

Received: 2020.02.23

Accepted: 2020.05.06

Available online: 2020.06.04

Published: 2020.07.29

# Analysis of Cervical Sagittal Balance in Treating Cervical Spondylotic Myelopathy: 1-Level Anterior Cervical Corpectomy and Fusion Versus 2-Level Anterior Cervical Discectomy and Fusion

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Data Collection B  
Statistical Analysis C  
Data Interpretation D  
Manuscript Preparation E  
Literature Search F  
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**Source of support:**

This work was supported by funding from the National Natural Science Foundation of China (Grant 31700854) and Scientific Research Foundation of Bengbu Medical College (BYKY18482D)

**Background:** Anterior cervical corpectomy and fusion (ACCF), together with anterior cervical discectomy and fusion (ACDF) are both effective clinical treatments for cervical spondylotic myelopathy (CSM). Cervical sagittal balance is critical to preserving normal alignment, and is also associated with clinical outcomes.

**Material/Methods:** We retrospectively reviewed patients who had suffered from CSM and had undergone 1-level ACCF or 2-level ACDF surgery between December 2016 and November 2017. Forty-eight patients were identified: 25 in the ACDF group and 23 in the ACCF group. All patients received follow-up for more than 12 months. The demographic data, radiographic parameters, and clinical efficacy were compared between and within groups, both pre- and postoperatively.


**Results:** Both groups acquired good clinical efficacy; both Japanese Orthopedic Association (JOA) scores and Neck Disability Index (NDI) scores improved significantly. At the final follow-up visit, patients in the ACCF and ACDF groups did not differ significantly in C2-C7 Sagittal Vertebral Axis (cSVA), T1 Pelvic Angle (TPA), Neck Tilt (NT), Thoracic Inlet Angle (TIA), JOA, or NDI scores. However, the ACDF group had a significantly larger Cobb angle and T1 Slope (T1S) than the ACCF group. The postoperative Cobb angle increased significantly only in the ACDF group, while postoperative T1S significantly increased in both ACCF and ACDF groups.

**Conclusions:** Anterior cervical surgery may change the sagittal balance in terms of T1S or Cobb angle. No significant difference was found between ACCF and ACDF in clinical outcomes or representative global sagittal parameters. ACDF achieved more lordosis improvement than ACCF, with higher T1S. Surgeons need to pay extra attention to cervical sagittal balance, rather than focusing solely on decompression.

**MeSH Keywords:** **Cervical Vertebrae • Neurosurgery • Orthopedics**

**Abbreviations:** **ACDF** – anterior cervical discectomy and fusion; **ACCF** – anterior cervical corpectomy and fusion; **CSM** – cervical spondylotic myelopathy; **cSVA** – C2–C7 sagittal vertebral axis; **CL** – cervical lordosis; **HRQOL** – Health-Related Quality Of Life; **JOA** – Japanese Orthopedic Association; **NDI** – Neck Disability Index; **NT** – neck tilt; **PI** – pelvic incidence; **PT** – pelvic tilt; **SS** – sacral slope; **T1S** – T1 slope; **TIA** – thoracic inlet angle; **TPA** – T1 pelvic angle; **ODI** – Oswestry Disability Index

**Full-text PDF:** <https://www.medscimonit.com/abstract/index/idArt/923748>

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## Background

Cervical spondylotic myelopathy (CSM) is a common and serious spinal cord disorder. In patients aged 55 years or older, about 10% show clinical CSM, and 50% show cervical spondylosis on MRI [1]. The compression of the cervical spinal cord or nerve roots often causes paresthesia or paralysis. Surgeons recommend decompression surgery to improve patients' quality of life, since complete decompression is the primary goal to prevent further neurological worsening.

Both anterior and posterior approaches are used in surgeries to treat CSM, including anterior cervical corpectomy and fusion (ACCF), anterior cervical discectomy and fusion (ACDF), laminoplasty, and laminectomy. Surgeons prefer an anterior approach in treating 1- or 2-level CSM, while the posterior approach is more favored in multi-level CSM without kyphosis [2].

ACCF and ACDF are two effective anterior procedures widely used in clinical practice, with unique advantages and disadvantages. Compared with ACCF, ACDF is superior in that it is associated with less surgical trauma, lower device-related complications, and more improved Cervical Lordosis (CL) [3]. However, ACDF is also accompanied by higher nonunion rates due to the larger graft-host interfaces [4]. Both discectomy and corpectomy may change alignment, which could further affect sagittal balance and clinical outcomes.

Cervical sagittal balance is critical to preserving normal alignment. It is also associated with clinical outcomes. Patients with poor sagittal balance are prone to spinal cord compression and high tension, and some researchers even believe that restoring the normal sagittal balance should be as important as decompression [5]. It has been reported that C2–C7 Sagittal Vertebral Axis (cSVA) is positively correlated with Neck Disability Index (NDI) and negatively correlated with SF-36 health survey scores among patients with posterior cervical fusion [6]. A study of 656 volunteers found that T1 Slope (T1S), T1 Slope-Cervical Lordosis (T1S-CL), and cSVA were all negatively correlated with EQ-5D scores [7]. Many studies have compared ACDF with ACCF for the treatment of CSM [8,9]; however, few studies have considered sagittal balance as an important aspect. Furthermore, the few studies that have discussed this issue did not focus on any global parameters, such as T1 Pelvic Angle (TPA), other than local cervical sagittal balance.

In our study, we retrospectively collected radiographic data and clinical outcomes for patients who underwent ACCF or ACDF to evaluate the effectiveness of surgeries from the perspective of sagittal balance.

## Material and Methods

We retrospectively reviewed patients who had suffered from CSM and had undergone ACCF or ACDF surgery between December 2016 and November 2017. The inclusion criteria included: 1) symptomatic CSM that failed to be resolved by conservative treatments; 2) treatment by 2-level ACDF or 1-level ACCF; and 3) a minimum of 1-year follow-up. The exclusion criteria included: cervical deformities, infection, tumor, other spinal surgical history, and age under 18 years. This study was conducted in accordance with the principles of the Declaration of Helsinki, and the study protocol was approved by the ethics committee of the First Affiliated Hospital of Bengbu Medical College, Bengbu, China (BYFY-2019KY03). Because of the retrospective nature of the study, patient consent for inclusion was waived.

### Surgical technique

All patients underwent a standard anterior surgery of the cervical spine. The surgery type was decided by the surgeon according to the characteristics of the spinal cord compression. Surgeons usually choose ACCF in patients with large osteophyte or focal ossification of the posterior longitudinal ligament, while they prefer ACDF in patients with disc herniation only. In the ACDF group, after discectomy and removal of osteophytes, cages (Zimmer Biomet Inc.) filled with autologous bone fragments were inserted into the disc spaces, and an anterior plate (Double Medical Technology Inc.) was utilized. In the ACCF group, after corpectomy and full decompression, a titanium mesh cage with autologous bone fragments and an anterior plate (Double Medical Technology Inc.) was used to isolate the vertebrae.

### Radiological assessment

Cervical sagittal balance was assessed by radiological parameters calculated on standing lateral X-ray images preoperatively and at the final follow-up visit (Figure 1). The parameters are defined as follows:

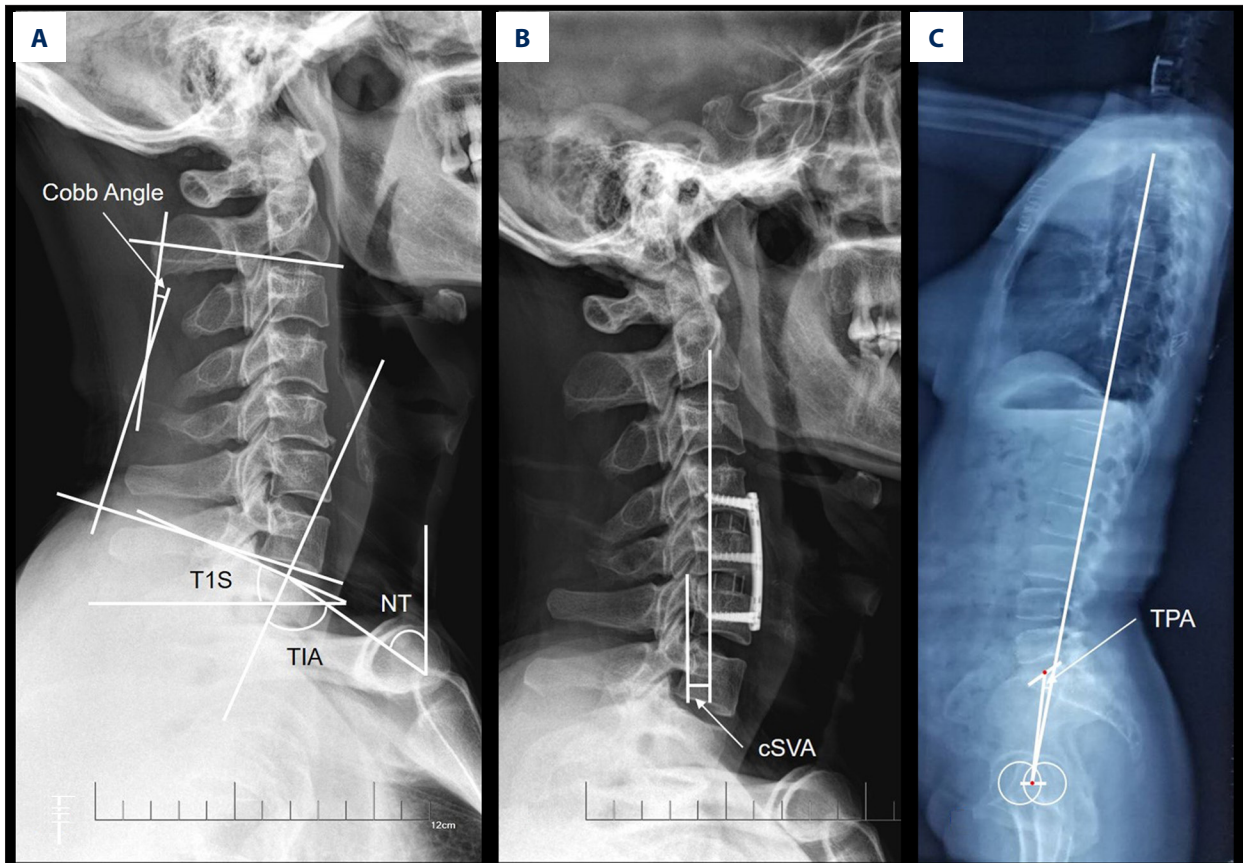
**Cobb angle:** Angle formed between the inferior endplate of C2 and the inferior end plate of C7.

**T1S:** Angle between a horizontal line and the superior endplate of T1 [10].

**Thoracic Inlet Angle (TIA):** Angle subtended by the vertical line at the middle of the superior endplate of T1 and a line connecting the middle of the superior endplate of the T1 to the upper end of the sternum [11].

**Neck Tilt (NT):** Angle between a vertical line drawn on the upper end of the sternum and a line connecting the middle of the superior endplate of the T1 to the upper end of the sternum.

**cSVA:** Distance between a plumb line dropped from the centroid of C2 to the posterior superior endplate of C7.



**Figure 1.** Cervical parameters on standing lateral X-ray images: **(A)** Cobb angle: Angle between inferior endplate of C2 and C7. T1S: Angle between a horizontal line and the superior endplate of T1. TIA: Angle between a vertical line and a line connecting the middle of the superior endplate of the T1 to the upper end of the sternum. NT: Angle between a vertical line and a line connecting the middle of the superior endplate of the T1 to the upper end of the sternum. **(B)** cSVA: Distance between a plumb line dropped from the centroid of C2 to the posterior superior endplate of C7. **(C)** TPA: Angle between the line from the centroid of T1 vertebrae to the femoral head axis and the line from the femoral head axis to the middle of the S1 superior endplate.

TPA: Angle between the line from the center of the femoral head axis to the centroid of T1 and a line from the femoral head axis to the middle of the S1 endplate [12,13].

### Clinical assessment

NDI and Japanese Orthopedic Association (JOA) scores were calculated to assess the pre- and postoperative clinical outcomes.

### Statistical analysis

For this study, the sample size was initially calculated in accordance with previous research [14]. To achieve statistical power of 80% and a confidence level of 95%, however, a sample size of at least 15 patients in each group was necessary [15].

Continuous data are presented as mean±standard deviation. Comparison between two groups was analyzed by Student

t test for continuous variables and chi-square test for categorical variables. All statistical analyses were performed in SPSS 18.0 for Windows (Chicago, IL, USA). Significance was accepted at  $p \leq 0.05$ .

### Results

In this study, a total of 48 patients were enrolled, including 25 patients (18 males, 7 females) in the ACDF group and 23 patients (16 males, 7 females) in the ACCF group. The average age of the patients was  $57.0 \pm 9.1$  years (range: 45 to 72) in the ACDF group and  $56.6 \pm 7.9$  years (range: 42 to 73) in the ACCF group. The follow-up time in the ACDF group was  $16.7 \pm 3.0$  months; in the ACCF group it was  $15.8 \pm 2.4$  months. In both groups, the demographic characteristics, including gender, age, operation segments, and follow-up time, were not significantly different (Table 1).

**Table 1.** Demographic data for patients in ACDF/ACCF group.

	Patients enrolled		P Value
	ACDF group	ACCF group	
Gender			0.86
Male	18	16	–
Female	7	7	–
Age (years)	57.0±9.1	56.6±7.9	0.88
Follow-up (months)	16.7±3.0	15.8±2.4	0.25
Operation segments			0.68
C3–5	3	2	–
C4–6	5	8	–
C5–7	17	13	–

**Table 2.** The clinical and radiological parameters of patients in ACDF/ACCF group.

	Preoperative		Final follow-up	
	ACDF	ACCF	ACDF	ACCF
Cobb	14.0±9.5	12.4±8.6	22.5±7.4**	17.2±7.9
T1S	23.0±7.2	20.1±6.6	27.7±5.8**	23.9±5.3#
TIA	73.3±8.7	71.0±9.0	77.6±7.7	74.8±8.7
NT	50.2±7.3	50.8±9.0	49.9±7.0	50.9±9.1
cSVA	11.6±3.9	12.3±4.3	12.2±4.2	11.0±3.9
TPA	20.6±5.0	19.0±5.1	19.6±4.1	19.3±5.7
JOA	7.4±1.2	7.5±1.2	12.7±1.4#	12.4±1.1#
NDI	32.5±2.7	31.9±3.2	12.5±2.3#	12.2±2.2#

\* Showed  $p < 0.05$  while compared to the ACCF group at the same follow-up time; # showed  $p < 0.05$  while compared to the pre-operative figure in the same group.

**Comparison of pre- and postoperative radiological parameters within each group**

In the ACDF group, the Cobb angle increased significantly after surgery, from 14.0±9.5 to 22.5±7.4 ( $P=0.001$ ), while in the ACCF group, the change showed no difference ( $P > 0.05$ ). T1S significantly increased in both groups, from 23.0±7.2 to 27.7±5.8 ( $P=0.014$ ) and from 20.1±6.6 to 23.9±5.3 ( $p=0.040$ ) in the ACDF and ACCF groups, respectively, at final follow-up. As for TIA, NT, cSVA, and TPA, there was no significant improvement in either group nor were there significant differences between the two groups ( $P > 0.05$ ) (Table 2).

**Comparison of radiological parameters between the ACDF and ACCF groups**

All preoperative parameters showed no differences between the two groups ( $P > 0.05$ ). At the last follow-up, the Cobb angle

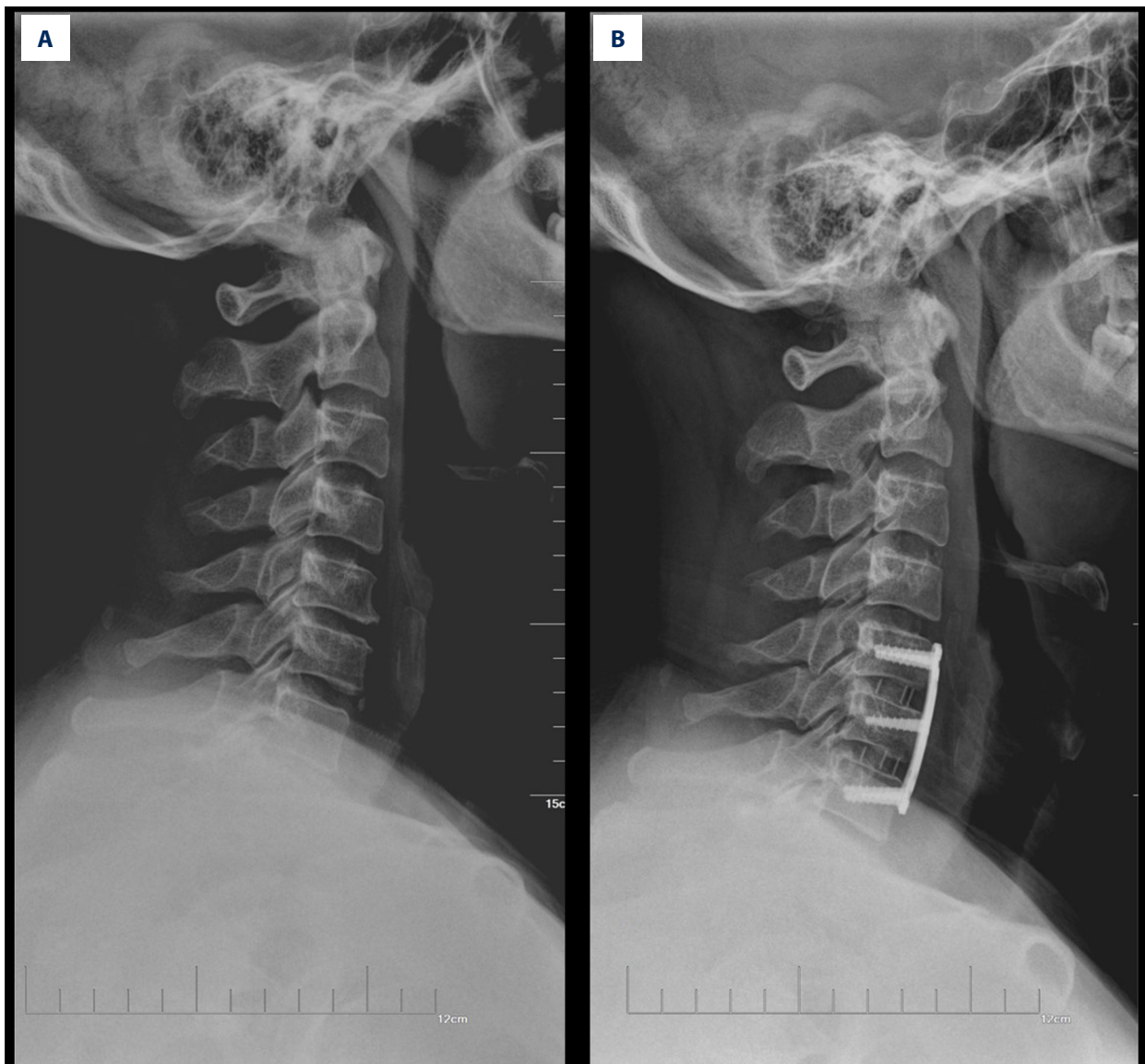
differed significantly between the two groups, measuring 22.5±7.4 in the ACDF group and 17.2±7.9 in the ACCF group ( $P=0.019$ ). Postoperative T1S was also larger in the ACDF group than in the ACCF group ( $P=0.021$ ) (Figures 2, 3).

**Comparison of clinical outcomes between the ACDF and ACCF groups**

The pre- and postoperative JOA and NDI scores did not differ significantly between the two groups ( $P > 0.05$ ). Nevertheless, the scores improved significantly in both groups after surgery ( $P < 0.05$ ).

**Discussion**

Anterior surgery is a common technique used to treat CSM, especially 1- or 2-level CSM. It directly decompresses the spinal



**Figure 2.** Preoperative lateral X-ray images of (A) a 48-year-old male patient who suffered from severe CSM (C5–C7) and underwent 2-level ACDF (postoperative lateral view), and (B) this patient in the final follow-up visit, showing that the instrumentation is well positioned.

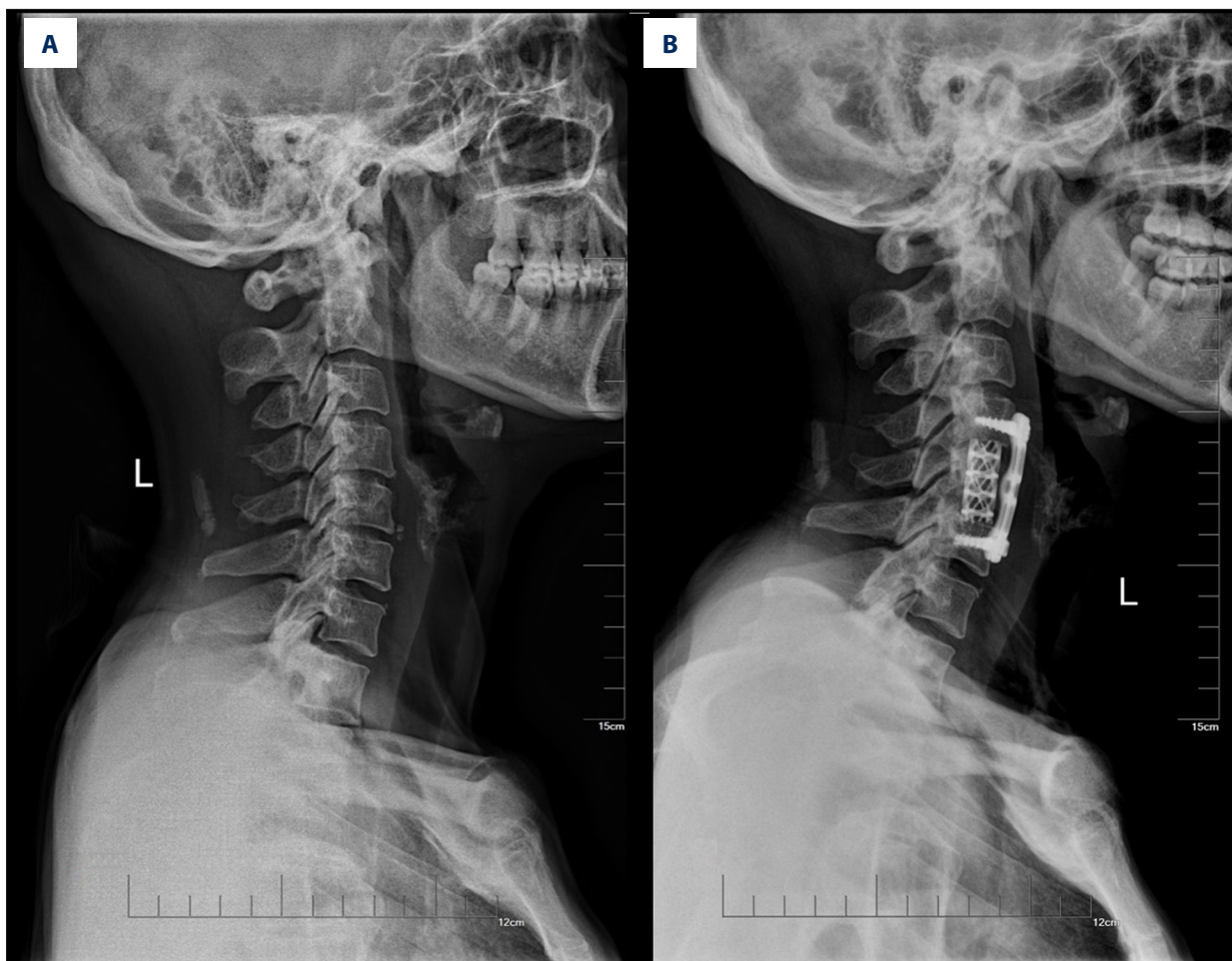
cord, restoring the intervertebral height and improving the curvature of the cervical spine [16]. ACCF works via autografting and achieves extensive decompression [17]. Compared with ACCF, ACDF results in less surgical trauma, fewer complications, and more improved CL [3]. However, ACDF may have a higher risk of incomplete decompression [4,18].

The primary goal of ACDF and ACCF is complete decompression. However, with the in-depth understanding of sagittal balance, more and more literature has highlighted the importance of cervical sagittal alignment. Sagittal balance closely associates with clinical prognosis. Kyphosis is negatively correlated with JOA score [19]. To reduce the energy consumption of

neck muscles and achieve satisfactory results, it is important to maintain lordosis after surgery [20]. In the present study, Cobb angle in the ACDF group improved more compared with the ACCF group, which agrees with previous studies [21,22].

There have been more than 20 parameters proposed for analysis of cervical sagittal balance [23]. We selected five of the most representative ones to describe local and global balance: T1S, TIA, NT, cSVA, and TPA.

cSVA is a classic sagittal parameter to evaluate cervical alignment, which associates closely with Health-Related Quality of Life (HRQOL) [24]. That is because energy consumption



**Figure 3.** (A) Preoperative lateral view of a 66-year-old female patient who underwent complete recuperation after ACCF (C4–C6). (B) Postoperative lateral view of the same patient in the final follow-up visit, showing a good positioning of the instrumentation.

increases as the center of gravity shifts. Among patients with multilevel posterior cervical fusion, cSVA positively correlates with NDI and negatively correlates with SF-36, with regression analysis suggesting a cSVA threshold value of 40 mm [6]. In addition, multiple linear regression indicates that, among the parameters of T1S, CL, SS, PI, thoracic kyphosis, lumbar lordosis, and femoral-sacral angle, T1S has the strongest correlation with cSVA [25].

T1S is a measure of the degree of forward tilt of the cervical spine, which means it can be affected by posture. It is similar to pelvic incidence (PI), with “TIA=NT+T1S” similar to “PI=sacral slope (SS)+pelvic tilt (PT)” [11]. A high T1S has been linked to postoperative cervical kyphosis [26], which may lead to spinal cord compression gradually developing into CSM. Also, higher T1S may increase the energy consumption of the posterior muscles, causing neck pain in some patients [27]. A T1S of 40° or higher has been reported to be significantly associated with poor clinical outcomes [28]. Furthermore, Huang et al.

found that T1S was significantly correlated with NDI scores, both pre- and post-operatively, and regression analysis indicated a threshold T1S value of 42° [29]. In our study, the T1S was well below 42°, and both ACCF and ACDF significantly improved the NDI score.

TPA is a new parameter representing global sagittal balance. It strongly affects HRQOL, with a better response to postoperative changes in sagittal alignment [30]. Banno et al. found that SVA is most closely related to the preoperative Oswestry Disability Index (ODI), while TPA most closely influences postoperative ODI [31]. TPA, rather than SVA or PT, is more likely to be a predictor of long-term postoperative outcomes. That is why we chose TPA as a representative parameter of global sagittal balance. Our results found that neither group showed a large difference between pre- and postoperative TPA, which indicates that the effect of cervical surgery on global sagittal balance may be limited.

In our research, ACCF and ACDF did not differ significantly in C2–C7 SVA, TPA, NT, and TIA. There were no significant differences in the JOA and NDI scores. However, the ACDF group had a significantly larger Cobb angle and T1S than the ACCF group. This is mainly because ACDF offers a more evenly distributed force on the vertebral body; the force is concentrated in the center of the plate. The lordosis angle of every interbody (TM-S, Zimmer Biomet Inc.) used in the ACDF procedure is 7°. These all contribute to the Cobb angle in ACDF. In contrast, in ACCF, the corpectomy and titanium mesh cage strengthen only the axial support.

Understanding the correlation between Cobb angle and T1S is not difficult: T1 connects the cervical and thoracic vertebrae. It is fixed to the sides of the ribs and does not change with position. To maintain a horizontal gaze, C2–C7 lordosis increases with increasing T1S [32].

In conclusion, anterior cervical surgery may change the sagittal balance in T1S or Cobb angle. ACDF achieves more lordosis improvement and higher T1S than ACCF. Both approaches have limited effects on other parameters that represent global sagittal balance. Surgeons should pay extra attention to

the balance of the cervical spine, rather than solely focusing on the decompression surgery itself, since sagittal imbalance (T1S >40°) has a potential risk of a poor clinical prognosis [29].

Some limitations in our research prevent us from conducting a comprehensive assessment. These include: 1) retrospective study design; 2) limited sample size; 3) short-term follow-up. We did not calculate the threshold of T1S due to the relatively small number of samples. Further studies could increase the sample size and follow-up period, or a double-blind randomized controlled trial could be conducted to more precisely characterize the impact of sagittal parameters on clinical outcomes.

## Conclusions

Anterior cervical surgery may change the sagittal balance in T1S or Cobb angle. There was no significant difference between ACCF and ACDF in clinical outcome and representative global sagittal parameters. ACDF achieves greater improvement of lordosis than ACCF, and also results in a higher T1S. Surgeons need to pay extra attention to the balance of the cervical spine rather than solely focusing on decompression.

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