Artificial Intelligence Can Automatically Measure Component Orientation, Lateralization, and Distalization on Postoperative Radiographs after Reverse Shoulder Arthroplasty

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INTRODUCTION: The wide variety of implants available for reverse shoulder arthroplasty (RSA) results in different combinations of glenoid, humeral, and global lateralization and component orientation, among many other parameters. Furthermore, *the final geometric configuration of RSA is also influenced by how the surgeon implanted components*; for example, the center of rotation of the same glenosphere will be different on each shoulder replaced depending on the severity of preoperative bone loss and how medial the surgeon reamed. As such, accurate measurement of the final geometry of the shoulder on postoperative radiographs is needed to correlate implant position with clinical outcomes. Manual measurements of multiple parameters in large numbers of radiographs are tedious, inefficient, subjective, and can potentially lead to measurement errors. Computer vision artificial intelligence (AI) tools offer the possibility of processing thousands of images in record time and routinely provide accurate and objective measurements. The purpose of this study was to develop an AI tool to automatically segment and annotate postoperative radiographs in order to automatically measure component orientation and global lateralization and distalization.

METHODS: The DICOM files corresponding to 144 postoperative anteroposterior radiographs after RSA were retrieved and uploaded into 3D-slicer v 5.2.2. for *manual segmentation and measurements*. One orthopaedic surgeon segmented all 144 radiographs identifying key bony landmarks and implant features **(Figure 1**). Next, the same DICOM files were randomly split into training (n=90), validation (n=22), and testing (n=32) sets. An AI segmentation model (U-net) with a pre-trained EfficientNet-b0 backbone was trained using the training and validation sets and used to develop an automated image-processing pipeline that *automatically segmented and annotated* the DICOM files to measure the following parameters: glenoid inclination angle (GIA) between the central post or screw of the baseplate and the floor of the supraspinatus fossa; humeral alignment angle (HAA) between the long axis of the humeral shaft and a line orthogonal to the metallic humeral bearing; the lateralization shoulder angle (LSA); and the distalization shoulder angle (DSA). The same four parameters (GIA, HAA, LSA, and DSA, **Figure 1**) were manually measured in the testing set by three independent evaluators. For each parameter, intraclass correlation coefficients (ICC) among the three independent manual measurements were calculated to evaluate the inter-observer agreement. The absolute difference in degrees, and ICC were calculated to compare the average manual measurement among three evaluators and AI-derived measurements.

RESULTS: All 32 images in the testing set were segmented and measured by the AI algorithm in 14.3 seconds. The ICCs (95% confidence interval) among the three human evaluators were 0.96 (0.93 - 0.98), 0.99 (0.97 - 0.99), 0.79 (0.55 - 0.90), and 0.90 (0.80 - 0.95), for GIA, HAA, LSA, and DSA, respectively. The absolute differences median (interquartile range) between AI-derived and the average manual measurement were 2.1º (2.2º) for GIA, 1.4º (1.6º) for HAA, 3.4º (4.9º) for LSA, and 2.1º (2.5º) for DSA, (**Figure 2**). The ICCs (95% confidence interval) between the AI-derived and the average manual measurements for GIA, HAA, LSA, and DSA were 0.85 (0.68 - 0.93), 0.98 (0.95 – 0.99), 0.89 (0.79 - 0.95), and 0.96 (0.93 – 0.98), respectively.

DISCUSSION AND CONCLUSION: An efficient AI-based tool was developed to automatically segment and annotate postoperative RSA radiographs. This tool was able to accurately measure GIA, HAA, LSA, and DSA. Once this tool is expanded to add several additional measurements, batch processing of large sets of postoperative radiographs will finally allow us to identify associations between the geometry of RSA as implanted by surgeon with outcomes and complications.

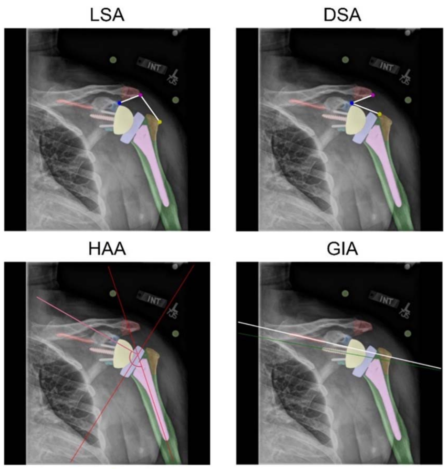

Figure 1. Images from the automatic segmentation and annotation software. LSA: Lateralization Shoulder Angle; DSA: Distalization Shoulder Angle; HAA: Humeral Alignment Angle; GIA: Glenoid Inclination Angle.

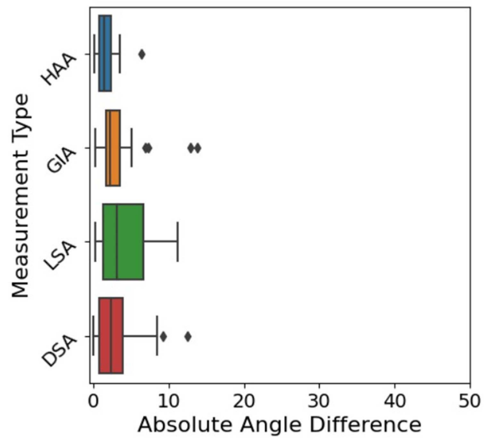

Figure 2. Boxplot showing the mean absolute angle difference in degrees and its interquartile range for each angle. LSA: Lateralization Shoulder Angle; DSA: Distalization Shoulder Angle; HAA: Humeral Alignment Angle; GIA: Glenoid Inclination Angle.