Internal Rotation In Adduction after Reverse Total Shoulder Arthroplasty Demonstrates Joint Orientation and Anatomic Biases in High and Low Performing Subjects

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INTRODUCTION:

Internal rotation in adduction is often limited after reverse total shoulder arthroplasty (rTSA), but the origins of functional deficit are unclear. Little data on underlying 3D humerothoracic, scapulothoracic, and glenohumeral joint relationships are available. No studies have directly compared individuals who can and cannot perform internal rotation in adduction.

METHODS:

Individuals >1-year postoperative to rTSA were imaged with biplane fluoroscopy in resting neutral and internal rotation in adduction poses. Subjects could either perform internal rotation in adduction to T12 or higher (high, N=7), or below the hip pocket (low, N=8). Joint orientations were analyzed via Euler angles derived from model-based markerless tracking of the scapula and humerus relative to the torso. 3D implant models were aligned to preoperative CT models to evaluate bone-implant impingement. Demographics, the American Shoulder and Elbow Surgeons score, Simple Shoulder Test, and scapular notching grade were recorded.

RESULTS:

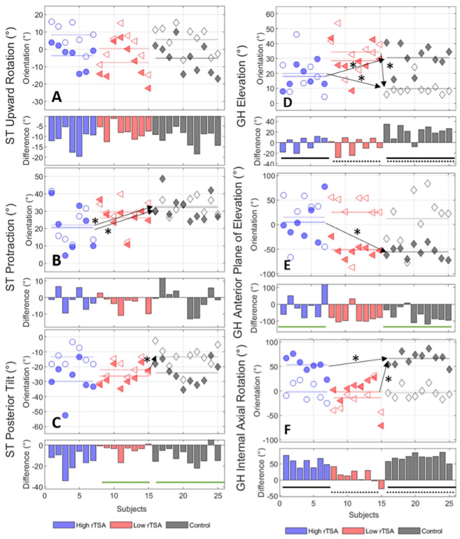
The SST was highest in the high group (11±1 versus 9±2, $p=0.019$). Two subjects per group had scapular notching (Grades 1 and 2), and three high group and four low group subjects had scapular neck impingement in adduction. In the neutral pose, the scapula had 7° more upward rotation in the high group ($p=0.100$), and the low group demonstrated 9° more posterior tilt ($p=0.017$) and 14° more glenohumeral elevation ($p=0.047$). In the internal rotation pose, humeral axial rotation was >45° higher in the high group ($p\leq0.008$) and the low group again had 11° more glenohumeral elevation ($p=0.058$). Large differences within subject groups arose from a combination of changes in the resting neutral and maximum internal rotation in adduction poses, not only the terminal arm position.

Figure 1: Scapulothoracic (ST) orientation angles for (A) upward rotation, (B) protraction and (C) posterior tilt and glenohumeral (GH) orientation angles in (D) elevation, (E) plane of elevation and (F) axial rotation in the neutral pose (open symbols) and internal rotation in adduction (IR) pose (solid symbols) for each subject: high IR (blue), low IR (red), control (grey). Horizontal lines in the scatter plots denote group means for neutral (dotted) and IR (solid) poses. * indicates where statistical significance was detected between rTSA groups and control subjects in a specific pose. The relative change between neutral and IR poses is shown in the bar graphs below the respective scatter plots (Difference = IR – neutral). Horizontal lines below bar graphs indicate statistical significance between the groups when comparing the differences (green $p \leq 0.01$, black $p \leq 0.05$).

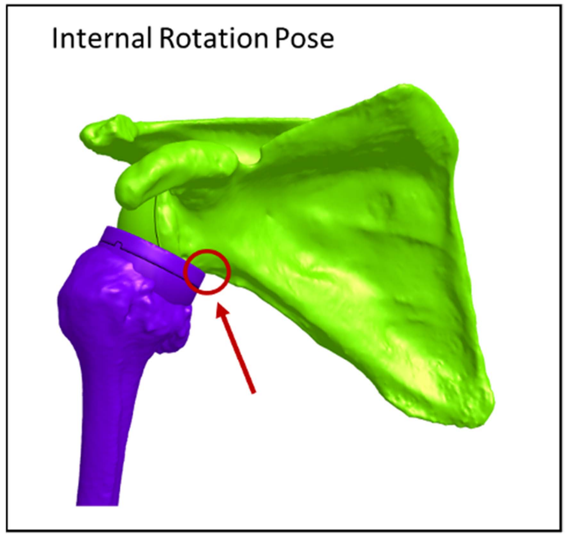
Figure 2: 3D models of a high internal rotation subject in the internal rotation in adduction pose, using subject-specific implant placement in the pre-operative bone. This model shows the potential for impingement of the polyethylene humeral component onto the antero-inferior scapular neck. Interestingly, this subject achieved high IR in adduction but demonstrated impingement. This illustrates that impingement/collision may not be the only indicator of achievable functional IR range of motion if scapulothoracic motion can compensate for the glenohumeral limitations.

DISCUSSION AND CONCLUSION:

Individuals who performed internal rotation in adduction after rTSA demonstrated differences in joint orientation and anatomic biases versus patients that could not. Resting scapulothoracic posture, humeral torsion, and restrictions/compensations in scapular and glenohumeral motion were characteristic of functional deficiency. Individuals with high internal rotation were more likely to differ in joint angles from healthy shoulders than those with low internal rotation. These data point toward modifiable implant design and placement factors, as well as foci for physical therapy to strengthen and mobilize the scapula and glenohumeral joint in response to rTSA surgery. Future computational models and preoperative planning software must consider 3D joint motion beyond basic glenohumeral bone-implant impingement when estimating functional range of motion. More study is required to determine the predictive capacity of these findings.



ST Upward Rotation (°)
ST Protraction (°)
ST Posterior Tilt (°)
GH Elevation (°)
GH Anterior Plane of Elevation (°)
GH Internal Axial Rotation (°)
Orientation (°)
Difference (°)
Subjects
High rTSA
Low rTSA
Control



Internal Rotation Pose