Shoulder Impingement: Systematic 3D Shape Analysis of Acromial Morphology

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Introduction

Shoulder impingement syndrome involves compression of the rotator cuff by soft tissue and bone.[1] Although the pathogenesis is multifactorial, a major component is the shape of the acromial undersurface and many attempts have been made to evaluate this morphology, including classification into flat, curved, and hooked stratifications.[2] Subsequent studies have demonstrated significant interobserver variation with such classifications.[2] This is likely due to the subjective nature of nonsystematic interpretation, lack of acknowledgment in the continuum of shapes, and difficulties with variable plane obliquity. The purpose of this study is to mathematically describe acromial morphology allowing objective comparison between patients with and without different severities of impingement.

Materials and Methods

Based on surgical findings, 84 subjects were stratified into the following groups: A) no surgical evidence of shoulder impingement (n=31), B) shoulder impingement without rotator cuff tear (n=22), or C) rotator cuff tear (n=31). 21 were female (mean age, 47 years; range, 20-69 years), 63 male (mean age, 41 years; range, 15-74 years). MR images were obtained at 1.5T (Siemens) with a dedicated shoulder coil within 14 days of surgery. Imaging parameters typically consisted of sagittal oblique SE sequences (TR/TE 500-800ms/10-20ms) with FOV 16cm, matrix 256x256, and slice thickness of 3mm with .9mm interslice gap. The entire acromion was imaged and all slices were used. DICOM images were converted to JPEG in original matrix dimension and left shoulders were flipped to compare one group of right shoulders. The image series were then imported into AutoCAD 2005 (Autodesk) and converted to three dimensions.

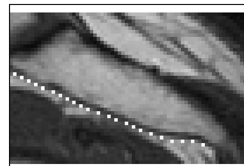


Figure 1: Points along acromial undersurface

Approximately 160 points were plotted along the entire acromial undersurface (Figure 1) and imported into Matlab (Mathworks). Utilizing b-splines to maximize smoothness and minimize error between points, a surface was constructed. The shape index was calculated for a 20 x 20 grid (400 points) on the surface. Shape index provides a mathematical measure of local shape for a given point, and ranges from -1 to 1 (Figure 2). All positive indices are convex and all negative indices are concave in shape. Additionally, normal vectors were determined at each of the 400 points on the acromial undersurface (Figure 3). The angle difference between this local normal vector and a normal vector of a plane of best fit (Figure 4) is a measure of local undersurface angulation.

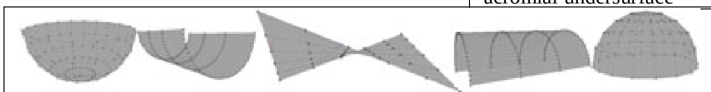


Figure 2: Shape Index (values from left to right: -1,-0.5,0,0.5,1)

Least squares regression was used to identify groups of data points that exhibited differences between subject groups. Additionally, logistic regression analysis was used to determine the extent to which the shape index or acromial angle values could be used for diagnosis.

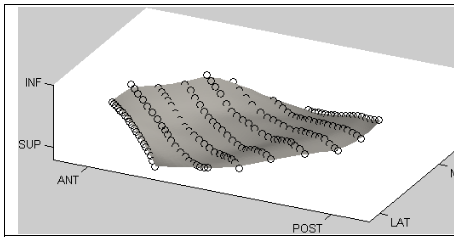


Figure 3: Surface reconstruction of acromial undersurface

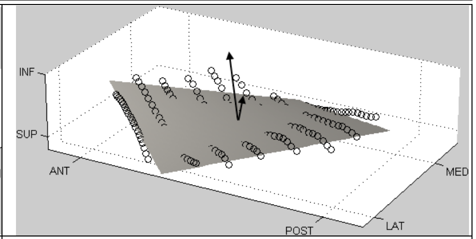
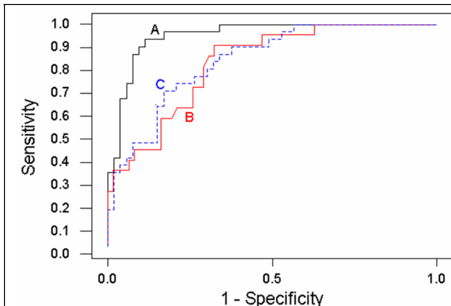


Figure 4: Plane of best fit with normal vectors of surface and plane

Results

It was observed that neither age nor gender was significantly associated with the shape index or local undersurface angulation. Both the shape index and local undersurface angulation datasets exhibited areas with significant differences across subject groups, however there was no demonstrable continuum of progression from groups A to C in either. In our analysis the local angulation was much more useful than the shape index in distinguishing between groups. Utilizing the local undersurface angulation dataset, p-values were calculated from an analysis of variance, indicating relative utility of that area in discriminating diagnostic groups. It was shown that the majority of significant values ($p<0.05$) corresponded anatomically to the lateral aspect of the undersurface of the acromion (Figure 5). Using the angulation from points in the most lateral portion of the acromion, a prediction model based on our sample demonstrated an overall diagnostic accuracy of 73.8% for distinguishing between the groups. Additionally, ROC curves were generated for each group (Graph 1). The area under the ROC curve was 0.952 for Group A, 0.833 for Group B and 0.844 for Group C. When the mean local undersurface angulation was used to build a diagnostic model, the weighted kappa for the agreement between actual and predicted assessments of condition was 0.762.



Graph 1: ROC curves for binary prediction models to diagnose groups based on acromial angle

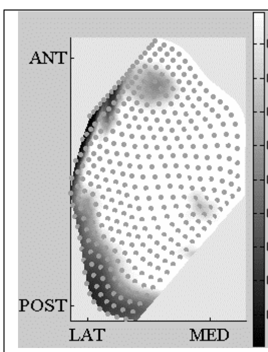


Figure 5: Overlay of p-values on acromial undersurface to distinguish between groups

Discussion

Our 3-D method for intrinsic shape determination has shown promise in distinguishing between impingement and non-impingement patients. To this end, local undersurface angulation proved more useful than shape index. Identifying patients by acromial shape is a realistic prospect and provides an example where the concept of shape interaction aids in understanding musculoskeletal disorders.

References

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2. Bigliani LU et al. The morphology of the acromion and its relationship to rotator cuff tears. *Orthop Trans*. 1986;10:216.
3. Jacobson SR et al. Reliability of radiographic assessment of acromial morphology *J Shoulder Elbow Surg*. 1995;4:449–453.