Analysis of Success Versus Poor Realignment in Patients with Cervical Deformity: In-Construct Angles Provide Novel Targets for Correction

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INTRODUCTION: Correcting cervical deformity (CD) has the potential to significantly improve patient function. However, previously described radiographic parameters cannot be measured intraoperatively. The present study investigates in-construct measurements of sagittal angles (SA) within the fusion from C2 to various thoracic vertebrae, which can be used as targets for CD correction.

METHODS: Patients with adult cervical deformity with either cervical kyphosis more than 10°, cSVA of more than 4 cm, CBVA more than 25°, and a LIV at T1 or caudal were included. Patients were categorized into the failed outcome group if they had a cSVA of more than 4 cm postoperatively. The in-construct measurements were based on patients' LIV. All patients had a C2-T1 SA. C2-T4 SA were compared between groups with LIV below T4, and C2-T10 SA between groups with LIV below T10. Change in C2-LIV SA described the sagittal correction within the fusion for each patient. Analyses between failed and successful realigned groups for clinical and radiographic characteristics were performed using t-test, X^2 analysis, and multivariate regression. Linear regression analysis was used to determine the C2-T1, C2-T4, C2T10 SA measures corresponding to a cSVA=4 cm and DJK =10°. HRQL analysis was done in patients with 1-year follow-up.

RESULTS:

A total of 143 patients with CD (mean age 63 yr, 60% female) were included with 73 having failed radiographic outcomes by high cSVA (51% Failed). Failure to correct cSVA was associated with worse baseline deformity including cSVA, T1S, C2S, TS-CL, with greater change in DJKA, and larger postop C2-T1 SA within the fusion (all p<0.05). Multivariate regression for variables with p<0.05 revealed that the postop C2-T1 in-construct angle independently predicted failed realignment outcome (OR= 1.25, CI 1.11-1.41; p<0.001). Using linear regression, a cSVA measurement of 4.0cm corresponded to a C2-T1-SA of -9.55°, C2-T4 SA of -0.37°, C2-T10-SA of 14.67°(all r>0.38, p<0.05). Linear regression revealed that postoperative C2-T10 SA was able to predict change in DJKA, where a change of 10° yielded a C2-T10 SA of 20.67°(r>0.57, p=0.02). While no difference in postop HRQL was observed between groups, improvement in C2-LIV SA was associated with improvement in NRS neck scores at 1 year (r>0.42, p=0.036).

DISCUSSION AND CONCLUSION:

Failure to restore cSVA patients was independently associated with undercorrection, as evidenced by significantly larger postoperative in-construct angles. From our analyses, optimal realignment of cSVA can be obtained when C2-T1, C2-T4, C2-T10 SAs have measures less than -9.55°, -0.37°, and 14.67° respectively. In-construct measures can be used as alignment targets to optimize radiographic outcomes and prevent DJK, thereby improving patient-reported outcomes.

Figure 1. The novel, in-construct angles are measures of sagittal alignment within the fused construct. The dots depict the centroids of C2 and lower thoracic vertebra as well as the superior and inferior edges of the posterior cortex of the lower thoracic vertebra. (A) C2-T1 SA is defined as the angle of a line from the centroid of C2 to the centroid of T1, and a line parallel to the posterior vertebral body of T1. (B) C2-T4 SA is the angle formed by a line from the centroid of C2 to the centroid of T4, and a line parallel to the posterior vertebral body of T4. (C) C2-T10 SA is defined as the angle of a line from the centroid of C2 to the centroid of T10, and a line parallel to the posterior vertebral body of T10.

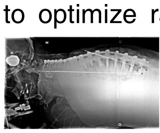
Figure 2: Intraoperative radiograph demonstrating in-construct angle (C2-LIV) can be used regardless of patient positioning

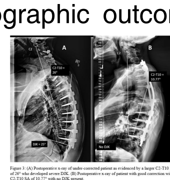

Figure 3: (A) Postoperative x-ray of under-corrected patient as evidenced by a larger C2-T10 SA of 26° who developed severe DJK. (B) Postoperative x-ray of patient with good correction with a C2-T10 SA of 10.77° with no DJK present.

Table 1: Comparison of Patients with Successful Versus Failed Cervical Realignment At Early Postperative Period

		Success (post-cSVA < 40 mm) (N= 73)	Failed (post-cSVA > 40 mm) (N= 70)	p-value
Demographics	Age	62.69±10.53	63.73±12.03	0.587
	Gender (%F)	69.00%	53.60%	0.082
	BMI	27.73±5.46	29.96±7.58	0.050
	Smoking	6.90%	8.80%	0.760
Surgical Characteristics	Anterior Only	4.50%	5.80%	
	Posterior Only	56.70%	63.80%	
	Combined (A/P)	38.80%	30.40%	0.581
	Anterior Osteotomy Grade	1.45±1.87	1.21±1.93	0.565
	Posterior Osteotomy Grade	2.89±4.09	3.79±3.99	0.309
	3CO performed?	15.10%	22.90%	0.287
	Levels Fused	**8.46±3.40**	**10.44±4.71**	**0.005**
	EBL	**651.69 ± 629.73**	**1108.41±970.34**	**0.002**
	Operative Time	362.24±175.54	418.83±187.72	0.072

Table 2: Radiographic Analysis of Patients with Successful Versus Failed Cervical Realignment At Early Postperative Period

		Success (post-cSVA < 40) (N= 73)	Failed (post-cSVA > 40) (N= 70)	p-value
Baseline	**T1S°**	**32.25±19.40**	**42.97±17.29**	**<0.001**
	cSVA (mm)	**40.86±21.00**	**64.37±13.76**	**<0.001**
	C2S°	**34.40±16.10**	**51.38±22.38**	**<0.001**
	TS-CL	**35.78±16.87**	**51.16±22.38**	**<0.001**
	C2-T1 SA°	**-2.12±13.46**	**6.20±13.53**	**<0.001**
	T4-T12 Kyphosis	41.74±19.40	45.04±17.66	0.296
	TPA	15.24±10.05	15.86±12.31	0.372
	SVA (mm)	1.71±52.77	10.32±74.83	0.437
	PI-LL	3.80±15.00	1.71±18.49	0.466
	PT	21.86±9.92	22.01±11.29	0.934
Change From Baseline Up to 3 Months	ΔT1S°	1.18 ± 16.22	0.38 ± 18.66	0.787
	Δ cSVA (mm)	-13.62±19.26	-11.81±13.85	0.545
	ΔTS-CL	-11.51±19.17	-15.60 ± 19.05	0.334
	ΔC2S°	-13.86±16.40	-17.61±19.05	0.214
	ΔT4-T12 Kyphosis	-1.47±12.94	2.31±13.35	0.091
	ΔC2-T1	-11.23±13.76	-11.29±12.49	0.979
	ΔC2-LIV	5.88±16.53	3.31±21.41	0.628
	ΔDJK angle	**6.33±7.09**	**10.45±11.94**	**0.026**
Postoperative In-Construct Measure	**C2-T1 SA°**	**-12.84±8.88**	**-5.23±9.33**	**<0.001**
DJK Analysis	DJK < -10°	9(14.8%)	17(29.8%)	0.074
	Severe DJK <-20°	2(3.3%)	6(10.5%)	0.153
	Revision Needed	3(4.1%)	4(5.75)	0.715

Table 3: In Construct Measurements at 3 Month Follow Up and Targets For Optimal Realignment

		N	Mean	p-value	In-Construct Target Goal at cSVA=4 cm	Mean Offset from Target
C2-T1 SA°	Success	72	-12.84±9.97			-3.29±8.88
	Failed	70	-5.23± 9.33	**<0.001**	-9.55°	4.32±9.33
C2-T4 SA°	Success	28	1.01± 7.56			1.38±7.56
	Failed	41	7.38±9.51	**0.004**	-0.37°	7.75±9.51
C2-T10 SA°	Success	6	21.38± 3.53			6.71±3.53
	Failed	19	30.98± 13.22	0.096	14.67°	16.31±13.22