Original Research

Clinical Outcomes, Survivorship, and Return to Sport After Arthroscopic Capsular Repair With Suture Anchors for Adolescent Multidirectional Shoulder Instability

Results at 6-Year Follow-up

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Background: Multidirectional shoulder instability (MDI) refractory to rehabilitation can be treated with arthroscopic capsulolabral reconstruction with suture anchors. To the best of our knowledge, no studies have reported on outcomes or examined the risk factors that contribute to poor outcomes in adolescent athletes.

Purpose: To identify risk factors for surgical failure by comparing anatomic, clinical, and demographic variables in adolescents who underwent intervention for MDI.

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

Methods: All patients 20 years or younger who underwent arthroscopic shoulder surgery at a single institution between January 2009 and April 2017 were evaluated. MDI was defined by positive drive-through sign on arthroscopy plus positive sulcus sign and/or multidirectional laxity on anterior and posterior drawer tests while under anesthesia. A 2-year minimum follow-up was required, but those whose treatment failed earlier were also included. Demographic characteristics and intraoperative findings were recorded, as were scores on the Single Assessment Numeric Evaluation (SANE), Pediatric and Adolescent Shoulder Survey (PASS), and short version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH).

Results: Overall, 42 adolescents (50 shoulders; 31 female, 19 male) were identified as having undergone surgical treatment for MDI with minimum 2-year follow-up or failure. The mean follow-up period was 6.3 years (range, 2.8-10.2 years). Surgical failure, defined as recurrence of subluxation and instability, was noted in 13 (26.0%) shoulders; all underwent reoperation at a mean of 1.9 years (range, 0.8-3.2 years). None of the anatomic, clinical, or demographic variables tested, or the presence of generalized ligamentous laxity, was associated with subjective outcomes or reoperation. Number of anchors used was not different between shoulders that failed and those that did not fail. Patients reported a mean SANE score of 83.3, PASS score of 85.0, and QuickDASH score of 6.8. Return to prior level of sport occurred in 56% of patients.

Conclusion: Adolescent MDI refractory to nonsurgical management appeared to have long-term outcomes after surgical intervention that were comparable with outcomes of adolescent patients with unidirectional instability. In patients who experienced failure of capsulorrhaphy, results showed that failure most likely occurred within 3 years of the index surgical treatment.

Keywords: posterior shoulder; anterior shoulder; multidirectional instability; glenoid labrum; pediatric and adolescent

Multidirectional shoulder instability (MDI) is a complex shoulder disorder that can be challenging to diagnose, manage, and treat. Diagnosis is classically based on the description published by Neer and Foster[22] in 1980, who described the problem as a shoulder that dislocates in at least 2 directions. However, patients with MDI can have various and sometimes nonspecific symptoms ranging from nonfocal shoulder pain to daily, recurrent shoulder dislocations.[7] On clinical examination, MDI can be identified with a combination of positive sulcus sign and laxity on anterior and posterior drawer tests.[13] Certain demographic factors, such as female sex and younger age, have been shown to influence the incidence and severity of presentation.[14] Generalized ligamentous laxity and

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connective tissue disorders have also been reported as risk factors for MDI.[14,23]

For most patients who have MDI, the initial treatment consists of a trial of rehabilitation exercises.[13] However, long-term studies have shown that nonoperative management with rehabilitation exercises has relatively poor outcomes, with satisfactory stability at long-term follow-up reported in as few as 30% of patients.[9,21] The patients for whom nonoperative measures fail present a challenging cohort for the orthopaedic surgeon. Proposed surgical treatments have included open capsular shift, arthroscopic thermal or laser-assisted capsulorrhaphy, and arthroscopic capsular repair or plication.[19] At present, arthroscopic capsular repair or reconstruction is the most common technique, with reported failure rates, defined as recurrent instability, ranging from 8% to 31%, a return-to-sport rate of 50% to 86%, and good functional outcomes.[5,17,20,28,29] However, these data are derived mainly from adult patient populations, and thus we have a limited understanding of long-term outcomes in adolescent athletes treated with arthroscopic capsular repair or reconstruction.

Given the paucity of outcome data in adolescent athletes treated with arthroscopic capsular repair or reconstruction for MDI, we sought to identify risk factors for surgical failure by comparing anatomic, clinical, and demographic variables in this population. Previous reports are available on outcomes in adolescent athletes treated with arthroscopic capsular repair or reconstruction for unidirectional instability, by which to compare outcomes in patients who have MDI.[3,10] We additionally collected functional outcome measures to better understand the long-term benefit of surgical intervention. The purpose of this study was to specifically evaluate MDI in an adolescent population to determine whether surgical intervention provides an overall benefit comparable with that in the adult population and to compare outcomes with adolescent athletes treated for unidirectional shoulder instability. We hypothesized that adolescent patients who had MDI were likely to experience worse outcomes compared with patients treated for unidirectional shoulder instability.

METHODS

Study Patients

After institutional review board approval was obtained, a retrospective review was performed on all children treated surgically for MDI at our dedicated pediatric hospital between January 2009 and April 2017. Surgery was indicated for children with symptoms consistent with MDI and failure to improve after at least 6 weeks of physical therapy. An initial hospital database search with Current Procedural Terminology code 29806 was performed to identify patients having undergone an arthroscopic capsulorrhaphy. Chart review was then performed to identify those patients who were treated for multidirectional instability and to exclude those managed for their unidirectional shoulder instability or frank traumatic dislocation event. Multidirectional instability was defined as the presence of a positive sulcus sign (Figure 1), capacious capsule identified by a radiologist on magnetic resonance arthrogram and/or intraoperatively (Figure 2), and drive-through sign on arthroscopy (Figure 3).

Figure 1. Representative case demonstrating positive sulcus sign. Images courtesy of SD Peds Ortho.

To meet inclusion criteria, patients also had to demonstrate multidirectional laxity on anterior and posterior drawer tests while under anesthesia, equating to a grade 2 subluxation or greater (defined as translation of the glenoid over the rim of the anterior or posterior glenoid rim with spontaneous reduction). A 2-year minimum follow-up was required for study inclusion; however, those whose treatment failed before that time point (subsequent dislocation or revision surgery for same problem) were included for calculation purposes. Sports activity (ie, sport type) was not consistently recorded for our cohort and was therefore not included. Further exclusion criteria were applied, including age older than 20 years, as we sought to focus on adolescents, and surgical intervention at a different facility before presentation at our institution.[1]

Surgical Management

A single surgeon (E.W.E.) treated all patients, and all were managed with an initial trial of at least 6 weeks of physical

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Ethical approval for this study was obtained from the University of California, San Diego Human Research Protection Program (project No. 170519X).

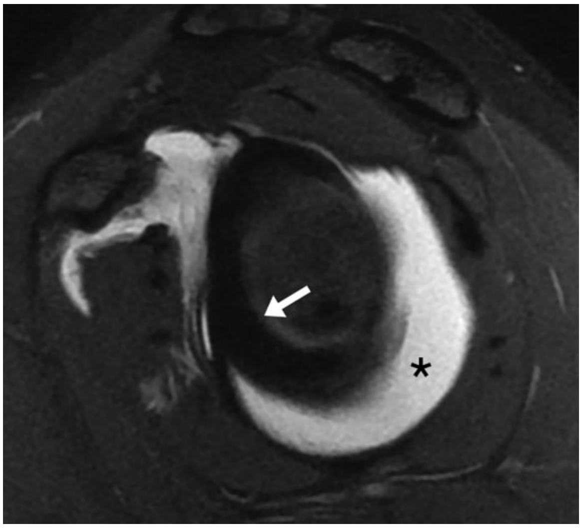

Figure 2. Sagittal T2-weighted, fat-saturated magnetic resonance image with arthrogram demonstrating intact circumferential labrum (arrow) with capacious capsule evident posterior and inferior (asterisk). Image courtesy of SD Peds Ortho.

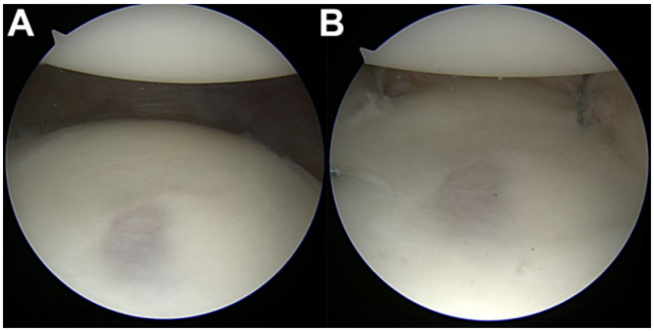

Figure 3. Representative case demonstrating (A) presence of drive-through sign of the glenohumeral joint as viewed through the posterior portal at the beginning of the case and (B) subsequent absence of drive-through sign after adequate capsular repair had been achieved. Images courtesy of SD Peds Ortho.

therapy before undergoing arthroscopic capsular plication with suture anchors (Figure 4). The method of plication involved the placement of single-arm suture anchors at the labroarticular junction for every clockface increment (or every ½ radian) starting at 7-o'clock (posteroinferior) and proceeding to 5-o'clock, 4-o'clock, and 8-o'clock (with care taken to close the posterior capsulotomy made by the cannula with this anchor). Further anchors would be placed at either the 3- or the 9-o'clock position as needed to maintain the humerus in a centralized position without overly distended capsule as viewed from the anterosuperior portal. Both the lowest anterior and posterior anchor plication included an inferior plication drawing the inferior capsule superiorly to reduce the inferior capaciousness.

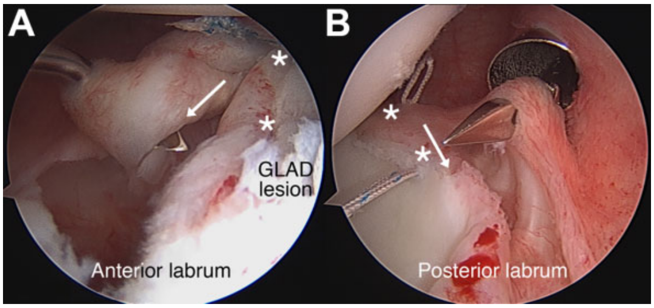

Figure 4. Representative case demonstrating a glenolabral articular disruption (GLAD) lesion (A) in the anterior aspect with intact anteroinferior labrum and (B) posterior labrum, both viewed from a superior position. Plication of the capsule was performed from inferior to superior (arrow direction) to perform an anteroinferior and posteroinferior capsulorrhaphy via placement of anchors (asterisks) in the glenoid (these represent the 4-, 5-, 7-, and 8-o'clock positions, with 5- and 7-o'clock anchors already tied with knots visible). The device was shuttled under the labrum to include that anatomic feature in the construct. Images courtesy of SD Peds Ortho.

A positive drive-through sign was observed in all cases, and confirmation of adequate capsular repair was confirmed by absence of the drive-through sign before portal closure.

Postoperative Management

Postoperatively, all patients were placed in a shoulder immobilizer with abduction pillow for 2 weeks of full-time wear (with permission to range the elbow when changing clothes) after which they progressed to a sling with donning and doffing privileges for an additional 4-week period (encouraging use for a total of 6 weeks). Physical therapy to restore range of motion and strength was started at the end of 2 weeks and continued for a minimum of 3 months after surgery. Progression through therapy entailed 5 phases. Phase 1 (2 weeks) involved pendulums; passive and active assisted range of motion with wand, wall, or pulley; and postural correction. Phase 2 (2 weeks) involved advancing range of motion via methods started in phase 1 but added isometrics and started scapular strengthening within range limits. Phase 3 (2 weeks) furthered the previous 2 phases and added light activities of daily living and upper body ergometer. Phase 4 (6 weeks) began active range of motion, progressive resistance exercises with light plyometrics, and running toward the end of the phase. Phase 5 (6 weeks or further depending on patient requirements and goals) incorporated multiangle strengthening, sport-specific drills (throwing program started, which continued until 6 months after surgery), and stabilization through functional ranges.

Athletes were cleared for return to sport pending evaluation by the treating surgeon, typically after 6 months postoperatively. Although stability testing was performed, the criteria for return to sport included >80% strength relative

TABLE 1
Patient Characteristics[a]

Mean age, y	15.8
Sex	
Male	19 (38)
Female	31 (62)
Laterality	
Left	22 (44)
Right	28 (56)
Generalized ligamentous laxity	
No	45 (90)
Yes	5 (10)

[a]Data are reported as n (%) unless otherwise indicated.

TABLE 2
Arthroscopic Characteristics by Sex[a]

	Total	Male	Female	*P* Value
Mean number of anchors	3.5	4.3	3.0	**.003**
Capacious capsule	34 (68)	9 (47)	25 (81)	**.014**
Labral tear	35 (70)	17 (89)	18 (58)	**.019**
Rotator cuff tear	28 (56)	13 (68)	15 (48)	.166
Synovitis	31 (62)	13 (68)	18 (58)	.464

[a]Data are reported as n (%) unless otherwise indicated. Bolded *P* values indicate statistically significant differences between male and female patients ($P < .05$).

to the uninjured arm, full range of motion, and clearance by physical therapy staff.

Outcome Measures

Charts were reviewed and demographic data collected. Operative report review focused on arthroscopic pathology and examination under anesthesia, such as drawer testing and range of motion. Arthroscopic variables were noted in the anterior and posterior planes and included labral tears, capsular capaciousness, rotator cuff tears, and synovitis. The number and location of surgical anchors placed were recorded. Outcome measures consisted of the 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 the duration and effort of postoperative physical therapy participation. Moreover, to limit response bias, an independent observer other than the surgeon (B.C.M.) collected outcome measures by telephone interview. These data were collected at the last date of follow-up (range, 2.8-10.2 years). Surgical failure was defined as any patient experiencing recurrent postoperative instability. Patient-reported outcomes were included for all patients, when available, regardless of failure status.

Statistical Analysis

Statistical testing was performed using SPSS Version 26.0 (IBM Corp), and alpha was set to $P < .05$ to declare significance. Continuous dependent variables were compared using 1-way analysis of variance (ANOVA). Variables were checked for normality and homogeneity of variance via the Shapiro-Wilk test and Levene test, respectively, before use of ANOVA. If either assumption was violated, the nonparametric Mann-Whitney *U* test was used. The continuous dependent variables include total anchors used, QuickDASH score, PASS score, and SANE score. Comparisons of these variables were made based on status of connective tissue disease, laterality, and sex. The chi-square test was used to compare categorical variables. Differences in the proportion of reoperation, return to sport, and intraoperative findings and repairs were compared based on status of connective tissue disease, laterality, and sex.

RESULTS

Patient Characteristics

We identified 50 adolescent shoulders (42 individual patients) that underwent surgical treatment for MDI (31 female [62%]; 19 male [38%]) and had a minimum 2-year follow-up or evidence of early failure. An additional 38 shoulders over the 8 years did not met criteria for follow-up. The mean patient age at the time of surgery was 15.8 years (range, 12.4-20.0 years), and the mean follow-up period was 6.3 years (range, 2.8-10.2 years). General ligamentous laxity of other joints was noted on examination in 5 of 50 (10%) cases. All patients reported completing a course of pre- and postoperative physical therapy. Patient characteristics are summarized in Table 1.

Arthroscopic Findings and Surgical Management

Capacious capsule was noted in 34 (68%) cases, with a predilection toward female sex (80.6% vs 47.3%; $P = .014$). Labral tear was noted in 35 (70%) cases, with a predilection toward male sex (89.5% vs 58.1%; $P = .019$). A partial rotator cuff tear (supraspinatus) was present in 28 (56%) cases, with no statistically significant differences between male and female sex (68% vs 48%; $P = .166$). Synovitis was present in 31 (62%) cases, with no statistically significant differences between male and female sex (68% vs 58%; $P = .464$). Patients received a mean ± SD of 1.9 ± 1 posterior anchors (range, 0-4 posterior anchors), 1.6 ± 1.4 anterior anchors (range, 0-5 anterior anchors), and 3.5 ± 1.5 total anchors (range, 1-7 total anchors). We found a statistically significant difference in total anchors used, with more anchors needed in male patients (4.3 vs 3.0; $P = .003$). Age and laterality were not associated with any of the arthroscopic findings. Findings are summarized in Table 2.

Outcome Measures

We found that 13 (26.0%) shoulders experienced surgical failure, defined as recurrence of subluxation and instability; all of the shoulders required reoperation. Time to

TABLE 3
Outcomes by Sex[a]

	Total	Male	Female	*P* Value
SANE, mean score	83.3	80.6	84.4	.462
PASS, mean score	85.0	80.2	86.9	.224
QuickDASH, mean score	6.8	9.1	5.9	.288
RTS, n (%)	28 (56)	13 (68)	15 (48)	.166
Surgical failure, n (%)	13 (26)	6 (32)	7 (23)	.481

[a]PASS, Pediatric and Adolescent Shoulder Survey; QuickDASH, short version of Disabilities of the Arm, Shoulder and Hand; RTS, return to prior level of sport; SANE, Single Assessment Numeric Evaluation.

reoperation occurred at a mean of 1.9 years (range, 0.8-3.2 years) after index surgery. In total, 64% of patients participated in subjective outcome scoring, including 3 of the 13 patients who experienced surgical failure. Patients reported a mean SANE score of 83.3, PASS score of 85.0, and QuickDASH score of 6.8. Return to prior level of sport (RTS) occurred in 56% of patients. None of the patient characteristics, including age and sex, or arthroscopic pathological findings were associated with subjective outcomes or reoperation. No statistically significant difference was found in the number of anchors for patients who experienced surgical failure (range, 1-7 anchors) compared with those who did not experience failure (range, 1-6 anchors) (mean, 3.8 vs 3.3 anchors; $P = .298$). Outcome data are summarized in Table 3. A survivorship curve demonstrated overall survivorship of 96% at 1 year after surgery and 76% at 3 years (Figure 5).

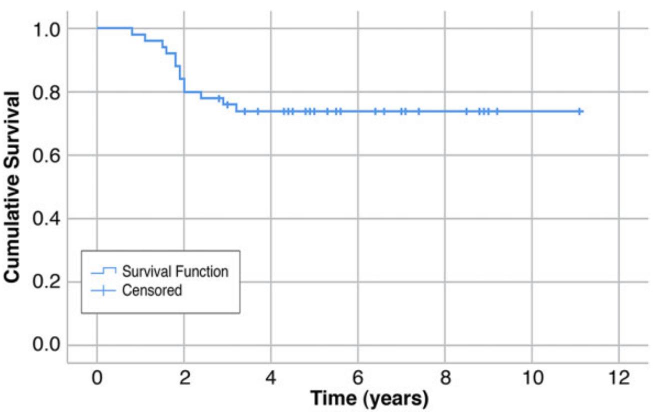

Figure 5. Survivorship curve demonstrating overall survivorship of 96% at 1 year after surgery and 76% at 3 years.

DISCUSSION

In this retrospective case series, 42 adolescents (50 shoulders) were identified as having undergone surgical treatment of MDI. At a minimum 2-year follow-up, 26.0% of shoulders experienced surgical failure requiring reoperation. None of the anatomic, clinical, or demographic variables tested, nor the presence of generalized ligamentous laxity, was associated with subjective outcomes or reoperation. The number of anchors used was not different between the surgeries that failed and those that did not fail. Patients reported a mean SANE score of 83.3, PASS score of 85.0, and QuickDASH score of 6.8. In total, 56% of patients achieved RTS.

Ample evidence has shown that surgical stabilization can be beneficial for adult patients who experience failure of nonoperative management for MDI.[5,17,20,28,29] Although younger age is considered a risk factor for MDI, the incidence and prognosis of this condition in adolescent athletes are poorly described in the literature. Youth, generalized joint laxity,[13,16] and female sex[21] are known risk factors that play into surgical failure in the adult population, but our findings suggested that these factors were not associated with adolescent surgical outcomes. It appears that the adolescent population can experience an overall benefit from surgical intervention that is comparable with the adult population and comparable with adolescent athletes treated for unidirectional shoulder instability.

Raynor et al[25] suggested that adult female patients with MDI reported higher rates of surgical failure than men, but previous work has not fully evaluated the variables that can determine success in the adolescent athlete of either sex. We found that sex played a significant role in type of associated pathology but was not associated with functional outcomes or surgical failure. In our cohort, female sex was significantly associated with a higher incidence of capacious capsule, while male sex was significantly associated with the presence of labral tear. Although the cause of these differences is unclear, it appears that despite these differences, surgical outcomes between adolescent male and female patients are otherwise equivalent. The specific cause of differences among sexes likely warrants further research.

As noted previously, presence of the drive-through sign was noted in all cases and was used to confirm MDI and to determine when adequate capsular repair had been achieved (Figure 3). Other pathologic conditions noted included capacious capsule (68%), labral tears (70%), rotator cuff tear (56%), and synovitis (62%). These findings are consistent with the adult literature, which has reported similar frequencies of arthroscopic findings.[25] Raynor et al[25] reported labral tearing in 64%, rotator cuff pathology in 45%, and synovitis in 38% of adult MDI patients treated with arthroscopic plication. Similarly, Baker et al[5] reported a 61% rate of labral tearing in adult MDI patients. Given the labral tear rate that we found here, it is important to consider that many of our patients likely had a combination of MDI from capsular laxity and additional traumatic labral tears. Interestingly, we did not identify any bony defects or loose bodies in our cohort, whereas Raynor et al reported an 11% rate of loose bodies and a 20% rate of Hill-Sachs lesions. A possible explanation is that younger patients have not experienced as many instability events over their lifetime and have not accumulated enough damage to the joint to generate bony injury and intra-articular loose bodies; however, further research is needed to confirm this explanation.

Prior work has argued that the use of too few anchors may be implicated in the failure of surgical management for shoulder instability.[6,8,24] Although this may be inherently true, we did not find that the number of anchors used for plication was statistically different between cases that failed and those that did not. This is particularly relevant in the adolescent shoulder, where space can be more limited than in the adult shoulder. Our findings argue that more anchors do not prevent surgical failure, and we therefore recommend that a conservative approach be taken when determining the number of anchors needed to attain adequate plication in these patients. However, consideration should be given to the presence, size, and location of associated labral tearing.

About 37% of adult MDI patients experience failure of nonsurgical management and require operative intervention; of those treated nonsurgically, only 47% are satisfied at long-term follow-up.[21] Therefore, a number of surgical options have been proposed to help manage MDI in adults. Open inferior capsular shift was first described by Neer and Foster[22] in 1980; at 2-year follow-up, they reported a failure rate of only 6%. Although open capsular shift remains a popular treatment, follow-up studies have reported failure rates ranging from 4% to 26%.[2,4,11,12,15,23]

In recent years, the operative management of MDI has gravitated toward arthroscopic techniques owing to improved technology and the inherent limitations of open procedures to address all of the affected regions of shoulder laxity. Arthroscopic treatment allows the surgeon to address anterior, inferior, and posterior disease simultaneously and with lower morbidity.[17,18] At present, arthroscopic capsular repair or reconstruction is the preferred technique; reported failure rates, defined as recurrent instability, range from 8% to 31%, the rate of return to sport is 50% to 86%, and good functional outcomes are achieved in adults.[5,17,20,28,29] However, these studies are limited by follow-up length. As we have shown, at least in adolescents, failure occurs between 0.8 and 3.2 years after surgery, and we posit that many of the previous studies did not capture failures occurring at longer follow-up. Furthermore, none of the aforementioned studies included an exclusively adolescent cohort, but the rate of surgical failure that we found in the current study appears to align with the adult population. A definitive explanation for the broad period during which failure can occur is unclear. We postulate that pathologic soft tissues continue to stretch out over time, which may contribute to later failures. However, further research is needed to fully explain these findings.

Given the paucity of data on MDI in adolescent athletes, it is challenging to perform a direct comparison of outcomes, and the aforementioned literature on adults consists of various definitions of MDI that may not be completely applicable to comparison with our younger cohort. However, surgical outcomes in unidirectional instability have been reported in this younger population, and these findings may help to provide a framework by which to assess outcomes. Failure of arthroscopic treatment for anterior instability in adolescent patients has been reported at rates of 21% to 24%, with a 77% rate of return to preinjury sport levels and a 95% rate of return to some sport participation.[26,27] Functional outcomes measured are reasonable at >2 years of follow-up, with a QuickDASH score of 10 and a SANE score of 72.[27] Adolescent posterior instability has shown a slightly lower reported rate of failure (12.5%), with reported functional outcomes including QuickDASH score of 17; PASS, 79; and SANE, 79.[3]

Despite the enhanced complexity of MDI, we report functional outcomes (QuickDASH score of 6.8; PASS, 85.0; and SANE, 83.3) and surgical failure rates (26%) similar to those reported in adolescent patients treated for unidirectional instability. However, in contrast to the previous literature on anterior instability, we found that the RTS in children with MDI was noticeably reduced, at only 56%. This reduced rate compared with unidirectional anterior instability outcomes could be related to the difference in duration of outcome. Previous studies on adolescents with unidirectional instability entailed mean follow-up periods of 2 to 4 years; our study, which had a mean follow-up of 6 years, would shift our patients out of both high school and college sports, potentially adversely affecting the response to this outcome question. Other possible explanations include specific characteristics of the typical MDI patient, such as sport predominance, sex predilection, psychosocial factors, and personal factors that may influence motivation to return to sport.[30] Future studies are needed to evaluate differences in functional outcomes and return to sport in those who experience surgical failure requiring reoperation versus those who do not experience failure.

The limitations of our study relate to the retrospective study design; however, we had a mean of >6 years of outcomes to evaluate and compare for prognostic factors. Regarding the diagnosis of MDI, we decided to use strict criteria reliant on both clinical examination and arthroscopic findings. As such, it is plausible that we excluded patients with only partial findings consistent with MDI. Moreover, we were unable to distinguish teenagers who had primary complaints of pain versus instability because they frequently presented with both. Therefore, we did not report on the number of presurgical instability events. Furthermore, we did not report on the type of preoperative sports participation, which could have provided valuable epidemiologic information.

Regarding return to sport, we were able to assess only the return to prior level of participation, so we cannot confirm whether the remaining 44% of our patients at least resumed an active youthful lifestyle. However, given that our reported outcome scores were almost identical to the patients with unidirectional instability, who had high (95%) overall return to activity, we believe that the overall activity level in this MDI cohort may not be as poor as perceived by the low rate of RTS. In addition, our loss of 38 of the 88 total shoulders during this study period, coupled with being unable to obtain outcome scores on 36% of the 50 shoulders, represents a potential selection bias to our outcomes. Finally, preoperative outcomes were not collected in this cohort and would have provided valuable insight into the patients' initial level of disability due to MDI. Despite these limitations, we believe that the data presented provide a valuable summary of outcomes after surgical intervention in an understudied population.

CONCLUSION

MDI is a complex disorder with historically poor outcomes in adult patients when treated nonoperatively. However, we showed that adolescent patients with MDI refractory to nonsurgical management had midterm failure rates after surgical intervention that were comparable with the failure rates of adolescents with unidirectional instability. Our case series showed that in adolescents who do experience failure, this failure will most likely occur within 3 years of index surgical treatment. Despite similar rates of surgical failure in adolescents with MDI versus adolescents with unidirectional instability, RTS rates remained lower in the MDI cohort. In adolescent athletes with MDI that is refractory to nonoperative management, surgeons should continue to use capsulolabral repair or reconstruction to enhance shoulder stability; in addition, it is important to counsel families and patients undergoing the procedure that functional outcomes are likely to remain high even if return to prior level of sport participation may not occur.

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