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Revision Arthroscopic Rotator Cuff Repair: Repair Integrity and Clinical Outcome

By Jay D. Keener, MD, Anthony S. Wei, MD, H. Mike Kim, MD, Edward S. Paxton, MD, Sharlene A. Teefey, MD, Leesa M. Galatz, MD, and Ken Yamaguchi, MD

Investigation performed at the Shoulder and Elbow Service, Department of Orthopaedic Surgery, Washington University, St. Louis, Missouri

Background: Literature regarding the outcomes of revision rotator cuff repair is limited. The purposes of the present study were to report the tendon repair integrity and clinical outcomes for a cohort of patients following revision arthroscopic rotator cuff repair and to examine factors related to tendon healing and the influence of healing on clinical outcomes.

Methods: Twenty-one of twenty-nine consecutive revision arthroscopic rotator cuff repairs with a minimum of two years of postoperative follow-up were retrospectively reviewed. Outcomes were evaluated on the basis of a visual analog pain scale, the range of motion of the shoulder, the Simple Shoulder Test, the American Shoulder and Elbow Surgeons score, and the Constant score. Ultrasonography was used to examine repair integrity at a minimum of one year following surgery. Ten shoulders underwent arthroscopic repair of a recurrent single-tendon posterior rotator cuff tear, whereas eleven shoulders had repair of both the supraspinatus and infraspinatus.

Results: The mean age of the twenty-one subjects was 55.6 years; thirteen subjects were male and eight were female. Complete preoperative and postoperative clinical data were available for nineteen subjects after an average duration of follow-up of thirty-three months. Significant improvements were seen in terms of postoperative pain ($p < 0.05$), the Simple Shoulder Test score ($p < 0.05$), the American Shoulder and Elbow Surgeons function ($p < 0.05$) and total scores ($p < 0.05$), active forward elevation ($p < 0.05$), and active external rotation ($p < 0.05$). Postoperative ultrasound data were available for all twenty-one shoulders after a mean duration of follow-up of twenty-five months. Ten (48%) of the twenty-one shoulders had an intact repair. Seven (70%) of the ten single-tendon repairs were intact, compared with three (27%) of the eleven supraspinatus/infraspinatus repairs ($p = 0.05$). Patient age ($p < 0.05$) and the number of torn tendons ($p = 0.05$) had significant effects on postoperative tendon repair integrity. Shoulders with an intact repair had better postoperative Constant scores ($p < 0.05$) and scapular plane elevation strength ($p < 0.05$) in comparison with those with a recurrent tear.

Conclusions: Revision arthroscopic rotator cuff repair results in reliable pain relief and improvement in shoulder function in selected cases. Approximately half of the revision repairs can be expected to be intact at a minimum of one year following surgery. Patient age and the number of torn tendons are related to postoperative tendon integrity. The postoperative integrity of the rotator cuff can have a significant influence on shoulder abduction strength and the Constant score.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

The absence of tendon healing following rotator cuff surgery is not uncommon and can lead to the need for revision surgery. The presence of a recurrent tear has been correlated with decreased function and strength of the shoulder compared with an intact repair[1-10]. There are several factors complicating a failed rotator cuff repair that can make revision surgery difficult. These include advanced tendon damage or degeneration, progressive rotator cuff muscle atrophy and fatty infiltration, capsular contracture and stiffness, and deltoid injury in cases of previous open repair[11-13]. On this point, the literature specific to the outcomes of revision rotator cuff repair is very limited[12-16], especially when compared with

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the volume of recent studies focusing on primary cuff repair. No studies, to our knowledge, have evaluated the structural integrity and the rate of tendon healing following revision rotator cuff repair. In addition, few studies have evaluated the clinical results of contemporary revision arthroscopic rotator cuff repair[15].

The primary purpose of the present study was to evaluate the tendon repair integrity and clinical outcomes for a cohort of patients following revision arthroscopic rotator cuff repair. The secondary purpose was to examine factors related to tendon healing following surgery and the influence of healing on clinical outcome.

Materials and Methods

Inclusion/Exclusion Criteria

We conducted a retrospective review of a cohort of patients following revision arthroscopic rotator cuff repair. Institutional review board approval was obtained prior to the review of the surgical case logs of the Shoulder and Elbow Service at Washington University. Eligible subjects included those with persistent pain and limited function following previous rotator cuff repair with documented failure of healing or retear (as determined on the basis of ultrasonography or magnetic resonance imaging) of the rotator cuff tendon or tendons. All recurrent tears involved the posterior part of the rotator cuff (the supraspinatus and/or infraspinatus tendon) with or without involvement of the subscapularis tendon. The primary indication for surgery was persistent shoulder pain despite a minimum six-month rehabilitation trial following the previous surgery.

The inclusion criteria were revision rotator cuff repair in which complete repair of the posterior rotator cuff defect was accomplished arthroscopically and a minimum duration of follow-up of two years. No subjects in the present series were thought to have symptomatic acromioclavicular joint arthritis. The exclusion criteria included isolated subscapularis tendon tears, partial revision repairs, irreparable rotator cuff defects, radiographic evidence of glenohumeral osteoarthritis, suprascapular or axillary nerve lesions, a failure of deltoid muscle healing after previous surgery, and loss of containment of the humeral head within the coracoacromial arch (humeral head escape).

Subjects

From March 2004 to June 2006, a total of twenty-nine patients who had undergone revision rotator cuff repair met all of the inclusion criteria. The medical records of all patients were reviewed to collect background information related to previous treatment and clinical presentation. All eligible patients were contacted for study recruitment. Of the twenty-nine eligible patients, twenty-one agreed to participate in the study. Of the eight eligible patients who were not included in the study, two could not be located despite an exhaustive search, two were unable to travel because of chronic medical illness, and four refused to participate in the study. Two of these patients declined because of ongoing litigation with Workers' Compensation, one refused because of prohibitive travel distance, and one refused for unspecified reasons.

A total of twenty-one subjects were retrospectively evaluated for the present study (Table I). The study group included thirteen men and eight women with an average age of fifty-six years (range, forty-seven to seventy-three years) at the time of surgery. The surgery was performed on the dominant shoulder in thirteen cases. Seventeen of the twenty-one patients had had one previous rotator cuff repair in the involved shoulder, three patients had had two previous repairs, and one patient had had three previous repairs. The previous operations included repairs that were isolated to the supraspinatus and/or infraspinatus tendon, with the exception of one operation that involved a combined supraspinatus and subscapularis repair. Three patients had had a single previous rotator cuff repair performed arthroscopically, sixteen patients had had one or more open or mini-open repairs, and two patients had had one previous arthroscopic and one mini-open rotator cuff repair. All but three patients had had the primary repair performed at an outside institution and were subsequently referred to the senior author (K.Y.) because of persistent shoulder pain and limited function following surgery. In most instances, we were not able to determine the method of tendon-to-bone fixation in the subjects with previous operations that had been performed at outside institutions. For the three subjects who had had the previous surgery at our institution, all repairs were originally performed with an arthroscopic double-row technique.

The clinical presentation of the subjects was variable. Eighteen subjects experienced persistent or increasing shoulder pain and limited function following surgery. Three subjects recovered well and had good shoulder function following previous surgery and subsequently reported a distinct repeat injury preceding clinical presentation. The median duration of time from the most recent previous failed rotator cuff repair to revision was 13.5 months (range, three to 252 months).

Recurrent tears were classified according to the number of involved tendons on the basis of preoperative imaging (magnetic resonance imaging and/or ultrasound) and were confirmed with intraoperative findings. Seven shoulders had an isolated supraspinatus tendon tear, ten had combined supraspinatus and infraspinatus tendon tears, two had an isolated infraspinatus tendon tear, one had combined supraspinatus and subscapularis tendon tears, and one had combined supraspinatus, infraspinatus, and subscapularis tendon tears.

Clinical Evaluation

According to the established shoulder service protocol, all patients completed a comprehensive questionnaire that included the American Shoulder and Elbow Surgeons (ASES) score[17] and the Simple Shoulder Test (SST)[18] outcome tools at the time of presentation and prior to treatment. Postoperatively, the subjects were clinically evaluated at a minimum of twenty-four months after the index procedure by an inde-

TABLE I Data on the Subjects

Subject	Age at Operation *(yr)*	Sex	Involved Side	Tear Type*	Number of Previous Operations	Time from Previous Operation to Index Operation *(mo)*
1	50.17	M	L	SS	1	60
2	62.33	F	R	SS/IS	1	19
3	73.00	F	R	SS/IS	1	10
4	49.66	M	R	SS	1	10
5	53.25	F	L	SS/IS	1	6
6	56.33	M	L	SS/IS	2	8
7	59.35	M	L	SS	1	18
8	68.25	M	R	SS	1	3
9	49.66	M	R	SS/IS	1	4
10	53.92	M	R	SS/SSC	1	21
11	54.83	M	L	SS	1	36
12	51.08	M	R	SS/IS/SSC	3	Unknown
13	50.92	M	R	SS/IS	1	11
14	49.66	F	L	IS	1	120
15	55.50	M	L	SS/IS	1	4
16	52.83	M	L	SS/IS	2	8
17	50.83	M	R	SS/IS	2	3
18	59.58	F	L	SS	1	252
19	46.50	F	R	SS	1	16
20	52.33	F	R	IS	1	168
21	68.58	F	R	SS/IS	1	21
Mean	55.65				1.24	40
Total		13M, 8F	12R, 9L			

*SS = supraspinatus, IS = infraspinatus, and SSC = subscapularis.

pendent examiner (A.S.W. or E.S.P.). Each subject completed a comprehensive questionnaire that included items regarding current pain, functional level, employment, and sporting activity as well as the need for repeat surgery. Pain was reported as the average amount of daily pain experienced by the subject and was recorded as a numerical value on a visual analog scale from 0 to 10. Physical examination included measurement of passive and active range of motion of the shoulder with a goniometer. Measured shoulder motions included forward flexion, abduction, external rotation with the arm at the side, and internal rotation behind the back. The strength of shoulder elevation was measured with an Isobex dynamometer (Cursor, Bern, Switzerland) in 90° of scapular plane abduction. Three strength measurements were obtained for each shoulder, and the mean was calculated. The Constant score[19] was tabulated for each subject and was converted to the age-adjusted normative value as expressed by Katolik et al.[20]. Strength measurements and Constant scores were calculated in the postoperative setting only because these measures were not routinely performed in the preoperative setting.

Ultrasonography

Each subject underwent high-resolution shoulder ultrasonography at a minimum of one year following the revision rotator cuff repair. A minimum interval of one year following surgery was chosen, on the basis of previous clinical reports[2,3,7,21], as a reasonable time point to assess repair integrity. Sonographic examinations were performed by one of three radiologists with extensive experience in musculoskeletal ultrasonography. Ultrasonography has been validated at this institution as an accurate means of evaluating the rotator cuff in both the preoperative[22,23] and postoperative[24] settings. Ultrasonography is particularly advantageous for assessing tendon integrity following surgical repair as this modality is less vulnerable to postsurgical artifact than magnetic resonance imaging. All subjects underwent standardized shoulder examinations as previously reported[22]. Examinations were performed in real time with the use of a Siemens scanner (Malvern, Pennsylvania) and a variable high-frequency linear array transducer (5 to 10 MHz). Views included multiplanar images of the rotator cuff muscle and tendons, facilitated by positioning of

the shoulder. The maximum anteroposterior diameter of each tear was measured on transverse views (perpendicular to the long axis of the cuff) and was designated as the width of the tear. The maximum amount of retraction was measured on longitudinal views (parallel to the long axis of the cuff) and was designated as the length of the tear.

Surgical Technique

All operations were performed by the senior surgeon (K.Y.). Each procedure began with a diagnostic arthroscopy with the patient in the beach-chair position. In five patients, the biceps tendon demonstrated substantial degenerative pathological changes. Of these patients, three had a biceps tenotomy and two had an arthroscopic biceps tenodesis. In four other shoulders, the biceps tendon was absent. No patient was noted to have a full-thickness cartilage lesion of the articular surface of the humeral head or glenoid. Two patients were found to have a full-thickness tear of the upper subscapularis tendon. In one shoulder, the subscapularis was repaired arthroscopically with suture anchor fixation. In the other, the subscapularis repair was performed through a small deltopectoral open approach.

The subacromial space was then inspected and the edges of the recurrent rotator cuff defect were identified. Traction sutures were placed in the edge of the torn tendon. Residual suture material was removed when necessary. Releases of adhesions between the torn tendon or tendons and the capsule, acromion, and deltoid fascia were performed. After the release of adhesions, the torn tendon was reduced to the greater tuberosity to confirm adequate mobility. The greater tuberosity was either abraded or lightly decorticated to facilitate bleeding of the osseous surface. In eighteen of the twenty-one shoulders, the torn tendon or tendons could be completely reduced over the greater tuberosity following the releases, and a double-row rotator cuff repair was performed. In fifteen of these shoulders, two rows of metallic corkscrew anchors loaded with number-2 braided suture (Arthrex, Naples, Florida) were placed in the superior aspect of the greater tuberosity. The torn tendon was repaired with a combination of horizontal mattress stitches from the medial anchors and simple sutures that were placed medial to the horizontal mattress sutures from the lateral row of anchors. In the remaining three shoulders with double-row fixation, horizontal mattress fixation was performed with use of anchors that were placed in the medial aspect of the greater tuberosity. The lateral aspect of the repair was secured with PushLock anchors (Arthrex) positioned in the lateral aspect of the tuberosity. In three shoulders, a single-row repair was performed. In these shoulders, the torn tendon was reducible to the greater tuberosity but did not cover the entire native footprint. In all shoulders, the primary rotator cuff defect was repaired and a complete repair (coverage of the entire humeral head) was noted. The present study included no shoulders in which only a partial rotator cuff repair was possible (e.g., those that had infraspinatus repair but an irreparable supraspinatus defect). In all cases, changes consistent with previous subacromial decompression and acromioplasty were seen; however, adequate resection of the anterior acromial edge was noted. Smoothing of the undersurface of the acromion was performed when irregular bone edges were seen; however, in no shoulder was a formal revision acromioplasty performed.

Postoperative Rehabilitation

In all subjects, the rehabilitation protocol consisted of a delayed progression of the normal postoperative rehabilitation phases. All shoulders were immobilized with a sling and pillow for a period of six weeks. Patients were allowed to remove the sling periodically for self-care and for elbow, forearm, and wrist range of motion, but no motion was permitted at the shoulder. At six weeks, passive range of motion of the shoulder was initiated with the use of a continuous passive motion machine or through prescribed physical therapy. Active-assisted and active range of motion were delayed until twelve weeks following surgery. Strengthening exercises for the rotator cuff and shoulder were delayed until four months after surgery. Return to work was individualized on the basis of the specific work demands of each patient. Employment requiring manual labor was typically delayed four to six months, depending on individual progression with rehabilitation.

Statistical Analysis

Postoperative clinical outcome data were compared with preoperative baseline data with use of pairwise comparisons. In order to determine the effect of repair integrity on shoulder function, clinical outcome data were compared between the patients with an intact repair and those with a recurrent rotator cuff defect with use of unpaired comparisons. A normality test of each variable with use of the Kolmogorov-Smirnov test showed that all continuous variables had normal distribution ($p > 0.05$), and thus all comparisons of these variables were made with use of parametric statistical tests (i.e., the paired t test or unpaired t test). Internal rotation behind the back was an ordinal variable, and therefore comparisons of this variable were made with use of nonparametric tests (i.e., the Wilcoxon signed rank test or Mann-Whitney U test). Data are shown as the mean and the standard deviation. For nonsignificant findings, p values and 95% confidence intervals are provided.

Source of Funding

One or more of the authors received outside funding or grants in excess of $10,000 from InScope. Neither they nor a family member received payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. The funds were used to pay for shoulder ultrasound examinations.

Results

There were no perioperative surgical complications. Twenty of the twenty-one subjects had complete postoperative clinical follow-up at a minimum of twenty-four months after surgery. The average duration of follow-up was thirty-three months (range, twenty-four to fifty months). One patient who was included for the purposes of studying tendon integrity was

TABLE II Postoperative Functional Scores

Outcome*	Value† (N = 20)
Visual analog scale pain score *(points)*	2.70 ± 2.62
Range of motion	
Forward elevation *(deg)*	146.7 ± 29.7
External rotation *(deg)*	53.7 ± 21.1
Internal rotation‡	2.40 ± 1.5
SST score *(points)*	8.9 ± 3.2
ASES score *(points)*	
Function	37.3 ± 12.9
Total	74 ± 24.9
Constant score *(points)*	
Unadjusted	67.7 ± 17.3
Age-adjusted	76.0 ± 20.2
Strength *(kg)*	3.68 ± 2.8

*SST = Simple Shoulder Test, and ASES = American Shoulder and Elbow Surgeons. †The data are given as the mean and the standard deviation. ‡Internal rotation range of motion was assigned five different values (1 = midthoracic, 2 = thoracolumbar junction, 3 = midlumbar, 4 = posterior belt line, and 5 = lateral iliac crest).

excluded from the clinical analysis because the duration of postoperative follow-up was less than twenty-four months and the patient was unable to return for repeat examination. This patient had an intact repair and was satisfied with the outcome of the procedure. At the time of follow-up, no patient had undergone a repeat shoulder operation and two subjects were receiving medical treatment for persistent shoulder pain.

Functional Results

Each subject was questioned about his or her ability to perform regular activities of daily living and work-related duties. Fifteen of the twenty subjects stated that they were able either to work normally or to perform activities of daily living without significant restrictions. Four of these subjects were retired, and eleven were employed at the time of follow-up. Five of the subjects stated they were disabled or were unable to perform normal activities because of persistent shoulder symptoms. Eleven subjects were able to perform their usual recreational or sporting activities, six stated they did not engage in recreational sports, and three stated that they were unable to perform these activities.

Complete postoperative functional data are provided in Table II. Comparisons were made between preoperative and postoperative functional outcomes for nineteen of the twenty-one subjects with complete data (Table III). One subject was excluded from this analysis because of incomplete preoperative data, and one was excluded because of missing clinical data at a minimum of two years after surgery. Significant improvements following revision rotator cuff repair were noted in terms of the visual analog scale pain score ($p < 0.05$), the SST score ($p < 0.05$), the ASES function score ($p < 0.05$), the total ASES score ($p < 0.05$), active forward elevation ($p < 0.05$), and active external rotation ($p < 0.05$). The mean final postoperative Constant score was 67.7 ± 17.3, the age-adjusted Constant score was 76.0 ± 20.2, and strength of scapular plane elevation was 3.68 ± 2.8 kg (Table II).

Final functional results were compared between patients who had an intact biceps tendon (n = 12) and those who had an absent tendon at the time of surgery or who underwent a biceps tenotomy or tenodesis (n = 8); one subject in the latter group was excluded because of incomplete postoperative clinical data. With the small numbers studied, the outcomes were similar, regardless of the status of the biceps tendon, in terms of the mean visual analog scale pain score (2.7 [95% confidence interval, 1.2 to 4.2] compared with 2.6 [95% confidence interval, 0.0 to 5.8]), the ASES total score (74.9 [95% confidence interval, 61.3 to 88.5] compared with 71.4 [95% confidence interval, 35.5 to 100]), the ASES function score (38.2 [95% confidence interval, 31.8 to 44.6] compared

TABLE III Comparison of Preoperative and Postoperative Functional Data*

Outcome†	Preoperative‡	Postoperative‡	P Value
Visual analog scale pain score *(points)*	6.1 ± 1.8	2.8 ± 2.6	<0.05§
SST score *(points)*	5.3 ± 3.2	8.8 ± 3.3	<0.05§
ASES *(points)*			
Function	20.4 ± 11.7	37.0 ± 13.1	<0.05§
Total	40.1 ± 16.0	73.0 ± 25.2	<0.05§
Range of motion *(deg)*			
Forward elevation	130.3 ± 37.3	146.7 ± 30.5	<0.05§
External rotation	44.7 ± 14.9	55.2 ± 21.7	<0.05§

*N = 19. †SST = Simple Shoulder Test, and ASES = American Shoulder and Elbow Surgeons. ‡The data are given as the mean and the standard deviation. §Significant.

TABLE IV Cuff Repair Integrity*

	Intact Repair	Recurrent Tear	P Value
Total *(no. of patients)*	10 (48%)	11 (52%)	—
Age† *(yr)*	51.9 (49.1 to 54.7)	59.1 (53.8 to 64.4)	<0.05†
Type of repair			0.05†§
Single tendon (n = 10)#	7 (70%)	3 (30%)	
Multiple tendon (n = 11)#	3 (27%)	8 (73%)	
Total number of operations†	2.30 (1.82 to 2.78)	2.18 (1.91 to 2.45)	0.64

*N = 21. †The values are expressed as the mean and the 95% confidence interval. †Significant. §Chi-square test. #The n value refers to the number of posterior rotator cuff tendons (supraspinatus, infraspinatus) repaired at the time of surgery.

with 34.4 [95% confidence interval, 12.9 to 50.0]), the SST score (9.1 [95% confidence interval, 7.5 to 10.7] compared with 8.2 [95% confidence interval, 2.7 to 12]), the Constant score (68.9 [95% confidence interval, 61.6 to 76.1] compared with 64.0 [95% confidence interval, 28.1 to 99.1]), and elevation strength (3.5 kg [95% confidence interval, 2.2 to 4.6] compared with 4.3 kg [95% confidence interval, 0.0 to 9.8]) for shoulders with an intact biceps tendon and those with an absent or treated biceps tendon, respectively.

Rotator Cuff Tendon Integrity

All twenty-one subjects underwent ultrasonography of the shoulder to evaluate rotator cuff tendon integrity at a minimum of one year following revision arthroscopic repair. The mean time from surgery to ultrasound examination was twenty-five months (range, fifteen to thirty-nine months). Ten (48%) of the twenty-one shoulders were noted to have an intact repair on follow-up ultrasonography (Table IV). The average age of the ten patients with an intact repair was 51.9 years, compared with 59.1 years for the eleven patients with a recurrent tear ($p < 0.05$).

In the group of ten patients with a single-tendon tear of the posterior portion of the rotator cuff (the supraspinatus or infraspinatus tendon), seven repairs (70%) were intact. In the group of eleven patients with tears of the supraspinatus and infraspinatus tendons, three repairs (27%) remained intact. The percentage of shoulders with an intact repair was significantly greater in the group of patients with a single-tendon tear than in the group of patients with tears involving both the supraspinatus and infraspinatus tendons ($p = 0.05$). In the two shoulders undergoing repair of the subscapularis tendon, the entire repair was noted to be intact at the time of follow-up.

TABLE V Comparison of Postoperative Changes in Functional Outcomes Between Intact and Retorn Repairs*†

Outcome†	Intact Repair	Recurrent Tear
Visual analog scale pain score *(points)*	–2.9 (–4.6 to –1.1)	–3.5 (–6.1 to –1.0)
Range of motion *(deg)*		
Forward elevation	8.5 (–1.7 to 18.7)	22.3 (0.60 to 44.0)
External rotation	14.8 (1.7 to 27.9)	7.3 (–6.3 to 20.9)
SST score *(points)*	3.0 (1.5 to 4.5)	3.9 (1.9 to 5.9)
ASES *(points)*		
Function	15.8 (10.8 to 20.8)	17.2 (11.8 to 22.6)
Total	29.5 (20.7 to 38.3)	35.4 (19.1 to 51.7)
Constant score *(points)*		
Unadjusted§#	76.2 (67.7 to 84.7)	60.7 (48.1 to 73.3)
Age-adjusted§	84.1 (73.3 to 94.9)	69.3 (54.1 to 84.5)
Scapular elevation strength§# *(kg)*	5.0 (2.6 to 7.4)	2.6 (1.2 to 4.0)

*N = 19, unless otherwise specified. †The values are given as the mean and the 95% confidence interval. †SST = Simple Shoulder Test, and ASES = American Shoulder and Elbow Surgeons. §Final score (n = 20). No preoperative comparison data were available. #The difference between the shoulders with an intact repair and those with a recurrent tear was significant ($p < 0.05$).

Functional Results Compared with Tendon Repair Integrity

The functional results for the nineteen subjects with complete preoperative and postoperative clinical data were compared between shoulders with an intact repair and those with a recurrent defect (Table V). With the small numbers studied, both groups had similar improvements in terms of the visual analog scale pain score, forward elevation and external rotation range of motion, the SST score, the ASES function score, and the total ASES score. While preliminary statistical analysis showed no significant difference between groups in terms of the above-stated clinical outcomes, post hoc power analysis demonstrated this study to have insufficient power to detect a significant difference for the total ASES (power = 0.37) and SST scores (power = 0.68). This power analysis was performed with use of recently proposed minimal clinically important difference (MCID) values for the ASES and SST scores for patients managed for symptomatic rotator cuff disease[25].

Shoulders with an intact repair had significantly greater final scapular plane elevation strength ($p < 0.05$) than those with a recurrent rotator cuff defect. Likewise, those with an intact repair had a significantly greater final Constant score ($p < 0.05$) in comparison with those with a recurrent cuff defect (Table V).

Discussion

Very little information is available regarding the clinical outcome of arthroscopic revision rotator cuff repairs. To our knowledge, no studies have investigated postoperative tendon integrity in this population. Previous studies specific to revision rotator cuff repair have primarily pertained to open repairs. Those studies have demonstrated reliable pain relief but less consistent improvement in shoulder function[12-14]. Djurasovic et al., in the largest series of revision rotator cuff repairs reported to date, noted reliable pain relief following open repair[12]. According to a modified Neer score, 69% of the eighty subjects had a satisfactory clinical result. The authors identified several prognostic factors that impacted the clinical results, including an intact deltoid origin, good-quality rotator cuff tissue, presurgical active elevation of at least 90°, and no more than one previous attempted rotator cuff repair. Lo and Burkhart reported the clinical results of arthroscopic revision rotator cuff repair in a study of fourteen patients, twelve of whom had large or massive tears[15]. The authors reported pain relief and improvement in function following surgery. Nine patients had a good or excellent outcome according to the modified University of California at Los Angeles scale, and improvements were noted in terms of pain and shoulder range of motion. Interestingly, the clinical failures in those previous studies were largely attributed to preexisting deltoid injury or poor-quality rotator cuff tissue rather than to suspicion of a recurrent rotator cuff tear.

The results of the present study suggest that revision arthroscopic rotator cuff repair can provide substantial improvement in terms of both shoulder pain and function in selected cases. Direct comparisons of outcomes between the present study and previous studies are difficult given differences in patient population, surgical technique, and, most importantly, measured outcome scales. A potential explanation for the comparatively favorable results of the present study can be provided in part by the selected patient population. Only 52% of the shoulders in this series had large or massive (two-tendon) posterior rotator cuff tears; this rate is much lower than previous studies of revision rotator cuff repair[12,13]. The subjects in the present series were also younger than those in previous studies. Furthermore, shoulders with severely deficient rotator cuff tissue that was either irreparable or only partially reparable were excluded from the present study. In addition, we excluded patients with deltoid injury or detachment sufficient to warrant surgical repair. Deltoid injury and excessive resection of the acromion have previously been cited as a major cause of clinical failure following revision rotator cuff repair[12-14,16].

Overall, 48% of the surgical repairs were intact at a minimum of one year after revision cuff repair. Given the fact that these shoulders already had had a failure of at least one previous attempted rotator cuff repair, it seems intuitive that the rate of postoperative tendon integrity in this series would be less than that following a primary repair. Often, the rotator cuff tissue in this setting is more degenerative because of the increased chronicity of the injury as well as iatrogenic tendon damage resulting from previous surgery. Although this rate of repair integrity is lower than that in some contemporary studies of primary arthroscopic rotator cuff repair[7-10,26-31], the postoperative rate of repair integrity in the present series is surprisingly comparable with the rates of primary repair seen at our institution, with Tashjian et al. noting an intact surgical repair in 67% of single-tendon repairs and 36% of multiple-tendon repairs following primary double-row rotator cuff repair[32].

The two factors that correlated with repair integrity included the age of the subject and the number of torn tendons. These factors also have consistently shown a strong association with tendon healing in studies of primary cuff repair. In the present study, 70% of the single-tendon posterior rotator cuff repairs were intact at the time of follow-up, which is comparable with the rates of previous studies of primary repairs involving tears of a similar size[1,2,4]. In comparison with primary repairs, there are several factors to consider that may explain our rate of repair integrity. First, almost half of the tears in this study involved only one posterior rotator cuff tendon. It is well recognized that rotator cuff tear size has a strong influence on the rate of tendon healing following surgical repair[1,6,7,10,27,29-31]. In addition, the rehabilitation protocol that was implemented in the present study was slower than usual and involved a six-week period of shoulder immobilization followed by a slow progression through the normal rehabilitation phases. Another factor to consider that is related to tendon integrity is the relatively young mean age of the patients in the study. Numerous previous studies have highlighted the importance of age with respect to healing capacity following rotator cuff repair[2,4,6,10,29,31].

The effect of repair integrity on clinical outcome following rotator cuff repair is controversial. Many studies have

shown improvement in shoulder function and pain relief in the absence of tendon healing, with similar outcomes being noted between shoulders with an intact repair and those with a recurrent tear[5,30,31,33]. However, numerous studies also have shown better shoulder function and strength in shoulders with an intact surgical repair[1,2,4-10,27,29,33]. In the present study, similar improvements in most clinical outcome measures were seen in shoulders with an intact repair and those with a recurrent defect. However, given the lack of power of the present study to determine that no significant difference exists between groups, conclusive statements regarding the effect of repair integrity on these outcomes cannot be made. Postoperatively, however, tendon integrity did have a positive effect on shoulder abduction strength and the Constant score. We are uncertain as to why some patients with recurrent tears showed some clinical improvement in comparison with the outcomes noted after their previous surgery. It is possible that the postoperative rehabilitation program and/or the treatment of associated biceps abnormalities benefited some subjects. Recurrent tears may have been tolerated in this series because, even in the shoulders with the largest recurrent tears, the teres minor and subscapularis tendons were spared and there were no cases of deltoid insufficiency.

The present study had several limitations that must be recognized. Our subjects represent a selected cohort and were selected for surgery on the basis of age, activity level, and the surgeons' impression of tear reparability. The results of the present study, therefore, are not applicable to all cases of failed rotator cuff repair surgery. Despite this limitation, we believe that the data presented here are novel and clinically relevant. It is important to recognize that the results of this study are short-term findings and that the durability of these results over time warrants further study. Given the specific and relatively uncommon nature of the study cohort, the number of subjects in this series was small and precluded subgroup analysis of the effect of various surgical variables on outcomes, such as the number of previous operations, the repair technique, and involvement of the subscapularis tendon. In addition, postoperative tendon integrity was assessed at a minimum of one year (mean, twenty-five months) whereas the clinical assessment was performed at a minimum of two years following surgery. This time point for the assessment of cuff integrity was chosen on the basis of a precedent set by previous studies[2,3,7,21]. However, it should be noted that the exact timeline for rotator cuff tendon healing following surgery in humans is unknown. The small number of subjects in the present study resulted in insufficient power to determine the influence of rotator cuff healing on most functional outcomes. The present study was retrospective and included a heterogeneous patient population. A comprehensive preoperative assessment of the subjects, including a strength assessment, was not possible. In addition, preoperative advanced imaging studies were not controlled. Precise measurement of the size of the tear was not performed preoperatively, which limits an evaluation of the effect of tear size on the surgical results. Staging of rotator cuff muscle atrophy and fatty changes was not routinely performed. This information may be helpful for identifying host factors that may influence tendon healing and clinical outcome. The quality of the rotator cuff tissue at the time of surgery was not graded in a prospective fashion, which further limited analysis regarding the effects of degenerative tissue changes on outcomes. Additional studies are needed to determine the effect of these factors on clinical outcomes and repair integrity in this population.

The strengths of the present study include the use of standardized and validated outcome tools for the assessment of shoulder function and tendon repair integrity. Independent examiners were used to evaluate both clinical outcome and tendon integrity. The study group was novel and represented an important cohort of patients to whom minimal research has been directed. Last, the present study evaluated the outcomes of contemporary arthroscopic rotator cuff repair techniques.

In conclusion, revision arthroscopic rotator cuff repair results in reliable pain relief and improvement in shoulder function in properly selected cases. Almost one-half of the revision tendon repairs were structurally intact at a minimum of one year following surgery. Patient age and the number of torn posterior rotator cuff tendons were significantly related to postoperative tendon integrity. The improvements in terms of the pain score and function were similar between shoulders with an intact repair and those with a recurrent tear, but the data were insufficiently powered to conclude that there was no difference between the groups. However, shoulders with an intact repair did have better Constant scores and shoulder strength than those with a recurrent tear. ■

Jay D. Keener, MD
Anthony S. Wei, MD
H. Mike Kim, MD
Edward S. Paxton, MD
Sharlene A. Teefey, MD
Leesa M. Galatz, MD
Ken Yamaguchi, MD
Shoulder and Elbow Service, Department of Orthopaedic Surgery (J.D.K., A.S.W., H.M.K., E.S.P., L.M.G., K.Y.) and Department of Radiology (S.A.T.), Washington University,
660 South Euclid Avenue, St. Louis, MO 63110

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