Deltoid Muscle Pressures During Arthroscopic Rotator Cuff Repair

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abstract

Full article available online at Healio.com/Orthopedics. Search: 20121217-15

The purpose of this study was to investigate deltoid compartment pressures during arthroscopic rotator cuff repair using modern pressure pumps to achieve visualization.

Twelve patients undergoing arthroscopic rotator cuff repairs were monitored for deltoid compartment pressure changes intraoperatively. Pre-, intra-, and postoperative intramuscular pressures were recorded. All patients demonstrated varying degrees of swelling due to fluid extravasation. Swelling was qualified as mild, moderate, or severe by clinical assessment and quantified objectively using a pressure monitor to record deltoid compartment pressures. Clinically, severe swelling occurred in 4 patients, all of whom underwent procedures lasting longer than 90 minutes. Objectively, no patient had evidence of dangerously elevated pressure measurements. The mean increase in compartment pressures was 9 mm Hg. All patients were treated and discharged as outpatients. No patient required more than oral narcotic analgesics for postoperative pain control beyond the postanesthesia care unit stay.

Arthroscopic rotator cuff repair may lead to clinically impressive swelling, but within the current study group, no evidence existed of clinically significant, persistent elevation of deltoid compartment measures using current arthroscopic techniques and arthroscopic pump systems. However, caution should be observed with regard to extended operative times and elevation of pump pressures.

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Drs McBrayer, Debelak, Fernicola, and Tu have no relevant financial relationships to disclose. Dr Baker is a consultant for Arthrex, Inc.

The authors thank Stryker Instruments, Kalamazoo, Michigan, for providing the equipment used in the study.

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doi: 10.3928/01477447-20121217-15

Figure: Illustration of compartment pressure measurement of the anterior, middle, and posterior compartments of the deltoid muscle in the shoulder.
Improvements in instrumentation and techniques have allowed surgeons to diagnose and treat many shoulder disorders arthroscopically, and many surgeons prefer arthroscopic rotator cuff repair to conventional open or mini-open rotator cuff repair due to improved tear size and pattern visualization, decreased deltoid morbidity, fewer spatial constraints, and decreased postoperative pain. Studies have demonstrated that current arthroscopic repair techniques allow surgeons to achieve excellent or satisfactory results in more than 90% of patients.

Arthroscopic repair remains a time- and expertise-intensive procedure. Patients requiring rotator cuff repair often have associated pathologic entities in the glenohumeral joint, subacromial space, and distal clavicle that require additional treatment that can lead to lengthy operative times and pronounced swelling around the shoulder. In addition, noticeable fluid extravasation during arthroscopic rotator cuff repair may be due to the lack of capsular restraints in the subacromial space.

Several studies have reported deltoid pressures after shoulder arthroscopy. None of these studies included patients undergoing arthroscopic rotator cuff repair or procedures requiring extended extracapsular time. Iatrogenic compartment syndrome, rhabdomyolysis, neurologic injury, respiratory distress, and skin necrosis have all been reported following arthroscopic procedures secondary to fluid extravasation. The purpose of the current study was to investigate deltoid compartment pressures during arthroscopic rotator cuff repair using modern pressure pumps to achieve visualization.

Materials and Methods

Institutional review board approval was obtained prior to the study. Fifteen patients were enrolled in the prospective study. Selection criterion was a high clinical suspicion of a rotator cuff tear based on physical examination and imaging studies. No patients were excluded based on concomitant medical or musculoskeletal disorders.

Twelve of the 15 patients underwent an arthroscopic rotator cuff repair. Three patients did not undergo rotator cuff repair and were thus excluded. Of the 12 patients undergoing arthroscopic rotator cuff repair, 6 were men and 6 were women. Mean patient age was 61 years. All patients underwent intra-articular examinations and subacromial procedures. Average tear size was 3 to 4 cm. Six patients underwent concomitant procedures, such as biceps tenotomy, Bankart repair, and arthroscopic excision of the distal clavicle (Table 1).

Intraoperatively, intramuscular pressures were recorded with an Intra-Compartmental Pressure Monitor System (Stryker Instruments, Kalamazoo, Michigan). Preoperative measurements were obtained immediately prior to skin incision and introduction of the arthroscope into the glenohumeral joint.

Because it is well documented that the deltoid is a multipennate muscle with fascial septations, measurements were obtained from the anterior, middle, and posterior regions of the deltoid. This protocol reduced the chance that an isolated pressure within 1 region of the deltoid could be overlooked. Anterior deltoid region measurements were obtained 2 to 3 cm distal and just medial to the anterior acromial edge. Middle or lateral measurements were recorded 3 to 4 cm distal to the acromion and over the middle region of the deltoid. Posterior deltoid region measurements were recorded 2 to 3 cm distal and just medial to the posterior acromial edge. The needle insertion sites were circled using a marking pen (Figure 1).

Postoperative measurements were obtained from the same regions as the preoperative measurements while avoiding passage of the needle through the same skin puncture sites. Measurements were not taken from arthroscopic portals. Care was taken to position the measurement needle within the deltoid muscle and to appropriately orient the measurement device.

An arthroscopic pump was used in each surgery. The Continuous Wave Pump (Arthrex, Inc, Naples, Florida) was used

### Table 1:

<table>
<thead>
<tr>
<th>Patient No./ Sex/Age, y</th>
<th>Rotator Cuff Tear</th>
<th>Patient Positioning</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/F/68</td>
<td>Crescent</td>
<td>Beach chair</td>
<td>RCR, biceps tenotomy, SAD</td>
</tr>
<tr>
<td>2/F/71</td>
<td>Crescent</td>
<td>Beach chair</td>
<td>RCR, Bankart repair</td>
</tr>
<tr>
<td>3/F/58</td>
<td>Crescent</td>
<td>Beach chair</td>
<td>RCR, SAD</td>
</tr>
<tr>
<td>4/F/55</td>
<td>Crescent</td>
<td>Beach chair</td>
<td>RCR, labral repair</td>
</tr>
<tr>
<td>5/M/54</td>
<td>U-shaped</td>
<td>Beach chair</td>
<td>RCR</td>
</tr>
<tr>
<td>6/M/37</td>
<td>Subscapularis</td>
<td>Beach chair</td>
<td>Subscapularis repair, labral repair</td>
</tr>
<tr>
<td>7/F/53</td>
<td>Crescent</td>
<td>Beach chair</td>
<td>RCR (revision)</td>
</tr>
<tr>
<td>8/F/68</td>
<td>Massive, L-shaped</td>
<td>Beach chair</td>
<td>RCR, SAD</td>
</tr>
<tr>
<td>9/M/60</td>
<td>Crescent</td>
<td>Beach chair</td>
<td>RCR, labral debridement</td>
</tr>
<tr>
<td>10/M/60</td>
<td>Massive, 2 tendons</td>
<td>Beach chair</td>
<td>RCR, biceps tenotomy</td>
</tr>
<tr>
<td>11/M/83</td>
<td>L-shaped</td>
<td>Lateral</td>
<td>RCR, biceps tenotomy, DCE</td>
</tr>
<tr>
<td>12/M/64</td>
<td>Longitudinal</td>
<td>Lateral</td>
<td>RCR</td>
</tr>
</tbody>
</table>

Abbreviations: DCE, distal clavicle excision; RCR, rotator cuff repair; SAD, subacromial decompression.

*Refers to supraspinatus tendon unless otherwise specified.
in 8 patients, and the Dyonics 25 Fluid Management System (Smith & Nephew, Andover, Massachusetts) was used in 4 patients. Pump pressures were uniformly set at 40 mm Hg. Three patients required additional intraoperative pump pressure settings to assist with visualization.

Two surgeons (P.J.F., C.L.B.) participated in the study. Patient positioning, pump settings and adjustment, repair technique, and all other aspects of the cases were performed in a routine fashion and were not varied. Ten patients were positioned in the beach-chair position and 2 were positioned in the lateral decubitus position, according to the surgeon’s preference.

The start time for each surgery was recorded as beginning when the arthroscope was positioned in the glenohumeral joint through a routine posterior starting portal. The subacromial time was recorded as beginning when the arthroscope was reintroduced above the posterior rotator cuff in the subacromial space. The end time was recorded as beginning when the arthroscope was removed from the subacromial space. No attempt was made to manually express extraneous fluid from the shoulder prior to postoperative measurements.

Clinical evaluation of swelling was a subjective description of the general shoulder swelling perceived at the end of surgery but prior to the postoperative measurements in the deltoid. In addition, the number of 3-L bags of arthroscopic irrigation, anchors, and cannulas used, the type of procedure performed, and the tear type were recorded. For each arthroscopic rotator cuff repair, an 8.25-mm lateral and a 7.0-mm anterior cannula (Arthrex, Inc) were used.

The correlations between the number of bags used, the clinical impression of swelling, intraoperative pressure increases, and surgical times were analyzed using correlation analysis. The relationships between the number of bags used and surgical time, between rotator cuff tear size and surgical time, and between tear size and the number of bags used were analyzed by linear regression analysis. The comparisons of the pressures between pre- and postoperative anterior, middle, and posterior deltoid compartment measurements were performed by paired t test. The comparisons of the pressure elevations among deltoid compartment measurements were analyzed with analysis of variance. The comparisons among the clinical assessments of swelling at each respective deltoid compartment were also analyzed with analysis of variance.

RESULTS

Twelve of the 15 patients enrolled in the study underwent arthroscopic rotator cuff repair. Of the 3 patients who did not undergo arthroscopic rotator cuff repair, 1 had an irreparable supraspinatus tear due to fatty atrophy; 1 had minimal (less than 50%) articular-sided rotator cuff tearing and adhesive capsulitis (treated with lysis of adhesions), and 1 had a partial (less than 50%) articular-sided supraspinatus tear (treated with debridement).

Table 2 shows pressure measurements in the 12 patients who ultimately underwent rotator cuff repair. The mean difference (9 mm Hg) between patients’ pre- and postoperative pressure measurements reached statistical significance in all 3 areas of the deltoid (anterior, $P=0.005$; middle, $P=0.007$; posterior, $P=0.001$). However, only 2 postoperative compartment measurements exceeded 30 mm Hg; in each instance, repeated measurements were taken, and the measurements fell below 30 mm Hg within minutes of the end of surgery. No measurements were taken in the postanesthesia care unit because no patient had clinical findings suggesting compartment syndrome. Two patients were monitored overnight because of a history of sleep apnea, but no patient required intravenous narcotics outside of their postoperative care unit stay.

Clinical assessment of swelling was associated with postoperative pressure measurements, but this did not reach statistical significance for the middle or posterior compartments ($P=0.203$ and 0.792, respectively). Clinical assessments regarding mild swelling were associated with smaller increases in pressure in the anterior compartment ($P=0.44$). Compartment measurements in patients with subjectively judged mild, moderate, and severe swelling averaged 14, 17, and 21 mm Hg, respectively.

A linear relationship existed between the number of bags used and the subacromial time of the procedure ($P=0.002$). No significant correlation was found between the amount of fluid (number of bags) used and the postoperative increase in pressure for any compartment.

A significant positive correlation existed between tear size and total operative time ($r=0.754; P=0.005$) (Figure 2). A significant positive correlation also existed between tear size and subacromial time ($r=0.841; P=0.001$) (Figure 3). Similarly, a significant positive correlation existed between tear size and the number of bags of arthroscopic irrigation used ($r=0.640; P=0.025$) (Figure 4).

Linear regression analysis demonstrated that as the tear size increased 1 cm, 1 additional 3-L bag of fluid was used. Linear regression models also demonstrated that as the tear size increased 1 cm, the average subacromial time increased by 16.3 minutes and the total operative time increased by 13.4 minutes.

DISCUSSION

Swelling after arthroscopic surgery is a fairly common finding, but an ensuing com-
Compartment syndrome is a rare entity. A literature search revealed several case reports of compartment syndrome of the shoulder resulting from arthroscopy, as well as from other seemingly trivial trauma, and 3 studies reporting in vivo deltoid compartment measurements during shoulder arthroscopy. None of these studies included patients undergoing arthroscopic rotator cuff repair or any other prolonged subacromial procedure.

Lee et al. used a slit catheter to measure deltoid compartment pressures in 24 patients. Eighteen surgeries were performed using gravity, and 6 were performed with an infusion pump with settings not specified. A minimal elevation of deltoid pressures occurred during intra-articular procedures (9 mm Hg). Subacromial procedure (extracapsular) deltoid pressures were as high as 48 mm Hg using gravity and 91 mm Hg using a pump. The authors found that pressures returned to normal rapidly after the gravity or pump pressure head was removed.

Ogilvie-Harris and Boynton studied deltoid pressures in 25 patients using a slit catheter for continuous measurements and a pressure pump with unspecified settings for fluid management. They noted that pressures after extracapsular procedures rose significantly more than during intracapsular procedures (72 vs.

### Table 2

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Preop Measurement, mm Hg</th>
<th>Postop Measurement, mm Hg</th>
<th>Swelling</th>
<th>Total Operative Time, min</th>
<th>Subacromial Time, min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ant</td>
<td>Mid</td>
<td>Post</td>
<td>Avg</td>
<td>Ant</td>
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<tr>
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<td>12</td>
</tr>
</tbody>
</table>

Abbreviations: Ant, anterior; Avg, average; Mid, middle; Post, posterior; Postop, postoperative; Preop, preoperative.

![Figure 2: Fitted line plot showing regression analysis results of total operative time vs tear size. Abbreviations: R-Sq, coefficient of determination; R-Sq (adj), adjusted coefficient of determination; S, error mean square.](image2)

![Figure 3: Fitted line plot showing regression analysis results of subacromial time vs tear size. Abbreviations: R-Sq, coefficient of determination; R-Sq (adj), adjusted coefficient of determination; S, error mean square.](image3)
27 mm Hg). Average operative time was 46 minutes.5

Carr and Murphy6 used the Intra-Compartmental Pressure Monitor System 295-1 (Stryker Instruments) to investigate deltoid and supraspinatus pressure measurements during shoulder arthroscopy in 24 patients. Gravity from an 8-ft height was used to assist in 8 intra-articular diagnostic arthroscopies, 8 transglennoid Bankart repairs, and 8 arthroscopic acromioplasties. Postoperative deltoid and supraspinatus measurements were highest in the acromioplasty group.8

In the current study, despite up to 116 minutes of total operative time (average, 78 minutes) and 96 minutes of subacromial time (average, 58 minutes), only 2 patients demonstrated deltoid pressures higher than 30 mm Hg. In these patients, pressures in the deltoid rapidly decreased within minutes after surgery, demonstrating that, within these parameters, deltoid pressures increase, but these elevations are modest and rapidly decrease at the end of surgery.

The authors used the Intra-Compartmental Pressure Monitor System for static measurements for several reasons. The monitor is easily accessible in most clinical institutions, making this study’s results reproducible. The monitor is reliable, and the possibility of it becoming dislodged or interfering with the procedure is minimal. In addition, the current study’s focus was to determine whether a prolonged, unsafe increase in deltoid pressures occurred after arthroscopic rotator cuff repair, and the authors do not believe that continuous pressure measurements are necessary for this purpose. Placing 3 slit measurement devices in the anterior, middle, and posterior deltoid would have been cumbersome.

This study’s finding that the amount of fluid used intraoperatively did not correlate with the postoperative pressure increase is not surprising; Carr and Murphy6 reported a similar finding. Most of the fluid is likely lost to surrounding catch bags, the operating room floor, and the surrounding subcutaneous soft tissues around the shoulder. No attempt to monitor these sites was made during the current study given the difficult nature and imprecise nature of that task.

CONCLUSION

A statistically significant increase in deltoid compartment pressures occurred after arthroscopic rotator cuff repair. No evidence existed of clinically significant, persistent elevation of deltoid compartment pressures using current arthroscopic rotator cuff repair techniques, including the use of a pump to regulate flow and the use of cannulas and current ablation and cautery technologies to keep inflow pressures low.

Postoperative elevated pressures were transient and resolved in minutes despite persistent clinical swelling. This study found no significant correlation between the amount of fluid used intraoperatively and the postoperative increase in pressure.

Arthroscopic rotator cuff repair may lead to clinically impressive swelling, but no evidence exists of a lasting effect of elevated deltoid muscle pressures using current arthroscopic pump systems. However, caution should be used with regard to extended operative times and elevated pump pressures.

REFERENCES