JSES International 7 (2023) 532–537

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Glenoid index: a new risk factor for recurrence of glenohumeral instability after arthroscopic Bankart repair

Agustin Albani-Forneris, MD[a], María Guillermina Bruchmann, MD[a], Luciano A. Rossi, PhD[a,*], Rodrigo Brandariz, MD[a], Damián Di Memmo, MD[b], Ignacio Tanoira, PhD[a], Maximiliano Ranalletta, PhD[a]

[a]Institute of Orthopaedics "Carlos E. Ottolenghi" Hospital Italiano de Buenos Aires, Buenos Aires, Argentina
[b]Radiology department, Hospital Italiano de Buenos Aires, Buenos Aires, Argentina

ARTICLE INFO

Keywords:
Shoulder
Instability
Glenoid labrum
Imaging magnetic resonance
General sports trauma
Glenoid index

Level of evidence: Level III; Retrospective Cohort Comparison; Prognosis Study

Background: The glenoid index (GI) (glenoid height to width ratio) has been shown to be a risk factor for instability in young healthy athletes. Nevertheless, whether the altered GI is a risk factor for recurrence after a Bankart repair remains unknown.
Methods: Between 2014 and 2018, 148 patients ≥ 18 years old with anterior glenohumeral instability underwent a primary arthroscopic Bankart repair in our institution. We assessed return to sports, functional outcomes, and complications. We evaluate the association between the altered GI and the probabilities of recurrence in the postoperative period. Intraclass correlation coefficient was used to determine interobserver reliability.
Results: The mean age at the time of surgery was 25.6 years old (19 to 29), and the mean follow-up was 53.3 months (29 to 89). The 95 shoulders who met the inclusion criteria were divided into 2 cohorts, 47 shoulders had a GI ≤ 1.58 (group A) and 48 had a GI > 1.58 (group B). At the final follow-up, 5 shoulders in group A (10.6%) and 17 shoulders in group B (35.4%) suffered a recurrence of instability. Those patients with a GI > 1.58 had a hazard ratio of 3.86 (95% confidence interval: 1.42-10.48) ($P = .004$) compared with those with a GI ≤ 1.58 of suffering a recurrence. When correlating GI measurements between raters, we observed an intraclass correlation coefficient of 0.76 (95% confidence interval: 0.63-0.84), these results fall under the qualitative definition of good interobserver agreement.
Conclusion: In young active patients with an arthroscopic Bankart repair, an increased GI was associated with a significantly higher rate of postoperative recurrences. Specifically, those subjects with a GI > 1.58 had 3.86 times the risk of recurrence than those subjects with a GI ≤ 1.58.

Anterior glenohumeral instability is one of the most frequent pathologies of the shoulder, especially in young competitive athletes.[16] In those patients who present the classic Bankart lesion, that is, isolated anteroinferior capsulolabral detachment, reinsertion of the capsulolabral complex (Bankart repair), has been shown to be associated with very good functional outcomes, high rates of return to sport, and very low rate of complications.[9,11]

However, in recent years, significant progress has been made in the recognition of some risk factors associated with unsatisfactory results with this procedure, mainly at the expense of a high rate of recurrences.[12,15,16] Among the risk factors for recurrence after arthroscopic Bankart repair (ABR) are glenoid bone loss, engaging Hill Sachs lesions, age < 20 years old, hyperlaxity, and contact sports.[12,15,16] A better understanding of the pathophysiology of recurrences is essential for shoulder surgeons due to the fact that the presence of one or more of these risk factors can change the patient's treatment strategy, leading the surgeon to add an associated procedure like a remplissage or directly to change the surgical technique toward a glenoid reconstruction surgery such as the Latarjet or the Eden-Hybinette procedures.

Owens et al[13] prospectively evaluated 714 young athletes who had no previous episodes of instability and reported that the glenoid index (GI) (glenoid height to width ratio) was a significant risk factor for glenohumeral instability. Specifically, the authors reported that those subjects with a GI > 1.58 had 2.64 times the risk of injury compared with those subjects with a ratio ≤1.58.[13] These

The ethics committee of the Hospital Italiano de Buenos Aires, Argentina (00010193; protocol number: 4810) approved this study.

*Corresponding author: Luciano A. Rossi, PhD, Institute of Orthopaedics "Carlos E. Ottolenghi" Hospital Italiano de Buenos Aires, Potosí 4215 (C1199ACK), Buenos Aires, Argentina.

E-mail address: luciano.rossi@hospitalitaliano.org.ar (L.A. Rossi).

https://doi.org/10.1016/j.jseint.2023.02.020
2666-6383/

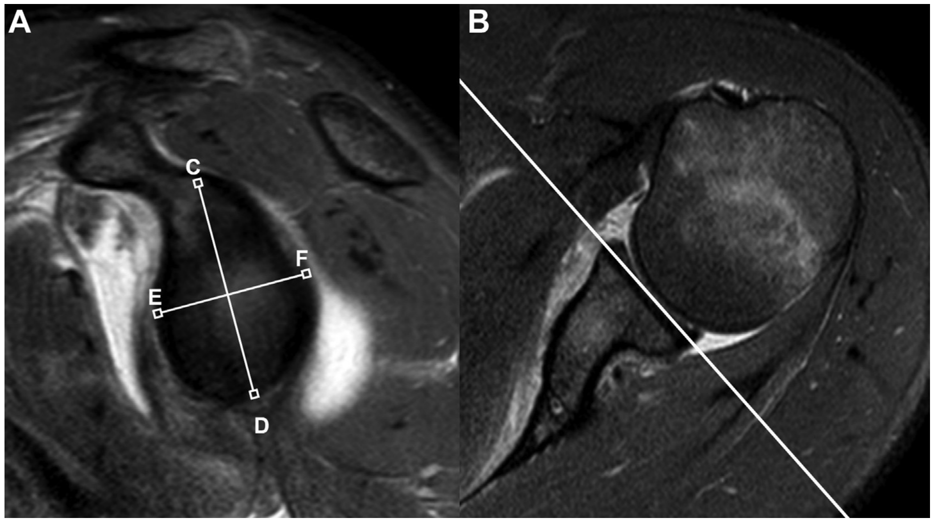

Figure 1 Shoulder T2 MRI sequences. (**A**) Sagittal plane of glena, glenoid height C-D, and glenoid width E-F. (**B**) Axial plane, with line represents the localization of the parasagittal plane image. The highest part and the widest part in the most lateral available parasagittal image of the glenoid are taken as reference to carry out the measurements. *MRI*, magnetic resonance imaging.

findings were later confirmed by other authors in the pediatric and adolescent populations.[18] Importantly, both studies evaluated healthy patients who had never had previous episodes of instability. Nevertheless, whether the altered GI is a risk factor for recurrence after an ABR remains unknown.

The purpose of this study was to compare the GI of patients operated on for ABR who had recurrences with those who did not and to determine if the GI is a risk factor for recurrence after ABR. We hypothesized that patients with dislocations after an ABR would have a significantly greater GI (relatively taller and narrower glenoid morphology) compared with controls with no postoperative recurrence.

Materials and methods

This was a retrospective comparative study. We identified 148 patients who underwent ABR for glenohumeral instability between 2014 and 2018 in our institution. All of the included patients were older than 18 years old with anterior glenohumeral instability with a minimum 2 years of follow-up. We excluded patients with glenoid bone loss, off-track Hill Sachs lesions, revision procedures, other types of instability, (eg, posterior or voluntary), anterior hyperlaxity, defined as external rotation of >90 with arms at the side (reaching the frontal plane), and inferior laxity was determined through the use of the Gagey hyperabduction test [4,6] and or in whom clinical or radiographic evaluations were absent at the final follow-up. The ethics committee of our institution approved this study (IRB No. 4810).

Evaluation

Preoperative and postoperative data were collected from our institutional prospective database. Preoperative and postoperative evaluation consisted of a patient-based questionnaire and the physical examination performed by a shoulder fellow who did not participate in the surgery. If any of the data were incomplete in the record, patients were contacted by telephone and then examined at a minimum 24-month follow-up to complete the information. On preoperative examination, all patients had positive anterior apprehension and relocation tests.

All patients were studied before surgery with anteroposterior and axillary glenohumeral views and magnetic resonance imaging. The preoperative glenoid bone loss was measured with the GI method according to Chuang et al.[3] To assess if the lesions were on track or off track, we used the method described by Di Giacomo et al.[5] Patient sports level was divided into competitive and recreational sports according to Araujo and Scharhag.[2] The distinctive types of shoulder-dependent sports were subdivided in an analog manner according to Allain et al[1]: noncollision/nonoverhead shoulder sport (G1), high-impact/ collision sport (G2), overhead sport (G3), and martial arts (G4). All surgery-related complications and reoperations were documented. For dislocations, patients were asked whether their shoulder had "popped out" or "dislocated," requiring manual or self-reduction. Subluxations were defined as any sensation of the shoulder "slipping" or "shifting."[17]

All preoperative magnetic resonance imaging (MRI) were performed in the 2 months prior to surgery in 1.5 tesla resonators and were evaluated by 2 blinded raters, a fellowship-trained musculoskeletal radiologist and shoulder-trained orthopedic surgeon measured glenoid height and width in sagittal T2 MRI sequences in order to obtain a GI for interobserver reliability (Fig. 1). Index measurements with more than a 10 percent difference between raters were reviewed in a consensus meeting to determine if this difference was attributed to human error at the time of measurement.

Patients were asked whether they had been able to practice sport again and whether they had been able to perform it at the same level as before the injury. The Rowe score was used as a global outcome measure.[14]

Surgical technique

The surgical technique for all of the cases in this series was an anterior arthroscopic stabilization performed in the lateral decubitus position with combined general endotracheal and regional anesthesia. All patients underwent primary arthroscopic anterior glenohumeral stabilization surgery for anterior shoulder instability using a knotted anchor technique with simple sliding knots. We used in all cases biodegradable anchors with double suture. After complete liberation and release of the capsulolabral ligament

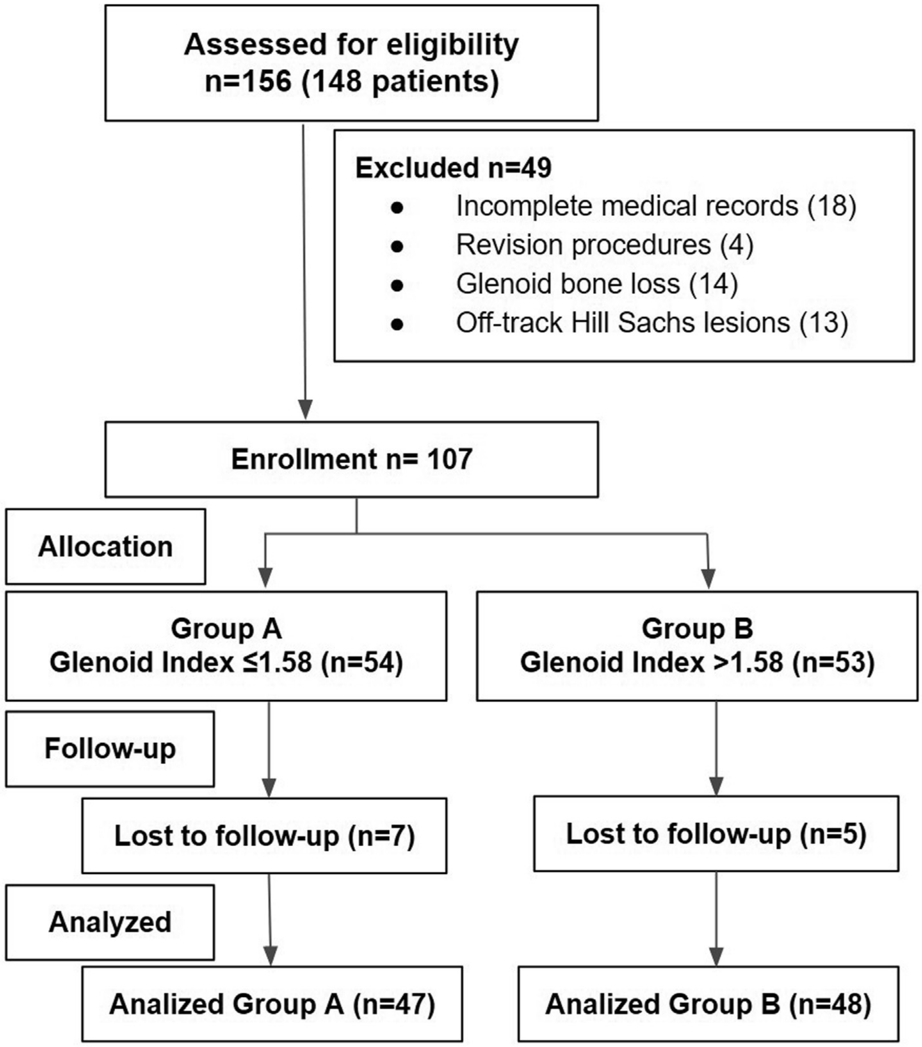

Figure 2 CONSORT flow diagram of the study cohorts.

beyond the 6-o'clock position, the labral edge was débrided. Then, the anterior and inferior glenoid rim and neck were abraded with a shaver. In both groups, anchors with no. 2 nonabsorbable sutures were placed on the cartilage edge of the glenoid surface (3.0 Bio-Corkscrews; Arthrex, Naples, FL, USA), a mean of 3.2 anchors (2 to 4) and 3.3 (2 to 4) were used in groups A and B, respectively. In all the patients, reinsertion of the anteroinferior capsulolabral complex was performed, including retensioning of the capsule and the inferior glenohumeral ligament. No patients in this series were treated with a posterior-inferior capsulolabral repair, rotator interval closure, superior labral anterior posterior repair, or remplissage.

Rehabilitation

A standardized postoperative physical therapy and rehabilitation program was used. The arm was supported in a sling for 4 weeks. After 1 week, supervised gentle physical therapy consisting of gradual passive range of motion was begun. Active-assisted range of motion exercises were started 2 weeks after surgery. When the patient could perform active forward elevation above the shoulder level, strengthening exercises were started. Running was authorized at 8 weeks. Return to sports was allowed when the patient was pain free without apprehension and full shoulder range of motion had been achieved.

Statistical method

Continuous variables were expressed as means and ranges whereas categorical variables were reported as frequencies and percentages. Continuous variables were compared using the independent samples *t*-test, where data were normally distributed, and the Mann–Whitney U test otherwise. Categorical variables were compared using chi-squared tests for independent groups and McNemar test for dependent groups. Kaplan–Meier survival curves were estimated considering the recurrence of shoulder instability as an endpoint. The incidence and time to recurrence were compared between both cohorts using Cox regression. We performed two time-to-event analyses: one crude and one adjusted for the possible confounding effect of three variables: the practice of contact sports, the competitive level of such practice at the time of the event, and age at the time of surgery. Hazard ratios (HRs) were reported with their 95% confidence intervals (CIs). Intraclass correlation coefficient (ICC) was used for interobserver reliability.

Table I
Demographics characteristics of groups.

Variables	Group A Glenoid index ≤1.58	Group B Glenoid index >1.58	*P* value
Patients (shoulders), n	46 (47)	46 (48)	
Glenoid index, mean (SD)	1.51 (0.05)	1.69 (0.09)	<.001
Male gender, n (%)	40 (85.10%)	40 (83.30%)	.813
Age (y), mean (range)	25.04 (19-29)	26.19 (23.7-28.6)	.525
Dominant shoulder involvement, n (%)	27 (57.40%)	25 (52.10%)	.600
Previous dislocation events, mean (range)	2.3 (1-.4)	2,1 (1-3)	.725
Sports practice, n (%)	38 (80.90%)	44 (91.70%)	.125
Type of sport, n (%)*			.266
G1 (noncollision/nonoverhead)	6 (15.80%)	9 (20.50%)	
G2 (high impact/collision)	17 (44.70%)	19 (43.20%)	
G3 (overhead sport)	10 (26.30%)	15 (34.10%)	
G4 (martial arts)	5 (13.20%)	1 (2.30%)	
Level of competition, n (%)†			.678
Recreational	13 (34.20%)	17 (38.60%)	
Competitive	25 (65.80%)	27 (63.40%)	
Preoperative Rowe score‡, mean (SD)	68.91 (5.15)	69.69 (6.39)	.521
Mean follow-up (mo), mean (range)	53.19 (29-86)	54.00 (33-86)	.829

SD, standard deviation.
*Type of sport was assigned according to the system by Allain et al.[1]
†Level of competition was assigned based on criteria by Araujo and Scharhag.[2]
‡According to the system by Rowe et al.[3]

Table II
Recurrence results between groups.

Variables	Group A Glenoid index ≤1.58	Group B Glenoid index >1.58	*P* value	HR (95% CI)
Recurrence of shoulder instability, n (%)	5 (10.6%)	17 (35.4%)	.004	3.86 (1.42-10.48)
Time to recurrence (mo), mean (range)	17.4 (5-28)	16.41 (5-42)	.696	-

HR, hazard ratio; *CI*, confidence interval.

Variables were considered statistically significant if $P < .05$. A post hoc power analysis was performed to detect a mean difference of 0.25 with $\alpha = .0$. Using a two-tailed *t*-test when N = 94 the power was 83%.

The statistical analysis was performed with the software IBM SPSS Statistics for Windows (Version 26.0.; IBM Corp., Armonk, NY, USA).

Results

A total of 156 shoulders in 148 patients who met the inclusion criteria underwent surgery during the study period. Forty-nine shoulders were excluded from the analysis and 12 shoulders in total were lost to follow-up (Fig. 2). Thus, the final analysis entailed 95 shoulders in 92 patients (88.5% follow-up). The 95 shoulders who met the inclusion criteria were divided into 2 cohorts, 47 shoulders had a GI ≤1.58 (group A) and 48 had a GI >1.58 (group B). In group A, the mean GI was 1.51 ± 0.05 and in group B was 1.69 ± 0.09 ($P < .001$). Most patients were male (84.2%), the mean age at the time of surgery was 25.6 years old (19 to 29), and the mean follow-up was 53.3 months (29 to 89). No statistically significant differences were found between groups according to gender, age, dominant shoulder involvement, number of previous dislocation events, sport practice, type of sport, level of competition, preoperative Rowe score, and follow-up (Table I).

At the final follow-up, 5 shoulders in group A (10.6%) and 17 shoulders in group B (35.4%) suffered a recurrence of instability. Those patients with a GI > 1.58 had a HR of 3.86 (95% CI: 1.42-10.48) ($P = .004$) compared with those with a GI ≤ 1.58 of suffering a recurrence. After adjusting for the potential confounding effect of practicing contact sports, level of sports participation, and age at the time of surgery, it was not observed clinically relevant differences regarding the univariate analysis results. Otherwise, the potential predictive capacity of the presence of a GI greater than 1.58 showed an even stronger association (HR: 5.22; 95% CI 1.73 to 15.70; $P = .003$). When correlating GI measurements between raters, we observed an ICC of 0.76 (95% CI: 0.63-0.84), these results fall under the qualitative definition of good interobserver agreement.[10] There was no difference in time to recurrence between group A (17.4 months, SD = 9.2) and group B (16.4 months, SD = 11.23) ($P = .696$) (Table II) (Fig. 3).

Of the 82 patients who practiced sports before the injury, 79 patients (96.3%) were able to return to sports at a mean time of 6 months after surgery. We found no significant differences between the groups regarding functional outcomes (Table III).

Discussion

The main finding of this study was that patients operated with an ABR who had a recurrence after the surgery had increased GI (taller and narrower glenoid morphology) than patients who did not suffered recurrences. Specifically, those subjects with a GI > 1.58 had 3.86 times the risk of recurrence than those subjects with a GI ≤ 1.58. Moreover, when correlating GI measurements between raters, we found a good interobserver agreement which resulted in an ICC of 0.76 (95% CI: 0.63-0.84).

Owens et al[13] were the first to demonstrate the association between an increased GI and the risk of glenohumeral instability. In their study, the authors followed 714 athletes who had never had an episode of glenohumeral instability for a period of 4 years. The authors found that the GI was found to be a significant risk factor for glenohumeral dislocation (HR, 8.12; 95% CI, 1.07-61.72; $P = .043$) when they controlled for history, sex, subject height, weight, and Beighton score. The authors divided the ratio into quartiles and

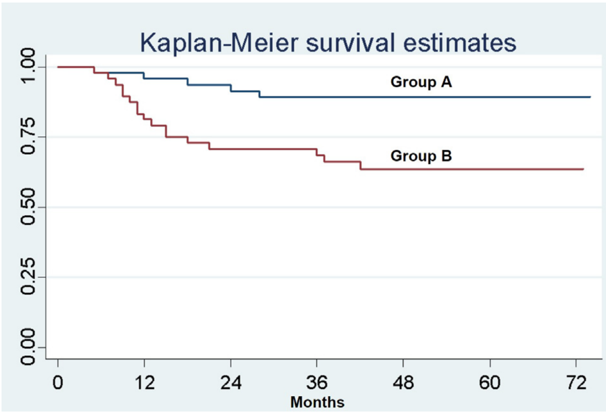

Figure 3 Kaplan–Meier survival estimates of both groups.

defined a cutoff value of 1.58 as the cutoff point that reached statistical significance. They concluded that those subjects with a GI > 1.58 had 2.64 times the risk of injury compared with those subjects with a GI ≤ 1.58.[13] In a similar study, Yellin et al[18] evaluated the association between GI and the risk of dislocation in the pediatric and adolescent population. The authors evaluated patients aged ≤19 years who had been diagnosed with radiographically confirmed anterior shoulder dislocation and who underwent glenohumeral magnetic resonance arthrography as well as those without dislocation with normal shoulder arthrogram studies (controls). The authors found that the mean GI in the dislocator group was significantly greater than the control group (1.55 ± 0.14 vs. 1.38 ± 0.08; $P < .001$).[18]

Although these findings are interesting from an academic perspective, their application is very difficult from a practical point of view, since an MRI of the two shoulders would have to be done in all healthy athletes to identify those with altered GI and consequently be able to apply preventive strategies. Nevertheless, in patients who have a first episode of glenohumeral dislocation, the GI could be a very useful tool for choosing the appropriate treatment. Narrower glenoids, and as a consequence with an altered GI, could be interpreted as a subcritical bone loss. Thus, this could be the explanation why patients with an altered GI have such an increased risk of recurrences.

Therefore, young athletes with anterior glenohumeral instability and an altered GI could benefit from surgical procedures that tend to increase the anteroposterior bone surface of the glenoid cavity, such as the Latarjet or the iliac bone graft. Several authors have shown favorable outcomes with these procedures in patients with glenoid bone loss, and the same could occur in patients with anterior glenohumeral instability associated with an altered GI.[7,8] Consequently, we believe that one of the strengths of this study, in addition to demonstrating the increased risk of recurrence in patients with an increased GI, is that it can serve as a starting point for future research evaluating treatment alternatives in this subgroup of risky patients.

Limitations

This study has some limitations that should be mentioned. First, this is a retrospective study. Second, we do not have a control group of patients operated with a glenoid reconstruction technique; therefore, we cannot assure that modifying the GI, at the expense of an anteroposterior glenoid augmentation, reduces the rate of recurrences.

Table III
Postoperative results between groups.

Variables	Group A Glenoid index ≤1.58	Group B Glenoid index >1.58	*P* value
Return to sports, n (%)	38 (100%)	41(93.20%)	.101
Time to return (mo), mean (range)	6.46 (5-8)	5.71 (4-6.25)	.389
Level of postoperative competition, n (%)†			.313
Recreational	21 (55.30%)	18 (43.90%)	
Competitive	17 (44.70%)	23 (56.1%)	
Rowe score*, mean (SD)	96.28 (8.75)	93.75 (13.74)	.289

†Level of competition was assigned based on criteria by Araujo and Scharhag.[2]
*According to the system by Rowe et al.[3]

Conclusion

In young active patients with an ABR, an increased GI was associated with a significantly higher rate of postoperative recurrences. Specifically, those subjects with a GI > 1.58 had 3.86 times the risk of recurrence than those subjects with a ratio ≤ 1.58.

Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Allain J, Goutallier D, Glorion C. Long-term results of the Latarjet procedure for the treatment of anterior instability of the shoulder. J Bone Joint Surg Am 1998;80:841-52.
2. Araújo CG, Scharhag J. Athlete: a working definition for medical and health sciences research. Scand J Med Sci Sports 2016;26:4-7. https://doi.org/10.1111/sms.12632.
3. Chuang TY, Adams CR, Burkhart SS. Use of preoperative three-dimensional computed tomography to quantify glenoid bone loss in shoulder instability. Arthroscopy 2008;24:376-82. https://doi.org/10.1016/j.arthro.2007.10.008.
4. Coste JS, Jund S, Lemaire M, Pascal B. Evaluation prospective arthroscopique du test de laxité du ligament gléno-huméral inférieur. Rev Chir Orthop 1999;85:61.
5. Di Giacomo G, Itoi E, Burkhart SS. Evolving concept of bipolar bone loss and the Hill-Sachs lesion: from “engaging/non-engaging” lesion to “on-track/off-track” lesion. Arthroscopy 2014;30:90-8. https://doi.org/10.1016/j.arthro.2013.10.004.
6. Gagey OJ, Gagey N. The hyperabduction test. J Bone Joint Surg Br 2001;83:69-74.
7. Gilat R, Haunschild ED, Lavoie-Gagne OZ, Tauro TM, Knapik DM, Fu MC, et al. Outcomes of the Latarjet procedure versus free bone block procedures for anterior shoulder instability: a systematic review and meta-analysis. Am J Sports Med 2021;49:805-16. https://doi.org/10.1177/0363546520925833.
8. Gilat R, Wong SE, Lavoie-Gagne O, Haunschild ED, Knapik DM, Fu MC, et al. Outcomes are comparable using free bone block autografts versus allografts for the management of anterior shoulder instability with glenoid bone loss: a systematic review and meta-analysis of “The Non-Latarjet”. Knee Surg Sports Traumatol Arthrosc 2021;29:2159-74. https://doi.org/10.1007/s00167-020-06194-z.
9. Hurley ET, Manjunath AK, Bloom DA, Pauzenberger L, Mullett H, Alaia MJ, et al. Arthroscopic Bankart repair versus conservative management for first-time traumatic anterior shoulder instability: a systematic review and meta-analysis. Arthroscopy 2020;36:2526-32. https://doi.org/10.1016/j.arthro.2020.04.046.
10. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159-74.
11. Memon M, Kay J, Cadet ER, Shahsavar S, Simunovic N, Ayeni OR. Return to sport following arthroscopic Bankart repair: a systematic review. J Shoulder Elbow Surg 2018;27:1342-7. https://doi.org/10.1016/j.jse.2018.02.044.
12. Nakagawa S, Mae T, Sato S, Okimura S, Kuroda M. Risk factors for the postoperative recurrence of instability after arthroscopic Bankart repair in athletes. Orthop J Sports Med 2017;5:2325967117726494. https://doi.org/10.1177/2325967117726494.

13. Owens BD, Campbell SE, Cameron KL. Risk factors for anterior glenohumeral instability. Am J Sports Med 2014;42:2591-6. https://doi.org/10.1177/0363546514551149.
14. Rowe CR, Patel D, Southmayd WW. The Bankart procedure: a long-term end-result study. J Bone Joint Surg Am 1978;60:1-16.
15. Trasolini NA, Dandu N, Azua EN, Garrigues GE, Verma NN, Yanke AB. Inconsistencies in controlling for risk factors for recurrent shoulder instability after primary arthroscopic Bankart repair: a systematic review. Am J Sports Med 2021;50:3705-13. https://doi.org/10.1177/03635465211038712.
16. Wagstrom E, Raynor B, Jani S, Carey J, Cox CL, Wolf BR, et al. Epidemiology of glenohumeral instability related to sporting activities using the FEDS (frequency, Etiology, direction, and Severity) classification system: a multi-center analysis. Orthop J Sports Med 2019;7:2325967119861038. https://doi.org/10.1177/2325967119861038.
17. Yang JS, Mazzocca AD, Cote MP, Edgar CM, Arciero RA. Recurrent anterior shoulder instability with combined bone loss: treatment and results with the modified Latarjet procedure. Am J Sports Med 2016;44:922-32. https://doi.org/10.1177/0363546515623929.
18. Yellin JL, Fabricant PD, Anari JB, Neuwirth AL, Ganley TJ, Chauvin NA, et al. Increased glenoid index as a risk factor for pediatric and adolescent anterior glenohumeral dislocation: an MRI-based, case-control study. Orthop J Sports Med 2021;9:2325967120986139. https://doi.org/10.1177/2325967120986139.