Quantifying 3D Volume of Glenohumeral Capsule Following a Shoulder Dislocation from Clinical MR Arthrogram Data

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INTRODUCTION: The glenohumeral joint is the most commonly dislocated joint, usually by an anterior shoulder dislocation [1]. This type of injury can result in permanent deformation of the glenohumeral capsule, which causes increased capsular laxity and increased capsular volume [2,3]. Capsular volume can be shown using MR arthrogram, in which contrast agent is injected into the glenohumeral joint. A gross assessment of capsular volume has been performed using 2D measurements of clinical MR arthrograms [3]; however, a more detailed assessment of global and regional capsular volume could potentially be determined using 3D reconstruction of clinical MR arthrogram images to provide a more representative assessment of capsular injury. Therefore, the aim of this study is to create and utilize 3D models of the glenohumeral capsule created from MR arthrograms to quantify capsular volume in healthy subjects and subjects who had experienced one or more anterior shoulder dislocations.

METHODS: Clinical MR arthrograms (slice thickness: 3mm in axial and coronal planes, 3.5 or 4mm in sagittal plane) of the glenohumeral joint in healthy subjects (n=8) and subjects that had sustained at least one anterior shoulder dislocation (n=8) were acquired. The capsular space was defined as the space within the glenohumeral capsule filled with the contrast agent during the MR arthrogram. The capsular space, humerus, and glenoid were segmented in MIMICS (version 17.0, Materialise NV, Belgium) from the coronal, sagittal, and axial view for each subject. Meshes created from each view were then combined in MeshLab (version 1.3.4, ISTI, Italy) by overlaying them to generate a higher resolution mesh for each subject **(Figure 1)**, and the volume of the capsular space was determined. The volume of the capsular space was also calculated with the superior portion removed because the inferior region of the capsule was expected to experience the greatest injury. This was standardized between subjects by removing any capsular space above the greater tuberosity of the humeral head. These volumes were then normalized to the size of the humeral head by fitting a sphere to the humeral head and dividing the capsular volume by the radius of the sphere cubed. The capsular volumes of each group were compared with a two-sample t-test with significance set at $p<0.05$.

RESULTS: The total capsular volume of the injured group was found to be 65% larger than the capsular volume of the healthy group ($p=0.027$) **(Figure 2)**. No significant difference in capsular\ volume was found between the healthy group and capsular volume of the inferior glenohumeral capsule **(Figure 3)**. A power analysis was conducted for capsular volume of the inferior glenohumeral capsule, and a total of 26 more subjects would be needed for the differences between the groups to be significant.

DISCUSSION: 3D models of the capsular space at the glenohumeral joint were successfully reconstructed from MR arthrograms and were able to show a significant difference in capsular volume between healthy and injured subjects when normalized to the size of the humeral head. Thus, these measurements could be used clinically to individualize treatment for patients that have experienced shoulder dislocation. This method was able to quantify total capsular volume but may not be ideal for examining injury to specific regions of the capsule due to the large slice thickness of the clinical MR arthrograms that was used to create the models. The joint position and amount of contrast agent injected into the joint was also not standardized between subjects. Future studies should utilize a methodology to assess injury to specific regions of the capsule by determining the volume of each specific region of the capsule following a shoulder dislocation.

SIGNIFICANCE/CLINICAL RELEVANCE: By quantifying capsular injury using MRI, surgical repair to the glenohumeral capsule following a shoulder dislocation can be individualized for each patient. Injury-specific repair could reduce the chance of recurrent shoulder instability, improving quality of life for patients.

REFERENCES: [1] Cutts et al. *Annals.* 2009 [2] Dewing et al. *AJSM.* 2008 [3] Hung Ng et al. *AJR.*. 2009

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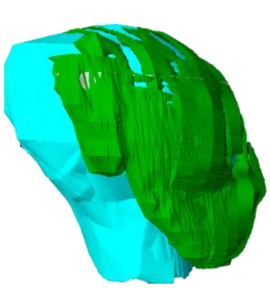

Figure 1. Posterior view of 3D reconstruction of glenohumeral capsule (green) and humeral head (blue) from MR arthrogram.

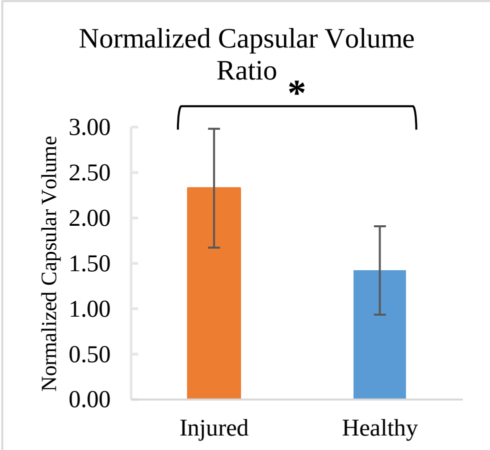

Figure 2. Total glenohumeral capsular volume in healthy and injured subjects calculated from 3D reconstruction of MR arthrogram. The normalized volume was 65% larger in the injured subjects than in the healthy subjects.

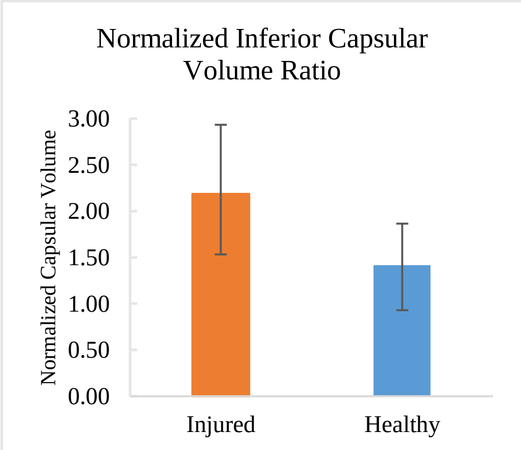

Figure 3. Glenohumeral capsular volume with superior portion removed in healthy and injured subjects calculated from 3D reconstruction of MR arthrogram. No significant difference in normalized volume was found between healthy and injured subjects