Reverse Shoulder Arthroplasty Implant Design Features that Minimize Change in Muscle-Tendon Length of the Deltoid and Rotator Cuff Muscles

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INTRODUCTION:

Increasing attention is being paid to restoring anatomic soft-tissue tension in the setting of reverse shoulder arthroplasty (RSA), which has implications for muscle and joint function. Therefore, the purpose of our study is to use a geometric model of the shoulder to determine 1) optimal implant design combination for minimizing change in deltoid and rotator cuff muscle-tendon length and 2) the relative impact of implant design characteristics on muscle-tendon lengths.

METHODS:

A geometric model of a native glenohumeral joint was developed, validated, and adjusted to represent small, medium, and large shoulders. Muscle-tendon lengths were assessed for the anterior deltoid, middle deltoid, posterior deltoid, and supraspinatus from 0 to 90° scaption, subscapularis from 0 to 60° internal rotation (IR) and 0 to 60° scaption, infraspinatus 0 to 60° external rotation (ER) and 0 to 60° scaption, and teres minor 0 to 60° ER at 90 deg scaption. RSA designs were modeled and virtually implanted, with any combination of the following: glenosphere size (30mm, 36mm, 42mm), glenosphere lateralization (+0mm, +5mm,+10mm), humeral offset (+0mm, +5mm, +10mm), humeral neck-shaft angle (135°, 145°, 155°). There were 243 RSA-shoulder size combinations included in the analysis. Descriptive statistics were used to compare absolute change in muscle-tendon length, and linear regression analysis used to assess strength of association between implant design parameter and individual muscle-tendon lengthening.

RESULTS:

Of 243 shoulder size-RSA construct configurations, the overall mean muscle-tendon lengths of the deltoid and rotator cuff muscles had a mean lengthening compared to native, although there was a large range of results for each muscle depending on implant characteristics. The supraspinatus muscle had the largest range of difference in muscle-tendon length based on implant configuration (-10.3% to 25.1%, medium shoulder). The construct that most closely restored anatomic muscle-tendon lengths were: small shoulder = 30mm glenosphere/+5mm glenoid lateralization/0 mm humeral offset/135° neck-shaft angle; medium shoulder = 36mm/5mm/0mm/135°; large shoulder = 30mm/10mm/0 mm/135°. Additionally, humeral neck-shaft angle had a strong association (Beta = 0.614 to 0.703, $p<0.001$) with deltoid muscle-tendon length, while glenoid lateralization and humeral offset had a moderate association (Beta = 0.406 to 0.555, $p<0.001$). Alternatively, glenoid lateralization had a strong association with muscle-tendon length of the supraspinatus, subscapularis, and infraspinatus (Beta = 0.602 to 0.724, $p<0.001$), while humeral offset had moderate association (Beta = 0.570 to 0.593, $p<0.001$). Teres minor muscle-tendon length had moderate association with glenoid lateralization (Beta = 0.509), humeral offset (Beta = 0.597), humeral neck-shaft angle (Beta = 0.506) ($p<0.001$).

DISCUSSION AND CONCLUSION:

Restoring anatomic muscle-tendon lengths about the shoulder in RSA is important for maintaining muscle and glenohumeral joint function. Smaller glenospheres with lateralized glenosphere (+5mm small and medium shoulders, +10mm in large shoulders), inlay humerus, and anatomic 135 deg neck-shaft angle best restores native deltoid and rotator cuff muscle-tendon lengths in RSA. Additionally, humeral neck-shaft-angle has the strongest association to deltoid length, while glenoid lateralization has strongest association to rotator cuff length.