

Inter- and Intra-rater Reliability of the Hart-ISSG Proximal Junctional Failure Severity Scale

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Study Design. Reliability/external validation study.

Objective. Investigate inter- and intrarater reliability of the Hart-International Spine Study Group (ISSG) Proximal Junctional Failure Severity Scale (PJFSS) and its correlation with operative revision in patients with proximal junctional failure (PJF).

Summary of Background Data. The Hart-ISSG PJFSS is a validated classification system for PJF. Reliability of the PJFSS has not been assessed.

Methods. Sixteen detailed clinical scenarios were assessed using the ISSG PJFSS classification in six categories: neurologic status, axial pain, instrumentation issue, proximal kyphotic

angle, level of upper instrumented vertebrae (UIV), and severity of UIV/UIV+1 fracture. Eleven spine surgeons evaluated each case in all six categories during two different assessments, and provided recommendations regarding operative revision or observation for each case. Inter- and intrarater reliability were calculated based on intraclass correlation coefficients.

Results. All intraclass correlation coefficients demonstrated “almost perfect” (0.817–0.988) inter-rater agreement for both assessments, except UIV/UIV+1 fracture severity during the second assessment, which demonstrated “substantial” agreement (0.692). Five of six categories had “almost perfect” mean intrarater reliability (0.805–0.981), while “instrumentation issue” demonstrated “substantial” mean agreement (0.757). Inter-rater reliability for recommendation of surgical intervention was “almost perfect” during both assessments (0.911 and 0.922, respectively). Mean PJFSS scores between the two assessments were significantly higher for cases recommended for operative revision (8.43 ± 0.90) versus cases recommended for observation ($P < 0.0001$).

Conclusion. The ISSG PJFSS is a reliable and repeatable classification system for assessing patients with PJF. Higher PJFSS scales correlate with recommendation for operative revision, extending prior external validation of the PJFSS.

Key words: adult spinal deformity, complications, proximal junctional failure, proximal junctional kyphosis, validation.

Level of Evidence: 3

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Adult spinal deformity (ASD) has become an increasingly recognized pathology with significant detrimental effects on patients' quality of life. With an aging population, this problem is anticipated to create greater medical and economic demands.¹ The prevalence of ASD has been reported to be as high as 60% in populations over the age of 60.² Properly selected surgical techniques for patients with ASD have been shown to lead to improvements in back pain, leg pain, and quality of life.^{3–9} The primary goals of surgery in adult patients with

debilitating spinal deformity are solid arthrodesis, neurological decompression, and maintenance/correction of coronal and sagittal alignment.^{8,10–12}

Coincident with better surgical achievement of global sagittal alignment^{13–16} has come an increase in pathological issues at the proximal junction of extended fusion constructs among ASD patients. These concerns have been described as Proximal Junctional Kyphosis (PJK) and Proximal Junctional Failure (PJF).^{17–22} The incidence of PJK and PJF is higher with modern surgical techniques such as three column osteotomy, segmental pedicle screw placement, and pelvic fixation.^{23–26} For example, Glattes *et al*²⁷ reported a 26% prevalence of PJK in adults with spinal deformity undergoing long posterior spinal fusion at a minimum of 2 years postsurgery.

Most authors have reported similar overall clinical outcomes for patients developing PJK compared with those who did not develop PJK.²⁸ This is not the case, however, for patients with mechanical failure at the proximal junction, previously termed “topping-off syndrome,” proximal junctional acute collapse, or fractures of the vertebrae at the top of long pedicle screw constructs.^{29–33} We have chosen to define this type of PJK as PJF to distinguish this more severe junctional problem from the more common and less problematic PJK.

The phenomenon of PJF is distinct from PJK in that it includes not only an increase in kyphosis but also structural failure of the vertebral body, the posterior osseoligamentous complex, or both. Unlike traditionally defined PJK, PJF is associated with higher morbidity potentially including increased pain, instability, neurologic injury, and need for revision surgery.^{17,22} As a potentially catastrophic complication after ASD surgery, PJF requires early diagnosis and management.

PJF typically occurs in the early postoperative period and may result from reciprocal changes in the unfused portions of the spine as well as increased loads and motion in the mobile segments adjacent to a long-level fusion. Given the frequent need for the extension of instrumentation proximal to these failures, the occurrence of PJF has clear clinical and economic significance. From a clinical standpoint, revisions subject the patient to additional risks of perioperative complications, and from an economic perspective, revisions nearly double the total cost of surgical treatment. Hart *et al*³¹ estimated an average cost of \$77,432 for revision surgery after PJF in 2008, a number that has presumably increased with continued increasing healthcare costs.

Given the recognized clinical and economic impact associated with revision procedures, it is important to identify methods to stratify treatment of patients suffering PJF postsurgically. In this context, the external validity of the International Spine Study Group (ISSG) Proximal Junctional Failure Severity Scale (PJFSS) has recently been demonstrated.²⁰ This classification, created using a modified Delphi technique, takes into account six distinct characteristics of PJF: neurological deficit, axial pain, instrumentation issue, change in kyphosis/posterior ligamentous complex integrity, fracture location, and level of upper instrumented vertebrae

TABLE 1. The ISSG Proximal Junctional Failure Severity Scale (PJFSS)

Characteristic	Severity Scale (Points)
Neurologic deficit	
None	0
Radicular pain	2
Myelopathy/motor deficit	4
Axial pain	
None	0
VAS 4 or less	1
VAS \geq 5	3
Instrumentation issue	
None	0
Partial fixation loss	1
Prominence	1
Complete fixation loss	2
Change in kyphosis/PLC integrity	
0–10°	0
10–20°	1
>20°	2
PLC failure	2
UIV/UIV+1 fracture	
None	0
Compression fracture	1
Burst/chance fracture	2
Translation	3
Level of UIV	
Thoracolumbar	0
Upper thoracic	1
<i>VAS indicates visual analog scale; PLC, posterior ligamentous complex; UIV, upper instrumented vertebrae.</i>	

(UIV) (Table 1). The goal of this study was to evaluate the reliability and external validity of this classification in assessing patients with PJF.

MATERIALS AND METHODS

Adult spinal deformity patients (18 yr or older) who underwent long-segment instrumentation and were diagnosed with PJF were retrospectively identified. Inclusion and exclusion criteria are given in Table 2. Patients received their management exclusively at one institution by the senior author (R.A.H.), and this study was approved by our Institutional Review Board. The medical records were reviewed for clinical characteristics including age, sex, neurological status, and pain severity (visual analog scale).

Clinical Vignettes

Clinical vignettes of 16 adult deformity patients were assembled using a standard format, including patient clinical history and examination of the spine and neurological systems, and assembled into a PowerPoint presentation. Imaging included pre- and postoperative computed tomography and 36 inch cassette anterior-posterior and lateral radiographs. All participants were provided Cobb angle assessments from UIV to UIV+2 pre- and postoperatively for each case.^{23,24,34} The cases

TABLE 2. Patient Selection Criteria

Inclusion Criteria
Age ≥ 18
Radiographic parameters
Cobb angle > 20
SVA > 5 cm
PT > 25
TK > 60
Previous deformity surgery
Exclusion criteria
Inflammatory arthritis
Inability to stand upright
Tumors
Trauma
Infection
Neuromuscular disease

SVA indicates sagittal vertical axis; PT, pelvic tilt; TK, thoracic kyphosis.

TABLE 3. Inter-rater Reliability of ISSG PJFSS

	Intraclass Correlation Coefficients	
	Assessment 1	Assessment 2
Neurologic deficit	0.975	0.972
Focal pain	0.988	0.987
Instrumentation issue	0.887	0.856
Change in kyphosis/PLC integrity	0.817	0.854
UIV-UIV+1 fracture	0.814	0.692
Level of UIV	0.979	0.984
Total PJFSS	0.971	0.965

ISSG indicates International Spine Study Group; PLC, posterior ligamentous complex; PJFSS, proximal junctional failure severity scale; UIV, upper instrumented vertebrae.

were then distributed on thumb drives to the surgeons for assessment and classification.

Participants

Eleven fellowship-trained spine surgeons participated in the study, including eight orthopedic surgeons with 3 to 17 years experience (mean ± SD; 10.6 ± 5.4 yrs) and three neurosurgeons with 9 to 16 years experience (mean ± SD; 11.7 ± 3.8 yrs). All participants received an anonymously labeled thumb drive containing relevant clinical information and radiographic studies. All reviewers underwent a teaching session and were provided with a written instructional sheet. Reviewers were asked to independently scale all cases using the ISSG PJFSS on the basis of the clinical vignettes and images. Additionally, at the end of each vignette, reviewers were asked to provide a recommendation regarding operative revision *versus* observation. After an interval of at least 4 weeks, each reviewer was asked to repeat the process on the same 16 cases presented in different orders.

Statistical Analysis

Statistical analysis was performed using IBM SPSS statistical software. Intraclass correlation coefficients (ICC) were calculated using an absolute agreement, two-way random

effect model for both inter-rater and intrarater agreement.³⁵ ICC values were interpreted using a standardized scale, with 0.00 to 0.20 indicating “slight agreement”; 0.21 to 0.40, “fair agreement”; 0.41 to 0.60, “moderate agreement”; 0.61 to 0.80, “substantial agreement”; and 0.81 to 1.00, “almost perfect agreement.”

RESULTS

Average patient age was 68.2 ± 5.2 years (60–78), and there were 14 females and two males. The mean inter-rater ICCs from the 11 provider participants are given in Table 3 for scales at assessments 1 and 2. The inter-rater agreement for each subscale was “almost perfect” (ICC range 0.814–0.988), with the exception of assessment of UIV-UIV+1 fracture during the second assessment, which showed “moderate agreement” (ICC = 0.692). The inter-rater agreement ICCs for total PJFSS scales for the two assessments were 0.971 and 0.965, both within the range of “almost perfect.”

Mean intrarater agreement ICCs for the various subscales ranged from 0.757 to 0.981, all within either the “substantial” or “almost perfect” range. The intrarater reliability ICC for the total PJFSS scales ranged from 0.724 to 1 across the 11 reviewers, again all either in “substantial agreement” or “almost perfect agreement.” These data are summarized in Table 4.

TABLE 4. Intra-rater Reliability of ISSG PJFSS

	Intraclass Correlation Coefficients		
	Mean	Range	95% Confidence Interval
Neurologic deficit	0.969	0.850–1.00	0.941–0.997
Focal pain	0.976	0.872–1.00	0.952–1.000
Instrumentation issue	0.757	0.228–1.00	0.602–0.911
Change in kyphosis/PLC integrity	0.912	0.458–1.00	0.810–1.000
UIV-UIV+1 fracture	0.805	0.463–1.00	0.692–0.918
Level of UIV	0.981	0.862–1.00	0.955–1.000
Total PJFSS	0.929	0.724–1.00	0.880–0.979

ISSG indicates International Spine Study Group; PLC, posterior ligamentous complex; PJFSS, proximal junctional failure severity scale; UIV, upper instrumented vertebrae.

TABLE 5. Intraclass Correlation Coefficients for Recommendation of Operative Revision

Intraclass Correlation Coefficients				
Inter-rater		Intrarater		
Assessment 1	Assessment 2	Mean	Range	95% Confidence Interval
0.911	0.922	0.913	0.615 – 1.000	0.840–0.986

Inter-rater agreements for ICCs regarding the recommendation of operative revision *versus* observation during the two assessments were both “almost perfect” (0.911 and 0.922). Intrarater agreement ICCs for recommendation for operative revision averaged 0.913, ranging from 0.615 to 1 across the 11 reviewers. Thus all scales were again in either “substantial” or “almost perfect” agreement (Table 5).

Finally, there was a significant correlation between recommendation for operative revision and higher ISSG PJFSS scales. Patients who received a recommendation of Observation (Figure 1A–G) had significantly lower mean ISSG PJFSS scales across the 11 reviewers when compared with the operative revision group (Figure 2A–G) in both

assessment one (5.17 ± 0.45 *vs.* 8.28 ± 0.87 respectively, $P < 0.0001$) and two (5.31 ± 0.61 *vs.* 8.58 ± 0.95 respectively, $P < 0.0001$).

DISCUSSION

Fellowship trained spine surgeons demonstrated “almost perfect” inter-rater agreement in all six subscales comprising the Hart-ISSG PJFSS classification, which includes neurologic deficit, axial pain, instrumentation issue, change in kyphosis, UIV-UIV+1 fracture, and level of UIV. Furthermore, when all assessments were summed to form the PJFSS total scale, assessments demonstrated “almost perfect” inter-rater agreement. Finally, patients recommended for operative revision

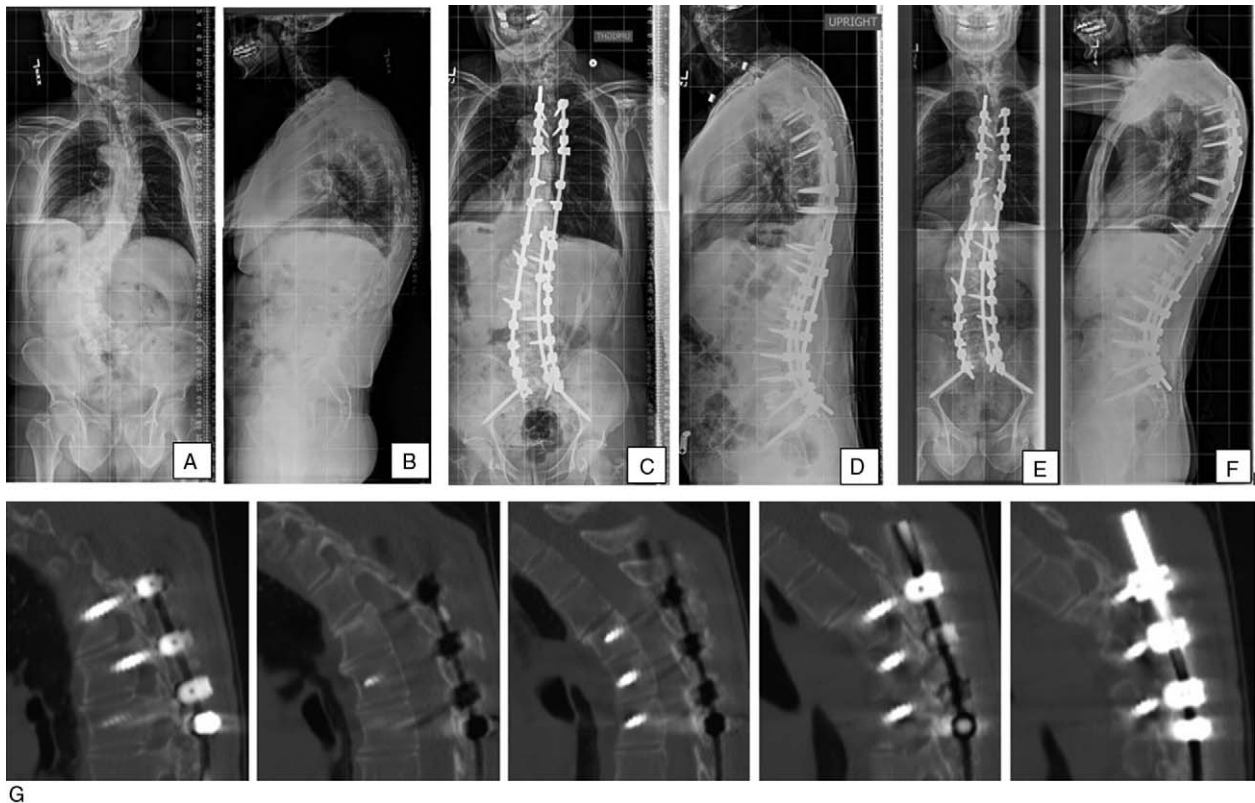


Figure 1. AP (A) and lateral (B) images of a 66-year-old man with a history of adolescent idiopathic scoliosis and a 2-year history of progressive low back pain and bilateral neurogenic claudication. No history of prior spinal surgery. AP (C) and lateral (D) postoperative images. Procedure performed was posterior spinal fusion from T4 to S1 with posterior column (Smith–Petersen) osteotomies from T10–11 through L5–S1 and an ALIF of L5–S1. Prophylactic rib tether to T4 was performed with off-label use of a sublaminar tape. Upper implant was bilateral pedicle screws. AP (E) and lateral (F) images taken 5 months postoperatively. He reported mild periscapular pain on the left. VAS was two; the change in PJK was 26° (T2 to T4). (G) Sagittal CT scan shows no loss of fixation and intact posterior column with compression fracture of UIV (T4). Mean PJFSS scores were 4.45 and 4.73 for the first and second ratings, respectively. 2/11 (18%) and 0/11 (0%) of reviewers recommended revision fusion during the two rating sessions, respectively. ALIF indicates anterior lumbar interbody fusion; AP, anterior-posterior; CT, computed tomography; PJFSS, proximal junctional failure severity scale; PJK, proximal junctional kyphosis; UIV, upper instrumented vertebrae; VAS, visual analog scale.

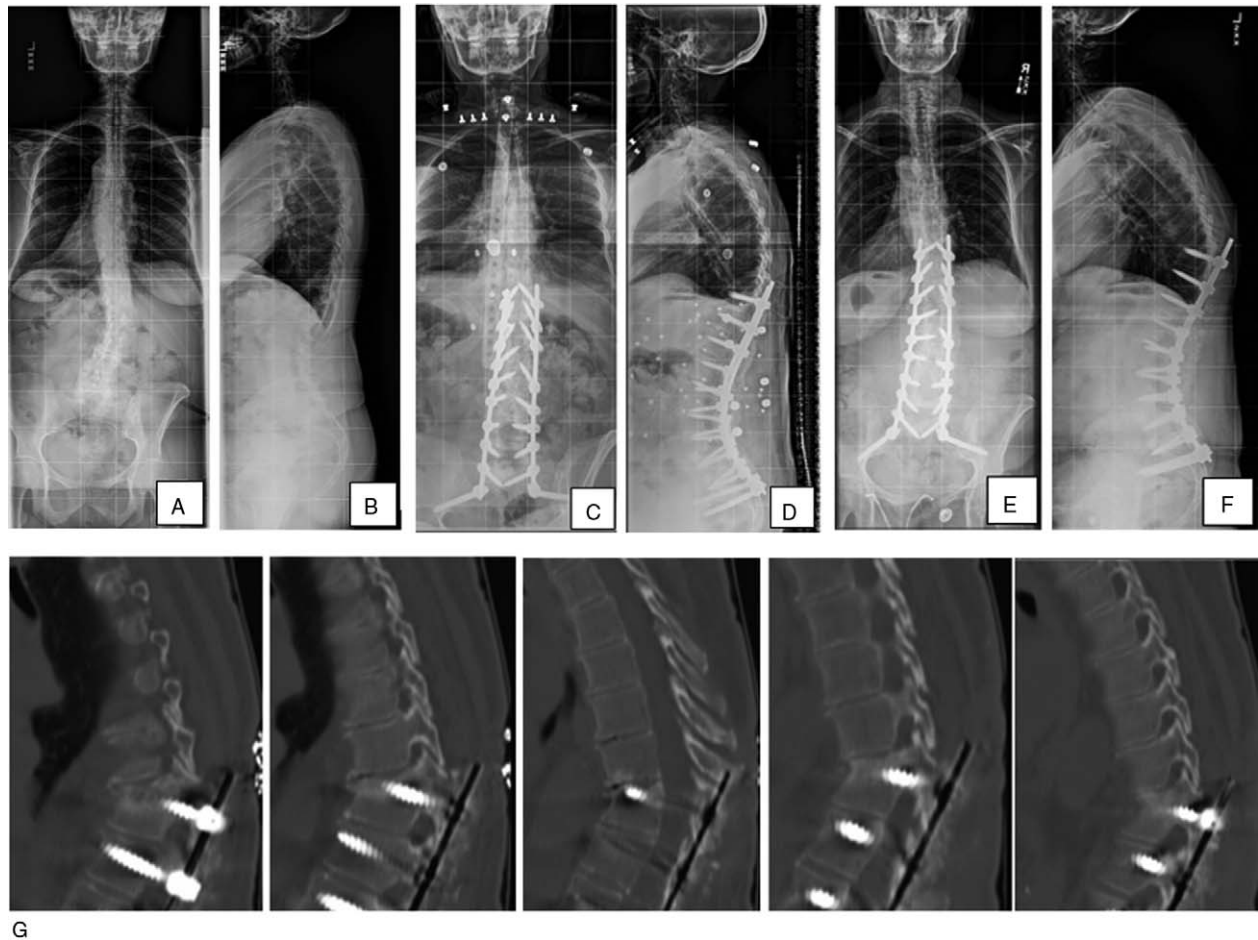


Figure 2. AP (A) and lateral (B) images of a 61-year-old woman with worsening back pain with neurogenic claudication. No history of prior spine surgery. AP (C) and lateral (D) postoperative images. Procedure performed was posterior instrumented. Fusion from T10 to S1 with TLIFs from L4-S1. UIV implant was bilateral pedicle screws. AP (E) and lateral (F) images taken 3 months postoperatively. She reported worsening pain in the midback over the prior 2 months radiating around the rib cage at T10 on the right. The VAS was 7; the change in PJK angle was 25.5°. (G) Sagittal CT scan shows separation of upper portion of pedicles at T10 bilaterally, signifying likely failure of the posterior osteo-ligamentous complex. Mean PJFSS scores were 8.82 and 9.45 for the first and second ratings, respectively. 10/11 (91%) and 11/11 (100%) of reviewers recommended revision fusion during the two rating sessions, respectively. AP indicates anterior-posterior; CT, computed tomography; PJFSS, proximal junctional failure severity scale; PJK, proximal junctional kyphosis; TLIFs, trans-foraminal lumbar interbody fusions; UIV, upper instrumented vertebrae; VAS indicates visual analog scale.

had significantly higher Hart-ISSG PJFSS scores compared with patients recommended for observation ($P < 0.0001$). In combination, these results support both the reliability of the PJFSS as well as its external validity.

PJF is an increasingly recognized postoperative complication associated with surgical management of patients who have undergone deformity correction.^{22,36,37} The establishment of a valid and reliable classification system has the potential to enhance our understanding and management of patient's affected by this pathology. In addition to the current results, the Hart-ISSG PJFSS classification has been externally validated with respect to recommendation for revision surgery in a separate evaluation.²⁰

Classification systems have potential value in both a research and a clinical care role.

In general, for classification systems to be effective in a clinical setting, they should be easy to use and enable clinicians to provide effective treatment focused on critical

aspects of the patient's pathology while avoiding the loss of critical information. While the PJFSS may seem overly complex to allow broad clinical application, we felt it was more important to include as many aspects as possible of pathology that might affect prognosis and treatment of patients with PJF. Whether the PJFSS is adopted in a clinical setting remains to be seen.

Even if the PJFSS does not become a routine part of clinical practice for ASD patients, we hope that it will be seen as a useful clinical research and educational tool. The current study shows that the PJFSS is a robust instrument for assessing the complication in this patient population, and as such should provide clinical researchers with a sound method of comparing incidence and impact of this complication across varying treatment and diagnostic groups. In addition, the PJFSS may also serve to focus surgeons' thinking about the various aspects of this pathology in a more structured way.

There has been a change in the approach taken in creating classification systems away from anatomically based systems with discreet “boxes” for differing fracture or pathology types. Several such systems have been proven to lack repeatability and reliability both across and among assessors.^{38–41} A more reliable approach uses a scale such as the PJFSS proposed here. Similar scales have been proposed and validated for spinal fractures.^{42–44} One benefit to such an approach is that reviewers do not need to have exact agreement to determine a level of severity as higher or lower for a given clinical example.

The “change in kyphosis/posterior ligamentous complex (PLC) integrity” domain of the PJFSS requires identification of presence or absence of PLC failure. This assessment is known to be difficult, even with computer assisted tomography scans and/or magnetic resonance imaging.^{42–44} Our case examples all included computed tomography scans, though none included magnetic resonance imaging. While the ICCs for PLC integrity were among the lowest of the six domains they still averaged over 0.8, thus falling in “almost perfect agreement” range.

All case presentations were in clinical vignette format and provided in a standardized manner to the participants. The subjective evaluation and clinical examination are thus unavailable, which is a limitation to case-based evaluations. Furthermore, data was collected in a retrospective manner from chart review, which also introduces limitations. Finally, although we have recently shown that kyphotic angle measurements at the proximal junction are highly reliable,⁴⁵ in this study, these radiographic assessments were provided directly to the participants, which may have artificially elevated the overall reliability of this classification system.

Despite these limitations, we believe that the Hart-ISSG PJFSS classification has the potential to improve the care of ASD patients with PJF by unifying approaches to their evaluation and management. The Hart-ISSG PJFSS classification is the first system shown to be a valid and reliable clinical tool in assessing patients with junctional problems after ASD surgery, and as such fills a need for those working to improve care for these complex patients.

➤ Key Points

- ❑ PJF remains a significant complication after adult spinal deformity surgery.
- ❑ The proposed PJFSS is shown to be reliable and valid in this case-based study.
- ❑ Use of the PJFSS in clinical research may allow a more granular analysis of techniques to prevent and treat PJFSS.

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