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Incidence of arthroscopic and open pediatric shoulder stabilization procedures across the United States: a Pediatric Health Information System database study

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Background: Shoulder instability in pediatric and adolescent patients can be treated operatively via arthroscopic or open procedures, but there a paucity of evidence to support the incidence of these treatment modalities over time. It is hypothesized that the overall rate of arthroscopic shoulder stabilization procedures will increase over time. Given advances in open stabilization techniques, we also hypothesized that the rate of open procedures may be increasing.

Methods: The Pediatric Health Information System database was queried for patients 19 years or younger who underwent arthroscopic or open surgery for shoulder instability and pediatric orthopedic surgeries between 2009 and 2019. Data from 37 of the 52 pediatric hospitals with Pediatric Health Information System data was included in the analysis. Annual and overall incidence rates were estimated for arthroscopic and open procedures, along with 95% confidence intervals. The yearly incidence for secondary (homolateral revisions) or primary contralateral arthroscopic and open procedures was also examined.

Results: 4747 patients underwent primary arthroscopic procedures and 384 patients had primary open procedures. There were 8.2 primary open shoulder stabilization procedures per 10,000 orthopedic surgical patients in 2009, which decreased by 19% to 6.7 per 10,000 orthopedic surgical patients in 2019. There was an increase seen in both arthroscopic and open secondary stabilization procedures. In 2009, there were 0.97 secondary arthroscopic procedures per 10,000 orthopedic surgical patients. This increased by 672% to 7.5 per 10,000 orthopedic surgical patients in 2019. No secondary open procedures were recorded in 2009; however, an increase to 2.6 secondary open procedures per 10,000 orthopedic surgical patients was seen by 2019.

Conclusion: This study shows a rise in primary arthroscopic pediatric shoulder stabilization surgeries across the U.S. over the last decade. There was a slight decrease in the rate of primary open shoulder stabilization surgeries and an increase in both arthroscopic and open secondary (homolateral revisions or primary contralateral) shoulder stabilization surgeries, implying an increasing revision burden in this population.

Shoulder instability occurs with variable incidence in pediatric and adolescent patients, with rates of incidence that may be as high as 8% in some young, athletic populations.[8] Classically, the mechanism of injury for young patients is sports related, with collision sports and contact sports presenting an increased risk as well as male sex.[8,18,22,35] Other than acute/traumatic injury, pediatric and adolescent patients can experience multidirectional shoulder instability, as a consequence from repetitive microtraumas in sport such as swimming and gymnastics, or secondary to underlying ligamentous laxity or congenital connective tissue disorders.[1,11,24,27] Studies have also shown that age plays a role in shoulder instability incidence. Rowe et al showed that out of 500 shoulder dislocations, 20% occurred in patients 10-20 year old, while only eight occurred in patients less than ten years old.[33] Similarly, Hovelius et al have demonstrated that 10% of primary dislocations in their cohort were

The Boston Children's Hospital Institutional Review Board determined this study to not be human subject's research and that it was exempt on 10/29/2020. IRB Number: IRB-P00037227.

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less than 22 year old, further highlighting the burden of this injury on young patients.[9]

Beyond the incidence of primary shoulder instability, there also poses a significant risk of recurrence in pediatric and adolescent patients. Estimates of recurrence are variable depending on the cohort, but the literature suggests a range from 75% to 100%.[5,20,32,37] The high recurrence prevalence, which mainly occurs in otherwise healthy, athletic young patients, presents an ongoing concern for pediatric physicians and surgeons. There remains a paucity of evidence on which treatment modalities are most effective at preventing and treating recurrence in young patients.

Following the reduction of the joint, treatment options for shoulder instability in pediatric patients range from conservative management to arthroscopic and open surgical procedures. However, some studies have shown increased recurrence rates with nonoperative vs. operative management, making surgical treatment the recommended treatment modality for young patients with shoulder instability and a desire to return to their preinjury activity levels.[3,12,22] Still, operative treatment outcomes may have a more unfavorable dislocation recurrence rate for both open and arthroscopic procedures in young active patients compared to older less active patients.[4,5,7,12,14,34]

This study aims to evaluate the incidence of primary and secondary arthroscopic and open shoulder stabilization in pediatric and adolescent patients across the United States over time. The goal of this assessment is to better understand which surgical options are preferentially being performed for primary and secondary stabilizations and how each procedure correlates with the subsequent need for surgical stabilization. We hypothesize that primary and secondary shoulder instability procedures will increase over time with a predominance of arthroscopic procedures but with the possibility of increased open procedures in recent years due to the rise in popularity of the open procedures for the treatment of complex primary instability and revision surgeries.

Materials and methods

Data was collected from the Pediatric Health Information System (PHIS) database. The PHIS database collects data on inpatient, ambulatory, emergency surgery, and observation encounter services at 52 tertiary-care pediatric hospitals across the United States that are affiliated with the Children's Hospital Association. The hospitals and the Children's Hospital Associated assure the quality and reliability of the data. All data within the database is deidentified, qualifying this study for institutional review board exemption. Children's Hospital Association has granted permission to report on deidentified PHIS data.

The PHIS database was queried for all patients 19 years or younger who underwent arthroscopic or open surgery for shoulder instability from 2009-2019. The study period was determined based on the earliest year with complete patient data within the database (2009) until time of original data collection in 2019. Patients were identified based on Current Procedural Terminology, Fourth Revision (CPT-4) procedure codes for shoulder instability repair corresponding to arthroscopic and open stabilization methods. CPT codes that were used include: 29806, 23455, 23460, 23462, 23465, and 23466. Procedures were grouped into the categories of open procedure, isolated arthroscopic procedure, concomitant arthroscopic procedure, and superior labrum anterior to posterior tear repair procedure based on these codes. Subsequent entries for patients were identified based on unique patient discharge ID. Patients who underwent one surgery were characterized as undergoing primary operations. Any duplicate entries for patients, based on unique patient discharge ID, who underwent multiple shoulder instability surgeries were qualified as secondary operations. Data on laterality is limited, so secondary operations are either contralateral or revision procedures. 37 out of the 52 centers in the PHIS database were included in the analysis based on the completeness of data during the study period, in concordance with previous methodology utilizing the PHIS database.[23,25,26] Data was only pulled for final counts if the site and years had data for all evaluated treatment modalities (arthroscopic stabilization and open stabilization). In addition to data on shoulder instability surgery, yearly hospital counts for unique patients seen for all pediatric orthopedic surgeries were also pulled to serve as a comparison group, resulting in 574,581 total patients.

Using first visit data, incidence rates were estimated for arthroscopic, open, isolated arthroscopic, concomitant arthroscopic, and superior labrum anterior to posterior tear repair procedures, along with 95% confidence intervals. All procedure was grouped based on CPT code. Incidence was calculated by dividing the total number of cases by the total number of orthopedic surgery patients. Yearly incidence rates were also estimated for these procedures. These incidence rates were represented as the number of patients who underwent the procedure per 10,000 orthopedic surgery patients. Complete patient data was later utilized to determine yearly incidence rates of secondary arthroscopic and open procedures. Linear regression modeling was used to assess for trends. We used median instead of mean to summarize age because the data was skewed. In this situation, median is the appropriate summary statistic to report.

Results

There were 4747 patients documented as having a primary arthroscopic procedure between 2009 and 2019. The median age at surgery was 16.5 years (range, 0.52-19.00 years), and 69% were male. 384 patients had a primary open procedure during the study window (Table I). The median age at surgery was 16.3 years (range, 0.45-18.93 years), and 65% were male. A box plot detailing the age distribution is shown in Figure 1. 43.5 arthroscopic surgeries per 10,000 orthopedic surgery patients occurred. This increased by 134% in 2019 resulting in 101.8 arthroscopic surgeries per 10,000 orthopedic surgery patients. Conversely, there were 8.2 primary open procedures per 10,000 orthopedic surgery patients in 2009, but this decreased by 19% to 6.7 per 10,000 orthopedic surgery patients in 2019 (Fig. 2). In 2009, there were 41,375 pediatric orthopedic surgery patients, and this increased by 48% to 61,422 patients in 2019.

Looking at secondary procedures, contralateral or revision, there was a yearly increase in both arthroscopic procedures and open procedures. Of the 5120 first surgery patients undergoing both arthroscopic and open stabilization, 8% (393/5120) had a secondary arthroscopic or open stabilization procedure. There were 313 who had an arthroscopic procedure, while 80 had an open procedure. In 2009, 0.97 secondary arthroscopic procedures per 10,000 orthopedic surgery patients were recorded, and this increased by 672% to 7.5 per 10,000 orthopedic surgery patients. There were no secondary open procedures recorded in 2009; however, this increased to 2.6 per 10,000 orthopedic surgery patients by 2019 (Fig. 3). Figures 4 and 5 show the trends in open procedure by procedure type from 2009 to 2019: open anterior/multidirectional capsulorrhaphy/labral repair, open Latarjet/coracoid transfer, and open posterior capsulorrhaphy/labral repair/± bone block transfer, for primary and secondary procedures, respectively.

Discussion

This study demonstrates a rise in primary arthroscopic shoulder stabilization procedures and a decrease in open shoulder

Table I
Initial procedure rates for 2009-2019.

Procedure	Cases	Total orthopedic surgery patients	Incidence rate (per 10,000)	(95% CI)
Any arthroscopic	4747	574,581	82.6	(80.30, 85.00)
Any open	384	574,581	6.7	(6.04, 7.39)
Isolated arthroscopic	4332	574,581	75.4	(73.18, 77.67)
Concomitant arthroscopic and SLAP tear repair	396	574,581	6.9	(6.24, 7.61)

CI, confidence interval; *SLAP*, superior labrum anterior to posterior.
Table of initial procedure rates for 2009-2019. Procedures include any arthroscopic procedure, any open procedure, isolated arthroscopic procedures, and concomitant arthroscopic and SLAP tear repair procedures.

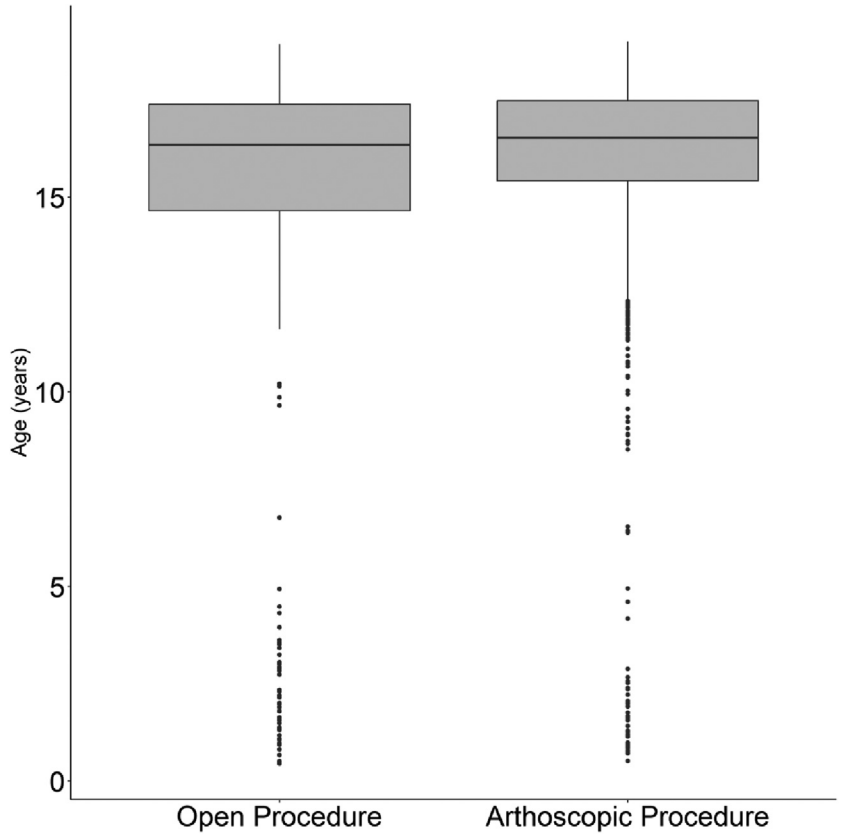

Figure 1 Box plot of age distribution in open and arthroscopic procedure cohorts. Age distribution in the open and arthroscopic procedure cohorts between 2009 and 2019. *Left*: age distribution of the open procedures cohort. *Right*: age distribution of the arthroscopic procedures cohort.

stabilization procedures over the ten-year study period (134% and 19%, respectively). 8% of patients required a secondary stabilization procedure, either contralateral or revision surgery, over the study period, in which there was an increase in both arthroscopic and open secondary procedures.

In 2019, 6.7 out of 10,000 orthopedic surgeries were primary instability stabilizations. Throughout the entire study period 8% of patients required secondary stabilization procedures, either contralateral or revision. Previous studies have demonstrated high incidence rates in both primary shoulder instability, 4.7%-8% depending on the cohort, and recurrent shoulder instability events, ranging from 75% to 100%.[5,8,20,32,37] Our incidence measures here differ because we are measuring shoulder instability procedures rather than shoulder instability events. By using a deidentified cohort, we are unable to say whether a patient who underwent a first-time shoulder stabilization procedure had one or multiple instability events prior to surgery.

Given the prevalence of shoulder instability and the high risk of recurrence, treatment of shoulder dislocations in pediatric and adolescent patients remains a controversial and challenging topic in the orthopedic community. An earlier systematic review by Zhang et al showed a doubling of arthroscopic shoulder stabilization surgeries from 2004-2009, with 90% of shoulder stabilization surgeries being arthroscopic.[38] However, their analysis included both pediatric and adult patients. A recently published study by Smith et al utilized the PHIS database to study shoulder stabilization procedures and found that 92.9% of procedures were arthroscopic Bankart repairs and the incidence of these procedures increased over time from 8.1 to 16.6 of 1000 orthopedic sports cases for the period of 2008-2017.[36] Their analysis differs from ours in that they do not separate primary and secondary procedures in their definition of incidence. Our study concords with these findings and in that we demonstrated a higher prevalence of arthroscopic procedures in pediatric patients, which increased by 134% over our study period. Primary open procedures were significantly less prevalent across all time points (384 open vs. 4747 arthroscopic) and decreased by 19%. These findings indicate a strong preference at pediatric centers in the US for treating pediatric patients arthroscopically when they present with shoulder instability.

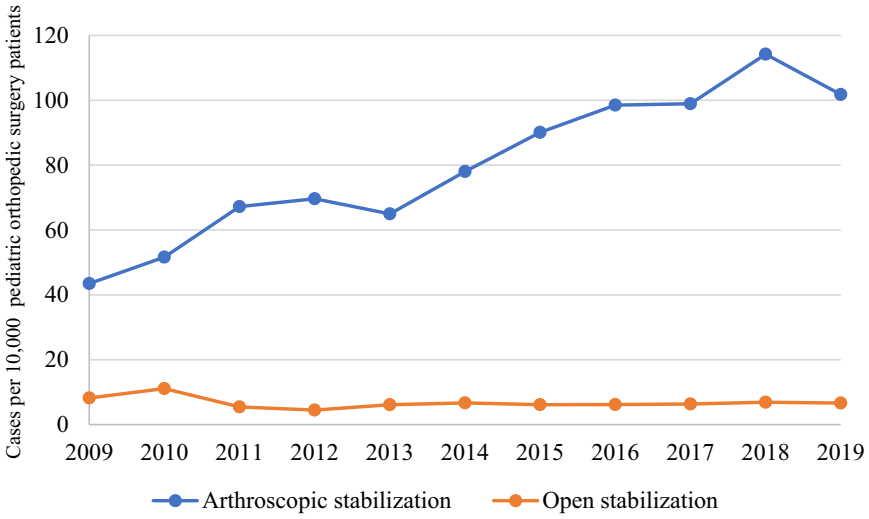

Figure 2 Trends in primary arthroscopic procedures and open procedures from 2009 to 2019. Line graph showing the trends in primary arthroscopic procedures and open procedures from 2009 to 2019. The —●— represents arthroscopic stabilization procedures and the —●— represents open stabilization procedures.

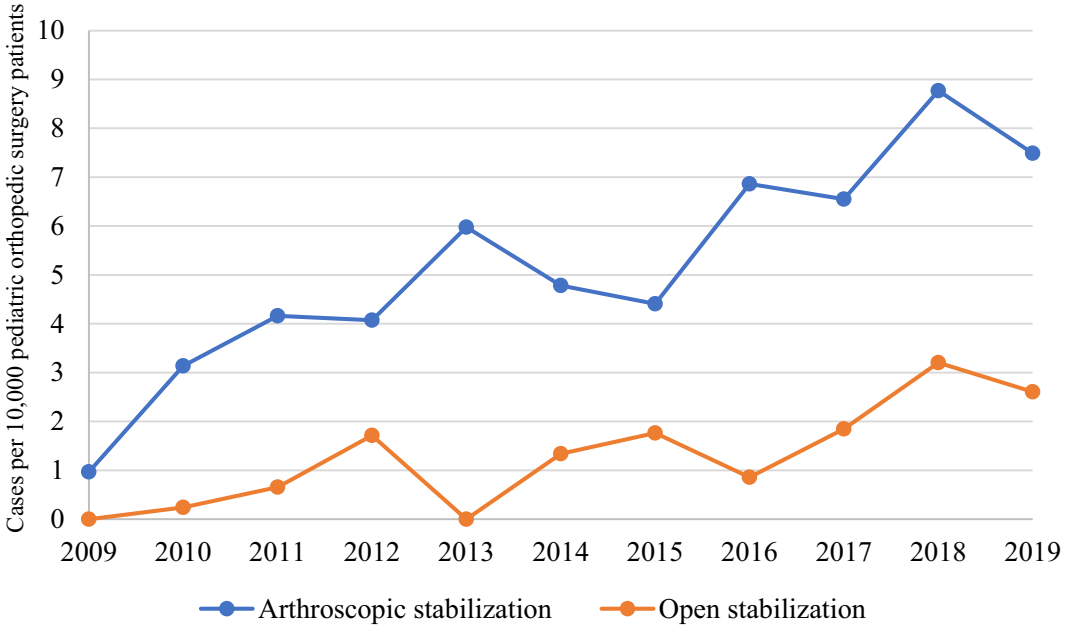

Figure 3 Trends in secondary arthroscopic procedures and open procedures from 2009 to 2019. Line graph showing trends in secondary (revision or contralateral) arthroscopic procedures and open procedures from 2009 to 2019. The —●— represents arthroscopic stabilization procedures and the —●— represents open stabilization procedures.

Speculative reasons for this preference may include less invasive surgeries requiring shorter rehabilitation, shorter surgery times, less complex procedural steps, advanced arthroscopic technology, and overall surgeon preference and comfortability. Regardless of the reason, it is essential to consider the possible sequelae of arthroscopic vs. open surgery when choosing the primary treatment in young patients, notably the risk of recurrence.

It remains unclear which surgical modality offers young patients with primary shoulder dislocations the best chance of recovery while limiting episodes of recurrence. Arthroscopic procedures for shoulder stabilization in skeletally premature patients have gained popularity over the last several decades given reports of improved outcomes compared to nonoperative treatment, possibly in the setting of less complex pathology seen in adolescent shoulder instability.[4,7,16,22] However, open procedures including open Bankart and Latarjet procedures are being assessed as treatment for both primary instability as well as recurrent instability after prior surgical stabilization.[14,17,34] Here, we show that for primary open procedures, there was a consistent preference for open Bankart procedures over the ten-year study period. Primary open Latarjet and posterior capsulorrhaphy procedures remained of lower incidence. As for secondary open procedures, Bankart and Latarjet procedures were performed in similar proportions, with Latarjet being performed at most 11 times in 2018. Only 2 secondary posterior capsulorrhaphy procedures were performed in the study period. These trends provide useful insight into the current

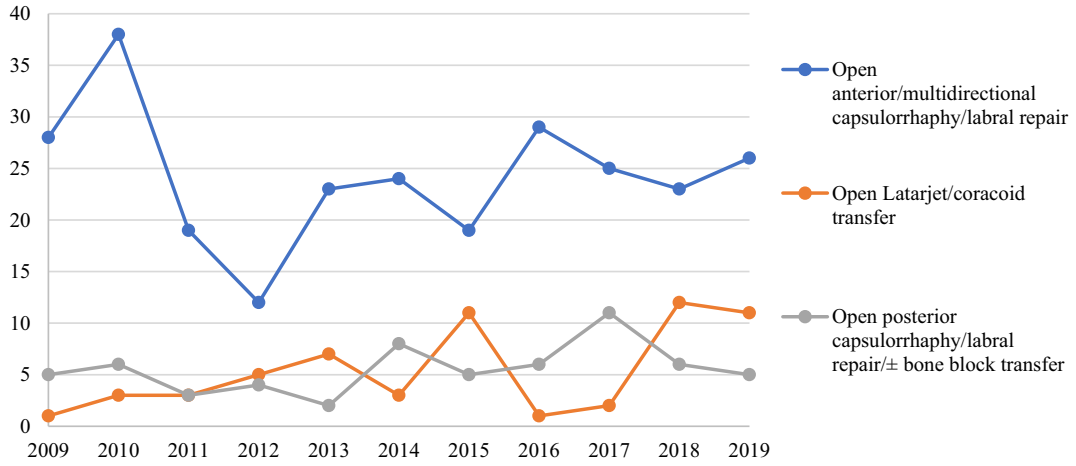

Figure 4 Trends in primary open procedures by procedure type from 2009 to 2019. Line graph showing the trends in primary open procedure by procedure type from 2009 to 2019. The —●— represents open anterior/multidirectional capsulorrhaphy/labral repair, the —●— represents open Latarjet/coracoid transfer, and the —●— represents open posterior capsulorrhaphy/labral repair/± bone block transfer.

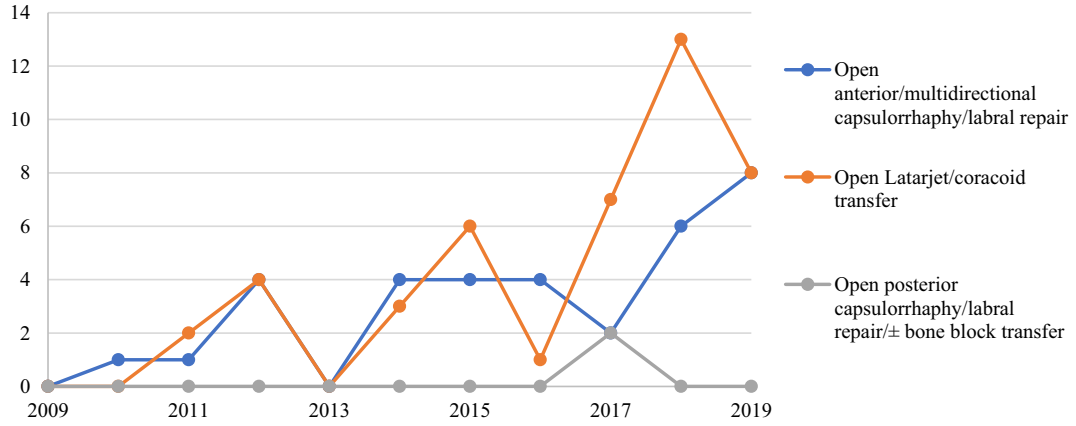

Figure 5 Trends in secondary open procedures by procedure type from 2009-2019. Line graph showing the trends in secondary (revision or contralateral) open procedure by procedure type from 2009 to 2019. The —●— represents open anterior/multidirectional capsulorrhaphy/labral repair, the —●— represents open Latarjet/coracoid transfer, and the —●— represents open posterior capsulorrhaphy/labral repair/± bone block transfer.

landscape of open treatment for shoulder instability, but there remain unclear guidelines on best practices. The challenge in treatment modality consideration is made more complicated by the fact that much of the literature focuses on adult and older adolescent/young adult populations, making it difficult to discern relative risks of recurrence in pediatric cohorts. For instance, when looking at meta-analyses comparing arthroscopic and open procedures, Freedman et al showed a significantly higher risk of recurrence in arthroscopic (trans glenoid sutures, arthroscopic tacks, and suture anchors) vs. open procedures.[6] In contrast, Petrera et al demonstrated no significant difference in outcomes when comparing arthroscopic and open repair with suture anchors.[31] However, both studies had an average age of patients in their mid-twenties. Considering the low numbers of open procedures at children's hospitals in our study, it may be that these young patients are being referred to adult sports/shoulder surgeons with more familiarity with surgical treatment of these bony defects, and are therefore not captured in our analysis.

A systematic review and quantitative synthesis conducted by Longo et al, found that there was significantly lower recurrence after surgical intervention (17.5%) vs. nonoperative management (71.3%) in pediatric and adolescent cohorts.[19] Shymon et al retrospectively compared outcomes after open and arthroscopic Bankart repairs and found that there was no significant difference and that both procedures led to high rates of failure, 4/28 (14%) for open and 17/71 (21%) for arthroscopic procedures.[34] When studying arthroscopic repair procedures and return to play outcomes the literature demonstrates favorable results for young patients. Mazzocca et al showed a low rate of recurrence (11%) and 100% return to play in patients younger than 20 years, while Jones et al showed similar results with a 13.3% recurrence rate and 100% return to play outcomes in patients aged 11 to 18 years.[12,22] Castagna demonstrated a slightly higher rate of recurrence at 21% and an 81% return to previous activity level rate in their cohort of 67 patients aged 13-18 years.[4] Although the literature suggests that surgical stabilization is effective in pediatric and adolescence patients for both primary instability events and recurrent dislocators, the lack of concrete evidence of preferred initial surgical modality and variable recurrence rates and return to play outcomes tend to a more complicated shared decision-making process between the patient, family, and surgeon.

It is important to understand best practices for treating recurrent shoulder instability. There is limited data analyzing trends in

secondary shoulder procedures. We show a substantial increase (672%) in secondary arthroscopic procedures over our study period. Interestingly, at the beginning of our study period, zero open procedures were performed for secondary shoulder instability, which increased to 2.6 per 10,000 orthopedic procedures by the final year. Although a slight increase, the finding of a rise from zero indicates shifting perspectives on best practices in this population. The increase in secondary procedures suggests that there may be a significant revision burden, demonstrated in previous studies.[5,15,20,21,30,32,37] However, given the limitations of the database, we cannot confirm if secondary procedures are homolateral revisions or primary contralateral procedures. There is a possibility that patients were in their late adolescence and may have been treated at an adult hospital for any subsequent procedures, excluding them from the PHIS database. Bonazza and Riboh conducted a review to synthesize management principles in recurrent shoulder instability in pediatric patients.[2] Their findings concluded that arthroscopic or open soft tissue procedures and Latarjet coracoid transfers were safe and effective options for revision shoulder stabilizations, although various factors must be taken into account when choosing the best option. Factors that they recommended were identifying all bony and soft tissue lesions and understanding that subsequent surgeries will likely require more complex surgical techniques.[2] In essence, it is impossible to suggest that there may be a singular best treatment modality in revision shoulder stability procedures because each patient must be assessed on a case-by-case basis. Our study suggests that there may be an ongoing optimization of best practices, and further analysis would help identify the specific surgical techniques associated with the trends we report here.

It is interesting to consider what may be leading to the stark increase in both primary arthroscopic stabilization procedures and all secondary procedures. Although we cannot show causative relationships with our dataset, we can speculate what factors may contribute to these trends. The increase in procedures we see may be secondary to overarching population change, with a larger population, in general, necessitating more surgeries or a larger population of children participating in sports that lead to these injuries. Previous literature has identified that increased sports participation is correlated with increasing rates of shoulder instability.[13,28,29] Likewise, the trend could be related to the growth of pediatric sports medicine surgeons at children's hospitals over time. The trend we see in increased revision burden may be secondary to the increase in primary procedures, and there may be a component of an increasing incidence of patients requiring bilateral surgery. If there is a fixed failure rate of the procedures, it would naturally lend to an increase in revisions as primary procedures increase over time. Aside from population change, further studies in this area of research could seek to understand which demographic and socioeconomic variables may be implicated in shoulder instability treatment choice and outcome, like the growing literature that exists for other pediatric injuries.[25,26] Hung et al showed that publicly insured patients had delayed access to diagnosis and treatment and a significantly increased rate of redislocation after surgery compared to privately insured patients.[10] Subsequent studies could further delineate socioeconomic variables that may correlate with our findings of increased secondary stabilization procedures.

The strengths of this study include the large sample size in a solely pediatric and adolescent population available for both arthroscopic (4747 patients) and open (384 patients) stabilization procedures, as well as the ability to compare this with overall orthopedic surgery during our study period (574,581). By using the total number of orthopedic surgery patients during our study period, we can more accurately delineate the prevalence of shoulder instability in this pediatric and adolescent cohort. Other strengths include the ability to highlight national data across multiple centers and geographical regions with a decade of date, allowing the findings here to be generalized across the country to tertiary pediatric centers.

There are several limitations of this large database study. The first is that a multicenter database is composed of only retrospective data, and there may be inaccuracies in data collection. It is also important to clarify that we cannot guarantee laterality when measuring for secondary procedures. This is an inherent limitation of using CPT codes and unique patient identifiers within the database because we can only specify that the patient underwent a subsequent shoulder stabilization surgery and not whether it was ipsilateral. There is the possibility that some of our secondary procedures were on contralateral sides and not recurrent injuries. As previously mentioned, there is also a chance that patients who underwent subsequent shoulder instability surgeries were not treated at large tertiary care pediatric hospitals because they aged into adult care. Another limitation of utilizing CPT coding is that we cannot examine differences in the number of patients with multidirectional instability vs. traumatic instability, given that the same CPT coding can be used to specify treatment for both pathologies (ie, the CPT code for capsulorrhaphy can be used for the treatment of both conditions). We are unable to comment on variables that may be causative for the findings we report on, such as length of time from injury to surgery, associated pathologies that may warrant one surgery option over another, and other demographic factors such as health care access, or factors that increased individual risk for recurrent surgery (such as sports participation, lack of access to physical therapy, etc.). This also includes having limited data to discern whether a patient was being treated for a primary or recurrent shoulder instability event or if they had had received prior shoulder instability treatments. Lastly, given the limitations of the retrospective data collected here, we cannot comment on clinically relevant patient reported outcomes.

Conclusion

This study shows a rise in primary arthroscopic shoulder stabilization surgeries and a decrease in the rate of open procedures in pediatric and adolescent patients across the U.S. over the last decade. There was an increase in arthroscopic and open shoulder stabilization surgeries for secondary procedures. These findings may suggest that there continues to be an increasing revision burden in this population, although secondary procedures may encompass primary contralateral procedures in this cohort. Further research is warranted to better define the indications for arthroscopic and open procedures for both primary and revision shoulder stabilization surgery, as well as factors that may decrease the need for revision procedures in this population.

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Conflicts of interest: Matthew D. Milewski, reports editorial royalties from Elsevier, Inc. and is also a board member/past president of Pediatric Research in Sports Medicine (PRiSM) Society, both are separate (unrelated) to this manuscript. All authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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