Preoperative Sacral Slope Change (ΔSS) Predicts Mechanical Complications after Adult Spinal Deformity Surgery

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INTRODUCTION:

Mechanical complications after adult spinal deformity (ASD) surgery – especially proximal junctional kyphosis (PJK) and rod fracture (Rod Fx) – remain common and challenging. PJK is reported in up to ~40% of cases and rod fractures in up to ~20%. Efforts to reduce these issues have focused on optimizing static alignment and bone quality (e.g. treating osteoporosis), yet high complication rates persist. One dynamic factor of interest is spinopelvic mobility measured by the change in sacral slope from standing to sitting (ΔSS). A larger ΔSS indicates greater pelvic retroversion (flexibility) when moving to a sitting posture. Limited pelvic compensation after long fusions has been linked to increased stress on adjacent segments in prior studies. We hypothesized that a greater preoperative ΔSS would be associated with higher rates of PJK and rod fracture after ASD surgery, and we investigated this relationship.

METHODS:

We retrospectively analyzed 181 patients (mean age 71 years, all female) with ASD who underwent long posterior fusions to the pelvis. Minimum follow-up was 2 years. Preoperative standing and sitting lateral spine radiographs were obtained to measure sacral slope, and ΔSS was calculated as the difference. Postoperative PJK and rod fractures were documented (noting whether each was symptomatic). Multivariate logistic regression was used to test whether ΔSS was an independent predictor of PJK and rod fracture, adjusting for covariates such as age, bone mineral density (BMD), and sagittal alignment parameters. We also performed ROC analysis to determine ΔSS cut-offs that best predicted these complications.

RESULTS:

Mechanical complications were frequent. PJK occurred in 47.0% of patients (85/181, with 11% symptomatic cases) and rod fracture in 49.7% (91/181, with 29% symptomatic). Patients who developed complications had significantly greater preoperative ΔSS than those without. For example, mean ΔSS was ~24° in symptomatic PJK cases versus ~11° in patients without PJK ($p < 0.001$); for rod fracture, mean ΔSS was ~20° versus ~9° without fracture ($p < 0.001$). In multivariate analysis, ΔSS remained an independent predictor of both PJK and rod failure. Each 1° increase in ΔSS raised the odds of a symptomatic rod fracture by about 10% (adjusted OR 1.10, 95% CI 1.05–1.15, $p < 0.001$), and ΔSS was also significantly associated with increased PJK risk ($p < 0.01$). Additionally, low BMD was independently linked to PJK ($p = 0.01$) but not to rod fractures. ROC analysis showed that a ΔSS ≥16° optimally predicted rod fracture (AUC 0.79, 73% sensitivity, 80% specificity), whereas a ΔSS ≥20° best predicted PJK (AUC 0.80, 74% sensitivity, 80% specificity). Thus, very high preoperative ΔSS values identified patients at markedly elevated risk for mechanical failure.

DISCUSSION AND CONCLUSION:

This study demonstrates that the dynamic spinopelvic parameter ΔSS has significant predictive value for postoperative mechanical complications in ASD surgery. Patients with large ΔSS values preoperatively were at substantially increased risk for both PJK and rod fracture following long-segment fusion. A high ΔSS reflects increased pelvic flexibility; such patients likely rely on pelvic retroversion to compensate for sagittal imbalance or limited hip motion. After fusion, this lost compensation can concentrate stress at the proximal junction or across the instrumentation, leading to PJK or rod breakage. These findings underscore that static alignment targets alone are insufficient for risk assessment—patient-specific spinal flexibility must be considered. Notably, patients with ΔSS in a high range (exceeding ~16–20°) should be flagged as high-risk. Surgeons might consider more robust constructs or other protective measures for these individuals. In summary, preoperative ΔSS is a valuable independent predictor of mechanical complications after ASD surgery. Incorporating dynamic (sitting) radiographs into preoperative planning can improve risk stratification and guide surgical strategies to reduce the incidence of PJK and rod fracture.