Should Acute Anterior Dislocations of the Shoulder Be Immobilized in External Rotation? A Cadaver Study

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Running title

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ABSTRACT

Introduction: The high recurrence rate associated with anterior shoulder dislocations may reflect inadequate healing of a Bankart lesion when the arm is immobilized in internal rotation. This study investigates the effect of external rotation (ER) of the humerus on the glenoid-labrum contact parameters of Bankart lesions in a human cadaveric model.

Methods: Ten human cadaveric shoulder girdles were fixed to a testing jig, a Bankart lesion was created arthroscopically, and a force sensor was placed between the detached labrum and the glenoid rim. The contact force between the glenoid labrum and the glenoid was measured in 60° of internal rotation, neutral rotation, and 45° of ER. The measurements were repeated three times in each position and the mean contact force calculated for each position of rotation.

Results: There was no detectable contact force with the arm in internal rotation. The contact force increased as the arm passed through neutral and reached a maximum at 45 degrees of ER. The contact force returned to 0 when the arm was returned to neutral. The mean contact force at 45 degrees of ER was 83.5 g.

Discussion and Conclusion: External rotation resulted in a significant increase in contact force between the labrum and glenoid. The improved soft-tissue contact parameters achieved in external rotation may influence the healing of a Bankart lesion. Immobilization of first-time anterior

shoulder dislocations in an external rotation brace may reduce the high recurrence rate associated with this injury.

INTRODUCTION

Acute post-traumatic anterior dislocation of the shoulder is associated with a Bankart lesion in up to 97% of young patients. [1-3] Management of the initial anterior shoulder dislocation remains controversial. Conventional non-operative management of sling immobilization with the arm in adduction and internal rotation has been applied widely. The recurrence rate for anterior instability after non-operative treatment in the young patient population is extremely high, and likely reflects a failure of adequate healing at the tissue-bone interface of the Bankart lesion when the arm is immobilized in internal rotation. [3-10]

Sling immobilization following dislocation is of questionable benefit. Hovelius and coworkers reported no difference in recurrence rate (50%) when a cohort of patients immobilized for three to four weeks was compared to a cohort who began early motion. [11] Early surgical intervention, in contrast, has proven to be superior to non-operative management in certain patient populations. [4, 9, 10] Arthroscopic treatment of acute shoulder dislocations has been reported to be successful in as high as 90% of patients.[9]

It is well known that the anteroinferior stabilizing structures of the shoulder are relaxed when the arm is positioned in the adducted and internally rotated position. This may allow medial displacement of the detached glenoid labrum after injury and account, in part, for the high recurrence rate. Several studies have employed modern imaging techniques to investigate how arm position might influence the position of tissues in a Bankart lesion. [12, 13] Itoi and co-workers recently used magnetic resonance imaging to assess the position of the Bankart lesion with the arm in internal versus external rotation in patients who had sustained a primary dislocation. [13] This study demonstrated that immobilization of the arm in external rotation better approximates or reduce the Bankart lesion anatomically to the glenoid neck compared to the conventional immobilization position of internal rotation. The position of the tissues following an acute dislocation may play an important role in the 'stability' achieved following healing. Itoi and colleagues also examined the effect of arm position on displacement of a simulated Bankart lesion. [14] Using electronic transducers in cadaveric specimens stripped of muscle, they identified a "coaptation zone" in which the edges of the simulated lesion remained approximated. [14]

To date, no study has assessed the effect of arm position on the contact force at the bone-labrum interface of a Bankart lesion. The objective of this study was to quantify the effect of external rotation of the humerus on the contact parameters of a Bankart lesion in a human cadaveric shoulder model. If we can improve the bone-soft tissue contact parameters at the site of injury, we may be able to reduce the recurrence rate after primary post-traumatic anterior shoulder dislocation.

METHODS

Ten fresh frozen human cadaveric shoulder girdles (age range 45-60 years old) were stripped of deltoid muscle to facilitate access to the rotator cuff musculature and the glenohumeral joint. Specimens were mounted through the medial border of the scapula to a testing jig. Using standard anterior and posterior arthroscopy portals, a Bankart lesion was created with a curved periosteal elevator. The elevator was introduced beneath the labrum and advanced medially along the glenoid neck for approximately one centimeter. Lesions were created from the 3 o'clock to the 6 o'clock position for the right shoulders, and from 6 o'clock to 9 o'clock for the left shoulders. [15] All irrigation fluid was removed from the joint. The medial border of the scapula was held vertically and the glenohumeral articulation held in neutral abduction. A rod was inserted retrograde into the humeral shaft and fixed to a mechanical rotation device to control rotation. A pin was inserted perpendicular to the long axis of the humerus into the bicipital groove, and a goniometer was fixed to the stand below the pin to facilitate accurate measurement of humeral rotation. A six-degree-of-freedom tracking device (Polhemus, Burlington, VT) was attached to the humeral head to record any translations or rotations of the humerus during testing. An electronic force sensor (0.12

mm thick, Flexiforce, TekScan, South Boston, MA) was passed beneath subscapularis and placed between the detached labrum and the anterior margin of the glenoid rim. A schematic of the testing apparatus is illustrated in Figure 1.

The contact force between the glenoid labrum and the glenoid was continuously measured while the humerus was rotated in an arc from 60 degrees of internal rotation to 45 degrees of external rotation and held for 20 seconds. The peak load at neutral rotation and at 45 degrees of external rotation were determined for each specimen in three successive runs. A repeated measures analysis of variance was applied to the data collected at these two points of rotation (Statistica, Statsoft, Tulsa, OK).

RESULTS

There was no detectable contact force with the arm in internal rotation. Only six of the ten specimens demonstrated any measurable contact force in the neutral position. The contact force increased significantly as the arm passed through neutral and reached a maximum at 45 degrees of external rotation ($p<0.05$). The interspecimen reproducibility revealed some variation between cadaver samples with regards to the maximum load achieved during external rotation. The mean contact force at 45 degrees of external rotation was 83.5 g (SD 37.7 g). Figure 2 presents a typical load versus time output from one of the specimens as the shoulder was rotated from internal rotation to 45 degrees of external rotation and held for 20 seconds and repeated 3 times. In this example, the contact force returned to baseline when the arm was returned to internal rotation. The load did however decrease during successive runs which reflects the viscoelastic nature of biologic tissues.

The variation within each cadaver specimen and reproducibility between specimens was examined. The intraspecimen maximum contact force in external rotation was found during the first run in all specimens and decreased between 3 and 11% with the two subsequent rotations (Figure 3). The reduction in force with repeated loading reflects the viscoelastic nature of the soft tissues. Three specimens were retested after 24 hours and the results were within 3.5 % of the results on the previous day.

The three-dimensional tracking data confirmed that the humeral head remained seated within the glenoid when the arm was taken from neutral rotation to 45 degrees of external rotation. Translations in all planes were less than 2 mm for all shoulders tested. Rotation analysis revealed the humeral head to be rotating about the superior-inferior axis.

DISCUSSION

The high rate of recurrence after non-operative treatment of anterior shoulder dislocations is well known. This risk appears to be age related; younger patients demonstrate higher rates of recurrence. [8, 11, 16] In addition, it has been demonstrated that in certain circumstances early surgical intervention may be superior to non-operative management of the anterior shoulder dislocation. [9, 10]

Several imaging studies of patients after anterior dislocations may help explain the high recurrence rate associated with non-operative treatment. In 1992, Jim and colleagues reported on 74 double-contrast CT arthrograms in a patient population in which instability was the most common complaint. [12] Patients were imaged in both internal and external rotation and the authors concluded that nearly all abnormalities of the anterior labrum or capsule were observed in internal rotation. This can be attributed to the tensioning of the anterior structures in external rotation, and their laxity in internal rotation, as has since been described with kinematic MRI studies. [17] More recently, in an *in vivo* magnetic resonance imaging study of anterior shoulder dislocations, Itoi *et al* demonstrated coaptation of Bankart lesions with external rotation of the arm. [13] Contact force and area between the labrum, capsule, and glenoid were significantly improved in external versus internal rotation.

In order for healing to occur at the interface of the Bankart lesion there must be adequate tissue apposition between the capsulo-labral complex and the glenoid. In addition to changes in tissue tension and position with arm rotation, intra-articular hematoma following an acute shoulder dislocation has also been implicated as a factor contributing to the high recurrence rate with non-operative treatment. Hematoma has been a consistent finding after acute shoulder dislocation, both by MRI and arthroscopy, and has been implicated in displacing the capsulo-labral complex from its anatomic origin. [18-20] Arthroscopic lavage and evacuation of the interposing hematoma has been reported to reduce the risk for recurrent dislocation when compared to non-operative management. [21] The above-mentioned studies suggest that the anterior capsular laxity and labral displacement associated with internal rotation, or caused by interposed hematoma, might help explain the failure of primary healing of the Bankart lesion and the subsequent high re-dislocation rate after conventional sling immobilization of the shoulder in internal rotation.

Several non-operative strategies to increase tissue contact at the injury interface have been described. Ishikawa *et al* reported on the application of a modified clavicular harness in patients determined to be at high risk for recurrence after a primary shoulder dislocation. [22] The authors reported no recurrences at one-year follow-up. Perugia and co-workers reported reduced re-dislocation rates over conventional sling immobilization when patients with primary traumatic dislocations were immobilized in sixty degrees of abduction for three weeks. [23] However, no effect of external rotation was addressed in this investigation.

Our results demonstrate that external rotation of the arm increases the contact load under a simulated Bankart lesion. Peak contact forces at the lesion were encountered at forty-five degrees of external rotation. No significant increase in force was found when external rotation was increased beyond 45 degrees. Our findings suggest that initial immobilization of anterior shoulder dislocations in this externally rotated position may be a preferable to conventional sling immobilization in adduction and internal rotation. This position will help in apposing the tissues which may facilitate healing or possibly decrease laxity of the repair.

The recent body of work from Itoi and colleagues supports the experimental findings on contact force of the current study. In contrast to Itoi's cadaver study [14], in which muscle was removed down to the capsule, we chose to keep the muscles present at the site of the capsule and measure contact force. It is possible that the muscle mass of subscapularis may contribute to labrum coaptation when the arm is placed in external rotation. In addition, we tested specimens in adduction, as this position may be more tolerable to the patient rather than having some amount of abduction or elevation. The role of elevation and external rotation on the contact force at the Bankart lesion is worthy of further study.

Our reproducibility data revealed moderate variation between specimens, with a mean contact load of 83.5 g and standard deviation of 37.7. Despite this variation, there was a consistent finding in all specimens tested of increased contact load with external rotation. The variation between samples may reflect differences in age, tissue elasticity, labral morphology, and subscapularis muscle mass. A viscoelastic response was also observed under repeated loading as expected with soft tissues. A limitation of this study is that the cadaver model eliminates any potential dynamic influences on the capsulo-labral tissues. In addition, our model included a Bankart lesion in isolation. In vivo, the Bankart lesion is often associated with a capsular injury that was not accounted for in this experiment.

The role of contact force in tissue-bone healing and recurrence rate of anterior dislocation remains to be determined, but it seems intuitive that for healing to proceed at a tissue interface, some contact force and tissue apposition is better than no force and no contact between the tissues. The magnitude of the load which may facilitate healing is beyond the context of the current study. Our findings, together with published imaging studies, suggest that immobilization in external rotation may provide tissue apposition at the anatomic site of injury. If this apposition could be maintained during a critical healing period, then this treatment strategy may be an improvement over conventional sling immobilization. A clinical study of this hypothesis is warranted.

In conclusion, external rotation of the arm resulted in a significant increase in contact force between the labrum and glenoid in a simulated Bankart lesion. The improved soft-tissue contact parameters achieved in external rotation may influence the healing of a Bankart lesion. Immobilization of first-time anterior shoulder dislocations in an external rotation brace may reduce the high recurrence rate associated with this injury.

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Figures

Figure 1

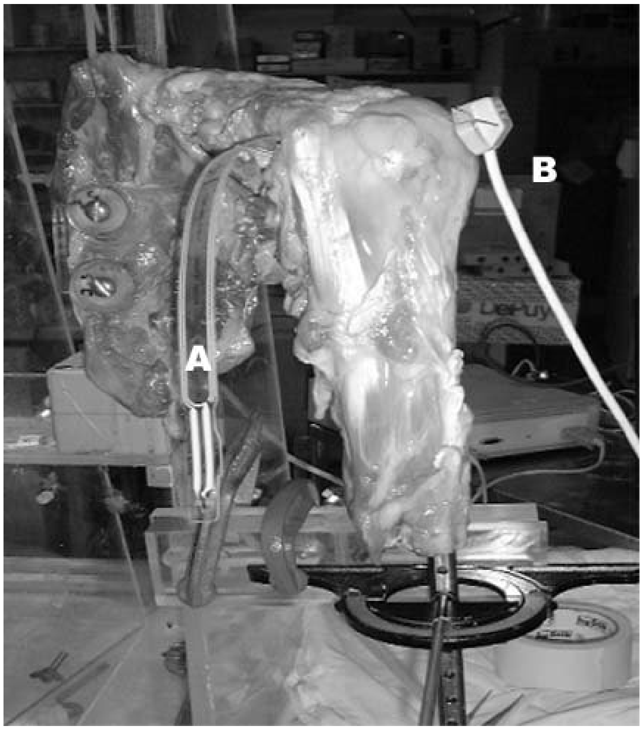

Figure 2

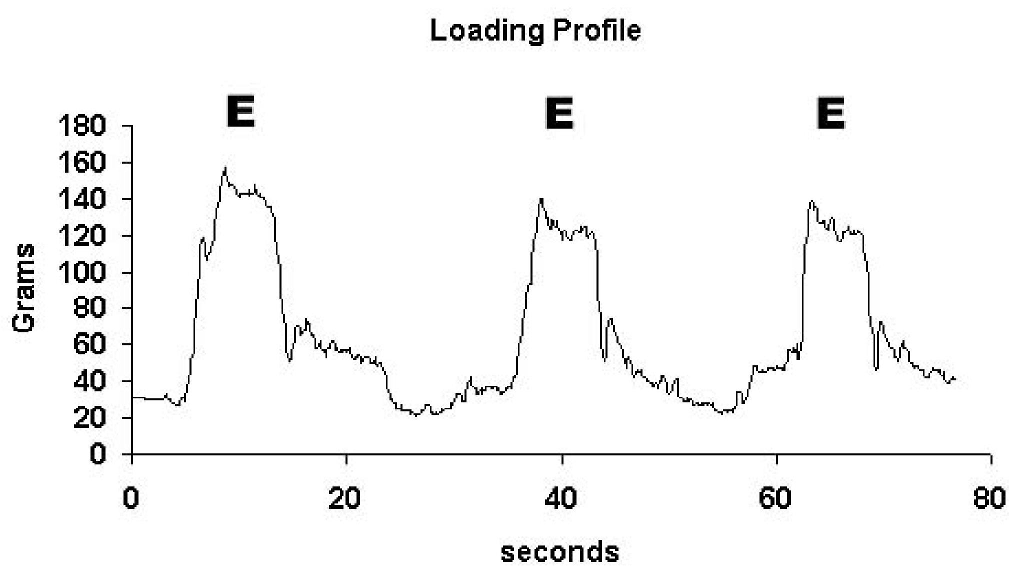

Figure legends

Figure 1 presents the experimental set-up. The medial border of the scapula was held vertically and the glenohumeral articulation held in neutral abduction. A rod was inserted retrograde into the humeral shaft and fixed to a mechanical rotation device to control rotation. An electronic force sensor (A) 0.12 mm thick, Flexiforce, TekScan, South Boston, MA) was passed beneath subscapularis and placed between the detached labrum and the anterior margin of the glenoid rim. A six-degree-of-freedom tracking device (B) (Polhemus, Burlington, VT) was attached to the humeral head to record any translations or rotations of the humerus during testing.

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