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Thoracic Inlet Angle as a Predictor of Recovery in Cervical Spine Surgery: A Cluster Analysis of Demographic Interactions on Radiographic and Functional Outcomes

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Background: Thoracic Inlet Angle (TIA) is a critical factor in understanding cervical alignment and predicting recovery outcomes following cervical spine surgery.

Research question: Analyze correlations between TIA and T1Slope, CL, and cSVA at multiple time points, perform cluster analysis based on PreopΔ, and assess how demographic interactions impact outcomes within each cluster.

Design: Multi-center retrospective study

Methods: In this study of 157 cervical spine surgery patients, correlations between TIA and T1Slope, CL, and cSVA were evaluated preoperatively and at 1 month, 1 year, and 2 years postop. Clusters based on PreopΔ divided patients into Cluster 0 (high PreopΔ), Cluster 1 (moderate PreopΔ), and Cluster 2 (low PreopΔ).

Results: TIA showed strong correlations with T1Slope ($r = 0.76$, $p < 0.001$) and CL ($r = 0.63$, $p < 0.001$), confirming TIA"s alignment impact. While Cluster 0, with the highest PreopΔ, experienced persistent alignment challenges, Cluster 2—despite lower PreopΔ—exhibited delayed functional recovery and significantly higher ODI scores at 2 years, particularly among smokers ($p < 0.001$). This finding diverges from expectations, suggesting that lower preoperative misalignment alone does not ensure better outcomes. Cluster 1 outcomes were heavily influenced by BMI and age, with older and high-BMI patients showing worse TIA and CL recovery. The interaction effects reveal that demographic factors like smoking, age, and BMI may sometimes outweigh alignment severity in determining functional recovery.

Discussion: High PreopΔ was linked to alignment difficulties, as expected, but functional recovery was notably poorer in Cluster 2 smokers, showing that demographic risks can heavily influence outcomes. Cluster 1 patients with high BMI and age showed exacerbated alignment and pain, suggesting these patients require weight management and targeted postoperative alignment support.