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Risk factors for anterior shoulder instability: a matched case-control study

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Background: Anatomic skeletal features of the shoulder play important roles in anterior shoulder dislocation. However, studies on the effect of the humeral structure are few. This case-control study aimed to analyze the risk factors of anterior shoulder instability, including glenoid and humeral factors.
Methods: Anterior shoulder instability was found in 64 of 10,035 individuals who underwent magnetic resonance imaging. Propensity score matching was used to select controls matched for age, sex, height, and weight. We analyzed the glenoid and humeral structural data using conditional logistic regression analysis and identified cutoff points using receiver operating characteristic curve analysis.
Results: Significant differences were found between the control and dislocation groups in the depth-to-width ratio (0.119 ± 0.034 vs. 0.105 ± 0.037, $P = .021$), height-to-width ratio (1.51 ± 0.13 vs. 1.67 ± 0.16, $P < .001$), humeral head diameter-to-glenoid fossa diameter ratio (1.56 ± 0.11 vs. 1.64 ± 0.20, $P < .001$), and humeral containing angle (67.3° ± 5.9° vs. 60.4° ± 5.9°, $P < .001$). The humeral containing angle (odds ratio, 0.95; $P = .024$) and the glenoid height-to-width ratio (odds ratio, 7.88; $P = .002$), adjusted for the depth-to-width ratio and diameter ratio, were associated with anterior shoulder instability. The cutoff point for the humeral containing angle was 64° and for the height-to-width ratio was 1.60.
Conclusions: This study revealed significant risk factors for shoulder instability in the Chinese Han population. The humeral containing angle and the glenoid height-to-width ratio were risk factors for anterior shoulder instability.
Level of evidence: Level III; Case-Control Design; Prognosis Study

Keywords: Anterior shoulder dislocation; demographic characteristics; humeral containing angle; ratio of glenoid height to width; cutoff point; matched case-control

Anterior shoulder instability caused by injuries is very common. It may lead to shoulder pain or dysfunction, injury to the glenohumeral structure, or osteoarthritis[3,7] and has a high recurrence rate.[11,19,20] The risk factors of anterior shoulder instability include muscle strength, especially the rotator cuff strength, age,[16] activity level,[14] and anatomic features such as the glenoid and coracohumeral morphology.[4]

The study protocol was approved by the Ethics Committee of the Second Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, China.

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A previous study showed that the coracohumeral distance and the height-to-width ratio of the glenoid were risk factors in instability cases.[15] Increased glenoid retroversion was a risk factor for the development of posterior instability of the shoulder.[6] A retrospective study by Hohmann and Tetsworth[8] reported that increased glenoid anteversion was a relevant factor in recurrent anterior shoulder dislocation on measuring the anatomic structure of the shoulder using computed tomography (CT) or magnetic resonance imaging (MRI). Previous studies have revealed no significant difference between CT and MRI.[2]

To our knowledge, anatomic skeletal features of the shoulder, including glenoid version, glenoid depth, glenoid height, glenoid width, glenoid height-to-width ratio, and coracohumeral distance, play important roles in anterior shoulder dislocation. However, the effect of humeral morphology on anterior shoulder instability has been seldom investigated. The goal of this matched case-control study was to analyze the risk factors of anterior shoulder instability, including glenoid and humeral factors.

Materials and methods

The study was designed as a matched retrospective case-control study. All participants provided written informed consent.

Patient selection

We included 10,035 individuals who underwent a shoulder MRI examination between 2015 and 2017 in the Second Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, China (Fig. 1). Patients were included if they met the inclusion criteria as follows: documented anterior shoulder dislocation on an available radiograph between the ages of 16 and 70 years. Patients were excluded if there was evidence of injuries to the posterior labrum, biceps anchor, or rotator cuff, previous shoulder dislocation with fracture, bony Bankart lesion, glenoid damage, or previous surgery of the glenoid or humerus. We excluded 2227 individuals because of incomplete data for height and weight and included 7808 patients. Of these 7808 individuals, 64 were diagnosed with anterior shoulder instability, as confirmed by the history, MRI scans, and x-ray imaging. Individuals in the control group were matched by age, sex, height, and weight, and had no previous shoulder injury, including fracture or dislocation, and no detected shoulder instability. They were selected by propensity score matching to balance the clinical characteristics of the 2 groups, allowing more accurate comparisons within the observational studies by simulating a randomized controlled trial.[18]

Outcome measures

Standard MRIs were performed using a 3-Tesla system in patients who presented with shoulder pain within 21 days to the clinic. According to a pre-established protocol,[8] 3 professional radiologists with the same level of experience performed the scans to obtain sagittal, axial, and oblique coronal images.

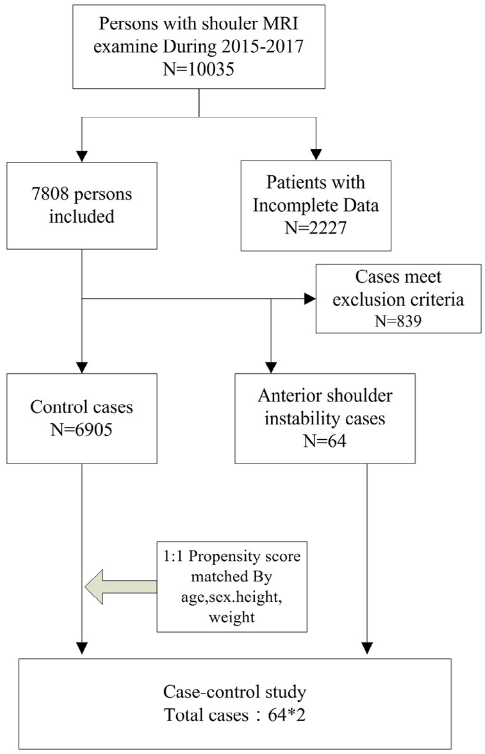

Figure 1 Flowchart illustrates the selection of the anterior shoulder instability group and the control group. *MRI*, magnetic resonance imaging.

Glenoid anteversion

As seen in Fig. 2, line A in the axial section is along the anterior and posterior margins of the glenoid. Line B, the axis of the supraspinatus fossa, is between the base of the glenoid neck and the base of the scapular spine as it converges with the scapular body. The angle between line A and line B is the glenoid version angle, shown as the α angle. Subtraction of 90° from the α angle ($\alpha - 90°$) gives the version angle. If the resulting angle ($\alpha - 90°$) is negative, it is glenoid retroversion; otherwise it is glenoid anteversion.[1,5,21]

Coracohumeral interval

The coracohumeral interval measured, as described before,[10] is shown in Fig. 3.

Glenoid height, width, and depth

Two experienced radiologists with the same level of experience reviewed the images and measured the glenoid height (shown as *h*), width (shown as *w*)[15] in Fig. 4, depth (shown as *d*) in Fig. 5, coracohumeral distance, humeral head diameter, glenoid diameter, humeral containing angle, and glenoid anteversion. The radiologists were blinded to the baseline assessments and shoulder instability events.

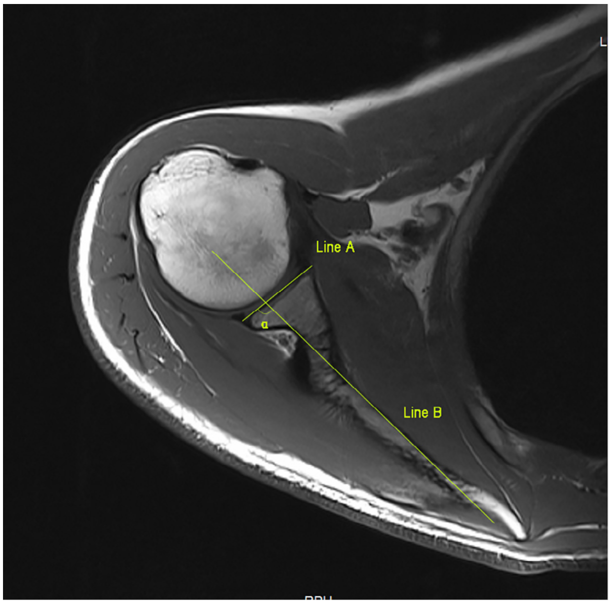

Figure 2 *Line A* in the axial section is along the anterior and posterior margins of the glenoid. *Line B* was drawn between the base of the glenoid neck and the base of the scapular spine as it converged with the scapular body. The angle between line A and line B is the glenoid version angle, shown as the α angle.

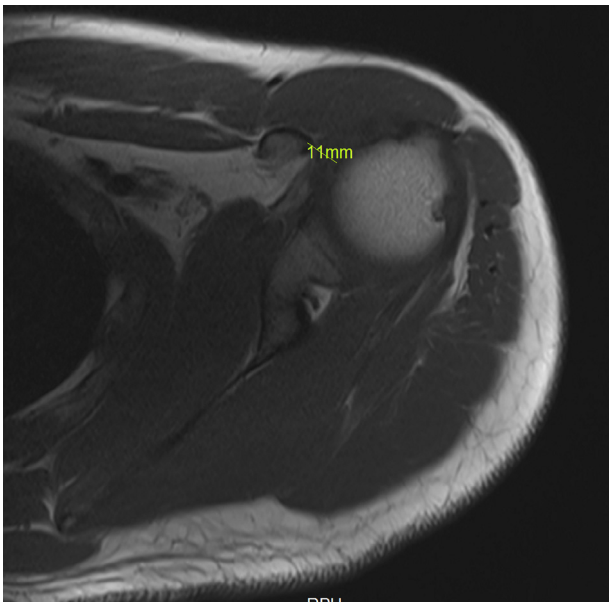

Figure 3 Measurement of the coracohumeral interval.

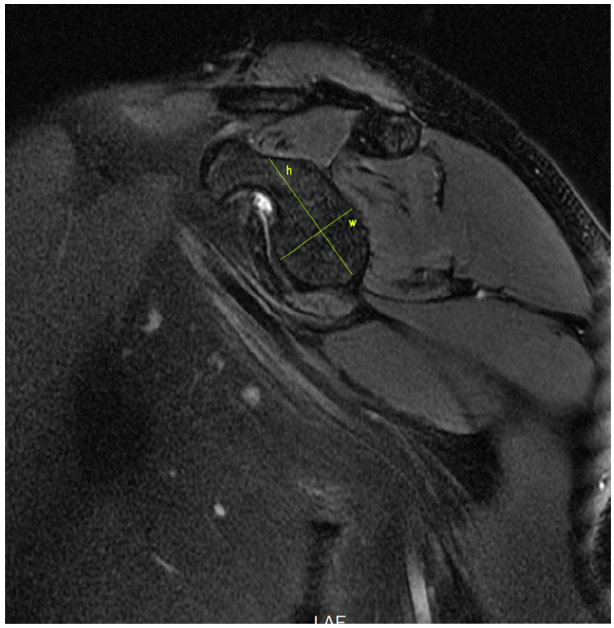

Figure 4 Measurement of glenoid height (shown as *h*) and glenoid width (shown as *w*).

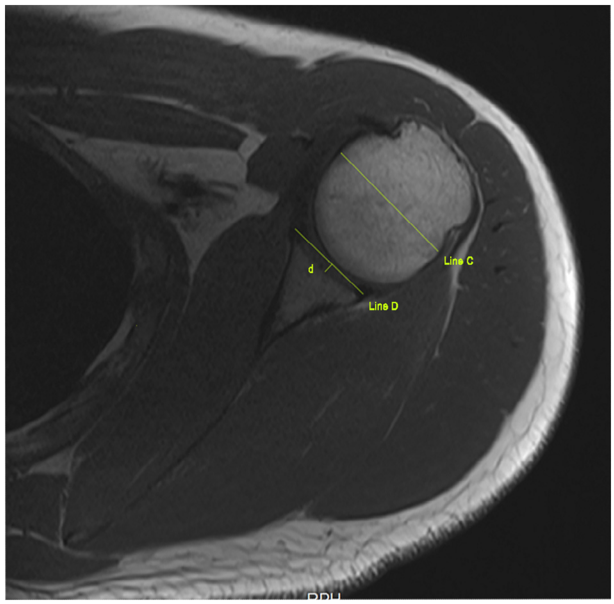

Figure 5 Reference *line C* is drawn through the anterior and posterior portions of the humeral head, which represents the plane of the humeral head. Another reference line (*line D*) is drawn through the anterior and posterior portions of the glenoid rim, which represent the plane of the glenoid fossa. Glenoid depth is shown as *d*.

Ratio of humeral head diameter to glenoid diameter

On the same axial image as Fig. 5, a reference line C is drawn through the anterior and posterior portions of the humeral head, representing the plane of the humeral head, and another reference line (line D) is drawn through the anterior and posterior portions of the glenoid rim, representing the plane of the glenoid fossa. The ratio of the diameter of the humeral head to the glenoid fossa is defined as line C/line D.

Humeral containing angle

First, the center of humeral head was defined as the minimal circle covering most of the humeral head.[9] Line E is drawn through the anterior of the glenoid rim and the center of humeral head (Fig. 6).

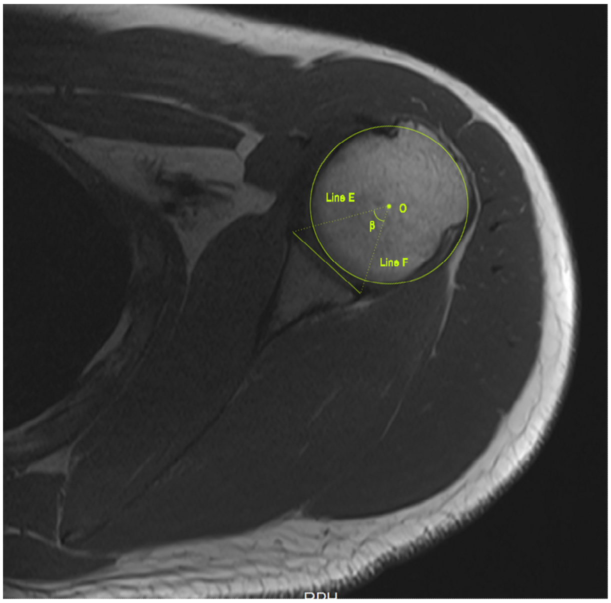

Figure 6 The center of humeral head is defined as the minimal circle covering most of the humeral head. *Line E* is drawn through the anterior of the glenoid rim and the center of humeral head. *Line F* is drawn through the posterior of the glenoid rim and the center of humeral head. The humeral containing angle (β) is defined as the angle between *lines E* and *F*.

Line F is drawn through the posterior of the glenoid rim and the center of humeral head. We defined the humeral containing angle as the angle between line E and line F. To our knowledge, this is the first time the humeral containing angle has been introduced to reflect the glenoid and humeral relationship in anterior shoulder instability.

Statistical analysis

A power calculation was performed to determine sample size. Initially, we calculated the median or mean ± standard deviation and interquartile range (IQR) for continuous variables and frequencies and proportions for categorical variables. For continuous variables, we used paired *t* tests to examine the differences between participants who experienced anterior instability events and those who did not. If the assumptions for the paired *t* test were not met, the Kruskal-Wallis test was used. For categorical variables, we examined the association between the variables and shoulder anterior instability using the paired χ^2 test. The parameters were further examined using conditional logistic regression analysis. Owing to the fairly large number of patients, cutoff points were identified after using receiver operating characteristic (ROC) curve analysis as a complementary approach.[12] All analyses were performed using SPSS 24 software (IBM, Armonk, NY, USA).

Results

We included 10,035 individuals who underwent MRI examination between 2015 and 2017 in the Second Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, China. We excluded 2227 individuals because of incomplete data. Of the included 7808 patients, 64 had anterior shoulder instability. The controls matched for age, sex, height, and weight were selected by propensity score matching. There were no significant differences in demographic characteristics between the 2 groups (Table I).

Table I Demographic characteristics of the patients with shoulder instability and the control group

Characteristic	Control group (n = 64)	Patients with SI (n = 64)	*P* value
Age, yr	38.0 ± 19.9	32.6 ± 15.1	.149
Sex			
Female	19	14	
Male	45	50	.312
Height, cm	168.64 ± 9.3	168.791 ± 8.1	.92
Weight, kg	72.2 ± 14.6	68.8 ± 12.2	.33
BMI, kg/m^2	25.45 ± 5.35	24.14 ± 3.86	.33

SI, shoulder instability; *BMI*, body mass index.
Continuous data are presented as mean ± standard deviation and categorical data as number.
Between-group differences were not statistically significant ($P \geq .05$).

The risk analysis of anterior shoulder dislocation is summarized in Table II. No significant differences were found between the control and dislocation group with respect to the coracohumeral interval (11.4 ± 2.7 vs. 11.5 ± 3.1, $P = .712$) or glenoid anteversion (3.04 [IQR, 0.62-5.29] vs. 1.70 (IQR, –3.97 to 5.90], $P = .213$). In contrast, there were significant differences between the control group and the dislocation group in the depth-to-width ratio (0.119 ± 0.034 vs. 0.105 ± 0.037, $P = .021$), height-to-width ratio (1.51 ± 0.13 vs. 1.67 ± 0.16, $P < .001$), humeral head diameter-to-glenoid fossa diameter ratio (1.56 ± 0.11 vs. 1.64 ± 0.20, $P < .001$), and humeral containing angle (67.3 ± 5.9 vs. 60.4 ± 5.9, $P < .001$). Because the values of depth-to-width ratio, diameter ratio, humeral containing angle, and height-to-width ratio had a $P < .05$ (Table II), they were further examined using conditional logistic regression analysis, as reported in Table III. Associations were observed between the height-to-width ratio (odds ratio, 7.888; 95% confidence interval, 2.136-29.127; $P = .002$), humeral containing angle (odds ratio, 0.95; 95% confidence interval, 0.908-0.993; $P = .024$), and the risk of anterior shoulder instability, with adjustments for age, sex, and body mass index. Subsequently, only these 2 parameters underwent ROC curve analysis.

Cutoff point

A comparison of cutoff points showed that individuals with anterior shoulder instability had a lower humeral containing angle and a larger humeral height-to-width ratio than those in the control group, identified by ROC curve analyses. The cutoff points for the humeral containing angle was 64° and for the height-to-width ratio was 1.60, using ROC curves in these analyses.

Table II Glenoid anatomy parameter in control and dislocated groups

Variable	Control group	Dislocated group	*P* value
Coracohumeral distance, mm	11.4 ± 2.7	11.5 ± 3.1	.712
Depth-to-width ratio	0.119 ± 0.034	0.105 ± 0.037	.021*
Diameter ratio	1.56 ± 0.11	1.64 ± 0.20	<.001†
Humeral containing angle,°	67.3 ± 5.9	60.4 ± 5.9	<.001*
Height-to-width ratio	1.51 ± 0.13	1.67 ± 0.16	<.001†
Glenoid anteversion,°	3.04 (0.62-5.29)	1.70 (−3.97 to 5.90)	.213

Diameter ratio, ratio of humeral head diameter to glenoid fossa diameter.
Data are presented as mean ± standard deviation or as median (interquartile range).
* Using paired *t* tests, $P < .05$.
† Using Kruskal-Wallis test, $P < .05$.

Table III Results of conditional logistic regression analysis for shoulder instability risk factors

Variable	Odds ratio	95% Confidence interval		*P* value
		Minimum	Maximum	
Height-to-width ratio	7.888	2.136	29.127	.002*
Humeral containing angle,°	0.950	0.908	0.993	.024*

Adjusted for depth-to-width ratio and the humeral head diameter-to-glenoid fossa diameter ratio.
* Significant difference ($P < .05$).

Discussion

The anatomic structures of the glenoid and humerus are important factors to consider in anterior instability or dislocation of the shoulder. In this study, data on the shoulder structure of patients with anterior dislocation of the shoulder were assessed by MRI. This study shows that the humeral containing angle and the glenoid height-to-width ratio are important factors in cases of anterior instability of the shoulder. To our knowledge, this study is a rare, detailed study revealing the association between anterior shoulder instability and shoulder structure, including glenoid and humeral factors.

Rotator cuff injuries include partial tears and complete tears of the rotator cuff. A previous study reported that rotator cuff injury was related to glenoid retroversion, and hence, it was excluded.[21] It was also important to differentiate the biceps anchor with a sublabral recess from a biceps anchor injury. The MRI features of the biceps anchor with a sublabral recess were (1) location (present only anterior to the biceps anchor); (2) contour (a thin defect with smooth margins); and (3) orientation (paralleling the course of the glenoid rim). The MRI features of biceps anchor injury were (1) location (at the biceps anchor and posteriorly) and (2) contour (irregular margin).[22]

The control group was selected using propensity score matching (nearest neighbors) of cases and controls to balance the clinical characteristics of 2 groups, allowing more accurate comparisons within observational studies by simulating a randomized controlled trial.[13] The matching technique, which takes into account several matching variables, ensures the assignment of a control to each case, even if the distribution of matching variables slightly differs among the groups of cases and controls, which is its major advantage compared with frequency matching. Because of potential residual confounding, regression models were also controlled for age (in years), sex, height, and weight.

Previous studies did not consider glenoid depth, glenoid height, and glenoid width to be risk factors of anterior shoulder instability.[15,17] In contrast, the glenoid height-to-width ratio played an important role in anterior shoulder instability. Individuals with a glenoid height-to-width ratio of greater than 1.58 (taller and thinner glenoids) had 2.64-times the risk of injury than those with a ratio of less than 1.58.[15] The results of the glenoid height-to-width ratio in this study were similar to those of previous studies.

Although we focused on the effects of glenoid anteversion, the results were inconclusive. Aygun et al[1] concluded that the angles of glenoid version on the dislocated side were significantly more anteverted in the study group than in the dominant and nondominant shoulders of the control group. However, a study by Peltz et al[15] showed that glenoid version was not significantly related to anterior shoulder instability. In our study, we did not identify a significant relationship between glenoid version and anterior shoulder instability in the Chinese Han population.

A previous study showed that the risk of instability increased 20% for every millimeter increase in coracohumeral distance.[15] In our study, we did not find a significant association between coracohumeral distance with anterior shoulder instability. The mixed results may be due to the different anatomic structures in different populations. Different age ranges and the sample size can also lead to inconclusive results.[8]

In this study, we investigated the association between the risk of anterior humeral instability and the ratio of the diameter of the humeral head to the glenoid fossa as well as the humeral containing angle. We revealed that the humeral containing angle was a risk factor for anterior humeral instability. The cutoff point for humeral containing angle was 64°.

This study has limitations and strengths. Only 64 anterior instability events were documented. The post hoc statistical power of the study, as calculated using PASS 11 software (NCSS Statistical Software, Kaysville, UT, USA), was 0.42 for glenoid anteversion, 0.98 for the humeral containing angle, and 0.97 for the height-to-width ratio. The glenoid anteversion has a limited statistical power, which was a limitation of this study.

Another possible limitation is the select and homogeneous nature of our study. The included population is ideal for a clinical study but may limit the extrapolation of findings to the general population, leading to the selective bias in this study.

Conclusion

This study revealed significant risk factors for shoulder instability in the Chinese Han population. The humeral containing angle and the glenoid height-to-width ratio were found to be risk factors for anterior shoulder instability. The anatomic variables of significance are also not surprising. A larger humeral containing angle was associated with a lower risk than a smaller humeral containing angle.

Disclaimer

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