

Three-dimensional Capsular Volume Measurements in Multidirectional Shoulder Instability

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Background: In a previous study undertaken to quantify capsular volume in rotator cuff interval or axillary pouch, significant differences were found between controls and patients with instability. However, the results obtained were derived from two-dimensional cross sectional areas. In our study, we sought correlation between three-dimensional (3D) capsular volumes, as measured by magnetic resonance arthrography (MRA), and multidirectional instability (MDI) of the shoulder.

Methods: The MRAs of 21 patients with MDI of the shoulder and 16 control cases with no instability were retrospectively reviewed. Capsular areas determined by MRA were translated into 3D volumes using 3D software Mimics ver. 16 (Materialise, Leuven, Belgium), and glenoid surface area was measured in axial and coronal MRA views. Then, the ratio between capsular volume and glenoid surface area was calculated, and evaluated with control group.

Results: The ratio between 3D capsular volume and glenoid surface area was significantly increased in the MDI group ($3.59 \pm 0.83 \text{ cm}^3/\text{cm}^2$) compared to the control group ($2.53 \pm 0.62 \text{ cm}^3/\text{cm}^2$) ($p < 0.01$).

Conclusions: From these results, we could support that capsular volume enlargement play an important role in MDI of the shoulder using volume measurement.

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Key Words: Shoulder; Multidirectional instability; Capsular volume

Introduction

Multidirectional instability (MDI) of the shoulder is a complex condition that causes excessive motion and translation in more than one direction. Its underlying pathology is increased capsular laxity and rotator cuff interval elongation.¹⁻³ Magnetic resonance arthrography (MRA) is a known gold standard method for evaluating shoulder instability, and is highly sensitive at detecting capsular laxity and redundancy.^{4,5} In a previous study undertaken to find relations between capsular areas using two-dimensional (2D) cross-sectional areas (CSA) and various instability conditions of the shoulder, significant difference was found between control and instability patients.¹

In our study, three-dimensional (3D) volume measurements

were performed in MDI patients and control groups, and the difference between them was significant and the differences from previous 2D results were examined.

Methods

An informed consent was taken from all study participants and the study has been approved by Institutional Review Board of Chosun University Hospital. Patients who underwent MRA examination in Chosun University Hospital from August 2010 to August 2013 were included in this study. Of the total 78 patients, 21 were diagnosed with MDI and the remaining 57 were not diagnosed with MDI. The exclusion criteria applied to all 41 study members were; glenoid bony deficiencies, engaging Hill-

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Sachs lesions and degenerative arthritic changes, rotator cuff tear, traumatic dislocation or previous surgery on the involved shoulder. Finally, 16 patients were used for the analysis as a control group.

The MRAs of 21 patients with mean age of 25.5 years (range, 17–38 years) with MDI were reviewed in a computerized search of radiologic and clinical files of Chosun University Hospital. All patients had a diagnosis of MDI based on clinical history, physical examination, MRA. And the patient was diagnosed with MDI having persistent instability symptom of the shoulder and global instability in physical examination. All patients had capsular stretch and no labral tear in MRA.

A control group of 16 cases with mean age of 29.8 years (range, 16–48 years) without clinical instability were identified. Members of the control group had no history of shoulder trauma and no evidence of instability by physical examination.

Contrast medium for MRA was injected using the rotator interval approach. Briefly, a 22-gauge spinal needle was placed in the glenohumeral joint and with 20 ml of normal saline with contrast media was instilled. Magnetic resonance imaging (MRI)

was performed with the patient's arm adducted and the hand in a neutral position.

All patients underwent MRA examinations using a 1.5-T unit (Avanto; Siemens, Erlangen, Germany) equipped with a phased-array HD shoulder coil. All subjects were imaged supine. The following MRA imaging sequences were used: axial, oblique coronal and oblique sagittal proton density turbo spin echo sequences.

Capsular areas in images were converted into 3D capsular model using 3D software Mimics ver. 16 (Materialise, Leuven, Belgium) (Fig. 1). The 3D boundary of the uniform high signal area corresponding to contrast material in the capsule was drawn automatically. Small amount of extra-capsular leakage of contrast material was removed manually to facilitate volume calculations. Capsular 3D volumes were measured automatically by the same program, and reference measurements of glenoid articular surface area was made by simply multiplying largest anterior to posterior (AP) distance in axial view by the largest superior to inferior (SI) dimension of the glenoid in coronal view (Fig. 2). Glenoid dimensions were measured using a PACS using

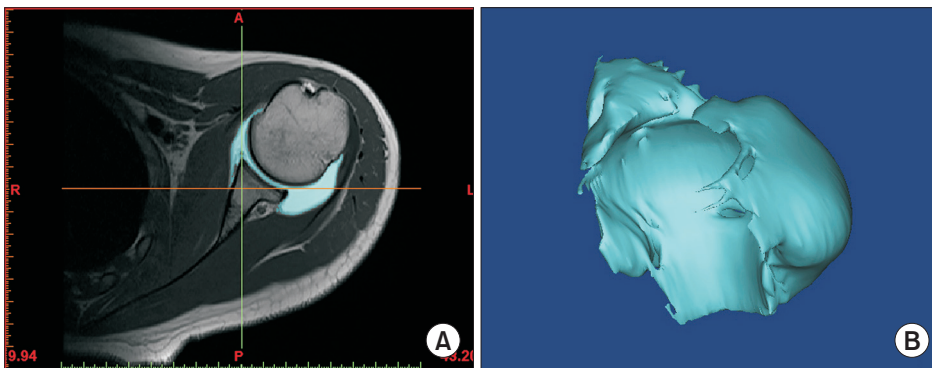


Fig. 1. Capsular areas of arthrograms axial views (A) were translated in terms of three-dimensional volume (B) using image-processing software.

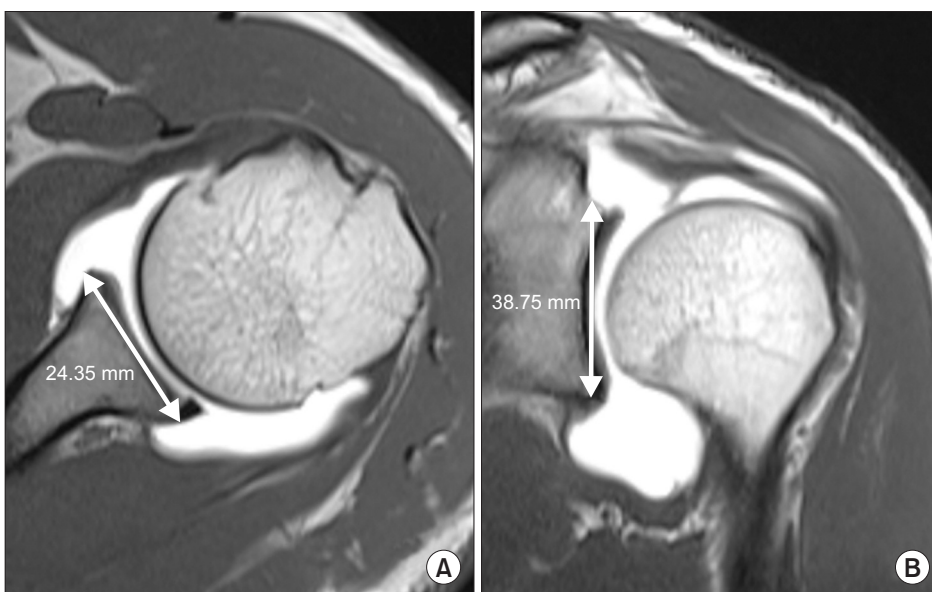


Fig. 2. Glenoid surface area was measured using axial (A) and coronal (B) magnetic resonance arthrography images.

a cursor, lengths were calculated automatically. These reference measurements were used to correct for variances in glenoid size by calculating ratios between glenoid articular surface areas and capsular fluid pocket volumes.

The capsular volume to glenoid surface area ratios were compared using the Student's t test. Statistical charts were generated using Excel 2007 (Microsoft, Redmond, WA, USA). Inter-group comparisons were conducted by using SPSS ver. 13.0 software (SPSS Inc., Chicago, IL, USA) and power analysis was performed using PASS 2008 software (NCSS, Kaysville, UT, USA). *p*-values of <0.05 were considered significant and values of <0.01 as highly significant.

Results

Mean capsular volume was $26.248 \pm 5.664 \text{ cm}^3$ in the instability group and $19.028 \pm 6.047 \text{ cm}^3$ in the control group (Fig. 3). Mean glenoid surface area was $7.45 \pm 1.29 \text{ cm}^2$ in the instability group and $7.41 \pm 1.43 \text{ cm}^2$ in the control group (Table 1). The 3D capsular volume to glenoid surface area ratios were significantly different between the instability and control groups ($3.59 \pm 0.83 \text{ cm}^3/\text{cm}^2$ and $2.53 \pm 0.62 \text{ cm}^3/\text{cm}^2$, respectively; ($p < 0.01$) with instability group showing the higher ratios.

Discussion

MDI of the shoulder is a complex problem to diagnose and treat.⁶ Various diagnostic methods have been suggested, but they are diagnosed by the clinical symptoms of the patient and physical examination of the physician, which may be subjective. There are various studies on the pathogenesis of MDI, studies on cadavers have found that an excessively redundant capsule

Table 1. Three-dimensional Capsular Volume and Glenoid Surface Area in Multidirectional Instability of the Shoulder

Patient No.	Age (yr)	Capsular volume (cm ³)	Glenoid surface (cm ²)
1	17	29.584	6.26
2	18	18.047	8.84
3	24	29.854	6.51
4	21	21.348	5.32
5	38	20.189	8.87
6	21	32.621	9.17
7	22	32.057	7.90
8	25	30.178	6.32
9	27	21.747	6.77
10	31	21.571	8.09
11	33	22.542	6.08
12	21	19.158	6.55
13	20	32.385	8.78
14	23	30.472	8.69
15	25	21.602	6.63
16	27	32.535	9.90
17	29	20.058	6.10
18	31	29.851	6.53
19	24	19.885	8.41
20	32	32.317	7.97
21	27	33.206	6.77
Average	26	26.248	7.45

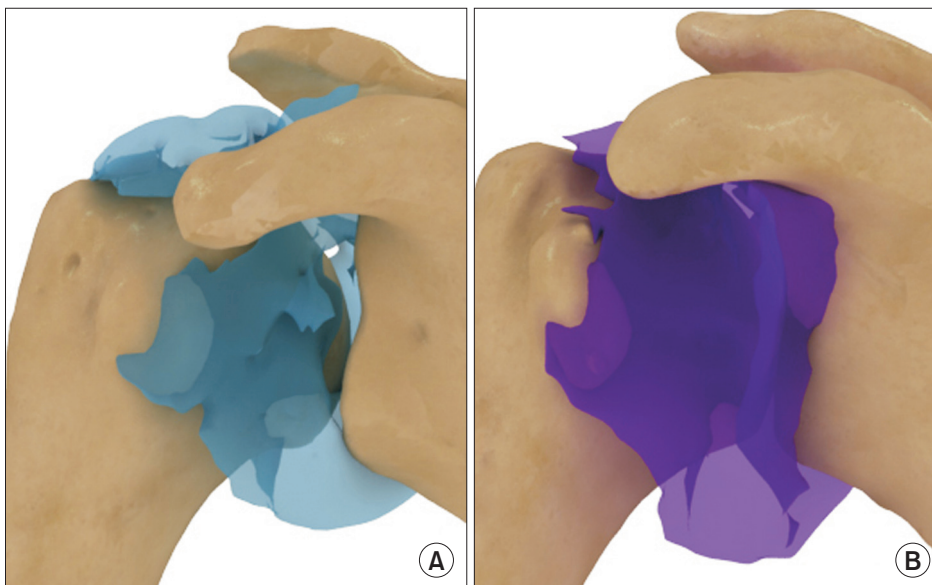


Fig. 3. Reconstructed three-dimensional model from the shoulder magnetic resonance arthrogram in normal (A) and in multidirectional instability of the shoulder (B). It is showing expansion of the capsular volume inferior pouch, especially.

is one of the important reasons for symptomatic laxity in MDI.^{7,8)} There have been attempts to diagnose MDI through objective radiological examinations. Some authors have tried to assess capsular width using MRA to facilitate objective evaluation.^{9,10)} Dewing et al.¹⁾ attempted to correlate capsular CSA, measured by MRA, with specific conditions like anterior, posterior, and MDI of the shoulder, and used maximum capsular distension distance and the size of the humeral head to correct for variances. Ng et al.¹¹⁾ evaluated the relationship between capsular width and number of dislocations, type of capsular attachment, presence of antero-inferior labral tear, and patient sex. They also compared the sensitivities and specificities of MRI and clinical tests in instability of the shoulder. However, radiologic examinations have played an additional role in the diagnosis of MDI and have not become a definitive diagnostic method. In a previous study undertaken to find relations between capsular areas using 2D CSA, the attempt to measure the increased joint volume in 2D would have been limited method.

We believe that the value accurate 3D volumetric measurements. We investigated the 3D volume measured by this method that is useful for MDI diagnosis. For each individual, the size of the joints may vary according to body type and body size. To correct this, we measured glenoid surface area in addition to the joint volume. The results showed that there was no significant difference in the glenoid surface between the MDI patients and the control group, but 3D capsular volume to glenoid surface area ratios was increased.

Nevertheless, our study has several limitations. First, only a limited number of patients were recruited, and the date doesn't follow the normal distribution curve. Furthermore, reference point which distinguishes the two groups couldn't be presented through this method. Thus, we suggest that a prospective study of larger scale needs to be conducted to determine the significance of intergroup differences. Second, we multiplied the AP and SI dimensions of the glenoid surface area, but it would be more accurate to calculate values based on 3D data. However, this was not possible because the glenoid surface was too indistinct in MRA images to measure accurately. Higher definition MRA would probably allow the accurate calculation of glenoid surface areas. Third, this study was performed retrospectively, and the diagnosis of MDI patients diagnosed by one expert may be inaccurate. Lastly, there is a limitation in that in a retrospective study, no shoulder can be defined as completely normal as opposed to MDI while setting the control group.

We suggest that the measurement of 3D volume through MRA can be an useful measurement method for MDI diagnosis. In addition, we can present a more objective diagnostic value through a larger scale prospective study. We think that it can be used to evaluate the results after surgical treatment such as arthroscopic thermal shrinkage management, arthroscopic capsular plication and open capsular shift. In addition, if multiple

3D images were superimposed, they might show the direction of capsular expansion, which would be helpful for surgical planning.¹²⁾ The 3D volume process through MRA will be worth researching.

Conclusion

This study provides 3D evidence that that 3D capsular volume to glenoid surface area ratios play an important role in diagnosing the MDI of the shoulder using volume measurement.

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