J Shoulder Elbow Surg (2013) 22, 150-157

JOURNAL OF SHOULDER AND ELBOW SURGERY

www.elsevier.com/locate/ymse

BASIC SCIENCE

Biomechanical effect of latissimus dorsi tendon transfer for irreparable massive cuff tear

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Background: The purpose of this study was to determine the biomechanical effects of latissimus dorsi transfer in a cadaveric model of massive posterosuperior rotator cuff tear.
Methods: Eight cadaveric shoulders were tested at 0°, 30°, and 60° of abduction in the scapular plane with anatomically based muscle loading. Humeral rotational range of motion and the amount of humeral rotation due to muscle loading were measured. Glenohumeral kinematics and contact characteristics were measured throughout the range of motion. After testing in the intact condition, the supraspinatus and infraspinatus were resected. The cuff tear was then repaired by latissimus dorsi transfer. Two muscle loading conditions were applied after latissimus transfer to simulate increased tension that may occur due to limited muscle excursion. A repeated-measures analysis of variance was used for statistical analysis.
Results: The amount of internal rotation due to muscle loading and maximum internal rotation increased with massive cuff tear and was restored with latissimus transfer ($P < .05$). At maximum internal rotation, the humeral head apex shifted anteriorly, superiorly, and laterally at 0° of abduction after massive cuff tear ($P < .05$); this abnormal shift was corrected with latissimus transfer ($P < .05$). However, at 30° and 60° of abduction, latissimus transfer significantly altered kinematics ($P < .05$) and latissimus transfer with increased muscle loading increased contact pressure, especially at 60° of abduction.
Conclusion: Latissimus dorsi transfer is beneficial in restoring humeral internal/external rotational range of motion, the internal/external rotational balance of the humerus, and glenohumeral kinematics at 0° of abduction. However, latissimus dorsi transfer with simulated limited excursion may lead to an overcompensation that can further deteriorate normal biomechanics, especially at higher abduction angles.
Level of evidence: Basic Science Study, Biomechanical, Cadaveric model.

Keywords: Massive cuff tear; latissimus dorsi transfer; range of motion; glenohumeral kinematics; contact pressure

A massive rotator cuff tear is defined as a tear involving more than two cuff tendons or as a tear with a length of at least 5 cm.[4] Some patients with massive tears have no symptoms; however, most individuals with massive rotator cuff tears show impaired function in their activities of daily living due

Institutional review board approval: not applicable (basic science study).
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1058-2746/$ - see front matter © 2013 Journal of Shoulder and Elbow Surgery Board of Trustees.
doi:10.1016/j.jse.2012.01.022

to pain, decreased range of motion, and decreased power of abduction and external rotation. Imaging studies show that in patients with rotator cuff tears, the humeral head can elevate superiorly, resulting in a decreased acromiohumeral distance; fatty infiltration is also a common finding on magnetic resonance images of patients with massive cuff tears.[3,10,21] The treatment plan for patients with massive rotator cuff tears is challenging because it must be tailored to meet the patients' desired activity level, as well as appropriately address the severity of the rotator cuff pathology.

Latissimus dorsi tendon transfer, introduced by Gerber et al[9] in 1988, is one of the surgical options available for irreparable massive cuff tears, especially in young patients who require a higher activity level in their daily lives. Currently, several studies support the latissimus dorsi transfer procedure as a salvage procedure,[2,7,8,11,12,18,23] although clinical outcomes have varied among patients. Warner[24] reported that late rupture of the transferred latissimus dorsi tendon and poor function were due to the relatively small size of the latissimus dorsi and suggested autogenous iliotibial band augmentation for a better outcome. At present, latissimus dorsi transfer is often performed with a reverse total shoulder arthroplasty in patients with cuff tear arthropathy whose active external rotation is deficient.[6]

Few cadaveric studies have been reported in the literature regarding the biomechanical influence of latissimus dorsi transfer using a massive rotator cuff tear model. Therefore, the purpose of this study was to determine the biomechanical influence of latissimus dorsi transfer using a cadaveric model of massive posterosuperior rotator cuff tear. Our hypotheses were that latissimus tendon transfer would restore abnormal glenohumeral joint kinematics created by massive cuff tear and that latissimus dorsi transfer would increase glenohumeral joint contact pressure.

Methods

Eight fresh-frozen human cadaveric shoulders with a mean age of 56.5 years (range, 45-65 years) were used. Specimens found on dissection to have pre-existing pathology, such as acromial fracture, limited range of motion, osteoarthritis, or rotator cuff tear, were excluded from the study. The specimens were stored at -20°C until the day before testing and thawed overnight at room temperature in preparation for dissection and testing. The specimens were kept moistened with physiologic saline solution to prevent dehydration. All soft tissues were removed except the glenohumeral joint capsule, coracoacromial ligament, coracohumeral ligament, and shoulder muscles. The supraspinatus, infraspinatus, teres minor, subscapularis, deltoid, and pectoralis major muscles were released from their origins, but their original insertions on the humerus were retained. The remaining portion of the latissimus dorsi was preserved for later use in the tendon transfer procedure. The glenohumeral joint was vented by a small incision through the rotator interval to isolate the influence of the negative intra-articular pressure, as well as to serve as an opening for insertion of the pressure measurement sensor. Suture loops were made with a modified Kessler stitch at the insertion of each muscle with No. 2 FiberWire (Arthrex, Naples, FL, USA). One line of action for the teres minor, two lines of action for the supraspinatus and infraspinatus, and three lines of action for the remaining muscles were used to load anatomically based on muscle fiber orientation. Three reference screws were inserted on the scapula (coracoid, anterior acromion, and posterior acromion) and the humerus (proximal bicipital groove, distal bicipital groove, and greater tuberosity) to provide consistent digitization markers to define local coordinate systems on each bone for kinematic measurements. The local coordinate systems were digitized during testing to measure the 3-dimensional position of each bone at all positions and in all conditions. An aluminum rod was inserted into the medullary canal of the humeral shaft and secured with several screws. The scapula was mounted in the anatomic resting position with 20° of anterior tilt in the sagittal plane on a multi-axis load cell (Assurance Technologies, Garner, NC, USA).[5,13] The aluminum rod inserted into the humerus was placed in a custom device that allows frictionless axial rotation of the humerus. The humeral rod was then attached to the arc of the testing system, which allows the specimen to be secured in different degrees of shoulder abduction (Fig. 1). Humeral axial rotation was defined based on the anatomic relationship between the bicipital groove and the anterolateral corner of the acromion as determined from a previous study.[14] When the bicipital groove was aligned with the anterolateral corner of the acromion at 90° of shoulder abduction, the humeral rotation was defined as 20° of external rotation.

The amount of muscle loading was determined based on physiologic muscle cross-sectional area ratios.[1,22,25] Specifically, the supraspinatus was loaded with 10 N; subscapularis, 24 N; infraspinatus/teres minor, 24 N; deltoid, 48 N; pectoralis major, 24 N; and latissimus dorsi, 24 N. A second, increased load condition (48 N) for the latissimus dorsi transfer was used to simulate increased muscle tension due to limited tendon excursion.

Testing was performed in the scapular plane (30° anterior to the coronal plane) at 0°, 30°, and 60° of shoulder abduction, considering a 2:1 ratio of glenohumeral-to-scapulothoracic abduction. First, we measured the amount of humeral head rotation due to muscle loading by holding the humerus at neutral rotation (0°) while loading all muscles simultaneously. After muscle loading, the humerus was allowed to rotate and the amount of internal rotation due to muscle loading was measured. Next, maximum internal rotation and external rotation were measured with 2.2 Nm of torque applied with a torque wrench after preconditioning for 5 cycles in each direction. Then, glenohumeral kinematics throughout the rotational range of motion were measured by digitizing the local coordinate systems of the glenoid and humerus by use of a MicroScribe 3DLX device (Revware, Raleigh, NC, USA) from maximum internal to maximum external rotation in 30° increments. Finally, glenohumeral contact area, pressure, and peak pressure were measured throughout the rotational range of motion with a Tekscan Pressure Measurement System (saturation pressure, 10.3 MPa) (Sensor 4000; Tekscan, South Boston, MA, USA). The Tekscan sensor was trimmed peripherally to insert into the glenohumeral joint through the rotator interval. Once the Tekscan sensor was inserted, muscle loading was applied and several trials of internal and external rotation were performed to ensure that the sensor covered the glenoid surface. Once the muscle loading was applied, the Tekscan sensor was calibrated by use of the resultant glenohumeral joint force measured from the multi-axis load cell with the spec-