Validation of Pelvic Incidence-Adjusted Regional Alignment Ranges in Primary Adult Spinal Deformity (ASD): Differential Evolution Analysis of 2-Year Surgical Outcomes

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INTRODUCTION:
Surgical planning for spinopelvic realignment with lower thoracic-pelvis fusion in ASD is challenging. Recent studies proposed segmental alignment targets for short fusions in degenerative spine. However, their utility in ASD may be limited, thus necessitating alignment ranges across regions.
METHODS: Patients who underwent ASD surgery with a UIV between T9-L1 and an LIV at S1/ilium were included. Demographics, spinopelvic alignment, and mechanical and junctional complications were summarized. Differential evolution optimization was performed to establish PI-specific ranges for T10-L2, L1-L4, and L4-S1 that minimized two-year complication rates. Multivariate logistic regression adjusting for age, sex, BMI, CCI, osteoporosis and prior fusion were performed to evaluate complication rates for patients outside the ranges.
RESULTS:
In total, 560 patients were included with a mean age of 65.5 years, 71% female, and a mean CCI of 1.9. Preoperatively, mean PI was 56.1°, PI-LL was 22.6°, T10-L2 was -9.8°, L1-L4 was 2.6°, and L4-S1 was 30.9°. Postoperatively, 26.6% experienced mechanical and junctional complications, including 17.5% radiographic PJF. Ideal ranges for T10-L2, L1-L4 and L4-S1 that minimized complications across PI categories are reported in Table 1. Patients outside the ideal ranges had higher rates of mechanical and junctional complications on both univariate (T10-L2: 30% vs 5%, L1:L4: 29% vs 2%, L4-S1: 29% vs 8%), and multivariate (6.9, 18.8, 4.5 times higher odds) analyses, commonly radiographic PJF (20% vs 2%, 20% vs 0%, 20% vs 4%) ($p<0.01$).
DISCUSSION AND CONCLUSION: This study is the first to empirically develop and evaluate prescriptive regional sagittal alignment ranges T10-L2, L1-L4 and L4-S1. Patients with alignment within these novel data-derived regions experienced fewer mechanical and junctional complications two-years after ASD surgery. Of note, T10-L2 junction was found to be universally kyphotic in patients with successful T10-pelvis with less complications which challenges its normative alignment found in healthy patients.

Table 1. Ideal Regional Ranges and Mean Spinopelvic Alignment by Pelvic Incidence

	35-45° PI (N = 95)	45-55° PI (N = 155)	55-65° PI (N = 155)	65-75° PI (N = 98)
Ideal Regional Ranges				
T10-L2 (°)	-8.2 – -5.0	-7.4 – -5.4	-6.9 – -4.8	-4.5 – 1.2
L1-L4 (°)	5.8 – 9.1	12.8 – 14.9	15.1 – 18.2	21.2 – 25.0
L4-S1 (°)	30.8 – 33.8	32.0 – 34.8	39.6 – 42.6	42.9 – 46.0
Spinopelvic Alignment				
C2 Tilt (°)	0.4 (5.2)	1.5 (5.0)	2.8 (4.3)	3.5 (5.7)
PT (°)	15.0 (7.3)	19.3 (7.2)	22.4 (7.0)	26.5 (7.4)
PI (°)	41.1 (2.6)	49.9 (2.9)	59.7 (2.9)	69.4 (2.8)
PI-LL (°)	-2.8 (11.3)	0.7 (11.7)	4.0 (10.2)	9.1 (10.3)
SVA (mm)	20.0 (45.5)	28.1 (43.3)	39.0 (38.2)	44.5 (48.8)

Abbreviations: PT = Pelvic Tilt, PI = Pelvic Incidence, PI-LL = Pelvic Incidence-Lumbar Lordosis, SVA = Sagittal Vertical Axis.