Cervical balance and clinical outcomes in cervical spondylotic myelopathy treated by three-level anterior cervical discectomy and fusion and hybrid cervical surgery
A CONSORT-compliant study with minimum follow-up period of 5 years
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Abstract
As the technology of combining with fusion and nonfusion procedure, cervical hybrid surgery (HS) is an efficacious alternative for treatment with cervical spondylotic myelopathy. While studies on cervical alignment between 3-level HS and anterior cervical discectomy and fusion (ACDF) were seldom reported. The effects of cervical imbalance on its related clinical outcomes are yet undetermined as well.

Patients with cervical spondylotic myelopathy, who underwent 3-level ACDF or HS, were included to compare cervical alignment parameters after surgery and then explore the relationship between cervical balance and clinical outcomes.

Forty-one patients with HS (HS group) and 32 patients who with ACDF (ACDF group) were reviewed from February 2007 to September 2013 with the mean follow-up of $90.3\pm25.5$ (m) and $86.3\pm28.9$ (m), respectively. Cervical alignments parameters including the C2 to C7 cervical lordosis (CL), C2 to C7 sagittal vertical axis, T1 slope. and T1SCL (T1 slope minus CL), and the clinical outcomes like neck disability index (NDI) and Japanese Orthopedic Association (JOA) score were measured and recorded preoperatively (PreOP), intraoperatively, and on the first preoperative day and the last follow-up (FFU). The balance and imbalance groupings were sorted based on the T1SCL: T1SCL $\leq 20^\circ$, balance; T1SCL $>20^\circ$, imbalance.

We found significant improvements ($P < .001$) in NDI and JOA at intraoperatively and FFU after ACDF and HS, and no difference on cervical alignment and clinical outcomes between the 2 procedures on the basis of intergroup comparisons. By between-subgroups comparisons, however, we found significant differences in CL and T1SCL at PreOP ($P < .05$). Nonetheless, there was no significant difference on the clinical outcomes between balance and imbalance subgroups at FFU at PreOP ($P > .05$), indicating that the change of T1SCL was not correlated to NDI and JOA at FFU.

Both HS and ACDF groups showed significant clinical improvements after surgery. There was no correlation between cervical balance and clinical symptoms.

Abbreviations: ACDF = anterior cervical discectomy and fusion, BMI = body mass index, CL = cervical lordosis, CSM = cervical spondylotic myelopathy, FFU = final follow-up, HS = hybrid cervical surgery, ImOP = immediately after operation, JOA = Japanese Orthopedic Association score, LL = lumbar lordosis, LP = laminoplasty, NDI = neck disability index, PI = pelvic incidence, PreOP = preoperation, PT = pelvic tilt, ROM = range of motion, RR = recovery rate, SS = sacral slope, SVA = C2-C7 sagittal vertical axis, T1SCL = T1 slope minus C2-C7 cervical lordosis.

Keywords: anterior cervical discectomy and fusion, cervical alignment, cervical balance, cervical spondylotic myelopathy, hybrid cervical surgery
1. Introduction

Research on the spino-pelvic alignment in sagittal plane has been widely reported. And the spino-pelvic mis-alignment can result in global sagittal imbalance in the upright standing position.1,2 One significant predictor of disability is the mismatch (≥9°) between lumbar lordosis (LL) and pelvic incidence (PI).3,4 Recently, T1 slope minus C2-C7 cervical lordosis (TISCL), analogous to PI-LL, has been applied to cervical alignment parameters,5 when TISCL ≤20°, cervical spine is considered balanced, and when TISCL > 20°, cervical spine is regarded as imbalanced. However, this indicator was rarely reported in the spine imbalance studies.

Anterior cervical disectomy and fusion (ACDF) is a standard and accepted procedure for treating cervical spondylotic myelopathy (CSM). Since recent decades, cervical total disc replacement has been designed to preserve the motion of the operated levels. As the concept of combining with fusion and arthroplasty technology where appropriate, cervical hybrid surgery (HS) was then proposed. Contrasted with posterior approach, both HS and ACDF showed superiority in the treatment of CSM with less invasion, preservation of posterior muscle-ligament complex and direct decompression.6,7 Though postoperative cervical sagittal alignment and cervical-balance were well established after ACDF,8 when TISCL ≥20°, cervical spine is considered imbalanced, and when TISCL > 20°, cervical spine is regarded as imbalanced. However, this indicator was rarely reported in the spine imbalance studies.

The primary goal of surgery is to improve the quality of life and neurological function regardless of the cervical balance status. While studies on lumbar surgery found no correlation between pelvic balance with clinical outcomes,8-10 the role of cervical balance has not been determined yet. Therefore, this study is performed on the patients with CSM underwent consecutive t3-level HS or ACDF more than 5years, to compare long-term cervical alignment parameters and clinical outcomes, and then to explore the relationship between cervical balance status and clinical outcomes.

2. Methods

2.1. Participants and surgical procedure

The study included patients with CSM who underwent HS or ACDF from February 2007 to September 2014. And it was approved by the local institutional review board and all the patients have signed informed consent. The inclusion criteria and exclusion criteria were shown in Table 1.

The main indications for multilevel anterior-approach were symptomatic multilevel degenerative disc disease with neuro-dysfunction after a 6-month conservative treatment.11 Generally, fusion technique was applied to more severe degenerative segment while nonfusion was used to the degenerative segment with ROM 26°; the loss of intervertebral space was <80% of the normal adjacent segment; no instability of the segment; no severe loss of lordosis; no obvious canal stenosis; and no obvious osteoporosis, although there was no consensus of the threshold for third to six.12

Table 1

The inclusion criteria and exclusion criteria in this study.

| Inclusion criteria | Exclusion criteria |
|--------------------|-------------------|
| Patients required surgery after at least 6-mo uncontrolled conservation treatment. | Patients’ radiological alignment parameters were too unclear to measure (n = 8). |
| Patients were performed consecutive 3-level HS or ACDF. | Patients were underwent previous cervical surgery (n = 2). |
| Patients possessed intact radiographic and clinical outcomes. | Patients had operation for cervical spine fracture or infection (n = 1). |

ACDF = anterior cervical disectomy and fusion, HS = hybrid surgery.

One senior spine surgeon performed all the cases of HS or ACDF in this study: During surgery, patients were placed in a supine position. An anterior right-sided incision was made and standard Smith-Robinson approach to the cervical spine was performed. Bilateral disectomy and uncinated process resection were conducted even with unilateral symptoms. After complete decompression, the artificial disc together with poly-ether-ether-ketone (PEEK) cage was implanted in HS, while 3 PEEK cages were inserted in ACDF. All patients were instructed to wear collar for 2 months after surgery.

The type of artificial disc was Prodisc-C (Depuy Synthes, New Brunswick, USA) and the PEEK cage was MC+ (LDR Medical, Troyes, France). In HS group, there were 36 cases implanted 2 cages+1 artificial disc and 5 cases with 1 cage+2 artificial discs; In ACDF group, 13 of 32 patients were implanted with anterior rigid plate.

2.2. Cervical alignment parameters

The parameters were measured from standing lateral X-ray of cervical spine (Fig. 1). The following cervical alignment parameters were included: C2 to C7 cervical lordosis (CL), C2 to C7 sagittal vertical axis (SVA), T1S and T1SCL. CL was the angle from lower endplate of C2 to lower endplate of C7, SVA was measured from C2 plumb line to posterior margin of the upper endplate of C7; T1S was from upper endplate of T1 to horizontal line.

Figure 1. Measurements of cervical alignment parameters on standard lateral X-ray. (A) Measurement of CL; (B) measurement of SVA and T1S. CL = C2-C7 cervical lordosis, SVA = C2–C7 sagittal vertical axis, T1S = T1 slope; CL was the angle from lower endplate of C2 to lower endplate of C7, SVA was measured from C2 plumb line to posterior margin of the upper endplate of C7; T1S was from upper endplate of T1 to horizontal line.
angle from lower endplate of C2 to lower endplate of C7; SVA was measured from C2 plumb line to posterior margin of the upper endplate of C7; T1S was from upper endplate of T1 to horizontal line. T1SCL was used to evaluate the cervical sagittal balance (T1SCL $\leq$ 20$^\circ$, balance; T1SCL $> 20^\circ$, imbalance).[13] The radiograph was obtained at preoperation (PreOP), immediately after operation (ImOP), and final follow-up (FFU).

CL, SVA, and T1S were measured by 3 experienced surgeons with at least duplicated measurement. Intraobserver and interobserver reliability were assessed using intraclass correlation (ICC) coefficients (excellent (>0.90), good (0.71–0.90), fair (0.51–0.70) and poor (<0.51)).

2.3. Clinical outcomes assessment

Life quality was assessed by neck disability index (NDI) and Japanese Orthopedic Association (JOA) score, which were evaluated at PreOP, ImOP, and FFU by questionnaire. The recovery rate (RR) of JOA was calculated by the Hirabayashi method: $\text{RR} = \frac{\text{PostOP JOA} - \text{PreOP JOA}}{17 - \text{PreOP JOA}} \times 100$. Further analysis was conducted to explore whether clinical outcomes differed between:

1. Patients with an imbalanced cervical spine at PreOP (subgroup U) who regained cervical balance at FFU (subgroup UB) compared with those who did not regain cervical balance (subgroup BU).
2. Patients with a balanced cervical spine at PreOP (subgroup B) that was maintained at FFU (subgroup BB) compared with those who lost cervical balance at FFU (subgroup BU).
3. Patients with cervical balance at FFU (subgroup UB + subgroup BB) either maintained at PreOP (subgroup BB) or regained by surgery (subgroup UB) compared with those with an imbalanced cervical at FFU (subgroup UB + subgroup BB) whatever the cervical-balance status (subgroup B or subgroup U) at PreOP.

Moreover, whether the change in T1SCL correlated with clinical outcomes needed to be confirmed. It contained potential correlations between the degree of the change in T1SCL and NDI at FFU, change of NDI at FFU, JOA scores at FFU, and RR of JOA scores at FFU.

2.4. Balance and imbalance subgroups

Further analysis was conducted to explore whether clinical outcomes differed between:

1. Patients with an imbalanced cervical spine at PreOP (subgroup U) who regained cervical balance at FFU (subgroup UB) compared with those who did not regain cervical balance (subgroup BU).
2. Patients with an imbalanced cervical spine at PreOP (subgroup BB) that was maintained at FFU (subgroup BB) compared with those who lost cervical balance at FFU (subgroup BU).
3. Patients with cervical balance at FFU (subgroup UB + subgroup BB) either maintained at PreOP (subgroup BB) or regained by surgery (subgroup UB) compared with those with an imbalanced cervical at FFU (subgroup UB + subgroup BB) whatever the cervical-balance status (subgroup B or subgroup U) at PreOP.

In terms of cervical alignment, CL was of no significance at ImOP compared with that of PreOP, but an improvement at FFU in HS group and ACDF group, respectively ($P < .05$). There was no difference on distribution of operated segments between the 2 groups ($P = .626$), so operation time ($P = .083$) and blood loss ($P = .061$) (Table 2). ICC for intraobserver reliability was 0.909 on CL, 0.943 on SVA, and 0.935 on T1S; ICC for interobserver reliability was 0.872 on CL, 0.914 on SVA and 0.844 on T1S.

2.5. Statistical analysis

Student t test or Mann–Whitney U test was used to compare cervical alignment parameters and clinical outcomes between HS and ACDF groups, and between balanced and imbalanced subgroups with the same surgery. Student t test was also used to compare clinical outcomes between balanced and imbalanced subgroups at FFU. ANOVA analysis was used to compare measurements among PreOP, ImOP, and FFU in the same group. $\chi^2$ test or Fisher test was performed on dichotomous between 2 groups. Pearson correlation analysis was utilized between T1SCL and clinical outcomes. The statistical analysis was performed using IBM SPSS Statistics 22.0 (International Business Machines Corporation, Armonk, NY) and $P < .05$ was defined as statistical significance.

3. Results

A total of 103 cases were originally included and 11 of them were excluded at baseline. Finally, 73 participants completed 5-year follow-up with a completing rate of 79.3%. Of whom, 41 patients underwent HS (HS group) and 32 patients were treated with ACDF (ACDF group). There was no significance in terms of age, gender, and body mass index between the 2 groups. The mean follow-up time was 90.3 $\pm$ 25.5 (m) and 86.3 $\pm$ 28.9 (m) in HS group and ACDF group, respectively ($P > .05$). There was no difference on distribution of operated segments between the 2 groups ($P = .626$), so operation time ($P = .083$) and blood loss ($P = .061$) (Table 2). ICC for intraobserver reliability was 0.909 on CL, 0.943 on SVA, and 0.935 on T1S; ICC for interobserver reliability was 0.872 on CL, 0.914 on SVA and 0.844 on T1S.

Table 2

| Demographic characteristics and surgery information between HS and ACDF group. |
| HS group | ACDF group | $P$ |
|---|---|---|
| Gender (M/F) | 20/21 | 17/15 | .713 |
| Age (y) | 55.5 $\pm$ 8.0 | 57.2 $\pm$ 8.3 | .494 |
| BMI (kg/m$^2$) | 25.4 $\pm$ 3.1 | 24.8 $\pm$ 3.4 | .429 |
| DM | 8 | 3 | .325 |
| Smoking | 11 | 6 | .418 |
| Follow-up (mo) | 90.3 $\pm$ 25.5 | 86.3 $\pm$ 28.9 | .523 |
| Operated segments | | | .626 |
| C3-C6 | 11 | 7 | |
| C4-C7 | 30 | 25 | |
| Operation time (min) | 109.1 $\pm$ 17.8 | 101.1 $\pm$ 21.1 | .083 |
| Blood loss (mL) | 99.4 $\pm$ 83.3 | 71.3 $\pm$ 37.1 | .061 |

ACDF: anterior cervical discectomy and fusion; BMI: body mass index; DM: diabetes mellitus; F: female; HS: hybrid surgery; M: male.
Clinical outcomes

Comparison on cervical alignment and clinical outcomes between HS and ACDF groups.

| Outcomes at PreOP | ACDF group | P     | HS group | ACDF group | P     |
|------------------|------------|-------|----------|------------|-------|
| RR JOA(%)        | 14.9±4.9   | .095  | 16.3±9.7 | 26.7±7.0† | .046  |
| SVA(cm)          | 2.2±1.0†   | .191  | 1.7±1.2  | 1.0±1.9    | .494  |
| T1S(°)           | 26.9±7.7   | .698  | 26.7±7.0†| 13.0±3.9   | .118  |
| T1SCL(°)         | 11.9±9.4   | .151  | 10.8±2.5 | 13.2±9.9   | .148  |
| NDI(°)           | 19.9±4.4†  | .648  | 9.9±3.2  | 12.5±8.2†  | .123  |
| JOA              | 14.9±0.8†  | .268  | 29.8±4.6 | 25.8±8.2   | .018  |
| RRJOA(%)         | 62.7±13.7  | .806  | 16.2±1.0†| 15.7±1.9†  | .281  |

ACDF = anterior cervical disectomy and fusion, CL = C2-C7 cervical lordosis, FFU = final follow-up after operation, HS = hybrid surgery, ImOP = immediately after operation, JOA = Japanese Orthopedic Association score, NDI = neck disability index, PreOP = pre-operation, RR = recovery rate, SVA = C2-C7 sagittal vertical axis, T1S = T1 slope, T1SCL = T1S minus CL.

Comparison on cervical alignment and clinical outcomes between HS and ACDF groups.

Comparison on cervical alignment and clinical outcomes inner- and inter balance subgroup and imbalance subgroup.

| Balance subgroup at PreOP | Imbalance subgroup at PreOP |
|---------------------------|------------------------------|
| HS group | ACDF group | P     | HS group | ACDF group | P     |
|----------|------------|-------|----------|------------|-------|
| CL at PreOP(°)            | 14.3±10.1† | .861  | -2.6±7.4 | -5.0±10.3  | .623  |
| SVA at PreOP(cm)          | 1.4±1.0    | .119  | 12.6±9.9 | 10.8±8.6   | .606  |
| SVA at FFU(cm)            | 1.7±1.0    | .152  | 22.2±1.0 | 2.4±9.9    | .653  |
| T1S at PreOP(°)           | 23.2±8.6   | .657  | 19.3±2.2 | 21.5±1.7   | .874  |
| T1S at FFU(°)             | 26.8±7.3   | .509  | 23.3±7.3 | 22.9±8.5   | .931  |
| T1SCL at PreOP(°)         | 8.9±7.9†   | .305  | 25.8±3.8 | 27.8±4.1   | .328  |
| T1SCL at FFU(°)           | 9.5±7.0    | .454  | 13.2±12.4| 16.5±9.3   | .524  |
| NDI at PreOP              | 39.7±3.8   | .104  | 39.4±4.4 | 37.9±3.0   | .380  |
| NDI at FFU                | 9.7±3.3    | .176  | 11.0±3.1 | 12.0±7.3   | .758  |
| JOA at PreOP              | 11.1±1.8   | .025  | 28.5±3.9 | 26.2±6.8   | .465  |
| JOA at FFU                | 16.3±1.0   | .140  | 12.0±6.6 | 10.3±2.1   | .085  |
| RR JOA(%)                 | 87.4±18.2  | .230  | 15.7±1.0 | 16.0±1.4   | .625  |

ACDF = anterior cervical disectomy and fusion, CL = C2-C7 cervical lordosis, FFU = final follow-up after operation, HS = hybrid surgery, JOA = Japanese Orthopedic Association score, NDI = neck disability index, PreOP = pre-operation, RR = recovery rate, SVA = C2-C7 sagittal vertical axis, T1S = T1 slope, T1SCL = T1S minus CL.

3.2. Correlation between cervical balance and clinical outcomes

Integrating data of HS and ACDF groups, analysis on balance status and clinical outcomes were shown in Table 6. Patients in subgroup U at PreOP belonging to subgroup UB compared with subgroup UU showed no differences in NDI or JOA scores and their changes (all P>.05), the same with the comparisons between subgroups BB and BU. There was also no significance in patients with cervical balance at FFU (subgroup UB+subgroup BB) compared with imbalanced cervical at FFU (subgroup UU+subgroup BU). Furthermore, the correlation analysis between the change of T1SCL and clinical outcomes showed no relationship between the change of T1SCL at FFU and NDI at FFU, change of NDI at FFU, JOA scores at FFU, and RR of JOA scores at FFU (all P>.05) (Table 7).

4. Discussion

It was reported that the maintenance and improvements of cervical sagittal balance might have an effect on clinical efficacy[14,15]. Which, however, was not a consensus in various procedures. The concept of cervical balance was evaluated by many factors. In most publications, cervical imbalance was defined as T1S > 40° or SVA > 40 mm[16]. Recently, T1SCL was considered a landmark for evaluating cervical balance with a threshold of 20°.

Protopsaltis et al[17] considered the balance between T1SCL mirrors the relationship between PI minus LL of ±9°. Hyun et al[5] found T1SCL mismatch might be associated with a greater degree of cervical spine malalignment and disability. Several studies have addressed changes in cervical alignment, focusing on sagittal balance before and after cervical surgeries[14,15]. This study first performed an analysis on cervical spine balance after consecutive 3-level ACDF or HS, concluding an identified imbalance correction (P=.688) between the 2 procedures was comparable.
improvement on cervical balance maintaining or correction with both approaches.

In the study of spino-pelvic parameters, Maciejczak et al[20] have defined balanced pelvis and unbalanced pelvis, they proposed that disturbances in pelvic balance may affect the quality of life. But they addressed radiological improvement of pelvic balance did not correlate with clinical outcomes,[8] similar to what we found. For patients with cervical imbalance, when a cervical spine had a higher T1S and worse alignment, it becomes bent over horizontally under a kyphotic force.[21] Therefore, the aim for imbalanced cases was to correct thoracic inlet and restore CL. In this study, HS or ACDF has corrected CL but not for T1S and T1SCL, which might be due to that most T1S at PreOP was in normal range (75.3%). Therefore, the study first proved that most patients who underwent such procedures were actually in cervical balance.

The difference in number of cervical-balanced patients between HS and ACDF group might be due to different surgical indication of HS and ACDF. HS was inclined to be selected for cervical-balanced cases, less degenerated adjacent segment disc and younger cohort[27] but the age has no significance in our study. Multilevel surgery, with a unique superiority on reconstruction compared with single-level surgery, allows more direction decomposition and adequate correction of the entity causing pressure.[22] Significantly and comparably, the cervical-balance reconstruction improved after both procedures, which was due to the less incision and protection of posterior muscle-ligament complex. Sakai et al[23] found postoperative cervical alignment and balance were maintained after ACDF but deteriorated following laminoplasty by a review on prospective cohort studies.[24,25] In addition, cervical alignment was reconstructed by anterior tissue release, preparation of endplate bed, the shapes and sizes of implants.[21]

There were no intersubgroup differences on cervical alignment parameters between HS and ACDF. It was the similar approach and anatomy structure of the 2 procedures that mattered. Although the dynamic implant in HS group, preservation of ROM, and different biomechanics of 1 or 2 levels compared with ACDF seemed to put not much impact on cervical alignment, which suggested that the key role was technique itself (such as adequate tissue release and osteophyte removal) rather than the types of implants.[23,24] The indifferent comparisons indicated that 3-level HS or ACDF achieved comparable efficacy on balance-maintaining and reconstruction.

The comparable clinical outcomes proved an identified efficacy for CSM patients who went through HS or ACDF. On earth, the goal of surgical procedures was to decompress the spinal cord and improve neurological function.[27] The reasons for slightly significant and comparably, the cervical-balance improvement on cervical balance maintaining or correction with both approaches.

### Table 5
Migration of patients to balanced and unbalanced cervical subgroups after HS and ACDF.

|                  | Balance subgroup at FFU | Imbalance subgroup at FFU |
|------------------|-------------------------|--------------------------|
| **HS group**     |                         |                          |
| Balance subgroup at PreOP |             |                          |
| 35 subgroup B    | 33 subgroup BB*         | 2 subgroup BU*           |
| 6 subgroup U     | 5 subgroup UB*          | 1 subgroup UU*           |
| Total            | 41 B+U                  | 3 BB+UB                  |
| **ACDF group**   |                         |                          |
| Balance subgroup at PreOP |             |                          |
| 20 subgroup B    | 16 subgroup BB          | 4 subgroup BU            |
| 12 subgroup U    | 9 subgroup UB           | 3 subgroup UU            |
| Total            | 32 B+U                  | 7 BB+UB                  |

ACDF = anterior cervical disectomy and fusion, B = balance, FFU = final follow-up after operation, HS = hybrid surgery, PreOP = preoperation, U = unbalance.

* BB means patients in cervical balance at PreOP and also in cervical balance at FFU; BU means patients in cervical balance at PreOP but in cervical imbalance at FFU; UB means patients in cervical imbalance at PreOP but in cervical balance at FFU; UU means patients in cervical imbalance at PreOP and still in cervical imbalance at FFU.

### Table 6
Clinical outcomes between balance and imbalance subgroups at FFU.

|                  | Balance at PreOP | Imbalance at PreOP | Balance/Imbalance at PreOP |
|------------------|------------------|--------------------|---------------------------|
|                  | Balance at FFU   | Imbalance at FFU   | Balance at FFU            |
| NDI at FFU       | 12.3 ± 6.5       | 9.5 ± 3.9          | 10.9 ± 6.2                |
| ΔNDI*            | 27.3 ± 6.5       | 26.3 ± 3.8         | 28.3 ± 7.0                |
| JOA at FFU       | 15.7 ± 1.3       | 16.5 ± 1.0         | 16.0 ± 1.6                |
| RR JOA (%)       | 79.7 ± 18.7      | 90.0 ± 20.0        | 84.1 ± 25.6               |

* ΔNDI is the change of NDI at FFU compared with PreOP; RR JOA is the recovery rate of JOA at FFU compared with PreO.

### Table 7
Correlation analysis between the change of T1SCL and clinical outcomes.

|                  | r               | P    |
|------------------|-----------------|------|
| ∆T1SCL and NDI at FFU | 0.071           | .571 |
| ∆T1SCL and ∆NDI* | −0.049          | .699 |
| ∆T1SCL and JOA at FFU | −0.064          | .611 |
| ∆T1SCL and RR JOA* | −0.077          | .540 |

FFU = final follow-up after operation, JOA = Japanese Orthopedic Association score, NDI = neck disability index, PreOP = preoperation, RR = recovery rate.

* ∆NDI is the change of NDI at FFU; ∆T1SCL is the change of T1SCL at FFU; ∆T1SCL and RR JOA* is the recovery rate of JOA at FFU.
regardless of balance or imbalance at PreOP. It was possible that 
decompression and stabilization, rather than balance status, were 
sufficient to obtain improvement in most sections.[8,9] Although the 
significance of disorders on spino-pelvic alignment in global sagittal 
imbalance of the whole body,[1,2] the cervical alignments seemed 
probable not as important as lumbar spino-pelvic parameters. The 
adequate decompression spared compensated space for the spinal 
cord recruitment even if the volume of spinal canal could be affected by alignment.[14,31] Finally, the global spine and lower extremities balance might be a result of 
compensatory mechanisms aiming at adapting body posture in 
response to regional cervical-imbalance.[32,33]

There were some limitations of this study. First, the sample of 
both groups was little and thus there might be some reporting 
bia. A larger population could support strength verification with 
a cohort study. In addition, there was no subgroup analysis on 
whether rigid-plating was used in ACDF, although anterior rigid-
plating may have an impact on cervical balance. Finally, the 
conclusion was only suitable for the patients with CSM who 
underwent 3-level HS or ACDF; it is not suitable for other 
cervical diseases or procedures.

5. Conclusions

Based on this retrospective study (evidence level III), there were 
identified improvements on cervical balance maintaining or 
imbalance-correction after both HS and ACDF, and the balance 
status was comparable between the 2 groups. There was no 
significance in cervical alignment and clinical outcomes between the 2 
procedures either at PreOP or at FFU. Most patients were in cervical 
sagittal balance and few balance status of CSM cases needed to be 
paid extra attention to. No correlation between the cervical balance 
and clinical outcomes, no matter what the cervical-
sagittal balance and few balance status of CSM cases needed to be 
procedures either at PreOP or at FFU. Most patients were in cervical 
sagittal balance and few balance status of CSM cases needed to be 

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