Type Of Lateralization On Reverse Shoulder Arthroplasty Impacts Posterior Deltoid Biomechanics In External Rotation

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INTRODUCTION: One of the most common concerns of reverse total shoulder arthroplasty (rTSA) is the lack of external rotation, which limits post-operative function. It has been shown that the posterior deltoid muscle can serve as an external rotator and may play a heightened role in rotator cuff insufficient rTSA shoulders. Modern rTSA designs have used glenoid and/or humeral lateralization to improve post-operative function and multiple studies have investigated the impact of lateralization on the middle deltoid in humeral elevation; however, no studies have investigated how lateralization affects the posterior deltoid in external rotation. Therefore, the purpose of this study was to leverage a well-established computational shoulder model to understand how the external rotation moment arm of the posterior deltoid is impacted by the glenoid and humeral lateralization of rTSA.

MATERIAL & METHODS: Sixteen CTs of non-osteoarthritic subjects were utilized to customize a well-established musculoskeletal computational shoulder model[1] and create 16 individual models. Anatomic muscle origins and insertions were identified for each subject and posterior deltoid was modeled with 2 lines of action (Fig. 1). Each model received a virtual RSA with 4 different configurations: 1) Medial Glenoid, Medial Humerus (MG/MH), 2) Medial Glenoid, Lateral Humerus (+7mm) (MG/LH), 3) Lateral Glenoid (+10mm), Medial Humerus (LG/MH) and 4) Lateral Glenoid (+10 mm), Lateral Humerus (+7 mm) (LG/LH). For all configurations, the glenoid sphere diameter was 36mm and the humeral neck/shaft angle was 135°. Implantation was standardized at 0° of glenoid version and tilt and stem was implanted in 20° of retroversion. Posterior deltoid external rotation moment arms (in mm) were computed throughout external rotation with the arm at 0°, 30°, 60° and 90° of abduction. All motions included clavicle and scapula kinematics. A repeated measures ANOVA test was used to assess the impact of implant configuration on the external rotation moment arms.

RESULTS: All rTSA configurations changed the post-operative position of the humerus compared to the native shoulder. The two medial humerus configurations resulted in less distalization compared to the two lateral humerus designs (15.0 ± 2.9 mm and 14.5 ± 2.8 mm vs 20.7 ± 3.5 mm and 20.1 ± 3.5 mm, for the MG/MH and LG/MH vs MG/LH and LG/LH respectively, $p<0.001$). Only the LG/LH configuration produced overall humeral lateralization relative to the native anatomy (5.2 ± 4.3 mm, $p<0.001$) and this was associated with the greatest posterior deltoid strain at 9.8 ± 1.5%. All rTSA configurations demonstrated that, on average, the posterior deltoid can generate external rotation, however the range of the moment arm was small to moderate (range 9.7 ± 2.6mm to 3 ± 1.6mm, Fig. 2). For all rTSA configurations, moment arm values were largest with the arm starting in neutral rotation (0°) and reduced as the arm externally rotated, with minimum values observed at 90° of external rotation. On average, the MG/MH configuration produced the lowest moment arm (average 5.8±2.0mm, $p<0.001$), whereas LG/LH produced the largest values throughout external rotation and all abduction angles ($p<0.001$). The two lateral humerus configurations showed larger moment arms at 0° and 30° of external rotation compared to the medial humerus configurations (9.1 ± 2.4mm and 9.7 ± 2.6mm vs 7.5 ± 2.0mm and 7.8 ± 2.1mm, $p<0.001$) and LG/MH had larger moment arm at 90° of external rotation compared to MG/LH (4.2 ± 1.7mm vs 3.5 ± 1.8mm, respectively) but lower than LG/LH (4.9 ± 1.9mm, $p<0.001$).

DISCUSSION: This study demonstrates that rTSA implant lateralization directly affects the ability of the posterior deltoid to externally rotate the arm. Although every configuration created an external moment arm, allowing the posterior deltoid to contribute to external rotation, the relatively small values suggest that the deltoid would require a substantial muscle force to achieve meaningful joint torques. Moreover, as the arm externally rotates, moment arm magnitudes decline, making sustained external rotation increasingly challenging. Among the configurations evaluated across a range of abduction angles, the most lateralized configuration (LG/LH) consistently produced the largest moment arms, while the most medialized configuration (MG/MH) produced the smallest. Isolated lateralization of either the glenoid or humerus (MG/LH vs. LG/MH) demonstrated angle-dependent effects: MG/LH produced a larger moment arm during early rotation (0° to 60°), but its advantage diminished with further rotation, and LG/MH surpassed it after 60° of external rotation. This shift reflects how the resulting distalization of the humerus in the MG/LH configuration alters the line of action of the posterior deltoid. It should be noted that the findings of this study are limited to the specific neck/shaft angle and glenoid size configurations, and more work needs to be done to explore the impact of these design choices. Overall, the findings highlight the link between implant lateralization and posterior deltoid biomechanics, suggesting that lateralization strategies should be carefully considered during pre-operative planning to potentially enhance post-operative external rotation of rotator cuff deficient shoulders.

SIGNIFICANCE/CLINICAL RELEVANCE: Humeral lateralization can increase the posterior deltoid moment arm and help in external rotation in rTSA.

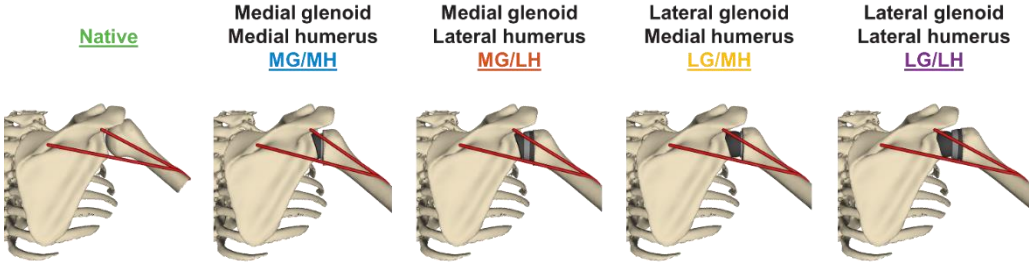

Figure 1: Overview of rTSA implant configurations. For each configuration, the red lines are the virtual representation of the medial and lateral fibers of the posterior deltoid in the musculoskeletal model. For the current study, data are reported by averaging the individual fibers.

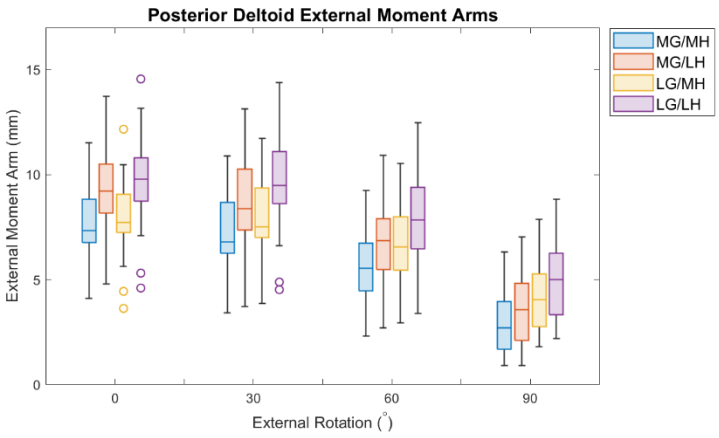

Figure 2: Posterior deltoid moment arms during External Rotation averaged across all abduction angles.