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Received, June 18, 2018.

Accepted, January 9, 2019.

Published Online, June 7, 2019.

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 Congress of Neurological Surgeons

Incidence of Acute, Progressive, and Delayed Proximal Junctional Kyphosis Over an 8-Year Period in Adult Spinal Deformity Patients

BACKGROUND: Proximal junctional kyphosis (PJK) is a common radiographic complication of adult spinal deformity (ASD) corrective surgery. Although previous literature has reported a 5 to 61% incidence of PJK, these studies are limited by small sample sizes and short-term follow-up.

OBJECTIVE: To assess the incidence of PJK utilizing a high-powered ASD database.

METHODS: Retrospective review of a prospective multicenter ASD database. Operative ASD patients > 18 yr old from 2009 to 2017 were included. PJK was defined as $\geq 10^\circ$ for the sagittal Cobb angle between the inferior upper instrumented vertebra (UIV) endplate and the superior endplate of the UIV + 2. Chi-square analysis and post hoc testing assessed annual and overall incidence of acute (6-wk follow-up [f/u]), progressive (increase in degree of PJK from 6 wk to 1 yr), and delayed (1-yr, 2-yr, and 3-yr f/u) PJK development.

RESULTS: A total of 1005 patients were included (age: 59.3; 73.5% F; body mass index: 27.99). Overall PJK incidence was 69.4%. Overall incidence of acute PJK was 48.0%. Annual incidence of acute PJK has decreased from 53.7% in 2012 to 31.6% in 2017 ($P = .038$). Overall incidence of progressive PJK was 35.0%, with stable rates observed from 2009 to 2016 ($P = .297$). Overall incidence of 1-yr-delayed PJK was 9.3%. Annual incidence of 1-yr-delayed PJK has decreased from 9.2% in 2009 to 3.2% in 2016 ($P < .001$). Overall incidence of 2-yr-delayed PJK development was 4.3%. Annual incidence of 2-yr-delayed PJK has decreased from 7.3% in 2009 to 0.9% in 2015 ($P < .05$). Overall incidence of 3-yr-delayed PJK was 1.8%, with stable rates observed from 2009 to 2014 ($P = .594$).

CONCLUSION: Although progressive PJK has remained a challenge for physicians over time, significantly lower incidences of acute and delayed PJK in recent years may indicate improving operative decision-making and management strategies.

KEY WORDS: Proximal junctional kyphosis, Adult spinal deformity, Incidence

Operative Neurosurgery 18:75–82, 2020

DOI: 10.1093/ons/ops128

Adult spinal deformity (ASD), a well-known source of both disability and pain, has a reported prevalence rate

reaching as high as 68% in patients over the age of 60 yr.¹ Bess et al have reported that patients with ASD have a health status worse than patients with chronic back pain, depression, hypertension, or diabetes.² Additionally, sagittal malalignment of the thoracolumbar spine has been shown to correlate with patient reported outcome scores.^{3–6}

Surgery for ASD correction is indicated after failing conservative therapies, such as physical therapy, bracing, or epidural steroid injections.^{7,8} Literature has shown that patients undergoing ASD correction improve substantially more than patients undergoing conservative management.^{9,10} However, ASD corrective surgery can be morbid and

ABBREVIATIONS: ASD, adult spinal deformity; BMI, body mass index; CCI, Charlson Comorbidity Index; CL, cervical lordosis; cSVA, C2–C7 SVA; FI, frailty index; PI-LL, pelvic incidence minus lumbar lordosis; PJK, proximal junctional kyphosis; PT, pelvic tilt; SVA, sagittal vertical axis; T1PA, T1 pelvic angle; T1S, T1 slope; TS-CL, T1 slope minus cervical lordosis; UIV, upper instrumented vertebra

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carries substantial risk of complication. A recent systematic review of complication rates following ASD correction estimated that the overall perioperative complication rate, occurring within 90 d of surgery, was between 24 and 36%.¹¹

Proximal junctional kyphosis (PJK), a radiographic complication associated with ASD surgery, has posed as one of the most significant challenges for modern spinal surgeons. PJK has previously been associated with poor patient-reported outcome scores and is a relatively common cause of the need for revision.¹²⁻¹⁵ Although the incidence of PJK following ASD correction varies widely,¹⁶ most studies report the incidence to be between 20 and 40%.¹⁷⁻²¹ One meta-analysis from 2016 of 14 studies and 2215 patients found that the overall incidence of PJK was 30% (ranging from 17 to 62%).¹⁶ However, current ASD literature regarding PJK is limited by short follow-up time, and high-powered studies describing the long-term incidence of PJK are lacking. The purpose of this study is to analyze the incidence of PJK in ASD patients over an 8-yr period following ASD correction. In addition, this study aims to categorize PJK cases in terms of the time of onset and define the incidence of acute PJK (PJK onset within 6 wk postoperatively), progressive PJK (acute PJK that continues to progress in curvature severity from 6 wk to 1 yr postoperatively) and delayed PJK (PJK onset 1, 2, or 3 yr postoperatively).

METHODS

Study Design

This study is a retrospective review of a prospective, multicenter ASD database.

Data Source

Patients were consecutively enrolled from 13 participating centers across the United States from 2008 to 2017. Each institution obtained approval from their local institutional review board to enroll patients in the prospective database, and informed consent was obtained from each patient at each site prior to enrollment. Database inclusion criteria were patients ≥ 18 yr undergoing either operative or nonoperative treatment for ASD defined as coronal Cobb angle $\geq 20^\circ$, sagittal vertical axis (SVA; distance between C7 plumb line and sacral posterior superior margin) ≥ 5 cm, pelvic tilt (PT) $\geq 25^\circ$, and/or thoracic kyphosis $> 60^\circ$.

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Database exclusion criteria were patients with spinal deformity of neuromuscular etiology, presence of active infection, or malignancy.

Data Collection

Patient demographic and clinical data collected for this study were age, sex, body mass index (BMI), comorbidity status, comorbidity severity (Charlson Comorbidity Index [CCI]), and frailty index scores (ASD-FI).^{22,23} Surgical data included surgical approach, operative time (op time), estimated blood loss, length of stay, construct length (levels fused), and technique (eg, osteotomy and decompression).

Full-length, free-standing lateral spine radiographs (36-inch cassette) were used to assess patients at baseline and 6-wk, 1-yr, 2-yr, and 3-yr follow-up intervals. Radiographs were analyzed using SpineView® (ENSAM, Laboratory of Biomechanics, Paris, France) software according to validated and standardized techniques previously described in the literature.²⁴⁻²⁶ Spinopelvic radiographic parameters assessed included PT, pelvic incidence minus lumbar lordosis (PI-LL), and T1 pelvic angle (T1PA). Global sagittal alignment parameters assessed included the SVA (C7-S1 SVA). Cervical alignment were assessed using thoracic T1 slope (T1S), C2-C7 cervical lordosis (CL), T1 slope minus cervical lordosis (TS-CL), and C2-C7 SVA (cSVA). For operatively treated patients, PJK (defined as a $\geq 10^\circ$ measure of the sagittal Cobb angle between the inferior endplate of the upper instrumented vertebra [UIV] and the superior endplate of the vertebra positioned 2 vertebral bodies above the UIV [UIV + 2]) radiographic measurements were also assessed at all follow-up visits.^{27,28}

Study Inclusion Criteria

Operative ASD patients with postoperative radiographic imaging and undergoing surgical treatment between the years of 2009 and 2017 were included for the study. Patients undergoing operative correction during the year of 2008 were excluded from analysis on the basis of incomplete data and a small sample size.

Statistical Analysis

All statistical tests were performed using SPSS software (v23.0; IBM, Armonk, New York). Descriptive analyses assessed means and frequencies of demographic variables, clinical characteristics, surgical variables, and radiographic alignment parameters. Independent samples *t*-tests compared acute (within 6 wk postoperatively), progressive (acute PJK that continues to progress in severity from 6 wk to 1 yr postoperatively), delayed (PJK that develops 1, 2, or 3 yr postoperatively), and overall PJK incidences amongst patients with and without prior spinal surgery. In addition, the incidence of PJK progressing to PFJ (defined as failure of instrumentation with a need for revision surgery) was assessed.²⁹ Chi-square analyses with post hoc testing assessed the annual and overall incidences of acute PJK, progressive PJK, and delayed PJK. Given that 2017 was the final year of data available for analysis, incidence calculations for progressive and delayed PJK were staggered in accordance with their respective final years of complete data. For example, the final year included for incidence analysis of progressive PJK and 1-yr-delayed PJK patients was 2016 (8-yr analysis), whereas the final year of incidence analysis for 2-yr-delayed PJK was 2015 (7-yr analysis). One-way analysis of variance (ANOVA) with Tukey post hoc testing assessed significant variation in annual PJK severity. The level of significance for all tests was set to $P < .05$.

RESULTS

Patient Demographics and Clinical Presentation

A total of 1005 operative ASD patients reached study inclusion criteria (Figure, Supplemental Digital Content). At presentation, patients were 59.3 ± 15.1 yr old, 73.4% female, 91.8% white, and had a mean BMI of 28.0 ± 9.0. On average, patients were also frail (ASD-FI: 0.33 ± 0.16) and had a mild comorbidity severity (CCI: 1.6 ± 1.7), despite having a high overall comorbidity prevalence of 73.8% (osteoarthritis, 37.7%; hypertension, 35.5%; depression, 22.5%; osteoporosis, 14.7%; anemia, 9.9%; heart disease, 9.8%; and diabetes, 9.0%). Only 5.9% of patients reported being smokers, and 2.7% reported drug/alcohol abuse. Regarding baseline spinopelvic alignment, patients on average presented with malaligned SVA (62.1 ± 69.2 mm), PT (23.4° ± 10.5°), PI-LL (15.1° ± 22.5°), and T1PA (22.1° ± 12.7°). Regarding the cervical spine, patients on average presented with normal alignment (T1 slope: 29.4 ± 13.5°; cervical lordosis [CL: 10.2° ± 16.3°], TS-CL [19.9° ± 11.8°], cSVA [29.3 ± 14.1 mm; Table 1]). Follow-up rates at postoperative time points were 61% at 1 yr, 40% at 2 yr, and 26% at 3 yr.

Cohort Surgical Details

On average, 43.2% of patients presented with a prior history of spine surgery. Regarding surgical approach, 0.6% of patients underwent an anterior only approach, 64.5% underwent a posterior only approach, and 34.9% underwent a combined approach. UIV placement had a trimodal distribution, with T3 (11.8%), T4 (14.6%), and T10 (25.4%) being the most frequent UIV levels. The most frequently occurring lower instrumented vertebra was fusion to the ilium (65.6%). The average construct length was 10.4 ± 4.5 levels fused, 57.5% of patients had an osteotomy (64.5% of 3-column), 58.1% of patients underwent a decompression, and 20.1% of patients underwent staged procedures. The mean operative time was 368.0 ± 136.9 min, the mean estimated blood loss was 1371.6 ± 1365.0 cc, and the mean inpatient length of stay was 7.7 ± 4.6 d. A total of 11% (111) of patients underwent reoperation, with 22 going on to have a second revision, 2 having a third revision, and 1 patient undergoing a fourth revision (Table 2).

PJK and Failure Incidence Assessment

The overall incidence of any type of PJK from 2009 to 2014, utilizing 3-yr follow-up radiographic data, was 69.4%. Overall PJK incidence rates remained stable between 2009 and 2014 ($P = .594$). An overall incidence of 48.0% was observed for acute PJK, 9.3% for 1-yr-delayed PJK, 4.3% for 2-yr-delayed PJK, and 1.8% for 3-yr-delayed PJK. The annual incidence of acute PJK has decreased from 53.7% in 2012 to 31.6% in 2017 ($P = .038$). The annual incidences of 1-yr-delayed and 2-yr-delayed PJK have also decreased, with 1-yr-delayed PJK incidence decreasing from 9.2% in 2009 to 3.2% in 2016 ($P < .001$), and the incidence of

TABLE 1. Patient Cohort Demographics, Clinical Characteristics, and Sagittal Radiographic Alignment Details

Demographics	Frequency (%) or mean (±standard deviation)
Age, yr	59.3 ± 15.1
Gender (female)	73.4%
BMI	28.0 ± 9.0
Race	
White	91.8%
Black	3.6%
Hispanic	2.6%
Asian	1.2%
Other	0.9%
Clinical characteristics	
Smoking status (yes)	5.9%
Drug/alcohol abuse (yes)	2.7%
Frailty Index Score (ASD-FI)	0.33 ± 0.16
Charlson Comorbidity Index Score (CCI)	1.64 ± 1.65
Overall comorbidity prevalence	73.8%
Anemia	9.9%
Arthritis	37.7%
Depression	22.5%
Diabetes	9.0%
Heart disease	9.8%
Hypertension	35.5%
Kidney disease	4.2%
Liver disease	1.7%
Pulmonary disease	5.4%
Neurological disorder	3.5%
Osteoporosis	14.7%
Perivascular disease	2.1%
Psychological disease	4.5%
Sagittal radiographic alignment parameters	
Spinopelvic	
Pelvic tilt (PT)	23.4° ± 10.5°
Pelvic incidence - lumbar lordosis (PI-LL)	15.1° ± 22.5°
C7-S1 sagittal vertical axis (SVA)	62.1 ± 69.2 mm
T1 pelvic angle (T1PA)	22.1° ± 12.7°
Cervical	
T1 slope (T1S)	29.4° ± 13.5°
Cervical lordosis (CL)	10.2° ± 16.2°
T1 slope: cervical lordosis (TS-CL)	18.9° ± 11.8°
C2-C7 cervical sagittal vertical axis (cSVA)	29.3 ± 14.1 mm

2-yr-delayed PJK decreasing from 7.3% in 2009 to 0.9% in 2015 ($P < .05$). Incidence rates for 3-yr-delayed PJK have remained minimal and stable over time (1.8% in 2009 to 0.0% in 2014; $P = .401$). The overall incidence of progressive PJK was observed to be 35.0% and has remained stable over time ($P = .297$) (Table 3; Figure 1A-1D). When assessing the incidence of progressive PJK amongst acute PJK patients, the incidence rate was determined to be 72.9%. No differences were observed amongst the overall incidences of any (69.2 vs 69.5%; $P = .942$), acute (48.8 vs 47.5%; $P = .759$), progressive (35.8 vs 34.7%; $P = .835$), 1-yr-delayed (9.0 vs 10.1%; $P = .621$), 2-yr-delayed

TABLE 2. Patient Cohort Surgical Details

Surgical details	Frequency (%), mean (±standard deviation), or mode (frequency of mode, %)
History of prior spinal surgery	43.1%
Approach	
Anterior only	0.6%
Posterior only	64.5%
Combined	34.9%
Upper instrumented vertebra	Modes: T3, T4, T10 (11.8%, 14.6%, 25.4%)
Lower instrumented vertebra	Mode: ilium (65.6%)
Construct length	10.5 ± 4.5 levels fused
Techniques	
Any osteotomy	57.5%
Smith peterson	54.6%
Pedicle subtraction	11.6%
Corpectomy	0.8%
Vertebral column resection	2.3%
3-Column	64.5%
Any decompression	58.1%
Staged procedure (yes)	20.1%
Operative time (op-time)	368.0 ± 136.9 min
Estimated blood loss	1371.6 ± 1365.0 cc
Inpatient length of stay	7.7 ± 4.6 d

(3.9 vs 5.2%; $P = .906$), and 3-yr-delayed (0.7 vs 0.7%; $P = .981$) PJK amongst patients with and without prior spinal surgery. The rate of PJK patients progressing to PJF was 3.4% at 1 yr, 5.3% at 2 yr, and 4.3% at 3 yr.

Curvature Severity of PJK Stratified by Modality of Onset

Progressive PJK patients exhibited the most severe PJK curvatures ($24.5^\circ \pm 9.7^\circ$), followed by acute ($18.9^\circ \pm 8.0^\circ$), 1-yr-delayed ($15.5^\circ \pm 5.8^\circ$), 3-yr-delayed ($13.9^\circ \pm 2.3^\circ$), and 2-yr-delayed ($12.7^\circ \pm 3.4^\circ$) PJK patients. No temporal trends were

observed between 2009 and 2017 in regard to PJK curvature severities (all, $P > .05$) (Table 4).

DISCUSSION

PJK is a well-known complication that may occur following correction of ASD. Previous literature has estimated that the overall incidence of PJK is between 20 and 40%. Several risk factors for the development of PJK have been described, including age older than 55 yr, large baseline deformity, PT, PI-LL, greater degree of operative correction, fusion to the lower lumbar vertebrae and sacrum, and posterior and anteroposterior approach.^{20,30-33} However, few studies have attempted to classify PJK based on onset, and high-powered studies with extended follow-up are generally lacking.

Key Results

In the present study, 1005 operative ASD patients were analyzed longitudinally for varying modalities of PJK onset. The overall incidence of acute, progressive, and delayed PJK from 2009 to 2014 was found to be 69.4%, which is higher than previously reported estimates of 5 to 61%.^{28,33-39} Several possible reasons for the increased incidence of PJK in this cohort are appreciated. The definition used for PJK in this study ($\geq 10^\circ$ measure for the sagittal Cobb angle between the inferior endplate of the UIV and the superior endplate of the UIV + 2) is a debatably lax criterion, in which previous papers have argued may blur the line between PJK and a normal postoperative reciprocal change.⁴⁰ Many studies to date have also analyzed the incidence of PJK with relatively short follow-up and, as a result, may fail to capture delayed PJK development, which may account for as much as 44% of PJK diagnoses.²⁷ Additionally, the data for this analysis were obtained from multiple centers throughout the United States that specialize in the treatment of ASD. As such, the database used for this analysis might be skewed towards more challenging cases than previous studies, as evidenced by the high rate of revision surgery (revision rate: 43.1%) and severe baseline deformity (mean baseline SVA: 62.1 ± 69.2 mm).

TABLE 3. Annual and Overall Incidences of Acute, Progressive, and Delay Proximal Junctional Kyphosis

PJK categorized by time of onset	2009 (n = 109)	2010 (n = 96)	2011 (n = 79)	2012 (n = 41)	2013 (n = 102)	2014 (n = 131)	2015 (n = 111)	2016 (n = 222)	2017 (n = 114)	Total (n = 1005)	P value
Acute	46.8%	49.0%	49.4%	53.7%	52.9%	54.2%	50.5%	47.7%	31.6%*	48.0%	.038
Progressive	25.8%	33.9%	35.0%	18.5%	41.3%	41.3%	37.9%	35.7%	–	35.0%	.297
1-yr delayed	9.2%	10.4%	20.3%*	12.2%	15.7%*	6.1%	9.9%	3.2%*	–	9.3%	<.001
2-yr delayed	7.3%	7.3%	2.5%	4.9%	2.0%	5.3%	0.9%*	–	–	4.3%	.129
3-yr delayed	1.8%	3.1%	2.5%	0%	2.9%	0%	–	–	–	1.8%	.401
Overall incidence	65.1%	69.8%	74.7%	70.7%	73.5%	65.6%	–	–	–	69.4%	.594

An asterisk (*) or bold values indicate statistical significance.

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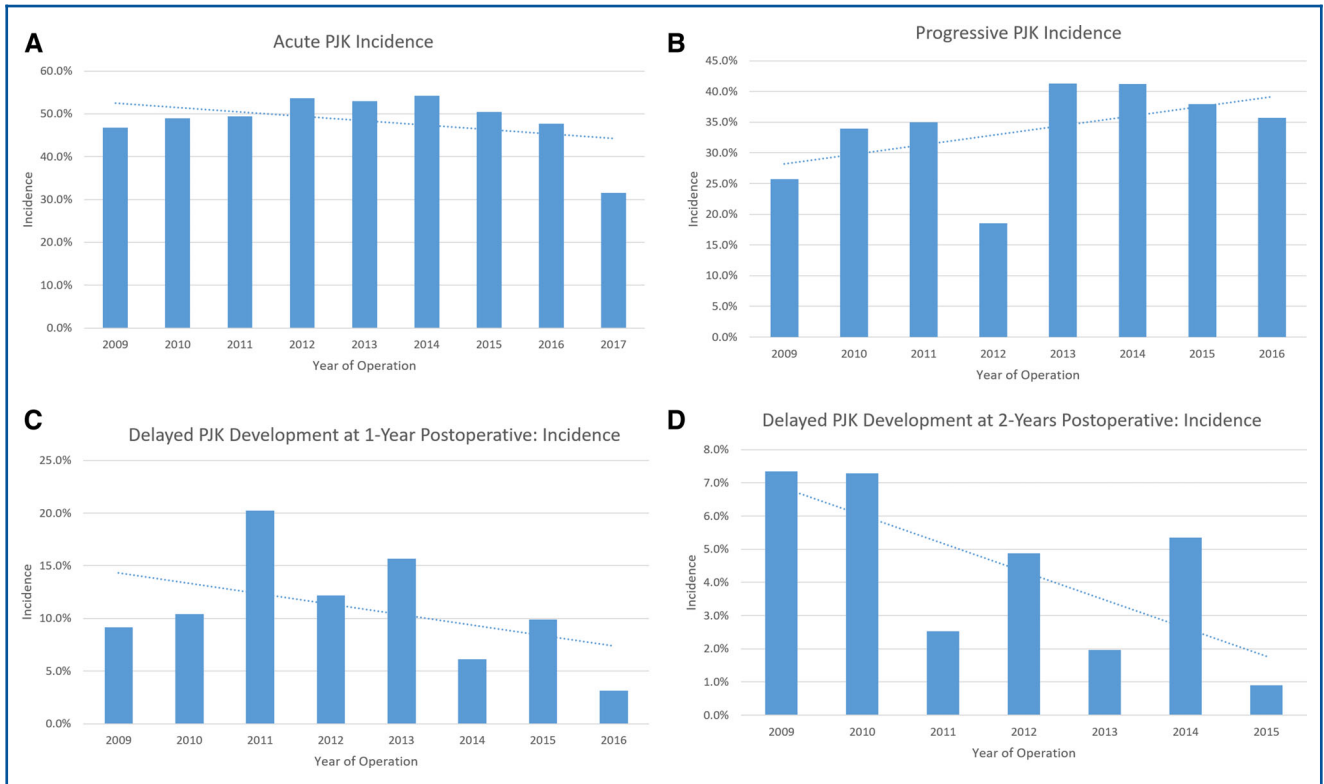


FIGURE. Annual incidences of acute, progressive, and 1- and 2-yr-delayed PJK. **A,** Annual incidence of acute PJK. **B,** Annual incidence of progressive PJK. **C,** Annual incidence of 1-yr-delayed PJK. **D,** Annual incidence of 2-yr-delayed PJK.

However, despite the high overall incidence of PJK described for this cohort, our study reports the incidence of acute PJK to be 48.0%, whereas the incidence of delayed PJK (1, 2, and 3 yr combined) was found to 13.6%. This finding falls in line with previous reports, indicating the majority of PJK cases to develop within the early postoperative period.²⁷ Previ-

ously, a study of 76 patients with adult scoliosis reported that 76% of PJK cases occurred within 3 mo postoperatively.⁴¹ The power and longevity of our study, in addition to findings from previous literature, provide further evidence that the majority of PJK cases will occur in the early postoperative period.

TABLE 4. Annual and Overall Mean Curvature Severities of Acute, Progressive, and Delay Proximal Junctional Kyphosis

PJK categorized by time of onset	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total	P value
Acute	18.1° ± 7.5°	19.5° ± 7.8°	20.6° ± 7.2°	18.0° ± 6.8°	20.7° ± 9.8°	18.8° ± 7.9°	19.2° ± 8.0°	18.2° ± 5.7°	17.1° ± 11.0°	18.9° ± 8.0°	.373
Progressive	23.0° ± 10.1°	25.5° ± 9.7°	25.9° ± 9.2°	21.4° ± 4.1°	24.3° ± 11.4°	25.4° ± 10.2°	22.5° ± 8.4°	24.3° ± 9.2°	–	24.3° ± 9.7°	.926
1-yr delayed	13.8° ± 3.8°	16.1° ± 8.0°	15.1° ± 6.7°	17.4° ± 3.5°	16.1° ± 5.0°	15.2° ± 5.8°	14.5° ± 4.1°	16.8° ± 8.9°	–	15.5° ± 5.8°	.940
2-yr delayed	12.3° ± 2.0°	14.4° ± 5.6°	12.3° ± 0.4°	14.9° ± 1.3°	12.2° ± 0.14°	11.7° ± 2.8°	7.9° ± 1.7°	–	–	12.7° ± 3.4°	.554
3-yr delayed	15° ± 1.8°	13.7° ± 2.3°	12.1° ± 1.7°	–	14.6° ± 3.3°	–	–	–	–	13.9° ± 2.3°	.666

An asterisk (*) or bold values indicate statistical significance.

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Interpretation

Although reports indicate that most PJK cases will develop in the perioperative period, PJK has also been described as a progressive process that can continue to worsen over the course of months or even years.^{9,41} Yagi et al found that PJK angles tended to progress in PJK patients even at long-term follow-up points, whereas they did not progress in non-PJK patients.⁴¹ Yagi reported that 35% of PJK patients had worsening PJK angles between 2-yr follow-up and final follow-up.⁴¹ In the present study, the overall incidence of progressive PJK was found to be 35.0% amongst all ASD patients and 72.9% amongst acute PJK patients. Whereas curvature progression and severity further than 1-yr follow-up was not assessed amongst progressive PJK patients within this analysis, these findings corroborate those described by Bridwell and Yagi that PJK is a progressive process that can continue to worsen in severity.

Of note, our findings also indicate a decline in acute and 1- and 2-yr-delayed PJK incidence amongst recent years. The decreasing incidence of acute PJK (53.7% in 2012 to 31.6% in 2017; $P = .038$), 1-yr-delayed PJK (9.2% in 2009 to 3.2% in 2016; $P < .001$), and 2-yr-delayed PJK (7.3% in 2009 to 0.9% in 2015; $P < .05$) described in this study is one that may corroborate advances in technology, surgical techniques, and preventative management strategies that have occurred over the last decade. For example, a recent review by Smith et al has identified increased understanding of risk factors for PJK, such as older age, low bone density, and overcorrection of lumbar lordosis. The utilization of junctional tethers intraoperatively has also been identified as an important factor that may reduce PJK rates by mitigating forces at the proximal junction.^{42,43} One recent study analyzing complication rates in 5803 patients undergoing ASD correction found a decreasing trend in morbidity from 37.9% in 2011 to 28.0% in 2014.⁴⁴

Despite recent trends delineating the declining rates of acute and delayed PJK incidence, our data describe a stable incidence of curvature progression (ie, progressive PJK) over the years studied (2010: 33.9% vs 2016: 35.7%; $P = .297$). Several studies have attributed the decrease in PJK rates to soft tissue protection, choice of valid level and instrumentation at the UTIV, adequate selection of material of rods, age-appropriate spinopelvic alignment goals, the use of junctional and posterior tethers, and ligament augmentation.^{34,45-47} Although this indicates that the onset of new PJK cases is diminishing, the patients who do develop PJK are exhibiting similar incidences of progressively worsening PJK curvatures. Recent developments, such as the Hart-International Spine Study Group PJK severity classification scale, have highlighted the dire outcomes associated with severe PJK, which typically result in surgical revision.^{15,48} Furthermore, a study by Bridwell and colleagues identified PJK curvatures of $\geq 20^\circ$ as a significant threshold for worse outcome scores in primary adult idiopathic/degenerative scoliosis.³² Our data show that progressive PJK patients on average had PJK curvatures of 24.3° by 1 yr, surpassing the threshold for adverse clinical outcomes and further highlighting the clinical significance of

progressive PJK. Given the high incidence of PJK and risk for continual curvature progression, further investigation is needed in order to identify risk factors, improve preventative management strategies, and aid in the development of innovative treatment technologies.

Limitations

Several limitations to this study are appreciated. Perhaps most importantly, the clinical impact of PJK is not unanimously agreed upon. Studies have shown that the current definition of PJK is associated with low revision rates and few neurological sequelae,^{13,28,49,50} and several studies have reported no significant correlation of clinical symptoms based on PJK.^{13,51-53} However, other studies have shown that a diagnosis of PJK is significantly associated with back pain, and an increasing PJK angle is associated with and is correlated to both pain and disability.¹²⁻¹⁵ Further research is needed before the clinical impact of the definition of PJK used for this study is fully realized. Additionally, although the multicenter methodology used for database correction increases the generalizability of our findings, the data analyzed for the purposes of this study may be skewed towards more complex cases than many other studies analyzing the incidence of PJK. Finally, although we were able to report extended follow-up for PJK, we were limited by loss of follow-up, which could contribute to selection bias.

CONCLUSION

This is a high-powered study analyzing the incidence of PJK with extended follow-up and provides valuable information regarding the incidence of varying developmental modalities of PJK onset. Although recent trends indicate that the onset of new acute and delayed PJK cases are diminishing, curvature progression remains a challenge for PJK patients and physicians. Further investigation into risk factors for PJK progression, as well as the quantification of health and disability status associated with acute PJK, progressive PJK, and delayed PJK, may benefit the development of improved management guidelines and clinical outcomes.

Disclosures

The International Spine Study Group (ISSG) is funded through research grants from DePuy Synthes and individual donations, which supported the current work. The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article. Dr Passias receives consulting fees from Medicea and SpineWave; serves on the Scientific Advisory Board for Allosource; receives teaching/speaking fees for Zimmer Biomet and Globus; has a grant from CSRS; and works on a research study for Aesculap. Dr Lafage owns stock in Nemarix; receives teaching/speaking fees from DePuy Synthes, NuVasive, K2M, and Medtronic; and is on the board of directors for Nemarix. Dr Smith receives royalties and fees for consulting and speaking/teaching from Zimmer Biomet; fees for consulting and speaking/teaching from NuVasive; fees for consulting from Carapedics; fees for speaking/teaching from K2M; and fellowship support from AOSpine and NREF. Dr Mundis receives royalties and fees for consulting from NuVasive and K2M; and grants from DePuy Synthes and NuVasive. Dr Nunley is an owner at and receives investment interest from Safwire

LLC; receives royalties from K2M; and receives royalties and fees for consulting from Zimmer Biomet. Dr Daniels receives royalties and fees for consulting from Stryker and Spineart. Dr Gupta receives royalties and fees for consulting from DePuy Synthes; owns stock in Johnson & Johnson and Procter & Gamble; receives fees for consulting from Orthofix; receives fellowship support and fees for speaking/teaching and honoraria from AOSpine North America; is on the board of directors for the Scoliosis Research Society; is treasurer for FOSA; and receives fellowship support from OMeGA. Dr Gum receives fees for consulting from Medtronic, NuVasive, Alphatec, Stryker, Acuity, K2M, and Mazor; fees for advising from NuVasive and K2M; royalties from Acuity; honorarium from Pacira Pharmaceuticals and Baxter; funds directly to the database company from NuVasive; research support from Norton Healthcare, Integra, Intellrod Spine Inc, International Spine Study Group Foundation, and Pfizer; and he is an employee of Norton Healthcare and owns stock in Cingulate Therapeutics. Dr Klineberg receives fees for consulting from DePuy Synthes, Stryker, Springer, and Trevana; honoraria from AOSpine and K2M; and fellowship support from AOSpine. Dr Burton receives fees for consulting from DePuy Synthes and Allosource; and is a patent holder for DePuy Synthes. Dr Hart receives royalties and fees for consulting from Seaspoine Orthopedics Corp, DePuy Synthes, Medtronic, Synthes GMBH, Innovasis, Titan Spine, K2M, and Globus Medical. Dr Schwab receives royalties and fees for speaking/teaching from and is a patent holder for Zimmer Biomet, NuVasive, K2M, and MSD; receives fees for speaking/teaching and consulting from Medtronic; and is on the board of directors and a shareholder for Nemaris. Dr Bess receives royalties and research support from K2M, Innovasis, and NuVasive; fees for consulting from K2M and Pioneer; royalties from Pioneer; and research support from DePuy Synthes Spine and Stryker. Dr Shaffrey is a patent holder for and receives royalties and fees for consulting from Medtronic, NuVasive, and Zimmer Biomet; owns stock in NuVasive; receives fees for consulting from K2M, Stryker, and In Vivo; and receives grants from the National Institutes of Health, Department of Defense, ISSG, DePuy Synthes, and AOSpine. Dr Ames receives fees for consulting from DePuy Synthes, Medtronic, and Stryker; receives royalties from Stryker and Zimmer Biomet; and is a patent holder for Fish & Richardson PC.

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Supplemental Digital Content. Figure. CONSORT 2010 patient flow diagram.

COMMENT

The authors present over 1000 patients and documented their proximal junctional kyphosis rates. The overall rate was approximately 69%, which is quite high compared to published rates, but more recent numbers are closer to 35%, which is more consistent with recent papers. The value of this paper is the numbers of patients and the follow-up. This is very useful, honest information and, given the high numbers of patients with good follow-up, probably provides an accurate representation of proximal junctional kyphosis rates and its trends over time as surgical techniques and understanding have evolved.

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