

The Effect of Cervical Fusion on Functional Sagittal Spinal Alignment Based on the Inflection Point: Case Series Study

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Abstract

Study Design: A retrospective radiologic study.

Objective: The inflection point is the disc space between a lordotic and kyphotic segment of spine. To our knowledge, there has been no study evaluating changes in functional sagittal alignment determined by inflection points after cervical fusion surgery. The purpose is to identify changes in functional sagittal alignment after cervical fusion as determined by functional segments between cervicothoracic and thoracolumbar inflection points.

Methods: Standing radiographs of the sagittal whole spine were taken in 62 patients who underwent cervical fusion procedures. We identified cervicothoracic and thoracolumbar inflection points in the sagittal plane and measured Cobb angles of resulting “functional” cervical, thoracic, and lumbar segments. We also measured the C2 and T1 sagittal vertical axis (SVA) distance to S1 and the anatomic cervical lordosis, thoracic kyphosis, lumbar lordosis, spinopelvic parameters, and T1 sagittal slope. We compared the pre- and post-op values.

Results: The functional cervical segment and T1 sagittal slope increased postoperatively. C2 and T1 SVA distance to S1 decreased postoperatively. In patients with a single level fusion or lower instrumented vertebra (LIV) proximal or equal to C6, functional cervical segment, and anatomic cervical lordosis increased postoperatively. In those with multiple level fusion or LIV distal or equal to C7, the C2 SVA distance to S1 decreased postoperatively.

Conclusions: After cervical fusion surgery, functional cervical sagittal parameters determined by the inflection point improve without changes in the anatomic sagittal parameters. Postoperative changes in functional sagittal parameters were affected by the number of fused levels and LIV.

Keywords

cervical vertebrae, fusion, functional sagittal alignment, spinal inflection point

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Introduction

Contemporary spine surgical techniques emphasize the achievement and maintenance of proper sagittal alignment. Accordingly, there has been growing interest in understanding normal sagittal spinal alignment,^{1,2} and the reciprocal effects of alignment changes on the different spinal regions.^{3,4} For instance, cervical lordosis has been shown to be reduced following thoracolumbar deformity correction.³ In contrast, cervical surgery can lead to improvements in the sagittal alignment of the entire spine.⁴

With respect to clinical significance, there are conflicting results regarding the influence of sagittal alignment on clinical outcomes following cervical spine surgery.^{5,6} This may be due to radiographic assessment techniques that measure alignment parameters based on anatomic definitions of cervical, thoracic, and lumbar spinal regions instead of functional parameters. Instead of using anatomic spinal regions, the sagittal Cobb angles based on the end vertebrae and inflection points, which are similar to the coronal Cobb angles based on the end vertebrae in patients with scoliosis, might be useful for functional evaluation and preoperative planning for cervical spinal deformity. The inflection points represent the actual location where the lordotic curvature transitions into the kyphotic curvature and the level of the inflection point determines the vertebral number of kyphosis and lordosis.⁷ As the level of the cervicothoracic inflection point descends, the length of the lordotic segment increases, while that of the kyphotic segment decreases. This inflection point creates an accurate description of the sagittal curvature in kyphosis and lordosis.⁷⁻⁹ We have previously reported this alternative method, which defines functional cervical, thoracic, and lumbar segments based on the cervicothoracic and thoracolumbar inflection points from adult volunteers and elucidated the changes while considering different age groups.¹⁰ To our knowledge, however, no studies have evaluated the influence of cervical fusion surgery on functional sagittal alignment parameters.

The purpose of the present study is to identify changes in functional sagittal alignment after cervical fusion, as determined by functional segments between the cervicothoracic and thoracolumbar inflection points.

Materials and Methods

This study was approved by the institutional review board at the institution of the corresponding author (IRB number: 2019-09-025).

This study included 62 patients who underwent cervical fusion surgery with a diagnosis of cervical spondylotic radiculopathy in a single center from 2003 to 2012 (Table 1, Figure 1). Cervical spondylotic radiculopathy was diagnosed when radicular symptoms and neurologic signs were consistent with abnormal radiologic findings on MRI or by a positive response to diagnostic nerve root blocks in the cervical spine. The indications for cervical decompression and fusion were cervical radiculopathy causing intractable pain with or without

Table 1. Demographics of the Study Population.

	Mean \pm standard deviation (percentage or range)
Age, years	56.8 \pm 11.9 (35-85)
Gender, male	33 (53.2%)
Follow-up period, months	22.0 \pm 18.3 (12-74)
Surgery type	
Anterior fusion surgery	57 (91.9%)
Anterior cervical discectomy and fusion	53 (85.4%)
Anterior cervical corpectomy and fusion	4 (6.5%)
Posterior fusion surgery	5 (8.1%)
Fused disc levels	
One disc level	28 (45.2%)
Two disc levels	18 (29.0%)
Three disc levels	11 (17.7%)
Four disc levels	5 (8.1%)
Lower instrumented vertebra (LIV)	
C2	1 (1.6%)
C4	2 (3.2%)
C5	8 (12.9%)
C6	20 (32.3%)
C7	28 (45.2%)
T1	3 (4.8%)
Pain (VAS)	
Preoperative	6.6 \pm 1.2
Final	1.6 \pm 2.0
Neck disability index (NDI)	
Preoperative	30.1 \pm 6.9
Final	5.9 \pm 6.6

neurologic deficits, despite non-surgical treatment for at least 6 weeks. We excluded patients who underwent surgeries for trauma, infection, tumor, congenital anomaly, or myelopathy, patients who underwent decompressive surgeries without fusion for the cervical radiculopathy, patients whose treated pathology included thoracolumbar levels below T1, and patients without pre- and post-operative whole spine standing radiographs (Figure 1). Patients with myelopathy were excluded because they might have balance issues while standing.

The patients' mean age was 56.8 \pm 11.9 years (35-85 years) and the mean follow-up period was 22.0 \pm 18.3 months (12-74 months, Table 1). Anterior cervical discectomy and fusion was the most common procedure (85.4%) and a single-level fusion was most common (45.2%). The most common lower instrumented vertebra (LIV) was C7 (45.2%). All patients exhibited postoperative improvement in their arm pain, as evaluated by visual analog scale (VAS) and neck disability index (NDI). All patients showed the complete or partial neurologic improvement of the motor weakness, paresthesia, or dysesthesia in their arms at the final visit after surgeries.

The acquisition of whole-spine standing radiographs at the preoperative and the final follow-up visits was carefully standardized. The patients were asked to stand straight with a relaxed head position and to look straight ahead with their arms crossed on their chests. Lateral radiographs were performed

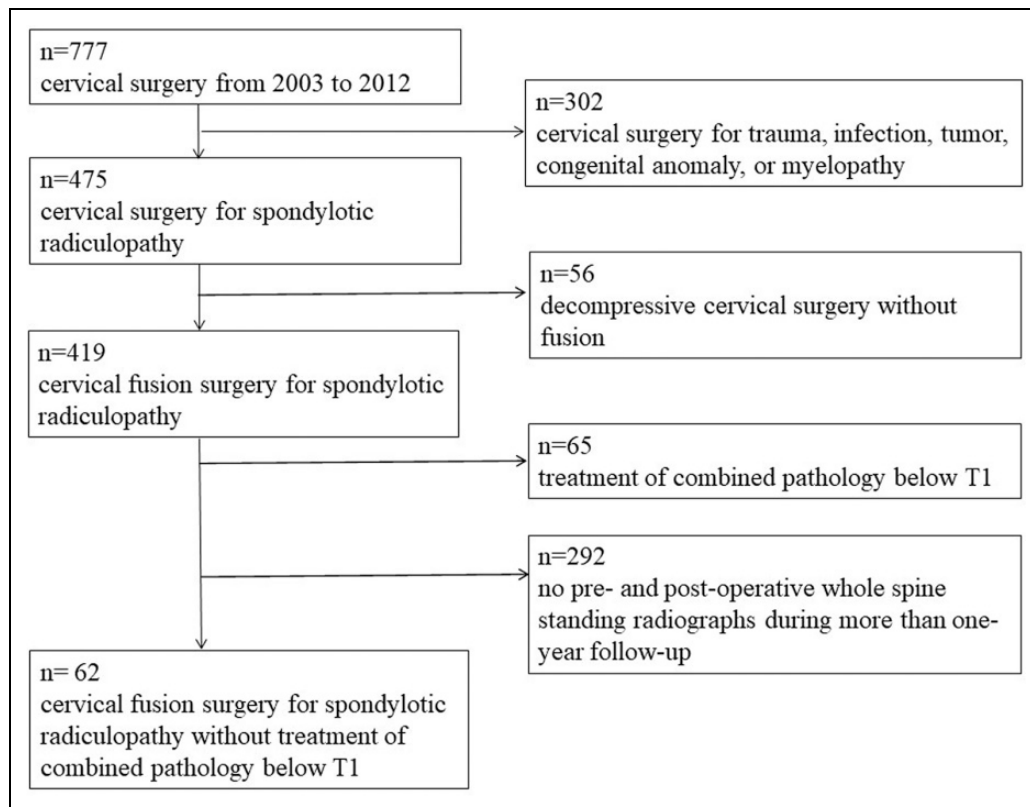


Figure 1. Cohort definition.

using standard radiographic techniques wherein the tube was centered at the level of the xiphoid process. The radiographic film cassette was placed 182 cm (72 inches) from the tube and radiographs were taken without magnification.

The functional sagittal alignment parameters based on the cervicothoracic and thoracolumbar inflection points were evaluated as we have previously described in Park et al.¹⁰ On lateral radiographs, we identified the cervicothoracic and thoracolumbar inflection points, which are the disc spaces between the lordotic and kyphotic segments of the spine. The inflection point is identified as the disc space between the most tilted vertebra at the cervicothoracic and thoracolumbar junctions. Marking the films from the bottom up, we drew the lower horizontal margin of the lateral radiograph, the first end vertebra (S1 superior endplate), second end vertebra (L5 inferior endplate), the third and fourth end vertebrae (on each side of the thoracolumbar inflection point), the fifth and sixth end vertebrae (on each side of the cervicothoracic inflection point) (Figure 2). Finally, we drew McGregor's line at the top. Next, the sacral slope was measured between the lower horizontal margin and the first end vertebra, the functional lumbar segment between the second and third end vertebrae, the functional thoracic segment between the fourth and fifth end vertebrae, and the functional cervical segment between the sixth end vertebra and McGregor's line.

We measured the anatomic parameters of cervical lordosis between McGregor's line and the inferior endplate of C7,

thoracic kyphosis between the superior endplate of T1 and the inferior endplate of T12, and lumbar lordosis between the superior endplate of L1 and the superior endplate of S1. We measured the pelvic incidence and pelvic tilt.

Additionally, we measured the T1 sagittal slope (measured as the angle between a horizontal line and the superior endplate of T1). The C2 sagittal vertical axis (SVA) distance to S1 and T1 SVA distance to S1 were measured from the C2 plumb line and T1 plumb line to the posterior superior corner of S1. We assigned a positive value when the sagittal angle was kyphotic or when the C2 plumb line was located anterior to the end vertebra.

We compared the radiologic parameters before and after the cervical fusion surgeries. We performed subanalyses stratifying the data by the number of levels fused and by the lower instrumented vertebra (LIV).

All statistical analyses were performed with SPSS version 13.0 for Windows (Chicago, IL, USA). Differences in continuous variables between the 2 different time points were examined with paired t-test. Values are expressed as mean values with standard deviation. It was considered significant when p was less than 0.05. Pearson correlation analysis was used to evaluate the influence of the sagittal parameters. In the previous study, the reliability statistics by ICC for Cobb angles were 0.777 for intra-observer reliability and 0.672 for inter-observer reliability.² The reliability statistics by ICC for SVA distance to S1 was 0.998 for intra-observer reliability and 0.965 for inter-observer reliability.²



Figure 2. Sagittal radiological parameters assessed with Cobb angle measurements. (α) Sacral slope (measured between the lower horizontal margin and the first end vertebra), (β) the functional lumbar segment (measured between the second and third end vertebrae), (γ) the functional thoracic segment (measured between the fourth and fifth end vertebrae), and (δ) the functional cervical segment (measured between the sixth end vertebra and McGregor's line).¹⁰

Table 2. Postoperative Changes in Sagittal Spinal Parameters: All Cases (Mean \pm Standard Deviation).

	Preop	Final	p value
Functional cervical segment (δ)	19.4 \pm 8.0	20.7 \pm 9.0	0.022
Functional thoracic segment (γ)	32.2 \pm 10.5	32.2 \pm 8.3	0.998
Functional lumbar segment (β)	46.5 \pm 9.4	47.1 \pm 8.1	0.265
Sacral slope (α)	35.0 \pm 8.2	36.3 \pm 7.6	0.091
Pelvic tilt	20.8 \pm 4.1	20.7 \pm 3.8	0.882
Pelvic incidence	53.7 \pm 7.5	53.3 \pm 8.2	0.546
Anatomic cervical lordosis	18.7 \pm 7.2	19.5 \pm 6.5	0.118
Anatomic thoracic kyphosis	31.9 \pm 10.0	31.6 \pm 8.2	0.655
Anatomic lumbar lordosis	46.4 \pm 9.2	47.0 \pm 7.5	0.353
T1 sagittal slope	17.8 \pm 5.7	19.4 \pm 6.2	0.001
C2 SVA distance to S1	23.5 \pm 18.0	17.9 \pm 14.1	0.001
T1 SVA distance to S1	21.3 \pm 16.7	16.7 \pm 13.0	0.003
Index operative level lordosis	1.1 \pm 7.3	5.9 \pm 6.6	0.001

Results

The functional cervical segment, T1 sagittal slope, and index operative level lordosis increased after surgery (Table 2). C2 and T1 SVA distance to S1 decreased after fusion surgery. The other functional parameters including the functional lumbar and thoracic segment did not change postoperatively. The other parameters including sacral slope, pelvic tilt, pelvic incidence, anatomic cervical lordosis, anatomic thoracic kyphosis, and anatomic lumbar lordosis did not change postoperatively.

The functional cervical segment was measured as the angle between McGregor's line and the inferior endplate of the sixth end vertebra. The sixth end vertebra varied before and after the operation. The sixth end vertebra was either C7 (14.5%), T1 (41.9%), T2 (37.1%), or T3 (6.5%) before operation and either T1 (29.0%), T2 (30.6%), or T3 (40.3%) after operation. Therefore, the amount of postoperative change between the T1 sagittal slope and the functional cervical segment was not the same.

Also, Pearson correlation analysis showed that the functional cervical segment was positively correlated with anatomic cervical lordosis, T1 sagittal slope, and index operative level lordosis, negatively with T1 SVA distance to S1 (Table 3). The anatomic cervical lordosis was positively correlated with T1 sagittal slope, but not correlated with C2 SVA distance to S1, T1 SVA distance to S1, and index operative level lordosis. Index operative level lordosis was positively correlated with functional cervical segment and T1 sagittal slope, but not correlated with anatomic cervical lordosis, C2 SVA distance to S1, and T1 SVA distance to S1.

In patients who underwent single level fusion, functional cervical segment, anatomic cervical lordosis, and T1 sagittal slope increased after surgery (Table 4, Figure 3). There was no change in C2 and T1 SVA distance to S1. In contrast, in the patients who underwent multi-level fusion, the T1 sagittal slope increased and the C2 and T1 SVA distance to S1 decreased postoperatively (Table 4, Figure 4).

Table 3. Correlation among the Postoperative Changes in Sagittal Spinal Parameters: All Cases (Pearson Correlation Coefficient/P value).

	Functional cervical segment (δ)	Anatomic cervical lordosis	T1 sagittal slope	C2 SVA distance to SI	T1 SVA distance to SI	Index operative level lordosis
Functional cervical segment (δ)	I	0.683/0.000	0.427/0.001	-0.184/0.152	-0.312/0.014	0.365/0.004
Anatomic cervical lordosis		I	0.535/0.000	-0.028/0.829	-0.187/0.146	0.238/0.063
T1 sagittal slope			I	-0.160/0.214	-0.220/0.086	0.265/0.037
C2 SVA distance to SI				I	0.641/0.000	-0.182/0.158
T1 SVA distance to SI					I	-0.241/0.059
Index operative level lordosis						I

Table 4. Postoperative Changes in Sagittal Spinal Parameters: Single Versus Multi-Level Cases (Mean \pm Standard Deviation).

	Single Level (n = 28)			Multiple Levels (n = 34)		
	Preop	Final	p value	Preop	Final	p value
Functional cervical segment (δ)	18.4 \pm 8.0	20.7 \pm 7.6	0.003	20.1 \pm 8.2	20.6 \pm 10.1	0.530
Functional thoracic segment (γ)	31.5 \pm 8.6	32.7 \pm 7.8	0.142	32.8 \pm 11.9	31.8 \pm 8.8	0.347
Functional lumbar segment (β)	48.7 \pm 8.1	48.7 \pm 5.5	0.992	44.6 \pm 10.0	45.8 \pm 9.1	0.189
Sacral slope (α)	38.0 \pm 8.7	37.5 \pm 6.1	0.597	32.5 \pm 7.1	35.3 \pm 8.7	0.173
Pelvic tilt	21.2 \pm 4.2	20.9 \pm 3.5	0.602	20.5 \pm 4.1	20.7 \pm 4.0	0.808
Pelvic incidence	54.7 \pm 7.7	53.8 \pm 9.1	0.425	52.8 \pm 7.3	52.9 \pm 7.5	0.870
Anatomic cervical lordosis	18.1 \pm 8.0	20.3 \pm 7.5	0.004	19.1 \pm 6.5	18.9 \pm 5.5	0.839
Anatomic thoracic kyphosis	31.9 \pm 9.2	32.0 \pm 7.8	0.900	32.0 \pm 10.8	31.2 \pm 8.6	0.446
Anatomic lumbar lordosis	48.5 \pm 8.0	48.2 \pm 6.2	0.698	44.7 \pm 9.8	46.0 \pm 8.4	0.168
T1 sagittal slope	17.2 \pm 5.8	19.7 \pm 7.3	0.001	18.3 \pm 5.6	19.1 \pm 5.3	0.001
C2 SVA distance to SI	20.3 \pm 18.7	16.1 \pm 12.8	0.225	26.1 \pm 17.3	19.4 \pm 15.1	0.000
T1 SVA distance to SI	19.2 \pm 15.3	14.7 \pm 11.8	0.148	23.0 \pm 17.8	18.2 \pm 13.9	0.001
Index operative level lordosis	0.4 \pm 6.4	4.3 \pm 6.7	0.001	2.5 \pm 7.8	7.3 \pm 6.4	0.001

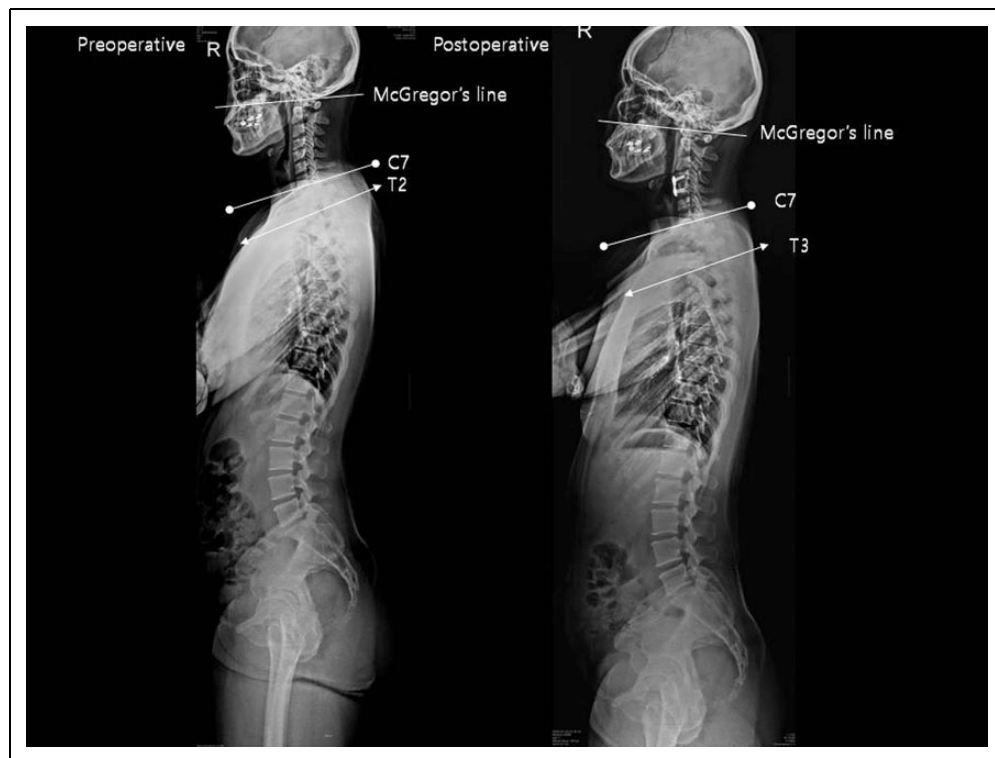
**Figure 3.** Radiographic changes in anatomic cervical lordosis and functional cervical segment. This 40-year-old woman underwent anterior cervical fusion at C4-C5. Postoperative radiographs demonstrated that anatomic cervical lordosis increased from 25.3° to 29.3° (lines with round ends). The functional cervical segment increased from 29.4° to 36.2° as the cervicothoracic inflection point changed from T2 to T3 (lines with arrow ends).



Figure 4. Radiographic change in distance between C2 SVA and S1. This 31-year-old man underwent anterior cervical fusion at C5-C6-C7. Postoperative radiographs showed that the distance between C2 SVA and S1 decreased postoperatively.

Table 5. Postoperative Changes in Sagittal Spinal Parameters: Stratified by Lower Instrumented Vertebra (LIV) (Mean \pm Standard Deviation).

	LIV proximal or equal to C6 (n = 31)			LIV distal or equal to C7 (n = 31)		
	Preop	Final	p value	Preop	Final	p value
Functional cervical segment (δ)	20.0 \pm 9.0	22.5 \pm 11.0	0.005	18.8 \pm 7.1	18.8 \pm 5.9	0.934
Functional thoracic segment (γ)	32.2 \pm 11.2	33.4 \pm 8.8	0.239	32.2 \pm 9.8	30.1 \pm 7.7	0.176
Functional lumbar segment (β)	47.9 \pm 8.2	48.2 \pm 7.7	0.643	45.0 \pm 10.3	46.0 \pm 8.4	0.303
Sacral slope (α)	36.1 \pm 7.6	37.6 \pm 8.4	0.184	33.9 \pm 8.8	34.9 \pm 6.7	0.308
Pelvic tilt	20.7 \pm 4.0	21.0 \pm 3.4	0.700	20.9 \pm 4.3	20.5 \pm 4.1	0.549
Pelvic incidence	54.5 \pm 7.9	53.3 \pm 9.5	0.277	52.9 \pm 7.1	53.3 \pm 6.7	0.472
Anatomic cervical lordosis	19.0 \pm 7.5	20.9 \pm 6.9	0.030	18.3 \pm 7.0	18.2 \pm 5.8	0.102
Anatomic thoracic kyphosis	31.3 \pm 9.9	32.6 \pm 8.6	0.122	32.5 \pm 10.3	30.6 \pm 7.9	0.446
Anatomic lumbar lordosis	48.0 \pm 7.9	48.3 \pm 6.4	0.622	44.9 \pm 10.3	45.6 \pm 8.3	0.431
T1 sagittal slope	17.3 \pm 5.0	19.6 \pm 5.5	0.002	18.2 \pm 6.3	19.1 \pm 6.0	0.001
C2 SVA distance to S1	22.8 \pm 20.0	17.1 \pm 14.5	0.085	24.2 \pm 16.2	18.7 \pm 13.8	0.000
T1 SVA distance to S1	22.5 \pm 18.6	16.7 \pm 13.8	0.047	20.0 \pm 14.7	16.6 \pm 12.5	0.009
Index operative level lordosis	0.8 \pm 7.6	4.9 \pm 6.9	0.001	3.2 \pm 6.5	6.9 \pm 6.4	0.001

In patients who had LIV proximal or equal to C6, functional cervical segment, anatomic cervical lordosis, and T1 sagittal slope increased after fusion surgery (Table 5, Figure 3). T1 SVA distance to S1 decreased after surgery. There was no change of C2 SVA distance to S1. In contrast, in patients who had LIV distal or equal to C7, the T1 sagittal slope increased and C2 and T1 SVA distance to S1 had decreased after fusion surgery (Table 5, Figure 4).

Discussion

In asymptomatic adults, Lee et al examined factors that influence cervical spine sagittal balance and global spinopelvic balance.¹ Seventy-seven volunteers without a history of spinal conditions were enrolled and spinopelvic parameters were evaluated, including pelvic incidence, sacral slope, thoracic kyphosis, and cervical lordosis (upper cervical lordosis:

C0-C2 angle, lower cervical lordosis: C2-C7 angle).¹ They found that there was no relationship between the cervical lordosis parameters, the lumbar lordosis parameters, and the spinopelvic parameters.¹ However, they did not evaluate these spinal alignment measures using functional sagittal alignment parameters defined by inflection points.

Berthonnaud et al. and Roussouly et al. performed pioneering studies to elucidate the concept of functional sagittal alignment based on the inflection point between lordosis and kyphosis.^{8,9} With asymptomatic adult volunteers, they evaluated the cervicothoracic and thoracolumbar inflection points between lordosis and kyphosis using a standing lateral radiograph of the whole spine.^{8,9} We previously reported that the functional lumbar segment, based on the thoracolumbar inflection point, decreased in the oldest age group.¹⁰ Pan et al. assessed a total of 205 asymptomatic volunteers while incorporating the inflection points into their evaluation.⁷ They found that the thoracolumbar inflection point was correlated with age and a reciprocal association between functional thoracic and functional lumbar segments.⁷ Our current findings build upon these studies by examining postoperative changes in functional sagittal alignment parameters in patients following cervical fusion surgery.

Kim et al. studied whether anterior cervical discectomy and fusion were associated with postoperative changes in spinal sagittal alignment.⁴ Forty-eight patients who had undergone single-level surgery were enrolled in their study from January 2011 to December 2012.⁴ Surgery was found to affect whole-spine sagittal balance postoperatively and was associated with decreased anatomic cervical lordosis, decreased sacral slope, and increased pelvic tilt.⁴ There was no effect of surgery on the SVA distance to S1, thoracic kyphosis, or lumbar lordosis.⁴ In contrast, our study involving patients who underwent single level fusions found that anatomic cervical lordosis, functional cervical segment, and T1 sagittal slope increased after anterior cervical fusion surgery. There was no change in C2 and T1 SVA distance to S1 postoperatively. Their finding that there was no effect of fusion surgery on the SVA distance to S1, thoracic kyphosis, and lumbar lordosis was concordant with the result of the current study. However, they found decreased anatomic cervical lordosis, which was different from our findings of increased anatomic cervical lordosis, functional cervical segment, and T1 sagittal slope. They found that single-level fusion surgeries in the cervical spine changed postoperative spinopelvic parameters, decreasing sacral slope and increasing pelvic tilt, which is discordant with the current study. Our study is more in line with a sagittal alignment study with asymptomatic volunteers, which showed that the change in cervical sagittal parameters was not related to spinopelvic parameters.¹ Also, the study by Kim et al. was different from the current study in that they did not evaluate patients using functional global alignment parameters based on inflection points, and they did not evaluate the effects of the number of levels fused and of the LIV on the sagittal alignment.⁴

Our study included important sub-analyses, stratifying the data by the number of levels fused and the location of LIV. A

reciprocal relationship exists between the primary problem and the secondary compensation to achieve a balance of the body through reciprocal changes.¹¹⁻¹³ If a primary problem disturbs the balance, the body attempts to restore the balance by utilizing secondary compensatory mechanisms. The increase in anatomic cervical lordosis and functional cervical segment in the cases with single-level fusion, or those with LIV proximal or equal to C6, are compensatory for any sagittal malalignment caused by the limited cervical fusion mass. Similarly, the decreased C2 and T1 SVA distance to S1 observed postoperatively in the cases with multi-level fusion or those with LIV distal or equal to C7 is compensatory for the sagittal malalignment caused by cervical fusion. This is because the extensive fusion nearly down to the thoracic spine may make it impossible to compensate for it with increases in anatomic cervical lordosis and functional cervical segment. These findings imply that postoperative compensations in the cervical alignment differ depending on the extent of the fusion levels in the cervical spine.

There are several limitations to this investigation. First, standard whole spine radiographs were used for assessment instead of a biplanar slot scanner (EOS imaging technology) that can provide even more true to axis images and more precise and accurate measurements. Fortunately, the reliability statistics by ICC for the Cobb angles and distances measured in the current study were excellent to moderate. Future studies could build upon ours by employing a biplanar slot scanner (EOS imaging technology). Second, we did not analyze flexion-extension films which may allow for further characterization of baseline and postoperative neck flexibility. It is possible that spinal flexibility, as well as patient age, significantly influence postoperative cervical spinal alignment. Also, the potential of reciprocal change related to the C2 SVA distance to S1 and T1 SVA distance to S1 might differ based on the degenerative status and the flexibility of the thoracic and lumbar spine. The range of age in the current study population was wide. Therefore, the degenerative status and the flexibility might be various. These would be areas for further investigation. Third, while we had a moderate sample size (62 patients) and follow up time (mean 22 months), it is possible that with a larger sample size and longer follow up time, our study would have been more sensitive for subtle postoperative changes such as reciprocal changes in the lumbar and thoracic functional segments following cervical surgery. However, to our knowledge, this is the first study identifying changes in the functional sagittal alignment of the whole spine after cervical fusion surgery. Clinicians need to consider functional compensatory changes after cervical fusion surgery. It highlights the importance of incorporating functional alignment parameters based on the cervicothoracic and thoracolumbar inflection points in future research.

In conclusion, we observed that functional cervical sagittal parameters determined by the inflection point improve after cervical fusion surgery. These changes in functional sagittal spinal alignment can be detected even when the changes in anatomic sagittal parameters show no significant postoperative

changes. Furthermore, we found that postoperative changes in functional sagittal parameters were affected by the number of fused levels and LIV.

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