Increased Lateral Humeral Offset Beyond Anatomic is Associated with Diminished Strength and Range of Motion following Reverse Total Shoulder Arthroplasty

Shaquille JC Charles, Clarissa Levasseur[1], Ajinkya Rai, Gillian E Kane, Maria A. Munsch, Jonathan D Hughes[2], William Anderst[1], Albert Lin[3]
[1]University of Pittsburgh, [2]UPMC Freddie Fu Sports Medicine Center, [3]Freddie Fu UPMC Sports Medicine Center

INTRODUCTION: Over the last decade, the United States has seen a dramatic increase in reverse total shoulder arthroplasties (rTSA)[1]. Cadaveric and computer simulations suggest that humeral retroversion (HR) and lateral humeral offset (LHO) are associated with strength and range of motion (ROM) after rTSA.[2,3] However, there is a lack of *in vivo* data to support those claims. The primary objective of this study was to characterize the association between LHO, strength, and ROM in patients who underwent rTSA. We hypothesized that greater LHO would be correlated with better strength and ROM, but this correlation would be altered by HR.

METHODS:

All rTSA were performed by one fellowship-trained shoulder surgeon with a 135 or 145-degree humeral implant. LHO and HR were measured using *pre*operative and *post*operative CT scans. LHO was measured as the distance between the medial edge of the coracoid process and the most lateral portion of the humerus using axial CT scans. HR was calculated as the difference between the humeral head (*pre*op) or the humeral implant (*post*op) angle and the epicondylar axis at the distal humerus. Postoperative strength was measured using one manufacturer's isokinetic dynamometer. Each patient performed each motion (abduction, adduction, flexion, extension, external rotation (ER), and internal rotation (IR) 3 times with 2-minute rest intervals at perceived exertion increasing from 50% to 75% to 100% effort across those three trials. Postoperative ROM during forward elevation and during ER were assessed using a goniometer, while IR was quantified according to the highest spinal level the patient could touch. Multivariate Generalized Estimating Equations (GEE) models were utilized for strength analyses, while multivariate linear regression modeling was employed for ROM analyses. Univariate associations informed multivariate analyses with significance set to 0.05.

RESULTS:

Thirty rTSA patients (14M, 16F, age: 71.8 $\pm$ 6.7 yrs) participated with an average postoperative follow up of 2.3±1.1 years. Regarding strength, after adjusting for significant covariates, higher *post*op LHO values were predictive of greater postoperative strength for all ranges of motion (p's < 0.05). Paradoxically, although greater *post*op LHO was predictive of greater postoperative strength, lateralization of the implant beyond *pre*op LHO (i.e. *post*op LHO > *pre*op LHO) was associated with poorer strength performance across all ranges of motion (*Figure 1*). Furthermore, we observed an interaction between *post*op LHO and *post*op HR for ER strength ($p < 0.001$). Increasing *post*op LHO was associated with greater ER strength among patients with a *post*op HR value less than 10° (ß=0.65, $p < 0.001$) or between 10-20° (ß=0.35, $p = 0.003$). However, increasing *post*op LHO was correlated with poorer ER strength among patients with a *post*op HR value greater than 20° (ß = -0.37, $p < 0.001$).

Regarding ROM, *greater post*op LHO was associated with poorer *active* ($p = 0.02$) and *passive* ($p = 0.01$) IR ROM (p's < 0.05). Similar to strength outcomes, greater deviations from *pre*op LHO was predictive of poorer IR ROM. However, postop LHO values were not associated with forward elevation or ER ROM. When considering ER ROM, change in LHO in combination with change in HR was predictive of both *active* ($p = 0.03$) and *passive* ($p = 0.001$) ER ROM. More specifically, patients with minimal deviations in HR (*post*op HR within 10° of *pre*op HR) while avoiding over lateralization of the implant beyond *pre*op LHO (*post*op LHO less than or equal to *pre*op LHO) displayed the greatest postoperative ER ROM (*Figure 2*).

DISCUSSION AND CONCLUSION:

While greater LHO may be predictive of greater postoperative strength, change in LHO may be a more important variable for optimizing postoperative strength and range of motion. Additionally, LHO should be considered in combination with HR for optimizing ER strength and ROM. Our findings suggest that strength and ROM are diminished when LHO is over lateralized beyond anatomic. Anatomic restoration of LHO or even slightly medialized combined with anatomic restoration of HR may be optimal. Although many studies have linked lateralization with better outcomes, the optimal amount of lateralization has yet to be characterized. In the context of our results, the ideal amount of lateralization may need to be individualized based on the preoperative LHO.

References: 1. Wagner et al., *JSES,* 2020. 2. Rhee et al., *JSES*, 2015. 3. Parry et al., *J.Ortho*, 2020.

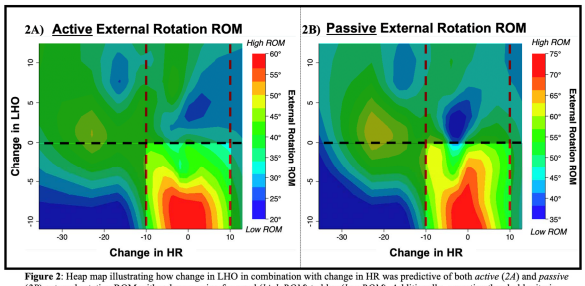

Figure 2: Heap map illustrating how change in LHO in combination with change in HR was predictive of both *active* (*2A*) and *passive* (*2B*) external rotation ROM with values ranging from red (*high ROM*) to blue (*low ROM*). Additionally, operative threshold criteria necessary to optimize postoperative external rotation ROM are detailed using dashed lines with shaded areas representing patients who do not met optimization criteria. *Criteria #1: post*-op HR is within 10° of *pre*-op HR (*dashed maroon lines*). *Criteria #2: Post*-op LHO is less than or equal to *pre*-op LHO (*dashed black line*).

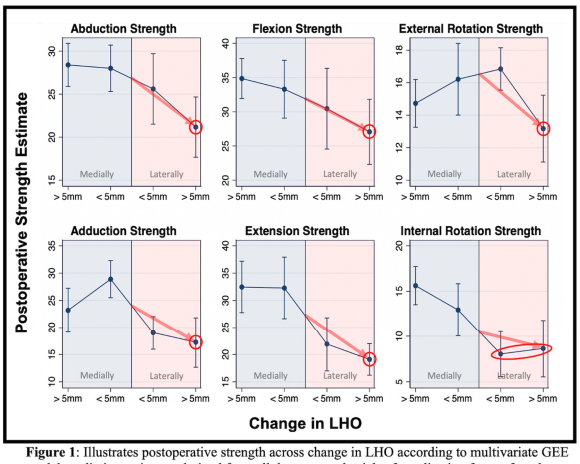

Figure 1: Illustrates postoperative strength across change in LHO according to multivariate GEE model prediction estimates derived from all three strength trials after adjusting for confounders. The *red circles* and *red arrows* highlight the lowest values according to model results.