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Posterior Shoulder Instability

Surgical Outcomes and Risk of Failure in Adolescence

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Background: Arthroscopic capsulolabral reconstruction has proven to be effective in treating posterior shoulder instability. Few studies have examined the risk factors that may contribute to poor outcomes in the adolescent population.

Purpose: To identify risk factors for surgical failure by comparing anatomic and subjective variations in children who underwent surgical intervention for posterior shoulder instability.

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

Methods: All patients undergoing arthroscopic shoulder surgery at one institution between 2011 and 2018 were reviewed. Patients >18 years old at presentation and those with Ehlers-Danlos syndrome were excluded. Posterior instability was defined as unidirectional subluxation on posterior drawer testing while under anesthesia. Two-year minimum follow-up was required, but those whose treatment failed earlier were included for calculation purposes. Demographics and intraoperative findings were recorded, as were Single Assessment Numeric Evaluation (SANE) scoring, Pediatric and Adolescent Shoulder Survey (PASS), and the short version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH) results. Major complication was defined as revision arthroscopy or redislocation, and minor complications included self-reporting a poor outcome score (eg, SANE score <65).

Results: A total of 48 children (23 girls and 25 boys) met criteria, with a mean age of 16.5 years (range, 12.4-17.9 years) and a mean follow-up of 3.75 years. Fifteen (31.3%) patients had a complication by our criteria, including 12.5% with surgical failures; regarding major complications, boys were treated successfully 96% of the time and girls 78% of the time ($P = .049$). Of the anatomic and subjective variables tested, only younger age ($P \leq .001$) and presentation type ($P < .05$) were correlated with complications. SANE scores differed significantly ($P < .002$) by presentation type, with mean scores of 52 (trauma), 94 (recurrent instability), and 81 (pain). QuickDASH scores demonstrated patients with a history of trauma (mean, 37), instability (mean, 9), and pain (mean, 11).

Conclusion: Adolescents treated surgically for posterior shoulder instability are at risk of treatment failure (when including outcome scores), and it appears that patients of female sex, younger age, and traumatic presentation are at the highest risk to require revision surgery or experience continued limitations secondary to their shoulder.

Keywords: posterior shoulder; instability; glenoid labrum; pediatric

Posterior shoulder instability accounts for approximately 2% to 5% of all shoulder instabilities in the general population.[12,15,16] However, recent studies on collegiate athletes and young military populations suggest a prevalence closer to 10% and rising, indicating that young athletes may be at a specific risk for developing posterior instability.[16,17,23]

Current literature reports that glenoid retroversion, repetitive sports trauma, seizures, and traumatic injury place adult individuals at risk for developing posterior shoulder instability (PSI).[24] Moreover, glenoid retroversion has been shown to be a specific risk factor for PSI development in young active adults.[16] However, the literature is limited in how these risk factors and others translate into surgical treatment outcomes, specifically after arthroscopic capsulolabral reconstruction, once PSI has developed.

In the past, surgical outcome studies for PSI have focused primarily on objective metrics: glenoid retroversion

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and surgical technique.[3,7,8,12,13,19] While these are important and have yielded consistent results within the adult population, the fixation on the 2 has left other important instability measurements, risk factors, and patient populations largely neglected. For instance, capsular laxity or capaciousness is a common arthroscopic and radiologic finding in PSI, yet no current study has quantified the degree of labral capsular capaciousness in its relation to surgical outcome for PSI. Furthermore, only select studies have evaluated subjective variables, such as sports or clinical presentation (traumatic, recurrent instability, and pain), in the context of PSI surgical failure, and even fewer studies have evaluated PSI by any means in the particularly vulnerable active adolescent population.[2,4,11,14] Only 1 previous study has evaluated a purely adolescent cohort with unidirectional PSI, although with a small sample size (22 patients) that was almost exclusively male.[25] Therefore, the purpose of this study was to identify (1) outcomes in boys and girls with PSI who underwent posterior capsulolabral reconstruction and (2) risk factors for surgical failure by comparing anatomic and subjective variations. Our hypothesis was that girls would have different outcomes from their male counterparts.

METHODS

Patient Selection

After institutional review board approval was obtained, a retrospective review was performed on all children treated surgically for PSI at our institution between 2011 and 2018. Surgery was indicated for children with symptoms consistent with posterior instability and failure to improve after 6 weeks of physical therapy. An initial hospital database search with Current Procedural Terminology code 29806 was performed. Posterior instability was defined for inclusion via the operative report specifically stating that the child demonstrated unidirectional subluxation on posterior drawer testing while under anesthesia (defined as motion greater than 1 quadrant of the humerus riding onto the posterior glenoid rim). Patients who demonstrated concomitant and significant anterior instability were excluded, but inferior subluxation (sulcus testing) was not an exclusion criterion, as surgery involved posteroinferior capsule plication. Two-year minimum follow-up was required, yet those whose treatment failed before that time point (subsequent dislocation or revision surgery for same problem) were included for calculation purposes. Further exclusion criteria were applied, including age >18 years, presence of confirmed Ehlers-Danlos syndrome, and surgical intervention at a different facility before presentation at our institution.

Chart Review

Charts were reviewed and coded for initial clinical presentation and sports participation to capture the heterogeneity of PSI. Patients' initial orthopaedic evaluations were coded as traumatic presentation, recurrent instability presentation, or pain-only presentation. Traumatic presentation was defined as patients presenting with pain after a recalled or emergent traumatic event. Trauma encompassed fall, contact sports injury, and motor vehicle accident. Patients in this category often had a known dislocation event that continued to elicit pain but without recurrent dislocation or subluxation. Recurrent instability presentation was defined as patients presenting with primary complaints of repeated subluxation, popping, or clicking with or without a previous injury regardless of any complaint of pain at the clinic visit. Pain-only presentation included patients who could not recall a specific pain-eliciting injury but nonetheless experienced shoulder pain without self-recognized subluxation events. Sports participation was grouped as noted in Table 1.

TABLE 1
Patient Characteristics

Mean age, y	16.5
Mean follow-up, mo	45
Injury side, n	
Left	17
Right	31
Sex, n	
Male	25
Female	23
Sport, n	
Football/rugby	13
All others[a]	33

[a]Gymnastics, soccer, horseback riding, and skateboarding, baseball, volleyball, etc.

Operative report review focused on arthroscopic pathology and physical examination, such as drawer testing and range of motion. Arthroscopic variables were noted in the anterior and posterior planes and included discrete labral tears and capsular capaciousness. Specific pathologies included extent of posterior labral tearing, anterior labral injury/fraying, posterior glenolabral articular disruption (GLAD) lesion, and partial rotator cuff injuries (PASTA type [partial articular supraspinatus tendon avulsion]) of the supraspinatus, infraspinatus, or subscapularis tendons. The number of surgical anchors placed was also recorded.

Outcome measures consisted of Single Assessment Numeric Evaluation (SANE), Pediatric and Adolescent Shoulder Survey (PASS), and the short version of Disabilities of the Arm, Shoulder and Hand (QuickDASH). At final follow-up, patients were asked about their self-perceived effort in physical therapy, on a scale of 1 to 5 (5 being the most effort). Moreover, to limit response bias, an independent observer other than the surgeon questioned patients directly if they believed that their shoulder had dislocated since their surgery.

Cohort stratification of outcomes into major, minor, and no adverse events was then performed. The cohort with major adverse events was defined as patients who had noted surgical failure confirmed by the surgeon or reported a subsequent dislocation event in independent interview. The cohort with minor adverse events was defined as reporting a SANE score <65 or the most extreme score on PASS question 1 (related to pain) or QuickDASH

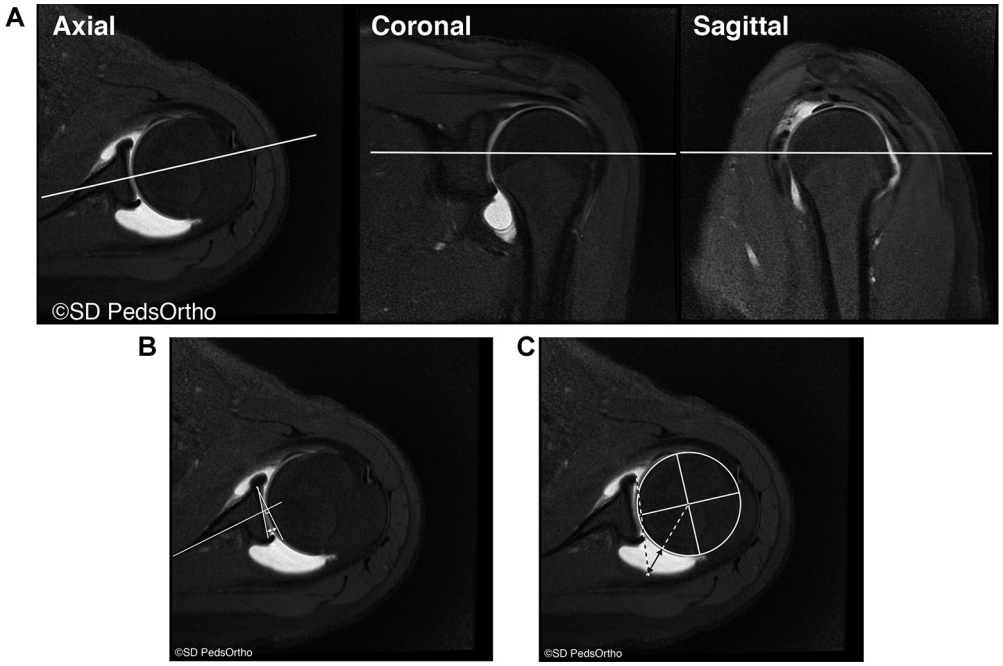

Figure 1. Magnetic resonance arthrogram measurements. A: Left shoulder magnetic resonance imaging with arthrogram demonstrates the positioning of the gantry line, representing the center of the humeral head in the axial, coronal, and sagittal planes. B: An example of the glenoid retroversion measurement captures the Friedman line along the scapular edge and the posterior angle of the glenoid, measured as the deviation from 90°. C: An example of the capaciousness measurement, with the center of the humeral head in the axial plane as a guide line to the posterior capsular edge.

questions 9 and 10 (related to pain and sensation). These values were elected to represent symptoms related to posterior labral pathology, owing to their known association with pain.

Radiographic Measurements

Magnetic resonance arthrograms performed preoperatively were examined in the picture archiving and communication system (PACS) by a trained reviewer to calculate glenoid version and quantify posterior capsular capaciousness. Axial T1 fat saturation (FS), coronal T1 FS, and sagittal T1 FS image planes were arranged split-screen to facilitate the positioning of the gantry line in the center of the humeral head across all 3 planes. The axial image was then scrolled to estimate the centermost cross section of the glenoid to ensure that the largest amount of the glenoid was visualized. Measurements were calculated in this position from the axial plane (Figure 1A).

Glenoid retroversion was calculated with the original 2-dimensional techniques of Friedman et al[9] and Saupe et al.[20] The original technique is detailed for computed tomography; however, Parada et al[18] adopted the technique for magnetic resonance images, yielding consistent results. With the Cobb angle feature, a reference line was placed through the anterior and posterior rim of the glenoid. A second reference line, known as the Friedman line, was then drawn from the middle of the glenoid to the medial rim of the scapular blade to represent the plane of the scapular body. If the scapula was not visualized in its entirety, a best-fit line was placed with the uttermost medial edge as a guide. The glenoid version angle was calculated from this intersection in the posterior direction (Figure 1B). Angles were reported as whole numbers, with retroversion recorded as a positive number (the amount deviated from 90°).

Quantifying the posterior capsular capaciousness was performed on the same images as the glenoid retroversion measurements and was developed by the authors to maintain consistency across patients, impart reproducibility, and best represent the pathology being evaluated. Gadolinium dye volume was recorded, most often 5 mL diluted appropriately for height and weight. With the ruler tool, 2 lines were drawn perpendicular in the axial plane, so their intersection marked the center of the humeral head. A third line was drawn from the labral tips to the outermost posterior capsular edge, as enhanced by T1 FS imaging. A fourth line was then placed intersecting the center of the glenoid and the new third line along the capsular edge. A measurement was taken from the capsular-edge intersection to the humeral head (Figure 1C). Results were recorded in millimeters, and the width was noted as posterior capaciousness. Patients with no capsular enhancement on magnetic resonance arthrogram were recorded as 0-mm posterior capaciousness.

Statistical Analysis

All continuous, normally distributed data were compared among outcome groups with analysis of variance, with means reported. For interval but noncontinuous data

TABLE 2
Operative/Clinical Variables and Outcome Results[a]

	Adverse Events				
	Major	Minor	None	Total	*P* Value
Glenoid retroversion, deg	5.95	4.10[b]	10.87	8.89	.006
Axial posterior capaciousness, mm	5.33	4.15	5.22	5.03	.656
PASTA lesion, n	4	3	10	17	.228
Initial contact age, y	15.3[b]	15.9	16.9	16.5	.001
Mean No. of anchors	2.33	2.56	2.72	2.64	.584
Mean SANE score at 36 mo	80.00	47.78[b]	86.85	78.58	.001
Mean PASS score	61.00[b]	58.56[b]	86.59	79.28	.001
Mean QuickDASH	29.55[b]	39.90[b]	9.09	17.15	.001
Mean postoperative months	32.33	44.44	47.48	45.02	.12
Sex, n					
Male	1[b]	3	21	25	.049
Female	5	6	12	23	
Presentation, n					
Traumatic	1	9[b]	1	11	<.01
Pain only	1	0	16	17	
Recurrent instability	4	0	16	20	
Sport					
Football or rugby	2	5	6	13	.1
All others[c]	4	4	25	33	

[a]Statistical analysis of the operative data related to surgical outcome. PASS, Pediatric and Adolescent Shoulder Survey; PASTA, partial articular supraspinatus tendon avulsion; QuickDASH, Short version of Disabilities of the Arm, Shoulder and Hand; SANE, Single Assessment Numeric Evaluation.
[b]$P < .05$ vs no complication.
[c]Gymnastics, soccer, horseback riding, skateboarding, baseball, and volleyball, etc.

(ie, self-reported effort in physical examination), the nonparametric Kruskal-Wallis test was utilized. Categorical data were compared among the outcome groups with the chi-square test. Alpha was set at $P < .05$ to declare significance, and SPSS (v 25; IBM Corp) was used for all analyses.

RESULTS

Of the 89 patients who met criteria for posterior instability, 54% (23 girls and 25 boys) completed follow-up questionnaires, with a mean age of 16.5 years (range, 12.4-17.9 years) at surgery and a mean follow-up of 3.75 years (range, 1.25-6.4 years), including patients with failed surgery before 2-year follow-up. None of the patients had a known history of seizure disorder. The clinical presentation of posterior shoulder instability included 11 patients with acute trauma, 20 with recurrent instability, and 17 with apparent atraumatic pain. Patients with a history of trauma had significantly worse PASS (mean, 60%) and QuickDASH scores (mean, 37) than the instability cohort (mean, 9; 89%) and pain cohort (mean, 11; 82%) ($P < .05$). Mean SANE scores were significantly different among the 3 presentation cohorts (traumatic, 52; recurrent instability, 94; pain, 81; $P < .002$). All variables noted are summarized in Table 2.

The overall failure rate in our cohort was 12.5%. Six patients (12.5%) met criteria for the major adverse event (all underwent a revision arthroscopy); 9 (18.8%) met criteria for the minor adverse event (all scored <65 on the SANE); and 33 (68.8%) experienced no adverse event. Comparisons of the presentation cohorts (traumatic, recurrent instability, and pain only) yielded significant differences in outcome scores or complication rates ($P < .05$). Of the 11 patients with a history of trauma, 9 (82%) had a minor complication, as opposed to 0% of patients with instability (0 of 20) or pain only upon presentation (0 of 17). Of the patients who had recurrent instability, 20% (4 of 20) had major complications, as compared with 6% (1 of 17) who had pain and 9% (1 of 11) with a history of trauma ($P < .001$).

Of these 48 patients, 38 had magnetic resonance arthrograms compatible with the PACS to complete radiographic measurements of glenoid version and posterior capaciousness. All 48 patients had an MRI capable of determining the following associated pathology: 6.25% with anterior labral fraying, 10% with posterior GLAD lesions, 43.8% with posterior labral tears, 45.8% with posterior capacious capsule, and 35% with partial rotator cuff tendon tears.

The degree of glenoid retroversion was actually significantly larger in the no-complication group (mean, 11; range, 2.2-18.2) as compared with the minor complication group (mean, 4; range, 0-9.4; $P = .006$). There was no significant difference between the major complication group (mean, 6; range, 0.6-13.9) and the no-complication group ($P = .21$) or minor complication group ($P = .99$). However, 37 of 38 patients demonstrated some degree of glenoid retroversion overall. Posterior capaciousness measurements did not

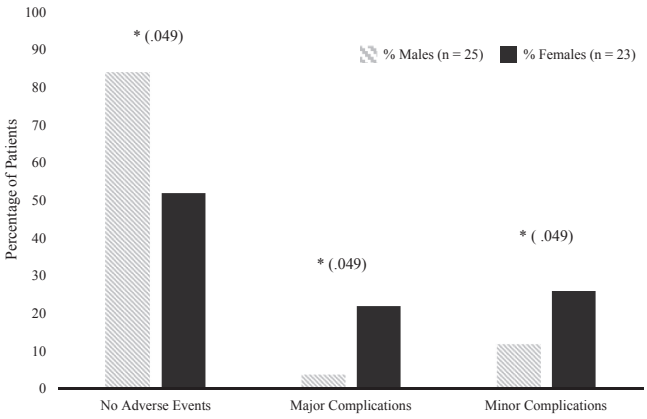

Figure 2. Sex stratification of surgical outcomes for posterior shoulder instability. *$P < .05$. Females have a significantly higher incidence of major and minor complications in regard to surgical intervention for posterior shoulder instability.

yield significant differences among outcome cohorts: major complication (mean, 5 mm), minor complication (mean, 4 mm), and no complications (mean, 5 mm; $P = .66$). There are no known measures of normal capsule distention in the literature. Similarly, anchor count, posterior GLAD lesions, presence of anterior labrum fraying, partial rotator cuff tendon tears, and discrete posterior labral tears did not correlate with surgical outcome (all P values $>.05$).

Patient age was significantly correlated with risk of complications after surgery for PSI ($P \leq .001$). Specifically, patients in the major and minor complication cohorts were significantly younger at presentation (mean, 15.5 years) than those in the no-complication cohort (mean, 16.9 years). There was no significant difference between the major and minor complication cohorts ($P = .59$). Sex also appears to play a role in the ultimate outcome: 5 of the 6 major complications occurred in girls, as did 6 of the 9 minor complications ($P = .049$). Of the 23 females in the study, 52% had no complications, as compared with 84% of males ($P = .049$) (Figure 2).

The failures in the major complication cohort occurred at a mean 32 postoperative months, but the findings of the minor complication group (poor outcome scores) were recorded at a mean postoperative 44 months ($P = .12$). However, the early SANE scores recorded at postoperative 3 to 6 months did not correlate significantly with the patients' long-term outcome scores ($P = .42$). Self-reported effort in physical therapy did not yield significant results: the median score of effort was 4 in the no-complication group, 4.5 in the minor complication group, and 4 in the major complication group ($P = .79$). The specific sport that patients played (or returned to play) did not yield any significant differences in outcomes ($P = .1$).

DISCUSSION

The incidence of PSI in the pediatric/adolescent population has been discovered to be more common than previously thought, but the knowledge regarding this population is limited.[22] There is ample evidence that surgical stabilization can be beneficial in this pathology type for adult patients.[5,11] Wooten et al[25] suggested that adolescents with traumatic PSI reported higher American Shoulder and Elbow Surgeons scores postoperatively than those with atraumatic PSI, but previous work has not fully evaluated the variables that can determine success in this younger age group. We found that sex and age played a significant role in outcomes rather than associated pathology, sports, or anatomic measures.

The clinical presentation of PSI is heterogeneous, ranging from acute trauma and recurrent instability to apparent atraumatic pain. Historically, the literature has classified these various subgroups in many ways: voluntary and involuntary, inherent and acquired, traumatic and atraumatic. Furthermore, this clinical variation is in part supported by an equally heterogeneous set of anatomic pathology in PSI, at least in cohorts that ranged in age from adolescents to seventh decade of life. Bahk et al[3] reported rates of 100% posterior labral lesions, 17% reverse Hill-Sachs lesions, 41% posterior glenoid/cartilage lesions, and 10% partial articular supraspinatus pathology among their patients with posterior instability. Savoie et al[21] reported that 51% of patients had a posterior labral lesion, 67% had a stretched posterior capsule, and 16% had a combination of the 2, arguing that there is no essential lesion to describe all variants of PSI. Furthermore, Antoniou[1] observed articular defects in 83% of 41 patients with traumatic PSI. Our pure pediatric/adolescent cohort demonstrated similar variation in associated pathology: 6.25% with anterior labral fraying, 10% with posterior GLAD lesions, 43.8% with posterior labral tears, 45.8% with posterior capacious capsule, and 35% with partial rotator cuff tendon tears.

Unfortunately, the literature is somewhat limited in its discussion of surgical outcomes as it relates to the minutia of this heterogeneity. Most reports examine surgical outcome as a function of surgical technique as opposed to specific pathology or presentation, often limiting the study group to traumatic presentation. Savoie et al[21] reported 2 of 92 arthroscopic capsulolabral repair failures amid their heterogeneous adult study group but did not infer a significant relationship between the failures. However, they did note that none of the 8 patients who underwent combined capsule plication and labral repair failed in their cohort. Similarly, Bradley et al[6] noted a low rate of surgical failures in their large heterogeneous cohort, 13 of 200. Bahk et al[3] reported that patients who underwent additional procedures, such as an anterior plication or reverse humeral avulsion of the glenohumeral ligament (RHAGL) repair and posterior capsulolabral repair, reported higher pain and instability scores at mean follow-ups of 5.5 years, as did patients <30 years old as compared with those >30 years old.

The only previous study of a predominately adolescent male cohort found that stability could be maintained in 92% at 2-year minimum follow-up when the sole pathology was isolated posterior labral tearing, which is very similar to the adult population–based studies discussed.[25] However, in our broader evaluation, adolescents as a group

demonstrated that, at almost 4 years after surgery, 87.5% had no further instability or required no further surgery and 68.8% were effectively happy with their outcomes based on patient-derived questionnaires and the lack of major complications.

Yet, if we focus on the male cohort of our sample, similar to the previous literature, then we see the same results, with a redislocation or revision surgery rate of only 4%. Therefore, girls had a significantly higher rate of major failure, with 78% successfully keeping the shoulder reduced after 2 years. Moreover, when we combine the outcomes of major and minor complications as previously defined, we see that boys were happy with their outcomes 84% of the time, as compared with girls at 52% of the time. This is a previously unreported outcome related to failure in this pathology type, predominately because females appear to sustain this injury pattern less frequently.

The role that age plays in the outcomes of posterior instability has been evaluated in previous cohorts of predominately adult patients. Bahk and colleagues[3] attributed these differences in outcomes to the athletically demanding nature of patients <30 years old. We also identified a difference in outcomes based on age, with the younger patients demonstrating worse outcomes. However, the mean age of our entire cohort at final follow-up was 19.8 years. Follow-up beyond a mean 3.7 years could yield even further disheartening results as patients remain active in their 20s, or perhaps the opposite would happen as they become more sedentary. Future research is needed to better evaluate the long-term outcomes. However, on the basis of our results, it is important to note that the adolescents in the major complication cohort had the overall shortest postoperative duration to discovery of surgical failure. This implies that if they can make it past 2 years without complication, then they are more likely to continue to experience positive postoperative results.

All of the patients in our cohort participated in sports of some type, consistent with current literature suggesting that active patients may be at a specific risk for the development of PSI. However, unlike previous authors, we did not see a difference in outcomes related to contact or noncontact sport participation during injury or return to these activities.

Interestingly, a higher degree of glenoid retroversion was correlated with a lower rate of surgical failure in our cohort. To our knowledge, only 1 study has examined the degree of retroversion as it relates to surgical outcome within a PSI cohort, and it yielded contradictory results in an adult population of 32 patients, with greater retroversion correlating with higher risk of failure.[11] Further complicating this analysis, in a cadaveric computed tomography study in 2018, Griffin et al[10] suggested that glenoid bone loss alters glenoid version in a meaningful way, calling for corrective measurements for every 5% of bone loss. Neither our study nor the adult study by Katthagen and colleagues[11] accounted for this observation by Griffin et al. However, it is worth noting that nearly all patients in the present study, 37 of 38, demonstrated some degree of glenoid retroversion, suggesting that, although it is unclear whether the degree of glenoid retroversion is a prognostic factor for PSI, it does agree with current literature in that glenoid retroversion may be a significant diagnostic factor for PSI.

The limitations of our study relate to the retrospective nature of the study design. Yet, we still had a mean of almost 4 years of outcomes to evaluate and compare for prognostic factors. Moreover, we were unable to evaluate all magnetic resonance images because they were not all compatible with our PACS (being created at outside institutions), and we attempted to develop a reproducible and standardized way to measure posterior capacious capsule on magnetic resonance imaging. There is a risk that this measurement was too dependent on the amount of contrast injected into the shoulders and that it does not accurately quantify the capsule looseness in the proposed objective manner. In addition, our follow-up rate of 54% represents a selection bias to the outcomes and failure rate reported.

The clinical and anatomic presentation of PSI is heterogeneous, and the story does not necessarily guide the outcome of patients treated surgically. The amount of posterior glenoid version and its role in surgical failure warrant further research.

CONCLUSION

Adolescents surgically treated for PSI appear to be at greater risk to score significantly worse on outcome scores (SANE, PASS, and QuickDASH) when they develop a subsequent failure, which occurs in 12.5% of patients. The patients without complications scored significantly better than those with major or minor complications and resumed normal activity levels. As such, it is important to counsel families and younger girls undergoing posterior capsulolabral reconstruction that their success may be limited over time and that they have a higher rate of revision surgery than older patients or their male counterparts.

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