THE EFFECT OF ARM POSITION AND CAPSULAR RELEASE ON ROTATOR CUFF REPAIR

A BIOMECHANICAL STUDY

JOSEPH D. ZUCKERMAN, JEAN-MARC LEBLANC, JACK CHOUKA, FRED KUMMER

From the Hospital for Joint Diseases, New York

A cadaver study was performed to determine the effect of arm position and capsular release on rotator cuff repair. Artificial defects were made in the rotator cuff to include only the supraspinatus (small) or both supraspinatus and infraspinatus (large). The defects were repaired in a standard manner with the shoulder abducted 30° at the glenohumeral joint. Strain gauges were placed on the lateral cortex of the greater tuberosity and measurements were recorded in 36 different combinations of abduction, flexion/extension, and medial/lateral rotation. Readings were obtained before and after capsular release.

With small tears, tension in the repair increased significantly with movement from 30° to 15° of abduction ($p < 0.01$) but was minimally affected by changes in flexion or rotation. Capsular release significantly reduced the force ($p < 0.01$) at 0° and 15° abduction.

For large tears, abduction of 30° or more with lateral rotation and extension consistently produced the lowest values. Capsular release resulted in 30% less force at 0° abduction ($p < 0.05$).

An understanding of the effect of arm position and capsular release on the tension in a rotator cuff repair is important for postoperative management. The goal of surgical repair of a rotator cuff tear is to restore integrity under minimal tension. The repair should be secure enough to allow early passive motion. The literature contains widely differing opinions on the method and position of postoperative immobilisation (Wolfgang 1974; Nixon and DiStefano 1975; Walker 1977; Cofield 1985; Hawkins, Misamore and Hobioka 1985; Ellman, Hanker and Bayer 1986; Matsen and Arntz 1990). These recommendations vary from an abduction orthosis to a sling with the arm at the side.

To date there have been no biomechanical studies that specifically address the question. We report the results of a cadaver study of rotator cuff fixation.

MATERIALS AND METHODS

Fourteen fresh cadaver forequarters were kept frozen at -20°C before being thawed to room temperature for testing. Anteroposterior and axillary radiographs were obtained to identify any bony or intra-articular abnormalities that could influence the results. The specimens were stripped of all soft tissue except for the four rotator cuff muscles and the glenohumeral joint capsule. Two specimens were found to have degenerative rotator cuff tears and were not used in the study.

Each of the remaining 12 shoulders was securely mounted on a constraining jig and fixed in an anatomical position with the medial border of the scapula perpendicular (Fig. 1). The humerus was left free so that it could be positioned as needed.

Two unidirectional strain gauges were mounted with cyanoacrylate adhesive on the greater tuberosity after removal of the overlying periosteum. Strain gauge A was placed 1 cm distal to the insertion of the supraspinatus tendon. Strain gauge B was placed 1 cm distal to the infraspinatus tendon insertion. The mechanical axes of the strain gauges were aligned parallel to the fibres of supraspinatus and infraspinatus (Fig. 2).

The measured strain on the bone distal to the tendon insertion was used to determine the force sustained by the tendon. Strain gauge readings were recorded by a

J. D. Zuckerman, MD, Chief, Shoulder Service
J.-M. Leblanc, MD, Research Fellow, Department of Bioengineering
J. Choueka, BS, Research Assistant, Department of Bioengineering
F. Kummer, PhD, Associate Director, Department of Bioengineering
Hospital for Joint Diseases Orthopaedic Institute, 301 East 17th Street,
New York, New York 10003, USA.

Correspondence should be sent to Dr J. D. Zuckerman.

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Fig. 1a

The experimental jig with the scapula bolted to the backplate. The humerus remained free and could be positioned in varying amounts of abduction (a), flexion/extension (b), or rotation (c).

Fig. 1b

Fig. 1c

Fig. 2

Location of strain gauges and method of repair for small tears (A,B) and large tears (C,D).

P-3500 strain indicator (Measurements Group, Inc, Raleigh, North Carolina), calibrated with a spring gauge dynamometer attached to sutures placed through drill holes proximal to the gauge and measuring the strains produced as a function of load and orientation of the applied force. The values for the force sustained by the repair were then interpolated from the calibration curve for a particular test condition and gauge reading.

The neutral position of the humerus was determined by placing it parallel to the medial border of the scapula and in line with the body of the scapula. From this 'zero' point, strain gauge readings were recorded with all combinations of the following positions:

1) Abduction (in the plane of the scapula): 0°, 15°, 30°, 60°, 90°, and 120° (Fig. 1a);

2) 30° flexion, neutral, and 30° extension (in the sagittal plane) (Fig. 1b);

3) 30° internal rotation, neutral, and 30° external rotation (Fig. 1c).

Specimen preparation. Two rotator cuff defects were produced in a standard manner for each specimen tested. The first represented a small tear involving only the supraspinatus tendon. A rectangular defect extending the entire width of the tendon and 1 cm medially was made at its insertion into the greater tuberosity along with the attached capsule (Fig. 2A). The second defect simulated a larger tear involving both the supraspinatus and infraspinatus tendons. A rectangular portion the entire width of the supraspinatus and infraspinatus tendons was excised in a similar manner, extending 2 cm

medially from the insertion at the greater tuberosity (Fig. 2C). Tendon-to-bone repairs were performed in a standard manner using horizontal mattress sutures of No. 2 Mersilene (Figs 2B,D). All repairs were performed with the humerus in 30° of abduction, a neutral position of flexion/extension, and in neutral rotation. However, for some 2 cm defects, 10° to 15° of external rotation was necessary to relieve tension on the sutures. Sutures were pulled laterally to bring the tendon edge to the bony trough. The sutures were tied sequentially in a posterior-to-anterior direction and the preparation kept moist throughout the testing with physiological saline solution.

All shoulders were tested with an intact cuff, after repair of a 1 cm (small) supraspinatus tear, and after repair of a 2 cm large tear. For each type of tear, testing was performed before and after release of the capsular attachments at the glenoid rim. Capsular release was performed in three of 12 small tear specimens and seven of 12 large tear specimens.

RESULTS

Small tears. In all tests, the tension in the repair remained essentially unchanged (less than 2 N) in abduction of 30°, 60°, 90° and 120°, regardless of rotation or flexion/extension. In the group without capsular release, tensions increased significantly ($p < 0.01$) when the arm was brought to 15° of abduction (Fig. 3). When the arm was lowered to 0° of abduction, values increased further in all positions tested. In 0° of abduction, extension consistently gave the lowest tension; tension was minimally affected by changes in rotation. The highest loads were consistently recorded in 0° of abduction and 30° of flexion. External rotation in this position resulted in extremely large loads which would have resulted in failure of the repair. However, this was not permitted in order to preserve the specimen for additional testing.

In the three specimens with capsular release, load values ranged up to 9 N, as compared with 35 N in the group without capsular release. There was a relatively minor increase in tension between 15° abduction and 0°. The capsular release group had a significant ($p < 0.01$) reduction in repair tension at 0° of abduction as compared to the group without capsular release.

Large tears. Five specimens were tested with intact capsular attachments and seven after capsular release. Supraspinatus tension in both groups was stable above 30° of abduction, regardless of the position of rotation or flexion/extension. With the capsule intact, loads increased sharply at 15° of abduction (average 20 N) and at 0° of abduction, maximum loads were obtained (> 50 N). Capsular release reduced the average tension at 0° of abduction to 39% of maximum values ($p < 0.05$). In addition, the repair held at 30° flexion after capsular release, while in the group with an intact capsule, 30° flexion regularly resulted in disruption of the repair.

Strain recordings distal to the infraspinatus tendon

were rarely significant. Only in the group without capsular release did significant increases in tension occur at 0° of abduction; these never exceeded 20 N. The negative values consistently appearing in abduction above 30° are due to unidentified stresses acting on the greater tuberosity.

Fig. 3

The effect of arm position on tension in repair of a 1 cm supraspinatus tear, before and after capsular release.

Test to failure of large tear. All repairs of large rotator cuff tears were finally tested to failure. Fixation failure occurred through bone in nine cases, through the supraspinatus muscle mass in two cases, and by disruption of the Mersilene suture in one. All failures at the tendon-to-bone attachment site occurred at the most anterior part of the repair, with the sutures pulling through the bone. The average failure load was 95 N.

Average torque to failure was 6 Nm. The lowest values of 1.5 to 3 Nm were obtained in the most osteoporotic specimens. The two specimens that failed at the musculotendinous junction had had release of the capsule and required the highest torques (21.8 Nm and 11.8 Nm). The torque applied by the weight of the arm (5.6% body-weight) acting as a lever arm of 33.4 cm from the humeral head, is approximately 12.8 Nm (France et al 1989). Therefore, on average, the tendon-to-bone

fixation in our specimens failed at less than half the torque produced by the weight of the arm alone.

DISCUSSION

The purpose of our study was to identify some of the factors that are important in determining the tension on the repair of small and large tears of the rotator cuff and especially the effect of capsular release.

For small tears, the supraspinatus loads increased at 15° of abduction and were greatest when the arm was lowered to 0° abduction. In this position, the loads did not exceed 50% of failure load except when the humerus was also flexed and laterally rotated. When a capsular release had been performed, there did not appear to be a position at which the repair was at risk.

For large tears, the supraspinatus loads increased significantly and followed a pattern similar to that shown after small tears. Flexion consistently generated the greatest loads and extension consistently produced the lowest. Capsular release, once again, significantly decreased the loads generated but, even following capsular release, flexion produced high loads which occasionally approached failure levels.

Our testing to failure showed that the bone was the weakest link in the repair, at least when healthy tendon tissue was available. This observation has been reported by others (Packer et al 1983). Bony failure occurred at the anterior part of the supraspinatus repair; loss of fixation of the intraspinal tendon to bone did not occur. These observations indicate that the greatest loads are sustained by the supraspinatus tendon anteriorly. We recognise the inherent limitations of applying the results of a laboratory study of cadaver tissue to the clinical setting. However, we feel that our study provides some relevant information about postoperative positioning following rotator cuff repair and the benefit of capsular release.

First, repair should be performed at or near the abduction position to be held after operation. If simple sling immobilisation is planned, the repair should be performed at or near zero abduction. By contrast, if postoperative abduction splinting is to be used, it need only be at a slightly greater angle of abduction than was necessary to perform the repair.

Second, the position of abduction has a much more

important influence upon repair tension than rotation or flexion/extension. However, if the arm is positioned in zero abduction, flexion should be avoided since it consistently produced the highest loads for both small and large tears.

Third, release of the capsular attachment at the glenoid rim significantly reduces the tension on the supraspinatus repair, especially for large defects. Capsular release allows positioning at zero abduction when repairs are performed at 30° abduction. This supports its use as a standard part of the technique of rotator cuff repair.

Fourth, when testing the security of a repair intra-operatively, the anterior part of the supraspinatus should be examined carefully. This is the most common site of failure and should determine the position of postoperative immobilisation and the programme of rehabilitation.

Fifth, the postoperative programme of passive movements should avoid flexion with the arm at zero abduction since this consistently produced the greatest tension on the repair. Flexion from an abducted position is to be preferred, since abduction of 15° or 30° consistently negated the effects of flexion.

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