjusting for sex, at 3 months postoperatively. Compared with those for patients with multiple-tendon involvement, patients with single-tendon involvement had 3-fold better abduction ($RR = 4.00$; 95% CI: 1.30–12.33; $P = 0.016$) and 3.15-fold better internal rotation ($RR = 3.15$; 95% CI: 1.19–8.36; $P = 0.021$). Patients who did not drink alcohol had 6.08-fold better anteflexion ($RR = 7.08$; 95% CI: 2.11–23.73; $P = 0.002$) and nearly 4-fold better abduction ($RR = 4.97$; 95% CI: 1.62–15.23; $P = 0.005$) than did patients who drank alcohol.

However, no factors were associated with ROM outcomes at 1.5 months (Table 4).

Discussion

Outcomes of Arthroscopic Rotator Cuff Repairs

This is the first report of factors associated with ROM after arthroscopic rotator cuff repair in a Chinese population. Having fewer tendons involved in the injury was associated with better postoperative abduction and internal rotation, and abstaining from alcohol was associated with better anteflexion and abduction at 3 months postoperatively. However, we did not find any factors associated with ROM at 1.5 months postoperatively.

Number of Tendon Involvement Is Associated with 3-Month Outcomes of RCT

The rotator cuff consists of four tendons, and having more tendons involved in the RCT was associated with poorer outcomes. A previous retrospective study of medical records for 1067 patients who underwent surgical repair of RCTs reported that the number of tendons involved was one of the variables that was strongly correlated with surgical outcomes, and a positive correlation was observed between degenerative changes and the number of tendons involved[13]. Another study that recruited 193 RCT patients who underwent arthroscopic surgery and completed a 2-year follow-up reported that multiple-tendon tears increased the odds of poor postoperative outcomes by 7.92-fold compared with those for single-tendon tears[14]. However, a study that compared the outcomes of isolated subscapularis tendon tears with combined subscapularis tendon tears repaired during arthroscopic surgery revealed no differences in functional restoration, pain relief, or patient satisfaction between groups[21]. Our study's results showed that, compared with multiple-tendon tears, single-tendon tears were associated with better postoperative outcomes, indicating that patients with RCTs involving multiple tendons require additional attention and support.

Alcohol Consumption Is another Factor Associated with 3-Month Outcomes of RCT

Tendon healing occurs in three overlapping phases, including inflammatory phase, proliferative phase, and the remodeling phase[22,23]. Ethanol has been reported to have a significant inhibitory effect on every phase of tendon healing. In a wound-healing study in BALB/c mice, mice given ethanol before injury had a decreased early inflammatory response, including reduced neutrophil activity, compared with control animals[24]. Another study reported that alcohol exposure inhibited the recruitment of inflammatory cells and endothelial cell activation in a burn injury model in rats; the immunosuppressive effects of ethanol persisted even after the ethanol had cleared from the animals' circulation[25]. Alcohol also inhibits the proliferative and remodeling phases of healing. Alcohol exposure can reduce the total collagen content in repaired tissue by up to 37%. Interestingly, the most significant effect of ethanol exposure on wounds may be associate with vascularity because angiogenesis can be reduced by up to 61%[26]. Additionally, fibroblasts showed proliferative capacity impairment of up to 50% following alcohol exposure, causing a reduction in wound breaking strength of up to 40%[27]. More specifically, a rat tendon injury model report suggested that rats that had ingested alcohol exhibited delayed tendon healing, including abnormal healing with abnormal tenocyte morphology and disorganized collagen bundles; the mean force required to re-rupture the tendon was also significantly decreased[28].

Although animal experiments have revealed a negative association between alcohol intake and tendon healing, the results of human studies remain controversial. A case–control study that recruited 249 RCT patients reported that alcohol intake increased the risk of RCTs in both sexes (men: $RR = 1.7$, 95% CI: 1.2–3.9; women: $RR = 1.9$, 95% CI: 0.94–4.1) and higher consumption was associated with greater tear sizes[29]. Zakaria *et al.* studied 1296 patients and showed that alcohol consumption was a potentially modifiable risk factor of spontaneous tendon ruptures[30]. However, Titchener *et al.* studied 5000 patients and found that alcohol intake was not associated with rotator cuff disease[31]. Another case control study also failed to find an association between alcohol consumption and RCT progression[32]. Moreover, Jain *et al.* reported that increased alcohol consumption was associated with better functional outcomes after operative treatment for RCTs[33]. This relationship was also reported for patients with arthroplasty[34]. In our study, we found that abstaining from alcohol intake was associated with better ROMs at 3 months after surgery, indicating that alcohol consumption may delay postoperative recovery of shoulder function.

Study Limitations

Our study had some limitations. First, our sample size was relatively small; we will expand our sample size in a future study. Second, the mean follow-up period for patients was relatively short (i.e., 3 postoperative months); further follow-up of this cohort is necessary. Third, the arthroscopic techniques used, and the affected tendons involved, in the enrolled patients were heterogeneous; this might have affected the robustness of the results. Fourth, we did not collect information regarding the extent of cigarette smoking or alcohol consumption, which may also impact the results. Finally, the study was performed in one tertiary care hospital in China; hence, our findings may not generalize to the broader population.

Conclusion

This was the first study to identify factors associated with outcomes of arthroscopic rotator cuff repair over a 3-month follow-up period in a Chinese population. Single-tendon involvement and abstaining from alcohol intake were independent factors that predicted better outcomes at 3 months after arthroscopic surgery. The results indicate that more attention should be paid for patients with multiple-tendon involvement and preoperative alcohol abstinence education is needed for patients who drinking alcohol to improve outcomes.

Conflict of Interests

All authors declare that they have no conflict of interest in this article.

References

1. Morag Y, Jacobson JA, Miller B, De Maeseneer M, Girish G, Jamadar D. MR imaging of rotator cuff injury: what the clinician needs to know. Radiographics. 2006;26:1045–65.
2. Lehman C, Cuomo F, Kummer FJ, Zuckerman JD. The incidence of full thickness rotator cuff tears in a large cadaveric population. Bull Hosp Jt Dis. 1995;54:30–1.
3. Jerosch J, Müller T, Castro WH. The incidence of rotator cuff rupture. An anatomic study. Acta Orthop Belg. 1991;57:124–9.
4. Milgrom C, Schaffler M, Gilbert S, van Holsbeeck M. Rotator-cuff changes in asymptomatic adults. The effect of age, hand dominance and gender. J Bone Joint Surg Br. 1995;77:296–8.
5. Vitale MA, Vitale MG, Zivin JG, Braman JP, Bigliani LU, Flatow EL. Rotator cuff repair: an analysis of utility scores and cost-effectiveness. J Shoulder Elbow Surg. 2007;16:181–7.
6. Chung SW, Park JS, Kim SH, Shin SH, Oh JH. Quality of life after arthroscopic rotator cuff repair: evaluation using SF-36 and an analysis of affecting clinical factors. Am J Sports Med. 2012;40:631–9.
7. Charousset C, Grimberg J, Duranthon LD, Bellaïche L, Petrover D, Kalra K. The time for functional recovery after arthroscopic rotator cuff repair: correlation with tendon healing controlled by computed tomography arthrography. Art Ther. 2008;24:25–33.
8. Huang SW, Wang WT, Chou LC, Liou TH, Chen YW, Lin HW. Diabetes mellitus increases the risk of rotator cuff tear repair surgery: a population-based cohort study. J Diabetes Complications. 2016;30:1473–7.
9. Daniels SD, Stewart CM, Garvey KD, Brook EM, Higgins LD, Matzkin EG. Sex-based differences in patient-reported outcomes after arthroscopic rotator cuff repair. Orthop J Sports Med. 2019;7:2325967119881959.
10. Robinson PM, Wilson J, Dalal S, Parker RA, Norburn P, Roy BR. Rotator cuff repair in patients over 70 years of age: early outcomes and risk factors associated with re-tear. Bone Joint J. 2013;95-B:199–205.
11. Gumina S, Arceri V, Carbone S, et al. The association between arterial hypertension and rotator cuff tear: the influence on rotator cuff tear sizes. J Shoulder Elbow Surg. 2013;22:229–32.
12. Baumgarten KM, Gerlach D, Galatz LM, et al. Cigarette smoking increases the risk for rotator cuff tears. Clin Orthop Relat Res. 2010;468:1534–41.
13. Feng S, Guo S, Nobuhara K, Hashimoto J, Mimori K. Prognostic indicators for outcome following rotator cuff tear repair. J Orthop Surg (Hong Kong). 2003;11:110–6.
14. Nho SJ, Brown BS, Lyman S, Adler RS, Altchek DW, MacGillivray JD. Prospective analysis of arthroscopic rotator cuff repair: prognostic factors affecting clinical and ultrasound outcome. J Shoulder Elbow Surg. 2009;18:13–20.
15. Hughes JD, Gibbs CM, Reddy RP, et al. Repair of high-grade partial thickness supraspinatus tears after surgical completion of the tear have a lower retear rate when compared to full-thickness tear repair. Knee Surg Sports Traumatol Arthrosc. 2021;29:2370–5.
16. Bayne O, Bateman JE. Long term results of surgical repair of full thickness rotator cuff tears. In: Bateman JE, Welsch RP, editors. Surgery of the shoulder. Philadelphia, Saint Louis, Toronto, London, B.C.: The C.V. Mosby Company; 1984. p. 167–71.
17. Unger T, Borghi C, Charchar F, et al. International society of hypertension global hypertension practice guidelines. Hypertension. 2020;75(6):1334–57.
18. Classification and diagnosis of diabetes: standards of medical care in Diabetes-2020. Diabetes Care, 2020, 43: S14-14S31.
19. Guo ZM, Lin TS, Zhang GM, et al. Observation of curative effect of rehabilitation exercise combined with optimal fumigation therapy after shoulder arthroscopic repair of rotator cuff injury. Chinese Journal of Bone and Joint Injury. 2021;36(11):1195–7.
20. Lee KW, Moon KH, Ma CH, Lee GS, Yang DS, Choy WS. Clinical and radiologic outcomes after medializing and not medializing rotator cuff tendon attachment site on chronic retracted rotator cuff tears. Art Ther. 2018;34:2298–307.
21. Cigolotti A, Biz C, Lerjefors E, de Iudicibus G, Belluzzi E, Ruggieri P. Medium- to long-term clinical and functional outcomes of isolated and combined subscapularis tears repaired arthroscopically. Arch Med Sci. 2021; 17:1351–64.
22. Sharma P, Maffulli N. Tendon injury and tendinopathy: healing and repair. J Bone Joint Surg Am. 2005;87:187–202.
23. Andarawis-Puri N, Flatow EL, Soslowsky LJ. Tendon basic science: development, repair, regeneration, and healing. J Orthop Res. 2015;33:780–4.
24. Fitzgerald DJ, Radek KA, Chaar M, Faunce DE, DiPietro LA, Kovacs EJ. Effects of acute ethanol exposure on the early inflammatory response after excisional injury. Alcohol Clin Exp Res. 2007;31:317–23.
25. Molina PE, Katz PS, Souza-Smith F, et al. Alcohol's burden on immunity following burn, hemorrhagic shock, or traumatic brain injury. Alcohol Res. 2015; 37:263–78.
26. Radek KA, Matthies AM, Burns AL, Heinrich SA, Kovacs EJ, Dipietro LA. Acute ethanol exposure impairs angiogenesis and the proliferative phase of wound healing. Am J Physiol Heart Circ Physiol. 2005;289:H1084–90.
27. Ranzer MJ, Chen L, DiPietro LA. Fibroblast function and wound breaking strength is impaired by acute ethanol intoxication. Alcohol Clin Exp Res. 2011; 35:83–90.
28. Hapa O, Cakici H, Gideroğlu K, Ozturan K, Kükner A, Buğdayci G. The effect of ethanol intake on tendon healing: a histological and biomechanical study in a rat model. Arch Orthop Trauma Surg. 2009;129:1721–6.
29. Passaretti D, Candela V, Venditto T, Giannicola G, Gumina S. Association between alcohol consumption and rotator cuff tear. Acta Orthop. 2016;87:165–8.
30. Zakaria MH, Davis WA, Davis TM. Incidence and predictors of hospitalization for tendon rupture in type 2 diabetes: the Fremantle diabetes study. Diabet Med. 2014;31:425–30.
31. Titchener AG, White JJ, Hinchliffe SR, Tambe AA, Hubbard RB, Clark DI. Comorbidities in rotator cuff disease: a case-control study. J Shoulder Elbow Surg. 2014;23:1282–8.
32. Yamamoto N, Mineta M, Kawakami J, Sano H, Itoi E. Risk factors for tear progression in symptomatic rotator cuff tears: a prospective study of 174 shoulders. Am J Sports Med. 2017;45:2524–31.
33. Jain NB, Ayers GD, Fan R, et al. Predictors of pain and functional outcomes after operative treatment for rotator cuff tears. J Shoulder Elbow Surg. 2018;27: 1393–400.
34. Rotevatn TA, Bøggild H, Olesen CR, et al. Alcohol consumption and the risk of postoperative mortality and morbidity after primary hip or knee arthroplasty—a register-based cohort study. PLoS One. 2017;12:e0173083.