Original Article

Anteroinferior Glenoid Rim Fractures Are a Relatively Common Finding in Shoulder Instability Patients Aged 50 Years or Older but May Not Portend a Worse Prognosis

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Purpose: To investigate the incidence of anteroinferior glenoid rim fractures (AGRFs) after anterior shoulder instability (ASI) in patients aged 50 years or older, identify risk factors for surgical intervention for AGRFs, compare initial treatment strategies, and compare clinical outcomes of patients with and without associated AGRFs. **Methods:** An established geographic medical record system was used to identify patients aged 50 years or older with ASI between 1994 and 2016. Patients with radiographic evidence of AGRFs were identified and matched 1:1 to patients without AGRFs. Outcome measures included recurrent instability, recurrent pain events, conversion to arthroplasty, and osteoarthritis graded with the Samilson-Prieto classification for post-instability arthritis. **Results:** Overall, 177 patients were identified, with a mean follow-up period of 10.8 years. Of these patients, 41 (23.2%) had AGRFs and were matched to 41 control patients without AGRFs. The average age was 58.6 and 58.2 years for the AGRF and control groups, respectively. Rates of surgical intervention (27% vs 49%), recurrent instability (12% vs 20%), progression of osteoarthritis (34% vs 39%), and conversion to arthroplasty (2% vs 5%) were similar between AGRF patients and controls. For patients with AGRFs, increased bone fragment size (odds ratio, 1.1) and increased body mass index (odds ratio, 1.2) correlated with an increased risk of surgery. The cutoff value for an increased risk of surgery in patients with AGRFs was a fragment size 33% of the glenoid width or greater. **Conclusions:** Of patients aged 50 years or older at presentation of ASI, 23.2% presented with an associated AGRF. A fragment size 33% of the glenoid width or greater and a higher patient body mass index were significant factors for surgical intervention; however, most patients did not require surgery and still showed acceptable clinical outcomes, and the most common reason for surgical intervention was a rotator cuff tear. Overall, the presence of an AGRF did not portend a worse prognosis as treatment strategies and long-term outcomes including recurrent instability, progression of osteoarthritis, and conversion to arthroplasty were similar to those in patients without AGRFs. **Level of Evidence:** Level III, retrospective comparative study.

The shoulder is the most commonly dislocated joint in the body owing to its dynamic range of motion and reliance on capsular and soft-tissue supporting structures.[1] Shoulder dislocations in older patients are relatively frequent, with some studies reporting that up to 20% of all first-time anterior dislocations occur in patients older than 60 years.[2,3] Although older patients are less likely to experience recurrent shoulder instability events, persistent morbidity due to rotator cuff injury, fracture, or nerve injury has been well documented.[2,4] Anteroinferior glenoid rim fractures (AGRFs), also known as "bony Bankart fractures," are typically associated with traumatic anterior glenohumeral instability events.[5] These occur as the dislocated humeral head impacts the anterior glenoid, labrum, and capsule during a dislocation event. Particularly in the older population, glenoid fractures may occur owing to weakened and osteoporotic bone.[6] Structurally, these lesions play a role in shoulder stability, but their impact on recurrent instability in the older patient is not as well studied as capsulolabral complex injuries in younger patients.[7-10]

The current literature regarding the risk of recurrent instability in patients with acute anterior glenoid rim fractures offers inconclusive findings. Robinson et al.[11] reported that the presence of an acute glenoid rim fracture after a first-time traumatic anterior dislocation was a significant risk factor for early redislocation after nonoperative management. Conversely, other investigations have suggested that the presence of a glenoid rim fracture after a primary shoulder dislocation does not increase the risk of recurrent instability for some patient groups.[12,13] It is clear that untreated chronic glenoid rim fractures may play a role in recurrent instability and arthritic progression owing to erosion, osteolysis, and continued bone loss.[14] A distinction must be made between acute rim fractures with an associated bone fragment and cases of attritional glenoid bone loss without a remaining bone fragment because treatment options and clinical outcomes differ.[15] For the purposes of this investigation, AGRF patients will encompass patients who experience acute fractures of the anteroinferior glenoid rim without attritional bone loss in the setting of anterior shoulder instability (ASI).

Much of the published literature on traumatic ASI has focused on younger patient populations. There remains a paucity of available data regarding traumatic shoulder dislocations associated with anterior glenoid rim fractures in older patients. The purposes of this study were to investigate the incidence of AGRFs after ASI in patients aged 50 years or older, identify risk factors for surgical intervention for AGRFs, compare initial treatment strategies, and compare clinical outcomes of patients with and without associated AGRFs. We

hypothesized that AGRFs would be prevalent in this patient population and would correlate with an increased likelihood of surgical intervention.

Methods

Study Population and Design

After institutional review board approval was obtained from both Mayo Clinic (16-007084) and Olmsted Medical Center (042-OMC-16), the Rochester Epidemiology Project (REP) was used to identify patients who experienced ASI between January 1994 and July 2016. The REP is an electronic collection system of complete medical records involving a United States—based geographic cohort of more than 500,000 patients, all of whom were residents of Olmsted County, Minnesota, or neighboring counties in southeast Minnesota and western Wisconsin. The methodology and generalizability of the REP have previously been described in detail.[16,17] Patient records were identified by searching for International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes for ASI. Patient charts were then individually reviewed in detail to confirm the diagnosis of ASI and obtain the necessary study details. All patients were assessed by a primary care, emergency medicine, or orthopaedic physician. Patients were included if they had 1 or more anterior shoulder dislocation at age 50 years or later and were aged 50 years or older when ASI was first diagnosed. The exclusion criteria consisted of patients with multidirectional instability, posterior shoulder instability, previous surgery on the affected shoulder, or an initial ASI event occurring before the age of 50 years.

Patients with AGRFs were identified by reviewing radiographs, computed tomography (CT) scans, or magnetic resonance imaging (MRI) scans of the affected shoulder. Images were initially reviewed by a musculoskeletal radiologist and were confirmed by the senior author (C.L.C.). The size of the AGRF bone fragment was measured on CT or MRI at the time of the instability diagnosis. The inferior portion of the glenoid rim was approximated to a true circle on sagittal views, and the size of the bone fragment was calculated as a percentage of the glenoid rim diameter.[18] Patients with radiographic evidence of an acute anterior glenoid rim fracture were matched 1:1 with patients who had ASI without a glenoid fracture. For the matched-cohort analysis, patients were only included if they had at least 2 years of follow-up. The groups were matched based on age (±5 years), sex, occupation (laborer vs non-laborer), and dominant-sided versus non—dominant-sided dislocation. The surgical criteria for patients with AGRFs were dependent on patient factors including degree of instability, activity level, size of the glenoid fragment, and chronicity of the injury.

Table 1. Patient Baseline Demographic and Clinical Data

	AGRF Group (n = 41)	Control Group (n = 41)	P Value
Age, yr	58.6 ± 4.9	58.2 ± 4.8	.741
Sex: male/female	22/19	22/19	>.999
BMI	31.4 ± 7.9	32.4 ± 7.3	.547
Dominant dislocation	22 (54)	20 (49)	.842
Occupation			.356
Laborer	10 (24)	9 (22)	
Non-laborer	31 (76)	28 (68)	
Unknown	0	4 (10)	
Current or former smoker	17 (41)	25 (61)	.421
Presence of diabetes	7 (18)	4 (10)	.393
Previous subluxations at age ≥ 50 yr	2 (5)	2 (5)	>.999
Previous dislocations at age ≥ 50 yr	4 (10)	3 (7)	>.693
Clinical follow-up, yr	10.1 ± 5.5	11.4 ± 6.3	.420

NOTE. Data are expressed as mean ± standard deviation or count (percentage).

AGRF, anteroinferior glenoid rim fracture; BMI, body mass index.

Patient medical records were reviewed to collect demographic data (age at diagnosis, sex, body mass index [BMI], and occupation), smoking history, presence of diabetes, previous surgery on the affected shoulder, injury characteristics, and radiographic characteristics at presentation. Information regarding treatment strategies (operative vs nonoperative) and surgical details (open vs arthroscopic stabilization, method for addressing the AGRF, labral repair, rotator cuff repair, Latarjet procedure, and so on) was recorded. Patients were considered to have trialed an initial course of nonoperative management if they did not undergo surgery within 6 months of initial presentation. Outcome measures included recurrent instability, recurrent pain events, conversion to arthroplasty, and osteoarthritis graded with the Samilson-Prieto classification for post-instability arthritis.[19]

Statistical Analysis

Data were collected and stored in Microsoft Excel 2010 (Microsoft) and analyzed with JMP Pro (version 14.1.0; SAS Institute). Patient characteristics were presented with descriptive statistics using means, percentages, and 95% confidence intervals of the mean when appropriate. Univariate analysis of clinical and radiographic characteristics was performed to identify independent risk factors for surgery, and logistic regression analysis was performed to determine odds ratios (ORs). To determine cutoff values for independent risk factors, receiver operating characteristic (ROC) analysis with calculation of the area under the ROC curve (AUC) was performed. After analysis of data for parametric or nonparametric assumptions, continuous variables were compared between age groups using the Student t test or Wilcoxon rank sum test; categorical variables were similarly compared by use of χ^2 analysis or the Fisher exact test. $P < .05$ was considered significant. Post hoc power analysis of the comparative analysis using rates of surgical intervention for each group yielded 21.4% power.

Results

Patient Demographic Data and Incidence

Our initial database query of patients aged 50 years or older with a history of an ASI event resulted in 422 patients. Subsequently, 177 patients with a clinically confirmed diagnosis of first-time ASI occurring at age 50 years or later were identified, with a mean age of 58.9 (range, 50-70 years). Of these patients, 41 (23.2%) had radiographic evidence of an AGRF at initial presentation for the shoulder instability event.

For the matched-cohort analysis, the 41 patients with AGRFs were matched in a 1:1 fashion with the control group without radiographic evidence of an AGRF. There were no differences in baseline demographic and clinical data between the 2 groups (Table 1). The mean total follow-up time for the overall cohort was 10.8 ± 5.9 years (range, 2.0-25.4 years).

Radiographic Findings

All patients underwent radiography at initial presentation. MRI scans were available for 48 patients (59%) overall and were performed at a median of 39 days (interquartile range [IQR], 14-117 days) after the initial instability event, and CT scans were available for 17 patients (21%) overall (14 AGRF patients and 3 controls) and were performed at a median of 7 days (IQR, 0-13.75 days) after presentation. Findings from radiographic evaluation of the 2 cohorts are presented in Table 2. An anteroinferior glenoid fracture was visible on radiographs in 35 patients in the AGRF cohort, whereas in 6, it was only visible on advanced imaging. Twenty patients had advanced imaging available for measurements, with a mean fragment size encompassing 25.6% (range, 11%-

Table 2. Radiographic Characteristics

	AGRF Group	Control Group	P Value
Radiography	n = 42	n = 42	
Hill-Sachs lesion	28 (68)	13 (32)	.002*
Humeral head fracture	5 (12)	4 (10)	.724
Samilson-Prieto grade	n = 27	n = 20	.975
0	18 (66)	13 (65)	
1	8 (30)	6 (30)	
2	1 (4)	1 (5)	
MRI	n = 18	n = 30	
Labral tear	15 (83)	16 (54)	.035*
Rotator cuff tear			.010*
Partial	9 (50)	6 (20)	
Complete	6 (33)	23 (77)	
Hill-Sachs lesion	14 (74)	14 (42)	.133

NOTE. Data are expressed as count (percentage).

AGRF, anteroinferior glenoid rim fracture; MRI, magnetic resonance imaging.

*Statistically significant ($P < .05$).

46%) of the transverse width of the articulating glenoid surface.

Management Decisions

There were no differences in treatment strategies between the 2 cohorts (Table 3). Overall, 11 patients with AGRFs (27%) and 16 controls (39%) received operative intervention at a median of 93 days (IQR, 24-135 days) after the anterior shoulder dislocation. In 8 of the 11 patients with AGRFs managed operatively, surgical intervention for the glenoid fracture was performed because of instability (median time to surgery, 20.5 days), consisting of suture anchor fixation alone in 4, screw fixation in 1, both suture anchor and screw fixation in 1, reverse total shoulder arthroplasty (rTSA) with glenoid bone grafting in 1, and the Latarjet procedure in 1. The patients with AGRFs who required more robust fixation beyond suture anchors alone (screw fixation or Latarjet procedure) had larger glenoid fragment widths (35%-45%). The individual patient who was treated with rTSA with glenoid bone grafting was treated 279 days after initial presentation. The remaining 3 patients underwent surgical intervention for a rotator cuff pathology exclusively. For patients in the control group, rotator cuff injury was the most common reason for surgical intervention (81%). Multiple dislocation events at age 50 years or later were not associated with an increased rate of surgical intervention ($P > .999$).

Risk Factors for Surgery in Patients With AGRFs

Patients with AGRFs who underwent surgery to address glenoid fractures had a greater BMI ($P = .035$) and an increased AGRF size ($P = .030$) (Table 4). On logistic regression analysis, unit increases in preoperative BMI (OR, 1.1; $P = .026$) and AGRF size (OR, 1.2; $P = .015$) were found to be significant factors associated

with surgery. All patients with a fragment size smaller than 20% were treated nonoperatively. Patients who required surgical stabilization of the glenoid fracture had fragment sizes ranging from 21% to 45% of the glenoid width. ROC curve cutoff values for surgical intervention were a fragment size of 33% (AUC, 0.79; sensitivity, 44%; specificity, 100%) and BMI of 33 (AUC, 0.72; sensitivity, 64%; specificity, 77%).

Outcomes and Complications

There were no differences in recurrent instability events after initial presentation (Table 5). Documented recurrent instability was observed in 5 AGRF patients (12%) and 8 control patients (20%) ($P = .547$). The median time to recurrent instability was 134 days (IQR, 36-1,266 days) and 954.5 days (IQR, 50.75-4,275.25 days) for the AGRF and control patients, respectively ($P = .306$). There were no differences in recurrent pain episodes after initial presentation between the 2 groups ($P = .078$). In patients who underwent operative intervention, there were no recurrent instability events postoperatively. No differences in physical examination findings for forward flexion ($P = .570$) and external rotation ($P = .601$) at 2 years' follow-up were observed between the 2 groups. Overall, 11 AGRF patients (27%) and 18 control patients (47%) reported returning to their occupations ($P = .067$). Arthritis progression based on an increased Samilson-Prieto grade was present in 9 AGRF and 9 control patients ($P = .780$) at final follow-up. Revision surgery was performed in 1 AGRF patient (9%) and 4 control patients (25%) ($P = .619$).

Overall, 1 AGRF patient (2%) and 2 control patients (5%) received rTSA. The AGRF patient underwent rTSA after initial nonoperative management, whereas the 2 control patients underwent eventual rTSA at 4.1 years and 11.4 months after the initial rotator cuff repair.

Table 3. Treatment Strategies

	AGRF Group	Control Group	P Value
Overall surgery	11	16	.172
Nonoperative treatment initially	1 (9)	5 (32)	.350
Surgical treatment initially	10 (91)	11 (68)	.350
Type of surgery			>.254
Open	4 (36)	4 (25)	
Arthroscopic	6 (55)	6 (37.5)	
Both open and arthroscopic	1 (9)	6 (37.5)	
Surgical pathology addressed			
Rotator cuff injury	6 (55)	13 (81)	.280
Labral injury	6 (55)	5 (31)	.264
Biceps injury	1 (9)	7 (47)	.105
Humeral fracture	1 (9)	0	.423

NOTE. Data are expressed as count (percentage).

AGRF, anteroinferior glenoid rim fracture.

Table 4. Risk Factors for Surgery in AGRF Patients

	Surgery	Nonoperative	P Value
BMI	35.8 ± 9.4	29.5 ± 6.5	.035*
AGRF size, %	30.1 ± 9.1	22 ± 5.7	.035*

NOTE. Data are expressed as mean ± standard deviation.
AGRF, anteroinferior glenoid rim fracture; BMI, body mass index.
*Statistically significant (P < .05).

Complications including adhesive capsulitis, infection, and nerve palsy were evaluated. Overall, adhesive capsulitis developed in 9 patients (3 AGRF patients vs 6 controls, P = .481), postsurgical infection developed in 1 control patient, and nerve palsy developed in 7 patients (2 AGRF patients vs 5 controls, P = .431).

Discussion

The primary finding of this study is that an AGRF is a relatively common finding in patients who experience an anterior shoulder dislocation at age 50 years or older. Patients with a glenoid fragment size 33% of the glenoid width or greater and a BMI of 33 of higher were more likely to undergo surgical intervention. In our overall cohort of ASI patients aged 50 years or older, 23.2% had radiographic evidence of an AGRF. The presence of an AGRF at the initial instability event did not significantly necessitate operative intervention, and most patients in the study (73% of AGRF patients and 61% of controls) did not require surgery after traumatic ASI. Concomitant rotator cuff pathology was the most common reason for surgery in both the AGRF cohort (55%) and control cohort (81%). Long-term outcomes including recurrent instability, revision surgery, progression of osteoarthritis, and conversion to arthroplasty were similar between the 2 groups.

Although concomitant rotator cuff injuries with anterior shoulder dislocation are well documented in elderly patients, the osseous pathoanatomy of anterior instability events in this population is not as clear.[2] In younger patients, injury to the anterior glenoid labrum is reported to be present in up to 97% of cases of primary anterior shoulder dislocation whereas the presence of associated glenoid rim fractures ranges from 8.6% to 16%.[15,20] In older patients with ASI, the prevalence of glenoid rim fractures is not as well studied. Abballe et al.[21] conducted an MRI investigation of patients aged 40 years or older and reported that 37.5% had visible glenoid bone defects at initial presentation; however, the location and type of glenoid bone defect were not clearly defined. Radiographic evidence of Hill-Sachs lesions and labral tears was more likely to be present in patients with AGRFs. These findings may be expected owing to the overlapping pathophysiology of an AGRF and a Hill-Sachs lesion. As the humeral head translates anteriorly during the shoulder instability event, a compression fracture may occur along the posterosuperior aspect of the humeral head as it collides with the anterior glenoid and labrum.[22] Hill-Sachs lesions rarely occur in isolation; accordingly, we would expect to observe coexisting injuries including anterior glenohumeral ligamentous or osseous pathologies.[22]

It is interesting to note that although AGRF patients were more likely to experience coexisting bony injuries including Hill-Sachs lesions, patients without AGRFs more commonly experienced concomitant rotator cuff injuries. This discrepancy may result from subtle differences in the mechanism of injury. During the initial traumatic instability event, energy transfer directly to osseous structures may result in AGRFs and associated bony lesions while sparing the rotator cuff. Conversely, if the force of impact is absorbed by the rotator cuff and supporting soft-tissue structures, this may reduce the likelihood of fracture, particularly in the older patient in whom asymptomatic age-related attritional tears are likely to be present.[23]

In this study, patients with AGRFs were surgically managed at a similar rate to the matched controls (27% vs 49%), and 73% of patients with AGRFs were treated conservatively. This finding suggests that the presence of an AGRF does not necessitate

Table 5. Outcomes

	AGRF Group	Control Group	P Value
Pain	25 (63)	33 (83)	.078
Recurrent instability	5 (12)	8 (20)	.547
Time to recurrent instability, d	134 (36-1,266)	954.5 (50.75-4,275.25)	.310
Return to work, d	49 (17-66)	45 (14-91)	.893
Return to work after surgery, d	54.5 (43.75-288.75)	90 (52.5-101.75)	
Progression of OA*	9 (34)	9 (39)	.780
Revision surgery	1 (9)	4 (25)	.619
Physical examination findings at final follow-up			
Forward flexion, °	155 (102.5-170)	150 (100-170)	.570
External rotation, °	50 (30-70)	50 (30-70)	.601

NOTE. Data are expressed as count (percentage) or median (interquartile range).
AGRF, anteroinferior glenoid rim fracture; OA, osteoarthritis.
*Data are reported for patients with radiographs available at final follow-up.

operative intervention and patients in this age group may be successfully managed nonoperatively. Spiegl et al.[24] developed a treatment algorithm for osseous Bankart lesions and reported encouraging clinical outcomes after using a conservative strategy for patients with small lesions (<5%), whereas patients with medium-sized (12.5%-25%) or large-sized (≥25%) Bankart fractures may benefit from a surgical treatment strategy.[25,26] Our findings follow a similar trend as a greater fragment size, particularly 33% or greater, was associated with a greater incidence of surgical intervention. Particularly for patients with a fragment size of 35% or greater, a more robust stabilization with screw fixation or the Latarjet procedure may be necessary to achieve adequate surgical stabilization, whereas those with smaller fragment sizes may be optimally treated with suture anchor fixation. Conversely, in younger patients, surgical stabilization after a first-time instability event is associated with a significantly decreased risk of recurrence and improved outcomes compared with nonoperative treatment.[27] Thus, in the younger age group, a lower threshold for surgical management is recommended after primary anterior shoulder dislocation. However, in the middle-aged to older population, repairing the AGRF may not be necessary for smaller fragments and nonoperative treatment may be sufficient to stabilize the shoulder.

Our results suggest that AGRFs may not significantly contribute to recurrent instability events in older patients. The current literature reports an overall rate of recurrent instability between 4% and 20% in elderly patients after primary traumatic anterior dislocation.[3,28] In our cohort, 14% of AGRF patients and 17% of control patients experienced recurrent instability. Regarding the time to recurrent instability between the 2 groups, although there were no statistically significant differences, the median time to recurrent instability was shorter in patients with AGRFs. Given the prevalence of concomitant rotator cuff tears in both groups, further investigation may be worthwhile to evaluate whether the presence of both an AGRF and a rotator cuff tear may contribute to an earlier recurrence of instability. Overall, the recurrence rate was low compared with younger patients. Duethman et al.[9] reported a 60.7% rate of recurrent instability after nonoperative treatment in a group of patients younger than 40 years. The difference in the overall recurrence rate between younger and older patients may be explained in part by the resultant pathologies after traumatic anterior instability: Whereas older patients tend to have concomitant rotator cuff injuries, younger patients are likely to have resultant damage to the anterior stabilizing structures and glenohumeral ligaments.[2] Additionally, younger patients may be involved in high-risk physical activities that contribute to an increased likelihood of redislocation.[10] To our knowledge, only 1 study has previously investigated AGRFs in older patients with respect to recurrent instability: Robinson et al.[11] performed an investigation of patients with first-time ASI and identified a subset of 27 patients with associated glenoid rim fractures aged between 35 and 80 years. They reported a 37% recurrence rate and determined that the presence of an isolated glenoid rim fracture and the presence of a bifocal fracture (glenoid rim and greater tuberosity) were both significant risk factors for redislocation.[11] However, all patients in their study were treated operatively owing to gross instability on initial assessment. Therefore, these findings may represent more severe cases and may not be generalizable to the entire spectrum of AGRFs.

Limitations

There are several important limitations to consider when interpreting the findings of our investigation. Given the retrospective nature of the study, the results and conclusions may be susceptible to the inherent biases of the retrospective process, including dependence on the accuracy and completeness of documentation within the patient records. Accordingly, information regarding comparisons of preoperative and postoperative range of motion after ASI was limited and unable to be analyzed in this study. Owing to the nature of the REP and retrospective design, standardized radiographic protocols and advanced imaging (MRI and/or CT) were not universally available for all patients. Because of the heterogeneity of available advanced imaging, comparisons between the 2 groups based on imaging characteristics must be carefully considered when interpreting these findings. It is possible that the number of AGRFs within our study may be under-reported given that CT scans are superior to radiographs and MRI scans for assessing glenoid fractures. Additionally, the ROC analysis to determine cutoff values for surgery based on glenoid fragment size was limited by available imaging and, as a result, must be interpreted with caution. Treatment strategies were based on physician preference because a standardized management protocol was not used for the included patients. Subsequently, certain valuable data points such as range of motion could not be accurately assessed in this study.

Conclusions

Of patients aged 50 years or older at presentation of ASI, 23.2% presented with an associated AGRF. A fragment size 33% of the glenoid width or greater and a higher patient BMI were significant factors for surgical intervention; however, most patients did not require surgery and still showed acceptable clinical outcomes, and the most common reason for surgical intervention was a rotator cuff tear. Overall, the presence of an AGRF did not portend a worse prognosis as treatment

strategies and long-term outcomes including recurrent instability, progression of osteoarthritis, and conversion to arthroplasty were similar to those in patients without AGRFs.

Acknowledgment

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