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Prospective analysis of arthroscopic rotator cuff repair: Prognostic factors affecting clinical and ultrasound outcome

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Summary The purpose of this study was to identify potential predictors of function and tendon healing after arthroscopic rotator cuff repair that will enable the orthopaedic surgeon to determine which patients can expect a successful outcome. Between 2003 and 2005, the Arthroscopic Rotator Cuff Registry was established to collect demographic, intraoperative, functional outcome, and ultrasound data prospectively on all patients who underwent primary arthroscopic rotator cuff repair. At total of 193 patients met the study criteria, and 127 (65.8%) completed the 2-year follow-up. The most significant independent factors affecting ultrasound outcome were age (odds ratio [OR], 1.08; 95% confidence interval [CI], 1.02-1.14; $P = .006$) and tear size (OR, 2.29; 95% CI, 1.55-3.38; $P < .001$). After adjustment for age and tear size, the intraoperative factors found to be significantly associated with a tendon defect were concomitant biceps procedures (OR, 11.39; 95% CI, 2.90-44.69; $P < .001$) and acromioclavicular joint procedures (OR, 3.85; 95% CI, 1.46-10.12; $P = .006$). In contrast to the ultrasound data, the functional outcome variables, such as satisfaction (OR, 3.92; 95% CI, 2.00-7.68; $P < .001$) and strength (OR, 10.05; 95% CI, 1.61-62.77; $P = .01$), had a greater role in predicting an American Shoulder and Elbow Surgeons score greater than 90. The progression from a single-tendon rotator cuff tear to a multiple-tendon tear with associated pathology increased the likelihood of tendon defect by at least 9 times, and therefore, earlier surgical intervention for isolated, single-tendon rotator cuff tears could optimize the likelihood of ultrasound healing and an excellent functional outcome.
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Rotator cuff tears are a prevalent condition in an aging population and represent a common source of shoulder pain in these patients. The surgical management of rotator cuff tears has evolved over the past decade from formal open repairs to mini-open repairs to all-arthroscopic techniques. Studies comparing arthroscopic and mini-open rotator cuff repairs have shown similar clinical outcomes and shoulder function. A recent systematic review comparing arthroscopic and mini-open rotator cuff repair studies reported a slight increase in the rates of revision rotator cuff repairs,

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infection, and arthrofibrosis requiring manipulation under anesthesia after mini-open repair. Numerous case series of arthroscopic rotator cuff repair (ARCR) have described improvement in overall shoulder function, range of motion, strength, and pain relief.*

The initial studies of ARCR used shoulder-specific outcome instruments and physical examination data.† Only recently have postoperative imaging modalities been adopted to evaluate healing after ARCR.‡ Although reported outcomes of ARCR have improved, there are areas that can be enhanced including prospective outcome studies, sample size, number of surgeons, and outcome assessment with validated, shoulder-specific outcome instruments and postoperative imaging assessment. The Arthroscopic Rotator Cuff Registry was established in 2003 to collect information prospectively on patients undergoing ARCR. To date, the Arthroscopic Rotator Cuff Registry is the largest prospective outcome study to evaluate ARCR performed by multiple surgeons using validated outcome scores and postoperative ultrasonography at a single institution. The purpose of this study was to identify potential predictors of function and tendon healing after ARCR that will enable the orthopaedic surgeon to determine which patients can expect a successful outcome. Our hypothesis was that there are a number of patient demographic, intraoperative, and functional outcome characteristics after ARCR that are significantly associated with clinical outcome and tendon healing at a minimum of 2 years.

Materials and methods

Between 2003 and 2005, the Arthroscopic Rotator Cuff Registry was established to collect demographic, intraoperative, functional outcome, and ultrasound data prospectively on all patients who underwent primary ARCR. The institutional review board approved the study proposal, and informed consent was obtained from all patients before the procedure by the study coordinator. Three hundred eleven consecutive patients scheduled to undergo ARCR were enrolled prospectively in the registry at 1 institution by 12 fellowship-trained surgeons in sports medicine or shoulder surgery over a 2-year period. Of these patients, 118 were excluded for the following reasons: ARCR was not performed, conversion to mini-open rotator cuff repair was done, revision rotator cuff repair was done, or glenohumeral osteoarthritis was present.

A total of 193 patients underwent all-arthroscopic repair of rotator cuff tear and met the inclusion criteria. The indications for surgery included an imaging study consistent with a rotator cuff tear and failure of nonoperative treatment with a rehabilitation program and corticosteroid injection. All patients were followed up for a minimum of 2 years after the index surgery, and the registry will continue to follow up patients until 5 years after surgery.

Patients who met the study criteria and completed the informed consent form filled out a preoperative questionnaire that included demographic and social history, detailed medical history, and surgical history. Demographic information, smoking history, use of pain medications (anti-inflammatories and narcotics), onset and duration of symptoms, and number of steroid injections in the affected shoulder were recorded. The intraoperative factors included both diagnostic information and concomitant procedures performed at the time of surgery. Intra-articular data included labral pathology (location and size), chondral lesions (location, size, and depth), and biceps tear (none, incomplete, or complete).

Rotator cuff pathology was described by lesion size, tear thickness (full or partial), and tendon(s) involved (single or multiple). The tear size was determined after bursectomy of the subacromial space but before rotator cuff debridement. Tear size was measured in the sagittal plane at its insertion into its respective anatomic footprint. The surgeon recorded the involved torn tendon (supraspinatus, infraspinatus, teres minor, or subscapularis) and determined whether there was an isolated supraspinatus tear or a tear that also disrupted part or all of the infraspinatus insertion. If there was more than 1 tendon torn, it was considered to involve multiple tendons. Because of the small number of 3-tendon tears, the 2- and 3-tendon tears were grouped together for statistical analysis. The details of the ARCR were recorded and included information on the number of suture anchors, the suture anchor row configuration (single or double), and the tissue quality (normal or poor). The tissue quality was considered to be either normal or degenerative based on tissue thickness and mobilization during arthroscopic assessment. Tissue thickness was determined with a tissue grasper and was compared with the surrounding intact rotator cuff as an internal control. The grasper was also used to determine whether the torn tendon could be mobilized back to its anatomic footprint. A torn tendon that was thinner than the surrounding intact tendons and could not be mobilized back to its insertion was considered to be degenerative. The additional procedures were also recorded, including acromioplasty (yes or no), superior labrum anterior-posterior (SLAP) procedures (none, debridement, or repair), biceps procedures (none, debridement, tenotomy, or tenodesis), or acromioclavicular (AC) joint procedures (none, AC joint coplaning, or distal clavicle excision) (Table I).

The American Shoulder and Elbow Surgeons (ASES) score,[28] a validated shoulder-specific outcome assessment instrument; physical examination including range of motion and strength; and manual muscle testing were completed preoperatively and after surgery at 1 year, 2 years, and 5 years. Strength testing was performed with a handheld dynamometer (Lafayette Manual Muscle Test System; Lafayette Instrument Company, Lafayette, IN).

Limited targeted ultrasound of the supraspinatus and infraspinatus tendons was performed at 1 year, 2 years, and eventually, 5 years after ARCR. The examinations were performed and interpreted by a single radiologist experienced in musculoskeletal ultrasound and was performed with mild internal rotation and hyperextension, scanning anteriorly in both longitudinal and transverse planes. Dynamic maneuvers were used to accentuate an abnormality. These included compression with the transducer to confirm the presence of fluid within a defect by producing redistribution of that fluid or positioning the extremity in real time to assess continuity of the repair better.[11] The ultrasound images were stored digitally on a workstation (Philips PACS, Philips Medical, Bothell, Washington), and tendon involvement, healing status (intact or defect), and surface area of defect were recorded.

* References 2, 4, 8, 14, 25, 29, 31, 32, 39, 40.
† References 2, 14, 19, 21, 29, 31, 33, 38-40, 43.
‡ References 1, 4, 6, 8, 11, 12, 18, 24-26, 35, 37.

Table I Demographic, intraoperative, functional outcome, and ultrasound data

Potential predictor	Scale
Demographic variables	
Age	Years
Tobacco history	Y/N
Pain	Y/N
Anti-inflammatory use	Y/N
Narcotic use	Y/N
Intraoperative variables	
Size	Centimeters
Tendons	Single or multiple
Tissue quality	Normal or poor
No. of anchors	Number
Row configuration	Single or double
AC joint procedures	None, AC joint coplaning, or distal clavicle excision
Biceps procedures	None, debridement, tenotomy, or tenodesis
SLAP procedures	None, debridement, or repair
Functional outcomes	
ASES score	Scale from 0-100
VAS 2 y	Scale from 0-10
Satisfaction	Delighted, pleased, mostly satisfied, mixed, mostly dissatisfied, unhappy, or terrible
Manual muscle testing	Pounds
Forward elevation	0°-180°
External rotation	0°-180°
Strength in FE	Scale from 1-5
Strength in ER	Scale from 1-5
Ultrasound data	
Healing	Intact or defect

VAS, Visual analog scale; *FE*, forward elevation; *ER*, external rotation.

All other collected data were stored by use of the System for Collaborative Transitional Research, under the direction of the study coordinator. The System for Collaborative Transitional Research is compliant with both the Health Insurance Portability and Accountability Act and 21 clinical review panel (CRP) Part 11.

Statistical analyses

Descriptive analysis consisted of frequencies and percentages for discrete data and means and SDs for continuous data. Inferential analyses included χ^2 and t tests to conduct univariate analyses of the prognostic factors for healing and other outcomes. Multivariate analyses were performed by use of logistic regression to identify prognostic factors for these outcomes. All multivariate analyses were age and size adjusted but were not adjusted for any other potential predictors. Given the relatively small number of events, a full parsimonious model was not feasible. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated by use of these logistic regression models as estimates of effect size. All analyses were performed with SAS software for Windows, version 9.1 (SAS Institute, Cary, NC).

Results

A total of 193 patients met the study criteria; of these, 129 (66.8%) completed a 1-year follow-up and 127 (65.8%) completed a 2-year follow-up. Of the 66 patients (34.2%) who were lost to follow-up, 47 (24.4%) could not be located, 13 (6.7%) were contacted but no longer wished to participate, 3 (1.6%) lived in a different state, and 3 (1.6%) underwent revision ARCR.

The mean age of the patients was 58.6 years, with a mean follow-up of 28.2 months. Of those who completed the 2-year follow-up, 60.7% (n = 77) were men and 39.3% (n = 50) women. Either active tobacco use or a history of tobacco use was reported by 34 patients (26.9%). In addition, 14 (10.9%) reported pain in the involved shoulder, oral analgesia was required in the form of anti-inflammatory medications in 10 (7.8%), and narcotic medications were used in 1 (0.8%).

At the index procedure, the rotator cuff tear and associated pathology were meticulously recorded. The mean rotator cuff tear size was 3.16 ± 1.40 cm (range, 0.5-7.0 cm); a single-tendon tear occurred in 76 cases (59.8%), and a multiple-tendon tear occurred in 51 (40.1%) (2 tendons in 46 [36.2%] and 3 tendons in 5 [3.9%]). According to the classification of DeOrio and Cofield,[10] the tears were small (0-1 cm) in 5 (3.9%), medium (1-3 cm) in 80 (63.0%), large (3-5 cm) in 32 (25.2%), and massive (>5 cm) in 10 (7.9%).

The surgeon also determined the quality of the torn rotator cuff to be normal in 87 cases (68.5%) and degenerative in 40 cases (31.5%). The mean number of suture anchors was 2.47 ± 0.99 (range, 1.0-6.0), and the suture anchor configuration was single row in 66 cases (52.0%) and double row in 61 (48.0%). Any additional pathology underwent concomitant surgical treatment at the time of ARCR. The biceps tendon was debrided in 19 cases (14.9%), underwent tenodesis in 6 (4.7%), and underwent tenotomy in 12 (9.4%). The AC joint underwent coplaning in 28 cases (22.0%) and distal clavicle excision in 15 (11.8%). SLAP tears were debrided in 35 cases (27.6%) and repaired in 1 (0.8%). A comparison of ARCR with concomitant procedures for single- and multiple-tendon tears is shown in Table II.

The functional outcome and ultrasound data are shown in Table III.

The risk factors that resulted in a tendon defect by ultrasound at the 2-year follow-up are shown in Tables IV and V. Increased age and tear size were found to be significant risk factors of a tendon defect after ARCR (Table III). For every year of increase in age, the odds of a tendon defect increased 1.08 times (95% CI, 1.02-1.14; $P = .006$). The odds of a tendon defect increased 2.29 times (95% CI, 1.55-3.38) for every centimeter of increase in rotator cuff tear size ($P < .001$), and for multiple-tendon tears the likelihood for a tendon defect was increased by 8.92 (95% CI, 3.43-23.18) compared with single-tendon tears ($P < .001$).

Table II Comparison of ARCR with concomitant procedures between single tendon and multiple tendons

	Single tendon (%)	Multiple tendons (%)	*P* value
No. of patients	76 (100)	51 (100)	
Acromioplasty	76 (100)	51 (100)	
AC joint procedures			.027
AC joint coplaning	17 (22.4)	11 (21.6)	
Distal clavicle excision	5 (6.6)	10 (19.6)	
Biceps procedures			.003
Debridement	11 (14.5)	8 (15.7)	
Tenodesis	2 (2.6)	4 (7.8)	
Tenotomy	3 (3.9)	9 (17.6)	

Table III Outcomes after ARCR

Outcome	Score
Satisfaction at 1 y	
Delighted	37.0%
Pleased	26.7%
Mostly satisfied	20.0%
Mixed	8.9%
Mostly dissatisfied	0.0%
Unhappy	6.7%
Terrible	0.7%
Satisfaction at 2 y	
Delighted	54.7%
Pleased	21.7%
Mostly satisfied	17.0%
Mixed	4.7%
Mostly dissatisfied	1.9%
Unhappy	0.0%
Terrible	0.0%
ASES score preoperatively	51.65 ± 23.97
ASES score at 2 y	92.43 ± 11.59
VAS at 2 y	0.54 ± 1.11
Manual muscle testing preoperatively (lbs.)	6.41 ± 6.24
Manual muscle testing at 2 y	10.66 ± 4.11
FE preoperatively (degrees)	153.64 ± 29.19
FE at 2 y	173.20 ± 9.62
ER preoperatively (degrees)	61.41 ± 19.53
ER at 2 y	74.08 ± 20.26
Strength in FE preoperatively	3.93 ± 1.021
Strength in FE at 2 y	4.79 ± 0.77
Strength in ER preoperatively	4.12 ± 0.98
Strength in ER at 2 y	4.73 ± 0.80
Ultrasound healing at 2 y	75.4%

VAS, Visual analog scale; *FE*, forward elevation; *ER*, external rotation.

After adjustment for age and tear size, the intraoperative factors determined to be significantly associated with a tendon defect (Table V) were cases that underwent biceps tenotomy or tenodesis, being 11.39 times more likely (95% CI, 2.90-44.69) to have a tendon defect than cases of ARCR without biceps pathology ($P < .001$). In addition, cases undergoing concomitant AC joint coplaning or distal clavicle excision had an increased odds of 3.85 times (95% CI, 1.46-10.12) for a tendon defect compared with cases of ARCR without AC joint pathology ($P = .006$). The likelihood of a tendon defect of a degenerative rotator cuff tear was 3.31 times higher (95% CI, 1.00-10.91) than for a rotator cuff tear with normal tissue quality ($P = .049$).

Table IV Risk factors for ultrasound defect after ARCR

Predictor variable	OR	95% CI	*P* value
Size	2.29	1.55-3.38	< .0001
Tendons	8.92	3.43-23.18	< .0001
Age	1.08	1.02-1.14	.0056

Table V Age- and size-adjusted risk factors for ultrasound defect after ARCR

Predictor variable	OR	95% CI	*P* value
Demographic data			
Pain	1.49	0.42-5.35	.54
Anti-inflammatory use	0.65	0.11-4.06	.65
Narcotic use	0.55	0.02-20.77	.75
Tobacco history	0.98	0.76-1.26	.88
Intraoperative data			
Biceps procedures	11.39	2.90-44.69	.0005
AC joint procedures	3.85	1.46-10.12	.0064
SLAP tears	0.89	0.27-2.97	.85
Tissue quality	3.31	1.00-10.91	.0495
Row configuration	0.43	0.10-1.77	.24
No. of anchors	1.16	0.46-2.88	.76
Fuctional outcome data			
Satisfaction at 1 y	0.77	0.48-1.24	.28
Satisfaction at 2 y	0.57	0.29-1.13	.10
Strength in forward elevation	0.18	0.01-2.36	.19
Strength in external rotation	0.20	0.03-1.14	.07
External rotation	0.98	0.95-1.00	.09
Forward elevation	1.01	0.95-1.08	.67
Manuel muscle strength	0.98	0.84-1.14	.82
ASES score preoperatively	0.99	0.96-1.02	.43
ASES score at 2 y	0.95	0.90-1.01	.08
VAS at 2 y	1.63	0.94-2.83	.08

VAS, Visual analog scale.

Prognostic factors that led to an excellent clinical outcome (ASES score >90) were also identified (Tables VI and VII). In contrast to the ultrasound data, the functional outcome variables had a greater role in predicting an excellent clinical outcome. The only intraoperative variable that affected clinical score was AC joint procedures, and patients who had concomitant AC joint coplaning or distal clavicle excision had a significantly negative association with ASES score (OR, 0.29; 95% CI, 0.13-0.64; $P = .003$). Patients who were satisfied at the 2-year follow-up were 3.92 times more likely (95% CI, 2.00-7.68) to have an ASES score greater than 90 compared with those who were

Table VI Prognostic factors for ASES score greater than 90 after ARCR

Predictor variable	OR	95% CI	*P* value
Age	1.02	0.98-1.06	.32
Size	0.80	0.59-1.10	.18
Tendons	0.42	0.19-0.97	.04

Table VII Age- and size-adjusted prognostic factors for ASES score greater than 90 after ARCR

Predictor variable	OR	95% CI	*P* value
Demographic data			
Pain	0.57	0.18-1.79	.33
Anti-inflammatory use	0.59	0.14-2.45	.47
Narcotic use	1.02	0.81-1.27	.89
Tobacco history	Not calculable	—	—
Intraoperative data			
Biceps procedures	0.57	0.19-1.70	.32
AC joint procedures	0.29	0.13-0.64	.0025
SLAP tears	0.54	0.20-1.46	.23
Tissue quality	2.10	0.64-6.85	.22
Row configuration	1.27	0.39-4.12	.69
No. of anchors	1.25	0.56-2.81	.59
Functional outcome data			
Satisfaction at 1 y	2.00	1.31-3.06	.0015
Satisfaction at 2 y	3.92	2.00-7.68	< .0001
Strength in forward elevation	10.05	1.61-62.77	.01
Strength in external rotation	1.81	0.54-6.10	.34
External rotation	1.02	0.99-1.05	.22
Forward elevation	1.03	0.98-1.09	.24
Manuel muscle strength	1.24	1.05-1.46	.01
Healing based on ultrasound image	0.38	0.11-1.34	.13

not satisfied ($P < .001$), and even those with a high satisfaction score at 1 year were 2.00 times more likely to have an ASES score greater than 90 at 2 years. Muscle strength was also shown to have a significant association with an excellent clinical outcome. A patient with full motor strength in forward elevation had a likelihood of 10.05 (95% CI, 1.61-62.77) to have an ASES score greater than 90 compared with patients with motor weakness ($P = .01$).

Discussion

This study is the largest prospective clinical study of ARCR using validated questionnaires and a postoperative imaging modality performed by 12 different fellowship-trained orthopaedic surgeons at a single institution. At short-term follow-up, a number of prognostic factors were identified with important implications in the management of rotator cuff disease. Although there was some overlap, the predictive factors for rotator cuff repair integrity by ultrasound differed from excellent ASES score. The associations that were identified will allow the orthopaedic surgeon to predict the likelihood of rotator cuff healing and successful functional outcome for a prospective surgical candidate.

Numerous studies have reported age and tear size as significant factors of tendon healing after rotator cuff repair, and the relationship between age and tear size has also been previously reported.[3,4,8,9,15,17] Our findings show that the size of the rotator cuff tear, as expressed in centimeters in the sagittal plane or single-tendon involvement versus multiple-tendon involvement, has the most significant association with tendon healing. The relative risk of a tendon defect after ARCR was increased by 2.29 times for every centimeter of increase in tear size or increased by 8.92 times from a single-tendon rotator cuff tear to a multiple-tendon tear. Age was also confirmed to be a significant independent risk factor for tendon defect and increased 1.08 times for every additional year. The rotator cuff tear size at the time of presentation was the single most important predictor of postoperative tendon healing. Given a relative risk of almost 9 times for a tendon defect after ARCR for multiple-tendon rotator cuff tears, surgical intervention when rotator cuff tears are limited to a single tendon could provide a higher probability of tendon healing.

After adjustment for age and tear size, multivariate regression analysis was performed to determine which of the other potential factors have a significant effect on tendon healing after ARCR. Biceps and AC pathology associated with rotator cuff tears and the quality of the torn rotator cuff tissue were determined to have significant associations with tendon healing. Cases of ARCR with concomitant biceps tenotomy or tenodesis had 11 times the risk of a tendon defect compared with cases of ARCR without biceps procedures. In addition, patients undergoing ARCR with either AC joint coplaning or distal clavicle excision showed a relative risk of almost 4 times compared with patients who had ARCR without AC joint procedures. Pathology involving the long head of the biceps and AC joint has been associated with massive rotator cuff tears and likely reflects the severity of rotator cuff degeneration rather than a result of the additional procedures.[3,5,20,23,27]

The quality of the torn rotator cuff tendon was also found to be an independent risk factor, and cases with poor tissue quality showed 3 times the failure rate compared with rotator cuff repair in normal tendons. Boileau et al[4] also described poor tendon healing with tear extension in the sagittal plane with associated tendon delamination. Some authors propose that delamination of the rotator cuff tendon occurs as a result of a separation between the thicker and more retracted articular layer from the posterior oblique fibers of the infraspinatus and superficial bursal layer, which may be a combination of transverse fibers

from the infraspinatus and supraspinatus.[35] Sugaya et al[35] recommended that both layers be repaired separately with double-row suture anchor fixation; the medial row provides fixation for the articular layer, whereas the lateral row addresses the more superficial layer.[34,35] Huijsmans et al[18] also reported more failed repairs by postoperative ultrasound in tendons characterized as poor quality by the surgeon.

The findings of our study show that the repair of an isolated supraspinatus tear without additional pathology or tissue degeneration provides the greatest likelihood of tendon healing. Yamaguchi et al[41,42] determined the natural history of rotator cuff tears that occur over time and showed a high correlation with advanced age. On the basis of longitudinal ultrasound studies, an asymptomatic rotator cuff tear became symptomatic over a mean of 2.8 years, and 39% of patients with a repeat ultrasound had progression of the rotator cuff tear.[42] Gerber and colleagues[44] reported that in massive rotator cuff tears treated conservatively, the tear size may increase and intramuscular fatty infiltration and osteoarthritis may occur, and there is a substantial risk of an irreparable tear within 4 years. Our study provides additional data to support early intervention for rotator cuff disease before tear progression, tissue degeneration, biceps involvement, and AC joint degeneration. It is hoped that repair of the rotator cuff tendon early in the disease process may alter the natural history of a torn rotator cuff.

There were several variables that did not have a significant association with tendon healing that are notable. None of the demographic factors, including anti-inflammatory use or tobacco use, had a significant effect on tendon healing. There were several functional outcome variables that had an association but did not reach statistical significance, such as external rotation range of motion, ASES score at 2-year follow-up, visual analog scale score at 2-year follow-up, and strength in external rotation. Of interest, none of the repair characteristics was found to influence tendon healing or clinical outcome significantly, including the number of suture anchors and row configuration.

The extent of tendon involvement and concomitant AC joint procedures were the only shared factors between tendon healing and excellent clinical outcome. ARCR involving a single tendon without concomitant AC joint procedures had a significant association with ASES score greater than 90. Despite such a strong association between biceps procedures and tendon healing, biceps pathology did not seem to have a strong effect on clinical outcome. These findings reiterate the higher likelihood of a successful clinical and radiographic outcome in isolated rotator cuff tears limited to a single tendon. In a long-term prospective study after open rotator cuff repairs, Cofield et al[7] reported that tear size was the most important determinant of a successful outcome, and factors associated with a larger tear size such as AC pathology and postoperative weakness also had a negative effect on outcome. The factors that also had a significant association with an excellent clinical outcome were functional outcome variables. Although these factors are not predictive of an excellent ASES score, they do indicate what variables lead to a successful clinical outcome. Patient satisfaction at 1-year and 2-year follow-up had the strongest association with ASES score greater than 90. In a study to determine variables related to patient satisfaction, O'Holleran et al[30] also reported a significant relationship between ASES score and satisfaction. They determined that patient-derived subjective variables of shoulder pain and function had the most robust relationship with satisfaction, and objective variables such as decreased and weakened forward elevation, impingement signs, and AC joint pain and tenderness also led to decreased satisfaction but to a lesser degree.[30] Our results also determined that strength in forward elevation had a strong association with an excellent ASES score and suggest that the ability to perform overhead activity has an important role in a successful clinical outcome. Interestingly, it was strength in external rotation that had a stronger association with tendon healing by ultrasound, but this did not reach statistical significance.

At short-term follow-up, ultrasound healing did not have a significant association with ASES score greater than 90. The relationship of tendon healing and clinical outcome is debated in the literature. There are several studies that report that healed rotator cuff tendons provide increased strength and improvement in range of motion.[16-18,36,39] Others show that tendon healing does not affect clinical outcome, and patients with a tendon defect still report excellent pain relief and high satisfaction.[22,27] Despite 17 of 18 patients having recurrent tears, Galatz et al[13] report excellent pain relief and improvement in functional outcomes at 12 months but a decline in ASES score at 2 years. Intermediate- and long-term studies are necessary to determine whether the clinical outcome deteriorates with persistent rotator cuff tears.

The major limitation of this study was the number of patients lost to follow-up. The rate of follow-up was 66.8% at 1 year and 65.8% at 2 years, and a lack of 100% follow-up increases the exclusion bias. There were numerous attempts made to contact patients and encourage postoperative follow-up, but many refused or could not be located. Multiple surgeons performed the ARCR by similar but not identical techniques. In addition, rehabilitation protocols were not standardized. The study provides data at 2-year follow-up but is designed to provide intermediate-term follow-up at 5 years with both subjective and objective outcomes.

In conclusion, this study was designed to identify independent predictors of subjective and objective outcomes after ARCR at a minimum of 2 years' follow-up. Risk factors of a tendon defect after ARCR were advanced age, large tear size, multiple-tendon tear, biceps tenotomy or tenodesis, AC joint coplaning or distal clavicle excision,

and poor tendon tissue quality. The prognostic factors for excellent clinical outcome were small tear size, lack of AC joint procedures, patient satisfaction, and restoration of strength in forward elevation. The predictive factors that overlapped between ultrasound healing and excellent clinical outcome were tear size and AC joint pathology, and progression of rotator cuff tear and associated pathology decreased tendon healing and worsened clinical outcome. The progression from a single-tendon rotator cuff tear to a multiple-tendon tear with associated pathology increased the likelihood of tendon defect by at least 9 times, and therefore, earlier surgical intervention for isolated, single-tendon rotator cuff tears could optimize the likelihood of ultrasound healing and an excellent functional outcome.

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