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Shoulder arthroplasty and its effect on strain in the subscapularis muscle

Thomas Wright *, Thomas Easley, Jessica Bennett, Aimee Struk, Bryan Conrad

Department of Orthopaedics and Rehabilitation, University of Florida College of Medicine, 3450 Hull Road, Gainesville, FL 32611, USA

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ABSTRACT

Background: Increasing the thickness of the prosthetic humeral head on subscapularis strain in patients undergoing total shoulder arthroplasty has not been elucidated. The optimal postoperative rehabilitation for total shoulder arthroplasty that does not place excessive strain on the subscapularis is not known. We hypothesize that the use of expanded non-anatomic humeral heads during shoulder replacement will cause increased tension in the repaired subscapularis. We identified a recommended passive range of motion program without invoking an increase in tension in the repaired subscapularis, and determined the impact of the thickness of the humeral head on subscapularis strain.

Methods: Eight fresh-frozen, forequarter cadaver specimens were obtained. An extended deltopectoral incision was performed and passive range-of-motion exercises with the following motions were evaluated: external rotation, abduction, flexion, and scaption. An optical motion analysis system measured strain in the subscapularis. The same protocol was repeated after performing a subscapularis osteotomy and after placement of an anatomic hemiarthroplasty of three different thicknesses.

Findings: For abduction and forward flexion, we observed a trend of decreasing strain of the subscapularis, as the laxity is removed with increasing humeral head component thickness. With the short humeral head, strain was similar to native joint with passive scaption and flexion but not with external rotation or abduction.

Interpretation: The passive range of motion that minimizes tension on the subscapularis is forward flexion and scaption. Therefore, passive forward flexion or scaption does not need to be limited, but external rotation should have passive limits and abduction should be avoided.

1. Introduction

Total shoulder arthroplasty (TSA) is performed with a surgical approach through the subscapularis. After surgery, rehabilitation of the shoulder is imperative to optimize the functional result. However, the subscapularis must be respected in the process of this rehabilitation or the repair will fail, resulting in a poorly functioning shoulder and in some cases shoulder instability. Using ultrasound after subscapularis tenotomy and repair in the course of performing a TSA, failure rates of the repair have been reported between 13 and 47% (Armstrong et al., 2006; Jackson et al., 2010). Weakness, anterior instability, glenoid loosening, and decreased function have all been described after a failed subscapularis repair (Miller and Kathuria, 2006; Miller et al., 2003, 2005; Moeckel et al., 1993; Utz et al., 2011). In an effort to decrease subscapularis failure rate in the setting of a TSA, many surgeons have begun performing a lesser tuberosity osteotomy as it has been shown to have a decreased failure rate when compared to direct tendon repair (Qureshi et al., 2008). Rehabilitation protocols are commonly designed to protect the subscapularis repair; however, there is little science supporting their specific recommendations (Wilcox et al., 2005).

The purpose of a shoulder replacement is to provide pain relief and increase function in a patient with a pathologic glenohumeral joint. The current trend is to replicate the patient's pre-existing normal shoulder anatomy as closely as possible with the shoulder replacement. However, in an attempt to stabilize the TSA many systems provide the surgeon with options of humeral heads that are much thicker than the normal humeral head. It is likely that the use of tall (thicker) or expanded non-anatomic humeral heads will cause an increase in the tension experienced in the repaired subscapularis. TSA instability is better managed with correction of glenoid version and embrication of the rotator cuff interval rather than by overstuffing the joint with a thick prosthetic head.

The primary purpose of this study was to identify the optimal manner to perform a passive range of motion (PRoM) program without invoking a large increase in tension in the repaired subscapularis. The secondary purpose was to determine the impact of varying the

* Corresponding author at: Department of Orthopaedics and Rehabilitation, PO Box 112727, Gainesville, FL 32611-2727, USA.
E-mail address: wrightw@ortho.ufl.edu (T. Wright).

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thickness of the humeral head on subscapularis strain using the same PRoM protocol.

2. Methods

2.1. Specimen preparation

Eight fresh-frozen, forequarter cadaver specimens (four females and four males) were obtained following International Review Board approval. Each specimen was mounted on a surgical holding device that clamped to the medial scapula eliminating scapular motion. Using an extended deltopectoral approach, the distal subscapularis and insertion site were well visualized.

A six-camera motion analysis system (Eagle, Motion Analysis Corp., Santa Rosa, CA, USA) was used to measure strain in the subscapularis. Four 2 mm reflective beads were carefully sutured to the subscapularis in a 1 cm^2 square-shaped arrangement to allow tissue strains to be measured. The superior two markers were sutured to the upper subscapularis and the inferior two markers were sutured to the lower subscapularis (Fig. 1). The primary outcome measure for this study was tissue strain of the upper and lower subscapularis. Strain was measured as the peak change in displacement from the resting tissue length, during PRoM movements (initial length − final length = strain in mm).

PRoM of the glenohumeral joint was measured using an electromagnetic tracking device (Liberty, Polhemus Inc., Colchester, VT, USA). The Polhemus device allowed the three-dimensional angulation to be tracked and recorded. Two Polhemus tracking sensors were attached: one to the mid-diaphysis of the humerus and one to the spine of the scapula. Before collecting data, the sensors were aligned to the anatomical axes of the specimen. A custom software program written in LabView (National Instruments, Austin, TX, USA) was used to collect data from the Polhemus system and calculate joint angles.

2.2. Experimental procedure

Both strain and range of motion data were collected simultaneously as the arms were moved through a PRoM in external rotation, abduction, flexion, and scaption for five cycles of each motion. To ensure that the tissues were at a steady state, data from the fifth cycle were used for analysis. The range of motion and strain data were synchronized *post hoc* by using a linear regression procedure to optimize the temporal alignment of the signals. The PRoM protocol was initially performed on each specimen in the intact condition to measure "normal" strain. The starting position for each set of conditions was always with the arm by the side and internally rotated like what would occur with the hand on the abdomen in the resting state. The exact same PRoM sequence was then repeated after placement of a short humeral head with repair of the osteotomy site and again after placement of a tall (thicker) and expanded head (even thicker). The subscapularis osteotomy was repaired back to the exact same spot after each set of conditions. No destructive loading of the subscapularis was performed. All implant components were part of the Equinoxe shoulder arthroplasty system (Exactech Inc., Gainesville, Florida, USA). Eight specimens were tested for all conditions, but two specimens were too small to be tested with the expanded humeral head arthroplasty. After exposure of the subscapularis and placement of the reflective markers, baseline strain was obtained using the above motions. The lesser tuberosity was then osteotomized in a consistent fashion, and a humeral head cut was made on the anatomic neck. The humeral canal was reamed and broached. Prior to placing the humeral stem, three drill holes were placed just lateral to the lesser footprint and three just medial to the footprint. One number 2 FiberWire (Arthrex, Naples, Florida, USA) suture was placed through the lateral hole then around the inserted humeral stem and out the medial hole. This was repeated for all three sets of holes, placing a total of three sutures. Once repaired, each suture acted as a cerclage around the lesser tubercle and stem exactly as is normally performed in surgery. This construct returned the lesser tubercle to its native footprint. Using the system replicator plate and a humeral head sized directly off the removed native head, the arthroplasty head was placed to exactly cover the native humeral head cut. The subscapularis was then repaired in the manner described. One figure of eight number two FiberWire was used in the rotator interval adjacent to the two tuberosities. The same passive motions were then performed with strain noted as in the intact state. The exact same surgical and testing procedures were repeated with the tall (4 mm thicker than short) and then expanded humeral heads (4 mm thicker than tall and 8 mm thicker than short) in each cadaver specimen.

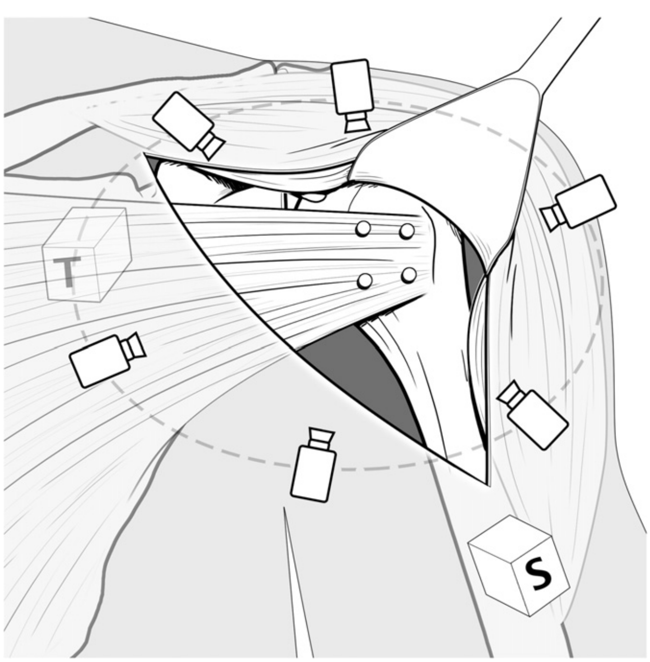

Fig. 1. Schematic drawing of the experimental setup with markers placed on the subscapularis.

3. Results

A general trend of decrease in tissue strain on the subscapularis was observed in abduction and external rotation following implantation of the shoulder arthroplasty components (Figs. 2–5). The apparent paradox of this is due to the tendon being under increased tension (all the laxity has been removed). At point zero there was less tendon laxity,

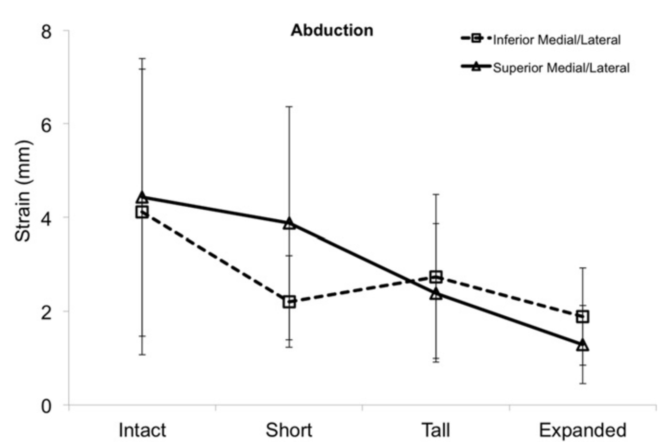

Fig. 2. Tissue strain for upper and lower subscapularis during abduction with different implant sizes.