Machine Learning Model for Predicting Acromial and Scapula Fractures After Reverse Shoulder Arthroplasty: Humeral Center of Rotation Offset as a Significant Predictor

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INTRODUCTION:

Acromial Stress Fractures (ASF) and Scapular Stress Fractures (SSF) are complications of Reverse Shoulder Arthroplasty (RSA), with reported incidences ranging from 0-15%. Management guidance is limited by small observational studies with heterogeneous methods, although poor outcomes are noted regardless of management strategy. Thus, prevention of these fractures is crucial for effective management and improved outcomes. Proposed risk factors for ASF/SSF fractures include female sex, older age, osteoporosis, inflammatory arthritis, trauma, smaller acromion, and chronic dislocation. However, the influence of RSA design and component placement on fracture risk is unclear, with conflicting evidence regarding lateralization, distalization, and humeral component inlay vs. onlay. This study aims to identify factors associated with ASF/SSF after RSA, and also develop a machine learning model to aid in prediction of fracture after RSA.

METHODS:

Data from 316 patients (ASF/SSF = 24; 292 = no fracture) who underwent RSA at an academic institution were obtained. Patient factors included age, sex, BMI, height, ethnicity/race, and primary indication for surgery. Grashey radiographs from pre- and immediately post-operative timepoints were identified, and HOROS DICOM viewer software was used to measure the following parameters: humeral lateralization from glenoid, humeral lateralization from acromion (Figure 1), acromiohumeral interval, size of proximal humerus perfect circle, and humeral center of rotation (COR) offset (Figure 1) as a quantitative measure of component inlay or onlay placement. Pre- and postoperative values wer. Dataset was split into training and test sets using a 70:30 split. A LASSO model was used for feature selection and to identify significant risk factors for scapula fracture. Model performance was evaluated using accuracy, AUC, F1 score, and G-mean.

RESULTS: ASF/SSF patients were more likely to be white ($p<0.001$), have a greater COR offset ($p=0.001$), a lower difference from pre- to postoperative lateralization of the acromion to greater tuberosity ($p=0.045$), and have rheumatoid arthritis diagnosis ($p<0.001$). The cohort without ASF/SFS was more likely to have an osteoarthritis diagnosis ($p<0.001$). The LASSO predictive model demonstrated good overall performance on the test dataset with an AUC of 0.75. Overall, the model exhibited an accuracy 0.783, and F1 of 0.825, and a G-mean of 0.545. Key features identified by the LASSO regression were COR offset (log(OR) = 1.288), pre-op acromion to greater tuberosity (cm) (log(OR) = 0.111), post-op humeral area (cm2) (log(OR) = 0.073), BMI (log(OR) = 0.034), weight (log(OR) = -0.022), pre-op glenoid to acromion (log(OR) = 0.006), difference in lateralization of the acromion to greater tuberosity(log(OR) = 0.003), difference in acromiohumeral interval (log(OR) = -0.463), and a primary diagnosis of osteoarthritis (log(OR) = -0.634) (Figure 2).

DISCUSSION AND CONCLUSION:

Our study found that increased COR offset, and thus onlay positioning of the humeral component, was the most influential risk factor for developing an ASF/SSF after RSA. Furthermore, RA and white race were risk factors for developing a fracture, while global lateralization of the humerus and diagnosis of OA were protective. Overall, the predictive LASSO model performs reasonably well in terms of accuracy and F1 score. These findings suggest that minimizing humeral COR offset while increasing global humeral lateralization may mitigate ASF/SSF in patients undergoing RSA, while there was no apparent association between fracture and distalization as measured by the acromiohumeral interval.

Figure 2: Forrest Plot of Coefficient values for LASSO regression variables with 95% confidence intervals

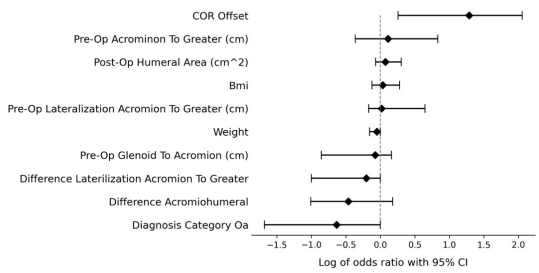

Figure 1 – Left: Humeral component center of rotation offset measurement, defined as the distance between the center of the perfect circle drawn at the proximal humerus (blue circle, green dot center) to the center of the same diameter circle placed within the humeral socket/tray (purple circle, orange dot center). Right: Global lateralization assessed from the lateral edge of the acromion (B) to the lateral edge of the greater tuberosity (C). Distance measured perpendicular to the glenoid plane.