AJSM PreView, published on June 27, 2011 as doi:10.1177/0363546511411699

Analysis of Risk Factors for Glenoid Bone Defect in Anterior Shoulder Instability

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Background: Glenoid bone defect is frequently associated with anterior shoulder instability and is considered one of the major causes of recurrence of instability after shoulder stabilization.

Hypothesis: Some risk factors are significantly associated with the presence, size, and type of glenoid bone defect.

Study Design: Cohort study (prognosis); Level of evidence, 2.

Methods: One hundred sixty-one patients affected by anterior shoulder instability underwent morphologic evaluation of the glenoid by computed tomography scans to assess the presence, size, and type of glenoid bone defect (erosion or bony Bankart lesion). Bone loss greater than 20% of the area of the inferior glenoid was considered ''critical'' bone defect (at risk of recurrence). Outcomes were correlated with the following predictors: age, gender, arm dominance, frequency of dislocation, age at first dislocation, timing from first dislocation, number of dislocations, cause of first dislocation, generalized ligamentous laxity, type of sport, and manual work.

Results: Glenoid bone defect was observed in 72% of the cases. Presence of the defect was significantly associated with recurrence of dislocation compared with a single episode of dislocation, increasing number of dislocations, male gender, and type of sport. Size of the defect was significantly associated with recurrent dislocation, increasing number of dislocations, timing from first dislocation, and manual work. Presence of a critical defect was significantly associated with number of dislocations and age at first dislocation. Bony Bankart lesion was significantly associated with male gender and age at first dislocation.

Conclusion: The number of dislocations and age at first dislocation are the most significant predictors of glenoid bone loss in anterior shoulder instability.

Keywords: shoulder instability; glenoid; bone loss; risk factors; computed tomography

Surgical treatment of anterior shoulder instability can be performed with open or arthroscopic techniques. Although current arthroscopic procedures showed similar results to open procedures, the recurrence rate of instability after arthroscopic treatment ranged between 0% and 20%.[20] For this reason, several efforts have been made to investigate and identify prognostic factors of arthroscopic shoulder stabilization.

In recent years, many authors focused on the importance of detection and quantification of glenoid bone defects associated with anterior glenohumeral instability.[#] This interest arose because several biomechanical studies showed that glenoid bone defects can impair shoulder stability.[7,15,16,25,29,34,51] Furthermore, clinical studies reported a significant correlation between recurrence rate after surgical treatment and the presence and severity of glenoid bone loss.[1,5,6,8,28,33,40,48] The critical limit of bone deficit over which the risk of recurrence after surgical repair becomes clinically relevant is reported to be about 20% to 25% of the glenoid width.[5,8,13,25,30,52]

The prevalence of glenoid bone defects in anterior glenohumeral instability has been reported in the literature to be from 8% to 90%.[**] This wide variability can be related to differences in study populations, imaging techniques, or glenoid injury patterns.

The bone defect is primarily located on the anterior rim of the glenoid[17,19,43] and can be found as a fracture (bony Bankart lesion), attributable to major trauma, or bone erosion caused by repetitive microtrauma, recurrent episodes of subluxation and dislocation.[5,7,9,17,18,24,29,43]

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The authors declared that they have no conflicts of interest in the authorship and publication of this contribution.

The American Journal of Sports Medicine, Vol. XX, No. X
DOI: 10.1177/0363546511411699

#References 3, 9, 13, 14, 17, 21, 43, 46.

**References 6, 8, 14, 18, 19, 36, 41, 44-46, 49.

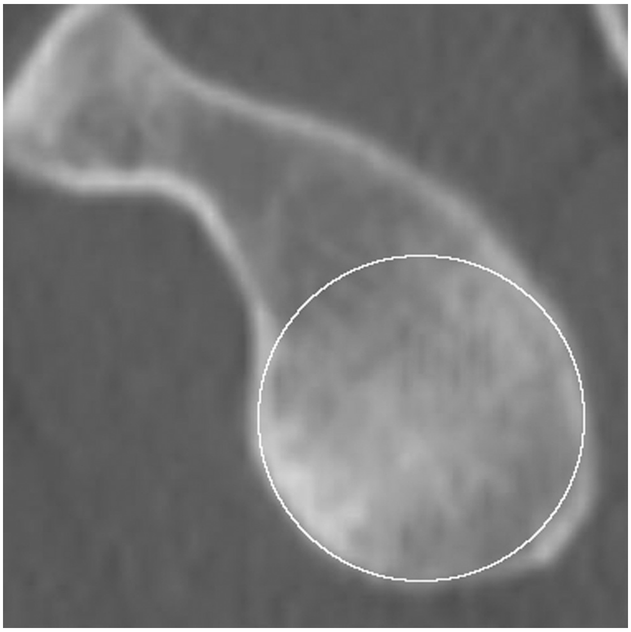

Figure 1. Multiplanar reconstruction CT image on oblique sagittal plane (en face view) of a normal glenoid (left shoulder). A best-fitting circle on the inferior glenoid, by selection of the outer cortex as a landmark, was drawn.

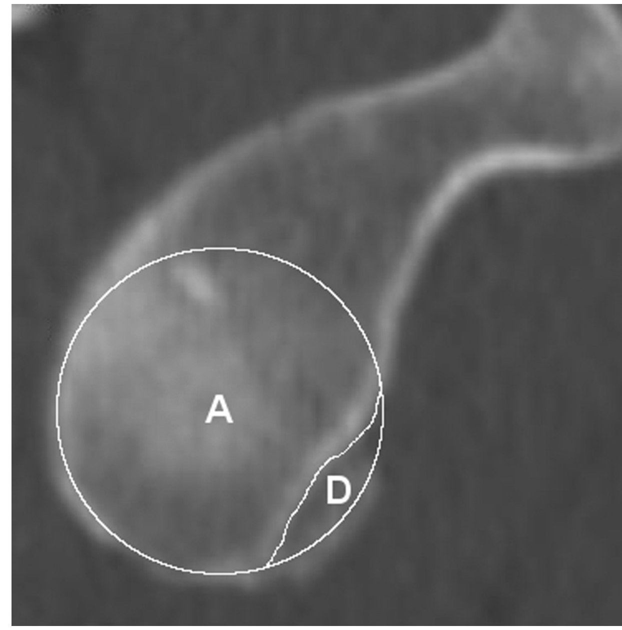

Figure 2. An identical circle was drawn on the affected glenoid (right shoulder). Bone defect was considered as the missing part of the circle. Areas of the entire circle (A) and bone defect (D) were measured.

Despite the great amount of studies on detection and quantification of glenoid bone loss, very little information exists regarding risk factors for its occurrence in anterior shoulder instability.[18,27,53]

The purpose of the present study was to analyze the association between glenoid bone loss detected on CT scans and some risk factors in a population of patients affected by anterior shoulder instability. The hypothesis of the study was that some risk factors were significantly associated with the presence, size, and type of glenoid bone defect.

MATERIALS AND METHODS

Study Population

For the present study, 161 patients were consecutively and prospectively enlisted who accepted our invitation to enter the study and signed an informed consent. The study protocol was previously approved by the local Institutional Ethical Committee.

A primary inclusion criterion was unilateral anterior shoulder instability with at least 1 episode of dislocation. We excluded patients with instability without dislocation; contralateral shoulder instability; previous fractures and/or surgery to both shoulders; and congenital or acquired inflammatory, neurologic, or degenerative diseases (systemic or local) involving the shoulder girdles.

CT Examination Technique

All patients underwent a CT scan of both shoulders with spiral multislice CT (LightSpeed Pro16, GE Healthcare, Milwaukee, Wisconsin) using filter for bone, 1.25-mm slice thickness with slice advancement of 0.6 mm, 200 to 300 mA, 120 kV, field of view of 30 cm, and matrix 512 × 512 pixels. Patients were placed in the supine position and scans were acquired during the examination for both shoulders. The scanning plane extended from the acromioclavicular joint to just below the glenoid.

Glenoid shape was assessed on CT images according to the "Pico" method.[3] Images were processed on a commercially available workstation (Advantage, version 4.2, GE Healthcare) in multiplanar reconstruction (MPR), according to oblique sagittal planes, and maintaining working axes parallel to the glenoid surface, to obtain oblique sagittal images of the glenoid articular surface (en face view). On this frontal image of the contralateral healthy glenoid, a circumferential area was drawn on the inferior part of the glenoid using the digital analysis software of the workstation. The best-fitting circle on the inferior glenoid was used, by selecting the outer cortex of the inferior glenoid as a landmark (Figure 1). Then an identical circumferential area was drawn on the affected glenoid, and the area of the entire circle (A) and the missing part of the circle (D) were measured (Figure 2). The size of the defect was expressed as percentage of the entire circle, according to the following formula: $D/A \times 100$.

All measurements were performed by the same radiologist who was well-experienced in musculoskeletal imaging.

Outcome Measurements

The presence of glenoid bone defect was considered the primary outcome of the study. Secondary outcome was the size of glenoid bone defect, expressed as a percentage of the area of the inferior glenoid. Another secondary outcome was the presence of a "critical" glenoid bone defect, using 20% bone deficit as a percentage of the circle area as described above, as the cutoff value. A further secondary outcome was the type of glenoid bone defect, considered as bone erosion or fracture (bony Bankart lesion).

Data Analysis

Statistical analysis was performed with statistical software (SPSS version 19, SPSS Inc, Chicago, Illinois). We considered the following predictors: age, gender, injury to dominant arm (no/yes), frequency of dislocation (acute/recurrent), age at first dislocation (years), time (months) elapsed from first dislocation to CT examination, number of dislocations, cause of first dislocation (traumatic/atraumatic), generalized ligamentous laxity (no/yes), type of sport (no sport/contact/noncontact/overhead), and manual work (no/yes). Continuous predictors were handled as continuous and checked for linearity using curve estimation plots and the Kolgomorov-Smirnov test. As nonlinearity was detected, they were modeled by applying logarithmic transformation.

Multivariate logistic and linear regression analyses were performed to investigate significant associations between potential predictors and outcomes. All predictors were initially included in the multivariate models, and elimination of nonsignificant predictors was performed by using a backward elimination approach at a 5% significance level.

Sample Size Calculation

Sample size was established according to the primary outcome of the study (presence of glenoid bone defect). In a previous study by Griffith et al[18] on 203 patients affected by anterior shoulder instability, the prevalence of glenoid bone defect was 71%. Confidence interval (CI) around this prevalence was calculated with the one mean procedure, by using the exact binomial estimate.[35] Given a width CI (W) equal to 0.14, and a confidence level of 95%, the total number of patients (N) required to obtain the expected proportion (P) of events (glenoid defect) was calculated using the following formula[22]: $N = 4z_{\alpha}^2 P(1 - P)/W^2 = 161$.

Based on this calculation, the expected number of events was 114. As 11 predictors were included in the analysis, sample size was considered adequate to satisfy the rule of thumb with 10 events per predictor variable, as suggested for logistic regression models.[37]

RESULTS

Descriptive statistics of study population are reported in Table 1. The CT imaging detected the presence of a glenoid bone defect in 116 cases (72%). Bone erosion was observed in 79 cases (49%) and bony Bankart lesion in 37 cases (23%). Size of the defect ranged from 0% to 33% (average 6.94% ± 6.92%). Glenoid bone loss greater than 20% (critical defect) was noticed in 12 cases (7.5%).

Results from multivariate logistic regression analysis for the presence of glenoid bone defect are reported in Table 2. Gender, number of dislocations, frequency of dislocation, and type of sport were significantly associated with the outcome. Male gender and increasing number of dislocations resulted in an increased odds ratio of reporting a glenoid defect. Acute dislocation and noncontact sports showed a significant protective effect on the risk of occurrence of glenoid defect in comparison with recurrent dislocation, and with contact and overhead sports, respectively.

Multivariate linear regression analysis for the size of glenoid defect (Table 3) showed that the timing from first dislocation, frequency of dislocation, number of dislocations, and manual work were significantly associated with the outcome. The model explained 46% of the variance in the size of bone defect. An increasing number of dislocations resulted in a greater percentage of bone loss of approximately 0.8%, and increasing time from first dislocation resulted in a greater percentage of bone loss with a factor of 0.15% per month. Patients with recurrent dislocation had on average approximately 5% greater bone defect than patients with acute dislocation, and manual workers showed on average approximately 2.5% greater bone defect than sedentary workers.

Multivariate logistic regression analysis for the presence of critical bone defect (Table 4) showed that age at first dislocation and number of dislocations were significantly associated with the outcome. Increasing age at first dislocation showed a protective effect against the risk of critical defect, while increasing number of dislocations resulted in an increased odds ratio for occurrence of a critical glenoid defect of approximately 9.5 times.

Multivariate logistic regression analysis for the presence of bony Bankart lesion (Table 5) showed that gender and age at first dislocation were significantly associated with the outcome. Males had an increased odds ratio for occurrence of bony Bankart lesion with respect to females. Increasing age at first dislocation had a lower risk of occurrence of bony Bankart lesion with respect to development of glenoid erosion.

DISCUSSION

Results of the present study showed that prevalence of glenoid bone loss was similar to that previously reported by Griffith et al.[18] The strongest predictors for the presence of a glenoid bone defect were recurrence of dislocation and increasing number of dislocations. Male gender revealed a significant association with the presence of glenoid defects as well, although its influence on the outcome was weaker. Patients with anterior shoulder instability practicing noncontact sports showed the lowest risk of developing a glenoid bone loss with respect to patients involved in contact or overhead sports. Recurrence of dislocation and increasing number of dislocations were also revealed to be strongly influential on the size of glenoid defect. These data confirmed results previously reported by other authors.[17,18,27,53] Increasing time from first dislocation and manual work were weak significant predictors of larger bone defect.

TABLE 1
Descriptive Statistics of Study Population

Variable	Range	Mean ± Standard Deviation	Median	n (%)
Gender				
Male				129 (80.1)
Female				32 (19.9)
Age, y	16-53	28 ± 8.5	26	
Injury to dominant arm				
No				50 (31.1)
Yes				111 (68.9)
Age at first dislocation, y	10-49	22.8 ± 7.3	20	-
Timing from first dislocation, mo	1-492	63.2 ± 80.9	36	-
Number of dislocations	1-50	8.6 ± 9.5	5	-
Frequency of dislocation				
Acute				18 (11.2)
Recurrent				143 (88.8)
Cause of first dislocation				
Traumatic				134 (83.2)
Atraumatic				27 (16.8)
Generalized ligamentous laxity				
No				113 (70.2)
Yes				48 (29.8)
Type of sport				
No sport				11 (6.8)
Contact				68 (42.2)
Noncontact				61 (37.9)
Overhead				21 (13)
Manual work				
No				95 (59)
Yes				66 (41)

TABLE 2
Multivariate Logistic Regression Model: Presence of Glenoid Defect[a]

			95% Confidence Interval	
Predictors	*P* Value	Odds Ratio	Inferior Limit	Superior Limit
Gender (male)	.012	4.29	1.38	13.30
No. of dislocations	.004	1.18	1.05	1.31
Frequency of dislocation (acute)	.003	0.17	0.03	0.48
Type of sport (noncontact)	.026	0.21	0.05	0.83

[a]R^2_N = .382, −2 LL (log-likelihood) = 141.23, Hosmer Lemeshow χ^2 = 2.74, P = .95.

TABLE 3
Multivariate Linear Regression Model: Percentage of Glenoid Defect[a]

			95% Confidence Interval	
Predictors	*P* Value	B	Inferior Limit	Superior Limit
Timing	.025	0.015	0.002	0.29
Frequency of dislocation (recurrent)	.003	5.04	1.74	8.33
No. of dislocations	<.0001	0.77	0.55	0.99
Manual work	.015	2.51	0.50	4.53

[a]R^2 = .463, $P < .0001$ after backward elimination approach.

TABLE 4
Multivariate Logistic Regression Model: Presence of Critical Defect[a]

Predictors	*P* Value	Odds Ratio	95% Confidence Interval	
			Inferior Limit	Superior Limit
Age at first dislocation	.006	0.03	0.003	0.37
No. of dislocations	.01	9.54	1.74	52.47

[a] R^2_N = .829, −2 LL (log-likelihood) = 66.67, Hosmer Lemeshow χ^2 = 6.32, P = .612.

TABLE 5
Multivariate Logistic Regression Model: Type of Glenoid Defect (Bony Bankart Lesion)[a]

Predictors	*P* Value	Odds Ratio	95% Confidence Interval	
			Inferior Limit	Superior Limit
Gender (male)	.015	8.72	1.53	49.81
Age at first dislocation	.001	0.74	0.02	0.35

[a] R^2_N = .424, −2 LL (log-likelihood) = 116.36, Hosmer Lemeshow χ^2 = 10.1, P = .258.

Analysis of the results also showed that age at first dislocation and number of dislocations were significant predictors of a critical bone defect. Particularly, increasing age at first dislocation dramatically reduced the risk of developing a critical defect. Nevertheless, it is arguable that older patients frequently had longer history of shoulder instability, although timing from first dislocation was shown to be associated with the size of bone defect, but not with occurrence of critical defect. Increasing number of dislocations resulted in a clinically relevant increase in odds ratio for occurrence of critical defect, although its association with the outcome was weaker than age at first dislocation. We finally observed that the risk of occurrence of bony Bankart lesion was significantly higher in males and younger patients.

Results of the present study can be interpreted according to the hypothesis that natural history of the unstable shoulder evolves toward a progressive glenoid bone loss. This can be caused both by major traumatic events, as dislocations, and by altered joint kinematics, with progressive bone erosion as a consequence of the increased contact forces at the anteroinferior glenoid. This hypothesis was previously tested in an experimental study by Greis et al,[16] who observed that a 30% glenoid defect led to a 300% to 400% increase of glenohumeral contact forces at the anteroinferior glenoid, when compared with the normal glenoid. This could explain the association between prevalence and severity of bone loss not only with number of dislocations, but also with variables related to the duration of the disease (age at first dislocation and timing from first dislocation), and physical activities involving repetitive use of the shoulder (manual work, and contact and overhead sports) that influence the load regimen to which the unstable shoulder is subjected during this time period.

Several authors suggested the use of preoperative CT examination to assess glenoid bone defects.[††] Detection and quantification of glenoid bone defects can be achieved by processing CT images in 2-dimensional MPR or using 3-dimensional volume-rendering technique scans. Bone loss can be quantified using different methods, which are substantially based on the observation that the inferior part of the glenoid has the shape of a true circle, which can be drawn on the sagittal en face view of the glenoid.[23,26,46] The amount of bone loss is calculated as a percentage of the intact glenoid by use of linear (glenoid radius or maximum width) or surface (area of missing glenoid) measurements, with or without comparison with the contralateral glenoid. Barchilon et al[2] showed that CT measurements of glenoid bone loss by use of linear and surface methods significantly correlate.

The surface area method was first proposed using 3-dimensional CT images and shown to be very accurate.[21,46] Subsequently, it was applied to MPR scans, named as the "Pico" method, and validated for reliability.[3,32] The Pico method, which was used in the present study, combines the advantages of the surface area method (direct measurement of the missing area of the glenoid) with those of the MPR technique (neither 3-dimensional reconstructions nor subtractions of images of the humeral head are required).

Although the amount of glenoid bone loss associated with a significant risk of recurrence after shoulder stabilization is still debated, many authors reported a significant increase in recurrence rate when a bone deficit was present ranging between 20% and 30%.[‡‡] For this reason, the most recent literature reviews and guidelines recommend bone

[††]References 2, 3, 13, 17, 21, 38, 43 ,46.

[‡‡]References 5, 8, 13, 30, 38, 39, 47, 52.

augmentation or coracoid transfer procedures when bone loss exceeds 25% of glenoid width.[4,10,12,31,38] In the present study, we chose a 20% bone loss of the inferior glenoid area as the cutoff value to define a "critical" defect size for the risk of recurrence. This value is equivalent to a 25% deficit of glenoid width, as demonstrated by Barchilon et al[2] using a trigonometric method.

Results of the present study have some clinical relevance. First, an adequate imaging study to assess glenoid bone defect is highly recommended in patients showing strong risk factors for severe bone loss, such as a long history of instability and a great number of dislocations. Second, early surgical treatment is advisable in anterior shoulder instability, especially for young male patients, manual workers, and contact and overhead athletes, in order to reduce the risk of progressive osseous damage of the glenoid that can compromise the chance for an arthroscopic treatment.

Nevertheless, our study has some limitations. First, patients with bilateral shoulder instability were not considered, as the Pico method is based on the measurement of the area of the inferior glenoid on the contralateral healthy shoulder, and therefore it cannot be used in the case of bilateral instability. Although the circle method is considered accurate even without contralateral shoulder assessment,[21] this hypothesis was not tested in the present study. Second, bone defects of the humeral head were not analyzed, although recent studies focused on the influence of Hill-Sachs lesion on the kinematics of the unstable shoulder.[11,42,50] Finally, our results may not be definitive, as studies in the literature with a similar study design, and therefore comparable with our work, are relatively few.

CONCLUSION

Natural history of the unstable shoulder evolves toward a progressive glenoid bone loss. Recurrence of dislocation, increasing number of dislocations, and age at first dislocation were the strongest predictors for the presence and size of glenoid bone defect. Bony Bankart lesion occurred more frequently in males and young patients.

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