Biomechanical Comparison of Three Latissimus Dorsi Transfer Sites for Reverse Shoulder Arthroplasty

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Introduction: Reverse total shoulder arthroplasty (RTSA) is most often performed to treat rotator cuff arthropathies with irreparable rotator cuff tears in order to return shoulder function and reduce pain [1]. Patients with full thickness rotator cuff tears which extend to the Teres minor lose active external rotation of the humerus, this leads to an inability to perform certain activities of daily living (ADLs). Latissimus dorsi transfer (tLD) procedures have been suggested to restore external rotation of the humerus. However, very few studies have demonstrated the potential benefits of a tLD by assessing only the muscle moment arm [2]. The aim of this investigation was to assess the biomechanical implications of three previously proposed tLD sites on external rotation, deltoid muscle forces, and force across the glenoid for ADLs.

Methods: An adapted version of the Newcastle Shoulder Model (NSM) [3] that describes a RTSA geometry [4] was used to investigate the biomechanics of three proposed tLD sites: Anterior, Posterolateral, and Posterodistal [2]. The skeletal structure of the model is based on a single cadaver (Visible Human Male dataset) and incorporates 31 muscles and 3 ligaments that are divided into 90 lines of action. The Latissimus dorsi (LD) is represented with 5 muscle elements which follow anatomical fascicle division [3]. The model works with inverse kinematics and static optimization techniques in order to predict muscle and joint contact forces for any given kinematic profile. For this investigation, a kinematic dataset that represented hygiene, feeding and everyday object ADLs were used as an input to the model (Table 1). There were four configurations of the model to represent the RTSA with the LD in the anatomical and the three transfer sites. All rotator cuff muscles (including Teres minor) were set to be inactive. Muscle forces and glenoid loading were compared across the three transfer sites and anatomical configurations.

Results: The moment arm results of the Latissimus Dorsi before tLD (anatomical) and after tLD consistently showed the LD changing from an internal rotator to an external rotator. The largest external rotation moment arm was observed for the anterior site (Fig 1). All tLDs moment arm magnitudes were larger than those of the native LD attachment. The average maximum Deltoid muscle forces across all motions for each transfer were much lower than when the LD was in the anatomical site (Fig. 2). Most apparent is the decline in the force of the Posterior Deltoid, who serves as the primary external rotator of the arm in the absence of any other external rotator muscle (e.g. the Teres Minor). The Anterior transplant position decreased the force required of the Posterior Deltoid the greatest (0.3 BW), followed closely by the Posterolateral site (0.29 BW). The Posterodistal site had the smallest reduction in Posterior Deltoid force (0.21 BW), though it was far better than the anatomical LD (no transfer). The average maximal glenoid loading across all motions for each transfer was separated into: Total force, Compression, Superior Shear, and Posterior shear (Fig. 3). The results mirror those of the Deltoid muscle force results, with the Anterior and Posterolateral transfer sites yielding the largest reductions in total joint contact force. The largest reduction was observed in the superior shear forces. The Posterodistal site, again, was the least effective transfer site; however, it still resulted in large reductions on the glensphere loading compared to the anatomical LD attachment.

Discussion: The model predicted that the Posterior Deltoid can generate the necessary external moment arm and compensate for the lack of external rotators; however, this requires high activations and increases the loading across the glenohumeral joint. A tLD has the potential to improve active external rotation due to the change in moment arm, converting the muscle from an internal rotator to an external rotator. This is possible even with low force input from the LD, since the large external rotation moment arm after the transfer can generated sufficient external rotation moments. As a result, the deltoid activation is decreased (Fig. 2) as well as the glenoid loading (Fig. 3). The anterior and posterolateral transfers reduced deltoid activation and glenoid loading the best, though the posterodistal transfer also produced favorable results. The joint contact results also suggested that the joint stability was not compromised in any of the tLD configurations, since the reaction forces were always constrained within the humeral cup.
Significance: All of the three tLD sites that were investigated in this study produced more favorable muscle and joint contact forces for the ADLs tested compared to the anatomical attachment of the LD. While it would be preferable to utilize the Anterior transfer site from a biomechanical standpoint surgical tendon reattachment at this site may be challenging through a single anterior incision. In general, a tLD at any of the three positions has the potential to improve the quality of life for patients that are deficient in active external rotation.

Acknowledgments:

References:

A set of kinematic data representing common ADLs were imported to the model for muscle and joint con

| 1. Ext/Int rotation in Adduction & 90°Abduction | 6. Drink From Mug |
| 2. Reach to opposite axilla | 7. Answer telephone |
| 3. Reach to opposite side of neck | 8. Brush left side of head |
| 4. Reach to side and back of head | 9. Lift block to shoulder height |
| 5. Eat with hand to mouth | 10. Lift block to head height |

Figure 1: LD Rotational Moment Arms in Humeral Internal/External Rotation in 90° of Abduction