Journal of Clinical Neuroscience 56 (2018) 121–126

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.elsevier.com/locate/jocn

Clinical study

Clinical and radiographic presentation and treatment of patients with cervical deformity secondary to thoracolumbar proximal junctional kyphosis are distinct despite achieving similar outcomes: Analysis of 123 prospective CD cases

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ARTICLE INFO

Article history:
Received 2 April 2018
Accepted 25 June 2018

Keywords:
Cervical deformity
Proximal junctional kyphosis
Clinical outcomes
Complications
Radiographic evaluation

ABSTRACT

CD development secondary to PJK was recently documented in adult spinal deformity patients after surgical correction for thoracolumbar ASD. This study analyzes surgical management of patients with CD secondary to proximal junctional kyphosis (PJK) versus patients with primary CD. Retrospective review of multicenter cervical deformity (CD) database. CD defined as at least one of the following: C2–C7 coronal Cobb > 10°, cervical lordosis (CL) > 10°, cervical sagittal vertical axis (cSVA) > 4cm, CBVA > 25°. Patients were grouped into those with PJK (UIV +2 < −10°) prior to cervical surgery versus who don't (Non-PJK). Independent t-tests and chi-squared tests compared radiographic, clinical, and surgical metrics between PJK and non-PJK groups. Of 123 eligible CD patients, 26(21.1%) had radiographic PJK prior to cervical surgery. PJK patients had significantly greater T2–T12 thoracic kyphosis (−58.8° vs −45.0°, p = 0.002), cSVA (49.1 mm vs 38.9 mm, p = 0.020), T1 Slope (42.6° vs 28.4°, p < 0.001), TS-CL (44.1° vs 35.6°, p = 0.048), C2-T3 SVA (98.8 mm vs 75.8 mm, p = 0.015), C2 Slope (45.4° vs 36.0°, p = 0.043), and CTPA (6.4° vs 4.6°, p = 0.005). Comparing their surgeries, the PJK group had significantly more levels fused (10.7 vs 7.4, p = 0.01). There was significantly greater blood loss in PJK patients (1158 ± 1063vs 738 ± 793 cc, p = 0.028); operative time, surgical approach, and BMP-2 use were similar (all p > 0.05). PJK patients experienced higher rates of complications 30 and 90 days post-operatively (23.1% vs. 5.2%, p = 0.004; 30.8% vs. 19.6%, p = 0.026), and more instrumentation failure 30 days postoperatively (7.8% vs. 1.0%, p = 0.004). Patients with cervical deformity secondary to PJK had worse baseline CD, despite no differences in HRQL or demographics. Surgical correction of CD associated with PJK required more invasive surgery and had higher complication rates than non-PJK patients, despite achieving similar clinical outcomes.

1. Introduction

Cervical deformity has increased in prevalence in the recent years and much effort has been focused on appropriately

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https://doi.org/10.1016/j.jocn.2018.06.040
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assessing the condition. Given the heterogeneous nature of cervical deformity as well as the varied degrees of severity of the condition, surgical correction for cervical deformity has been focused on alignment correction and nerve decompression. The development of cervical deformity specifically resulting from adult thoracolumbar spinal deformity surgical correction as well as the high-risk pathologies of the cervical deformity population necessitate much consideration. Recent advances in understanding cervical deformity alignment targets and techniques have allowed for positive short-term clinical outcomes, though the lasting effects and robustness of deformity correction are challenging. Revision rates for cervical deformity correction are variable but have been reported to range from 9% to 20%, resulting from wound infection, nonunion, and other causes [1–4].

Surgical planning for adult thoracolumbar spinal deformity correction must take into consideration of the risk of a patient developing junctional kyphosis, a common concern among surgeons. Proximal junctional kyphosis (PJK) is defined as loss of alignment or construct failure at the upper-most instrumented vertebra (UIV) or one or two levels proximal to the UIV. PJK can be caused by insufficient fusion construct, over-correction, and/or poor bone quality and results in a compression fracture at the adjacent level, fixation failure, or spondylolisthesis [3,5].

Despite the occurrence of PJK being well described for patients with thoracolumbar deformities, the literature is sparse in investigating cervical deformity secondary to thoracolumbar PJK versus patients with primary cervical deformity. Cervical deformity development after adult thoracolumbar spinal deformity corrective surgery has been well documented [6–8]. One study found that rates of cervical deformity rose over the course of 2-year follow-up for adult spinal deformity corrective surgery and another showed that cervical malalignment could be predicted at 2-years using baseline factors in adult spinal deformity patients [9,10]. One study found that patients who underwent three-column osteotomies with the UIV in the upper thoracic spine who developed PJK also tended to develop concomitant cervical deformity [11]. Another study reported a 15% incidence of new onset cervical deformity in adult spinal deformity patients who developed PJK after surgical correction [12].

Cervical deformity development secondary to PJK has recently been documented in adult spinal deformity patients after surgical correction for thoracolumbar adult spinal deformity. This study aims to compare baseline radiographic measures, surgical management, complication rates, and clinical outcomes between patients with cervical deformity secondary to PJK versus patients with primary cervical deformity.

2. Methods

2.1. Data source

This study is a retrospective review of a prospectively-collected database of cervical deformity patients enrolled from 13 sites within the United States. Internal Review Board approval was obtained at each participating site prior to study initiation and informed consent was given by each included patient. Inclusion criteria for the database were patients ages ≥18 years, and radiographic evidence of cervical deformity at baseline assessment, defined as the presence of at least 1 of the following: cervical kyphosis (C2-7 Cobb angle > 10°), cervical scoliosis (C2-7 coronal Cobb angle > 10°), C2-7 sagittal vertical axis (cSVA) >4 cm, or chin-brow vertical angle (CBVA) >25°. Patients with active tumors or infections were excluded from the study.

2.2. Patient grouping

Patients were stratified at baseline presentation based on the presence or absence of PJK (PJK or non-PJK). PJK was present if the patient had previous thoracolumbar fusion and the proximal junctional angle measured by the angle between the UIV and the vertebra two segments cranial to the UIV (UIV + 2) at baseline was ≥10° [13].

2.3. Data collection

Demographic and clinical data collected included patient age, sex, body mass index (BMI), history of prior cervical surgery, and Charlson Comorbidity Index (CCI). Surgical data collected included operative time, estimated blood loss, surgical approach, off-label use of bone morphogenetic protein 2 (BMP-2), osteotomy use and number of osteotomies, levels fused, and instrumentation used.

Patients were evaluated using full-length free-standing lateral spine radiographs (36″ long-cassette) at baseline and 1 year postoperative follow-up visit. Radiographs were analyzed using dedicated and validated software (SpineView®; ENSAM, Laboratory of Biomechanics, Paris, France) at a single center with standard techniques [14–16]. Measured cervical spine parameters included cSVA (offset from the C2 plumbline and the postero-superior corner of C7), C2–C7 lordosis (CL: Cobb angle between C2 inferior endplate and C7 inferior endplate), T1 slope minus CL (TS-CL: mismatch between T1 slope and cervical lordosis), and CBVA (angle subtended between the vertical line and the line from the brow to the chin). Measured spinopelvic parameters (Fig. 1) included: sagittal vertical axis (SVA: C7 plumb line relative to the posterior-superior corner of S1), pelvic incidence minus lumbar lordosis (PI-LL: mismatch between pelvic incidence and lumbar lordosis), and pelvic tilt (PT: angle between the vertical and the line through the sacral midpoint to the center of the two femoral heads). Upper cervical parameters were also assessed, including the C0–C2 angle, C0 slope, C1 slope, and C2 slope.

2.4. Clinical outcomes assessment

Clinical outcomes were assessed using modified Japanese Orthopaedic Association (mJOA), Neck Disability Index (NDI). EuroQol Five-Dimensions (EQ-5D), and Numeric Scale Rating (NSR) Back and Neck scores at baseline and follow-up for patients with these time points (3-month, 6-month, 1-year).

2.5. Statistical analysis

PJK and non-PJK groups were compared for radiographic, clinical and surgical metrics using independent *t*-tests and Pearson χ^2 tests for continuous and categorical variables, respectively. Two-sided p-values <0.05 were considered to be statistically significant. All statistical analysis was conducted in SPSS version 23.

3. Results

3.1. Patient demographics

Out of 123 included cervical deformity patients, 26 (21.1%) had radiographic PJK prior to their cervical surgery. The most common diagnoses of patients without PJK were degenerative kyphosis, cervical myelopathy, and stenosis. There were no significant differences in age, gender, BMI, CCI, or history of prior cervical surgery (p > 0.05, Table 1). PJK and non-PJK patients had similar rates of

Fig. 1. Case examples of two patients, one with PJK (A) and one without PJK (B) prior to their cervical deformity surgery. Patient A is a 65-year-old woman and Patient B is a 52-year-old woman. The two patients have similar baseline demographics and health-related quality of life metrics. Patient A (with PJK) has greater baseline deformity and underwent a more invasive surgery, with one adverse event post-operatively, while Patient B did not have any complications.

history of smoking, diabetes, and osteoporosis (all $p > 0.05$). Fewer PJK patients were able to walk without any aid at baseline than cervical deformity patients without PJK (23.1% versus 43.3%, $p = 0.047$).

3.2. Baseline radiographic alignment between PJK and non-PJK groups

In comparing baseline radiographic parameters between the two groups (Table 2), PJK patients displayed significantly greater T2–T12 thoracic kyphosis (−58.8° vs −45.0°, $p = 0.002$), cSVA (49.1 mm vs 38.9 mm, $p = 0.020$), T1 Slope (42.6° vs 28.4°, $p < 0.001$), TS-CL (44.1° vs 35.6°, $p = 0.048$), and C2-T3 SVA (98.8 mm vs 75.8 mm, $p = 0.015$). PJK patients also had greater malalignment in with increased C2 Slope (45.4° vs 36.0°, $p = 0.043$), C2-S1 (−12.6° vs −1.3°, $p = 0.033$) and CTPA (6.4° vs 4.6°, $p = 0.005$). In looking at Ames adult cervical deformity classification modifiers at baseline, PJK patients had a higher percentage of cSVA grade 1 (4–8 cm) modifier than non-PJK patients (PJK: 76% versus non-PJK: 52.6%, $p = 0.048$) and more non-PJK patients had a grade 0 (<4 cm) cSVA modifier (PJK: 12% versus non-PJK: 39.2%, $p = 0.005$). TS-CL, horizontal gaze, and mJOA modifier distributions were similar between PJK and Non-PJK patients.

Table 1
Demographics and Surgical Details compared between cervical deformity patients with and without pre-operative PJK. Significance was set at $p < 0.05$.

Demographic variable	PJK	Non-PJK	P Value
Age	63.26 ± 11.14	59.87 ± 10.87	0.162
Body Mass Index	30.34 ± 7.54	29.87 ± 8.34	0.789
Charlson Comorbidity Idex	0.625 ± 1.01	0.750 ± 1.11	0.618
Gender (% Female)	18 (75%)	55 (57.3%)	0.086
Prior Cervical Surgery	11 (45.8%)	41 (44.1%)	0.528
History of Smoking	6 (28.6%)	29 (33.3%)	0.798
Diabetes	1 (4.2%)	16 (16.7%)	0.189
Osteoporosis	4 (16.7%)	11 (11.5%)	0.497
Ambulatory Status (% walking without any aid)	42 (43.3%)	6 (23.1%)	0.047*
Surgical Variable	PJK	Non-PJK	P Value
Levels Fused	10.68 ± 6.08	7.42 ± 3.76	0.01*
Estimated Blood Loss (cc)	1158.1 ± 1062.6	737.9 ± 792.9	0.028*
Operative Time (min)	349.0 ± 155.1	361.6 ± 213.2	0.778
BMP-2 Use	14 (58.3%)	38 (49.4%)	0.490
Surgical Approach			
Anterior Only	2 (7.7%)	18 (18.6%)	0.240
Posterior Only	17 (65.4%)	45 (46.4%)	0.122
Combined	7 (26.9%)	34 (35.1%)	0.491
Posterior LIV	T6	T4	0.004*
Osteotomy Use			
Partial Facet	1 (3.8%)	5 (5.2%)	0.627
Complete Facet	0 (0.0%)	6 (6.2%)	0.341
Smith-Peterson Osteotomy	10 (38.5%)	16 (16.5%)	0.018*
Opening Wedge	1 (3.8%)	0 (0.0%)	0.211
Closing Wedge	5 (19.2%)	17 (17.5%)	0.781
Vertebral Column Resection	2 (7.7%)	4 (4.1%)	0.606
Rods and Screws			
Transition Rods	13 (54.2%)	15 (19.5%)	0.002*
Pars Screw	10 (38.5%)	12 (12.4%)	0.004*
Lateral Mass Screw	20 (76.9%)	49 (50.5%)	0.013*

Table 2
Baseline Radiographic Measurements between PJK and Non-PJK patients. PT = pelvic tilt, PI-LL = pelvic incidence minus lumbar lordosis, SVA = sagittal vertical axis, TK = thoracic kyphosis, T1PA = T1 pelvic angle, CTPA = cervical-thoracic pelvic angle, TS-CL = T1 slope minus cervical lordosis. Significance was set at $p < 0.05$.

Radiographic parameter	PJK	Non-PJK	P Value
PT	22.85 ± 13.03	19.24 ± 10.99	0.157
PI-LL	3.48 ± 23.86	1.86 ± 16.08	0.683
C7-S1 SVA	11.67 ± 67.26	5.87 ± 73.92	0.719
C2-S1 SVA	64.86 ± 75.74	43.07 ± 77.85	0.236
C2-S1	−12.63 ± 17.59	−1.29 ± 23.02	0.033*
T4-T12 TK	43.85 ± 17.81	37.84 ± 15.49	0.092
T2-T12 TK	58.78 ± 23.9	45.04 ± 18.13	0.002*
T1PA	16.71 ± 14.87	13.63 ± 11.45	0.258
CTPA	6.44 ± 2.7	4.57 ± 2.71	0.005*
T1 Slope	42.64 ± 20.21	28.41 ± 15.91	<0.001*
TS-CL	44.08 ± 15.19	35.64 ± 18.32	0.048*
C2-C7 CL	−0.44 ± 25.62	−7.87 ± 18.43	0.120
C2-C7 SVA	55.23 ± 21.96	45.45 ± 25.54	0.101
C2-T3	−18.5 ± 23.77	−16.64 ± 19.69	0.703
C2-T3 SVA	98.82 ± 40.38	75.75 ± 39.01	0.015*
C2 Slope	45.4 ± 17.56	36.04 ± 19.66	0.043*
C1 Slope	5.2 ± 19.64	0.36 ± 17.3	0.236
C0 Slope	−0.85 ± 16.37	−1.91 ± 14.95	0.763
C0-C2 Angle	38.02 ± 13.08	32.53 ± 12.15	0.072

3.3. Surgical details between PJK and Non-PJK groups

The PJK group had significantly more levels treated (10.7 vs 7.4 levels, $p = 0.01$) and their average posterior LIV was more caudal (T6 versus T4, $p = 0.004$, Table 1). There were significantly more posterior column osteotomies performed in the PJK group (38.5% vs 16.5%, $p = 0.018$). Posterior lateral mass screws and pars screws were used significantly more frequently for patients with PJK than non-PJK (lateral mass: 76.9% vs. 50.5%, $p = 0.013$; pars: 38.5% vs. 12.4%, $p = 0.004$). There was significantly greater blood loss in patients with PJK (1158 ± 1063 cc vs 738 ± 793 cc, $p = 0.028$). However, operative time, surgical approach, and BMP-2 use did not significantly differ between the two groups (all $p > 0.005$).

3.4. Complication comparison between PJK and Non-PJK groups

Overall complication rates between PJK and Non-PJK patients were similar (Table 3). PJK patients experienced higher rates of minor complications 30 and 90 days postoperatively (23.1% vs. 5.2%, $p = 0.004$; 30.8% vs. 19.6%, $p = 0.026$). The most common minor complications experienced by PJK patients were minor vascular injury, loss of radiographic correction, and dysphagia. PJK patients also had higher instrumentation failure 30 days postoperatively (7.8% vs. 1.0%, $p = 0.004$).

3.5. Clinical outcomes

In comparing clinical outcomes between PJK and non-PJK patients, there were no significant differences in health-related quality of life scores at baseline, 3 months, 6 months, or 1 year for NDI, EQ-5D, mJOA score, NRS for back or neck pain (all $p > 0.05$, Table 4).

3.6. Case examples

Fig. 1 demonstrates two cervical deformity patients at baseline, one with PJK from a prior adult spinal deformity surgery and one patients without PJK (Fig. 1 and Table 5). Patient A is a 65-year-old woman with a CCI of 0. Patient B is a 52-year-old female with a CCI of 0. Patient A experienced one adverse event after discharge and patient B had no complications. The two patients have similar baseline demographics and health-related quality of life responses. Patient A (with PJK) has greater baseline deformity and underwent a more invasive surgery, with one adverse event post-operatively, while Patient B did not have any complications (Table 5).

Table 3
Complications compared between cervical deformity patients with and without PJK. Significance was set at $p < 0.05$.

Complication	PJK	Non-PJK	P Value
Any Complication (at any time point)	16 (61.5%)	63 (64.9%)	0.458
Re-Operation (any time)	6 (23.1%)	13 (13.4%)	0.180
Any Major	7 (26.9%)	25 (25.8%)	0.543
Any Minor	9 (34.6%)	29 (29.9%)	0.038*
Post 90-day complications	8 (30.8%)	19 (19.6%)	0.003*
Post 30-day minor complications	6 (23.1%)	5 (5.2%)	0.001*
Post 30-day Adverse Events	5 (19.2%)	12 (12.4%)	0.049*
Any Adverse Events	7 (26.9%)	22 (22.7%)	0.414
Cardiopulmonary	4 (15.4%)	10 (10.3%)	0.337
Dysphagia	5 (19.2%)	11 (11.3%)	0.002*
Dysphonia	0	3 (3.1%)	0.487
Electrolyte	0	1 (1.0%)	0.789
Gastrointestinal	0	3 (3.1%)	0.487
Infection	3 (11.5%)	9 (9.3%)	0.486
Instrumentation Failure	2 (7.8%)	1 (1.03%)	0.004*
Musculoskeletal	0	0	–
Neurologic	7 (26.9%)	23 (23.7%)	0.457
Operative	1 (3.8%)	7 (7.2%)	0.465
Organ Failure	0	2 (2.1%)	0.621
Radiographic	2 (7.7%)	5 (5.2%)	0.457
Renal	0	0	–
Vascular	0	2 (2.1%)	0.621
Wound	0	0	–

Table 4
Health-Related Quality of Life Scores compared between the PJK and Non-PJK patients. NDI = neck disability index, EQ5D = EuroQol Five Dimensions, mJOA = modified Japanese Orthopaedic Association, NSR = numeric scale rating. Significance was set at p < 0.05.

Time Point	Outcome measure	PJK	Non-PJK	P Value
Baseline	NDI	51.49 ± 17.09	48.68 ± 17.49	0.467
	EQ5D	0.74 ± 0.07	0.72 ± 0.06	0.157
	mJOA	13.43 ± 2.74	13.56 ± 2.66	0.845
	NSR Neck	6.88 ± 2.67	6.87 ± 2.27	0.098
	NSR Back	4.81 ± 3.57	5.25 ± 2.95	0.949
3 Month	NDI	42.86 ± 20.34	42.63 ± 18.96	0.961
	EQ5D	0.75 ± 0.1	0.76 ± 0.07	0.595
	mJOA	14.22 ± 2.13	14.36 ± 2.85	0.847
	NSR Neck	4.41 ± 3.53	4.49 ± 2.71	0.533
	NSR Back	4 ± 3.34	5.05 ± 2.97	0.452
6 Month	NDI	36.33 ± 22.2	33.62 ± 20.58	0.638
	EQ5D	0.75 ± 0.06	0.78 ± 0.09	0.130
	mJOA	14.6 ± 2.67	14.2 ± 2.82	0.624
	NSR Neck	3.88 ± 3.3	4.07 ± 2.99	0.117
	NSR Back	4.41 ± 3.48	5.12 ± 2.93	0.690
1 Year	NDI	39.49 ± 20.92	36.1 ± 19.3	0.529
	EQ5D	0.77 ± 0.09	0.79 ± 0.07	0.597
	mJOA	13.55 ± 2.88	14.21 ± 2.94	0.490
	NSR Neck	4.53 ± 2.96	4.06 ± 2.93	0.140
	NSR Back	4.29 ± 3.6	4.58 ± 3.02	0.881

Table 5
Comparison of two patients in case example in terms of demographics, baseline health-related quality of life metrics, surgical details, baseline radiographic measures.

	Patient A (PJK)	Patient B (no PJK)
Demographics		
Age (years)	65	52
Gender	Female	Female
Charlson Comorbidity Index	0	0
Ambulatory Status	3	5
Baseline HRQLs		
Neck Disability Index	64	84
Modified Japanese Orthopaedic Association	12	12
EuroQol Five Dimensions	0.647	0.666
Surgical Details		
Levels Fused	C2-T6	C2-T2
Estimated Blood Loss (cc)	1000	350
BMP use	Yes	No
Complications	1 adverse event after discharge	None
Baseline Radiographic Measures		
C2–C7 CL (°)	14.6	−7.4
cSVA (mm)	58.7	−1.7
T1 Slope (°)	51.1	11.4
TS-CL (°)	36.5	18.8
T4-T12 TK (°)	43	36
C2-T3 (°)	−19	−2
C2-T3 SVA (mm)	101	12.7
C2 Slope (°)	39.4	15

4. Discussion

Cervical deformity development secondary to PJK has recently been reported following surgical correction of ASD. The diagnosis, management, and prevention of PJK after ASD surgical correction has remained a challenge and increased attention has been focused on this complication. Prevalence rates of PJK following long fusions for ASD treatment vary widely in the literature, ranging from 6% to 62% [17]. This study aimed to analyze the surgical management and outcomes of patients with CD secondary to thoracolumbar ASD versus patients with primary CD. We found that 21.1% of CD patients in our prospective series of surgical cervical deformity patients had pre-operative PJK. CD patients with PJK had worse baseline deformity, despite no differences in demographics or HRQLs. Correction of CD with PJK required more invasive surgery and had higher minor complications than CD patients without PJK, despite achieving similar outcomes.

This is the first study to compare a population of cervical deformity patients with and without pre-operative PJK resulting from thoracolumbar ASD surgery. We found a prevalence of 21.1% of pre-operative PJK cases in this CD population. This rate is similar to previously published data on ASD patients who develop PJK after thoracolumbar correction, who report rates of 26–29% [11,13,17]. One group reported a 47.7% rate of post-operative CD development in an ASD population without pre-operative CD [18]. They showed that pre-operative T1 slope cervical lordosis mismatch was an independent predictor for CD development in ASD patients. We found that patients who developed CD secondary to thoracolumbar PJK had higher pre-operative T1 slope and higher TS-CL than patients with primary CD (Table 2). In addition, CD patients with PJK had higher C2-T3 SVA and C2 slope than patients without PJK, similarly to a study looking at PJK patients who develop cervical deformity after adult spinal deformity correction [12]. These findings emphasize the simultaneous occurrence of cervicothoracic as well as cervical specific malalignments inherent to these patients; effectively representing more severe deformities at baseline. In addition, more cervical deformity patients with PJK were non-ambulatory, with fewer patients being able to walk on their own without a cane or any other aid as compared to the cervical deformity patients without PJK.

We also found no differences in any demographic factors between the two groups. Osteoporosis is an established risk factor for PJK development, though our PJK patients did not have a significantly higher rate of osteoporosis than the non-PJK patients. Operative time, surgical approach, and BMP-2 use were similar between PJK and non-PJK patients. PJK patients underwent more invasive surgeries, with longer fusions and greater blood loss than patients without pre-operative PJK. There were no differences in overall complication rates between the PJK and non-PJK group, though PJK patients experienced higher rates of minor vascular injury, dysphagia, and loss of radiographic correction, as well as higher instrumentation failure at 30-days post-operative. This could be attributed to the more invasive surgeries of the PJK patients. The increase in minor complications in the PJK cohort again emphasizes the more severe deformity cases of the patients with PJK and the necessary more invasive surgeries.

Our study found no differences between outcome scores between CD patients with and without PJK for NDI, EQ-5D, mJOA, or NRS neck and back pain scores. Glattes et al demonstrated that PJK patients did not have lower outcome scores than patients without PJK in an ASD population [13]. Kim et al. also evaluated clinical outcome differences between patients with and without PJK and found no significant differences in SRS outcome scores, as well as similar scores in the SRS pain, self-image, function, and satisfaction subdomains between PJK and non-PJK patients [19]. Glattes and colleagues suggested that two possible explanations for the lack of difference in outcome measures between groups were that either there truly are no clinical differences in patient-reported outcomes in patients with radiographic PJK or that the SRS questionnaire is not sensitive enough to be able to evaluate these PJK patients adequately and accurately [13]. However, with longer follow-up we would expect differences in outcome measures as these patients are not at risk for DJK, though this is muted because the CD patients with PJK because they are revision surgeries.

The present study is the first to report the incidence of CD secondary to thoracolumbar PJK versus patients with primary CD and to describe their alignment, demographics, surgical details, complications and clinical outcomes following surgical correction of CD.

We acknowledge several limitations. Firstly, this is a retrospective and multi-center study comprised of high volume institutions with experienced spinal deformity surgeons, which might compromise the generalizability of the results. This study should also be evaluated with longer follow-up to fully assess the differences in long-term radiographic and clinical outcomes for cervical deformity patients with and without PJK.

5. Conclusion

We report a prevalence of pre-operative PJK of 21.1% among CD cases. Patients with CD secondary to PJK had worse baseline CD, despite no differences in HRQL or demographics. Surgical correction of CD associated with PJK required more invasive surgery and had higher complication rates than non-PJK patients, despite achieving similar outcomes. Future studies should investigate these differences with longer follow-up and in a larger cohort of patients.

6. Ethical review committee statement

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.

7. Levels of evidence

Level III.

Acknowledgements

The International Spine Study Group (ISSG) is funded through research grants from DePuy Synthes and individual donations, and supported the current work.

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