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Original Article

Impact of over distraction on occurrence of axial symptom after anterior cervical discectomy and fusion

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Abstract: Objective: A retrospective review was undertaken to evaluate the impact of over distraction on cervical axial symptoms (AS) after anterior cervical discectomy and fusion (ACDF). Methods: The retrospective review included 421 patients who underwent ACDF for one or two segments. Of these, 78 patients for whom complete follow-up data were available were selected for inclusion in the analysis. X-rays of the cervical vertebra were performed immediately after the surgery, 3 months postsurgery, and at a final follow up (6-24 months). According to the presence/absence of AS, the patients were divided into a symptom group (Group S) and a nonsymptom group (Group N). The ratio of intervertebral height change, change in the overall cervical curvature, change in the local curvature of the surgical segment, cervical total range of motion (ROM), and Japanese Orthopaedic Association (JOA) recovery rate were compared and analyzed. A linear regression analysis of the ratio of intervertebral height change and the symptom and severity of the AS according to the Visual Analogue Scale (VAS) was carried out. Results: The total incidence of AS was 33.97%. C5 nerve root palsy occurred in one case in Group S after the surgery. The neurologic symptoms of both groups were significantly alleviated after the surgery. The ratio of intervertebral height change in Group S was significantly higher than that in Group N at the last follow-up ($P < 0.05$). However, the changes in the overall cervical curvature, local curvature of the surgical segment, cervical ROM, and JOA recovery rates were not statistically significant ($P > 0.05$). In Group S, 37% of the patients had symptoms that occurred in the chest area, and the ratio of intervertebral height change was significantly positively correlated with the VAS score of the AS ($r = 0.893$). Conclusions: The occurrence of postoperative AS will significantly increase if the ratio of intervertebral height change of the surgical segment after ACDF is over 10%.

Keywords: Cervical spondylosis, anterior cervical fusion, height of intervertebral space, axial symptoms, physiological curvature

Introduction

Axial symptoms (AS) are common after cervical spinal surgery, especially after posterior cervical laminectomy, with a reported incidence as high as 60-80% [1, 2]. AS may cause shoulder and neck pain and movement restrictions after surgery. These symptoms can adversely affect the patient's life, work, and the curative effect of the treatment. Since AS following cervical spinal surgery were first described by Kawaguchi in 1999 [3], they have been widely recognized and studied. Different hypotheses have been proposed for the occurrence of AS after posterior cervical laminectomy. These include a decrease in cervical activity and the destruction of the posterior cervical muscle ligament complex. Many solutions have been proposed to address these problems [1-4].

Anterior cervical discectomy and fusion (ACDF) was first proposed for cervical spondylosis in 1958 [7]. Since then, ACDF has been more widely used than posterior cervical laminectomy for cervical spondylosis because of its desirable clinical effects [5, 6]. However, in a follow-up study of patients who underwent ACDF, the authors reported that these patients experienced AS [8]. In addition, as decompression in ACDF is achieved through compartment of muscles, the cervical muscle ligament in anterior surgery is less damaged compared with posterior surgery. Therefore, the generation mechanism and influential factors of AS after ACDF

Table 1. Assessment criteria for axial symptom

Grade	Clinical performance
Excellent	No abnormal feeling, tenderness and muscle spasm occur in neck.
Good	Mild symptoms occur when tired and catching a cold, but recover soon, without obvious impact on daily work and life; no or mild tenderness, no or mild spasm occur in neck muscle, without need of painkillers.
Passed	Symptoms often appear (< 100 d/a), has certain impact on daily work and life, mild tenderness or spasm occur in neck muscle, need take oral drugs, analgesic effect is good.
Bad	Frequent symptoms (> 100 d/a) significantly affect the daily work and life, obvious tenderness or convulsion occurs in neck muscle, need to take painkillers, analgesic effect is general or not good.

surgery are obviously different from posterior surgery. However, there have been few studies of AS after ACDF surgery, and the reasons and influential factors have not been identified.

This retrospective review included patients who were treated with ACDF in our hospital from January 2010 to October 2012. We analyzed the relationship between postoperative over distraction of intervertebral fusion segments and postoperative AS.

Materials and methods

Inclusion and exclusion criteria

The inclusion criteria were: (1) patients with a myelopathic disease or nerve root cervical spondylopathy cervical spondylosis with typical clinical manifestations who failed to respond to conservative treatment administered for 3 months or more; (2) patients with intervertebral disc herniation or cervical stenosis involving two segments or fewer in C3-C7; (3) patients who had previously underwent ACDF.

The exclusion criteria were patients with: (1) AS before the surgery; (2) cervical vertebra trauma, tumors, severe osteoporosis, or congenital malformations; (3) intervertebral disc herniation or cervical stenosis involving more than two segments in C3-C7; (4) rheumatic or rheumatoid arthritis disease or other serious systemic diseases and metal allergies; (5) incomplete information during the period of follow up or lost to follow-up.

General information

Four hundred twenty-one patients who had undergone ACDF for 1-2 segments in our hospital from January 2010 to October 2012 were included in this retrospective analysis, and the incidence of postoperative cervical AS was recorded. Among these, 78 patients for whom complete follow-up data were available were selected for this study. Of these, 42 were males, and 36 were females. Their ages ranged from 42-73 years, and the average age was 56.4 years. There were 31 cases of cervical spondylotic myelopathy, 47 cases of nerve root cervical spondylopathy, 51 cases of single segment fusion, and 27 cases of double segmental fusion. The postoperative follow-up lasted for 11-37 months, with an average of 18.5 months.

According to the presence/absence of postoperative AS, the patients were divided into a symptom group (Group S, n = 35) and a nonsymptom group (Group N, n = 43).

Surgical method

Cervical plexus nerve block anesthesia was used. The patient lay in a supine position, with his/her neck overextended. During the surgery, a C-arm X-ray machine was used for perspective location. The anterior longitudinal ligament and annulus fibrosus of the lesional segment were cut open via the right side of the anterior portion using a transverse incision or a sternocleidomastoid front oblique incision approach. Two-thirds of the intervertebral disc in the intervertebral space was then scraped using a curette. A Caspar spacer (cervical vertebral body spacer) was used to open the intervertebral space. The remainder of the intervertebral disc and posterior longitudinal ligament were then scraped to expose the dura mater. Hyperplastic osteophytes in the rear of the centrum were removed, and the nerve root canal was extended. We scraped the cartilage endplate and scarpe osseous endplate into a rough surface with punctiform bleeding. An appropriately sized interbody fusion cage was implanted into the intervertebral space and fixed with an anterior titanium plate. The circumference of the neck was fixed 4-6 weeks after the surgery.

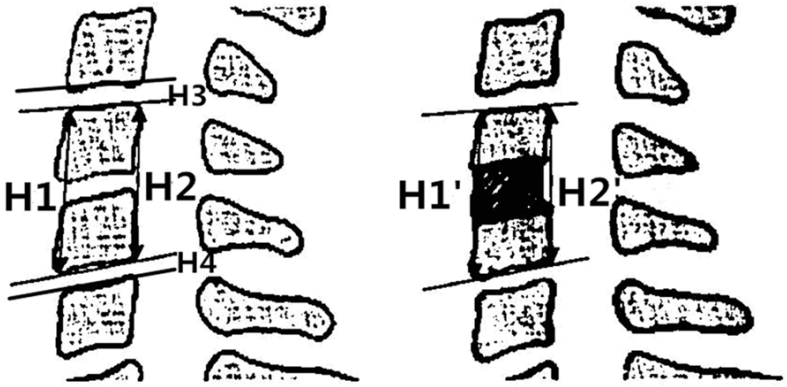


Figure 1. Δh = (H1'+H2')/2-(H1+H2)/2.

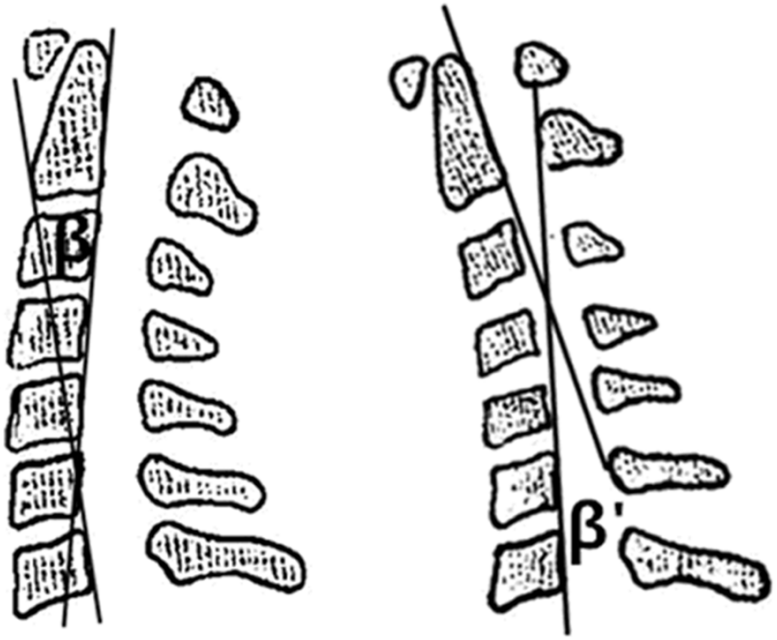


Figure 2. Measurement of C2-C7 angle (β) = (H3+H4)/2.

Follow-up and measurement index

Follow-up examination: All the patients underwent a preoperative X-ray examination of the cervical vertebrae in the anterioposterior and lateral position. CT and MRI of the cervical intervertebral disc and X-rays of the cervical vertebrae in the anterioposterior and lateral position were performed immediately after the surgery, 3 months postsurgery, and at a final follow up. A dynamic X-ray examination of the cervical vertebrae was carried out during the final follow up.

AS assessment: The neck AS evaluation criteria proposed by Zeng Yan [9] were used in the postoperative evaluations. The patients without AS were classified as excellent or good, and those with AS were classified as passed or bad (**Table 1**).

The ratio of intervertebral height change: The proportion to distance between the upper vertebral endplate and lower vertebral endplate in surgical section before and after the surgery (Δh = height after surgery-height before surgery) to the average intervertebral height of adjacent surgical segments ($\bar{h}$), namely $\Delta h \div \bar{h} \times 100\%$, was used to evaluate the range of intervertebral space distraction (**Figure 1**).

Range of motion (ROM): The ROM was measured using the difference in the angles between the lines parallel to the posterior margin of the C2 and C7 vertebral body (**Figure 2**) in the cervical lateral X-ray film in the biggest proneness and rear protraction via the Penning method [10].

Overall cervical spine curvature measurement: Overall cervical spine curvature: measuring angle of C2-C7 Cobb. It means to appraise local curvature of cervical spine surgery by the angles between the lines parallel to the trailing edge of C2 and C7 vertebral body (**Figure 3**). Both the angle between the lines parallel to the inferior margin of the upper vertebral body and the angle between the lines parallel to the superior margin of the inferior vertebral body in the operated section were measured (**Figure 3**).

Nerve function assessment: The Japanese Orthopaedic Association (JOA) score was used to assess the patients' neurological function before and after the surgery. The improvement rate after the treatment was calculated. The

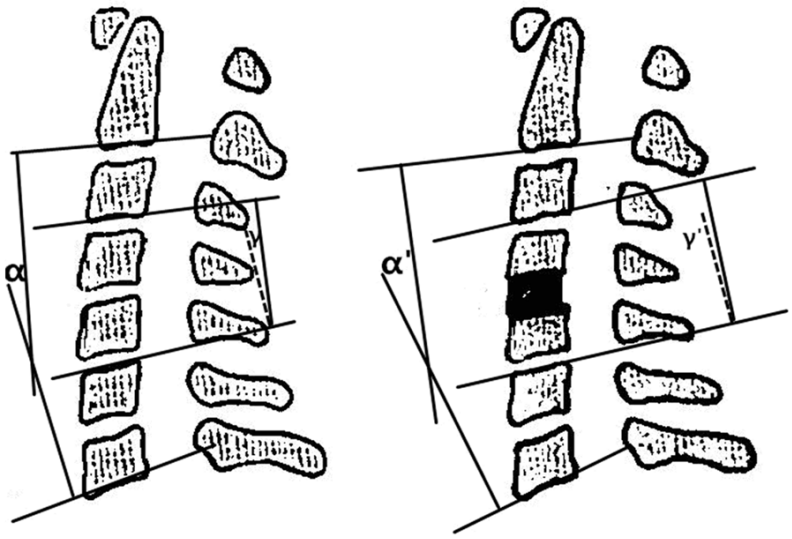


Figure 3. Measurement of C2~C7 Cobb angle (α), local Cobb angle of surgical segment (γ).

improvement in the JOE scores after the treatment was calculated as follows: [(post-treatment score-pretreatment score/17-pretreatment score] × 100%.

Severity of AS: The severity of AS was assessed using the Visual Analogue Scale (VAS), with scores ranging between 0 and 10.

Statistics analysis

SPSS13.0 software was used for the statistical analysis. All measurement data was performed with normality and the homogeneity of variance test. The data were expressed as the mean ± standard deviation. The *t*-test was used for the comparison between groups. The intervertebral height change ratio and the severity of the AS were analyzed with bivariate regression analysis. A significance level of 0.05 was used.

Results

Among the 421 patients who underwent ACDF surgery, 143 had postoperative cervical AS, giving a total incidence of 33.97%. Postoperative C5 nerve root palsy occurred in one case in Group S. This patient gradually recovered after treatment for 3 months. No serious postoperative complications occurred in the patients in Group N. All the patients were followed up for 11-37 months, with an average of 18.5 months.

The ratio of intervertebral height change (15.54% ± 11.53) of the surgical segment at the last follow up in Group S was significantly higher than that in Group N (9.73% ± 9.16). There was no significant difference in the overall cervical curvature change between Group S (increase of 2.15° ± 2.06 compared with presurgery) and Group N (increase of 2.28° ± 2.37 compared with presurgery) at the final follow up. The difference in the local curvature change of the surgical segment at the last follow up after the surgery between Group S (1.56° ± 7.34) and Group N (2.59° ± 5.67) was not statistically significant (**Table 2**). However, the number of patients in Group S with reduced curvature after the surgery was significantly higher than the number of patients with reduced curvature in Group N, (**Figure 4**). At the last follow up after the surgery, there was no significant difference in the ROM of Group S (32.88° ± 2.73) versus Group N (33.10° ± 2.66) (**Table 2**). At the last follow up, the postoperative neurological function of the two groups was significantly better, and there were no statistically significant between-group differences in their postoperative JOA scores or neural function improvement rates (**Table 3**). The X-ray results showed that all surgical segments had achieved bone fusion 6 months after the surgery.

In Group S, 37% (13/35) of patients had symptoms in the forebreast (**Figure 5**), 45.71% had symptoms in the right collarbone (area 1), 14.29% had symptoms in the left clavicle (area 2), 20% had symptoms in the right first and second chest rib joint (area 3), 17.14% had symptoms in the ilateral collarbone (area 1-2), and 2.86% had symptoms in the forebreast area under the neck (area 1-4).

In Group S, the ratio of intervertebral height change of 80% (28/35) was more than 10%. The bivariate regression analysis of the ratio of intervertebral height change and the VAS of the AS showed that the ratio of intervertebral height change was significantly positively related to the VAS of the AS ($r = 0.893$, $P < 0.001$) (**Figure 6**).

Table 2. Comparison of post-operative follow-up index between group S and group N

Item	Group S (n = 35)	Group N (n = 43)	P
The intervertebral height change ratio %	15.54 ± 11.53	9.73 ± 9.16	0.015
The change of overall cervical curvature °	2.15 ± 2.06	2.28 ± 2.37	0.804
The change of local curvature of surgical segment °	1.56 ± 7.34	2.59 ± 5.67	0.496
The overall activity of cervical vertebra °	32.88 ± 2.73	33.10 ± 2.66	0.724

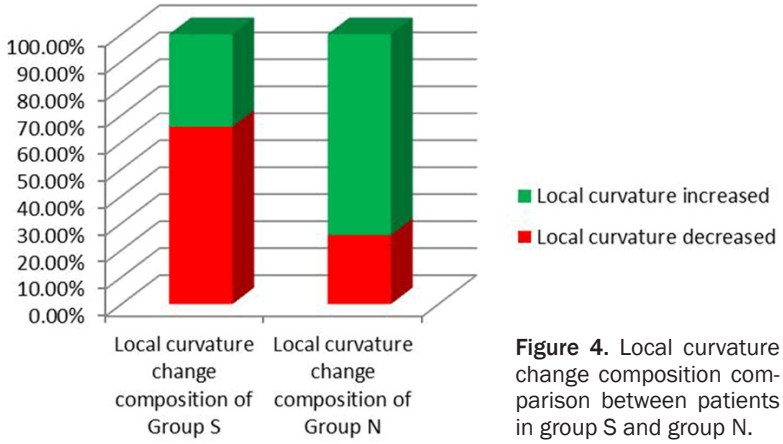


Figure 4. Local curvature change composition comparison between patients in group S and group N.

Table 3. JOA score comparison before and after surgery between group S and group N

Item	Group S (n = 35)	Group N (n = 43)	P
Before surgery	8.11 ± 2.51	8.77 ± 2.42	0.247
After surgery	13.34 ± 2.92	13.40 ± 3.03	0.939
Improvement rate	62.58 ± 23.90	60.77 ± 26.44	0.755

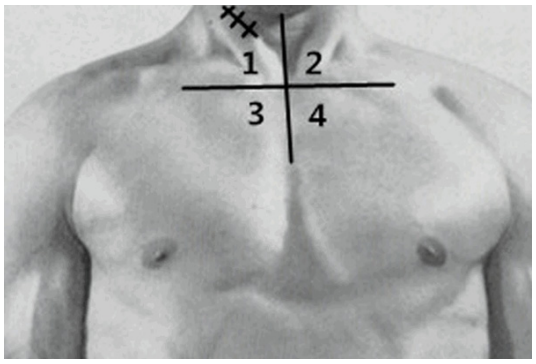


Figure 5. Sites in forebreast with axial symptoms: 1, 2 collarbone head on both sides, the first and second chest and rib joint of both sides of 3, 4.

Discussion

AS are common after cervical posterior surgery, with an incidence rate as high as 60-80% reported in the literature [1, 2]. The occurrence of AS can cause great inconvenience to patients, affecting their working and social lives and the curative effect of the treatment [11]. Various mechanisms have been put forward to explain the occurrence of AS. These include a decrease in postoperative ROM, damage to the posterior muscle-ligament complex during surgery, a change in the physiological curvature of the cervical vertebrae, and intervertebral instability. Additional causes that have been suggested are a postoperative increase in compensatory movement of adjacent segments caused by long-term cervical spinal immobilization, as well as inflammatory reactions caused by a stimulus or damage of the intervertebral joint capsule and its surrounding cervical dorsal rami nerves by the intraoperative intervertebral joint capsule suspension line [1, 12-15].

Much attention has been paid to AS because of their high incidence and impact on patients. To ameliorate the occurrence of AS, researchers have proposed various surgery-related improvements, including keeping the C7 spinous process and C2 half spinalis process, reducing bone grafting, and early functional exercise. Some of the aforementioned have shown some success [16-19]. However, the exact causes of AS have not been identified, and no effective treatments have been developed.

According to Kawakami et al. [8], the incidence of AS in patients following ACDF surgery was as high as 38.3%. AS after ACDF surgery are not obviously correlated to the recovery of neural function, but they seriously affect the curative effect of the treatment. However, most clinicians have not placed great importance on ACDF-related complications.

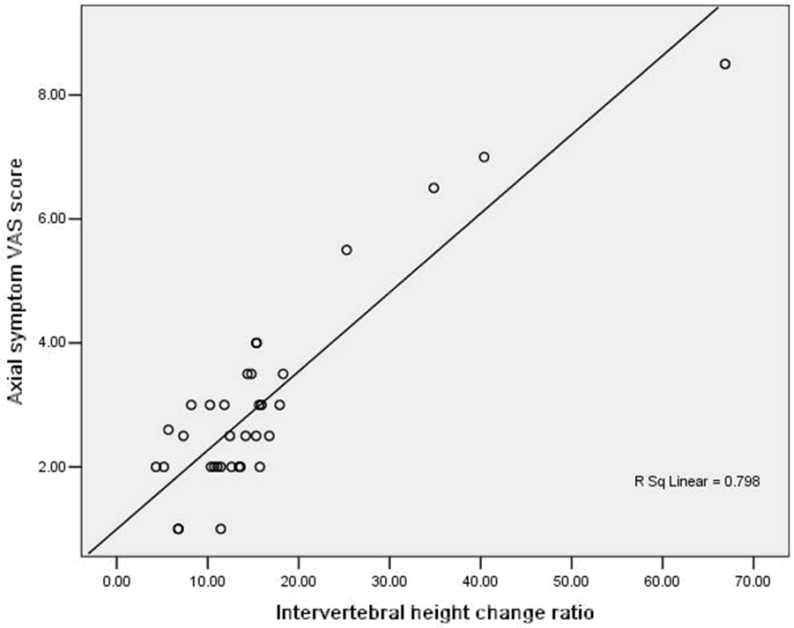


Figure 6. Intervertebral height change ratio was significantly positively related to axial symptom VAS score.

In terms of the special complication, we conducted a review and follow-up study of 421 patients who underwent ACDF for 1-2 segments. In the present study, the incidence of complications was 33.97%, which is close to that reported in the literature [8]. In addition, the sites of AS in the patients who underwent ACDF were not the same as those who underwent cervical posterior surgery. In the present study, 37% of the patients had pain in the forebreast under the neck, mainly in the bilateral collarbone and 1-2 chest rib joints (**Figure 5**). The location of the AS in 63% of the patients was roughly the same as that of the patients with cervical posterior surgery, mainly in the back of the neck and back of the bilateral humeral [1].

In a study of the causes of AS in 60 patients after ACDF, Kawakami et al. [8] reported that the occurrence rate of fusion segment kyphosis was higher in patients with obvious AS than in those without obvious AS. As a result of the decrease in cervical lordosis in local operation section, kyphosis causes the imbalance of neck muscles and in harmony of zygapophyseal joints, eventually leading to the occurrence of AS. With respect to the origin of kyphosis, Kawakami proposed that it may be related to improper intervertebral distraction of the surgical segment. It can be observed that there exist the bone graft, intervertebral collapse, and settlement of implants in patients with the intervertebral opening length of the operation section < 2 mm or > 5 mm, which will result in kyphosis and the decrease of cervical lordosis of the cervical vertebra in local in operation section.

In this study, only patients who underwent ACDF surgery for one or two segments were enrolled. Patients who underwent ACDF for three or more segments were excluded because of the impact on overall curvature and activity. There was no statistically significant difference in the overall cervical spinal curvature or local curvature of the surgical segment and ROM between the two groups (**Table 2**; **Figures 7-10**). However, the decrease in the local curvature of the surgical segment after the surgery was clearly greater in Group S than in Group N (62% of patients vs. 27%) (**Figure 4**), indicating local convex change tendency (**Figure 9**). Hence, AS after ACDF surgery may be associated with a reduction in the lordosis of fused segments postoperatively.

In the present study, there was a significant between-group difference in the distraction of the intervertebral height of the surgical segment before and after the surgery (**Table 2**). The ratio of intervertebral height change of the patients in Group S was considerably higher than that in Group N. In addition, the value for both groups was not negative. This shows that distraction of the postoperative segment was achieved postsurgery in both groups and that the range of distraction was apparently higher in Group S than in Group N. The regression analysis of the postoperative VAS of the AS and the ratio of the intervertebral height change reflected the positive correlation between the severity of the AS and the range of intervertebral distraction (**Figure 6**). This result may be explained as follows: Insufficient distraction of

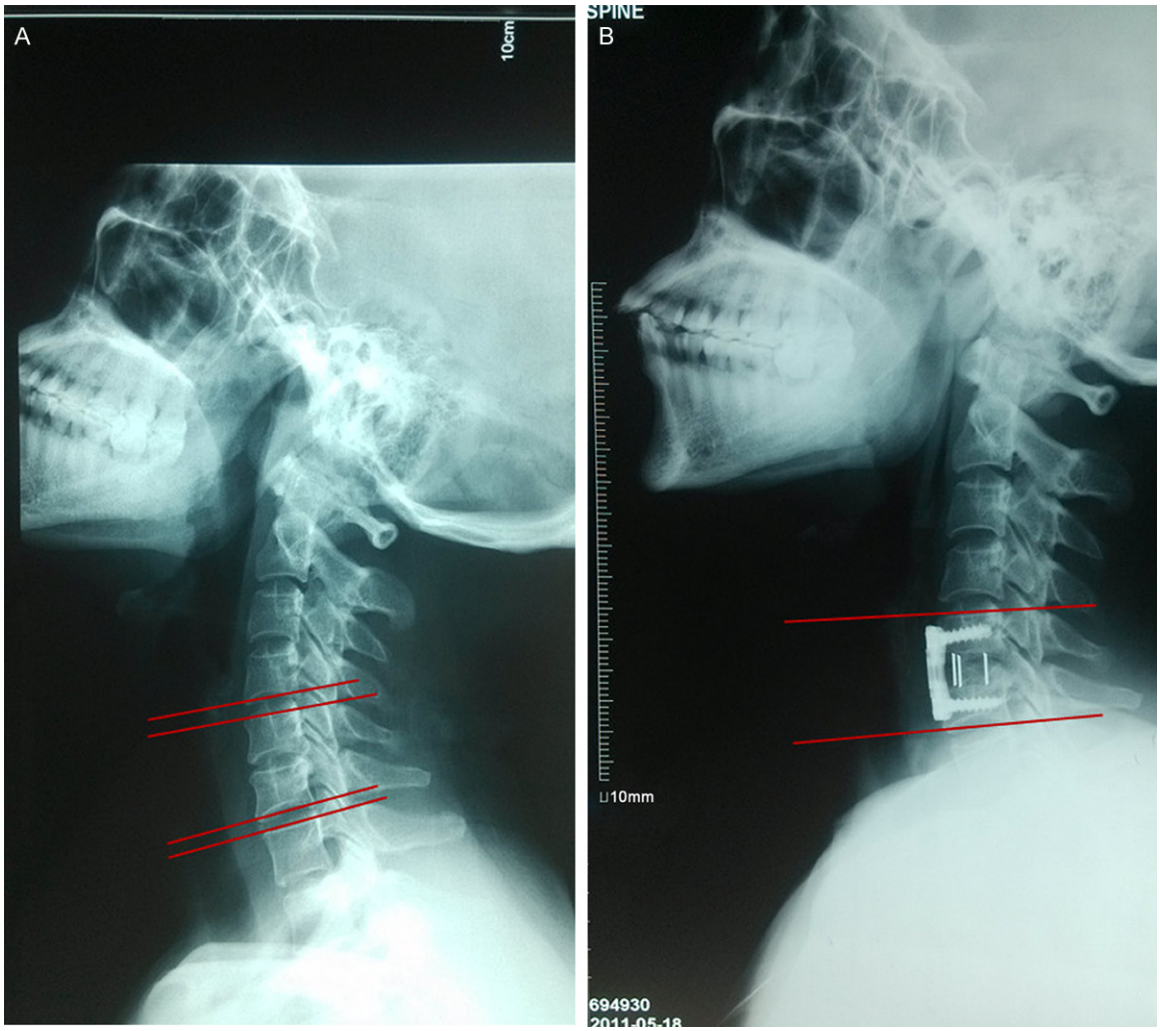


Figure 7. Group S, 46 y, female, "bad" in post-operative AS assessment, cervical lateral position X ray. A: Preoperative intervertebral height: 3.19 cm, average intervertebral height of adjacent segment: 0.73 cm; B: Post-operative intervertebral height: 3.68 cm, intervertebral height change ratio before and after surgery was 67.12%.

the surgical segment rarely occurs because of the wide application of Caspar in ACDF, and full distraction of the surgical segment to effectively restore the height of the intervertebral space is important to improve the surgical curative effect and to restore and maintain the cervical physiological curvature. Therefore, operators tend to fully distract the intervertebral space, resulting in over distraction (**Figure 7**).

Over distraction may cause joint capsule and ligament injury and increase the distance between the upper and lower intervertebral joint, potentially causing dislocation or subluxation. The resulting mechanical stimulation or damage of the intervertebral ligament and sinus vertebral nerve in the intervertebral joint capsule causes AS. In addition, if the intervertebral implant is too high, the pressure between the upper and lower endplate will increase, potentially causing osteonecrosis, intervertebral collapse, sedimentation, and protrusion, eventually resulting in AS.

According to the results of the present study, the occurrence of AS was not obviously correlated to the recovery of neural function after the surgery (**Table 3**), which is consistent with the previous literature [8]. The occurrence of C5 nerve root palsy in one patient in Group S may have been associated with over distraction of the surgical segment and distraction stimulus of the C5 nerve root. However, because of a lack of cases, a further study is needed.

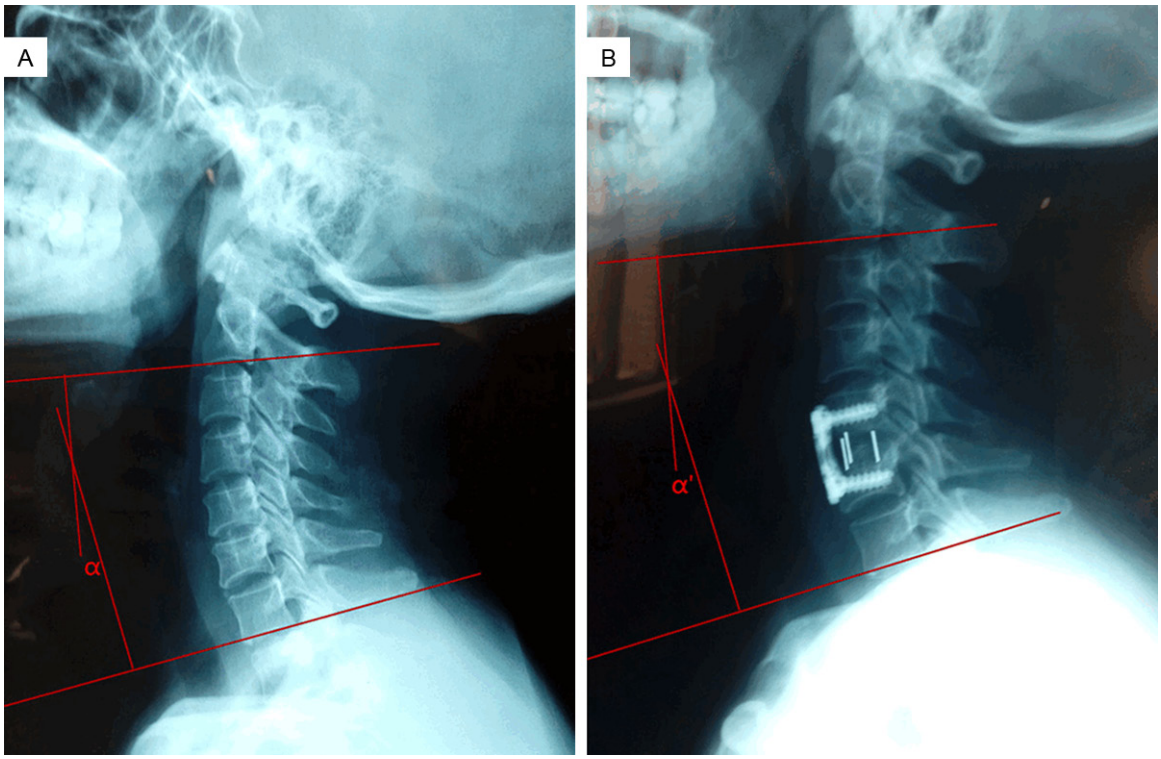


Figure 8. Group S, 46 y, female, "bad" in post-operative AS assessment, cervical lateral position X ray. A: Post-operative cervical lateral curvature: 11.0°; B: Post-operative cervical lateral curvature: 11.3°.

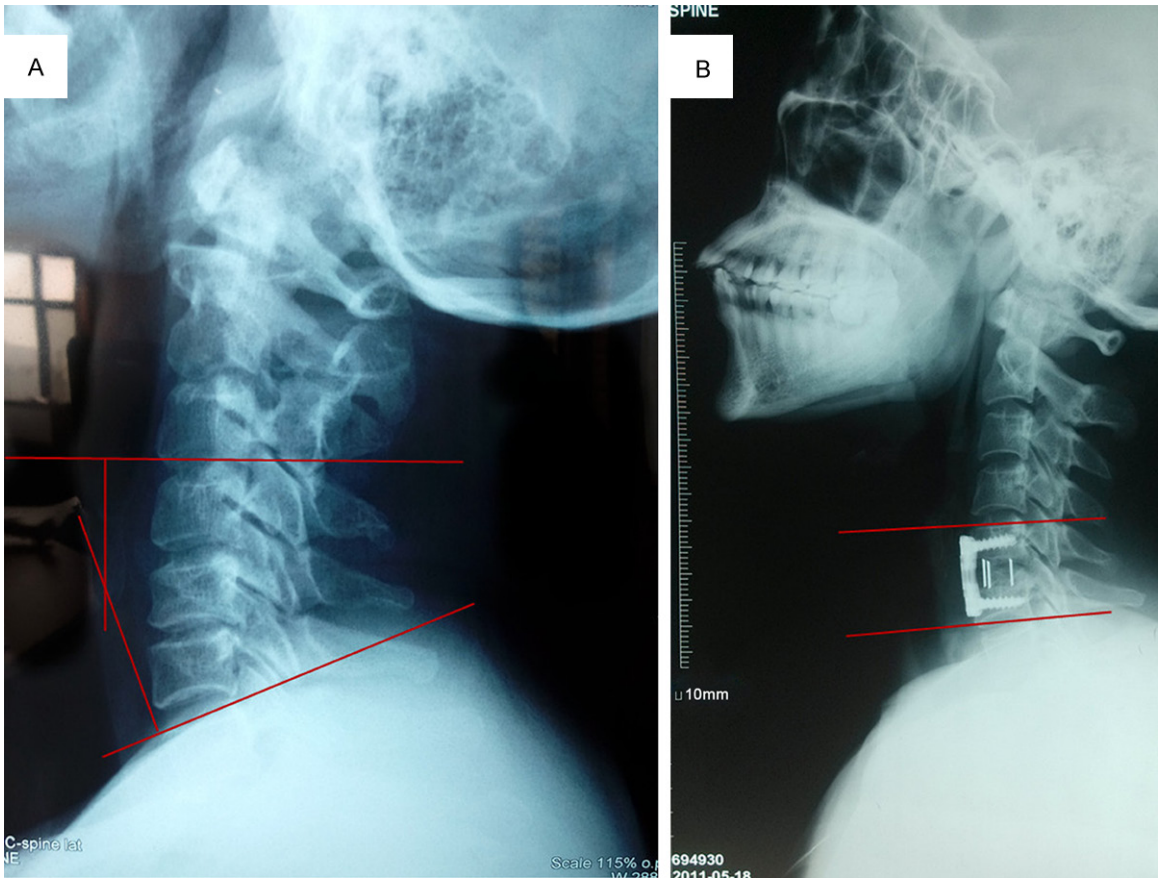
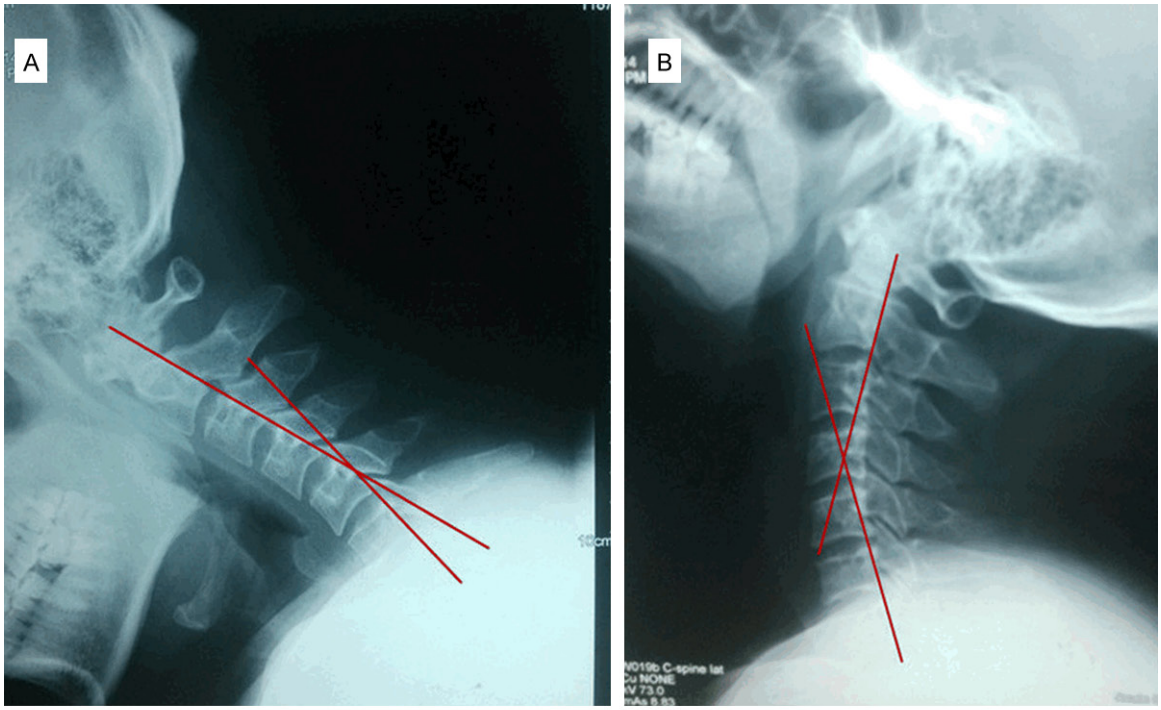


Figure 9. Group S, 50 y, female, "bad" in post-operative assessment, cervical lateral position X ray. A: Preoperative local cervical lateral curvature: 20.7°; B: Post-operative local cervical lateral curvature: 5.1°.



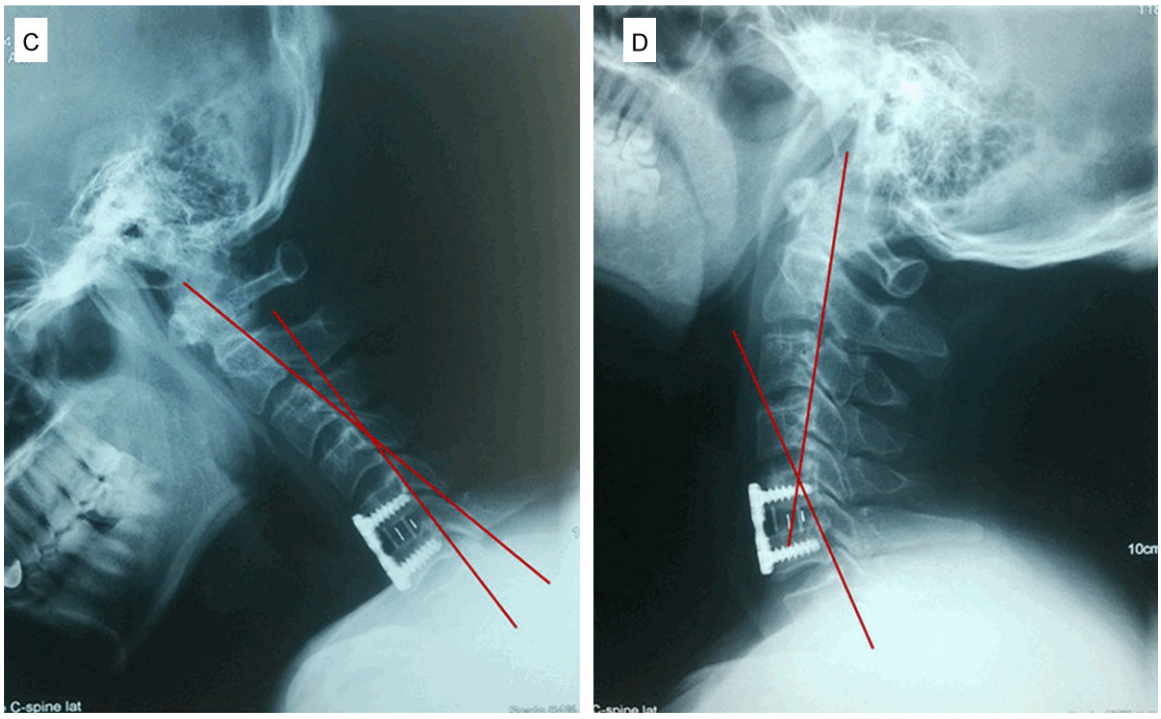


Figure 10. Group S, 54 y, male, "bad" in post-operative AS assessment, dynamic cervical spine X-ray. A: Preoperative flexion position Angle is 16.7°; B: Preoperative hyperextension angle is 30.1°; C: Post-operative flexion position angle is 13.7°; D: Post-operative hyperextension angle is 29.7°. Cervical range of motion: 46.8° and 43.4°.

Over distraction of the intervertebral space in ACDF surgery may not only increase the incidence of AS and negatively affect treatment outcomes but also excessively pull the nerve

root and spinal cord. This may cause palsy and nerve root damage, resulting in postsurgical adverse effects on the functional recovery of the spinal cord and even spinal cord damage. Therefore, it is strongly recommended that the intervertebral height in ACDF should be moderately increased to avoid over distraction.

Moderate distraction of the intervertebral space not only expands the intervertebral space and intervertebral foramen but also allows the tension of surrounding soft tissue to return to normal. Effective recovery of the height of the cervical anterior column during the surgery plays a critical role in ACDF. However, as yet, no consensus has been reached on the optimum height to aid recovery.

The measurement index used in Kawakami's study is an absolute value, with individual differences, such as height or race, not considered. As a consequence, the proportion of change in the intervertebral height of the surgical segment (Δh) to the average intervertebral height of the adjacent segment before surgery ( ) was used to evaluate the intervertebral height of the surgical segment. We found that 80% of patients in whom the ratio of intervertebral height change was over 10% were in Group S. Considering the possible positive correlation between the ratio of the intervertebral height change and the severity of AS after surgery, the following is suggested to decrease the incidence of postoperative AS: The average intervertebral height of adjacent surgical segments of patients undergoing ACDF should be measured, and the intervertebral range of distraction of the surgical segment should be calculated. A ratio of intervertebral height change under 10% should be maintained.

The present study shows that AS are common after ACDF surgery. The occurrence of AS may be associated with the change in the curvature of the cervical fusion segment after surgery and over distraction of the surgical segment. Moderate distraction of the intervertebral space and selection of an appropriately sized intervertebral prosthesis may play critical roles in reducing AS after surgery. In ACDF surgery, to ensure its curative effect, prevent intervertebral collapse and kyphosis of fused segments, and prevent AS, care should be taken to avoid over distraction of the surgical segment.

Conclusions

The occurrence of postoperative AS will significantly increase if the ratio of intervertebral height change of the surgical segment after ACDF is over 10%. Selecting an appropriately sized fusion material and moderately distracting the intervertebral space can significantly decrease the occurrence of postoperative AS.

Disclosure of conflict of interest

None.

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