

# Endplate Abnormalities in Cervical Spondylotic Myelopathy and Association with Pre- and Post-operative(Single-level ACDF with a Zero-P Implant)Sagittal Parameters and Clinical Outcomes.

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## Research article

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# Abstract

**Background:**Endplate abnormalities in cervical spine were closely related to pre- and post-operative symptoms, and might lead to a certain complication. However, the related researches are few, and the associations between endplate abnormalities and clinical outcomes need more evidence. Correlations between endplate abnormalities and pre- and post-operative cervical sagittal parameters also remain unknown. The purpose of this study was to explore endplate abnormalities in cervical spondylotic myelopathy, and to find potential associations of endplate abnormalities with preoperative cervical sagittal parameters, disc degeneration and symptoms, and clinical outcomes after ACDF.

**Method:**We enrolled 65 patients (34 males, 31 females) who were diagnosed with CSM and were subjected to single-level ACDF with a Zero-P implant at our hospital from 2015 to 2018. The patients were divided into two groups according to whether the endplate was abnormal. We conducted a retrospective study to compare the clinical and radiological results among the two groups.

**Results:**The average age in endplate abnormality group was higher than it in no abnormality group ( $P < 0.001$ ). T1S was significantly higher in abnormality group than in the normal group of preoperative ( $P < 0.05$ ) and kept significantly different from postoperative and 1 year follow up ( $P < 0.05$ ). No significantly different was found between the two groups as for CA, cSVA, intervertebral height and preventable soft-tissue thickness. The incidence rate of interbody cage subsidence was 25.9% in 2 years follow up, which was significantly higher than that in the normal group ( $P < 0.05$ ). The fusion rate in endplate abnormality group was 89%. No significant difference was found between the two groups. The Miyazaki grade of the disc in endplate abnormality group was significantly higher than it in the normal group ( $P < 0.01$ ). Significant difference was detected on NDI between the two groups.

**Conclusions:** Endplate abnormalities in cervical spondylotic myelopathy were associated with older age, disc degeneration, decrease of intervertebral height and increase of TS before cervical surgery. Patients in endplate abnormality group showed increase in NDI pre- and post-operation, and more phenomenon of subsidence.

## Introduction

Vertebral endplate abnormalities refer to the structural defects in the vertebral endplates[1]. Previous studies usually focus on the vertebral endplates in lumbar spine and several types of endplate defects were introduced, such as Schmorl's nodes, erosive defects, and arc type[2–4]. Endplate abnormalities have a close relationship with intervertebral disc degeneration (IVD) and pain in lumbar[5, 6].

Tomaszewski et al. [7] found cervical intervertebral disc degeneration had a strong correlation with endplate calcification by observation of human cadavers. And they concluded endplate calcification prevent nutrition supply to the intervertebral disc. Harada et al. [8] divided cervical endplate defects into typical abnormality and atypical abnormalities according to the morphological characteristics of endplates on MRI, and found endplate defects were associated with pain and adjacent segment

degeneration after cervical surgery. The former is a representative of the traditional Schmorl node, and the latter (Corresponding to Schmorl's nodes, erosive defects, and arc type in the lumbar spine) is defined by greater size and shape irregularity (Fig. 1), which may eventually have a different impact on the overall degenerative spine contour and related clinical outcomes of patients.

Cervical spondylotic myelopathy (CSM) is a degenerative disorder which can lead to neurological dysfunction and neck pain. Anterior cervical discectomy and fusion (ACDF) is a standard procedure for treating patients with CSM. Previous studies demonstrated that some cervical sagittal parameters were associated with the advancing of CSM and they also influenced clinical outcomes after ACDF [9–11]. C2-C7 sagittal vertical axis (cSVA), T1 slope (T1S) and C2-C7 Cobb angle (CA) are important parameters associated with cervical sagittal alignment and clinical symptoms. Increasing CA and T1S are correlated with decreasing preoperative NDI (Neck disability index), and high cSVA is an independent predictor of high preoperative NDI in patients with CSM [12]. Tang et al. [13] found C2-C7 SVA negatively correlated with SF-36 (Short Form 36-Item) and positively correlated with NDI scores, especially when cSVA > 40mm postoperatively.

Some researchers noticed endplate abnormalities in the cervical spine were closely related to pre- and post-operative symptoms, and might lead to a certain complication, such as adjacent segment degeneration (ASD) [8]. However, the related researches are few, and the associations between endplate abnormalities and clinical outcomes need more evidence. Correlations between endplate abnormalities and pre- and post-operative cervical sagittal parameters also remain unknown. The purpose of this study was to explore endplate abnormalities in cervical spondylotic myelopathy, and to find potential associations of endplate abnormalities with preoperative cervical sagittal parameters, disc degeneration and symptoms, and clinical outcomes after ACDF.

## Materials And Methods

We enrolled 65 patients (34 males, 31 females) who were diagnosed with CSM and were subjected to single-level ACDF with a Zero-P implant at our hospital from 2015 to 2018. Patients who underwent surgery for symptomatic degenerative lesions were included if preoperative T1 and T2 weighted MRI and X-ray images of the surgical segment could be measured and structural morphology could be evaluated. Patients who underwent other procedures during the follow-up period, those lost to follow-up, and those who did not undergo dynamic roentgen stereogrammetric analysis at least 2 years postoperatively were excluded.

The patient was given general anesthesia and supine. The right lateral incision was used to expose the operative segment. Removal of compression materials such as intervertebral disc and osteophyte, and posterior longitudinal ligament resection was performed according to the severity of dural sac compression. The endplate cartilage was scrapped in order to prepare it for bone grafting. Appropriate Zero-P was implanted into intervertebral space. Patients were asked to move under the ground with neck support for 24 hours.

Query the demographic information of each patient which included age, body mass index (BMI), sex, and smoking status. Other variables included operation time (minutes), length of hospitalization, operative segments, blood loss and duration of symptoms (months).

Preoperative MRI (T1- and T2-weighted) was assessed for endplate abnormalities using the method outlined by Samartzis et al. [2–4] and refer to the vertebral endplates abnormalities in lumbar spine.

NDI, SF-36 and Japanese Orthopedic Association score (JOA) were evaluated at preoperative, and postoperative, 1 year and 2 year follow-up. The phenomenon of subsidence and fusion conditions was evaluated at final follow-up. Subsidence was interpreted as a decrease of more than 3 mm in the height of the surgical segment between the final follow-up image and the image obtained immediately after surgery. Radiological fusion is defined as the interspinous distance motion  $\leq 2^\circ$  on X-ray and / or the distance motion  $\leq 2$  mm on flexion–extension X-ray. The intervertebral discs were graded using the Miyazaki disc degeneration grading system [14] (grade 1–5, the higher the grade, the more serious the intervertebral disc degeneration).

## **Sagittal parameters on the lateral radiographs were as follows:**

**T1S:** Draw a straight line along the superior endplate of T1 vertebral body. The angle between the line and the horizontal line is the T1 inclination angle.

**cSVA:** The distance between the plumb line passing through the center of C2 and the plumb line passing through the center of C7.

**Cobb angle:** Draw a straight line along the upper endplate of the upper vertebra and the lower endplate of the lower vertebra, and the angle between the two lines.

**Intervertebral height:** The measured height is the average of the height of the front half and the rear half.

**Pre-vertebral soft-tissue thickness:** It was determined by evaluating the soft tissue thickness from the front of the c3-7 vertebral body to the back of the trachea.

## **Statistical analysis**

SPSS of Windows version 23.0 was used for statistical analysis. T test and chi square test were used to analyze the differences between the two groups.  $P < 0.05$  was considered statistically significant.

## **Results**

A total of 65 patients (34 males, 31 females) were included. The patients were divided into two sub-groups according to the morphological characteristics at the surgical segment. 41.5% patients (27/65)

had endplate abnormalities. The average age in endplate abnormality group was  $60.89 \pm 8.01$  yr, significantly higher than the  $53.76 \pm 8.52$  yr in no abnormality group ( $P < 0.001$ ). Gender, duration of symptoms, body mass index (BMI), smoking status, operation time, length of hospitalization and blood loss were not significantly different between the two groups (Table 1).

Table 1

Comparison of the enrolled populations based on Demographic and Endplate Abnormalities

	No Endplate Abnormalities (n=38)	Endplate Abnormalities (n=27)	p-value
Age (year)	$53.76 \pm 8.52$	$60.89 \pm 8.01$	0.001
Sex (male/female)	19/19	15/12	0.195
Operation time (minutes)	$118.95 \pm 30.65$	$114.44 \pm 22.76$	0.441
Length of hospitalization	$5.92 \pm 1.71$	$5.89 \pm 1.93$	0.612
Operative segments			
C3-4	12	9	
C4-5	11	11	
C5-6	13	6	
C6-7	2	1	
Blood loss	$143.16 \pm 31.63$	$135.96 \pm 31.83$	0.403
Body mass index (BMI)	$25.20 \pm 6.04$	$25.91 \pm 3.83$	0.636
Current smoker (Y/N)	17/21	13/14	0.074
Duration of symptoms	$10.21 \pm 4.22$	$12.30 \pm 5.68$	0.178

Cervical sagittal parameters were compared between the two groups before and after surgery. T1S was significantly higher in abnormality group than in the normal group of preoperative ( $P < 0.05$ ) and kept significantly different at postoperative and 1 year follow up ( $P < 0.05$ ). T1S was not significantly different in 2 years follow up and the changes of T1S (Pre vs F/U 2y) between the two groups were not significantly different. No significantly different was found between the two groups as for CA, cSVA, intervertebral height and prevertebral soft-tissue thickness. The incidence rate of interbody cage subsidence was 25.9% in 2 years follow up, which was significantly higher than that in the normal group ( $P < 0.05$ ). The fusion rate in endplate abnormality group was 89%. No significantly difference was found between the two groups (Table 2). The Miyazaki grade of the disc in endplate abnormality group was  $4.26 \pm 0.76$ , which was significantly higher than the  $3.66 \pm 0.91$  in the normal group ( $P < 0.01$ ) (Table 3).

## Table 2

### Comparisons of radiologic parameters

	No Endplate Abnormalities (n=38)	Endplate Abnormalities (n=27)	p-value
T1S (°)			
Pre	24.23±3.48	27.91±5.45	0.004
Post	25.29±3.34	28.37±5.6	0.046
F/U 1y	24.36±3.37	27.48±5.64	0.036
F/U 2y	25.17±3.84	27.68±5.56	0.068
ΔT1s (°)(Pre vs F/U 2y)	0.94±2.47	-0.23±3.16	0.100
CA (°)			
Preoperative	12.93±5.94	13.82±2.07	0.052
Post	15.74±4.58	16.86±2.07	0.053
F/U 1y	15.53±4.83	16±1.75	0.177
F/U 2y	14.52±4.72	14.71±1.55	0.103
ΔCA (°)(Pre vs F/U 2y)	1.58±3.05	0.89±1.77	0.170
cSVA (mm)			
Pre	18.86±4.78	17.07±3.12	0.073
Post	23.4±4.53	22.18±2.32	0.401
F/U 1y	21.92±4.59	21.07±2.01	0.567
F/U 2y	22.46±4.50	21.12±2.15	0.315
ΔcSVA (mm) (Pre vs F/U 2y)	3.60±2.41	4.05±2.71	0.490
Intervertebral height (mm)			
Pre	5.36±1.41	4.26±1.46	0.008
Post	7.67±1.35	7.97±0.90	0.288
F/U 1y	6.79±1.46	7.00±0.73	0.775
F/U 2y	6.46±1.37	5.82±0.67	0.027
ΔIH(Pre vs F/U 2y)	1.10±0.99	1.56±1.77	0.220
Prevertebral soft-tissue Thickness (mm)			
Pre	12.72±3.05	14.11±3.16	0.080
Post	16.83±2.91	17.46±3.28	0.460

F/U 1y	14.03±2.79	14.26±2.76	0.747
F/U 2y	13.24±2.39	13.55±2.60	0.616
Δ(Pre vs F/U 2y)	0.52±1.70	-0.22±1.37	0.074
Subsidence	5.3%	25.9%	0.044
Fusion	95%	89%	0.642

Table 3

Comparison of Miyazaki grading of cervical disc degeneration in two groups

	No Endplate Abnormalities (n=38)	Endplate Abnormalities (n=27)	p-value
Miyazaki grading	3.66±0.91	4.26±0.76	0.006

Cervical endplate abnormalities had associations with symptoms and clinical outcomes before and after ACDF. SF-36 and JOA scores were increasing and NDI was decreasing after the surgery both in the normal group and endplate abnormality group. Significant difference was detected on NDI between the two groups. Abnormality group had significantly higher preoperative NDI scores and the scores remained higher in postoperative and 1 year follow up compared to the normal group (P<0.05). There was no significant difference in pre- and post-operative JOA and SF-36 between the two groups (Table 4).

Table 4

Quality of Life Parameters

	No Endplate Abnormalities (n=38))	Endplate Abnormalities (n=27)	p-value
<b>JOA</b>			
Pre	10.58±1.52	10.15±1.88	0.215
Post	13.13±1.51	13.11±0.97	0.885
F/U 1y	12.90±1.83	13.22±1.60	0.431
F/U 2y	13.26±1.81	13.52±1.74	0.512
△JOA(Pre vs Post)	2.55±1.52	2.96±1.79	0.101
△JOA(Pre vs F/U 2y)	2.68±1.89	3.37±2.13	0.075
<b>NDI</b>			
Pre	19.53±4.94	23.00±4.18	0.012
Post	14.74±4.06	17.63±4.78	0.011
F/U 1y	12.97±3.35	15.78±4.37	0.020
F/U 2y	12.08±3.59	13.56±2.82	0.080
△NDI(Pre vs Post )	-4.79±2.94	-5.37±3.21	0.678
△NDI(Pre vs F/U 2y)	-7.45±3.02	-9.44±5.17	0.145
<b>SF-36</b>			
Pre	43.90±6.52	41.70±5.91	0.150
Post	52.32±7.38	51.89±6.80	0.813
F/U 1y	53.18±7.06	52.96±6.05	0.895
F/U 2y	53.74±7.92	53.33±5.38	0.808
△SF-36(Pre vs Post)	8.42±4.66	10.19±5.47	0.408
△SF-36(Pre vs F/U 2y)	9.84±4.18	11.63±5.74	0.184

## Discussion

The endplate is composed of bone endplate and cartilage endplate. As an important part of the vertebral structure, endplate plays a role of mechanical conduction. At the same time, endplate is one of the main ways for nutrients to reach intervertebral disc[15]. Previous studies found endplate abnormalities were common in lumbar spine[16]. The morphologies of endplate abnormalities observed on MRI included Schmorl's nodes, notch type, erosive defects, rim defects and et al[2, 4]. Endplate abnormalities had close associations with intervertebral disc degeneration, Modic changes and clinical symptoms[5, 6, 17]. Age,

slippage and endplate morphology are potential risk factors for endplate abnormalities. However, little is known about the relationship between endplate abnormalities and cervical sagittal parameters before and after the cervical surgery. And whether the endplate abnormalities have influence on symptoms and clinical outcomes in cervical need more evidence.

This study compared age, gender, BMI, smoking status and duration of symptoms between the normal group and endplate abnormality group, and explored whether operation time, length of hospitalization and blood loss were significantly different between the two groups (Table 1). Only age was found significantly different between them, which was consistent with previous research[3]. This illustrated that endplate abnormality may not influence the procedure of the cervical surgery.

Previous studies demonstrated that some cervical sagittal parameters were associated with endplate signal changes (Modic changes) and clinical outcomes. T1S was defined as the angle between a horizontal line and the superior endplate of T1[18]. It was found that T1S was significantly higher in patients with Modic changes (MCs) than normal group, and disc in the MCs group also had more severe disc degeneration[19]. In this study, we found preoperative T1S was significantly higher in abnormality group than in the normal group ( $P<0.05$ ), and intervertebral height at the surgery segment was significantly lower in abnormality group ( $P<0.05$ ) (Table 2). Intervertebral disc degeneration was significantly more severe in abnormality group (Table 3). Considering changes of endplate morphology impair its permeability and associated with disc degeneration, the endplate plays an important role in the development of disc degeneration[20]. Lv B and colleagues believed cervical balance impaired when T1S is greater than  $25^\circ$ , which may accelerate disc degeneration and MCs at C5-6[11]. T1S kept significantly different in postoperative and 1 year follow up ( $P<0.05$ ) (Table 2). To sum up, the changes of T1S are caused by three factors: first, intervertebral disc degeneration leads to the loss of intervertebral height, which leads to the increase of T1S; second, some endplate abnormalities lead to vertebral collapse, which eventually leads to the increase of T1S; third, patients with endplate abnormalities have more severe symptoms, limited cervical movement, and forced posture, which leads to the increase of T1S. This study didn't find prevertebral soft-tissue thickness. Cobb angles and cSVA were associated with endplate abnormalities. NDI decreased, JOA and SF-36 increased in both groups after surgery, which means the patients can achieve good clinical outcomes by the surgery. NDI was significantly higher in endplate abnormality group before the surgery and kept significantly different in postoperative and 1 year follow up ( $P<0.05$ ) (Table 4). This trend was similar to T1S. Song and yang[21] pointed out that the Schmorl node can create a channel for disc herniation in patients with Scheuermann's disease, which leads to rapid onset of spinal cord injury. Although rare, this example suggests that structural endplate abnormalities may increase the risk of cervical spondylosis. Similar principles can be applied to this study, and can explain why endplate abnormalities lead to a higher incidence of symptoms of cervical spondylotic myelopathy.

Subsidence indicated loss of surgical segment height after the surgery. Intervertebral height in endplate abnormality group was significantly lower in 2 years follow up compared to the normal group ( $P<0.05$ ) (Table 2). The main reason for the low fusion rate in the abnormal endplate group is that the endplate

destroys the vertebral bone and causes the fusion cage to sink. On the other hand, it is considered that some endplates are not treated or not completely treated during the operation, which causes the fusion cage to sink. The decrease of intervertebral height (Pre vs F/U 2y) showed no significant difference between the two groups. Intervertebral height changes are affected by many factors, intervertebral disc degeneration will lead to the loss of intervertebral height, settlement will lead to the loss of intervertebral height, under the comprehensive influence of the above results are not statistically significant. ACDF surgery using Zero-P implants showed high fusion rates. In this study, both groups had satisfied fusion rates[22]. No significant difference was found between them (Table 2).

## Limitations

This retrospective study includes some limitations. First, endplate abnormalities had sub-types according to their morphological characteristics, we only divided the patients into two groups and didn't analyse different endplate abnormalities separately because of small sample size. In addition, the relationship between endplate abnormalities and disc degeneration, cervical sagittal parameters and clinical outcomes needs prospective study to confirm.

## Conclusion

Endplate abnormalities in cervical spondylotic myelopathy were associated with older age, disc degeneration, decrease of intervertebral height and increase of T1S before cervical surgery. Patients in endplate abnormality group showed increase of NDI pre- and post operation, and more phenomenon of subsidence. Nevertheless, the author believes that ACDF should be performed in CSM patients with surgical indications, regardless of whether the endplate is abnormal or not. Whether the endplate is abnormal is only a better judgment of the postoperative effect.

## Abbreviations

IVD: Intervertebral disc degeneration; CSM: Cervical spondylotic myelopathy; ACDF: Anterior cervical discectomy and fusion; cSVA: C2-C7 sagittal vertical axis; T1S: T1 slope; CA: C2-C7 Cobb angle; NDI: Neck disability index; SF-36: Short Form 36-Item ; ASD: Adjacent segment degeneration; BMI: Body mass index; JOA: Japanese Orthopedic Association score ; MCs: Modic changes .

## Declarations

## Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

## Consent for publication

Written informed consent for publication was obtained from all participants.

## Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

## Competing interests

The authors report no conflicts of interest in this work.

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None.

## Authors' contributions

WYD conceived and designed the study; ZL and ZW collected; ZL, RYL, and ZW analyzed and interpreted the patient data. ZL and RYL wrote the paper. All authors read and approved the final manuscript. All authors have read the journal policies and have no issues relating to journal policies. All authors have seen the manuscript and approved to submit to your journal. The work described has not been submitted elsewhere for publication, in whole or in part. The authors read and approved the final manuscript.

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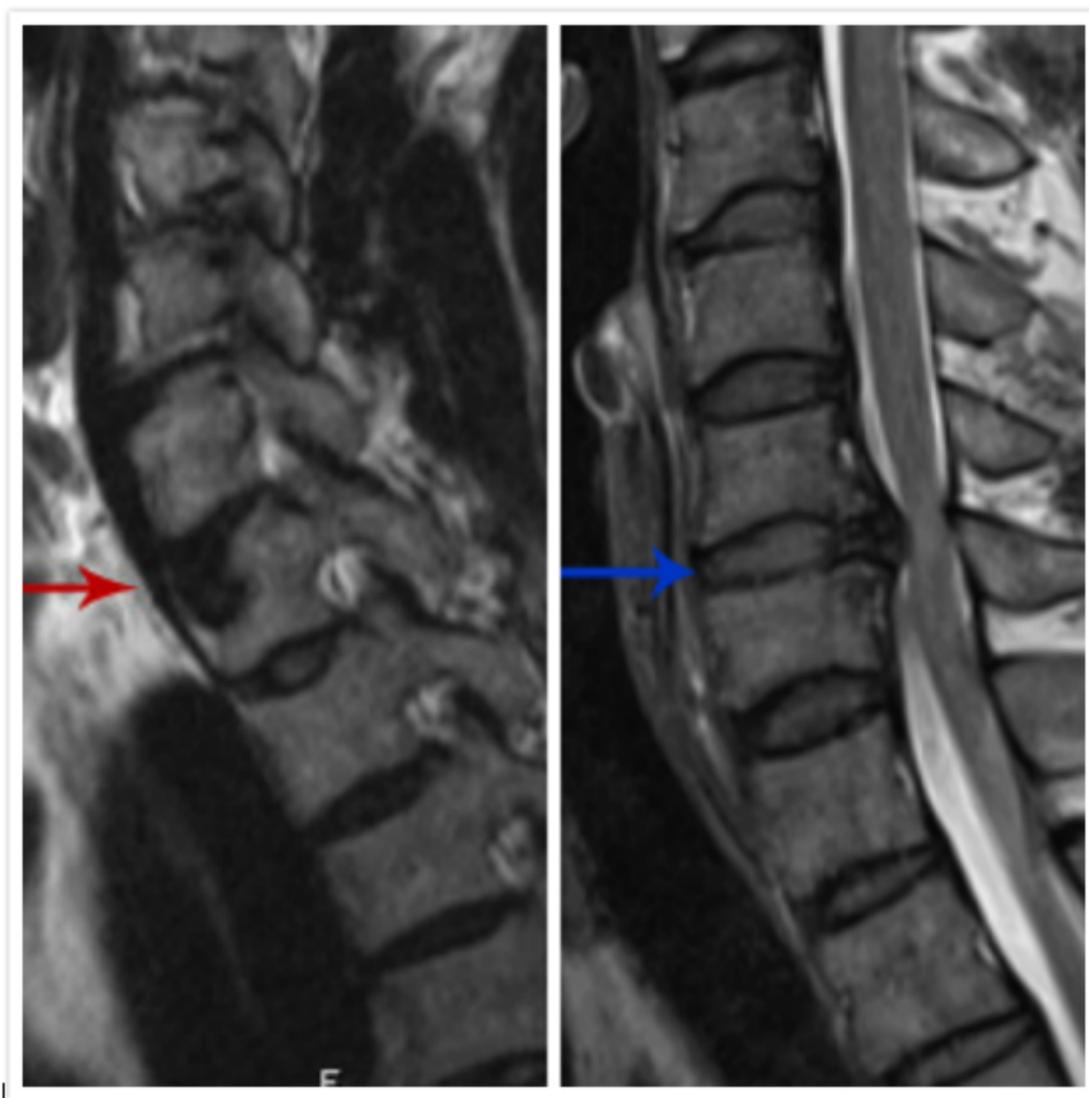
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## Figures



## Figure 1

Typical (left) and atypical (right) endplate abnormal sample images. The typical endplate abnormality (red arrow) refers to the traditional Schmorl's node. Atypical endplate abnormalities (blue arrows) are irregular in shape and size. It is not discussed separately in this paper.