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Original Article

Changes of cervical sagittal balance parameters after anterior cervical corpectomy and fusion: correlations with clinical outcomes

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Abstract: Objectives: To explore the changes of cervical sagittal balance parameters after anterior cervical corpectomy and fusion and its correlation with clinical outcomes. Methods: A retrospective study of 127 cases of anterior cervical corpectomy and fusion in cervical spondylosis from Jan 2011 to Dec 2016 was performed. The patient's age, gender, JOA score, VAS score, NDI score and other indicators were measured. The sagittal parameters of the cervical vertebrae (T1-S, C2-7 Cobb, C0-2 Cobb, SVA) were measured by X-ray, and the sagittal position before and after surgery was analyzed for parameter changes and correlation with clinical outcomes. Measurement data were expressed as mean ± standard deviation. Single-sample Kolmogorov-smirnov test (K-S test) and paired sample t test were used for analysis. Spearman sagittal parameters were used for clinical efficacy correlation analysis. Results: A total of 127 patients were enrolled, including 60 males and 67 females, aged (51.2 ± 10.8) years old. After 1 year follow-up of ACCF, the JOA score of this group increased from 10.03 ± 4.24 points to 14.22 ± 3.99 points, the VAS score decreased from 3.34 ± 2.00 points to 1.40 ± 1.36 points, the NDI index decreased from 41.70% ± 14.87% to 22.09% ± 12.90%, and the difference was statistically significant ($P<0.05$). The sagittal parameter T1-S was increased from preoperative 23.54 ± 6.18 to 27.06 ± 7.13, the C2-7 Cobb was increased from preoperative 12.79 ± 5.29 to 15.31 ± 6.44, the SVA was increased from 24.81 ± 8.74 mm to 27.92 ± 8.45 mm, the C0-2 Cobb was decreased from preoperation 22.13 ± 7.93 to 20.37 ± 7.64, and the difference was statistically significant ($P<0.05$). Correlation analysis between the sagittal parameters and the changes of clinical outcomes index showed that the C2-7 Cobb angle change value was positively correlated with the JOA change value and the T1-S change value ($P=0.008$/$P=0.001$). The NDI (Neck disability index, NDI) and C0-2 Cobb change values were negatively correlated ($P=0.042$/$P=0.001$). Conclusions: The short-term clinical effect of cervical vertebrae ACCF in the treatment of cervical spondylosis is significant. The cervical vertebra has a certain self-compensation mechanism, which can maintain the local sagittal balance by changing C2-7, C0-2 and T1-S. The changes of sagittal parameters of the cervical spine before and after surgery have a certain correlation with clinical outcomes.

Keywords: Cervical sagittal parameters, anterior cervical surgery, clinical effects

Introduction

Anterior cervical corpectomy decompression and fusion (ACCF) surgery is one of the common treatments for cervical spondylosis. ACCF can resect the diseased disc and epiphysis, and fully decompress the spinal cord and/or nerve root, thus effectively improving clinical symptoms [1]. At the same time, the cervical curvature can be corrected to some extent, and a part of sagittal sequence can be restored. ACCF may be more effective in improving postoperative symptoms in patients with greater cervical curvature [2, 3].

At present, the study of the spinal sagittal parameters is mainly focused on the thoracolumbar and spine-pelvic sagittal deformities while few studies are conducted on the cervical spine. As the best segment of spine mobility and flexibility, the sagittal parameters of cervical spine are larger than other segments in the normal range [4]. Patients with cervical spondylosis often face changes in the loss in cervical intervertebral space height, normal physiological curvature, reduction in the area of nerve root canal, posterior longitudinal ligament and ligamentum flavum compression spinal cord, which in turn aggravate the degree of degener-

ation of the intervertebral disc, followed by the change in the sagittal parameters of the cervical vertebra. Both cervical anterior and posterior surgery can restore the sagittal sequence to a certain extent. In addition to the comprehensive assessment of physical fitness and strict control of surgical indications, patients with cervical spondylosis should also fully consider the curvature of the cervical vertebrae and its degree of correction in order to effectively improve the symptoms of the pain in neck and shoulder and numbness of the limbs, thus to obtain satisfactory clinical effects [2, 5]. Therefore, a full understanding of the cervical spine compensation mechanism is a challenge for spine surgeons.

This paper made a review on the cases of patients treated by ACCF and analyzed the pre- and post-operative one-year sagittal parameters and the relevant data about clinical effects. The paper aims to: 1. analyze the clinical effect of ACCF surgery for cervical spondylosis; 2. compare the cervical sagittal parameters pre- and post- operations; 3. discuss the correlation between cervical sagittal parameters and clinical effects after ACCF.

Materials and methods

General data

The retrospective analysis was made on the 127 patients who accepted ACCF surgery for cervical spondylosis in HwaMei Hospital from January 2011 to December 2016, including 60 males and 67 females, aged 33-76 years, mean ages 51.2 ± 10.8 year old. The inclusion standards: 1. Patients who were diagnosed as cervical spondylosis with the obvious symptoms of nerve compression had accepted conservative treatment, but in vain; 2. Patients who accepted single-phase ACCF surgery; 3. Patients who had the retrospective study with the complete data and follow-up more than 12 months. The exclusion standards: 1. Patients who suffered cervical vertebrae fracture; 2. Spinal infections, tumors or developmental malformations; 3. History of previous neck trauma or surgery; 4. Severe osteoporosis (BMD T<-2.5 SD).

Surgical process

Patients were under general anesthesia, at the supine position. The shoulder and back were set on the thin pillow and the neck was slightly extended. After disinfecting the drape, the transverse incision on the right side of the neck was taken, followed by cutting the skin, subcutaneous and fascia. After separating between the vascular sheath and the visceral sheath, the incision was extended to the front edge of the vertebral body. Then, the anterior vertebral fascia was incised and the C-arm fluoroscopy was used to determine the responsible segmental intervertebral space. The intervertebral disc and the degenerated nucleus pulposus tissue were removed to reach the posterior longitudinal ligament. Subtotal resection (groovectomy) was performed on vertebral bone between lesions. The posterior longitudinal ligament and the posterior margin of the vertebral body were incised, and the nucleus pulposus from the spinal canal were removed to decompress thoroughly. The Caspar spreader to the appropriate height was moderately open to restore physiological lordosis and intervertebral height. The end plate was dealt with, and a titanium mesh of a suitable size was selected. The broken bone block of the vertebral body was filled and then placed in a decompression tank, and pressed to a firm fit. The surface of the titanium mesh is flush with the front edge of the vertebral body or is 1 to 2 mm lower, and should not be placed too deeply. Fix and lock the steel plate. After the internal fixation position of the fluoroscopy is satisfactory, the negative pressure drainage tube is placed, and then closing the incision.

Follow-up and efficacy evaluation criteria

The patients were followed up for 3, 6, and 12 months after surgery. Patients who had accepted the surgery for more than 1 year or patients in different places were followed up by telephone. The JOA scores were used to evaluate the spinal cord function before and after surgery, the VAS scores were used to evaluate the pain, and the NDI scores were used to evaluate the cervical function [6]. The sagittal parameters of the cervical vertebra include [7-9]: 1. T1-S: the angle between the upper endplate tangential line and the horizontal plane of the T1 vertebral body. T1 is the base of the cervical vertebra, and the increase of its inclination is a direct factor for the imbalance of the cervical anterior tilt; 2. Cervical lordosis angle (C2-7 Cobb): the angle between the endplate tangen-

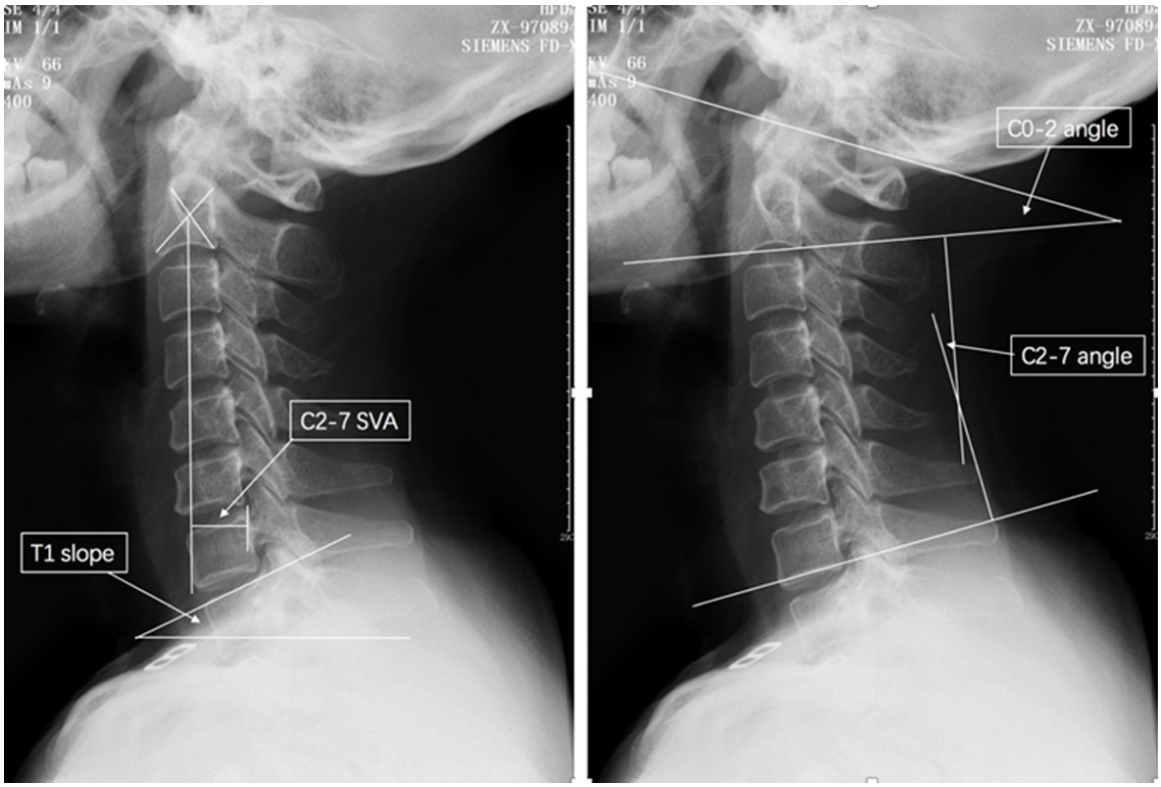

Figure 1. Parameters description. C0-2 angle (C0-2 Cobb): The angle between McGregor line and the inferior surface of the axis. C2-7 angle (C2-7 Cobb): Angle between the lower plate of C2 and the lower plate of C7. C2-7 SVA: The distance from the posterior, superior corner of C7 to the plumbline from the centroid of C2. T1 slope (TS): Angle between a horizontal line and the superior endplate of T1.

Table 1. Cervical imaging and clinical effects statistics (n=127)

	Pre-OP	Post-OP (1 Yrs)	P*
C0-2 Cobb (°)	22.13 ± 7.93	20.37 ± 7.64	<0.001
C2-7 Cobb (°)	12.79 ± 5.29	15.31 ± 6.44	<0.001
T1-Slope (°)	23.54 ± 6.18	27.06 ± 7.13	<0.001
SVA (mm)	24.81 ± 8.74	27.92 ± 8.45	<0.001
VAS	3.34 ± 2.00	1.40 ± 1.36	<0.001
JOA	10.03 ± 4.24	14.22 ± 3.99	<0.001
NDI (%)	41.70 ± 14.87	22.09 ± 12.90	<0.001

Note: Values are presented as mean ± standard deviation. *p<0.05, statistical significance(paired sample t test,). SVA, Sagittal vertical axis; VAS, Visual Analogue Scale; JOA, Japanese Orthopaedic Association Scores; NDI, Neck disability index.

tial line on C2 and the tangential line of the endplate of C7 is a protective factor for maintaining cervical stability; 3. C0-2 Cobb: the angle between McGregor'S line and the endplate of the C2 vertebral body; 4. SVA: The horizontal distance from the plumb line of the geometric center of the C2 vertebral body to the upper posterior angle of the endplate of the C7 vertebral body is an effective parameter for measuring the sagittal balance of the cervical spine (**Figure 1**).

Statistical method

SPSS 20.0 software (produced by SPSS Company, the United States) was adopted for statistical analysis. Measurement data were represented by mean ± standard deviation, and analyzed by a single sample Kolmogorov-smirnov test (K-S test) and paired sample t test. Spearman's rank correlation analysis was used to determine the sagittal parameters of the cervical spine and the correlation between clinical outcomes. *p* values less than 0.05 were considered statistically significant.

Results

All the operations were performed by the same group. The operation time was 45~191 min, with an average of 97 ± 32 min. The blood loss was 30~200 ml, with an average of 96.0 ± 22.5 ml. The surgical incision healed by the first intention.

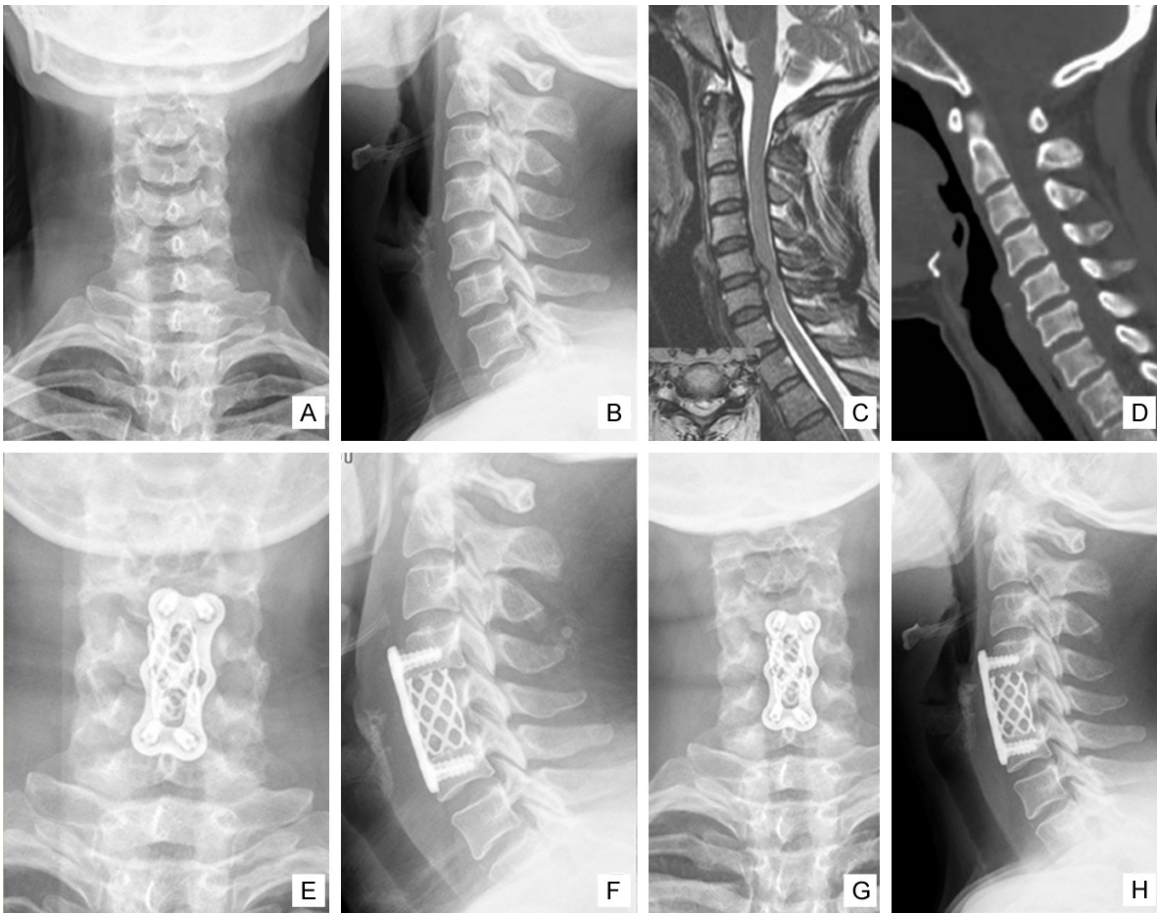

Figure 2. Typical imaging data. F, 40 y, both upper limbs pain and numbness for 1 year, aggravated for 2 months. A, B. Cervical X-ray indicates the degeneration of the cervical curvature and the formation of the anterior and posterior margin of the vertebrae. C, D. Preoperative MRI showed C5/6 disc herniation with spinal stenosis. E, F. Cervical X-ray after 3 months of ACCF. G, H. X-ray 1 year follow-up after operation, the internal fixation is in good position.

Evaluation of the clinical effects of ACCF

After 1-year follow-up, the JOA score of this group was increased from preoperative 10.03 ± 4.24 points to 14.22 ± 3.99 points, and VAS score was decreased from 3.34 ± 2.00 points to 1.40 ± 1.36 points, NDI index was decreased from 41.70% ± 14.87% to 22.09% ± 12.90%. The differences were statistically significant ($P<0.05$) (**Table 1**). During the follow-up period, all the patients with X-ray films showed that the internal fixation was safe and effective, with no broken nails, no obvious intervertebral cage displacement. One patient had the symptom of C5 nerve root palsy about 1 week after the surgery, and got better after six months of conservative treatment. There were no cerebrospinal fluid leakage, recurrent laryngeal nerve injury, and complications such as postoperative infection, esophageal fistula and death (Typical case **Figure 2**).

Changes of sagittal parameters of cervical vertebrae after ACCF

The 1-year follow-up found that the sagittal parameters T1-S of this group were increased from preoperative 23.54 ± 6.18 to 27.06 ± 7.13, the C2-7 Cobb was increased from preoperative 12.79 ± 5.29 to 15.31 ± 6.44, SVA was increased from preoperative 24.81 ± 8.74 mm to 27.92 ± 8.45 mm, and C0-2 Cobb was decreased from preoperative 22.13 ± 7.93 to 20.37 ± 7.64. The difference was statistically significant ($P<0.05$) (**Table 2**).

Correlation between the changes of the sagittal parameters and the clinical effects

The correlation analysis between the sagittal parameters and the changes of clinical efficacy variation showed that the change value of C2-7 Cobb angle was positively correlated with the

Table 2. Correlation between the change of imaging parameters and clinical effects

	JOA$^{\Delta}$	NDI	VAS	C0-2 Cobb	C2-7 Cobb	T1-Slope
NDI	0.022 (0.805)	-	-	-	-	-
VAS	0.017 (0.847)	-0.034 (0.707)	-	-	-	-
C0-2 Cobb	-0.069 (0.441)	-0.079 (0.379)	-0.021 (0.810)	-	-	-
C2-7 Cobb	0.234* (0.008)	-0.181* (0.042)	0.045 (0.612)	-0.029* (0.001)	-	-
T1-Slope	0.111 (0.215)	0.063 (0.480)	-0.008 (0.933)	-0.171 (0.055)	0.250* (0.001)	-
SVA	0.025 (0.776)	-0.132 (0.140)	-0.005 (0.951)	-0.065 (0.466)	0.120 (0.180)	-0.070 (0.436)

Note: *When the confidence (on both sides) is 0.01, suggesting significantly correlated (Spearman's rank correlation analysis). JOA$^{\Delta}$: Improvement rate of JOA score = (Postoperative score - Preoperative score)/(17 - Preoperative score) × 100%).

127 patients with ACCF were followed up for 1 year in this study, which found that most patients felt that the neck pain and shoulder pain were reduced or disappeared after the surgery, the numbness of the upper limbs and fingers was decreased or returned to normal, the cotton sensation was disappeared, and the cervical vertebra movement was normal.

The changes of JOA score, VAS score, NDI index and the improvement of neurological function after operation further proved that ACCF can effectively improve the symptoms of nerve and spinal cord compression in patients with cervical spondylosis and achieve good clinical effects.

JOA change value and the T1-S change value (P=0.008/P=0.001), and was negatively correlated with NDI (Neck disability index) and C0-2 Cobb change value (P=0.042/P=0.001) (**Table 3**).

Discussion

Analysis of the clinical effects of ACCF for cervical spondylosis

Currently, a variety of surgical methods are widely used to treat cervical spondylosis, including anterior cervical discectomy and bone graft fusion (ACDF), anterior cervical subtotal corpectomy and decompression fusion (ACCF), laminoplasty, laminectomy, and so on [10, 11]. ACDF and ACCF can achieve good postoperative effects such as segmental decompression, recovery of intervertebral height and cervical spine anterior flexion correction [12]. When compression comes from posterior vertebral body (such as osteophyte, OPLL, etc.), ACCF is widely used because it can directly remove compression behind vertebral body and fully expose decompression field of vision. The short-medium-term follow-up research showed that in patients with cervical spondylosis, the symptoms of spinal nerve compression decreased or disappeared 1 year after ACCF, and the quality of life of these patients was significantly improved [13, 14].

Relationship between sagittal parameters of cervical vertebrae after ACCF and its changes

The ACCF treatment can change the sagittal parameters of the cervical spine and affect its part of or even total sagittal sequence. As an effective parameter to measure the sagittal position of the cervical spine, there is a certain correlation between T1-S, C2-7 and SVA parameters. In the past, T1-S was considered to be a risk factor for cervical instability [15, 16]. An increase in T1-S resulted in a compensatory forward tilt of the cervical spine and an increase in SVA. The lordosis angle (Cobb angle) is the protective factor for maintaining the sagittal balance of the cervical spine. The lordosis angle changes adaptively due to the change in the size and direction of T1-S. One year after the follow-up of this study, T1-S was increased compared with preoperative, and the lordosis angle and SVA were also increased. In other words, any size of T1-S will have a C2-7 Cobb and SVA accordingly. The three parameters are closely related and compensate for each other. The sagittal sequence of the cervical spine remains relatively stable. In addition, this study found that the postoperative C0-2 Cobb was reduced compared with preoperative, which may be related to the compensatory adjustment of C2-7 Cobb increased spine to ensure that the patients are able to maintain functional horizontal gaze. The preoperative T1-S was

Table 3. Correlation between imaging parameters and clinical effects before and after ACCF

	JOA (post-op)	NDI (pre-op)	NDI (post-op)	VAS (pre-op)	VAS (post-op)	C0-2 Cobb (pre-op)	C0-2 Cobb (post-op)	C2-7 Cobb (pre-op)	C2-7 Cobb (post-op)	T1-S (pre-op)	T1-S (post-op)
JOA (Pre-op)	0.286$^{\Delta}$	-0.041	0.026	0.004	0.078	-0.008	-0.039	0.019	0.049	0.011	-0.070
JOA (Post-op)		-0.063	0.042	-0.123	-0.21$^{\Delta}$	0.094	0.030	-0.017	-0.034	-0.199$^{\Delta}$	-0.132
NDI (Pre-op)			0.260$^{※}$	0.030	0.014	0.059	0.083	0.039	0.084	0.163	0.084
NDI (Post-op)				0.013	-0.144	0.031	0.014	-0.015	-0.083	0.044	-0.155
VAS (Pre-op)					0.170	0.019	0.032	-0.015	0.058	0.108	0.023
VAS (Post-op)						-0.008	0.014	-0.074	0.138	0.140	-0.002
C0-2 Cobb (Pre-op)							0.916$^{※}$	-0.177$^{\Delta}$	-0.078	-0.049	0.073
C0-2 Cobb (Post-op)								-0.244$^{※}$	-0.152	-0.012	0.048
C2-7 Cobb (Pre-op)									0.539$^{※}$	-0.083	-0.050
C2-7 Cobb (Post-op)										0.004	0.035
T1-S (Pre-op)											0.652$^{※}$

Note: $^{\Delta}$When the confidence (on both sides) is 0.05, suggesting significantly correlated; $^{※}$when the confidence (on both sides) is 0.01, suggesting significantly correlated (Spearman's rank correlation analysis). ACCF, anterior cervical corpectomy and fusion.

positively correlated with lordosis angle and SVA, and the lordosis angle was negatively correlated with SVA; the correlation remained the same 1 year after surgery.

Changes of sagittal parameters and clinical effects after cervical fusion

ACCF can effectively treat cervical spondylosis and significantly improve the quality of life of patients. Xiao [17] performed cervical anterior/posterior decompression surgery on 55 patients with cervical spondylosis and Parkinson's disease. The symptoms of postoperative static tremor were significantly improved. After 1-year follow-up, the sagittal parameters were correlated to the scoring of the quality of life, and SVA was negatively correlated with the SF.36 score. When SVA>40 mm, the surgical outcome was significantly affected. The results of this study showed that after one year, the difference in the value of sagittal parameters of the cervical spine SVA, the clinical effects of VAS Score, and the NDI index had no statistics significance. Kim [18] found that 64 patients who underwent posterior decompression of the posterior longitudinal ligament of the cervical spine were found to have kyphosis when the T1-S>25° preoperatively, which had a strong impact on the clinical effects. The results of this study indicate that the cervical sagittal parameters T1-S and SVA have no significant correlation with the clinical effects of ACDF after cervical spondylosis.

The JOA score, VAS score and NDI index were significantly improved in the first year after operation, indicating that ACCF has significant clinical effects on the treatment of cervical spondylosis. Cervical sagittal parameters were positively correlated with JOA and NDI before and 1 year after operation. Therefore, we believe that the sagittal parameter C2-7 Cobb is related to clinical effects after ACCF.

In conclusion, the short-term clinical effects of ACCF in the treatment of cervical spondylosis are notable. The cervical vertebra has a certain self-compensatory mechanism, which can maintain the sagittal balance of the spine by changing C2-7, C0-2 and T1-S. After 1-year follow-up, it was found that cervical C2-7 Cobb had a certain correlation with the clinical effects. However, the article still has some defects. For example, the number of cases is limited, the data is slightly biased, and problems of long-term titanium net deposition and loss of intervertebral space height are not considered.

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Disclosure of conflict of interest

None.

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