Time to Development, Clinical and Radiographic Characteristics, and Management of Proximal Junctional Kyphosis Following Adult Thoracolumbar Instrumented Fusion for Spinal Deformity

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Study Design: A retrospective review.

Objective: To study time to development, clinical and radiographic characteristics, and management of proximal junctional kyphosis (PJK) following thoracolumbar instrumented fusion for adult spinal deformity (ASD).

Summary of Background Data: PJK continues to be a common mode of failure following ASD surgery. Although literature exists on possible risk factors, data on management remain limited.

Methods: A retrospective review of medical records of 289 consecutive ASD patients who underwent posterior segmental instrumentation incorporating at least 5 segments was conducted. PJK was defined as proximal kyphotic angle >10 degrees.

Results: PJK occurred in 32 patients (11%) at a mean follow-up of 34 months (range, 1.3–61.9 ± 19 mo). Sixteen (50%) patients were revised (mean, 1.7 revisions; range, 1–3) at a mean follow-up of 9.6 months (range, 0.7–40 mo); primary indications for revision were pain (n = 16), myelopathy (n = 6), instability (n = 4), and instrumentation protrusion (n = 2). Comparison of preindex and postindex surgery radiographic parameters demonstrated significant improvement in mean lumbar lordosis (24 vs. 42 degrees, $P < 0.001$), pelvic incidence-lumbar lordosis mismatch (30 vs. 11 degrees, $P < 0.001$), and pelvic tilt (29 vs. 23 degrees, $P < 0.011$). The mean T5–T12 kyphosis worsened (30 vs. 53 degrees, $P < 0.001$) and the mean global sagittal spinal alignment failed to improve (9.6 vs. 8.0 cm, $P = 0.76$). There was no apparent relationship between the absolute PJK angle and revision surgery ($P > 0.05$).

Conclusions: The patients in this series who developed PJK had substantial preoperative positive sagittal malalignment that remained inadequately corrected following surgery, likely resulting from a combination of inadequate surgical correction and a significant compensatory increase in thoracic kyphosis. In the absence of direct relationship between a greater PJK angle and worse clinical outcome, clinical symptoms and neurological status rather than absolute reliance on radiographic parameters should drive the decision to pursue revision surgery.

Key Words: adjacent segment failure, complications, instrumentation, kyphosis, proximal junctional kyphosis, spine

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With an increasing prevalence of adult scoliosis secondary to the demographic shift toward an older population in many developed countries, including the United States,[1] the number of complex spine procedures for patients with adult spinal deformity (ASD) has increased substantially over the last decade. There has been increasing literature demonstrating efficacy of adult deformity surgery for patients who are symptomatic with intractable back pain, radiculopathy, or neurogenic claudication.[2–5] Improved understanding of the importance of sagittal spinal alignment and increasing recognition of the role of the pelvis in sagittal alignment have led to development of ideal realignment goals that are associated with better health-related quality of life after surgery to correct deformity.[6] However, despite considerable advances in the surgical treatment of ASD, these procedures continue to be associated with relatively high rates of complications.[2,7–11]

Proximal junctional kyphosis (PJK) refers to the development of kyphosis at the segments immediately

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cephalad to a spinal fusion construct. Its definition has been somewhat arbitrarily applied and has been described as the angle created between the inferior endplate of the most cephalad fused vertebrae and the superior endplate of the first or second mobile vertebrae cephalad to the most proximal fused segment.[12–18] Kyphosis of > 5–15 degrees, whether absolute or change from preoperative to postoperative measures, has been defined as abnormal.[19–21] Although development of PJK following long-segment instrumented spinal fusion remains a challenging and poorly understood complication, several surgical nuances have been suggested to reduce its occurrence. These include preserving the superjacent facets and supraspinous ligament, selecting the upper-most instrumented vertebrae (UIV) to be at a level without posterior column deficiency (eg, laminectomy), listhesis, rotation, or junctional kyphosis, and avoiding a UIV location at the apex of the deformity in either coronal or sagittal planes.[13–18]

PJK develops in a significant number of patients after adult deformity surgery, adding to the morbidity and cost of these complex spine procedures.[15,16,18,21–30] Previous reports describing rates of PJK and risk factors predisposing to the condition have varied, including some reports that have failed to determine any demographic, radiographic, or instrumentation-related risk factors.[17,18,22,25,26,31–33] Due in part to the heterogeneity of cases reported, the quoted incidence ranges from 9% to 46%.[15,16,18,21–28,34,35] Reoperation rates are less commonly reported and range from 0% to 18%.[18,29,31,34,36] The considerable range in reoperation rates may reflect inconsistency between radiographic findings and clinical symptoms. In the present study, we reviewed a consecutive series of adults who developed PJK following surgical correction of spinal deformity, with the objectives of assessing time to development, clinical and radiographic characteristics, and management of PJK.

METHODS

Patient Population

This study was approved by the institutional review board (IRB) of the hospital (IRB #15093). A retrospective review of the medical records and radiographs of consecutive adult (above 18 y) thoracolumbar spinal deformity patients who underwent posterior segmental instrumentation using all pedicle screw constructs spanning at least 5 vertebral segments was conducted. This procedure was termed the index procedure. The diagnosis of ASD was based on the presence of ≥ 1 of the following radiographic criteria: scoliosis curve (idiopathic or degenerative) > 30 degrees, sagittal or coronal imbalance > 5 cm, thoracic kyphosis (TK) > 60 degrees (T3 or T5–T12), lumbar lordosis (LL) < 30 degrees, or thoracolumbar kyphosis (T10–L2) > 20 degrees. Patients with history of spinal surgeries before the index procedure were not excluded. Basic preoperative data collected included: age and diagnosis at time of index surgery, sex, presence/absence of osteopenia/osteoporosis, smoking status, body mass index, prior spinal surgery, neurological status, and medical comorbidities. Operative reports, hospital records, and follow-up clinic notes were available and reviewed for all patients. Operative details were collected from hospital charts and included: surgical exposure used, staged versus same day surgery, length of surgery, estimated blood loss, number of levels fused, blood transfusions, type of bone graft used, type of instrumentation, osteotomies performed, and intraoperative complications.

Radiographic analysis was performed on posteroanterior and lateral 36-inch full-length standing radiographs obtained with the knees and hips fully extended and the hands resting on the clavicle. Spinal measurements were performed according to the *Spinal Deformity Study Group Radiographic Measurement Manual* and were obtained preoperatively, postoperatively, at last follow-up, and immediately before revision surgery (if performed).[37] On the lateral radiographs, sagittal vertical axis (SVA) was measured as the horizontal distance from the C7 plumb line to the posterosuperior corner of the S1 vertebral body. TK was measured from the cephalad endplate of T5 to the caudal endplate of T12, and LL was measured from the caudal endplate of T12 to the cephalad endplate of S1. Pelvic parameters, including pelvic incidence (PI), pelvic tilt (PT), and sacral slope, were also measured at the same time intervals as previously described.[38] The proximal junction was defined as the caudal endplate of the UIV to the cephalad endplate of 2 vertebrae proximal to the UIV (ie, UIV + 2). The proximal junctional angle was measured as the angle between the inferior endplate of the UIV and the superior endplate of the UIV + 1 or UIV + 2, depending on which measure produced the greatest angle (Fig. 1). PJK was defined as a proximal kyphotic angle > 10 degrees.

Statistical Analyses

Summary statistical analysis was performed using SPSS software version 16 (SPSS version 16; SPSS Inc.). For continuous variables, paired samples *t* tests were used to calculate statistical significance. Statistical analyses were 2-sided, and a probability value < 0.05 was considered statistically significant. Demographic data, length of follow-up, and time to initial revision after index surgery are presented as mean values ± 1 SD.

RESULTS

Of the 289 cases that met the inclusion criteria, PJK occurred in 32 patients (11%) at a mean follow-up of 34 months (range, 1.3–61.9 ± 19 mo). Among these patients, the mean age at the time of index surgery was 66 years, with female predominance (F:M ratio of 3:1) and an average body mass index of 30. Details of the patients with PJK are summarized in Table 1. The most common comorbidities among these patients included: osteopenia/osteoporosis, hypothyroidism, history of smoking, osteoarthritis, peripheral neuropathy, and movement disorder (Table 2). At the time of index surgery, 94% of the patients were not smokers. Seventeen (53%) of the patients who developed PJK had undergone ≥ 1 spinal surgeries before the index procedure. Indications for

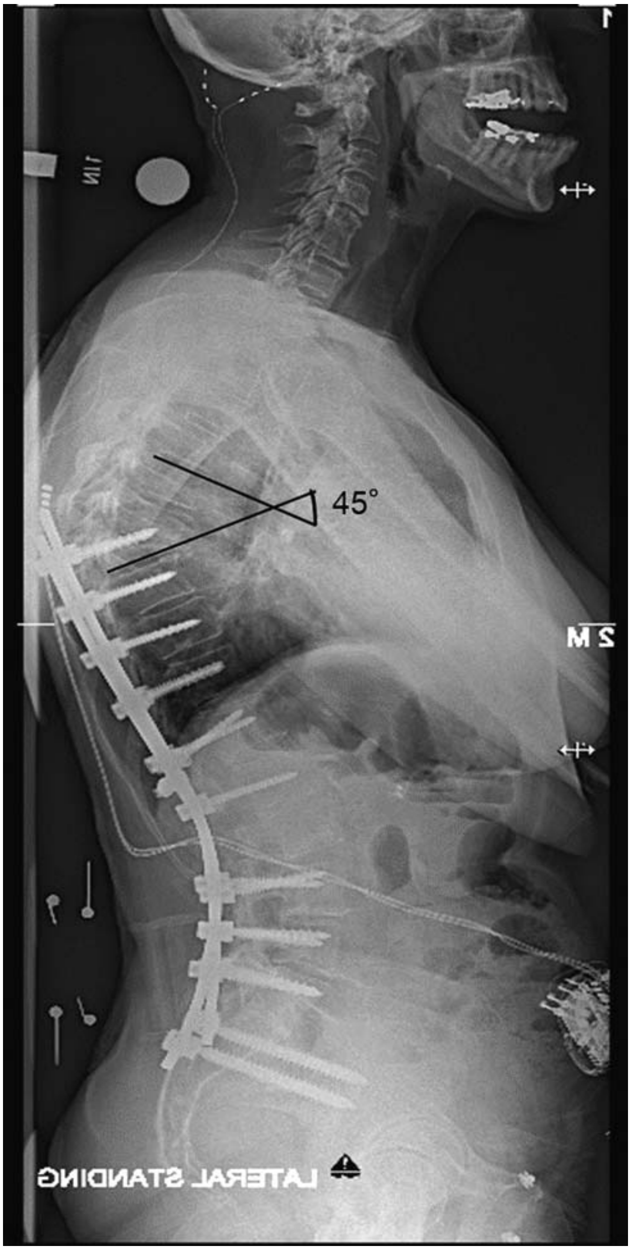

FIGURE 1. Representative x-ray demonstrating calculation of proximal junctional kyphosis angle.

TABLE 1. Patient Characteristics*

Sex	24 female/8 male	3:1
Prior surgery†	17	53%
	Average	SD (Minimum–Maximum)
Age (y)	66	7 (46–80)
Body mass index	30	7 (17–47)
Follow-up (mo)‡	34	19 (1.3–61.9)

*At index surgery.
†Average of 2.9 prior surgeries each for revision cases.
‡From index surgery.

TABLE 2. Medical Comorbidities*

Medical Comorbidities†	No. Patients [n (%)]
Smoker (current, previous, never)	2/8/22 (6/25/69)
Osteopenia/osteoporosis	10 (31)
Hypothyroidism	10 (31)
Osteoarthritis	7 (22)
Essential tremor/Parkinson disease	4 (13)
Peripheral neuropathy	4 (13)
Prostate/pelvic radiation	2 (6)
Chronic renal insufficiency	2 (6)
Rheumatoid arthritis	1 (3)
Dementia	1 (3)
Fibromyalgia	1 (3)
Polio	1 (3)
Autoimmune disease	1 (3)

*At index surgery.
†Relevant medical comorbidities included.

previous surgeries (before index) varied and ranged from degenerative spondylosis to complex kyphoscoliosis, with degenerative scoliosis representing the majority of cases.

For the index surgeries, the most common UIV was T10/T11 (94%), with 1 patient each having a UIV of T4 or L1. The most common lower-most instrumented vertebra (LIV) was the sacrum (94%) with addition of iliac fixation in 84% (25/30) of these patients. The remaining 2 patients had an LIV at the L5 level. Development of a compression fracture in the proximal junctional region (UIV, UIV + 1, or UIV + 2) at any point during follow-up occurred in 25 patients (78%), and pseudarthrosis at any location within the construct developed in 11 (34%) patients. Of the 32 cases of PJK, 16 (50%) were revised (mean of 1.7 revisions per revised patient; range, 1–3 revisions) at a mean follow-up of 9.6 months (range, 0.7–40 mo) (Table 3). Primary indications for revision included: pain (n = 16), myelopathy (n = 6), instability (n = 4), and instrumentation protrusion (n = 2) (Table 4). Figures 2 and 3 show representative images of one of the patients who developed PJK and underwent revision surgery.

Comparison of preindex and postindex surgery radiographic parameters demonstrated significant improvement in mean LL (24 vs. 42 degrees, $P < 0.001$), PI-LL mismatch (30 vs. 11 degrees, $P < 0.001$), and PT (29 vs. 23 degrees, $P < 0.011$) (Table 5). Although these lumbopelvic sagittal alignment parameters demonstrated significant postoperative improvement, the mean T5–T12 kyphosis worsened (30 vs. 53 degrees, $P < 0.001$) and the mean global sagittal spinal alignment (SVA) failed to improve (9.6 vs. 8.0 cm, $P = 0.76$). There was no apparent relationship between the absolute PJK angle and revision surgery; specifically, a greater PJK angle was not significantly associated with a greater likelihood of revision surgery ($P > 0.05$) (Table 6).

DISCUSSION

Long-segment adult instrumented fusion may be indicated for management of conditions such as degenerative lumbar scoliosis, positive sagittal malalignment, transition syndrome, and revision spine surgeries. Management of

TABLE 3. Surgical and Follow-up Details of Patients With Proximal Junctional Kyphosis

Surgery	Previous Surgery (Before Index Procedure)	Diagnosis at Index Surgery	New Compression Fracture	Subsequent Revisions	Time to Initial Revision (mo)
T10–iliac (17) T11–iliac (6) T10–S1 (5) T11–L5 (1) L1–iliac (1) T11–L4 (1) T4–iliac (1)	17 (53%)	26 degenerative scoliosis 6 adjacent segment disease secondary to prior surgery	25 (78%)	16 (50%) Average 1.7 revisions	9.6 (0.7–40)

adult spine deformity has undergone significant changes over the last decade. The use of stronger segmental pedicle screw constructs has enabled better correction of deformity by facilitating more aggressive osteotomies, such as multilevel Smith-Petersen osteotomies, pedicle subtraction osteotomies, and posterior vertebral column resections.[39–41] Improved appreciation of the importance of overall spinal sagittal alignment and the role of the pelvis in spinal alignment has generated clearer surgical realignment goals to optimize improvement in health-related quality of life following surgical management of adult deformity patients.[6,42] In addition to medical and perioperative complications common in this group of patients secondary to multiple comorbidities and older age,[8,10,11] complications related to increased stress placed on the adjacent segments, possibly due to the rigid fixation, remain of concern. PJK developing adjacent to long-segment instrumented fusions following adult surgical deformity surgery remains poorly understood and continues to be a significant source of morbidity.[13,16,18,21,26,43]

Although many potential risk factors for the development of PJK have been proposed, there remains relatively limited understanding of the pathophysiology underlying PJK.[21] Various theories proposed for PJK include extensive paraspinal muscle dissection at the UIV, disruption of the supraspinous and interspinous ligament (posterior tension band), improper end-vertebra selection, proximal severe disk degeneration, compression fracture at the UIV or vertebrae above the UIV, instrumentation failure at the proximal construct, facet violation, screw pullout, or vertebral body/pedicle fracture.[13–18,21,25,26,36,43–46] Preoperative factors such as preexisting degenerative changes or 1-level junctional kyphosis of >5 degrees above the proposed UIV have also been implicated as risk factors.[22]

The incidence of PJK in the adult population is significant and ranges from 10% to 40%. This variability is due primarily to a somewhat arbitrarily applied definition in addition to differences in duration of follow-up. Lee et al[22] reviewed 69 patients treated with instrumented posterior spinal fusion and reported a 46% incidence of abnormal proximal kyphosis at the proximal junction of the instrumentation at 2-year follow-up in patients with adolescent idiopathic scoliosis. Similarly, Glattes et al[26] examined 81 patients with instrumented segmental posterior spinal fusion and reported the incidence of PJK as 26%, with a mean junctional sagittal Cobb angle in patients with PJK of 19.4 degrees (range, 11–33 degrees). Yagi et al[18] reported an overall 20% incidence of PJK after surgery for adult idiopathic scoliosis at an average follow-up of 4.3 years. Likewise, Kim et al[13] and Mendoza-Lattes et al[16] reported an incidence of 37.5% and 35% for PJK at 7.8 and 2.8 years of mean follow-up, respectively. The incidence of PJK in the present study was 11% at a mean follow-up of 34 months, which is on the lower side of the spectrum of PJK previously reported (range, 9.2%–40%).

Rhee et al[47] in a study comparing anterior versus posterior treatment for AIS implicated the posterior approach as a risk factor for development of PJK. On the contrary, patients with a T1 through T3 UIV, combined anteroposterior surgery, and increased sagittal sacral vertical line difference were found to have a higher likelihood of developing PJK in a retrospective review by Kim et al.[28] Even among the better described risk factors, little understanding of the relative contribution of each to the development of PJK exists. Some experts have suggested that early occurrence of PJK may relate to extensive paraspinal muscle dissection at the UIV, disruption of the supraspinous and interspinous ligament (posterior tension band), or facet violation, whereas PJK presenting at long-term follow-up may relate more to end-vertebra selection, proximal severe disk degeneration, compression fracture at the UIV or vertebrae above the UIV, instrumentation failure at the proximal construct, or instrumentation failure.[30]

TABLE 4. Indications for Revision Surgery

- Pain (16)
  - Focal only: 9 (1 with concomitant rod fracture, 1 with concomitant screw protrusion)
  - Radicular only: 1
  - Both focal and radicular: 6
- Signs of myelopathy (6)
  - 5 directly related to PJK
  - 1 secondary to dural kinking at level of recent PSO*
- Signs of instability (4)
  - 3 directly related to PJK
  - 1 case of instability at distal junction*
- Other (2)
  - Screw protrusion at PJK†

94% revised for pain were for focal pain with or without associated radicular pain. Only 1 case revised solely for radicular pain.

*Only 2 revisions not performed directly for PJK (these patients had additional revisions for PJK).

†Additional screw protrusion listed under pain category.

PJK indicates proximal junctional kyphosis.

FIGURE 2. Preoperative posteroanterior and lateral standing long cassette radiographs demonstrating flat-back deformity (3 degrees of lumbar lordosis), significant positive sagittal imbalance (>27 cm), and subtle left convex degenerative lumbar scoliosis.

Significant correction of sagittal malalignment by long-segment instrumented fusion using segmental pedicle screw constructs from the thoracolumbar junction to the sacrum, as well as older age, smoking, osteopenia, and severe global sagittal positive malalignment have been previously reported as risk factors for vertebral fracture in the proximal junction regions resulting in PJK, as was also seen in the present study.[17] As fracture of the UIV or supradjacent vertebrae has been shown to be one of the etiologies for PJK after long-segment instrumented fusion, prophylactic vertebroplasty has been tried at the UIV for elderly or osteoporotic patients.[17] Hart et al[33] suggested that prophylactic vertebral augmentation (2-level vertebroplasty) is cost-effective compared with the cost of performing revision fusion surgery for proximal junctional acute collapse after multilevel instrumented lumbar fusion in female patients over the age of 60 years. Kebaish et al[29] in a cadaveric model demonstrated significantly lower rates of PJK with 2-level kyphoplasty. However, there is lack of high-quality evidence in favor of prophylactic kyphoplasty at the proximal junction and the use of bone cement potentially reduces the nutrient supply to adjacent intervertebral disk, and thus may potentially accelerate disk degeneration. In addition, cement augmentation while potentially adding to the strength of the vertebra, alters the load transfer in adjacent vertebrae decreasing the ultimate load to failure of adjacent vertebrae, which may facilitate subsequent collapse of adjacent vertebrae.[48]

Patients with PJK may present with pain, neurological deficit, ambulatory difficulty, or abnormal posture.[17,18,49] Multiple studies, including the present, have shown that not all cases of PJK require revision. Yagi et al[18] reported an overall incidence of PJK of 20%; only 12.5% of patients who developed PJK required revision surgery with most of the patients with PJK reporting similar mean Scoliosis Research Society outcome scores and Oswestry Disability Index as the non-PJK group. Similarly, despite a radiologic incidence of 41%, only 13% required revision surgery in the study by Maruo et al,[34] in which they cited change in LL >30 degrees and preexisting TK >30 degrees as independent risk factors for PJK. Recently, McClendon et al[49] reported pain as a main contributor for need for treatment following development of PJK in their surgical series of 7 patients with PJK, a finding seen in the present study as well in which all patients who underwent revision for PJK had significant local pain. In addition to pain, development of myelopathy, instability, or abnormal protrusion of the instrumentation secondary to PJK can also warrant

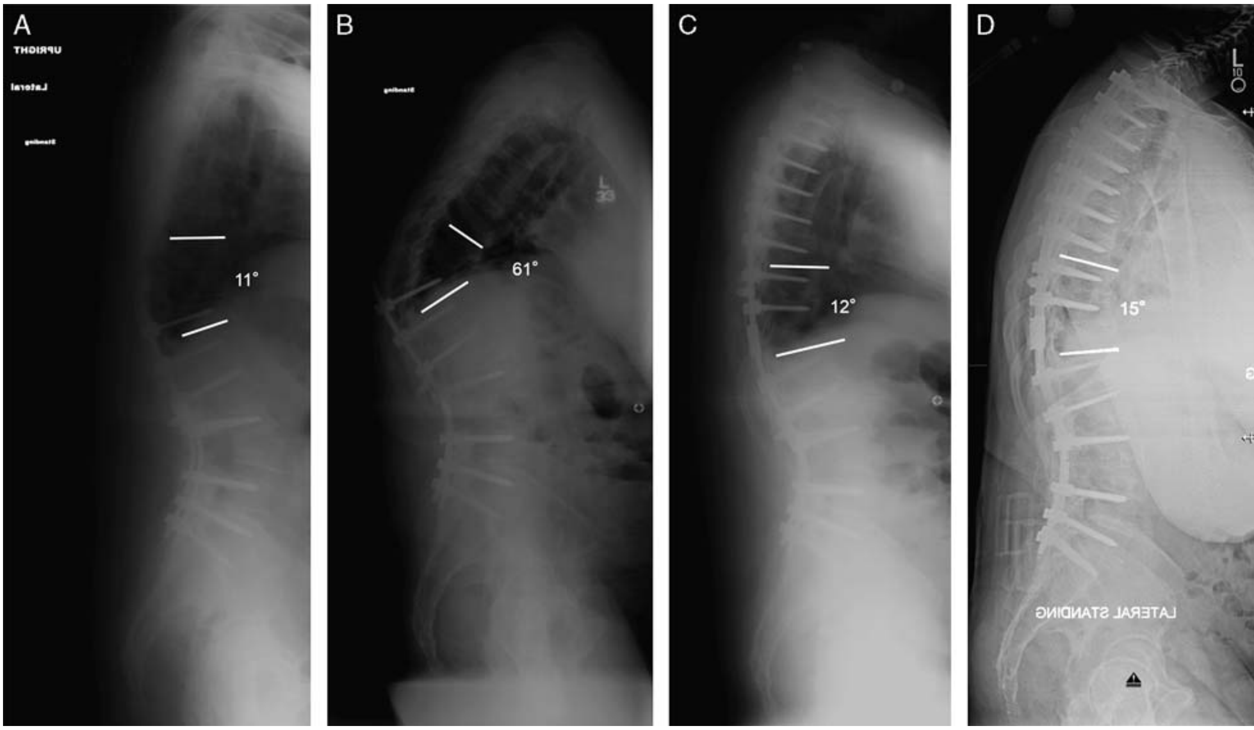

FIGURE 3. A, Lateral standing long cassette radiograph of the patient 2 weeks after index surgery demonstrating significant improvement in lumbar lordosis (44 degrees) and sagittal imbalance (4.4 cm). B, Notice development of focal kyphosis (61 degrees from T9 to T11) resulting from new anterior wedge compression deformity at T11 and increased sagittal imbalance, 15 cm on the radiograph preoperative to revision surgery (6 wk after index surgery). C, Lateral long cassette radiograph 1 week after revision demonstrating correction of previous T9–11 PJK (12 from 61 degrees) and improved sagittal balance (5 from 15 cm) with maintenance of correction of previous T9–11 PJK, but some loss of sagittal balance (9.3 cm) at follow-up radiograph (D) at last follow-up (42 mo after index surgery). PJK indicates proximal junctional kyphosis.

revision surgery as was seen in the present study (Table 4).[17,18,49]

In the present series, all patients who underwent revision surgery for PJK did so for worsening of clinical symptoms attributed to the PJK. When pain was the indication for revision, it was present only focally at the level of PJK in 9 cases, radicular only in 1 case, and both focal and radicular in 6 cases. The pain described by these patients is likely a combination of both a focal pain syndrome related to the level of PJK, whether neurogenic or osteogenic, and the well-described clinical syndrome attributable to sagittal decompensation, which is increasingly recognized as a critical factor impacting functional outcome.[6,42] Preservation of the normal anatomic spinal curvature (cervical lordosis, TK, and LL) is known to be critical for efficient coupling of muscle activation and motor movement, energy absorption, and maintenance of posture.[6,42] Myelopathy was a result of focal compression at the site of PJK in 5 of 6 cases with the remaining case experiencing myelopathy at the level of the PSO. Three of the 4 cases revised for instability were at the level of PJK, whereas 1 patient experienced distal spondylolisthesis. A single patient was revised secondary to instrumentation protrusion.

The finding that not all patients in this study were revised corresponds with previous reports which demonstrate

TABLE 5. Imaging Characteristics

	Preoperative* (Revised/Not Revised) (deg.)	Postoperative*† (Revised/Not Revised) (deg.)	P‡
Sagittal vertical axis (mm)	96 (105/89)	80 (80/80)	0.76
T5–T12 kyphosis	30 (26/34)	53 (47/58)	< 0.001
Lumbar lordosis (LL)	24 (24/24)	42 (43/41)	< 0.001
Pelvic incidence (PI)	54 (54/54)	53 (56/50)	NS
Pelvic tilt	29 (28/30)	23 (24/23)	0.011
PI-LL mismatch	30 (30/30)	11 (13/9)	< 0.001

*Relative to index surgery.
†Average of 48 days from index surgery.
‡Calculated with Fisher Exact (χ^2) paired t test.

TABLE 6. PJK: Time to Development and Measurement (Revised vs. Not Revised)

	Time to PJK Diagnosis (range) (d)	Patients With Early PJK Diagnosis [n (%)]	PJK Angle Preoperatively (deg.)	PJK Angle Postoperatively (deg.)	PJK Angle Before Revision (deg.)	PJK Angle at Last Follow-up (deg.)
Overall	194	12 (38)	9	27	N/A	27
Required revision	214 (4–885)	5 (31)	8	22	31	19
No revision	174 (33–967)	7 (44)	11	33	N/A	40

PJK indicates proximal junctional kyphosis.

that, although radiographic findings of adjacent segment disease are relatively common, there does not seem to be a consistent correlation with clinical symptoms in many cases.[17,18,32] More than the development of PJK itself, the clinical symptomatology tends to drive the need of surgical intervention as demonstrated in a recent study by O'Shaughnessy et al,[32] in which patients with instrumentation in the lower thoracic spine despite having a higher incidence of PJK required fewer revision surgeries compared with patients with instrumentation extending into the upper thoracic spine. Thus, routine prophylactic extension of fusion into the thoracic spine solely to obviate the problem of PJK may not necessarily be warranted in patients with adult scoliosis.[28] This has been echoed in a number of studies in which there was no difference in prevalence of PJK based on whether the UIV was in the upper thoracic versus lower thoracic/upper lumbar spine.[35,50,51] Similarly, there was no difference in the incidence of PJK depending on the selection of UIV at T9–L1 level in a study by Kim et al.[24] Considering that PJK defined radiographically has been infrequently associated with revision surgery and seems to have a limited impact on clinical outcomes for the majority of patients, there has been an attempt to distinguish PJK from proximal junctional failure, which has been defined as a change of >10 degrees of kyphosis between the UIV and the vertebra 2 levels above the UIV, along with presence of $1\geq$ of the following: fracture of the vertebral body of UIV or UIV + 1, posterior osseoligamentous disruption, or pullout of instrumentation at the UIV.[33,35,51]

Recent advances in our understanding of overall global spinopelvic alignment, as well as reciprocal changes and compensatory mechanisms in the unfused spine after spinal instrumentation for adult scoliosis have added further insights into understanding PJK.[52] Evaluation of TK and the balance between the LL and TK also seem to be important factors in the development of PJK.[16,34,52] Correction of SVA to near zero may also be a risk factor for development of PJK, as reported by Mendoza-Lattes et al[16] who suggested that a correction goal of SVA within 5 cm rather than to zero may reduce the risk of PJK. In the present study, the mean SVA before the index procedure was nearly 100 mm, reflecting a patient population with significant positive sagittal malalignment. However, following the index procedure, there was no significant improvement in the mean SVA (80 mm). The index procedure did produce a significant improvement in the LL, PI-LL mismatch, and PT, but this was accompanied by a significant compensatory worsening of the TK, counteracting the improvement in the SVA that would have been expected from improvement of these lumbopelvic parameters. Collectively, these data suggest that compensatory changes in TK following aggressive correction of LL for adult deformity may be a factor associated with the development of PJK.[52] Whether these compensatory changes are driven by a failure to achieve adequate sagittal alignment following surgical treatment or perhaps by a tendency for some patients to naturally revert to a closer approximation of their preoperative sagittal alignment remains unclear.[16] Although preoperative factors, such as increased PT (61.7 vs. 54.9 degrees) and greater SVA (67.9 vs. 38 mm), have recently been reported to correlate with sagittal decompensation (defined as SVA > 80 mm) after treatment of degenerative scoliosis with long-segment thoracolumbar instrumentation,[53] the present study did not differ significantly in pelvic measurements with those patients requiring revision and did not seem to change between preoperative and last follow-up assessment.

Notably, in the present study, the patient population had a high rate of osteoporosis/osteopenia, obesity, prior surgeries, advanced age, smoking history, and movement disorders, all of which alone or in combination may play some role in predisposing to the development of PJK.[11] For example, poor bone quality is a risk factor for compression fractures, which often are seen in conjunction with PJK, whereas obesity, smoking, and previous pseudarthrosis are known to compromise fusion, and may predispose to PJK.[54,55]

In many cases, the surgeon is left to focus on potentially modifiable risk factors in hopes of preventing or delaying the development of proximal junctional degeneration and PJK. Factors described as potential mitigators to the development of PJK include less rigid constructs, strict adherence to the avoidance of damage to adjacent segment ligamentous structures such as the facet joints and posterior tension band, and limitation of length of fusion construct when possible.[44] Although the literature demonstrates similar rates of PJK in patients with fusion extending to lower thoracic and upper thoracic spine, compression fracture has been reported to be more frequently observed in patients with fusion ending in the lower thoracic spine compared with fusion extending to the upper thoracic spine, where subluxation remains a most common mechanism for PJK. Hence, strategies to avoid PJK may include vertebral augmentation to prevent fracture in the proximal junctional regions and avoiding damage to the superjacent facets and supraspinous ligament to prevent PJK. Recent studies have attempted to circumvent the development of PJK through the use of transition rod constructs.[56] Less rigid constructs at the rostral-most end of long fusions, such as laminar or transverse process hooks rather than pedicle screws, as well as dynamic stabilization techniques have been developed.[46]

This study has several limitations including the retrospective design, lack of standardized measures of clinical outcome, and the lack of a control group, which could have further delineated risk factors for PJK; however, the primary objective of this study was not to define the risk factors for PJK, which are well reported in the literature.[13–15,18,21,22,26,28,32,53] In addition, although follow-up of 34 months is likely adequate to capture those patients developing early proximal kyphosis, those patients who go on to develop delayed adjacent level breakdown of the fusion construct with kyphotic deformity may have a different underlying pathophysiology and risk factors not assessed in this review, which may likely contribute to a higher incidence of PJK with time. In addition, longer follow-up of patients with PJK is prudent as this subgroup may eventually become symptomatic and require revision surgery.

CONCLUSIONS

As the prevalence of adjacent level disease is likely to increase given a greater number of spinal fusions being performed, better characterization of this complication, including recognition of preoperative risk factors is important. On the basis of the present study, special attention should be given to achieving appropriate postoperative sagittal spinopelvic alignment. The patients in this series who developed PJK had substantial preoperative positive sagittal malalignment that remained inadequately corrected following surgery. This likely resulted from a combination of inadequate surgical correction and a significant compensatory increase in TK. In the absence of direct relationship between a greater PJK angle and worse clinical outcome, clinical symptoms and neurological status rather than absolute reliance on radiographic parameters should drive the decision to pursue revision surgery. Long-term follow-up of patients is important to monitor development of clinical symptoms that might require surgical management.

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