Clinical and Anatomic Predictors of Outcomes After the Latarjet Procedure for the Treatment of Anterior Glenohumeral Instability With Combined Glenoid and Humeral Bone Defects

William R. Mook,*† MD, Maximilian Petri,*† MD, Joshua A. Greenspoon,* BSc, Marilee P. Horan,* MPH, Grant J. Dornan,* MSc, and Peter J. Millett,*†‡ MD, MSc
Investigation performed at the Steadman Philippon Research Institute and The Steadman Clinic, Vail, Colorado, USA

Background: The Latarjet procedure for the treatment of recurrent anterior shoulder instability is highly successful, but reasons for failure are often unclear. Measurements of the ''glenoid track'' have not previously been evaluated as potential predictors of postoperative stability.

Hypothesis: There are clinical and anatomic characteristics, including the glenoid track, that are predictive of outcomes after the Latarjet procedure.

Study Design: Case series; Level of evidence, 4.

Methods: Patients who underwent the Latarjet procedure for anterior shoulder instability with glenoid bone loss before October 2012 were assessed for eligibility. Patient-reported subjective data that were prospectively collected and retrospectively reviewed included demographic information, patient satisfaction, pain measured on a visual analog scale (VAS), questions regarding instability, Single Assessment Numeric Evaluation (SANE) scores, American Shoulder and Elbow Surgeons (ASES) scores, Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) scores, and Short Form–12 Physical Component Summary (SF-12 PCS) scores. Anatomic measurements were performed of the coracoid size (surface area and width), width of the conjoined tendon and subscapularis tendon, estimated glenoid defect surface area, Hill-Sachs interval (HSI), and projected postoperative glenoid track engagement. Failure was defined as the necessity for revision stabilization or continued instability (dislocation or subjective subluxation) at a minimum of 2 years postoperatively.

Results: A total of 38 shoulders in 38 patients (33 men, 5 women) with a mean age of 26 years (range, 16-43 years) were included. The mean follow-up for 35 of 38 patients (92%) was 3.2 years (range, 2.0-7.9 years); 25 of 38 had undergone prior stabilization surgery, and 6 had workers' compensation claims. All mean subjective outcome scores significantly improved ($P < .05$), with a high median satisfaction score of 9 of 10. Eight patients had failures because of continued instability. Patients with moderate or higher preoperative pain scores (VAS $\geq$3) had a negative correlation with postoperative SF-12 PCS scores ($\rho = 0.474$, $P = .022$). Patients with outside-and-engaged (Out-E) or ''off-track'' lesions were 4.0 times more likely to experience postoperative instability (relative risk, 4.0; 95% CI, 1.32-12.2; $P = .33$). The width of patients' coracoid processes was also directly associated with postoperative stability ($P = .014$). Moreover, 50% (4/8) of failures demonstrated Out-E glenoid tracks (off-track lesions) versus 16% (4/25) of those without recurrent instability ($P = .033$). Five of 8 failures were considered as such because of subjective subluxation events, not frank dislocations. Four of the 6 patients with workers' compensation claims had failed results ($P = .016$).

Conclusion: Workers' compensation claims were associated with continued instability, and patients with higher preoperative pain levels demonstrated lower SF-12 PCS scores postoperatively. The concept of the glenoid track may be predictive of stability after the Latarjet procedure and may be helpful in surgical decision making regarding the treatment of Hill-Sachs lesions at risk for persistent engagement. Although stability and patient satisfaction are high after the Latarjet procedure, subjective complaints of subluxation may be more common than previously estimated.

Keywords: Latarjet procedure; Hill-Sachs lesion; glenoid bone loss; shoulder instability; glenoid track; shoulder dislocation

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When anterior shoulder instability persists after initial surgical repair, one should evaluate glenoid and humeral bony loss in addition to the potential failure of soft tissue structures from the index stabilization procedure. The importance of identifying[6] and quantifying[§] glenoid bone loss has been demonstrated in the evaluation and treatment of patients with recurrent anterior shoulder instability. Humeral defects (Hill-Sachs lesions) and their location also may play a role in persistent glenohumeral instability.[6,32] Current surgical techniques can be divided into 4 nonmutually exclusive categories: (1) open or arthroscopic anteroinferior capsulolabral repairs with or without capsular shift, (2) anatomic versus nonanatomic bony augmentation procedures guided by the size of the glenoid and/or humeral bone deficit, (3) posterior capsulodesis and rotator cuff tenodesis procedures of the Hill-Sachs lesion (remplissage), and/or (4) partial or total prosthetic arthroplasty options for the treatment of bony defects less amenable to biological reconstruction.

Burkhart and De Beer[6] found an unacceptable high failure rate of arthroscopic repair in patients with bone defects involving greater than 25% of the glenoid face width. They emphasized the importance of identifying the defect and tailoring the surgical procedure to the known deficit. Since their initial report, increased awareness of osseous deficits of the glenoid has led to numerous reports of favorable short- to long-term outcomes after coracoid transfer procedures, including the Latarjet procedure, in patients with anteroinferior glenoid bone deficits.[1,14,15] Furthermore, because objective radiographic quantification of humeral-sided bony lesions has not been easily translated into clinical practice and the importance of these lesions has not been reproducibly demonstrated, humeral-sided Hill-Sachs lesions have largely been ignored. The importance of the medial extension of a Hill-Sachs lesion as it relates to its size, as opposed to strict quantification of the volume of a Hill-Sachs lesion, has been described by Yamamoto and colleagues[32] with the concept of the "glenoid track." The glenoid track concept estimates the likelihood of engagement between the injured glenoid and the articular contact area of the humeral head, or Hill-Sachs interval (HSI), when the arm is in an abducted and externally rotated position.[8,32]

Additionally, several authors have described anatomic variations of the coracoid among the general population[2,5,9,21] to help guide surgical decision making regarding the use of the coracoid as a local bone graft, as opposed to alternative grafting options. Combined quantification of the anatomy of the coracoid, glenoid, and Hill-Sachs lesion has also yet to be correlated with the outcomes of the Latarjet procedure. Anatomic variables such as the size of the conjoined tendon, thickness of the subscapularis tendon, size and location of the Hill-Sachs lesion, and size of the postoperative glenoid track may also be important in the success of the Latarjet procedure.

The goals of our study were 3-fold: (1) to quantify the local osseous and soft tissue anatomy of patients undergoing the Latarjet procedure relative to their bipolar bone loss, (2) to evaluate the diagnostic reproducibility and prognostic utility of these radiological measurements, and (3) to correlate preoperative patient characteristics with the outcomes of the open Latarjet procedure. We hypothesized that there are anatomic variations in the local anatomy and preoperative patient characteristics that are predictive of postoperative stability and patient-reported subjective outcomes.

METHODS

Institutional review board approval was obtained before initiation of this study.

Study Population

Patients were included in the analysis if they had undergone an open Latarjet procedure for anterior shoulder instability with glenoid bone loss between December 2005 and October 2012 by the senior surgeon (P.J.M.). Patients were excluded from the analysis if they had underlying moderate to severe glenohumeral arthrosis according to the Samilson and Prieto[26] classification or had preoperative axillary nerve palsy or brachial plexopathy. In addition, patients were excluded if they had a full-thickness rotator cuff tear or rotator cuff fatty infiltration of Goutallier grade 3 or 4.

Surgical Indications and Technique

The indications for the Latarjet procedure were persistent anterior shoulder instability with an anteroinferior glenoid osteochondral defect in which the length of the defect on the sagittal plane was greater than the radius of half the widest anteroposterior distance of a best-fit circle centered on the inferior two-thirds of the glenoid.[13] This defect size was chosen based on the work of Gerber and Nyffeler,[13] demonstrating that the force required to dislocate the shoulder is at least 30% less than an intact glenoid in a biomechanical model and unlikely to be compensated for by a soft tissue procedure alone.

All procedures were performed by the senior surgeon (P.J.M.). The technique follows the sequence described by

[§]References 3, 4, 6, 7, 13, 23-25, 29, 30, 32.

[‡]Address correspondence to Peter J. Millett, MD, MSc, Center for Outcomes-Based Orthopaedic Research, Steadman Philippon Research Institute, 181 West Meadow Drive, Suite 1000, Vail, CO 81657, USA (email: drmillett@thesteadmanclinic.com).

*Steadman Philippon Research Institute, Vail, Colorado, USA.

[†]The Steadman Clinic, Vail, Colorado, USA.

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Edwards and Walch[10] and was a modification of the technique originally described by Latarjet.[18,19] A subscapularis split was used in all cases, and the coracoid was positioned in the lying position with the inferior surface of the coracoid positioned along the glenoid neck. Two solid 3.5-mm fully threaded cortical screws were used for fixation. The capsule was closed with the arm in 30° of abduction, 30° of forward flexion, and 30° of external rotation. The capsule was repaired in a side-to-side manner with the coracoacromial ligament being used to augment the capsule. Excessive shortening of the capsule was avoided.

Postoperative Rehabilitation

Patients were allowed early passive range of motion with restrictions of 30° of external rotation progressing to full passive motion at 4 weeks and avoidance of resisted elbow flexion for 6 weeks. This was followed by strengthening at 6 weeks and progressive return to sport conditioning generally occurring at 4 to 5 months.

Prospective Data Collection

Data were prospectively collected, stored in a surgical registry, and retrospectively reviewed. Demographic and clinical data included patient sex, age, dominant shoulder, surgical history, and characteristics of injury. Data regarding concomitant injuries, ancillary treatments, and perioperative complications were also collected. In addition, American Shoulder and Elbow Surgeons (ASES) scores, Single Assessment Numeric Evaluation (SANE) scores, Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) scores, and Short Form–12 Physical Component Summary (SF-12 PCS) scores were collected preoperatively and postoperatively. At the time of final follow-up, patients were also asked several questions regarding the level of pain with various activities including sleep, recreation, activities of daily living, and work as well as specific questions regarding instability. Failure was defined strictly and broadly as continued postoperative instability at a minimum of 2 years postoperatively, and this included any patient who required revision instability surgery, reported a recurrent dislocation, or complained of even "occasional" symptoms of subjective subluxation or apprehension.

Radiographic Imaging

Anatomic characteristics were collected from preoperative cross-sectional imaging (magnetic resonance imaging [MRI] or computed tomography [CT]) of each patient. Measurements included the effective surface area (mm^2) of the transferred coracoid (Figure 1), surface area of the glenoid osteochondral defect (mm^2) using the best-fit circle method (Figure 2), ratio of the coracoid surface area:glenoid defect surface area, greatest width of the conjoined tendon[12] measured on a sagittal cut, greatest width of the subscapularis tendon[12] measured on an axial cut, and length of the HSI[8] (Figure 3). We quantified the length of the HSI, as described by Di Giacomo and colleagues,[8] as the width of the Hill-Sachs lesion plus the width of the bone bridge between the rotator cuff attachments and the lateral aspect of the Hill-Sachs lesion (Figure 3). This measures the medial extent of the Hill-Sachs defect.

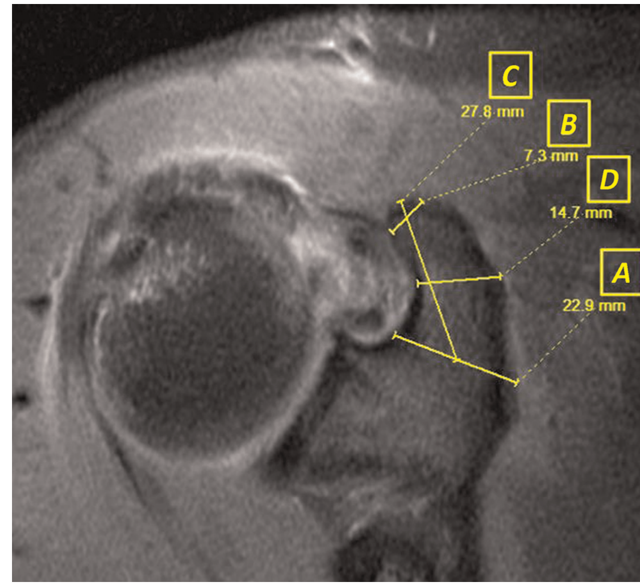

Figure 1. Measurement and calculation of the approximate dimensions and effective surface area (mm^2) of the cortical surface of the coracoid. The effective cortical surface area of the coracoid was approximated using dimensions of an idealized trapezoid: ½(*Base 1* + *Base 2*) × *Height*. The length of the base of the coracoid (base 1; *A*) was measured from the most superomedial point just anterior to the coracoclavicular ligament on the axial image that provided the greatest length. The approximate width of the tip of the coracoid (base 2; *B*) was measured in the axial image that provided the greatest cortical width on an axial cut 3 mm from the tip. The length of the coracoid (height; *C*) was measured from the midpoint of the base 1 measurement (*A*) to the furthest anterolateral extension of the coracoid surface. The maximal width of the waist of the coracoid (*D*) was measured as on the axial cut that provided the maximal length nearest to the midpoint of the longitudinal length of the coracoid.

Calculation of Glenoid Track

Using the measurements obtained above, the projected postoperative glenoid track width was approximated (Figure 4).[12] Additionally, it was determined whether each patient would be expected to have an outside-and-engaged (Out-E) or "off-track" compared with inside-and-non-engaged (In-NE)[22] or "on-track" lesion based on their underlying coracoid anatomy and amount of bipolar bone loss (Figure 5). We projected the potential for "engagement" between the humeral head and the glenoid track postoperatively by estimating the width of the anticipated glenoid track as the width of the preoperative glenoid plus the maximal width of the waist of the coracoid process and comparing that to the length of the HSI (Figure 5). If the

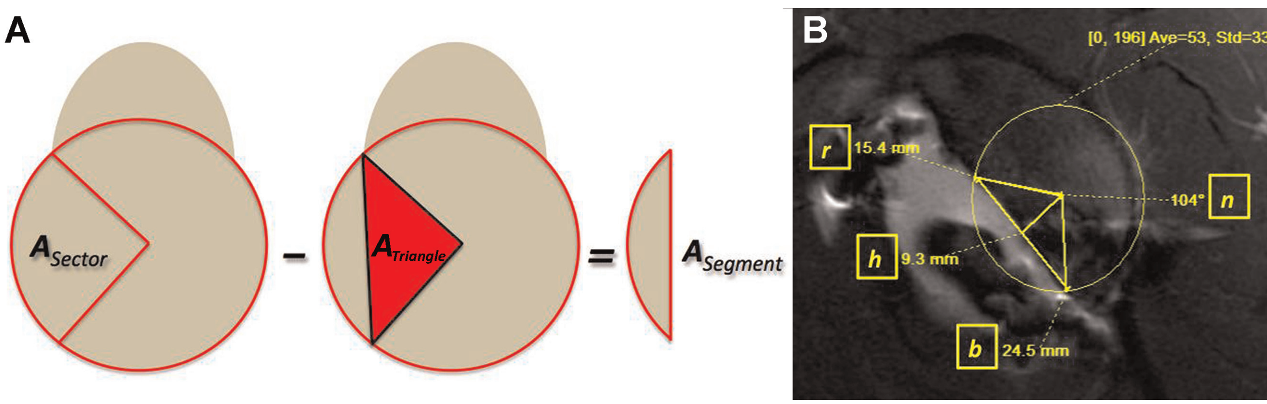

Figure 2. Measurement and calculation of the approximate surface area (mm^2) of the glenoid osteochondral defect. (A) The surface area of the glenoid osteochondral defect was approximated by calculating the area of a segment of bone loss of a best-fit circle on the inferior two-thirds of the glenoid: *Area of the segment of a circle (osteochondral defect)* = *Area of the sector of a circle* (*X*) – *Area of the triangle* (*Y*). (B) The area of the sector of the circle was estimated by measuring the number of degrees of the central angle of the sector and the radius of the sector. Area of the sector: $Y = (n/360)/\pi r^2$, where n is the number of degrees of the central angle, and r is the radius. The area of the triangle within the sector was determined by measuring the length of its base, b, and height, h, and calculating the arc of the triangle accordingly: $A_{triangle}$ = ½*base*(*height*).

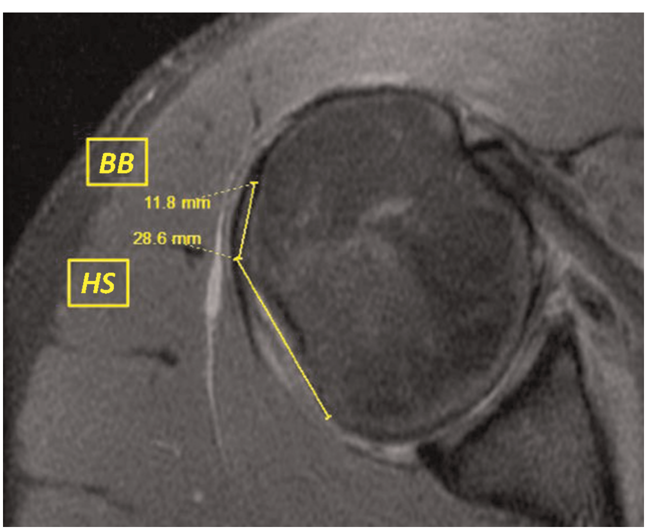

Figure 3. Measurement of the Hill-Sachs interval is the width of the Hill-Sachs lesion, *HS*, on the axial cut in which the most medial point of the *HS* is found plus the width of the bone bridge, *BB*, between the rotator cuff attachments and the lateral aspect of the Hill-Sachs lesion.[32]

projected postoperative glenoid track was greater than the HSI, we considered it as an In-NE on-track interaction (Figure 5B), and if it was less than the HSI, we considered it as an Out-E or off-track interaction (Figure 5C).[22]

Two rounds of measurements were performed by both the primary and secondary observers to determine the interrater and intrarater reliability of measurements, with the second round of measurements occurring at least 2 weeks after the initial round. Interrater reliability was based on each observer's first round of measurements, and intrarater reliability was based on measurements from the primary observer only. Intraclass correlation coefficients (ICCs) were rated as follows: <0.01, poor agreement; 0.01 to 0.20, slight agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; and 0.81 to 1.00, almost perfect agreement.[17]

Statistical Analysis

Statistical power was considered for the paired comparisons between pre- and postoperative outcome scores. Assuming an alpha of 0.05, 30 patients were sufficient to detect an effect size of d = 0.53 with 80% power. Paired Student t tests were used to test for differences between mean pre- and postoperative subjective outcome scores. Independent t tests were used to compare outcome scores between Out-E and In-NE groups, except for patient satisfaction, which was assessed with the nonparametric Mann-Whitney U test. To evaluate association between dichotomous variables, the Fisher exact test was performed and reported with the relative risk ratio (RR) and its confidence interval. Measurement reliability was assessed with the single-measure, 2-way random-effects, absolute agreement definition of the ICC. All calculations were performed using SPSS version 20 (IBM Corp).

RESULTS

Demographic Data

A total of 38 patients (38 shoulders) underwent the Latarjet procedure (Table 1) and met the inclusion criteria for this study (Figure 6). There were 33 male and 5 female patients, with a mean age of 26 years (range, 16-43 years). Twenty-five patients (66%) underwent a prior surgery on the index shoulder for instability. The dominant arm was

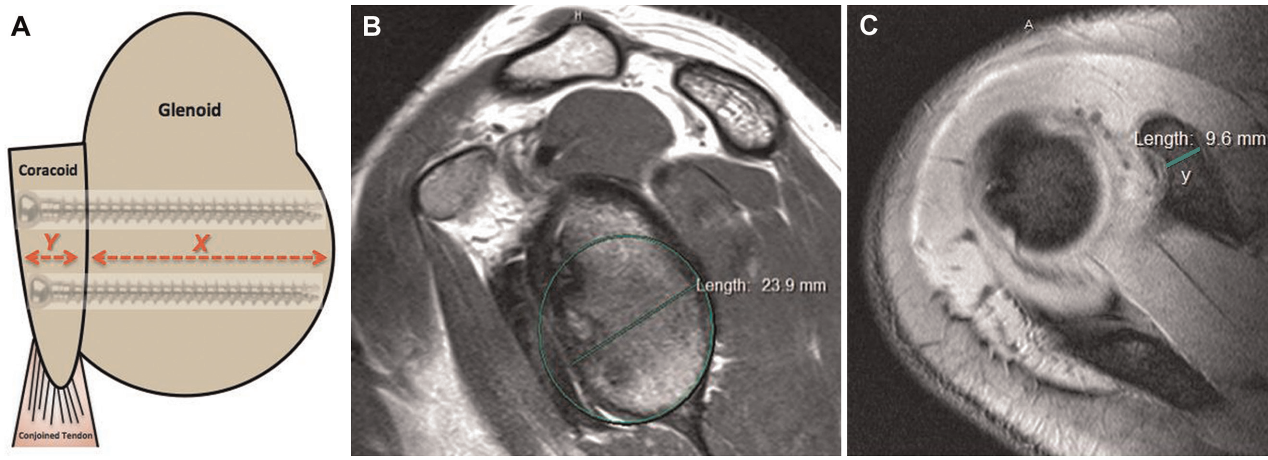

Figure 4. Projected postoperative glenoid track width. (A) The projected postoperative glenoid track width ($x + y$) was approximated by adding the width of the glenoid on the sagittal cut, demonstrating the anteroinferior articular osteochondral defect (x) by use of (B) a line that bisected the center of the best-fit circle and (C) the maximal width of the waist of the coracoid process measured axially (y).

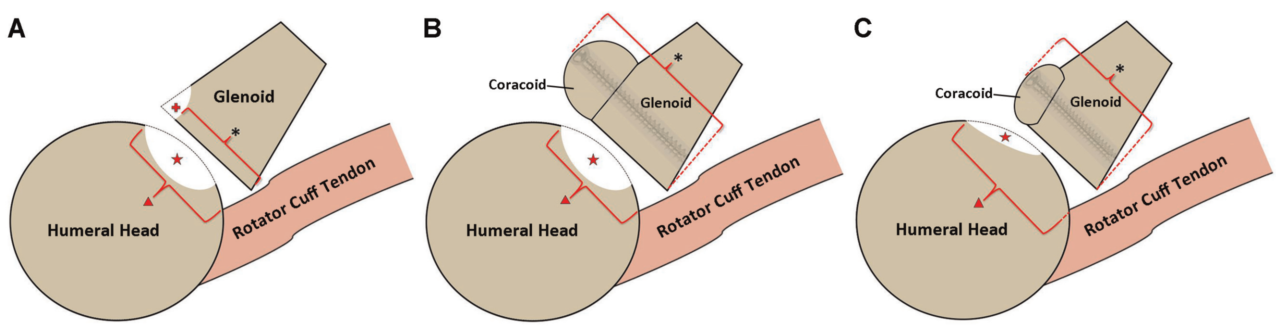

Figure 5. Determination of the potential engagement of the postoperative glenoid track and the Hill-Sachs lesion. (A) Axial representation of the preoperative location of a large Hill-Sachs lesion (star) relative to the anteroinferior glenoid osteochondral defect (cross) with the arm in an abducted and externally rotated position in which engagement occurs; therefore, the lesion is outside-and-engaged. (B) Depiction of a postoperative glenoid after coracoid transfer in which the interaction with the Hill-Sachs lesion is projected as inside-and-nonengaged, where the length of the projected postoperative glenoid track (asterisk) is greater than the Hill-Sachs interval (triangle). (C) Depiction of a postoperative glenoid after coracoid transfer in which the interaction with the Hill-Sachs lesion is projected as outside-and-engaged, where the length of the projected postoperative glenoid track (asterisk) is less than the Hill-Sachs interval (triangle).

affected in 20 of 38 patients (53%). Six patients (16%) had workers' compensation claims. The mean time from the onset of symptoms to the Latarjet procedure was 2.0 years (range, 5 days to 11.9 years), with some patients sustaining an acute injury in the setting of chronic instability and thus prompting surgery. Five patients who proceeded to secondary surgeries after the Latarjet procedure (3 revision stability procedures, 1 clavicle fracture, 1 manipulation/lysis of adhesions) were excluded from the analysis of subjective outcomes because the results may have reflected the second surgery rather than the surgery of interest. Of the remaining 33 patients eligible for follow-up, 1 patient refused to complete an outcome questionnaire but stated during his clinical evaluation at final follow-up that his shoulder was stable (as also evidenced by his ability to maintain employment as a mountain climbing guide), leaving 32 patients available for follow-up. A minimum 2-year follow-up was completed by 29 of 32 (91%) eligible patients.

Radiographic Data

Relevant preoperative 3-dimensional imaging studies (32 MRI/6 CT) were available for all 38 patients included in this study. In general, intrarater reliability was superior to interrater reliability on most measures and ranged from substantial (0.605, engagement prediction of Out-E vs In-NE) to almost perfect (0.952, coracoid surface area). Interrater reliability was more variable and ranged from poor (0.174, glenoid track width) to almost perfect (0.964, engagement prediction of Out-E vs In-NE). Radiographic approximations, statistical associations with postoperative instability (yes/no), and their repeatability are summarized in Table 2.

TABLE 1
Summary of Results by Patient[a]

Patient No.	Age and Sex	Glenoid Track Length, mm	Hill-Sachs Interval, mm	Engagement	Recurrent Instability	Follow-up, y	Further Surgery
1	36, M	30.1	26.5	In-NE	No	6.2	
2	43, M	35.6	35.1	In-NE	No	2.0	
3	36, M	31.7	19.3	In-NE	No	5.8	
4	37, M	42.1	26.2	In-NE	No	2.2	
5	26, M	36.8	26.4	In-NE	No	2.5	
6	20, M	36.9	22.0	In-NE	No	4.4	
7	33, M	34.4	29.2	In-NE	Yes	2.0	
8	34, M	38.6	31.2	In-NE	No	2.4	
9	22, M	43.8	25.7	In-NE	Yes	2.0	
10	20, M	45.2	30.5	In-NE	No	2.0	
11	30, M	37.9	33.1	In-NE	Yes	7.9	
12	24, M	41.0	27.8	In-NE	No	2.5	
13	25, M	32.8	21.9	In-NE	No	2.1	
14	27, M	36.2	22.7	In-NE	No	3.6	
15	24, M	40.6	32.6	In-NE	No	3.7	
16	18, F	24.6	22.9	In-NE	No	3.0	
17	26, M	32.9	28.7	In-NE	No	2.0	
18	20, M	37.3	26.3	In-NE	No	2.0	
19	25, M	40.5	26.5	In-NE	No	3.8	
20	16, M	41.5	29.2	In-NE	No	6.7	
21	23, F	30.4	29.7	In-NE	Yes	3.0	
22	24, F	32.1	26.9	In-NE	No	2.0	
23	19, M	49.6	24.7	In-NE	No	2.4	
24	22, M	40.8	30.0	In-NE	No	3.7	
25	18, M	40.2	36.6	In-NE	No	2.4	
26	33, M	35.5	31.4	In-NE	Unknown	None	
27	26, M	32.9	30.0	In-NE	No	None	Surgery for clavicle fracture at 5.3 y postoperatively
28	39, M	42.0	36.0	In-NE	No	None	
29	16, F	35.0	25.2	In-NE	No	3.6	
30	23, M	30.8	31.1	Out-E	No	2.4	
31	18, F	35.9	36.2	Out-E	Yes	2.0	
32	20, M	42.6	50.0	Out-E	No	2.8	
33	29, M	31.0	32.2	Out-E	Unknown	None	
34	18, M	38.4	42.0	Out-E	Unknown	None	
35	21, M	36.3	40.8	Out-E	No	None	Surgery at 316 d postoperatively for OA and adhesive capsulitis
36	22, M	33.5	37.2	Out-E	Yes	None	Revised for instability (no date given)
37	42, M	36.4	37.6	Out-E	Yes	None	Revised for instability at 77 d postoperatively
38	21, M	37.1	40.0	Out-E	Yes	None	Revised for instability at 573 d postoperatively

[a]F, female; In-NE, inside-and-nonengaged interaction; M, male; OA, osteoarthritis; Out-E, outside-and-engaged interaction.

Factors Associated With Postoperative Instability

Of 35 patients, 27 (77%) reported that they have not had symptoms of instability since surgery. Eight patients had failed results because of continued instability, 3 underwent revision instability surgeries, 5 reported self-reducing subluxations, and 1 of these patients reported occasional subluxations with activities of daily living and instability that interfered with sports participation. An analysis of radiographic measurements associated with postoperative instability indicated that patients with Out-E (4/8; 50%) bony lesions were more likely to have postoperative instability than patients with predicted In-NE (4/25; 16%) lesions (P = .033). Patients with Out-E (off-track) lesions were 4.0 times more likely to experience postoperative instability (RR, 4.0; 95% CI, 1.32-12.2; P = .033). The width of patients' coracoid processes was directly associated with postoperative stability (P = .014) (Table 2). Two of 6 (33%) patients with subjective complaints of subluxation had Out-E lesions. All 3 (100%) of those who underwent revision surgery had Out-E lesions. Twenty-one of 25 (84%) without recurrent instability had In-NE lesions.

TABLE 2
Summary of Results of Radiographic Measurements (n = 38) and Interrater and Intrarater Reliabilities[a]

	Radiographic Measurement, Mean ± SD or n (%)	*P* Value	Intrarater Reliability	Interrater Reliability
Coracoid surface area, mm^2	377.74 ± 71.8	.829	0.952	0.380
Glenoid sector area, mm^2	292.23 ± 76.5	.621	0.875	0.435
Coracoid to glenoid defect ratio	2.73 ± 1.1	.244	0.751	0.458
Conjoined tendon width, mm	8.31 ± 1.6	.352	0.859	0.962
Subscapularis width, mm	5.57 ± 1.3	.245	0.875	0.459
Hill-Sachs interval, mm	30.68 ± 6.5	.150	0.771	0.784
Glenoid width, mm	25.55 ± 4.3	.682	0.646	0.462
Coracoid width, mm	11.16 ± 1.5	**.014**	0.845	0.634
Glenoid track, mm	36.71 ± 4.9	.502	0.687	0.174
Out-E:In-NE	9 (23.7):29 (76.3)	**.033**	0.605	0.964

[a]Bolded values represent statistical significance ($P < .05$). In-NE, inside-and-nonengaged interaction; Out-E, outside-and-engaged interaction.

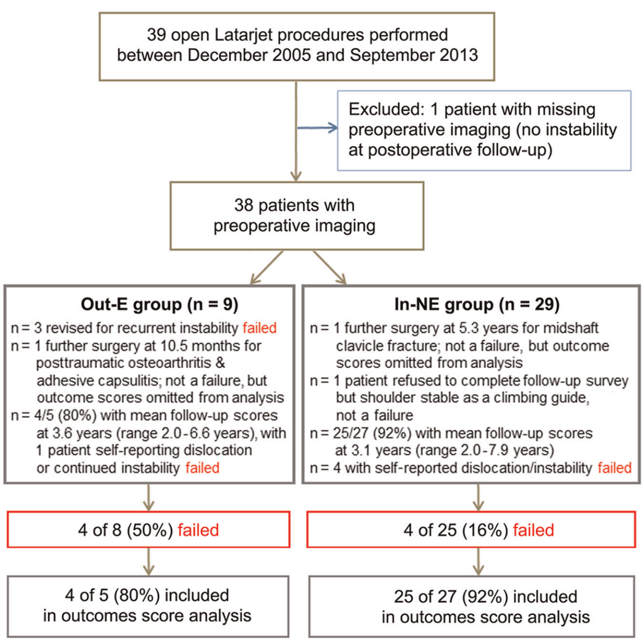

Figure 6. Diagram of patient cohort.

Of the 38 patients, 3 patients (8%) required further surgical interventions for shoulder stabilization. One patient had an iliac crest bone graft performed for nonunion of his coracoid process with failed hardware. Another patient developed coracoid nonunion, necessitating revision surgery that was performed by an outside surgeon. Debridement and soft tissue repair were performed. The rationale for not undertaking a bony procedure was not provided. A third patient indicated that he had undergone revision but did not specify the procedure. Two patients (5%) proceeded to undergo subsequent surgery on the index shoulder unrelated to recurrent instability. These procedures were (1) lysis of adhesions and chondral debridement for newly developed posttraumatic osteoarthritis and adhesive capsulitis at 10.5 months postoperatively and (2) operative fixation for a midshaft clavicle fracture at 5.3 years postoperatively. Four of 6 (67%) patients with workers' compensation claims had failure with continued instability, and patients with workers' compensation claims were significantly more likely to have postoperative instability ($P = .016$).

Analysis of Subjective Outcomes

The 5 patients who proceeded to secondary surgeries (3 revision stability procedures, 1 clavicle fracture, 1 stiffness release) were excluded from the analysis of subjective outcomes because the results may have reflected the second surgery rather than the surgery of interest. For the 33 patients remaining, a minimum 2-year subjective follow-up (mean, 3.2 years; range, 2.0-7.9 years) was completed by 29 patients (91%), with 1 stable patient refusing to complete the survey and 3 patients being lost to follow-up. All subjective outcome scores significantly improved from preoperative values (Table 3). The median score of patient-reported satisfaction with outcomes was 9 of 10 (range, 2-10). There was a negative correlation between the level of postoperative pain and patient satisfaction ($\rho = 0.711$, $P < .001$). We also found a correlation between preoperative and postoperative pain ($\rho = 0.457$, $P = .028$). Twenty-one of 26 patients (81%) who participated in sports postoperatively were able to do so at or near preinjury levels. Conjoined tendon width was correlated with the SF-12 PCS score ($\rho = 0.389$, $P < .014$). No other preoperative radiographic measurements were significantly associated with the postoperative outcome scores investigated ($P > .05$).

DISCUSSION

The most important findings of our study were that measurements of the glenoid track in the setting of the Latarjet procedure are reproducible and predictive of postoperative stability. Predictions of glenoid track engagement indicate that the native coracoid size, glenoid width, and size and location of the Hill-Sachs lesion are all important variables for surgical planning and may affect surgical outcomes. Applying the concept of the glenoid track to the preoperative assessment of these variables in patients undergoing the Latarjet procedure demonstrated that

TABLE 3
Summary of Preoperative and Postoperative Clinical Outcome Scores[a]

	Baseline Assessment	Final Follow-up	*P* Value
SF-12 PCS	46.6 (34.0-58.0)	54.7 (41.9-59.5)	**<.001**
SANE	60.3 (1.0-87.0)	87.0 (49.0-100.0)	**<.001**
ASES	70.2 (28.3-100.0)	89.2 (56.6-100.0)	**<.001**
QuickDASH	32.8 (2.2-80.0)	7.1 (0-34.0)	**<.001**
Patient satisfaction	N/A	Median: 9/10	

[a]Baseline assessment occurred at a mean of 53 days (range, 381 to 0 days) before surgery, and final follow-up occurred at a mean of 3.3 years (range, 2.0-7.9 years) after surgery. Values are reported as mean (range) unless otherwise indicated. Bolded values represent statistical significance ($P < .05$). ASES, American Shoulder and Elbow Surgeons; N/A, not applicable; QuickDASH, Quick Disabilities of the Arm, Shoulder and Hand; SANE, Single Assessment Numeric Evaluation; SF-12 PCS, Short Form–12 Physical Component Summary.

an Out-E or "off-track" relationship portended a significantly greater likelihood of continued instability. Therefore, small Hill-Sachs lesions should not necessarily be ignored in all patients undergoing the Latarjet procedure. This is especially true if the Hill-Sachs lesion is medial in nature, resulting in a large HSI, and/or if the patient has a relatively undersized coracoid process and coexisting large glenoid bone defect.

Metzger et al[22] and Di Giacomo et al[8] have independently evaluated and clinically confirmed the importance of the concept of the glenoid track in the evaluation of patients with anterior shoulder instability both arthroscopically and with preoperative imaging. Recommendations to consider bony augmentation have been endorsed by both groups of authors when it is determined that the size of the glenoid defect coupled with the size and location of the Hill-Sachs lesion results in a prediction of engagement or an off-track lesion or Out-E lesion, respectively. By extending the application of this concept to a cohort of patients undergoing the Latarjet procedure, we have demonstrated its potential utility in surgical planning in this setting. On the basis of our findings, we recommend that all 3 bony variables of potential glenoid track engagement be measured preoperatively. If engagement is predicted, the site of vulnerability should be assessed and addressed at the time of surgery. If the glenoid defect is relatively large compared with the size of the coracoid, both persistent instability and nonunion could lead to failure, and the surgeon could consider the use of an alternative bone graft option, such as an iliac crest autograft or distal tibial allograft. Conversely, if the native coracoid appropriately matches the size of the glenoid defect, but the Hill-Sachs lesion is medially located or has a large volume, a concomitant humeral-sided procedure should be considered. When the Hill-Sachs defect is deep and the HSI is small, remplissage could be considered. When the Hill-Sachs lesion is located more medially (large HSI) or is large and deep, grafting of the Hill-Sachs defect or partial prosthetic arthroplasty should be considered.

However, not all patients with a projected Out-E or off-track postoperative interaction between their humerus and glenoid had continued instability. The relative sling effect of the conjoined tendon is likely responsible for the stability in these patients. The dynamic sling effect of the conjoined tendon and the dynamic buttressing role of the subscapularis tendon are difficult to assess quantitatively using anatomic surrogate measures, and in this study, the anatomic measurements that were evaluated (width of subscapularis tendon, width of conjoined tendon, etc) were not statistically associated with stability outcomes. Therefore, preoperative static measurements of tendon widths are unlikely helpful in predicting their influence on dynamic postoperative stability in this capacity.

We also attempted to quantify the surface area of the glenoid osteochondral defect using a best-fit circle technique and a simple geometric calculation of the area of the missing segment of the circle (Figure 2). We also estimated the surface area of the coracoid that would replace the glenoid defect using a calculation of the surface area of an idealized trapezoid (Figure 1). We correlated the ratio of these 2 surface area values with patient-reported outcome scores and postoperative stability; however, no statistical relationships were demonstrated. This could ultimately be explained by an overwhelming dynamic sling effect of the conjoined tendon. Additionally, our measurements of the amount of bone loss were less repeatable than our other radiographic measurements. The lower repeatability with these measurements between observers could also partially account for our lack of statistical correlation. Although the interobserver and intraobserver reliabilities of the ratio of the coracoid size to glenoid bone loss were moderate and substantial, respectively, the reliability of our measurements were similar to those of e Souza et al[11] for intrarater reliability of 0.751 compared with their 0.80 utilizing a best-fit circle method for approximation but inferior in our interrater reliability of 0.458 compared with their 0.82.

Finally, with all mean subjective clinical outcomes statistically improving and a high median patient satisfaction score of 9 of 10, we have demonstrated that the Latarjet procedure is a reliable option for the treatment of anterior shoulder instability in patients with anteroinferior glenohumeral bone loss. Our failure rate due to continued instability is higher than that in previously reported series at 8 of 35 patients (23%), although unlike most previous studies, patients with subjective symptoms of subluxation (5/35; 14%) were deemed to have failures in our series. Four of 6 patients with active workers' compensation claims reported subjective subluxations; therefore, secondary gain issues may also have played a role in the subjective complaints of these patients.

Nonetheless, subjective complaints of at least occasional subluxations may be more common than previously estimated. If these patients with subjective complaints of instability were not classified as having failures and we used revision instability surgery as our threshold for failure, then our failure rate would be 9% (3/35), which compares favorably with rates in the previous series of Hovelius et al[14] reporting 3% with redislocations and 13% with residual instability, Allain et al[1] reporting no redislocations but 12% with apprehension, and Schmid and associates[27] reporting 4% with redislocations and 10% with unspecified shoulder complaints. We did find a significant correlation between preoperative and postoperative pain, which confirms previous work conducted by Schmid et al.[27]

Limitations

Our study has several notable limitations. Our proposed method of calculating the surface area of a glenoid bone defect, as well as the effective size of the coracoid process, necessitates multiple measurements of length approximating the lateral articulating surfaces. There is often obliquity to the imaging cuts relative to the desired plane of measurement, which is more exaggerated in all standard imaging planes relative to the coracoid versus the glenoid face. The reasons for the relative increased image plane obliquity for the coracoid are its curved shape, the trajectory from superomedial to inferolateral, and the convention of creating image sequences based on the scapular body axis. We acknowledge that 3-dimensional image reconstructions are likely the most accurate means to describe the pathoanatomy of the shoulder for surgical planning. However, the described technique was developed to most accurately approximate the anatomy utilizing imaging sequences most readily available to the practicing orthopaedic surgeon.

Moreover, in the case of the glenoid, angle measurements after the placement of a manually placed best-fit circle were used to determine the surface area of glenoid bone loss. This resulted in decreased levels of interobserver and intraobserver reliability of these values. Additionally, while our observers were blinded to one another's measurements and results of the study, the measurements were conducted retrospectively and suffer from biases inherent to this type of analysis. Therefore, our final results regarding the bony anatomy of the coracoid relative to bone loss of the glenoid should be interpreted with some caution. Our results may be confounded by the small differences in measurements of both soft tissue and osseous structures because of the mix of both preoperative CT and MRI modalities available for measurement. It would be preferable to eliminate this variability in future studies by utilizing one imaging modality for estimating the bony anatomy, preferably CT with 3-dimensional reconstructions, and the implementation of software to calculate bone loss, thereby obviating the need for manual measurements and the placement of a best-fit circle. Each additional length and angle measurement that we performed introduced an additional source of human error and is likely accountable for the decreased repeatability of our measurements that relied initially on a best-fit circle. With regard to the evaluation of pathoanatomy necessitating the measurement of both osseous and soft tissue structures, such as the HSI, the literature is lacking in evidence to support the best imaging modality. MRI may be more appropriate than CT to determine the HSI as it allows for better definition of the rotator cuff insertion site compared with CT, but further studies of this are indicated.[28]

Our measurements are based primarily on preoperative MRI. Although excellent intraclass and interclass coefficients have been demonstrated between MRI estimates of bone loss and arthroscopic findings by some authors,[11,16,20] CT with 3-dimensional reconstructions are generally considered the gold standard for quantifying bone loss of the shoulder. Nonetheless, any method that relies on the manual placement of a best-fit circle by an examiner may be plagued with issues of repeatability even if CT is utilized. Subtle differences in circle drawing can cause considerable discrepancies in area values, the inferior two-thirds of the glenoid is not always completely circular in shape, and musculoskeletal radiologists may be more apt to reproducibly estimate bone loss.[11,14,31] Finally, validation of our proposed measurements by correlating intraoperative findings will be critical to future studies.

CONCLUSION

Although the Latarjet procedure reliably improves patient-reported functional outcomes and leads to high levels of patient satisfaction, subjective complaints of subluxation may be more common than previously estimated. Workers' compensation claims were associated with continued instability, and patients with higher preoperative pain levels demonstrated lower SF-12 PCS scores postoperatively. The concept of the glenoid track is likely predictive of stability after the Latarjet procedure and may be helpful in surgical decision making regarding the treatment of Hill-Sachs lesions at risk for persistent engagement. Prospective evaluation, validation, and correlation with intraoperative findings of the proposed measurements of bipolar glenohumeral bone loss encountered with anterior shoulder instability will be an important next step in the study of this challenging clinical problem.

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