The Outcome and Structural Integrity of Arthroscopic Rotator Cuff Repair with Use of the Double-Row Suture Anchor Technique

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Background: The reported rate of failure after arthroscopic rotator cuff repair has varied widely. The influence of the repair technique on the failure rates and functional outcomes after open or arthroscopic rotator cuff repair remains controversial. The purpose of the present study was to evaluate the functional and anatomic results of arthroscopic rotator cuff repairs performed with the double-row suture anchor technique on the basis of computed tomography or magnetic resonance imaging arthrography in order to determine the postoperative integrity of the repairs.

Methods: A prospective series of 105 consecutive shoulders undergoing arthroscopic double-row rotator cuff repair of the supraspinatus or a combination of the supraspinatus and infraspinatus were evaluated at a minimum of two years after surgery. The evaluation included a routine history and physical examination as well as determination of the preoperative and postoperative strength, pain, range of motion, and Constant scores. All shoulders had a preoperative and postoperative computed tomography arthrogram (103 shoulders) or magnetic resonance imaging arthrogram (two shoulders).

Results: There were thirty-six small rotator cuff tears, forty-seven large isolated supraspinatus or combined supraspinatus and infraspinatus tendon tears, and twenty-two massive rotator cuff tears. The mean Constant score (and standard deviation) was 43.2 ± 15.1 points (range, 8 to 83 points) preoperatively and 80.1 ± 11.1 points (range, 46 to 100 points) postoperatively. Twelve of the 105 repairs failed. Intact rotator cuff repairs were associated with significantly increased strength and active range of motion.

Conclusions: Arthroscopic repair of a rotator cuff tear with use of the double-row suture anchor technique results in a much lower rate of failure than has previously been reported in association with either open or arthroscopic repair methods. Patients with an intact rotator cuff repair have better pain relief than those with a failed repair. After repair, large and massive rotator cuff tears result in more postoperative weakness than small tears do.

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

Several investigators have studied the clinical outcomes after arthroscopic rotator cuff repair and have reported that the short-term clinical outcomes are comparable with those of the traditional open and mini-open repair techniques[1-5]. More recently, investigators have attempted to correlate the integrity of the arthroscopic repair with postoperative function and have demonstrated widely varying results, with generally high failure rates[6-9]. All of those previous studies were performed with use of a simple single-row suture repair technique.

The concerns raised in those reports about repair integrity after arthroscopic surgery have resulted in a number of studies designed to analyze various repair techniques[10-12]. Specifically, those studies have evaluated the biomechanical strength, contact area, and failure modes of single-row suture anchor, double-row suture anchor, and transosseous repairs

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performed with various suturing patterns in relation to their ability to restore the native rotator cuff footprint. One of the implications of those studies and recent reports on double-row suture anchor fixation is that the repair techniques that are better able to restore the normal footprint of the rotator cuff will be stronger and have the best chance for healing because of the larger contact area[2]. The purpose of the present study was to evaluate the short-term results of arthroscopic repair with use of the double-row suture anchor technique and to correlate these results with the integrity of the rotator cuff as determined with postoperative arthrography.

Materials and Methods

Inclusion and Exclusion Criteria

Between 1999 and 2003, 197 all-arthroscopic rotator cuff repairs were performed by the senior surgeons (L.L. and B.T.). All shoulders in the present study had either an isolated supraspinatus tear or a supraspinatus tear with an infraspinatus extension. Seventeen shoulders in the present study had fraying of the subscapularis identified at the time of arthroscopy. However, no shoulder that required operative repair of the subscapularis tendon was included in the study. Shoulders with a full-thickness tear of at least one tendon as documented on a preoperative computed tomography arthrogram that had undergone repair of the rotator cuff lesion with use of the double-row suture anchor technique and had been followed for a minimum of two years after surgery were included in the present study. All shoulders had postoperative arthrography, a computed tomography arthrogram, or a magnetic resonance imaging arthrogram at a minimum of six months after surgery in order to evaluate the integrity of the rotator cuff repair. Approximately 750 rotator cuff repairs (including approximately 500 arthroscopic repairs and 250 open repairs) were performed during the period of the study. However, the exclusion criteria for entry into the study included single-row repair, open repair, a concomitant subscapularis tear, the refusal of the patient to have a postoperative arthrogram, and a duration of clinical follow-up of less than two years. One hundred and five shoulders met the inclusion criteria. The present study received institutional review board approval, and all patients were enrolled in compliance with this protocol.

The indication for surgery was the failure of conservative treatment, defined as a trial of physical therapy with the goal of strengthening of the rotator cuff, deltoid, and scapular stabilizers. The study cohort included ninety-five patients (forty-eight women and forty-seven men) who had had a mean age of fifty-two years (range, thirty-six to seventy-nine years) at the time of surgery. Ten patients had a bilateral procedure. The mean duration of follow-up was thirty-six months (range, twenty-four to fifty-eight months). Seventy-six patients had surgery on the dominant shoulder.

Classification of Rotator Cuff Tears

Each rotator cuff lesion was also evaluated in both the coronal and sagittal planes at the time of arthroscopy. In the coronal plane, the lesion was evaluated, according to the classification system of Patte, as distal (thirty-six tears; 34.3%), intermediate (forty-seven tears; 44.8%), or retracted (twenty-two tears; 21%)[13]. In our experience, we have found that the degree of coronal plane retraction, and not the absolute size of the lesion, has the greatest impact on the technical difficulty of repair of rotator cuff tears. Small tears were defined as supraspinatus ruptures with retraction to the articular margin on the humerus (Patte type 1). Large tears were defined as either intermediate or retracted supraspinatus lesions according to the Patte classification system (Fig. 1). All of the retracted supraspinatus tears were associated with at least an intermediate-level infraspinatus tear and were therefore classified as massive rotator cuff tears. Therefore, none of the retracted supraspinatus tears in our series were classified as large rotator cuff tears. In order to incorporate the sagittal plane of these tears into our classification scheme, we also considered supraspinatus tears that extended into the infraspinatus to be large tears as long as the degree of infraspinatus retraction was not greater than distal retraction as defined by Patte. Massive tears were defined as those that were characterized by a supraspinatus tear with retraction to the level of the glenoid and

Fig. 1

Illustrations depicting the Patte classification system for rotator cuff tears in the coronal plane. Stage 1 indicates retraction to the margin of the articular surface on the humerus, Stage 2 indicates retraction between the articular margin of the humerus up to the glenoid, and Stage 3 indicates retraction of the tendon to the level of the glenoid. (Reprinted, with permission, from: Patte D. Classification of rotator cuff lesions. Clin Orthop Relat Res. 1990;254:81-6.)

Fig. 2

Computerized tomography arthrogram showing a large rotator cuff tear following double-row suture anchor reconstruction. In cases of larger and massive tears, resection or release of the rotator interval is often performed in order to adequately mobilize the torn tendons for a so-called tensionless repair. As a result, leakage of contrast medium into the subacromial space as can be seen here is not a reliable method of assessing the integrity of the footprint reconstruction. Rather, evaluation of the integrity of the footprint is the method that we used to classify the structural integrity of rotator cuff repairs in shoulders with large and massive tears.

an infraspinatus tear that was at least of intermediate grade (that is, one with retraction medial to the articular margin of the humerus).

Patient Evaluation and Determination of the Structural Integrity of Repair

All patients underwent a standard history and physical examination and completed a standardized questionnaire that included pain scales and subjective functional assessments preoperatively and at least two years postoperatively. The visual analog scale score for pain (range, 0 to 15 points, with 0 points representing maximum pain), the Constant score, and the active range of motion were recorded for each shoulder[14]. All patients had computed tomography arthrography (103 shoulders) or magnetic resonance arthrography (two shoulders) preoperatively and at a mean of twenty-three months (range, six to forty-one months) postoperatively.

The structural integrity of the rotator cuff repair was evaluated by examining the computed tomography or magnetic resonance imaging arthrography images of the footprint reconstruction. An intact repair was defined as a complete anatomic reconstruction of the footprint. Intratendinous leakage, although stratified separately, was considered to be consistent with an intact repair. In cases of small tears, resection or release of the rotator interval was never necessary; thus, structural failure of the rotator cuff repair was considered to have occurred when there was any extravasation of contrast medium into the subacromial space. In cases of large and massive tears, an intact repair was defined as a complete anatomic reconstruction of the footprint. As the operative technique that was used to mobilize the torn tendon edges in cases of large and massive tears always required resection or release of the rotator interval to achieve an anatomic reduction, leakage of contrast medium into the subacromial space after rotator cuff repair could not be used as a method to evaluate the structural integrity of these repairs (Fig. 2). Rather, the arthrograms demonstrating extravasation of contrast medium through the footprint reconstruction were classified as demonstrating either small transtendinous leaks or large extravasations, although both were considered to be failures of repair. This subclassification was made in order to determine if the extent of leakage of contrast medium, and, therefore, the failure of repair, was correlated with the functional outcome. As described by Boileau et al., a transtendinous leak was considered to be evidence of partial healing[1].

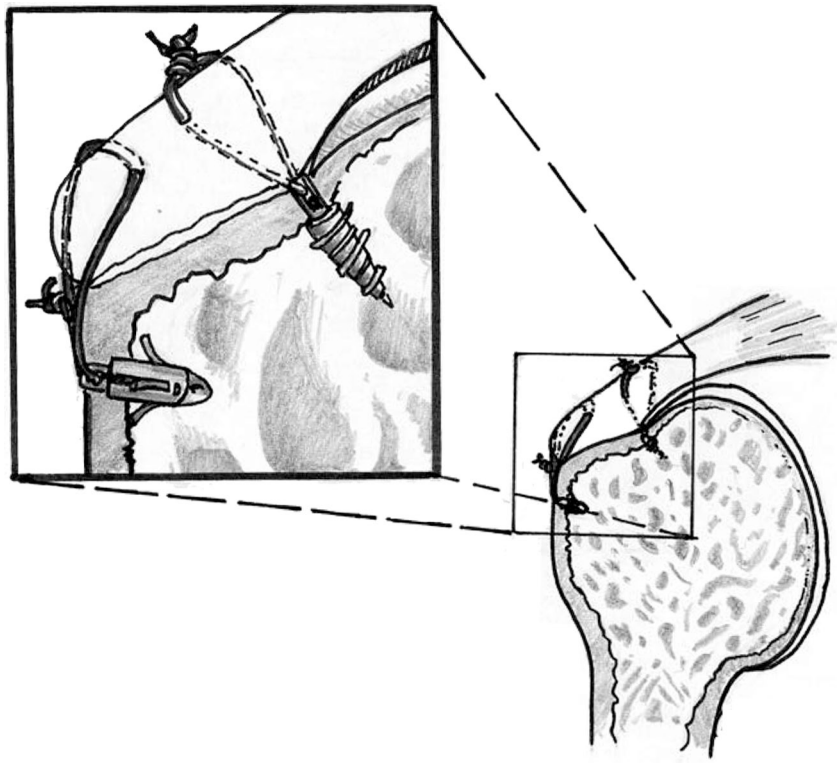

Fig. 3
Illustration depicting the restoration of the rotator cuff footprint with use of a double-row of suture anchors.

Strength-Testing

Manual strength-testing was performed for each shoulder preoperatively and at a minimum of two years postoperatively with use of a portable isometric dynamometer (Isobex 2.0; Cursor, Bern, Switzerland). Strength-testing was performed with the arm in 90° of abduction in the scapular plane and neutral rotation while the patient was standing with the dynamometer at shoulder level. The patient was instructed to hold this position with maximum force for three seconds during the measurements.

Arthroscopic Rotator Cuff Repair

All patients in the present study underwent regional anesthesia with an interscalene block before entrance into the operating room. The patients were placed in the beach-chair position with the arm forward flexed with 3 kg of traction. Three to five arthroscopic portals were used to perform the rotator cuff repair. Typically, these portals were placed posteriorly, posterolaterally, laterally, anterolaterally, anteriorly, and anteroinferiorly. The subacromial space was cleared of bursa, reactive synovitis, and subdeltoid adhesions, and acromioplasty was performed prior to inspection of the rotator cuff in order to classify the tear. The coracohumeral ligament, the superior capsule, and/or the rotator interval were released as needed in order to maximize the mobility of the rotator cuff prior to repair. Adequate release of the cuff was achieved when the tissue edges could be easily reduced over the greater tuberosity with use of a grasper instrument in order to avoid the so-called tension overload phenomenon[15].

After the greater tuberosity had been gently decorticated with a burr or shaver, the first anchor was placed at the junction of the articular cartilage and the medial aspect of the footprint on the greater tuberosity (Fig. 3). The sutures were passed through the tendon medially with use of a curved suture-passing device (Spectrum; Linvatec, Largo, Florida) as a shuttle relay device in a horizontal mattress pattern. As described by Lo and Burkhart[3], a medial row and a lateral row of anchors were placed on the border of the anatomic footprint of the superior rotator cuff (Fig. 4-A). The mean number of suture anchors (G2 anchor; Mitek, Raynham, Massachusetts) used for footprint reconstruction in the present series was 3.7. The sutures (#2 Ethibond; Ethicon, Somerville, New Jersey) from the lateral anchor were passed through the tendon edges either as U stitches, a lasso-loop, or simple stitches (Fig. 4-B). We believe that the lasso-loop technique allows for superior fixation in the tissues by approximating a Mason-Allen configuration through the rotator cuff (Figs. 4-C and 4-D). Fifty-nine shoulders with fraying, tearing, or instability of the biceps tendon were managed with biceps tenotomy (nine shoulders) or tenodesis (fifty shoulders). A subacromial decompression with acromioplasty was performed in all shoulders.

Rehabilitation

Our postoperative rehabilitation protocol restricted patients to pendulum exercises starting on the first postoperative day and continuing for three weeks, with the extremity resting in a

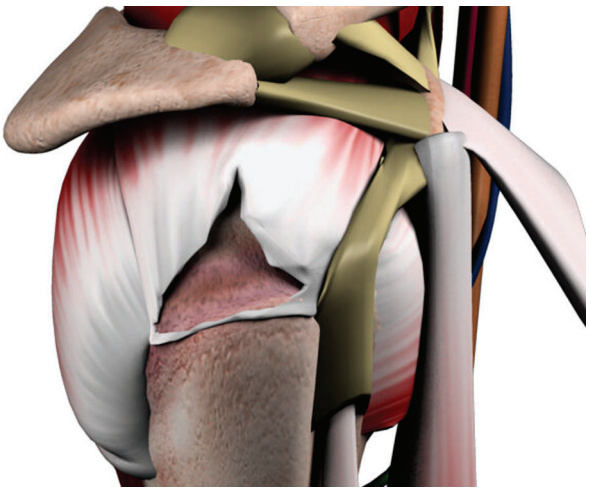

Fig. 4-A

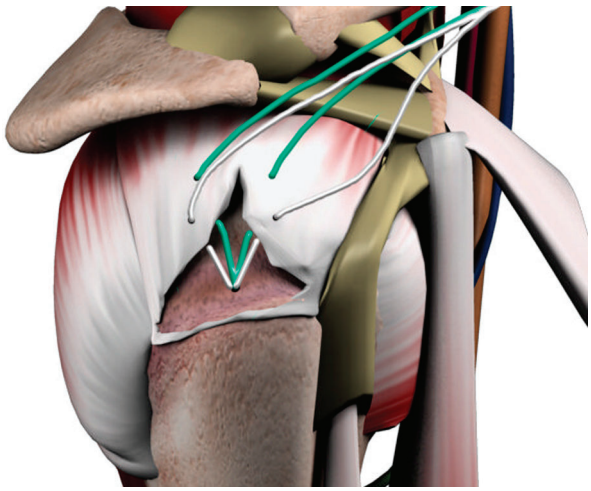

Fig. 4-B

Fig. 4-A In our experience, double-row suture anchor fixation is used for tears that have complete or near complete detachment of the tendon footprint in the sagittal plane. (Permission to reproduce this figure must be obtained from T.A.G. Medical Products, Kibbutz Gaaton, Israel.) **Fig. 4-B** The medial row of sutures is passed through the cuff prior to passing the sutures through the lateral edge of the torn tendon. (Permission to reproduce this figure must be obtained from T.A.G. Medical Products, Kibbutz Gaaton, Israel.)

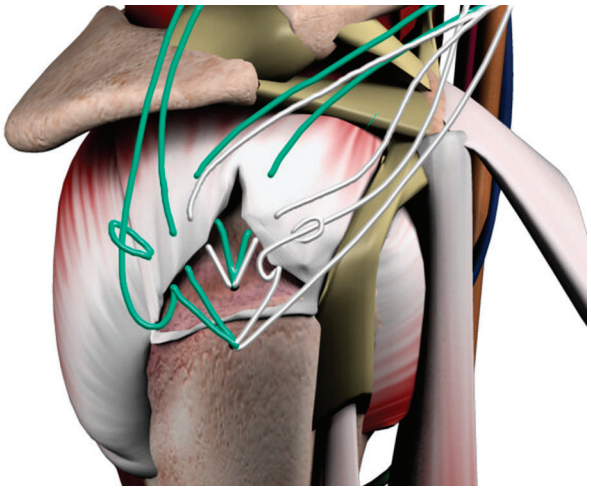

Fig. 4-C

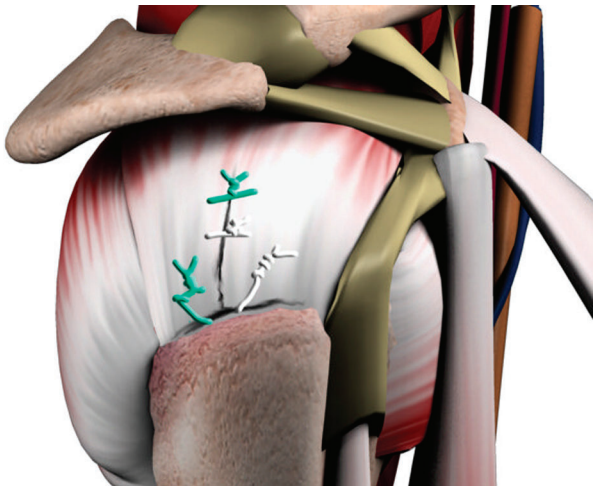

Fig. 4-D

Fig. 4-C The lasso-loop technique was used on the lateral row of sutures. We believe that this technique provides superior fixation in comparison with the simple suture configuration for the lateral row. (Permission to reproduce this figure must be obtained from T.A.G. Medical Products, Kibbutz Gaaton, Israel.) **Fig. 4-D** The completed double-row repair with reduction of the tendon over the entire surface area of the tendon footprint. (Permission to reproduce this figure must be obtained from T.A.G. Medical Products, Kibbutz Gaaton, Israel.)

30° abduction pillow made from a generic large stockinette and foam padding or pillow when the exercises were not being performed. After three weeks, the patients were instructed to commence passive range-of-motion exercises in the plane of the scapula with the assistance of a physical therapist. Active motion exercises were not permitted until six weeks after surgery, and hydrotherapy was strongly encouraged.

Statistical Analysis

Measurements are expressed as the mean and the standard deviation. The means were compared with use of the Student t test for continuous variables. The level of significance was set at $p < 0.05$. Single-variable regression analysis was used to determine if relationships between the etiology of the rotator cuff tear, the age of the patient, the duration of symptoms, and the Workers' Compensation status had a significant effect on the clinical outcome parameters evaluated in the present study.

Results

Pain Score, Strength, and Motion

Overall, the patients experienced marked pain relief after rotator cuff repair. The mean pain score on the visual an-

TABLE I Clinical Outcomes for Double-Row Rotator Cuff Repair in 105 Shoulders

	Preop.	Postop.	P Value
Pain score*† (maximum, 15) *(points)*	4.7	12.8	<0.0001
Active forward flexion†	108°	147°	<0.0001
Abduction	94°	142°	<0.001
Strength† (maximum, 25) *(kg)*	2.9	6.3	<0.001
Constant score† (maximum, 100) *(points)*	43.2	80.1	<0.001

*0 points represents maximum pain. †The values are given as the mean.

alog scale improved from 4.7 ± 4.2 (range, 0 to 15) preoperatively to 12.8 ± 3.0 (range, 5 to 15) postoperatively ($p < 0.0001$) (Table I). Shoulders with intact rotator cuff repairs had significantly more pain relief than did shoulders with failed repairs, with mean postoperative pain scores of 13.3 ± 2.6 (range, 5 to 15) and 11.2 ± 3.6 (range, 5 to 15), respectively ($p = 0.02$).

The active range of motion significantly improved after rotator cuff repair. The mean forward flexion improved from 108° ± 39° (range, 30° to 150°) preoperatively to 147° ± 12° (range, 90° to 150°) postoperatively ($p < 0.0001$). The mean abduction increased from 94° ± 40.5° (range, 20° to 150°) preoperatively to 142° ± 18° (range, 60° to 150°) postoperatively ($p < 0.001$). Strength also improved significantly after rotator cuff reconstruction, from a mean of 2.9 ± 1.4 kg (range, 0 to 8 kg) preoperatively to a mean of 6.3 ± 2.7 kg (range, 2 to 12.5 kg) postoperatively ($p < 0.001$).

In an attempt to determine the impact of failure of rotator cuff repair on the clinical outcome, we divided the shoulders into two cohorts (those with an intact rotator cuff repair and those with a failed repair) and compared the clinical outcomes between the groups. The mean forward flexion was 151° for the shoulders with an intact repair, compared with 142° for those with a failed repair ($p = 0.74$). The mean Constant score was 80.8 ($p = 0.17$) for the shoulders with an intact repair, compared with 76.4 for those with a failed repair. The mean strength was 12.9 kg for the shoulders with an intact repair, compared with 11.4 kg for those with a failed repair ($p = 0.32$). Interestingly, the mean postoperative pain score was 12.9 for shoulders with an intact rotator cuff repair as compared with only 11.4 for those with a failed repair ($p = 0.014$). A trend toward superior clinical outcomes was observed in shoulders with an intact rotator cuff repair, although pain was the only category in which a significant difference was achieved.

Overall, with the numbers studied, single-variable regression analysis of our data points did not reveal a significant relationship between age at the time of surgery, the degree of fatty infiltration, the duration of symptoms prior to surgery, or the duration of the follow-up period and the ultimate clinical outcome. Biceps tenotomy or tenodesis, when analyzed as an independent variable, did not produce a significant difference in the outcome parameters studied. In addition, Workers' Compensation status, the etiology of the tear (degenerative or traumatic), and the preoperative status of the biceps tendon did not have a significant influence on the ultimate outcome

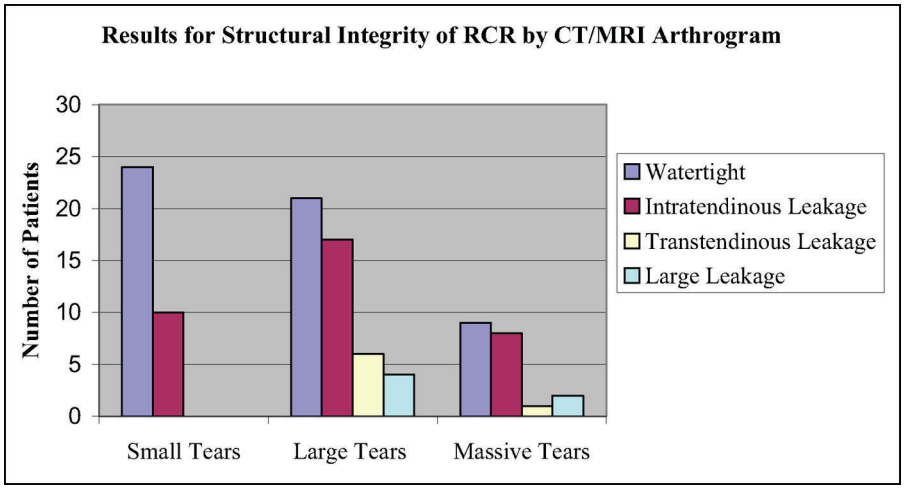

Fig. 5

Histogram illustrating the structural integrity after double-row rotator cuff repair according to the size of the tear.

in our study population, with the number of patients studied.

Constant Scores

The mean Constant score was 43.2 ± 15.1 points (range, 8 to 83 points) preoperatively and 80.1 ± 11.1 points (range, 46 to 100 points) at a minimum of twenty-four months postoperatively ($p < 0.001$) (Table I).

Analysis of Structural Integrity of Repair with Computed Tomography or Magnetic Resonance Imaging Arthrography

Only twelve of the 105 shoulders in the present study had structural failure of the double-row suture anchor repair as assessed with computed tomography or magnetic resonance imaging arthrography after a mean of twenty-three months of follow-up (Fig. 5). This result reflects the total number of repairs with structural failure as defined above, with eight shoulders having a small transtendinous extravasation and four having a large leak of contrast material[6]. There were no failures of repair in shoulders with small rotator cuff tears. In addition, the outcomes for shoulders that had undergone postoperative computed tomography or magnetic resonance imaging arthrography after less than twenty-four months of follow-up were compared with those for shoulders that had undergone the imaging study at a minimum of twenty-four months of follow-up in order to determine if this variation significantly impacted the clinical or radiographic result. The postoperative Constant score was 79.7 for the forty-four shoulders that had computed tomography or magnetic resonance imaging arthrography after less than twenty-four months of follow-up, compared with 81.1 for the sixty-one shoulders that had the imaging study after at least twenty-four months of follow-up ($p = 0.5$). We also compared the failure rates between these two groups of shoulders. Failure of the rotator cuff repair was documented in four of the forty-four shoulders that had the imaging study after less than twenty-four months follow-up, compared with eight of the sixty-one shoulders that had the imaging study after at least twenty-four months of follow-up; however, with these small numbers, this difference was not significant ($p = 0.27$). The numbers of shoulders that had failure of the rotator cuff repair in the large and massive rotator cuff tear cohorts were too small to analyze.

Comparison of Clinical Outcome Measures According to Tear Size

A comparative analysis of the clinical outcome measures in the present study between shoulders with small, large, and massive rotator cuff tears was performed. We could not identify any significant differences in the outcome measures between shoulders with large rotator cuff tears and those with massive rotator cuff tears. However, when the clinical outcome measures from the group of shoulders with small rotator cuff tears were compared with those for shoulders with either large or massive rotator cuff tears, there were several significant differences. The group of shoulders with small rotator cuff tears achieved a mean strength of 7.19 ± 3.0 kg (range, 2 to 12.5 kg) after rotator cuff repair, compared with only 5.4 ± 1.92 kg (range, 3 to 9 kg) for the group of shoulders with massive tears and 6.11 ± 2.53 kg (range, 2.0 to 12.0 kg) for the group of shoulders with large tears ($p < 0.05$ for both comparisons). Interestingly, the amount of preoperative active abduction and forward flexion was significantly lower in the group of shoulders with large and massive rotator cuff tears than in the group of shoulders with small rotator cuff tears ($p < 0.05$), although the postoperative values for these variables did not differ significantly between the groups. Finally, we could not identify any difference between the groups with regard to the preoperative and postoperative values for pain, the Constant score, or active external or internal rotation ($p > 0.05$).

Complications

There were no surgical complications.

Discussion

The technique for double-row suture anchor fixation for arthroscopic rotator cuff repair was first described by Lo and Burkhart[3]. Those authors proposed that by placing two rows of suture anchors, one on the medial side of the footprint and the other on the lateral side, a more anatomic repair configuration could be achieved. The result, they hypothesized, would be a stronger repair construct and a larger contact area for healing, yielding superior clinical outcomes and a more durable rotator cuff repair.

To our knowledge, the present report describes the first study to prospectively evaluate the structural integrity of arthroscopic rotator cuff repairs performed with use of the double-row suture anchor technique and to correlate the integrity of these repairs with clinical outcomes. The rate of structural failure after double-row fixation was only 11% and, to our knowledge, this value represents the lowest rate of structural failure after either open or arthroscopic repair as reported in the literature. Galatz et al., in a study on the results of all-arthroscopic reconstruction of large or massive rotator cuff tears with use of single-row suture anchors and simple sutures, reported recurrence of the tear in seventeen of eighteen patients as assessed with ultrasonography[6]. Boileau et al., in a study of sixty-five consecutive patients who had been managed with arthroscopic repair of an isolated supraspinatus tear with the tension band suture technique, reported that forty-six of the sixty-five repairs remained structurally intact as demonstrated with computed tomography arthrography or magnetic resonance imaging at a minimum of six months after surgery[1]. Interestingly, Boileau and colleagues used a coronal plane classification system proposed by Thomazeau in order to assess the size of the supraspinatus tears so that thirty-two of the sixty-five patients, despite having only one tendon tear, were classified as having a large tear. Sugaya et al. conducted a retrospective study in order to compare the clinical and structural outcomes of arthroscopic rotator cuff repairs performed with use of double-row and single-row suture anchor fixation[2]. Thirty-nine patients managed with

single-row suture anchor repair and forty-one patients managed with double-row suture anchor repair were evaluated clinically and with magnetic resonance imaging before and after surgery. The investigators reported that double-row suture anchor fixation resulted in a significantly stronger repair with a lower failure rate, although the use of magnetic resonance imaging without intra-articular contrast medium made it difficult to draw definitive conclusions about the integrity of these repairs. Gleyze et al. evaluated the structural integrity of arthroscopic repairs of isolated supraspinatus tendons in a multicenter study and found that fifty-three of eighty-seven repairs remained intact[4]. Wilson et al. performed second-look arthroscopy for thirty-three patients who had had arthroscopic staple fixation of tears varying in size from small to large and reported that twenty-two of the thirty-three repairs remained intact at the time of arthroscopic staple removal, approximately three months after surgery[5]. Our clinical results compare favorably to those published in the literature for rotator cuff repair with use of open, mini-open, or arthroscopic techniques[8,14,16-24].

In the present study, the structural integrity of rotator cuff repairs was analyzed with use of computed tomography or magnetic resonance imaging arthrography. Charousset et al., in a recent study that analyzed the accuracy of computed tomography or magnetic resonance imaging arthrography for the detection of both partial and full-thickness rotator cuff tears, reported that the method demonstrated 99% sensitivity and 100% specificity for the analysis of lesions involving the supraspinatus[25]. Other authors also have advocated computed tomography arthrography as an excellent imaging modality for the evaluation of rotator cuff pathology[26-30]. One important consideration in the present study was related to the analysis of rotator cuff integrity with use of computed tomography arthrography after the repair of large and massive tears. We believe that it is critically important to assess the thickness and integrity of the footprint reconstruction rather than the presence or absence of leaking contrast medium after rotator cuff reconstruction in patients with larger tears because our operative technique for releasing retracted cuff tears often includes excision of part or all of the rotator interval. This technique is sometimes necessary in order to obtain adequate mobilization of the retracted tendons and is an excellent technique for preventing excessive tension at the site of a rotator cuff repair. Furthermore, we suspect that at least some of the intratendinous leakage identified during the analysis of postoperative images may, in fact, have been the result of contrast medium traveling along the suture line through the tendon, although it is difficult to determine the importance of this observation.

At the present time, the optimal technique and anchor-suture configuration have not been established for arthroscopic rotator cuff repair[1]. Nevertheless, why might double-row suture anchor fixation explain the superior results of this study with regard to repair integrity? Within the last few years, several investigators have analyzed the anatomy of the rotator cuff footprint as well as the strength, contact area, and contact pressure of various repair configurations in order to determine the optimal construct for tendon healing after rotator cuff repair. Apreleva et al. evaluated the three-dimensional structure of the rotator cuff footprint and determined that single-row suture anchor repairs provide only point fixation in the area immediately surrounding the anchor and, therefore, cannot restore the anatomic footprint[12]. Tuoheti et al. performed a cadaver study to compare the contact pressure and contact area associated with three different repair methods: single-row suture anchor fixation, transosseous repair, and double-row suture anchor fixation[11]. The authors reported that the contact pressures for double and single-row suture anchor fixation were not significantly different and that both generated significantly higher contact pressure than did the transosseous repair. However, their study also demonstrated that the contact area for single-row fixation was limited to the area immediately surrounding the anchor whereas the double-row suture anchor fixation had the largest and most anatomic contact area of the three fixation methods studied. Therefore, they concluded that the double-row suture anchor method was likely to be superior to the single-row technique for optimizing tendon healing after rotator cuff repair. Waltrip et al. compared the strength of double-row, single-row, and transosseous repairs in a cadaver study[10]. They found that the mean number of cycles to failure for the double-row suture anchor repairs was significantly greater than those for the single-row simple suture repairs or the transosseous repairs performed with a mattress stitch. Since 88.6% of the repairs in our study healed completely without structural failure after a minimum of twenty-four months follow-up, the double-row suture anchor technique may be the optimal construct for arthroscopic rotator cuff repair.

Several authors have identified a strong correlation between improved functional results and intact rotator cuff repairs[1,6,9,31]. Indeed, our study supports this trend even if significance was not achieved. In the twelve shoulders from the present series that had either partial healing or complete failure of the repair, the strength of the rotator cuff was diminished relative to that in shoulders with an intact repair of the same size tear. Interestingly, pain relief in shoulders with intact rotator cuff repairs significantly improved as has been observed in other studies[1,6,31,32].

One potential weakness of the present study is that it represents an evaluation of structural integrity and clinical outcomes after a mean of thirty-six months. Other authors have reported on the long-term clinical outcomes of rotator cuff repair[33,34], but we suspect, as Boileau et al. suggested, that patients with an intact rotator cuff repair will continue to do well in the long term and may even have improvement[1]. A second weakness of the present study is that we did not track the number of rotator interval releases performed for mobilization of the torn tendons in large and massive rotator cuff tears and, therefore, we cannot assess the impact of rotator interval release as an independent variable on the outcome parameters studied. Finally, although our results related to structural integrity support arthroscopic double-row suture anchor fixa-

tion as the optimal repair technique, we did not perform a randomized direct comparison of single-row, arthroscopic double-row, and open double-row repair, so we are unable to definitively conclude that this technique for rotator cuff repair is superior to all others.

In conclusion, the double-row suture anchor technique for arthroscopic rotator cuff repair resulted in superior tendon healing as compared with previously studied open and other arthroscopic methods of repair. Intact rotator cuff repairs resulted in markedly improved pain relief in comparison with repairs that failed or only partially healed. Shoulders with repaired large and massive rotator cuff tears had less strength than those with smaller tears. These findings suggest that the double-row suture anchor configuration may be the optimal repair construct for arthroscopic rotator cuff repair, although long-term studies will be needed to validate this concept. ■

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