Influence of Reverse Shoulder Arthroplasty Lateralization on Glenohumeral Muscle Moment Arms

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Introduction: Reverse shoulder arthroplasty by lowering and medializing the center of rotation of the shoulder has been demonstrated as a viable option for the management of rotator cuff tear arthropathy and massive unrepairable rotator cuff tears. However some authors have described reverse shoulder prostheses with a more lateralized offset in order to improve stability and function, especially in axial rotation by re-tensioning the rotator muscles. The purpose of our study was to determine and compare the moment arms of the shoulder muscles with reverse shoulder prostheses with different amounts of lateralization.

Methods: Six, fresh frozen cadaveric hemi-thoraces were used on a custom-made testing device (Fig.1). Electromagnetic tracking sensors (Liberty, Polhemus, Inc.) were rigidly fixed to the thorax, scapula, and humerus to record 3D kinematics. Nine different muscle subregions--deltoid (anterior, middle, posterior), pectoralis major (clavicular, sternal), infraspinatus, teres minor, latissimus dorsi and teres major-- were attached via suture to a rotational potentiometer equipped pulley and pneumatic cylinder to record tendon excursion and apply a passive muscle force, respectively. To test the specimen, the arm was manually moved through the complete range of motion through 3 cycles of motion in three separate movement planes; abduction, anterior flexion, and axial rotation. Each specimen was tested in its native condition and in 3 degrees of glenosphere lateralization after the implantation of a reverse shoulder joint prosthesis by an experienced shoulder surgeon. The implant used in this study was the Comprehensive® Reverse Shoulder System (Biomet, Inc.) with lateral offsets 0mm, 3mm, and 6mm. The tendon and joint displacement method was used to calculate muscle moment arms through the full range of shoulder abduction (AMA), flexion (FMA) and rotation (RMA) for the 9 different muscle subregions.
Results: The increase in lateral offset did not modify the AMA of the shoulder muscles, but the FMA of the anterior deltoid was considerably increased after lateralization, shifting from 49.1 mm at 0mm offset to 79.6mm at 6mm offset (Figures 2). Lateralization also modified the RMAs of the shoulder muscles. With the humerus at 0° abduction, a lateral offset of 6mm increased the external RMA of the infraspinatus and teres minor from 3.2mm to 26.3mm and from 0.3mm to 18.6mm, respectively, relative to the 0mm offset. The internal RMAs of the clavicular and sternal heads of the pectoralis major were also increased in the 6mm offset condition from 0.2mm to 29.5mm and from 14.7mm to 55.2mm, respectively, relative to the 0mm offset (Figure 3). With the humerus at 90° abduction, lateralizing from 0mm to 6mm increased the external RMAs of the teres minor and posterior deltoid from 3.5mm to 21.7mm and from 11.8mm to 25.3mm, respectively, and increased the internal RMAs of the teres major and latissimus dorsi from 3.7mm to 26.1mm and from 6.7mm to 33.4mm, respectively.
Figure 2: Anterior flexion muscle moment arms of the anterior, middle, and posterior regions of the deltoid, pectoralis-major at clavicular and sternal insertions, and subscapularis using an implant with 0mm offset and 6mm offset.
Figure 3: Axial rotation muscle moment arms with the arm in 0° of abduction of the infraspinatus, teres minor, and posterior deltoid using an implant with 0mm offset and 6mm offset.

**Discussion:** Lateralization of the reverse shoulder prosthesis significantly modifies the muscle moment arms of the shoulder, particularly anterior flexion and axial rotation. In anterior flexion, lateralization enhances the efficiency of the anterior deltoid; possibly enabling patients to achieve greater function during activities of daily living that include overhead motion. In axial rotation, lateralization restores the efficient RMAs to levels close to those of the intact condition, minimizing drops in external and internal rotation function associated with reverse shoulder arthroplasty.

**Significance:** The lateralization of the glenosphere during reverse shoulder arthroplasty increases the muscle moment arms of several muscles associated with anterior flexion and axial rotation relative to those found with a more medially positioned glenosphere. These increases in the muscle moment arms will likely increase the upper extremity function following reverse shoulder arthroplasty.

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