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Commentary

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See the article "Proximal Junctional Failure Development Despite Achieving Ideal Sagittal Correction According to Age-Adjusted Alignment Target in Patients With Adult Spinal Deformity: Risk Factor Analysis of 196 Cases Undergoing Low Thoracic to Pelvic Fusion" via https://doi.org/10.14245/ns.2448734.367.

Risk Factors, Biomechanics, and Prevention Strategies for Proximal Junctional Failure in Adult Spinal Deformity Surgery – A Commentary on "Proximal Junctional Failure Development Despite Achieving Ideal Sagittal Correction According to Age-Adjusted Alignment Target in Patients With Adult Spinal Deformity: Risk Factor Analysis of 196 Cases Undergoing Low Thoracic to Pelvic Fusion"

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Proximal junctional failure (PJF) remains a significant complication following adult spinal deformity (ASD) surgery, even when ideal sagittal correction is achieved. The primary objective of this study was to identify risk factors for the development of PJF in patients who achieved ideal sagittal correction according to age-adjusted alignment targets. Park et al.[1] utilized a retrospective case series of 196 patients who underwent low thoracic to pelvic fusion for ASD. Radiographically, PJF was considered when the proximal junctional angle (PJA) exceeded 28° with a difference in PJA of more than 22°, while clinically, PJF was identified when revision surgery for junctional complications was required.

The study revealed that 21.9% of patients developed PJF despite achieving ideal age-adjusted sagittal correction. The multivariate logistic regression analysis identified several statistically significant risk factors for PJF: advanced age, large preoperative sagittal vertical axis (SVA), nonuse of transverse process (TP) hook at the uppermost instrumented vertebra (UIV), and high lumbar distribution index (LDI). Older patients and those with osteoporosis were more likely to develop PJF ($p < 0.05$). This finding aligns with previous studies that have noted age-related decline in musculoskeletal integrity and decreased bone quality as risk factors for PJF.[2] Patients with larger preoperative SVA were at greater risk of PJF. A larger SVA often necessitates more extensive correction, which may increase stress at the junctional region. The nonuse of TP hooks significantly increased the risk of PJF (odds ratio [OR], 5.556; $p = 0.028$). TP hooks are believed to provide a "soft landing" for the transition from the fixed to the unfixed spine. A high LDI, which measures the proportion of lumbar lordosis distributed in the lower lumbar spine, was found to be a strong predictor of PJF (OR, 1.136; $p < 0.001$). Excessive LDI may create higher shear forces at the UIV, predisposing the region to failure.

The findings of this study are consistent with prior research on PJF, reinforcing the multifactorial nature of this complication. The significant impact of age and osteoporosis on PJF risk underscores the need for tailored surgical planning in elderly patients. It also raises questions about whether the age-adjusted pelvic incidence minus lumbar lordosis scheme adequately accounts for age-related musculoskeletal changes. The role of preoperative C7-SVA as a risk factor reflects the biomechanical stress imposed by larger deformities.[3] Greater preoperative misalignment requires more aggressive corrections, which can increase reciprocal forces on the junctional region. The use of TP hooks at the UIV to reduce PJF risk has been supported in previous studies. TP hooks may reduce the abrupt change in stiffness at the transition from fused to unfused segments,[4] thereby lowering stress on the proximal vertebra. The present study's finding that nonuse of TP hooks increases the odds of PJF by over 5 times strengthens the argument for the routine use of TP hooks in ASD surgery. The relationship between LDI and PJF is particularly insightful.[3] While previous studies have emphasized the importance of overall lordosis, the present analysis highlights the role of lordosis shape. A harmonious correction that matches the native spinal shape may reduce risk of PJF postoperatively. Future studies should aim to validate these findings in larger, prospective, multicenter cohorts.

Fundamentally, PJF development after surgery is determined by several biomechanical forces acting on the spinal column: the corrective force of the spinal instrumentation that is holding the spine in place, the screw-bone interface, and the biomechanical load the spinal is exposed to from daily activities. Ideally, both static and dynamic loads should be minimized and should not the limit of screw-bone interface or it will cause loosening of fixation at UIV or cause junctional fractures, thus lead to proximal junctional kyphosis/PJF. Static load during erect standing can be reduced by achieving optimal alignment, thereby lessening the forward bending moment arm. However, this static load can change based on patient's postures including erect standing, relaxed standing versus sitting. These difference postures can expose the junctional level to different amount of forward pulling force. Dynamic load during movement, such as the transition from lying to sitting, sitting to standing, and during walking, also contributes to junctional stress. Addressing these biomechanical challenges requires a comprehensive understanding of load distribution and spinal kinematics.[5,6] A promising avenue for future research is the use of gait analysis with construct stress modeling and biomechanical modeling. These advanced techniques could provide deeper insights into how patients' movements impact the load on the spine. By understanding the dynamic forces at play, surgeons may be able to design more effective preventive strategies.

• **Conflict of Interest:** The author has nothing to disclose.

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