The Era of Segmentation: Ideal Regional Alignment Ranges to Minimize Mechanical Complications in Upper Thoracic-Pelvis Adult Spinal Deformity Surgery

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INTRODUCTION: Previous literature has shown that under- and over-correction of segmental and regional thoracic kyphosis (TK) and lumbar lordosis (LL) is associated with mechanical complications. However, prescriptive alignment ranges to optimize clinical outcomes have not been established.

METHODS:

Surgical ASD patients with a UIV above T5 and an LIV at S1/ilium were included. Differential evolution, an iterative optimization algorithm, was performed to establish TK magnitude-specific ranges for T1-T5, T5-T9, and T9-L1, and PI-specific ranges for L1-L4, and L4-S1 that minimized two-year complication rates. Multivariate logistic regression adjusting for age, sex, BMI, CCI, frailty, osteoporosis, and prior fusion were performed to evaluate complication rates for patients outside the ranges.

RESULTS:

Among 285 patients, mean age was 62.9 years, 83% were female, and mean CCI was 2.0. Preoperatively, mean PI was 55.7°, PI-LL was 21.1°, T1-T12 was -33.6°, L1-L4 was -0.4°, and L4-S1 was 35.0°. Postoperatively, 40% experienced mechanical complications, including 32% radiographic PJK or PJF. Ideal regional ranges that minimized complications are reported in Table 1. In the thoracic spine, T5-T9 was the primary contributor to global TK, though increasing percent contribution from T1-T5 (16% in Low TK to 21% in High TK) and T9-L1 (18% to 26%) was noted with increasing TK magnitude. In the lumbar spine, L4-S1 was the primary contributor to global LL, with relatively equivalent percent contribution from L1-L4 (35%) and L4-S1 (65%) across PI categories. Patients outside these ranges had higher mechanical complications on both univariate (43% vs 21%, 43% vs 20%, 44% vs 18%, 44% vs 13%, and 44% vs 16%, respectively) and multivariate (3.4, 4.4, 4.5, 6.6, and 4.6x higher odds, respectively) analyses ($p<0.01$).

DISCUSSION AND CONCLUSION: This study proposes prescriptive regional sagittal alignment ranges for both thoracic and lumbar spine in upper thoracic-pelvis fusions for ASD. Preoperative surgical planning should carefully consider these novel data-derived regional ranges to minimize complications.

Table 1. Ideal Regional Ranges for Thoracic and Lumbar Spine

Ideal Regional Thoracic Alignment By TK Magnitude			
Region	**High TK (Max TK = -77.5 ± 13.7)**	**Medium TK (Max TK = -52.8 ± 4.8)**	**Low TK (Max TK = -32.3 ± 8.7)**
T1-T5	-11.8 – -8.7	-8.8 – -4.0	-6.6 – -3.0
T5-T9	-27.5 – -24.7	-25.8 – -20.1	-22.6 – -15.9
T9-L1	-14.0 – -11.2	-10.9 – -6.8	-7.4 – -3.8

Ideal Regional Lumbar Spine Alignment By PI Category				
Region	**<45° PI**	**45-55° PI**	**55-65° PI**	**>65° PI**
L1-L4	12.3 – 18.1	19.3 – 24.4	22.5 – 27.0	22.8 – 27.7
L4-S1	34.5 – 38.5	38.2 – 42.1	42.2 – 46.6	45.2 – 48.7

Abbreviations: TK = Thoracic Kyphosis, PI = Pelvic Incidence.