Biomechanical Analysis of Different Modes of Reverse Total Shoulder Arthroplasty for Proximal Humerus Reconstruction

Mathangi Sridharan, Alyssa Li Tomkinson, Mikayla Romana Mefford, Kasra Rahmati, Frank Petrigliano, Nicholas M Bernthal, Tyler R Clites, Andrew Jensen, Lauren Elisabeth Wessel

INTRODUCTION: Radical or wide resection is the standard treatment for malignant primary tumors of the proximal humerus. Allograft prosthetic composite (APC) reconstruction with reverse total shoulder arthroplasty (rTSA) is emerging as an alternative to the shortcomings of traditional endoprosthetic hemiarthroplasty in order to preserve soft tissue attachments, but there is limited data comparing various recontructive methods. This study examined the load to failure between two methods of proximal humerus reconstruction: reverse total shoulder endoprosthetic reconstruction and reverse allograft prosthetic composite (APC) reconstruction.

METHODS: Ten cadaveric humeri (5 matched pairs) from adult donors were utilized. Each specimen underwent resection of bone and soft tissue 6cm from the greater tuberosity to simulate massive bone loss. One side from each matched pair was randomized to undergo implantation with a reverse endoprosthesis construct; the other received a reverse APC construct. All constructs were cemented. Biomechanical testing was performed by a 6-degrees-of-freedom robotic KUKA manipulator. Each specimen underwent 200 cycles of forward elevation, abduction, and adduction while the KUKA robot held a physiologic compression force across the glenohumeral joint. The proximal portion of each specimen was then clamped in place and subjected to a continuous external rotation moment at a rate of 1 degree/second until failure. Failure was defined as one of the following endpoints: periprosthetic fracture, bone-cement separation, implant-cement separation, or plate or screw pullout (for APC constructs only). Paired *t-tests* were used to compare removal torque between matched pairs (R studio). Significance was set at $P<0.05$.

RESULTS: Removal torque of reverse endoprosthesis constructs was significantly higher than reverse APC constructs, 48.1+/-11.3 Nm (95% CI 34.1-62.1 Nm) vs. 19.4 +/- 10.2 Nm (95% CI 6.73-32.1 Nm), P=0.005. All reverse endoprosthesis constructs failed with periprosthetic spiral fracture. Reverse APC constructs failed predominantly with bone-cement separation at the allograft-native bone interface followed by screw pullout from the allograft component.

DISCUSSION AND CONCLUSION: Reverse endoprosthesis constructs fail at significantly higher loads and different mechanisms than reverse APC constructs. Endoprosthesis constructs in the setting of massive bone loss have similar stability to historical analyses of standard, cemented rTSA, which can inform post-operative protocols after oncologic reconstruction. There should be high clinical threshold with appropriate soft tissue stabilization to perform APC constructs.

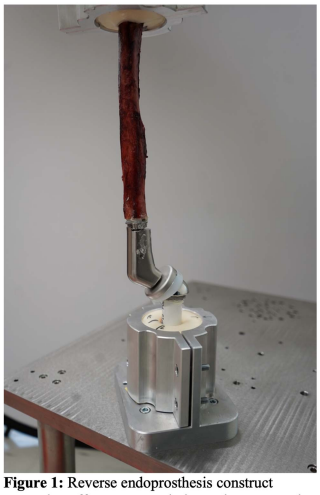

Figure 1: Reverse endoprosthesis construct secured to effector arm and glenosphere secured to test base of Kuka robotic manipulator

Figure 2: Robotic KUKA manipulator applying external rotation moment to reverse APC construct

Table 1: Load to Failure Between Reverse Endoprosthesis and Reverse APC Constructs

Specimen	Implant size (mm)		Removal torque, Nm (side)	
	Endoprosthesis	APC	Endoprosthesis	APC
1	11x75	10	48.8 (R)	14.9 (L)
2	14x75	10	46.7 (L)	13.6 (R)
3	12x75	10	32.5 (R)	10.1 (L)
4	16x75	10	64.3 (R)	22.8 (L)
5	11x75	10	48.1 (L)	35.7 (R)
Mean (SD)	-	-	48.1 +/- 11.3	19.4 +/- 10.2
95% CI	-	-	34.1-62.1	6.73-32.1

SD, Standard Deviation
CI, Confidence Interval
R, Right; *L,* Left