Glenoid Tilt Affects Kinematics during the Hand-to-Back Motion that are Associated with Clinical Outcomes after Reverse Shoulder Arthroplasty

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INTRODUCTION:

Internal rotation is not reliably improved after reverse shoulder arthroplasty (RSA)[1-2]. Surgical parameters such as glenosphere size, lateralization, and retroversion have been associated with internal rotation (IR) after RSA[1-2]. Previous studies have reported IR based upon measuring of how far up the spine a patient reaches when placing their hand behind their back. There is a paucity of accurate *in vivo* kinematics data to quantify how the glenohumeral joint and scapula contribute to the hand-to-back motion. The aim of this study was to determine effects of surgical technique and prosthesis geometry on movement patterns and patient-reported outcomes (PROs) after RSA. We hypothesized that kinematics and contact path that are influenced by greater glenosphere size, inferiorized glenoid tilt, and lateralization during hand-to-back would be associated with better PROs.

METHODS:

Patients who received RSA within previous 1-5 years for rotator cuff arthropathy, irreparable cuff tear, or arthritis and were at least 18 years old at testing and had completed a supervised postoperative physical therapy and rehabilitative program were included. RSA was performed by a single surgeon using a standard 135-degree humeral implant or a 145-degree humeral implant. After patients consented to participate in this IRB-approved study, lateralization, glenosphere size, and eccentricity were recorded from surgical notes. Humeral retroversion and glenoid tilt were measured on postoperative CT. Participants performed 3 trials of hand-to-back motions while synchronized biplane radiographs of the shoulder were collected at 50 images/s for 2 seconds (90 kV, 50mA, 2ms pulse width). Digitally reconstructed radiographs, created from subject-specific segmented bone tissue of the humerus and scapula with their respective implants, were matched to biplane radiographs with sub-millimeter accuracy[3] to determine six degree-of-freedom scapular and humeral kinematics. For all six rotations (glenohumeral (GH) abduction, plane of elevation and internal/external (I/E) rotation, as well as scapular upward rotation, protraction, and tilt) the contribution of each rotation to the motion was found by summing the absolute, instantaneous changes in rotation angles across the motion and normalizing them to the total amount of motion of all six rotations. The average end position, peak angles, and range of motion (ROM) of all 6 rotations were found. ASES, DASH, and CMS scores were collected at testing. Implant characteristics and surgical techniques (humeral retroversion, glenosphere size, lateralization, neckshaft angle, and glenoid tilt) that predicted kinematics (peak angles, ROM, end-range, and contributions of the scapular (rotation, protraction, and tilt) and GH joint (abduction, plane of elevation, and rotation) rotations to the total motion) were identified using multiple linear regression using forward selection with software. The center of contact between a 3D CAD model of the polyethylene and the glenosphere was calculated and the superior/inferior (SI) and anterior/posterior (AP) locations were averaged across corresponding movement angles to establish contact path. Associations between the most anterior, posterior, inferior, and superior points on the contact path and surgical technique were also identified using multiple linear regression using forward selection. Pearson's correlations were used to evaluate associations between either kinematics or contact path and PROs. Significance was set at $p < 0.05$ for all statistical analysis.

RESULTS:

The study cohort comprised 35 patients who received RSA (17M, 18F, 72.8±7.3 years) and agreed to participate with an average follow up of 2.2±1.1 years. The hand-to-back motion was primarily achieved with GH rotation, plane of elevation, and scapular retraction (Figure 1). Inferiorly tilted glenoid and larger glenosphere size were the only significant parameters that influenced kinematics. More inferior tilt was associated with less abduction ($p = 0.035$), protraction ($p=0.007$), and posterior scapular tilt ($p=0.014$) as well as more scapular upward rotation ($p=0.018$), adduction ($p=0.005$), anterior/posterior plane of elevation ($p=0.005$), and retraction ($p=0.003$) (Table 1). Larger glenosphere size was associated with more adduction ($p=0.042$) and scapular tilt ROM ($p=0.019$) as well as less abduction ($p=0.011$), GH rotation ($p=0.012$), and posterior contact path ($p=0.003$). Less peak abduction was correlated with less IR ROM ($p=0.025$), and more scapular upward rotation was associated with more favorable ASES scores ($p=0.047$) (Table 1). More scapular tilt was correlated with more favorable DASH scores ($p=0.047$).

DISCUSSION AND CONCLUSION:

Glenoid tilt and size may be the most influential surgical technique and implant parameters affecting the hand-to-back motion, which may impact patient satisfaction. More neutral tilt was associated with more IR ROM, suggesting modifications to tilt may be a significant parameter for IR performance after RSA. Overall, this study established *in vivo* kinematics of the hand-to-back motion after RSA and found that altering glenoid tilt and size to increase peak abduction, upward rotation as well as scapular tilt ROM may lead to improved outcomes.

1) Hochreiter, et al. (2021) JSES Int. 2) Werner et al. (2021) JSES. 3) Bey, et al. (2006) J Biomech.

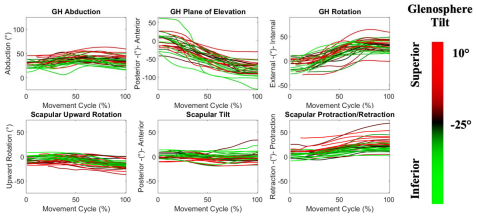

Figure 1: GH and scapular kinematics. Scapular protraction, rotation, and tilt as well as GH rotation, abduction, and plane of elevation throughout the progression of the hand-to-back motion.

Table 1: Glenoid tilt and size associations with kinematics and arthrokinematics

More Inferiorly Tilted Glenosphere		
Kinematic/Arthrokinematic Variables	Beta	p-value
Less Peak Abduction	0.389	0.035
More Peak Upward Rotation	-0.371	0.018
More Upward Rotation ROM	-0.308	0.026
Less Peak Protraction	0.797	0.007
More Peak Adduction	-0.499	0.005
More Peak Posterior Plane of Elevation	-1.068	0.008
More Anterior Plane of Elevation Endrange	-1.135	0.005
Less Peak Scapular Posterior Tilt	0.374	0.014
More Peak Scapular Retraction	-0.574	0.003
Less Endrange Protraction	0.791	0.009
Larger Glenosphere Size		
Kinematic/Arthrokinematic Variables	Beta	p-value
More Peak Adduction	1.076	0.042
More Scapular Tilt ROM	1.151	0.019
Less Endrange Abduction	-1.778	0.011
Less Endrange Rotation	-1.995	0.012
Less Peak Posterior Contact	-0.658	0.003