

Outcomes After Arthroscopic Revision Rotator Cuff Repair

Dana P. Piasecki, MD, Nikhil N. Verma, MD, Shane J. Nho,* MD, MS,
Sanjeev Bhatia, Nicole Boniquit, Brian J. Cole, MD, MBA,
Gregory P. Nicholson, MD, and Anthony A. Romeo, MD
*From the Section of Shoulder & Elbow Surgery, Division of Sports Medicine,
Department of Orthopedic Surgery, Rush University Medical Center,
Rush Medical College of Rush University, Chicago, Illinois*

Background: Although a number of reports have documented outcomes after open revision rotator cuff repair, there are few studies reporting results after arthroscopic revision.

Hypothesis: Arthroscopic repair of failed rotator cuff results in significant improvement in shoulder functional outcome and pain relief.

Study Design: Case series; Level of evidence, 4.

Methods: Multiple variables including demographic data, the number of prior ipsilateral shoulder surgeries, and tear size were recorded from chart review. An independent examiner then measured shoulder strength, range of motion, and shoulder functional outcome scores including American Shoulder and Elbow Surgeons score, Simple Shoulder Test, and visual analog pain scale. Paired *t* tests were performed to compare preoperative and postoperative measures. Additionally, contingency table analysis was performed to identify prognostic factors for failure of repair requiring further surgery and American Shoulder and Elbow Surgeons score less than 50.

Results: Fifty-four patients (88.5%) were available for follow-up evaluation with a mean age of 54.9 ± 10.1 years (range, 22.7-82.5 years) and a mean follow-up of 31.1 ± 11.9 months. American Shoulder and Elbow Surgeons scores improved from 43.8 ± 5.7 (mean \pm 95% confidence interval) before revision to 68.1 ± 7.2 at final follow-up ($P = .0039$). The Simple Shoulder Test improved significantly from 3.56 ± 0.8 before surgery to 7.5 ± 1.1 at most recent follow-up ($P < .0001$). Visual analog pain scale scores improved from 5.17 ± 0.8 to 2.75 ± 0.8 ($P = .03$), and forward elevation increased from $121.0^\circ \pm 12.3^\circ$ to $136^\circ \pm 11.8^\circ$ postoperatively ($P = .025$). Greater than 1 prior shoulder surgery was associated with cases that required additional surgery ($P = .031$). Female gender ($P = .007$) and preoperative abduction less than 90° ($P = .009$) were associated with American Shoulder and Elbow Surgeons scores less than 50.

Conclusion: Arthroscopic revision rotator cuff repair may be a reasonable treatment option even after prior open repairs and provides both improved pain relief and shoulder function. Nonetheless, results are not completely optimal. Female patients and those who have undergone more than 1 ipsilateral shoulder surgery are at increased risk for poorer results.

Keywords: revision; arthroscopic rotator cuff repair; shoulder; failure

With advances in arthroscopic surgery, excellent results have been reported after primary arthroscopic repair of rotator cuff tears,^{9,16,29} approaching or even surpassing those of open repair.⁹ Outcomes after revision surgery, however, have received much less attention, with existing reports almost exclusively describing the results after open revision techniques. Among this small group of studies, outcomes are generally worse than after primary repair,^{8,20,21,24} with the majority of patients reporting fairly

predictable pain relief but inconsistent and often minimal functional gains.^{1,6,7,17}

Despite the theoretical benefits of arthroscopically approaching revision cases, including improved visualization and classification of tear configuration and size, appreciation of previously unrecognized joint lesions, minimization of deltoid disruption, and decreased risk of postoperative stiffness,¹³ we are aware of only 2 reports documenting the results of arthroscopic revision rotator cuff surgery. Lo and Burkhart¹³ reported a single-surgeon experience with 14 consecutive cases revised arthroscopically and evaluated at a minimum of 1 year postoperatively

(mean, 23 months). The majority of these tears (11 of 14) were classified as massive, 4 of which could only be repaired partially. After surgery, these authors reported significant improvements in active motion and University of California at Los Angeles scores, with 64% of outcomes classified as good to excellent, a finding that is comparable to those reported for open techniques. More recently, Trantalis et al²⁶ reported a single-surgeon case series of 5 patients who demonstrated medial row failure after arthroscopic double-row rotator cuff repair and subsequently underwent arthroscopic revision rotator cuff repair. Although validated shoulder outcome scores were not employed, the authors noted that 4 of 5 patients had some improvement in symptoms at a mean follow-up of 26.4 months.

The purpose of our study was to report functional outcomes after arthroscopic revision rotator cuff repair and to identify prognostic factors that may predict attributes associated with failure of arthroscopic revision rotator cuff repair.

MATERIALS AND METHODS

Between January 2004 and December 2006, all patients undergoing arthroscopic revision rotator cuff repair of full-thickness cuff tears, with a minimum 1-year follow-up, were reviewed. All patients underwent the informed consent process and the study was approved by the Institutional Review Board. Three fellowship-trained orthopaedic surgeons in either shoulder surgery or sports medicine performed all the surgeries in a high-volume clinical practice. The inclusion criteria were patients who had failed prior rotator cuff repair, by either open or arthroscopic means, and underwent revision arthroscopic repair of full-thickness rotator cuff tears for relief of shoulder pain and improvement in function. Cuff tears consisting of a full-thickness tear of 1 tendon and a partial-thickness tear of another tendon were included in the analysis. Exclusionary criteria included patients with only partial-thickness or irreparable tears, or any tears that were converted to an open procedure.

Patients who met the study criteria completed a preoperative questionnaire, which included demographic and social history, detailed medical history, and surgical history. Demographic information (age, gender, hand dominance, side of rotator cuff tear), number of prior shoulder surgeries on the ipsilateral extremity, occupation, history of rheumatoid arthritis, history of diabetes, tobacco use, and alcohol use were all recorded. Because a large proportion of our cohort included workers' compensation patients, the *Canadian Classification and Dictionary of Occupations*²

was used to classify preoperative work level as sedentary, light work, medium work, heavy work, or very heavy work.

Intraoperative data included both diagnostic information as well as concomitant procedures. Rotator cuff tears were classified arthroscopically based on size (length), thickness (full or partial), and tendons involved. Tears were assessed after bursectomy of the subacromial space but before rotator cuff debridement. All surgeons measured tear size in the sagittal plane at the involved tendon's insertion into its respective anatomic footprint, and the DeOrto and Cofield⁶ classification was recorded (small, medium, large, or massive). For massive, contracted, immobile tears, we began by repairing the subscapularis tendon to its anatomic position on the lesser tuberosity and the infraspinatus tendon to its anatomic position at the leading edge at the upper border of the bare area. By first restoring the subscapularis and infraspinatus back to their anatomic positions, we believe that using these principles provided a more anatomic rotator cuff repair than beginning the repair with margin convergence. Once the subscapularis and infraspinatus were reduced, then every attempt was made to try to determine a fixation construct for the supraspinatus tendon without margin convergence. The decision to use single-row or double-row fixation largely depended on the tissue quality and tension on the repair. If the tissue quality was appropriate, double-row fixation with a suture-bridge construct was performed. If the tissue quality was compromised, a single-row fixation was performed due to concerns of overtensioning the repair and failure at the tendon-suture interface.

Additional diagnoses were also recorded, including osteophyte of the undersurface of the acromion (yes or no), biceps lesion (yes or no), acromioclavicular joint osteoarthritis (yes or no), and glenohumeral osteoarthritis (yes or no). The number of anchors and row configuration (single or double) were also recorded at the time of surgery.

Postoperatively, patients took part in a standardized rehabilitation protocol: 6 weeks of shoulder immobilization and passive range of motion (ROM), then 6 weeks of active ROM, followed by 12 weeks of rotator cuff strengthening and conditioning. Due to logistical issues, we did not objectively measure cuff integrity using MRI or arthrography unless clinically warranted. However, compliance with rehabilitation, time to maximum medical improvement, complications, and repeat shoulder surgeries were recorded in the chart review. All compensable patients underwent functional capacity evaluation by an independent examiner trained in workers' compensation rehabilitation to determine the patient's ability to return to work at a preoperative level (yes or no).

At final follow-up, patients were examined by an independent observer, an orthopaedic sports medicine research

*Address correspondence to Shane J. Nho, MD, MS, Rush University Medical Center, 1725 West Harrison Street, Suite 1063, Chicago, IL 60612 (e-mail: snho@hotmail.com).

Presented at the 35th annual meeting of the AOSSM, Keystone, Colorado, July 2009.

One or more of the authors has declared a potential conflict of interest: Dr Romeo has received research or institutional support, miscellaneous funding, royalties, and stock options and is a consultant or employee of Arthrex; Dr Verma has received research or institutional support and is a consultant or employee of Smith & Nephew; Dr Cole has received research or institutional support and royalties and is a consultant or employee of Arthrex, has received research or institutional support and miscellaneous funding and is a consultant or employee of Genzyme, and has received research or institutional support and is a consultant or employee of Zimmer; Dr Nicholson has received research or institutional support from EBI, has received royalties and stock options and is a consultant or employee of Zimmer, and has received royalties from Innomed.

fellow removed from clinical and surgical decision making. The patients completed validated, clinical outcome instruments including Constant-Murley score,⁵ Single Assessment Numeric Evaluation (SANE),²⁸ American Shoulder and Elbow Surgeons (ASES) score,¹⁵ Simple Shoulder Test (SST),¹² and visual analog pain scale (VAS).^{19,22,25} Forward elevation in the scapular plane and external rotation with the arm at the side were measured on both extremities with a goniometer. Rotator cuff strength was assessed in both extremities using a manual muscle dynamometer (Lafayette Manual Muscle Test System, Lafayette Instrument Company, Lafayette, Indiana) in forward elevation and external rotation with the arm at the side. Postoperative shoulder strength was quantified further as a ratio of the force exerted by the affected shoulder relative to the force exerted by the unaffected shoulder. Arthroscopic revision rotator cuff repairs were considered failures if patients required additional surgery during the follow-up period or if patients had an ASES score less than 50 points.

Descriptive analysis consisted of frequencies and percentages for discrete data and means and standard deviations for continuous data. Paired *t* tests were performed to compare preoperative and postoperative measures including ROM, VAS, SST, and ASES scores. Contingency table analysis included the Fisher exact test to conduct univariate analyses of the prognostic factors for return to work at preoperative levels, time to maximum medical improvement, failure of repair requiring revision, and ASES scores less than 50 (GraphPad software, GraphPad Software, Inc, La Jolla, California). *P* values of less than .05 were considered to be statistically significant.

RESULTS

Sixty-five patients who underwent arthroscopic revision of full-thickness rotator cuff tears met the study inclusionary criteria, but 1 was excluded because the tear was deemed irreparable and 3 were excluded for conversion to an open procedure. Of the 61 patients meeting the study criteria, 54 patients (88.5%) were available for follow-up. The study group consisted of 54 patients with a mean age of 54.9 ± 10.1 years (range, 22.7-82.5 years) and a mean follow-up of 31.1 ± 11.9 months (range, 12.4-78.5 months). With the exception of 7 patients, all study participants had greater than 2 years of follow-up. Of these 54, 36 arthroscopic revision rotator cuff repair procedures were performed by Surgeon A, 11 revisions were performed by Surgeon B, and 7 were performed by Surgeon C.

Demographic information for the cohort is provided in Table 1. Right shoulder involvement occurred in 34 patients (63.0%) compared with the left shoulder in 20 (37.0%). The dominant extremity was involved in 32 cases (59.3%), compared with 22 nondominant (40.7%). Thirty-nine of the 53 patients (72%) were workers' compensation patients with preoperative work levels categorized as follows: 4 sedentary, 3 light work, 8 medium work, 18 heavy work, 6 very heavy work. A total of 88 prior procedures were reported on the ipsilateral shoulder (mean, 1.69 \pm

1.03; range, 1-5 per patient). Thirty-one patients (57.4%) had had only 1 prior rotator cuff repair, and 23 (42.6%) had undergone multiple prior operations. With regard to prior procedures, 36 patients (66.6%) had previously undergone an acromioplasty procedure, 10 patients (18.5%) had previously had a biceps tenotomy or tenodesis, and 12 patients (22.2%) had previously had a distal clavicle resection. Of the 88 prior rotator cuff repairs, 56 (64%) had been performed through an open approach and 32 (36%) had been done arthroscopically.

At the revision procedure, the mean rotator cuff tear size was 2.9 ± 1.6 cm (range, 1.0-6.0 cm). According to the DeOrto and Cofield classification,⁶ there were 18 (33.3%) small, 15 (27.8%) medium, 17 (31.5%) large, and 4 (7.4%) massive tears. There were 33 (61.1%) single-tendon tears and 21 (38.9%) multiple-tendon tears. Any additional injuries and procedures were recorded by the surgeon at the time of the arthroscopic revision rotator cuff repair; these included acromioplasty in 74.1% ($n = 40$), biceps tenodesis or tenotomy in 38.9% ($n = 21$), distal clavicle resection in 22.2% ($n = 12$), and chondroplasty for glenohumeral osteoarthritis in 9.3% ($n = 5$). Thirty-three tears (61.1%) were treated with single-row configuration, while 21 tears (38.9%) were revised with a double-row construct, using a mean of 2.98 ± 1.11 (range, 1-6) anchors per case. Double-row constructs were employed by Surgeon A in 12 of 36 cases (33.3%), by Surgeon B in 9 of 11 cases (81.8%), and by Surgeon C in 0 of 7 cases (0.0%).

Clinical outcomes along with 95% confidence intervals are summarized in Tables 2 and 3 (mean \pm 95% confidence interval). The ASES scores improved from 43.8 ± 5.7 before revision to 68.1 ± 7.2 at final follow-up ($P = .0039$). The SST scores improved significantly from 3.56 ± 0.8 before surgery to 7.5 ± 1.1 at most recent follow-up ($P < .0001$). The VAS scores improved from 5.17 ± 0.8 to 2.75 ± 0.8 ($P = .03$), and forward elevation increased from $121.0^\circ \pm 12.3^\circ$ to $136^\circ \pm 11.8^\circ$ postoperatively ($P = .025$). The calculated strength ratio relative to the contralateral shoulder was 0.75 ± 0.17 in forward elevation and 0.77 ± 0.16 in external rotation.

Six patients (11.1%) had failure of their arthroscopic revision rotator cuff repair, requiring additional surgery. Two patients, 70 and 63 years of age, had persistent pain and were determined to have a persistent, symptomatic rotator cuff tear with coexistent glenohumeral arthritis, subsequently undergoing a reverse shoulder arthroplasty at 6 months and 30 months, respectively, after arthroscopic revision rotator cuff repair. One patient, 41 years of age, had persistent pain and weakness and underwent open rerevision rotator cuff repair with Restore Orthobiologic patch (DePuy Orthopaedics, Warsaw, Indiana) augmentation at 8 months after revision, requiring an additional open revision attempt and extensive debridement at 31 months after arthroscopic revision rotator cuff repair. Another patient underwent arthroscopic debridement and removal of loose bodies at 15 months after the arthroscopic revision rotator cuff repair. One patient was noted to have wound drainage 1 week after surgery that necessitated an open irrigation, debridement, excision of sinus tract, and primary wound closure. The last patient, 70 years of age,

TABLE 1
Demographic Characteristics of Arthroscopic Revision Rotator Cuff Repair Cohort (N = 54)

Demographic Category	Characteristic
Age at surgery	Mean 54.9 ± 10.1 years (range, 22.7-82.5 years)
Gender	Male (75.9%) Female (24.1%)
Dominant-side involvement	Yes (59.3%) No (40.7%)
Comorbidities	Diabetes mellitus (11.3%) Rheumatoid arthritis (5.6%)
Social history	Current/recent tobacco user (40.7%) Alcohol intake >6 drinks/week (9.3%)
Medications before surgery	Nonsteroidal anti-inflammatory drugs (50.0%) Corticosteroids (1.8%) Narcotic pain medication (11.1%)
Prior shoulder surgeries	Total number of prior procedures in cohort: 88 Mean number of prior surgeries per patient: 1.69 ± 1.03 (range, 1-5) Prior surgeries done through open approach: 64% Prior surgeries done arthroscopically: 36%
Preoperative imaging	Acromioclavicular joint arthrosis visible on radiograph: 31.5% Glenohumeral arthritis visible on radiograph: 18.5% Proximal humeral head migration on radiograph: 18.5% Cuff tear evident on MRI: 87.0% Fatty infiltration seen on MRI: 9.3%
Cuff tear characteristics	Mean tear size 2.9 ± 1.6 cm (range, 1.0-6.0 cm) Category ^a : small (33.3%), medium (27.8%), large (31.5%), massive (7.4%) Tendons torn: supraspinatus (98.1%), infraspinatus (29.6%), subscapularis (16.7%)
Operative technique	Single-row anchor configuration: 61.1% Double-row anchor configuration: 38.9% Margin convergence: 48.1% Mean number of anchors used 2.98 ± 1.11 (range, 1-6)
Concomitant procedures	Acromioplasty: 74.1% Biceps tenotomy or tenodesis: 38.9% Distal clavicle resection: 22.2% Chondroplasty for glenohumeral osteoarthritis: 9.3%

^aTear size groupings based on the DeOrto and Cofield classification.⁶

TABLE 2
Comparison of Preoperative and Postoperative Outcomes (Means ± 95% Confidence Interval)^a

Outcome	Preoperative	Postoperative	P Value
ASES score (0-100)	43.8 ± 5.7	68.1 ± 7.2	.0039
SST score (0-12)	3.56 ± 0.8	7.5 ± 1.1	<.0001
Visual analog pain scale (0-10)	5.17 ± 0.8	2.75 ± 0.8	.0300
Forward elevation ROM (deg)	121.0 ± 12.3	136 ± 11.8	.0250
External rotation ROM (deg)	45.5 ± 5.5	51.7 ± 5.4	.1310

^aASES, American Shoulder and Elbow Surgeons; SST, Simple Shoulder Test; ROM, range of motion.

had a postoperative infection that required arthroscopic irrigation and debridement 6 weeks after arthroscopic revision rotator cuff repair and underwent a repeat arthroscopic rotator cuff repair 4 months after the initial arthroscopic revision rotator cuff repair.

Of the 6 patients who had failure of their revision arthroscopic revision rotator cuff repair, 5 had undergone

TABLE 3
Postoperative Strength Ratios, Constant Scores, and SANE Scores (Mean ± 95% Confidence Interval)^a

Clinical Outcome	Postoperative Mean
Forward flexion strength ratio	0.75 ± 0.17
External rotation at side strength ratio	0.77 ± 0.16
SANE score (0-100)	68.1 ± 8.3
Constant-Murley score (0-100)	60.4 ± 6.7

^aStrength ratio is defined as operative shoulder strength divided by nonoperative shoulder strength. SANE, Single Assessment Numeric Evaluation.

at least 2 prior ipsilateral shoulder operations. A history of greater than 1 prior ipsilateral shoulder operation was associated with a higher failure rate as defined by additional surgical procedures ($P = .031$); moreover, the odds ratio for failures after greater than 1 prior ipsilateral shoulder operation was 8.33 (95% confidence interval, 0.9-77.1). Tear size was not predictive of postoperative failure ($P = .1$). Female gender ($P = .007$) and preoperative active abduction less than 90° ($P = .009$) were factors that demonstrated a significant association with an ASES score less

TABLE 4
Univariate Analysis to Determine Prognostic Factors Associated With Failure of Arthroscopic Revision Rotator Cuff Repair

Potential Factor	Additional Surgery (P Value)	ASES Score <50 (P Value)
Age	1.000	.200
Gender	1.000	.007
Dominant extremity	1.000	.700
Rheumatoid arthritis	.216	1.000
Diabetes	1.000	.215
Workers' compensation	.334	.453
Tobacco use	.682	1.000
Alcohol use	1.000	.570
>1 prior surgery	.031	.120
Surgical approach at index surgery (open, mini, arthroscopic)	1.000	.151
Preoperative active forward elevation >120°	.651	.042
Preoperative active abduction >90°	.409	.009
Tear size	1.000	.290
Acromioplasty	1.000	.570
Biceps procedure	.661	.705
Distal clavicle resection	1.000	1.000

than 50 (Table 4). Among workers' compensation patients, a lower-intensity preoperative work level ($P = .04$), non-smoking status ($P = .014$), and smaller tear size ($P = .033$) were all associated with an increased return to work at full duty.

DISCUSSION

The principal findings of this study suggest that arthroscopic revision of failed prior rotator cuff repair can provide significant improvements in both pain and function with a relatively low clinical failure rate. Having 2 or more prior ipsilateral shoulder surgeries was determined to have a significant association with arthroscopic revision rotator cuff repair that required additional surgery. Additionally, female gender and the inability to preoperatively use the shoulder above 90° of abduction or 120° of elevation was significantly associated with poor clinical outcome.

Despite a number of series reporting excellent results after primary arthroscopic rotator cuff repair,^{9,16,27,29} published outcomes after revision have generally been less satisfactory. The majority of published revision studies reference an open approach to revision, with generally consistent postoperative pain relief but often unsatisfactory functional gains.^{1,17} In one of the earliest reports of revision outcomes, DeOrio and Cofield⁶ noted their experience with open revision in 27 patients, in whom 63% had persistent pain after revision and an average active abduction gain of only 8° (overall 58% poor results). Subsequent reports have demonstrated improved results, but none

have approached the benefits of primary repair. Djurasovic et al⁷ reported their retrospective experience with 80 consecutive open revision cases, 64% of which were for massive tears. The authors noted 58% good to excellent results, defined by only occasional soreness and greater than 140° of active elevation. Overall, 86% of patients noted marked pain relief, while 1 in 3 continued to have significant functional deficits.

The only prior published report of arthroscopic revision rotator cuff repairs using validated shoulder outcome scores is that of Lo and Burkhart,¹³ who described a single surgeon's experience with 14 consecutive cases. Eleven of the 14 cases were classified as massive tears,⁶ 6 of which involved 3 tendons. At a mean of 23 months after revision, the authors noted significant improvements in University of California at Los Angeles scores and active motion (elevation to 153°, external rotation to 44°), with overall 64% good to excellent results. Thirteen of 14 patients were satisfied with their outcome; 5 returned to their pre-morbid level of function. Our study group differed in that massive tears were found in only 7.4% of the cohort. Nonetheless, tear size was not found to have a significant association with failure. Although our numbers were too small to show a significant association between tear size and later revision failure, it is quite possible that our outcomes reflect an "easier to fix" revision population than has been described in prior reports. The findings in the present study also reported significant improvements in functional outcomes and ROM; however, the postoperative clinical scores do not reach the same level as primary arthroscopic rotator cuff repair.^{4,11,18}

There were only 6 patients (11.1%) who required additional surgery after failed arthroscopic revision rotator cuff repair. Five of these patients had undergone at least 2 prior ipsilateral shoulder operations. Greater than 1 prior shoulder procedure was a significant predictor of failure after revision, an intuitive finding echoed in the open study by Djurasovic et al.⁷ Clinical failure, as defined by an ASES score less than 50, had a significant association with female gender, preoperative active forward elevation, and preoperative active abduction. Female gender has been reported in some primary rotator cuff repair studies to be a negative prognostic factor associated with shoulder functional outcome.^{3,5,10,23,30} Other studies, however, found minimal differences in clinical outcome between men and women after open rotator cuff repair.¹⁴ Finally, the inability to preoperatively elevate or abduct the arm above shoulder level has been significantly associated with poor postoperative shoulder function in open revision rotator cuff repair studies.⁷

These results suggest that arthroscopic revision rotator cuff repair can salvage shoulder comfort and function at an acceptably high rate, and underscore the potential advantages of approaching revision rotator cuff surgery arthroscopically. Complex tear pattern recognition and mobility may be better assessed and taken advantage of using arthroscopic techniques. We would agree with Lo and Burkhart, for instance, that U-type tears,¹³ which are less mobile from medial to lateral, may be more difficult to appreciate and fix through an open approach. Also noted is the ubiquitous scarring that occurs after an index repair

procedure, and the often difficult task of identifying and sufficiently mobilizing all portions of the involved cuff tendons. Without the visualization afforded by arthroscopy, this portion of the procedure would be exceptionally difficult. Previously unrecognized and untreated intra-articular lesions may also be recognized via an arthroscopic approach. Lo and Burkhart¹³ noted insufficient prior acromioplasty, and untreated subscapularis, biceps, and superior labral anterior and posterior lesions in a number of their cases, as did we. One of the greatest benefits of arthroscopic revision, however, may be the relatively minimal trauma afforded the deltoid insertion. Common to the previous reports on open revision have been the particularly inferior outcomes associated with compromise of the deltoid after index repair,^{6,7,17} Bigliani et al¹ noted 9 of 13 patients with prerevision deltoid deformity with a subsequent unsatisfactory result after open revision, highlighting the importance of preserving the integrity of this muscle and its insertion. Our findings also report that patients who have had more than 1 prior rotator cuff repair have a significant association with failed arthroscopic revision rotator cuff repair. Although the direct causation was not investigated in the present study, multiple prior surgeries, whether via an open or arthroscopic approach, may theoretically increase the risk of failure by compromising the deltoid muscle as well as rotator cuff tendon integrity.

There were a number of limitations in the present study. Inherent in the design of a retrospective review is the absence of a comparison group, with only historical controls used to draw comparisons. The study criteria included any patient with a rotator cuff tear who had undergone prior repair, and therefore the cohort was heterogeneous in terms of workers' compensation status, number of prior procedures, type(s) of procedures, surgical approach, and intraoperative findings. Seventy-two percent of our patients were workers' compensation cases, many of whom had jobs with "heavy" or "very heavy" work requirements. Although strenuous employment often predisposes patients to complicated rotator cuff tears and frequent retears, this population is somewhat unique. The size of our cohort was also somewhat small. Even though there were a total of 54 patients in the study, analysis was often done on smaller selected demographic groups. A larger number of patients would increase the power of the study, allowing for more externally valid conclusions on arthroscopic revision rotator cuff repair failures as well as prognostic factors; moreover, differences between tear size subgroups may become apparent. Furthermore, repair constructs, determined at the time of revision according to surgeon preference, were slightly varied and the heterogeneity could have biased the results. Postrevision imaging, not performed for reasons of study cost, would have been helpful to assess anatomic healing of the arthroscopic revision rotator cuff repair. Strength measurements were not adjusted for dominant side involvement, as it is not part of the Constant-Murley score protocol; additionally, strength measurements were not contrasted between preoperative and postoperative states. Finally, our definition of "failure" included patients who required reoperation and ASES scores less than 50. Although we feel confident our failure rate accurately

represents the most disabled patients in our series, a more sensitive definition of failure may have uncovered other patients with inferior outcomes.

There were a number of strengths of the study. The present study was the largest study to report on arthroscopic revision repair of full-thickness rotator cuff tears in a tertiary shoulder practice with a high percentage of follow-up. Previously, only 2 studies^{13,26} have reported outcomes of arthroscopic revision rotator cuff repair, the largest of which had 14 patients. Additionally, the present study used validated, shoulder-specific functional outcome measures as evaluated by an independent examiner. The study also performed determined prognostic factors that were associated with failures as defined as patients that required additional surgery or ASES scores less than 50.

Arthroscopic revision rotator cuff repair may be a reasonable treatment option even after prior open repairs and provides both improved pain relief and shoulder function. However, patient expectations should be tempered in comparison with primary procedures.

REFERENCES

1. Bigliani LU, Cordasco FA, McIlveen SJ, Musso ES. Operative treatment of failed repairs of the rotator cuff. *J Bone Joint Surg Am.* 1992;74(10):1505-1515.
2. *Canadian Classification and Dictionary of Occupations.* Ottawa, ON: Information Canada; 1974.
3. Cofield RH, Parvizi J, Hoffmeyer PJ, Lanzer WL, Ilstrup DM, Rowland CM. Surgical repair of chronic rotator cuff tears: a prospective long-term study. *J Bone Joint Surg Am.* 2001;83(1):71-77.
4. Cole BJ, McCarty LP 3rd, Kang RW, Alford W, Lewis PB, Hayden JK. Arthroscopic rotator cuff repair: prospective functional outcome and repair integrity at minimum 2-year follow-up. *J Shoulder Elbow Surg.* 2007;16(5):579-585.
5. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res.* 1987;214:160-164.
6. DeOrto JK, Cofield RH. Results of a second attempt at surgical repair of a failed initial rotator-cuff repair. *J Bone Joint Surg Am.* 1984;66(4):563-567.
7. Djurasovic M, Marra G, Arroyo JS, Pollock RG, Flatow EL, Bigliani LU. Revision rotator cuff repair: factors influencing results. *J Bone Joint Surg Am.* 2001;83(12):1849-1855.
8. Ellman H, Hanker G, Bayer M. Repair of the rotator cuff: end result study of factors influencing reconstruction. *J Bone Joint Surg Am.* 1986;68:1136-1144.
9. Gartsman GM, Khan M, Hammerman SM. Arthroscopic repair of full-thickness tears of the rotator cuff. *J Bone Joint Surg Am.* 1998;80:832-840.
10. Katolik LI, Romeo AA, Cole BJ, Verma NN, Hayden JK, Bach BR. Normalization of the Constant score. *J Shoulder Elbow Surg.* 2005;14(3):279-285.
11. Lafosse L, Brozka R, Toussaint B, Gobezie R. The outcome and structural integrity of arthroscopic rotator cuff repair with use of the double-row suture anchor technique. *J Bone Joint Surg Am.* 2007;89(7):1533-1541.
12. Lippitt SB, Harryman DT, Matsen FA. A practical tool for evaluating function: the simple shoulder test. In: Matsen FA, Fu FH, Hawkins RJ, eds. *The Shoulder: A Balance of Mobility and Stability.* Rosemont, IL: American Academy of Orthopaedic Surgeons; 1993:545-559.
13. Lo IK, Burkhart SS. Arthroscopic revision of failed rotator cuff repairs: technique and results. *Arthroscopy.* 2004;20(3):250-267.
14. Mallon WJ, Misamore G, Snead DS, Denton P. The impact of preoperative smoking habits on the results of rotator cuff repair. *J Shoulder Elbow Surg.* 2004;13(2):129-132.

15. Michener LA, McClure PW, Sennett BJ. American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form, patient self-report section: reliability, validity, and responsiveness. *J Shoulder Elbow Surg.* 2002;11(6):587-594.
16. Murray TF Jr, Lajtai G, Mileski RM, Snyder SJ. Arthroscopic repair of medium to large full-thickness rotator cuff tears: outcome at 2- to 6-year follow-up. *J Shoulder Elbow Surg.* 2002;11(1):19-24.
17. Neviaser RJ. Evaluation and management of failed rotator cuff repairs. *Orthop Clin North Am.* 1997;28(2):215-224.
18. 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(1):13-20.
19. Ohnhaus EE, Adler R. Methodological problems in the measurement of pain: a comparison between the verbal rating scale and the visual analogue scale. *Pain.* 1975;1(4):379-384.
20. Packer NP, Calvert PT, Bayley JI, Kessel L. Operative treatment of chronic ruptures of the rotator cuff of the shoulder. *J Bone Joint Surg Br.* 1983;65(2):171-175.
21. Post M, Silver R, Singh M. Rotator cuff tear: diagnosis and treatment. *Clin Orthop Relat Res.* 1983;173:78-91.
22. Revill SI, Robinson JO, Rosen M, Hogg MI. The reliability of a linear analogue for evaluating pain. *Anaesthesia.* 1976;31(9):1191-1198.
23. Romeo AA, Hang DW, Bach BR Jr, Shott S. Repair of full thickness rotator cuff tears: gender, age, and other factors affecting outcome. *Clin Orthop Relat Res.* 1999;367:243-255.
24. Samilson RL, Binder WF. Symptomatic full thickness tears of rotator cuff: an analysis of 292 shoulders in 276 patients. *Orthop Clin North Am.* 1975;6(2):449-466.
25. Scott J, Huskisson EC. Graphic representation of pain. *Pain.* 1976;2(2):175-184.
26. Trantalis JN, Boorman RS, Pletsch K, Lo IK. Medial rotator cuff failure after arthroscopic double-row rotator cuff repair. *Arthroscopy.* 2008;24(6): 727-731.
27. Watson EM, Sonnabend DH. Outcome of rotator cuff repair. *J Shoulder Elbow Surg.* 2002;11(3):201-211.
28. Williams GN, Gangel TJ, Arciero RA, Uhorchak JM, Taylor DC. Comparison of the Single Assessment Numeric Evaluation method and two shoulder rating scales: outcomes measures after shoulder surgery. *Am J Sports Med.* 1999;27(2):214-221.
29. Wilson F, Hinov V, Adams G. Arthroscopic repair of full-thickness tears of the rotator cuff: 2- to 14-year follow-up. *Arthroscopy.* 2002;18(2):136-144.
30. Yian EH, Ramappa AJ, Arneberg O, Gerber C. The Constant score in normal shoulders. *J Shoulder Elbow Surg.* 2005;14(2): 128-133.

For reprints and permission queries, please visit SAGE's Web site at <http://www.sagepub.com/journalsPermissions.nav>.