Comparative Analysis of Muscle Activation and Radiographic Parameters Following Reverse Total Shoulder Arthroplasty

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INTRODUCTION: Reverse total shoulder arthroplasty (RTSA) is predominant in over 70% of shoulder arthroplasty cases[1], aiming to enhance stability and range of motion through deltoid tensioning and altered shoulder moment arms. Lateralization and distalization shoulder angles (LSA and DSA, respectively) have shown mixed outcomes as imaging predictors of improved PROMs[2, 3]. Additionally, Reverse shoulder angle (RSA) and beta angle, measures of the glenoid component inclination, have been linked to post-op complications and range of motion changes[5]. Finally, Acromiohumeral distance (AHD) and Center of Rotation (COR), direct measurements of lateralization and distalization, have also been proposed as predictors of clinical outcomes in RTSA with contrasting results[6]. Despite these relationships, the impact of imaging parameters on deltoid tension and muscle activation during dynamic tasks remains unclear. The primary objective of this study was to investigate the connection between shoulder implant and alignment measures in RTSA with functional activation of the deltoid muscles during active abduction and scaption (abduction in the scapular plane) tasks. We hypothesized that measures of lateralization and distalization of the prosthesis would be associated with a change in the mechanical efficiency of the deltoid fibers.

METHODS: Thirteen patients (n=13) were prospectively enrolled in an ongoing, IRB approved study in patients undergoing reverse total shoulder arthroplasty (RTSA) utilizing the same implant system. After a minimum of 4 months post-operation, patients participated in a laboratory session where they performed three repetitions of shoulder abduction and scaption movements. A 16-channel, wireless electromyography system (Noraxon EMG) was used to measure muscle activation timing and relative magnitude for the trapezius (upper/middle/lower fibers) and deltoid (anterior/middle/posterior) muscles during the overhead tasks. All EMG signals were filtered (4^{th} order Butterworth; bandpass 50Hz-500Hz), rectified, and enveloped via root mean square with a moving window (100 ms). All amplitude was normalized to a series of maximal voluntary isometric contraction tasks to isolate the muscles of interest. To compare relative activation changes, the maximal activation ratios were calculated between the anterior deltoid and upper trapezius, mid deltoid and upper trapezius, as well as anterior and mid deltoid muscles for both tasks. Radiographic assessments, including lateralization shoulder angle (LSA), distalization shoulder angle (DSA), beta angle, reverse shoulder angle (RSA), center of rotation distance (COR), and acromiohumeral distance (AHD), were measured by a shoulder fellowship-trained surgeon using the most recent radiographic series for all patients. A multivariate linear regression analysis (SPSS v26) was used to correlate EMG ratios with radiographic measurements.

RESULTS SECTION: The cohort comprised 6 males and 7 females, with a mean age of 70.5 (57-81) years. EMG measurements were taken at a mean of 8.4 (4-16) months post-operation. The average values for radiographic measures are presented in Table.1. The results revealed a significant positive correlation (P=0.019) between LSA and the ratio of anterior to mid deltoid excitation ($R^2 = 0.65$). Additionally, a trend (P=0.09) toward a positive correlation was observed between DSA and the ratio of upper trapezius to mid deltoid excitation. No significant correlations were identified between the remaining radiographic measurements and the EMG activation ratios.

DISCUSSION: The observed correlation between Lateralization Shoulder Angle (LSA) and mid deltoid activation (Figure 1), as found in our study, illuminates the relationship between lateralization and a significant shift in muscle activation during abduction, specifically from the anterior deltoid to the mid deltoid, which is biomechanically coherent. By indicating that lateralization can channel excitation towards the mid deltoid, our findings provide valuable insights into the biomechanical basis that underlies the connection between LSA and the heightened range of motion and improved Constant scores, as previously reported[1]. Conversely, these same correlations were not evident for other radiographic measurements in our study. Despite the fact that other studies[3-5] have found associations between those measurements and clinical outcomes, we did not observe these connections in our series. This disparity may stem from various factors, including the relatively small size of our cohort, the specific choice of movement tasks, and the particular muscle groups that were subjected to assessment. These factors represent the primary limitations of our study. Despite these limitations, we were able to establish a significant link between lateralization measurement and the activation pattern of deltoid muscle. This implies the existence of an unidentified mechanism that can elucidate the correlation of radiographic measurements on patient-reported outcomes and range of motion.

SIGNIFICANCE/CLINICAL RELEVANCE: Our study uncovered a correlation between certain radiographic measurements, notably Lateralization Shoulder Angle (LSA), and a shift in muscle activation toward the mid deltoid, potentially enhancing biomechanical function. This study is significant for connecting radiographic measurements with muscle dynamics post RTSA, suggesting potential optimization of surgical techniques and emphasizing the broader relevance of considering muscle dynamics in understanding surgical outcomes in musculoskeletal contexts.

REFERENCES: [1] Mayfield et al., *JSES International*. 2023; [2] Imiolczyk et al., J Shoulder Elbow Surg. 2023; [3] Boutsiadis et al., J Shoulder Elbow Surg. 2018; [4] Helmkamp et al., J Shoulder Elbow Surg. 2018; [5] Duethman et al., JSES Int. 2020; [6] Berthold et al., J Clin Med. 2021

Table 1. Mean Values for the studied Radiographic Measurements.

Radiographic Measurement	Mean (range)
Distalization Shoulder Angle (DSA)	55.8º (37.4º-76.3º)
Lateralization Shoulder Angle (LSA)	84.5º (72.6º-99.8º)
Reverse Shoulder Angle (RSA)	92.4º (78.4º-104.3º)
Acromiohumeral Distance (AHD)	25.7 (22.8-46.9) mm
Center of Rotation distance (COR)	48.4 (41.6-58.1) mm
Beta angle	85.5º (78.4º-96.)

Figure 1. Anterior/Mid-Deltoid Ratio and Lateralization Shoulder Angle (LSA) on Abduction task.