

## Arthroscopic Repair of Full-Thickness Tears of the Rotator Cuff\*

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**ABSTRACT:** We present the results of arthroscopic repair of full-thickness tears of the rotator cuff in seventy-three patients (thirty-nine men and thirty-four women). The average age of the patients at the time of the operation was 60.7 years (range, thirty-one to eighty-two years). All of the patients were followed for at least two years (average, thirty months; range, twenty-four to forty months). The shoulders were evaluated with the rating scale of the University of California at Los Angeles, the shoulder index of the American Shoulder and Elbow Surgeons, and the functional rating scale of Constant and Murley. In addition, the patients completed the Short-Form 36 Health Survey (SF-36) preoperatively and at the yearly follow-up evaluations.

Eleven tears were small (less than one centimeter in length), forty-five were medium (one to three centimeters), eleven were large (more than three to five centimeters), and six were massive (more than five centimeters). The average length of the tear was twelve millimeters, and the average width was twenty-seven millimeters. Sixty-nine tendons were repaired anatomically, and four were repaired an average of three millimeters (range, two to eight millimeters) medial to the anatomical insertion of the tendon. An average of 2.3 (range, one to four) suture anchors were used in the repair. Sixty-three glenohumeral joints were normal, and ten had an intra-articular lesion. Seven patients had a concomitant resection of the acromioclavicular joint. The average duration of the operation was fifty-six minutes (range, thirty-five to ninety minutes).

The active and passive ranges of motion improved significantly after the procedure ( $p = 0.0001$ ). The strength of resisted elevation improved from 7.5 to 14.0 pounds (3.4 to 6.3 kilograms) ( $p = 0.0001$ ). The average total score according to the rating scale of the University of California at Los Angeles improved from 12.4 to 31.1 points; the average total score according to the shoulder index of the American Shoulder and Elbow

Surgeons, from 30.7 to 87.6 points; and the average absolute score according to the rating system of Constant and Murley, from 41.7 to 83.6 points ( $p = 0.0001$  for all comparisons). The average score for the pain component of the rating scale of the University of California at Los Angeles improved from 2.4 to 8.6 points; fifty-seven (78 per cent) of the seventy-three patients rated the relief of pain as good or excellent on the visual-analog scale. The average score for satisfaction improved from 0.4 to 4.6 points; sixty-six patients (90 per cent) rated their satisfaction as good or excellent at the time of the most recent examination. None of the shoulders were rated as good or excellent before the operation, whereas sixty-one (84 per cent) were so rated at the most recent follow-up evaluation after the index procedure. In addition, significant improvements ( $p = 0.0015$ ) were noted in the scales and summary measures of the SF-36.

Arthroscopic repair of full-thickness tears of the rotator cuff produced satisfactory results with regard to traditional orthopaedic criteria as well as with regard to patient-assessed criteria such as satisfaction, pain relief, and general health. The arthroscopic method offers several advantages, including smaller incisions, access to the glenohumeral joint for the inspection and treatment of intra-articular lesions, no need for detachment of the deltoid, and less soft-tissue dissection. However, these advantages must be considered against the technical difficulty of the method, which limits its application to surgeons who are skilled in both open and arthroscopic procedures on the shoulder.

Operative skills have advanced sufficiently so that full-thickness tears of the rotator cuff can be repaired with arthroscopic techniques. The proposed advantages of the arthroscopic method are that it involves smaller skin incisions, provides access to the glenohumeral joint for the inspection and treatment of intra-articular lesions, does not require detachment of the deltoid, and necessitates less soft-tissue dissection. The purpose of this study was to evaluate the results of arthroscopic repair performed by one surgeon at one institution.

### Materials and Methods

Seventy-eight consecutive patients had arthroscopic repair of a full-thickness tear of the rotator cuff between

\*No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article. No funds were received in support of this study.

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January and December 1994. The criterion for inclusion in this study was a full-thickness, reparable tear of at least one rotator-cuff tendon. A tear was considered to be reparable if the tendon could be restored to, or within ten millimeters of, its anatomical insertion when traction was applied to the tendon. If the tendon could not be positioned appropriately, sites at which its mobility was limited were inspected and released as necessary. Mobility of the tendon was limited by the contracture of a number of anatomical structures, including the superior aspect of the glenohumeral joint capsule and the coracohumeral ligament. Adhesions to the inferior surface of the acromion and to the inferior aspect of the deltoid fascia also limited the ability to free the retracted tendon. If the torn tendon could not be mobilized adequately or if the tendon was absent, the lesion was considered to be irreparable. A more detailed description of the determination of the reparability of tears of the rotator cuff has been published<sup>13</sup>.

The uniformity of the study group was maintained as much as possible so that the effects of this new procedure could be investigated. Thus, individuals who had had a previous procedure on the shoulder, those who had a partial-thickness tear of the rotator cuff, and those who had an irreparable tear were excluded. Patients who had filed a Workers' Compensation claim were also excluded because various issues may have affected their outcome; Misamore et al.<sup>21</sup> recently documented inferior results among patients who had filed such a claim. Patients who had an acute tear were also excluded because they had often sustained substantial trauma with additional osseous or soft-tissue damage.

A minimum of two years of follow-up was required for inclusion in the study. Five patients who had been followed for less than two years were excluded. However, a review of the demographic data and operative findings demonstrated that these patients were representative of the entire patient population. Two of the five patients could not be located, one had died of an unrelated cause, and two were evaluated one year postoperatively but were lost to follow-up before the two-year minimum. Therefore, seventy-three patients (thirty-nine men and thirty-four women) who had had a unilateral procedure on the shoulder were evaluated. The average duration of follow-up was thirty months (range, twenty-four to forty months). The patients were evaluated at six weeks; at three, six, nine, and twelve months; and yearly thereafter.

The average age at the time of the operation was 60.7 years (range, thirty-one to eighty-two years). Fifty-two patients had involvement of the dominant shoulder, and twenty-one had involvement of the non-dominant shoulder. The average duration of the symptoms before the operation was eighteen months (range, six to 144 months). Fifty-two patients had had an average of 1.7 (range, one to eight) preoperative subacromial injec-

tions of cortisone, administered by either the referring physician or one of us (G. M. G.).

#### *Preoperative Assessment*

In order to allow the results of the present study to be compared with those of others in the literature, data were collected with use of the rating scale of the University of California at Los Angeles<sup>8</sup>, the rating system of Constant and Murley<sup>5</sup>, and the shoulder index of the American Shoulder and Elbow Surgeons<sup>27</sup>. The rating scale of the University of California at Los Angeles is a 35-point scale with 10 points for pain, 10 points for function, and 5 points each for motion, strength, and patient satisfaction. The rating system of Constant and Murley is a 100-point scale with 15 points for pain, 20 points for function, 40 points for active range of motion, and 25 points for strength. The shoulder index of the American Shoulder and Elbow Surgeons consists of a pain score and a section including ten self-assessed activities of daily living. Pain is assessed by the patient on a 10-point visual-analog scale (with 0 points indicating no pain and 10 points, unbearable pain). This score is subtracted from 10, and the resulting number is multiplied by 5 for a maximum total of 50 points. The ten activities of daily living are each scored from 0 to 3 points (with 0 points indicating an inability to perform the task and 3 points, normal function); the total of these ten scores is multiplied by 5/3 for a maximum total of 50 points. Thus, the total possible score for the entire index is 100 points. In addition, the patients completed the Short-Form 36 Health Survey (SF-36)<sup>33,34</sup> preoperatively and at the yearly examinations.

The active ranges of motion were measured with the system of Constant and Murley and included forward elevation, abduction, external rotation with the arm in abduction, and internal rotation behind the back. Passive elevation and external rotation (with the arm in adduction) were measured to the nearest 5 degrees by the examiner with a handheld goniometer. Internal rotation behind the back was recorded as the most cephalad vertebral level reached by the extended thumb. The operating surgeon recorded all measurements during the initial physical examination and subsequent follow-up visits. No attempt was made to increase the precision of the measurements by requiring the evaluation to be performed by a blinded examiner, evaluating test-retest validity, measuring interobserver and intraobserver reliability, instructing the patient before the measurements, or asking the patient to perform warm-up exercises before the evaluation.

The strength of resisted elevation was measured with a dynamometer with the arm elevated 90 degrees in the scapular plane and internally rotated; the result was recorded in pounds. Lidocaine was not injected into the subacromial space before the shoulder was examined, so it was not possible to quantify how much of the loss of strength was due to pain.

Anteroposterior glenoid, axillary, and supraspinatus outlet radiographs were made routinely. Imaging studies (magnetic resonance imaging or arthrography) were performed if necessary. Sixty patients had preoperative imaging studies: sixteen had arthrography and forty-four had magnetic resonance imaging. There were no false-negative arthrograms or magnetic resonance images.

The primary indication for the operation was persistent pain in the shoulder that had not responded to a minimum of six months of non-operative treatment consisting of avoidance of painful activities, use of non-steroidal anti-inflammatory medication, and participation in a home physical-therapy program designed to maintain or improve the range of motion of the shoulder and to increase the strength of the uninvolved muscles<sup>11</sup>. Cortisone was injected into the subacromial space if pain had not decreased after two to three months of oral administration of non-steroidal anti-inflammatory medication or if the use of such medication was contraindicated.

#### *Rights of the Patients*

In order to maintain patient confidentiality throughout the investigation, each patient was assigned a unique identification number. The identification number was kept separate from the name so that the statistician did not know the patient's identity. Before the start of the investigation, statistical analysis was performed to quantify the number of patients that would be required in order for statistically valid conclusions to be drawn. All patients provided written, informed consent stating that they understood the purpose of the study as well as the potential risks and benefits of the operation. Patients were informed that they had the right to operative or non-operative care other than that proposed in the study. They were also informed that they had the right not to participate in the study even if they chose the type of care described in the study. The patient's understanding of these rights was documented in writing.

#### *Operative Technique*

Before the administration of the general anesthetic, an interscalene block was given in order to diminish postoperative pain. The patient was placed in the sitting position. The glenohumeral joint was inspected, and intra-articular lesions were treated as necessary.

The arthroscope was then removed from the joint and was redirected into the subacromial space. Any bursal tissue that impeded a clear view of the torn tendon was removed. The length of the tear as well as any medial retraction was recorded. The tendon was grasped with a surgical instrument, and the reparability of the tendon (the ability of the tissue to hold sutures and thus to be used in the repair) was determined<sup>13</sup>. The tendon must be sufficiently mobile to allow it to be attached to the humerus. Occasionally, there were adhesions between the tendon and the superior aspect of the gleno-

humeral joint capsule, the coracohumeral ligament, the acromion, the deltoid fascia, or a combination of these, that limited excursion. Adhesions were removed with a motorized shaver or electrocautery until full excursion was possible, and then the arthroscopic subacromial decompression was completed<sup>11</sup>.

The purpose of the acromioplasty was to create adequate space for the rotator-cuff tendons. As the thickness and shape of the acromions varied, the amount of bone removed during the acromioplasty also varied. The goal was to achieve a flat acromial undersurface. As all of the patients in the present study had a chronic tear of the rotator cuff, impingement was considered to be part of the pathological process regardless of whether or not it was the cause of the tear. Osteophytes in the inferior part of the acromioclavicular joint were removed if necessary, as determined on the basis of preoperative radiographs or by inspection at the time of the operation. The acromioclavicular joint was removed only if the patient had had preoperative localized pain or tenderness of the joint on physical examination<sup>12</sup>.

A cancellous bed was prepared at the site of the repair by removal of a thin layer of cortical bone with a power burr. No trough was utilized. A suture anchor was inserted lateral to the cancellous bone surface in the denser metaphyseal bone. A number-2 braided, non-absorbable suture was placed approximately five millimeters from the margin of the tendon. The number of suture anchors varied with the length of the tear. After all repair sutures were inserted, an additional suture was placed in the margin of the tendon and traction was applied to reduce the tendon to its repair site and to allow the suture to be tied without tension. The tendon was repaired with the arm at the side. If this could not be accomplished, the tendon was repaired medially<sup>20</sup>. Abduction of the arm was not necessary for any of the repairs. The number-2 sutures were tied so that the knot was on the bursal surface of the tendon. Absorbable sutures were not used. The traction suture was removed after all of the repair sutures were tied. Longitudinal tears were repaired with simple monofilament sutures, as dictated by the geometry of the tear.

It is recommended that two surgeons be present during the procedure, as this technique requires many complicated maneuvers. A detailed description of the operative technique has been published previously<sup>15</sup>.

#### *Postoperative Management*

The arm was maintained in a sling in 15 degrees of abduction, and an ice-pack wrap was used to decrease swelling and pain in the shoulder. Passive elevation and external rotation were started on the afternoon of the operation and were continued at home for six weeks. The patient was discharged to home on the morning after the operation. Active range-of-motion exercises were begun at six weeks and were continued until the twelfth week, at which point strengthening exercises

TABLE I  
SCORES FOR THE SHOULDER-RATING SYSTEMS\*

	Preoperative (points)	Most Recent (points)
Rating scale of University of California at Los Angeles <sup>8</sup>		
Total score	12.4 ± 4.2	31.1 ± 3.2
Pain	2.4 ± 1.7	8.6 ± 1.6
Function	3.7 ± 2.2	8.9 ± 1.2
Flexion	3.6 ± 2.2	4.9 ± 0.3
Strength	2.3 ± 1.0	4.1 ± 0.9
Satisfaction	0.4 ± 0.5	4.6 ± 0.9
Shoulder index of American Shoulder and Elbow Surgeons <sup>27</sup>		
Total score	30.7 ± 15.7	87.6 ± 12.8
Pain	7.7 ± 1.7	1.4 ± 1.6
Function	11.4 ± 5.7	26.8 ± 8.0
Rating scale of Constant and Murley <sup>5</sup>		
Absolute score	41.7 ± 12.8	83.6 ± 9.0
Age-adjusted score†	43.3 ± 11.6	84.0 ± 7.5
Pain	3.6 ± 2.6	12.9 ± 2.3
Function	3.4 ± 1.9	18.8 ± 1.5
Elevation	7.6 ± 2.5	9.8 ± 0.6
Abduction	6.2 ± 2.6	9.6 ± 1.1
External rotation	6.8 ± 2.2	9.5 ± 1.2
Internal rotation	6.7 ± 2.1	9.1 ± 1.2
Strength	7.5 ± 4.7	14.0 ± 5.4

\*The values are given as the average and the standard deviation. The differences between the preoperative and the most recent scores were significant ( $p = 0.0001$ ), according to the Wilcoxon signed-rank test.

†The age-adjusted score is an average of the age-stratified data.

with rubber tubing were begun. The strengthening exercises were designed to strengthen the deltoid, the infraspinatus, the supraspinatus, the scapular rotators, and the biceps. The range-of-motion and strengthening exercises were continued for one year.

At each follow-up examination, the patient assessed the pain in and function of the shoulder as well as his or her level of satisfaction with the three shoulder-rating systems. The examiner documented the active and passive ranges of motion as well as the strength of resisted elevation. At the yearly follow-up examinations, after arrival in the clinic but before the examination, the patient completed the SF-36. No postoperative imaging studies (ultrasound, magnetic resonance imaging, or arthrography) were performed.

#### Statistical Analysis

The Wilcoxon signed-rank test was used to evaluate the preoperative and most recent scores for significant differences. The Wilcoxon rank-sum test was used to test for preoperative and postoperative differences between the patients who had a normal glenohumeral joint and those who had an abnormal glenohumeral joint. The Spearman rank correlation was used to determine the relationships between several independent variables, including the preoperative and postoperative overall

scores on the rating scale of the University of California at Los Angeles; the preoperative and postoperative strength of resisted elevation; the age of the patient; and the length, width, and total area of the tear. Standard statistical software (SAS, Cary, North Carolina) was used to analyze the data.

## Results

### Operative Findings

Sixty-three glenohumeral joints were normal, and ten had an intra-articular lesion. Serious intra-articular abnormalities were defined as those that needed operative treatment or that were expected to alter the postoperative rehabilitation or the outcome<sup>17</sup>. Three patients had osteoarthritis of the humeral head; three had osteoarthritis of the humeral head and the glenoid; two had a partial tear of the biceps tendon; one had osteoarthritis of the humeral head, a tear of the anterior aspect of the glenoid labrum, and a partial tear of the biceps; and one had a proliferative synovitis.

As the tendons of the supraspinatus, infraspinatus, and teres minor blend together to form the rotator cuff, identification of the involved tendons is somewhat arbitrary. Nonetheless, we used our best clinical judgment to determine the pattern of the tear. Forty patients had a tear of the supraspinatus; twenty-five, a tear of the supraspinatus and the infraspinatus; five, a tear of the supraspinatus, infraspinatus, and teres minor; and three, a tear of the supraspinatus, infraspinatus, and superior portion of the subscapularis.

The size of the tear was measured with a calibrated arthroscopic probe. All shoulders were positioned in 15 degrees of abduction, 10 degrees of elevation, and 5 degrees of external rotation for the measurement. The length of the tear was measured as the distance from the anterior border of the greater tuberosity at the bicipital

TABLE II  
SCORES FOR ACTIVITIES OF DAILY LIVING  
ACCORDING TO THE SHOULDER INDEX OF THE  
AMERICAN SHOULDER AND ELBOW SURGEONS<sup>27\*</sup>

	Preoperative (points)	Most Recent (points)
Putting on coat	1.55 ± 0.76	2.93 ± 0.30
Sleeping	0.96 ± 0.95	2.62 ± 0.70
Reaching behind back	1.01 ± 0.79	2.70 ± 0.46
Toileting	2.39 ± 0.84	2.97 ± 0.16
Combing hair	1.59 ± 0.96	2.89 ± 0.36
Reaching high shelf	0.96 ± 0.95	2.67 ± 0.58
Lifting 10 lbs. (4.5 kg) above shoulder	0.53 ± 0.78	2.22 ± 0.99
Throwing overhead	0.55 ± 0.80	2.34 ± 0.90
Working	1.33 ± 1.05	2.81 ± 0.99
Sports activities	0.52 ± 0.82	2.67 ± 0.73

\*The values are given as the average and the standard deviation. The differences between the preoperative and the most recent scores were significant ( $p = 0.0001$ ), according to the Wilcoxon signed-rank test.

TABLE III  
PASSIVE RANGE OF MOTION\*

	Preoperative	Most Recent
Elevation ( <i>degrees</i> )	135 ± 22	149 ± 4
External rotation ( <i>degrees</i> )	66 ± 12	78 ± 10
Internal rotation	L1 ± 4 levels	T9 ± 3 levels

\*The values are given as the average and the standard deviation. The differences between the preoperative and the most recent values were significant ( $p = 0.0001$ ), according to the Wilcoxon signed-rank test.

groove to the intact portion of the tendon posteriorly on the greater tuberosity. Eleven tears were small (less than one centimeter long), forty-five were medium (one to three centimeters long), eleven were large (more than three to five centimeters long), and six were massive (more than five centimeters long). The average length was twelve millimeters (range, five to sixty millimeters). The width of the tear was measured as the distance from the margin of the lateral border of the greater tuberosity to the edge of the tendon. The average width was twenty-seven millimeters (range, zero to thirty millimeters). The average area of the tear was 324 square millimeters (range, fifty to 1255 square millimeters). In terms of the area, seventeen tears were small (twenty-five to 100 square millimeters), twenty-five were medium (101 to 350 square millimeters), eighteen were large (351 to 600 square millimeters), and thirteen were massive (more than 600 square millimeters).

Sixty-nine tendons were repaired anatomically, and four were repaired an average of three millimeters (range, two to eight millimeters) medial to the anatomical insertion of the tendon. Side-to-side repair was performed as dictated by the geometry of the tear. An average of 2.3 (range, one to four) suture anchors were used. During the period of this study, a wide variety of suture anchors (including metallic screw-in anchors, metallic expandable anchors, and polyethylene expandable anchors) were used. We currently use metallic screw-in anchors exclusively. The average duration of the operation was fifty-six minutes (range, thirty-five to ninety minutes). Seven patients had resection of the acromioclavicular joint.

#### Complications

There were no intraoperative or perioperative complications. No patient had a neural injury, wound infection, or drainage from the wound. The suture anchors did not cause any complications. No patient needed manipulation for postoperative stiffness.

#### Shoulder-Rating Systems

All three rating systems reflected significant improvement in the status of the shoulder when the preoperative scores were compared with the scores at the time of the most recent follow-up ( $p = 0.0001$ ) (Table I). The average total score increased from 12.4 to 31.1

points with use of the rating scale of the University of California at Los Angeles and from 30.7 to 87.6 points with use of the shoulder index of the American Shoulder and Elbow Surgeons. The average absolute score with use of the system of Constant and Murley improved from 41.7 to 83.6 points, and the average age-adjusted score (an average of the age-stratified data<sup>4</sup>) improved from 43.3 to 84.0 points.

**Satisfaction:** The rating scale of the University of California at Los Angeles was used to rate the level of satisfaction. The average score for satisfaction was 0.4 point preoperatively and 4.6 points postoperatively. Preoperatively, none of the patients rated their satisfaction as good or excellent (a score of 4 or 5 points). Postoperatively, sixty-six (90 per cent) of the seventy-three patients rated their satisfaction as good or excellent and seven (10 per cent) rated it as fair or poor (a score of 0 to 3 points).

**Pain:** The procedure resulted in a significant reduction in pain ( $p = 0.0001$ ). Preoperatively, no patient had no or minimum pain (a score of 0, 1, or 2 points on the visual-analog scale). Postoperatively, fifty-seven patients (78 per cent) had no or minimum pain, eleven (15 per cent) had moderate pain (3 or 4 points), and five (7 per cent) had severe pain (5 to 10 points).

**Function:** Function of the shoulder was assessed with the function component of the rating scale of the University of California at Los Angeles (Table I) and the scores for the ten activities of daily living included in the shoulder index of the American Shoulder and Elbow Surgeons (Table II). Preoperatively, three patients (4 per cent) rated the function as good or excellent (8, 9, or 10 points) and seventy patients (96 per cent) rated it as fair or poor (0 to 7 points) according to the rating scale of the University of California at Los

TABLE IV  
SCORES FOR THE SHORT-FORM 36 (SF-36) HEALTH SURVEY<sup>33,34\*</sup>

	Preoperative ( <i>points</i> )	Most Recent ( <i>points</i> )
Physical function	57.2 ± 25.7	76.6 ± 27.1
Physical role function	24.6 ± 37.4	75.7 ± 40.4
Bodily pain	27.7 ± 19.7	68.2 ± 24.1
General health	70.8 ± 28.7	72.4 ± 21.8
Vitality	50.6 ± 24.2	62.8 ± 18.4
Social function	57.5 ± 31.2	84.0 ± 25.5
Emotional role function	62.1 ± 43.8	82.4 ± 34.3
Mental health	70.3 ± 22.2	78.2 ± 19.3
Physical component summary	34.1 ± 9.1	46.6 ± 10.8
Mental component summary	48.7 ± 13.1	52.6 ± 9.4

\*All values are given as the average and the standard deviation. The differences between the preoperative and the most recent scores were significant ( $p = 0.0015$ ), according to the Wilcoxon signed-rank test, except for the general health score and the mental component summary score.

TABLE V  
SPEARMAN RANK CORRELATIONS FOR COMPARISON OF VARIOUS PARAMETERS\*

	University of California at Los Angeles <sup>8</sup>		Strength of Resisted Elevation		Length of Tear	Width of Tear	Area of Tear	Age of Patient
	Preoperative Score	Most Recent Score	Preoperative	Most Recent				
University of California at Los Angeles								
Preoperative score	1.00	0.081	0.417 (0.0002)	0.067	0.067	-0.049	0.015	-0.157
Most recent score		1.00	0.309 (0.008)	0.515 (0.0001)	-0.161	-0.092	-0.122	-0.043
Strength of resisted elevation								
Preoperative			1.00	0.456 (0.0001)	-0.244 (0.037)	-0.131	-0.199	-0.448 (0.0001)
Most recent				1.00	-0.407 (0.0003)	-0.310 (0.008)	-0.373 (0.001)	-0.368 (0.001)
Length of tear					1.00	0.676 (0.0001)	0.906 (0.0001)	0.336 (0.004)
Width of tear						1.00	0.912 (0.0001)	0.292 (0.012)
Area of tear							1.00	0.346 (0.003)
Age of patient								1.00

\*The values are given as the r values, with the p values in parentheses.

Angeles; postoperatively, sixty-seven patients (92 per cent) rated the function as good or excellent and six (8 per cent) rated it as fair or poor. There was significant improvement in all ten activities of daily living that were assessed with the shoulder index of the American Shoulder and Elbow Surgeons ( $p = 0.0001$ ).

Range of motion: The active and passive ranges of motion were significantly improved at the most recent follow-up evaluation ( $p = 0.0001$ ) (Tables I and III).

Strength: The strength of resisted elevation improved 87 per cent, from an average of 7.5 pounds (3.4 kilograms) preoperatively to an average of 14.0 pounds (6.3 kilograms) at the most recent follow-up evaluation. This improvement was significant ( $p = 0.0001$ ).

General health: All of the scores according to the SF-36, with the exception of the score for general health and the mental component summary score, improved significantly ( $p = 0.0015$ ) (Table IV).

#### Correlation of Variables

Age was not significantly correlated with either the preoperative ( $r = -0.157$ ) or the postoperative ( $r = -0.043$ ) overall score according to the rating scale of the University of California at Los Angeles, but it was correlated with the preoperative ( $r = -0.448$ ,  $p = 0.0001$ ) and postoperative ( $r = -0.368$ ,  $p = 0.001$ ) strength of resisted elevation as well as with the area of the tear ( $r = 0.346$ ,  $p = 0.003$ ) (Table V).

#### Effect of Glenohumeral Abnormalities

The average preoperative score according to the rating scale of the University of California at Los Angeles

was 23.7 points for the sixty-three patients who had a normal glenohumeral joint and 10.9 points for the ten who had a serious glenohumeral lesion ( $p = 0.22$ ). The average postoperative scores were 31.2 and 29.9 points, respectively ( $p = 0.23$ ). These differences were not found to be significant, with the numbers available. This comparison indicates that the identification and treatment of intra-articular lesions leads to results that are similar to those for patients who do not have an intra-articular lesion.

#### Analysis of Unsatisfactory Results

Twelve patients had a fair or poor result (a total score of less than 29 points according to the rating scale of the University of California at Los Angeles) at the most recent examination after the index procedure and before any subsequent procedures. Symptomatic arthrosis of the acromioclavicular joint developed in two patients within one year postoperatively. One patient had subsequent arthroscopic resection of the acromioclavicular joint, and the result was excellent at the most recent evaluation. The other patient refused an additional operation. The remaining ten patients did not demonstrate any consistent pattern to account for the fair or poor results.

#### Discussion

During the last decade, the operative repair of full-thickness tears of the rotator cuff has gradually shifted through three phases: open repair, combined open and arthroscopic repair (so-called mini-open repair), and, most recently, arthroscopic repair alone. Successful re-

sults have been documented after arthroscopic repair of stage-2 impingement and partial-thickness tears<sup>6,7,10,11,16,31</sup>. Orthopaedic surgeons now use arthroscopic techniques for many of the elements that make up the operative repair of a full-thickness tear — namely, acromioplasty, release of the coracoacromial ligament, bursal resection, and removal of adhesions.

However, several authors have reported poor results when patients who had a full-thickness tear were managed with arthroscopic subacromial decompression without repair of the defect in the cuff<sup>9,11,25,28</sup>. Most investigations have supported the concept that subacromial decompression must be combined with repair of the tendon in patients who have a chronic full-thickness tear<sup>22,37</sup>.

The mini-open method involves arthroscopic evaluation of the glenohumeral joint and arthroscopic acromioplasty combined with open repair of the full-thickness tear<sup>14</sup>. In initial studies, Blevins et al.<sup>2</sup> found that fifty-seven (89 per cent) of sixty-four patients were satisfied and Paulos and Kody<sup>26</sup> reported that sixteen of eighteen patients had a good or excellent result. Both sets of authors were careful to point out that the limited incision used in the repair restricts the use of this technique to the treatment of smaller, less retracted tears located in the anterior portion of the rotator cuff (the anterior one-half of the infraspinatus and the supraspinatus).

As orthopaedists have performed the mini-open repair, they have gained familiarity with the arthroscopic appearance of full-thickness tears of the rotator cuff. There have also been improvements in arthroscopic instruments, suturing techniques, suture anchors, and knot-tying. The ability to arthroscopically measure the tear and assess the quality of the tendon and its reparability has improved<sup>13</sup>. By performing arthroscopic operations for glenohumeral instability, orthopaedic surgeons have also developed expertise in other applicable techniques, such as preparing bone for soft-tissue attachment<sup>29,35</sup>. These developments have allowed the open portion of the mini-open technique to be eliminated and the repair to be performed exclusively with the arthroscopic technique.

Snyder et al.<sup>30</sup> and Gazielly et al.<sup>18</sup> documented their results with arthroscopic methods similar to those described in the present study. Snyder et al. reported an excellent or good result for forty-one (87 per cent) of forty-seven patients. Gazielly et al., in a study of fifteen patients, reported that the average score according to the system of Constant and Murley improved from 58.1 to 87.6 points. The present study documents our experience with the arthroscopic repair of full-thickness tears of the rotator cuff.

We noted substantial improvement in the scores of all three shoulder-rating systems when the preoperative scores were compared with the scores at the most recent evaluation. Although neither the system of Constant

and Murley nor the shoulder index of the American Shoulder and Elbow Surgeons specifically defines an excellent or poor score, Ellman et al.<sup>8</sup> defined a score of 34 or 35 points according to the rating scale of the University of California at Los Angeles as excellent, a score of 29 to 33 points as good, and a score of less than 29 points as fair or poor. Ellman et al. also stated that good and excellent results correspond with Neer's<sup>23,24</sup> definition of a satisfactory result and that fair and poor results correspond with Neer's definition of an unsatisfactory result. Accordingly, in the present study, sixty-one patients (84 per cent) had a good or excellent result and twelve (16 per cent) had a fair or poor result.

There was also marked improvement in each of the components of the shoulder-rating systems. At the most recent evaluation, sixty-six patients (90 per cent) rated their satisfaction with the shoulder as good or excellent compared with no patients preoperatively. The average pain score on the visual-analog scale of the shoulder index of the American Shoulder and Elbow Surgeons improved from 7.7 to 1.4 points. Fifty-seven patients (78 per cent) rated the postoperative relief of pain as good or excellent. The function of the shoulder improved according to the scores for all ten activities of daily living included in the shoulder index of the American Shoulder and Elbow Surgeons, and sixty-seven patients (92 per cent) rated the function of the shoulder as good or excellent at the most recent follow-up. Patients were particularly pleased with the improved ability to sleep comfortably. The active range of motion improved in all measured planes; the average preoperative score for the motion component of the system of Constant and Murley was 27.2 (of a possible 40) points, whereas the average postoperative score was 37.9 points. The increases in the passive range of motion were smaller but also were significant. The strength of resisted elevation improved significantly from 7.5 pounds (3.4 kilograms) preoperatively to 14.0 pounds (6.3 kilograms) postoperatively. There was improvement in all scales and summary measures of the SF-36, with the exception of the general health score and the mental component summary score.

Direct comparison of the results of the present study with those of previous studies on the open repair of full-thickness tears of the rotator cuff is difficult because of the various rating systems used. Bigliani et al.<sup>1</sup> summarized the results of a number of articles on open repair and reported good or excellent results in terms of both pain relief (85 to 100 per cent of patients) and function (70 to 95 per cent of patients). Good or excellent results were reported for forty-two (84 per cent) of fifty patients in the study by Ellman et al.<sup>8</sup>, for sixty-four (51 per cent) of 126 patients in the study by Vastamaki<sup>32</sup>, and for forty-five (69 per cent) of sixty-five patients in the study by Wolfgang<sup>36</sup>. Hawkins et al.<sup>19</sup> reported that eighty-six (86 per cent) of their 100 patients had relief of pain. The level of improvement of the

various parameters described in the present study suggests that arthroscopic repair of full-thickness tears produces equivalent results.

Currently, we treat full-thickness tears of the rotator cuff arthroscopically; no open operations are performed. The use of the arthroscopic technique allows us to inspect the glenohumeral joint and to avoid detaching the origin of the deltoid. The size of the tear is not a factor; we have more difficulty repairing chronic retracted tears, regardless of size, than we do repairing large or massive mobile tears. Although we cannot document our impressions statistically, we believe that arthroscopic repair results in an improved cosmetic appearance, decreased pain postoperatively, and more rapid gains in motion compared with open operative treatment of similar lesions.

The present study has a number of weaknesses. Although the investigation was prospective, the patients were not randomized and the investigator was not blinded. In addition, the follow-up period was relatively short; we are continuing to follow these patients so that we can evaluate the results after longer periods of time. There is evidence, however, that the maximum improvement occurs in the first year after repair of the rotator cuff and that additional improvement is unlikely. We found, as did Misamore et al.<sup>21</sup> and Bokor et al.<sup>3</sup>, that improvement occurred only during the first year after the operation. We excluded patients for whom the repair was a revision operation and those who had filed a Workers' Compensation claim; this selection bias may have improved our overall results. We also excluded patients who had an irreparable tear. The determination of reparability remains a challenge not only during arthroscopic operations but also during traditional open repair.

Caution is advised for orthopaedic surgeons who are considering the transition from open to arthroscopic

techniques. The orthopaedic surgeon not only must master each of the individual elements described here but also must perform them in a precise and timely fashion. Experience is required in order to recognize the pattern of the tear as viewed through the arthroscope. Mobilization of the tendon can be difficult in a patient who has a retracted tear. Suture anchors must be placed accurately so that the repaired tendon rests in the desired location. The orthopaedist must manage multiple strands of suture material within the tight confines of the subacromial space and tie secure knots with use of arthroscopic tools.

Orthopaedic surgeons who attempt this technique will find it useful to have a skilled assistant surgeon present. In an era of declining reimbursement, this is a disadvantage compared with the traditional open technique.

The present report is based on our experience; therefore, it must be assumed that a learning curve affected the results. Because this study took place at a time when the techniques and equipment of arthroscopic repair of the rotator cuff were evolving, additional refinements will invariably occur as the procedure is used more widely.

At present, these techniques can be recommended only for use by experienced orthopaedic surgeons who are familiar with the normal and abnormal anatomy seen during both open and arthroscopic operations on the shoulder. A thorough understanding of the various conditions that produce pain in the shoulder is also necessary. An orthopaedic surgeon who performs open repairs infrequently should not attempt the arthroscopic procedure. The open operation is relatively simple and has a documented history of success<sup>8,19-21,36</sup>. In contrast, the arthroscopic technique is technically demanding and is still in the developmental stage.

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