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Biomechanical effects of rotator interval closure in shoulder arthroplasty

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Background: Subscapularis dysfunction remains a significant problem after shoulder arthroplasty. Published techniques have variable recommendations for placing a rotator interval closing suture in attempts to off-load the subscapularis repair site, the implications of which have yet to be examined in the literature. The goals of this study were to investigate the biomechanical benefit of the rotator interval closing suture on the subscapularis repair strength and to analyze the effect on shoulder range of motion.

Methods: Sixteen matched cadaveric shoulders underwent a subscapularis tenotomy and shoulder arthroplasty. The subscapularis tenotomy was repaired, and motion at physiologic torsional force was recorded. One of each matched pair was randomly assigned to receive an additional rotator interval closure suture. Each specimen then underwent a standardized cyclic loading with measurement of gap formation and load to failure.

Results: The rotator interval closing suture significantly increased the ultimate load to failure of the subscapularis repair (452 N vs. 219 N; $P = .002$) and decreased gap formation at the subscapularis repair site. Measurement of the shoulder motion showed no significant difference between shoulders with and without the rotator interval closing suture.

Discussion: We report the additional biomechanical benefit that the rotator interval closing suture provides to the subscapularis repair site after shoulder arthroplasty. This suture acts to improve the load to failure of the subscapularis repair and to decrease gap formation under cyclic load. Furthermore, it does not detrimentally affect shoulder external rotation or overall arc of rotation. Our findings support the application of this off-loading technique after subscapularis repair during shoulder arthroplasty.

Level of evidence: Basic Science Study; Biomechanics

Keywords: Subscapularis; shoulder arthroplasty; biomechanics; subscapularis dysfunction; subscapularis repair; subscapularis tenotomy; rotator interval closure

The total shoulder arthroplasty is a reliable and successful treatment for shoulder arthritis.[5,6,36,40] The most common surgical approach currently requires violating the subscapularis with subsequent repair. Unfortunately, the rate of failure of this repair remains high and places patients at risk for instability, decreased motion, poor functional outcome scores, and premature glenoid loosening.

To protect the subscapularis repair after shoulder replacement, closure of the rotator interval has been advocated by numerous authors in an attempt to reduce tension at the repair site, yet there is significant variation in its use in the literature.[2,3,12,13,18,26,34,37] In the sports medicine literature, closure of the rotator interval has been shown to decrease external

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rotation when it is used as a treatment for instability in the native shoulder.[4,7,20,41] After shoulder arthroplasty, maximizing postoperative shoulder external rotation is a highly sought after goal that has a direct impact on patients' functional outcomes. The effect of closure of the rotator interval during shoulder arthroplasty has not been investigated, and its utility is currently in question.

In the presented study, we investigate the biomechanical effect that closing the rotator interval has on the subscapularis repair site. We secondarily evaluate the implication that this technique has on shoulder range of motion.

Materials and methods

This is a cadaveric study designed to compare subscapularis repair strength and shoulder range of motion after shoulder arthroplasty with and without rotator interval closure. Sixteen matched (8 right and 8 left) shoulders were obtained with an average age of 73 years and an intact rotator cuff. Use of paired upper extremities allowed an internal control for tendon strength as well as bone density. All shoulders were dissected free of the deltoid musculature to expose the underlying rotator cuff musculature. A subscapularis tenotomy was performed 1 cm from the tendon insertion on the lesser tuberosity. Shoulder arthroplasty was then performed according to standard procedures using a press-fit stem. The subscapularis tenotomy was closed with 3 No. 5 FiberWire (Arthrex, Naples, FL, USA) sutures in a Mason-Allen fashion.

The distal humerus was then potted in 10-cm-diameter polyvinyl chloride end caps using dental cement (Heraeus Kulzer Inc, South Bend, IN, USA). A custom jig was applied to the most medial aspect of the scapula. A materials testing machine (MTS 858 Mini-Bionix Test System, Minneapolis, MN, USA) was then used to apply a torsional force of 1500 N·mm with the shoulder at neutral and 90° of abduction. The angle at which 1500 N·mm of resistance was achieved was recorded. A single shoulder of the matched pair was randomly assigned to rotator interval closure, which was performed by placement of a single No. 5 FiberWire suture in a figure-8 fashion within the lateral 1 cm of the rotator interval between the tendons of supraspinatus and subscapularis (Fig. 1). This specimen was again subjected to torsional testing, and maximal rotation at 1500 N·mm was recorded. Following this, the medial aspect of the subscapularis musculature was dissected free from the scapula, and the proximal musculotendinous junction was secured to the MTS machine by suture. The proximal third of the humerus was placed in a vise such that the machine would be able to apply load to the proximal musculotendinous junction of the subscapularis in line with its natural line of pull. The specimen was cyclically loaded to 100 N at 1 Hz for 1000 cycles, which has previously been shown to simulate postoperative rehabilitation forces.[13,34] Gap formation at the tenotomy site was measured by digital photography at 100, 200, 500, and 1000 cycles. Gap formation was analyzed through use of digital image measurement software (ImageJ 1.48; Wayne Rasband, National Institutes of Health, Bethesda, MD, USA), allowing determination of the gap area and the average gap formation at each time point. Last, a load to failure test was performed at a loading rate of 2 mm/s, and the maximal force at which failure occurred and the mechanism of failure were recorded.

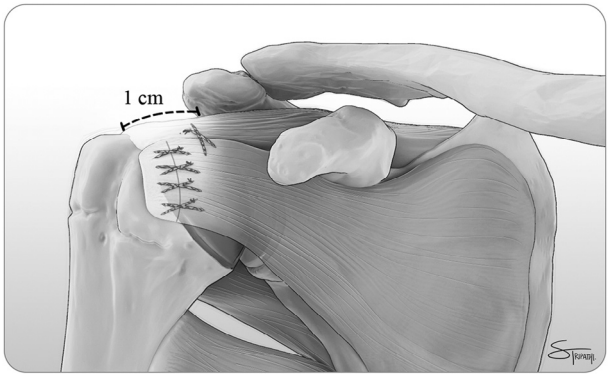

Figure 1 Rotator interval suture placement.

Results

In all, 16 cadaveric shoulders were analyzed. Analyzing matched pairs allowed internal control with right and left shoulders distributed equally between the 2 experimental arms. The rotator interval closing suture significantly increased the ultimate load to failure of the subscapularis repair, with average load to failure of 452 N with interval closure vs. 219 N without rotator interval closure ($P = .002$) (Fig. 2). Cyclic loading of the specimen was performed and gap formation measured at regular intervals, allowing comparison of those specimens both with and without rotator interval closure as demonstrated in Figure 3. Rotator interval closure statistically significantly decreased gap formation at the subscapularis repair site under cyclic loading in our samples ($P = .0002$). The average shoulder external rotation and arc of motion for shoulders with and without the rotator interval closure suture were similar both at neutral and at 90° of abduction as illustrated in Table I. No significant difference was found between the 2 cohorts in regard to external rotation or overall range of motion.

Discussion

This study demonstrates the biomechanical benefit provided by the rotator interval closing suture, resulting in an increase in strength to the subscapularis repair site after shoulder arthroplasty. In addition, testing was unable to demonstrate a significant difference in shoulder motion after addition of this rotator interval closing suture. An increase in load to failure as well as a decrease in gap formation was demonstrated. Gap formation and weakness of the subscapularis repair have been previously demonstrated to have detrimental effects on subsequent subscapularis function and shoulder outcomes in vivo.[2,17,18,24,27,28]

There have been significant questions as to the utility and detriment of the addition of the rotator interval closing suture. It is widely believed that closure of this soft tissue interval could improve strength yet may result in decreased external rotation of the shoulder. External rotation of the shoulder in arthroplasty is critical to a successful outcome as it allows restoration or preservation of important activities of daily living,