

# Development and Validation of a Novel Risk Stratification Model for Proximal Junctional Kyphosis after Posterior Spinal Fusion

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## INTRODUCTION:

Proximal junctional kyphosis (PJK) is a common radiographic finding after adult spinal deformity surgery and is a frequent cause for revision surgery. PJK is typically defined as 1) a proximal junctional sagittal Cobb angle greater than 10 degrees, and 2) at least 10 degrees greater than the preoperative measurement. Although prior studies have identified risk factors for developing PJK, there are currently no classification systems that accurately identify patients at risk for developing PJK among patients undergoing posterior spinal fusion.

**METHODS:** We performed a retrospective cohort study of all patients who had posterior spinal fusion between July 2004 and March 2022 who had a minimum follow-up duration of 2 years. All patients who had fusion for neoplasia or spinal fracture were excluded. Patient-specific (e.g., age, body mass index, and comorbidities) and surgery-specific (e.g., length of fusion and type of osteotomy) factors were collected. Patients were randomized into a learning cohort (80%) and a validation cohort (20%). All variables that qualified for inclusion in bivariate analysis were moved to multivariable logistic regression, seeking factors associated with developing PJK. A scoring system was developed based on the regression coefficients of the model, and receiver operating characteristic (ROC) curves were constructed.

## RESULTS:

Two-hundred-eighty-seven patients were included in the analysis, and a total of 40 patients (14%) developed PJK. In bivariate analysis, having degenerative scoliosis, fusion of T8-T9, use of a transforaminal lumbar interbody fusion (TLIF) cage at L1-L2, and having autoimmune disease were all associated with PJK and were moved to multivariable analysis. Based on multivariable logistic regression the following scores were assigned: autoimmune disease - 1 point; degenerative scoliosis - 1 point; fusion of T8-T9 - 2 points; and TLIF L1-L2 - 2 points. In the validation cohort, the risk of PJK among patients with 0 points was 4.8% (1 out of 21; learning cohort: 3 out of 95 [3.2%]); the risk among patients with 1 to 2 points was 24% (8 out of 34; learning cohort: 22 out of 127 [17%]); and the risk among patients with 3 points or more was 50% (1 out of 2; learning cohort: 5 out of 8 [62%]). The area under the curve (AUC) for the learning cohort was 0.73, while the AUC for the validation cohort was 0.70.

## DISCUSSION AND CONCLUSION:

Our novel scoring system for stratifying patients into low, moderate, and high risk for PJK demonstrated good discriminatory ability and has potential benefit for surgical planning and patient education. Future studies may test the reliability and validity of this scoring system as a clinical prediction tool.

Table I Multivariable logistic regression analysis of factors associated with developing proximal junctional kyphosis.

Variables	Regression Coefficient (95% Confidence Interval)	Standard Error	P value	Score
Degenerative scoliosis	1.3 (0.24 to 2.4)	0.55	<b>0.017</b>	1
Autoimmune disease	1.3 (0.16 to 2.4)	0.56	<b>0.024</b>	1
Fusion of T8-T9	1.7 (0.64 to 2.8)	0.55	<b>0.002</b>	2
TLIF L1-L2	2.0 (0.26 to 3.8)	0.91	<b>0.025</b>	2

T = thoracic; L = Lumbar; TLIF = transforaminal lumbar interbody fusion. **Bold** indicates statistical significance,  $P < 0.05$ . The variable "three-column osteotomy" did improve model fit slightly, but did not reach statistical significance and was omitted from the final model.

Table II Novel scoring based system to determine the risk of developing proximal junctional kyphosis (PJK) after posterior spinal fusion.

PJK Score	Learning cohort			Validation cohort		
	N	PJK prevalence	OR, P-value*	N	PJK prevalence	OR, P-value*
0	95	3 (3.2%)		21	1 (4.8%)	
1	63	10 (16%)	2.7, <0.001	19	4 (21%)	2.3, 0.044
2	64	12 (19%)		15	4 (27%)	
3+	8	5 (63%)		2	1 (50%)	

  

Risk factors	Score	Total score	Absolute risk (%, 95% CI)*	Interpretation
Degenerative scoliosis	1	Average (0.95 ± 0.93)	14 (9.9 to 18)	Average risk
Autoimmune disease	1	0	3.4 (0.28 to 6.6)	Low risk
Fusion of T8-T9	2	1-2	19 (13 to 25)	Moderate risk
TLIF L1-L2	2	3+	60 (30 to 90)	High risk

\*Prevalence of PJK in the total population (combined learning and validation cohorts) reported as mean with the bootstrapped 95% confidence interval (CI) between parentheses. T = thoracic; L = Lumbar; TLIF = transforaminal lumbar interbody fusion.