Over-correction of Curvature in Surgical Segments Cause the Non-surgical Curvature Loss in One- and Two-level Anterior Cervical Discectomy and Fusion

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Abstract

Background: In some patients with anterior cervical discectomy and fusion (ACDF), the correction degree of cervical curvature after surgery is less than that of the surgical segment curvature, which we defined as non-surgical curvature loss (NSCL). This study aims to elucidate the notification of NSCL and its possible causes.

Methods: A retrospective analysis was conducted on 122 patients with one- or two-level ACDF from October 2012 to June 2017. The pre-operative and post-operative Cobb angle of C2-7, surgical segments and non-surgical segments were measured and analyzed by lateral cervical X-ray.

Results: All patients were followed up for 22.87 ± 3.15 months. Both one- and two-level ACDF could improve the cervical curvature. In the evaluation of NSCL, it was found that the incidence was 37.50% (27/72) in one-level ACDF and 48.00% (24/50) in two-level ACDF. Furthermore, the NSCL does not spontaneously recover after surgery. By comparing patients with and without NSCL, it was found that patients with NSCL had a significantly higher correction degree in the surgical segments, while the degree of NSCL was significantly and positively correlated with the correction degree of the surgical segments. For patients with a slight correction degree of surgical segment, the cervical curvature was well-improved and maintained post-operatively.

Conclusion: In summary, the correction of the surgical segment curvature in ACDF should not be overemphasized, because excessive correction may cause NSCL. Even if the surgical segment curvature is only slightly corrected, a good improvement in cervical curvature can still be attained.

Background

Cervical disc degenerative disease (CDDD) is a common clinical spinal surgery disease, which has a great impact on the quality of life of middle-aged and elderly patients[1-5]. At present, although this is challenged by many new surgical treatments[5-7], anterior cervical discectomy and fusion (ACDF) is still the best choice for the treatment of CDDD[8-10]. After decades of clinical application, the clinical effect of ACDF has been fully demonstrated.

In most cases, the focus of ACDF surgery is "decompression.". However, for patients with pre-operatively poor curvature, in addition to the decompression of the nerve to relieve symptoms, it is also vital to improve the cervical curvature[11-13]. Especially for patients with multi-level ACDF, the improvement and maintenance of the cervical curvature after surgery is crucial for the relief of symptoms.

Theoretically, ACDF surgery will only affect the curvature of the surgical segments, while the curvature of non-surgical segments should not be affected. This means that the "correction degree of the C2-7 Cobb angle - correction degree of the surgical segments" should be close to zero. However, it has been noted that in many patients, it was observed that there's a loss in the non-surgical segment curvature. For these

patients, this means that the degree of improvement in cervical curvature is partly compromised. Therefore, the investigators aims to determine the causes for this. Based on this, it was hypothesized that the over-correction of the surgical segment curvature would lead to compensatory curvature loss in the non-surgical segments, as shown in **Figure-1**. That is, the correction of the surgical segment curvature should be appropriate, but not excessive, which could cause the loss in the non-surgical segment curvature, or even new degeneration.

The present study defined the phenomenon as “non-surgical curvature loss (NSCL)”, and the aim of the present study was to verify the validity of the argument that the "over-correction of the surgical segment curvature can actually lead to NSCL".

Methods

Study Design

The present retrospective study was conducted in one large spine center, and a total of 122 patients who suffered from a poor cervical curvature, and were treated on a one- or continuous two-level ACDF between C3-7 with Zero-P spacer from October 2012 to June 2017 were consecutively included into the study. The investigation included the pre-operative data, and the 3-, 12- and 24-month follow-up results. The inclusion criteria for the present study were clearly defined, as follows: (1) the patient's symptoms and radiological results were consistent with the typical diagnosis of one- or two-level CDDD; (2) the patient's pre-operative C2-7 Cobb angle was less than 10°; (3) the patients were successfully followed up before surgery, and at 3, 12 and 24 months after surgery; (4) no cervical surgery was performed during the follow-up.

Implant and Surgical Technique

One senior spinal surgeon from our team performed all the surgical procedures using the standard ACDF technique. Briefly, after thorough decompression and scraping off of the cartilaginous endplate, the proper Zero-P spacer (Synthes GmbH, Oberdorf, Switzerland) was implanted in the intervertebral space, with artificial bone grafting. Then, four screws were implanted and locked. The correct position of the implants was identified by lateral fluoroscopy before the incision was closed.

Radiological Evaluation

Lateral cervical radiograph examination was performed at each follow-up time point. The tube to subject distance was 72 inches, with the radiographic tube centered at the C4-C5 intervertebral disc without magnification. Lateral radiographs of the cervical spine were taken when the patient was in a comfortable standing position, with the upper extremities positioned naturally at the sides of the trunk, while looking straight forward. All radiograph images were transferred to a computer in DICOM format, and the measurements were performed by two independent observers. After an agreement was reached between the observers, each parameter was independently measured twice by two spine surgeons. The

measured items of the cervical sagittal parameters in the radiographs included the Cobb angle of C2-7, surgical segments, and non-surgical segments.

Statistical Analysis

The analysis was conducted using Stata version 13.1 (Stata-Corp LP, College Station, TX, USA). The level of significance was set at $P < 0.05$. All clinical and radiological measurements were taken by two independent and experienced observers. Chi-squared analysis and unpaired t -test were used, respectively, for categorical and continuous data between groups, while paired t -test was used to compare the data of the one group from different time points. A statistical power with a significant level (alpha) of 0.05 was calculated using the G-Power software (version 3.1.9.4) when there was a statistical difference[14]. All values were expressed in mean $\pm$ standard deviation or percentage.

Results

Patient Characteristics

A total of 122 patients met the inclusion criteria, and agreed to accept one-level ($n=72$) or two-level ($n=50$) ACDF. The average follow-up period was 22.87 ± 3.15 months. There were 11 C3/4 segments, 43 C4/5 segments, 89 C5/6 segments, and 29 C6/7 segments. The specific data is presented in **Table-1**. By the end of the final follow-up, no patient needed a second operation for the original CDDD.

Both One-level and Two-level ACDF Could Greatly Improve and Maintain the Cervical Curvature

Considering that all patients included in the present study had a poor cervical curvature (C2-7 Cobb angle of $< 10^\circ$) before surgery, the correction of the cervical curvature was particularly important. As shown in **Table-2**, it was found that the pre-operative C2-7 Cobb angle of one-level ACDF was $4.05 \pm 5.18^\circ$, and at the final follow-up, it was $10.91 \pm 8.82^\circ$ ($P < 0.0001$, statistical power=99.99%). The pre-operative C2-7 Cobb angle of two-level ACDF was $2.46 \pm 7.27^\circ$, and at the final follow-up, it was $10.29 \pm 8.64^\circ$ ($P < 0.0001$, statistical power=99.94%). Furthermore, the pre-operative Cobb angle of the surgical segment curvature in one-level ACDF was $-2.04 \pm 6.28^\circ$, and at the final follow-up, it was $4.81 \pm 5.17^\circ$ ($P < 0.0001$, statistical power=100.00%). The pre-operative Cobb angle of the surgical segment curvature in two-level ACDF was $-1.02 \pm 7.14^\circ$, and it was $8.66 \pm 6.99^\circ$ at the last follow-up ($P < 0.0001$, statistical power=100.00%). It can be observed that the cervical curvature in patients with both one- and two-level ACDF significantly improved after surgery. In addition, as shown in **Figure-2**, no further loss of cervical curvature occurred after the patient's improvement, indicating that the cervical curvature was well-maintained after ACDF.

The Description of "Non-surgery Segment Degradation (NSCL)"

By evaluating the cervical curvature of these above patients, it was found that in some patients, there was a similar situation, as shown in **Figure-1**. Theoretically, the improvement in cervical curvature by ACDF should only be reflected in the surgical segments, that is, there should be a significantly positive correlation between the "correction degree of the surgical segments" and "correction degree of the C2-7

Cobb angle". As shown in **Figure-3**, the results at post-operative three months were analyzed, and it was found that the correlations in both one- and two-level ACDF were relatively poor ($R=0.0696$, $P=0.5612$ for one-level group, $R=0.0999$, $P=0.4897$ for two-level group), indicating there's the mismatching. After ACDF surgery, although the surgical segments curvature was corrected, the non-surgical segments curvature degraded, which was defined as NSCL.

After the evaluation of the cervical curvature in all patients, it was found that NSCL was not rare, with an incidence of 37.50% (27/72) in patients with one-level ACDF and 48.00% (24/50) in patients with two-level ACDF while there was no significant difference between the two groups ($P=0.2475$). Moreover, patients with NSCL were separately followed up, as shown in **Table-3 and Figure-4**. In addition, both were in the one- and two-level ACDF, and the degree of NSCL at post-operative three months was similar to that at the final follow-up ($P=0.7129$ for one-level patients, $P=0.6995$ for two-level patients). These results suggest that NSCL may persist for a long time after surgery, and will not recover automatically with the extension of time.

The Over-correction of Surgical Segments Is One of the Causes of NSCL

As shown in **Table-4 and Figure-5**, the comparison between patients with NSCL and those without NSCL revealed that the correction of the surgical segment curvature in patients with NSCL was significantly higher than that of patients without NSCL in both one- and two-level ACDF. Furthermore, for patients with NSCL, the correlation between the "correction degree of surgical segments" and "degree of NSCL" were analyzed, and both one- and two-level patients presented strong positive correlations. These results suggest that the over-correction of the surgical segment curvature does, to some degree, lead to the development of NSCL.

The Cervical Curvature Can Be Greatly Maintained after Surgery in Patients with Slight Segmental Correction

In the previous results, it was demonstrated that the over-correction of the surgical segment causes the development of NSCL. Can the cervical curvature be improved and maintained if the surgical segments are only slightly correct? In this section, patients with only a slight correction of the surgical segment were separated ($<3^\circ$ in one-level ACDF, $<6^\circ$ in two-level ACDF), and an analysis was conducted. The results revealed that, as shown in **Table-5 and Figure-6**, the post-operative recovery of the cervical curvature in this group of patients was also very satisfactory, and a relatively stable level was maintained throughout the follow-up period.

Discussion

At present, ACDF is still the first-line surgical method for the treatment of CDDD, and its surgical effect has been confirmed by clinical application for decades^{1-3,8-10}. The treatment of CDDD focuses on relieving neurological symptoms and reconstructing the spinal structure[15-17]. The ways to relieve neurological symptoms are similar, which mainly depend on the operator's operation and experience.

However, the reconstruction of the spinal structure differs from person to person, and there are great differences among patients, which require physicians to treat each patient's unique "personality" separately.

The poor curvature of the cervical spine is a common clinical condition, and for these patients, the "reconstruction of the spinal structure" is really important[18]. The correction of the cervical curvature is mainly achieved by reconstructive surgery. By reviewing the information of patients who have previously received one- or two-level ACDF surgery, patients with poor curvature before surgery were separated, and the changes in cervical curvature after surgery were analyzed. It was found that although ACDF surgery can significantly improve the cervical curvature, in part of these patients, the correction degree of the cervical curvature was less than the correction degree of the surgical segments, which means that the curvature of non-surgical segments degraded after the ACDF surgery, and this was defined NSCL.

Theoretically, there should be a strong positive correlation between the "correction degree of the surgical segments" and "correction degree of the C2-7 Cobb angle", which we didn't see in this study. We believe that NSCL is more or less responsible for this phenomenon and the high incidence suggests that NSCL is a common phenomenon. Furthermore, a separate analysis of the follow-up results for patients with NSCL was conducted, and the results revealed that the NSCL was maintained up to the final follow-up, and its degree did not differ from the results at three months. This means that NSCL is persistent, and does not recover over time.

By reviewing the retrospective data, it was found that NSCL often occurs in patients with a high degree of correction in the surgical segments. That is, NSCL may be a compensatory reduction in cervical curvature, and the self-adjustment of the cervical would avoid excessive changes in the cervical curvature. Accordingly, the correction degree of the surgical segments in patients with and without NSCL were compared, and it was found that there was a significant difference between the two groups. Furthermore, it was found that there was a significant positive correlation between the "correction degree of surgical segments" and "degree of NSCL" in patients with NSCL. This means that the more the degree of the surgical segment curvature is corrected, the more severe the NSCL would become, confirming that the over-correction of the surgical segment curvature is one of the important causes of NSCL. In addition, it was found that the cervical curvature of patients with only a slight correction of surgical segments was well-improved and maintained after surgery.

In summary, it could be concluded that in ACDF surgery, the correction of the curvature in the surgical segments should not be over-emphasized, because excessive correction may cause NSCL. Furthermore, even if the curvature of the surgical segment is only slightly corrected, this can still attain a good improvement in the cervical curvature. It is noteworthy that ACDF can significantly improve the cervical curvature with or without the occurrence of NSCL, but the pathological significance of NSCL lies more in the destruction of the non-surgical segment curvature and the possible new degenerative symptoms in the later stage.

The limitations of the present study mainly lie in the quantification and definition of the "slight correction of surgical segments", and the "3°" and "6°" were only determined based on the surgeon's experience. Although positive results were obtained, a more accurate quantification result could not be obtained. Hence, this could not provide more specific guidance for ACDF surgery. Furthermore, the follow-up time was only 24 months. Therefore, further follow-ups are needed to obtain more objective results.

Conclusion

For patients with poor cervical curvature before surgery, ACDF is a very effective surgical method, which can relieve the symptoms of nerve compression and improve cervical curvature. However, during ACDF surgery, the over-correction in the curvature of the surgical segments may cause the occurrence of NSCL. The presence of NSCL may lead to new CDDD and associated symptoms, which is a condition that needs to be avoided during cervical spine surgery. The results of the present study demonstrate that the curvature of the cervical spine can be well-improved and maintained after surgery, even with the minor correction of the segmental curvature. Therefore, the correction of surgical segment curvature in one- and two-level ACDF surgery should not be over-emphasized.

Declarations

Ethics approval: This study has institutional review board (IRB) approval / research ethics committee approval, and the document has been attached to the submission.

Consent of participate: All of the 64 patients gave informed consent and agreed to participate in the study.

Consent for publication: Written informed consent for publication was obtained from all participants.

Availability of data and material: The original data are available and attached to the submission as the supplement.

Competing interests: The authors declare that they have no conflict of interest.

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Authors' contributions:

Guo Yingjun: (1) Data analysis; (2) Article writing;

Liu Hao: (1) Instructor of the study; (2) One of the ACDF operator;

Yang Yi: Application of ethical certification;

Meng Yang: Data collection;

Ding Chen: Communication with patients;

Hong Ying: Leader of nursing team;

Wang Beiyu: Language polishing;

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Tables

Table-1: Patients' Characteristics

Item		Data
Number of Cases		122
Sex (M/F)		71/51
Age (Years)		51.58±12.69
Follow-up Period (Months)		22.87±3.15
Number of Segments	One-level	72
	Two-level	50
Locations of Segments	C3/4	11
	C4/5	43
	C5/6	89
	C6/7	29

Table-2: Follow-up Results of Cervical Curvature

Items	Groups	Pre-operative	3 Months	12 Months	24 Months
C2-7 Cobb Angle	One-level	4.05±5.18	11.00±9.61	11.04±8.96	10.91±8.82
	Two-level	2.46±7.27	10.71±9.11	10.43±8.18	10.29±8.64
Surgical Segments Cobb Angle	One-level	-2.04±6.28	4.43±5.18	4.46±4.88	4.81±5.17
	Two-level	-1.02±7.14	8.45±7.24	8.46±6.81	8.66±6.99

Table-3: Changes in the Degree of NSCL

Items	Groups	3 Months	Final Follow-up	P Value
Degree of NSCL	One-level (n=27)	10.20±5.23	9.68±4.81	0.1106
	Two-level (n=24)	11.70±3.75	11.25±4.02	0.3032

*Note: NSCL, non-surgical curvature loss

Table-4: Comparison of Surgical Segments Correction between Patients with or without NSCL

Item	Groups	non-NSCL	NSCL	P Value	Statistical Power
Correction Degree of Surgical Segments	One-level	5.40±3.91	8.22±3.99	0.0049	82.44%
	Two-level	7.23±3.51	11.88±5.37	0.0008	94.38%

*Note: NSCL, non-surgical curvature loss

Table-5: Follow-up Results of Cervical Curvature in Patients with Slight Correction of Surgical Segments Curvature

Items	Groups	Pre-operative	3 Months	12 Months	24 Months
Surgical Segments Cobb Angle	One-level (n=10)	6.60±2.85	13.41±4.94	13.87±5.49	12.64±5.40
	Two-level (n=11)	5.18±5.43	13.15±7.69	12.35±7.28	12.13±8.34

Figures

Figure 1

Radiological Manifestation of Typical Case with NSCL Figure-1A shows the pre-operative radiograph and Figure-1B shows the post-operative radiograph. Compared with pre-operative characteristics, the curvature of surgical segments greatly improved while the curvature of non-surgical segments degraded, compromising the improvement of C2-7 Cobb angle.

Figure 2

Radiological Follow-up of One- and Two-level ACDF Figure-2A, follow-up of C2-7 Cobb angle in one-level ACDF; Figure-2B, follow-up of C2-7 Cobb angle in two-level ACDF; Figure-2C, follow-up of surgical segments Cobb angle in one-level ACDF; Figure-2D, follow-up of surgical segments Cobb angle in two-level ACDF.

Figure 3

Correlation Analysis between Correction Degree of Surgical Segments and C2-7 Cobb Angle in One- and Two-level ACDF Figure-3A, correlation analysis between correction degree of surgical segments and C2-7 Cobb angle in one-level ACDF; Figure-3B, correlation analysis between correction degree of surgical segments and C2-7 Cobb angle in two-level ACDF.

Figure 4

Comparison of NSCL Degree at 3 Months and Final Follow-up Figure-4A, comparison of NSCL degree at 3 months and final follow-up in one-level ACDF; Figure-4B, comparison of NSCL degree at 3 months and final follow-up in two-level ACDF.

Figure 5

The Relationship between Over-correction of Surgical Segments Curvature and the Occurrence of NSCL
 Figure-5A, comparison of correction degree of surgical segments curvature between one-level ACDF patients with and without NSCL; Figure-5B, correlation analysis between correction degree of surgical segments curvature and degree of NSCL in one-level ACDF; Figure-5C, comparison of correction degree of surgical segments curvature between two-level ACDF patients with and without NSCL; Figure-5D, correlation analysis between correction degree of surgical segments curvature and degree of NSCL in two-level ACDF.

Figure 6

Radiological Follow-up of One- and Two-level ACDF with Only Slight Correction in Surgical Segments Curvature Figure-6A, radiological follow-up of one-level ACDF with only slight correction in surgical segments curvature; Figure-6B, radiological follow-up of two-level ACDF with only slight correction in surgical segments curvature.