Surgical Parameters are Associated with Kinematics, Contact Path, and Clinical Outcomes after Reverse Shoulder Arthroplasty during Hand-to-Head Motion

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INTRODUCTION: Reverse shoulder arthroplasty (RSA) is a common procedure to reduce pain and restore function in patients with rotator cuff arthropathy[1]. External rotation (ER) is a common post-surgical assessment of function because it is an essential component of many activities of daily living. Patient-specific and surgery-specific factors, such as lateralization, preoperative teres minor muscle fatty degeneration, and latissimus dorsi tendon transfer, have been shown to influence range of motion and strength in ER[2]. The aim of this study was to determine the effects of surgical technique and prosthesis geometry on *in vivo* kinematics, contact path, and patient-reported outcomes (PROs) during the hand-to-head motion after RSA. We hypothesized that greater lateralization and retroversion, in addition to a lower humeral neck-shaft angle, would be most associated with kinematics and contact path patterns that correlate with improved PROs during this functional motion.

METHODS:

Thirty-five RSA patients consented to participate in this study with an average follow up of 2.2±1.1 years. Lateralization, glenosphere size, and eccentricity were recorded from surgical notes while humeral retroversion, glenoid tilt and lateral humeral offset (LHO) were measured on postoperative CT. Participants performed hand-to-head motions while synchronized biplane radiographs were collected. Digitally reconstructed radiographs were matched to biplane radiographs to determine scapular and humeral kinematics with sub-millimeter accuracy[3]. 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, average end position, peak angles, and range of motion (ROM) were found. Additionally, the superior-inferior (SI) and anterior-posterior (AP) points of the movement throughout the motion were found to establish contact path. ASES, DASH, and CMS scores were collected, and ROM was measured at testing. Strength was measured while patients performed internal/external rotation. Implant characteristics and surgical techniques that predicted kinematics were identified using multiple linear regression. Associations between kinematics and clinical measurements (PROs, clinical ROM, and strength) were evaluated with Pearson's correlations. Significance was set at $p<0.05$ for all statistical analysis.

RESULTS: The hand-to-head motion in this study was primarily performed via glenohumeral elevation and rotation as well as scapular upward rotation (Figure 1). Scapular tilt and protraction minimally contributed to the motion. From beginning to the end of the motion, the contact path tended to move from anterior to posterior as well as inferior to superior on the glenosphere (Figure 2). The only association found between surgical technique and peak rotational kinematics was that less retroversion was associated with more peak abduction (B = -0.470, p = 0.035). No associations were found between either ROM or end position and surgical technique. Implant type, retroversion, and glenoid tilt were all found to be associated with peak posterior contact path (p = 0.012) such that the 135° inlay implants were 2.0mm more posterior (B = -0.198), a 10° decrease in retroversion resulted in 1.1mm more posterior contact path (B = -0.110), and a 10° decrease in glenoid tilt resulted in a 1.3mm more posterior contact path (B = -0.131). No association was found between peak superior contact path and surgical technique. CMS scores improved with more superior contact path (R = 0.631 p < 0.001), greater peak abduction angle (R = 0.572, p < 0.001), and more abduction ROM during the hand-to-head motion (R = 0.534, p = 0.001). DASH scores improved with more peak scapular upward rotation (R = -0.405, p = 0.017). No other correlations between PROs and kinematics were identified. Higher peak external rotation during the hand-to-head motion was associated with more peak torque in external rotation during testing (R = 0.362, p = 0.035). No other associations were found. For clinically measured ROM, external rotation at 90° increased with more peak abduction (R = 0.376, p = 0.029), abduction ROM (R = 0.446, p = 0.008), and upward rotation ROM (R = 0.415, p = 0.015). External rotation at 90º was not significantly associated with any other parameter in this study.

DISCUSSION AND CONCLUSION:

The main components of the hand-to-head motion are abduction, rotation, and scapular upward rotation. Plane of elevation, scapular tilt, and protraction may be less involved during this movement. Retroversion influences abduction, and abduction performance may impact patient-reported outcomes and ROM; positive outcomes that relate to retroversion may have an underlying kinematic basis. Superior contact path and scapular upward rotation are kinematic components that may also improve outcomes. Future studies should determine which techniques can increase superior paths, scapular upward rotation and abduction in ER as well as establish a healthy-shoulder kinematic database to determine how well RSA restores native motion.

REFERENCES: 1) Churchill and Garrigues. (2016). JBJS Reviews. 2) Consigliere, et al. (2022). JSES. 3) Bey, et al. (2006) J Biomech.

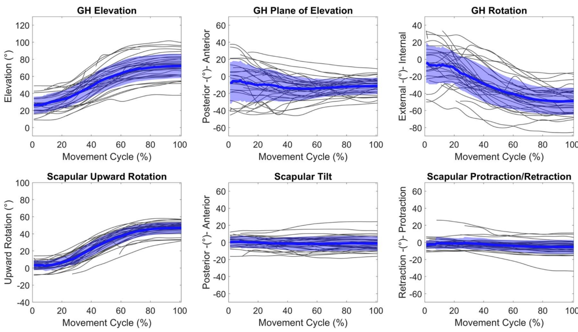

Figure 1: Kinematics of the hand-to-head motion. *The thick line indicates group average kinematics through the motion, with shaded regions indicating ± 1 standard deviation. Individual kinematics curves for the 35 participants are represented by thin black lines.*

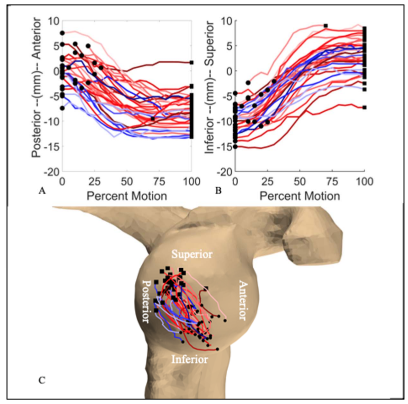

Figure 2: Contact path during the hand-to-head motion. *2A demonstratess the progression of the implant in the anterior-posterior direction while 2B demonstrates the progression of the impant in the inferior-superior direction. 2C shows the contact path on the glenosphere. Blue lines correspond to patients with 135° humeral neckshaft angle, and red lines correspond to patients with 145° humeral neckshaf anglest. Darker shades represent more retroversion while lighter shades indicate less retroversion. The motion of each contact path begins at the circle and ends at the square.*