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# Clinical and surgical results related to anterior-only multilevel cervical decompression and instrumented fusion for degenerative disease

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ABSTRACT

*Introduction:* Anterior-only multilevel cervical decompression and fusion surgery (AMCS) on 3-5-levels is challenging due to potential complications. Also, outcome predictors after AMCS are poorly understood.
*Research Question:* We hypothesize that in patients with at most mild/moderate cervical kyphosis (CK) of the cervical spine, restoration of cervical lordosis (CL) positively influences clinical outcomes.
*Methods:* Analysis of consecutive patients presenting with symptomatic degenerative cervical disease or non-union undergoing AMCS. We measured CL from C2 to C7, Cobb angle of fused levels (fusion angle, FA), C7-Slope, and sagittal vertical axis C2-7 (cSVA, stratified into ≤4cm\>4cm). Patients with excellent outcome were grouped in BEST-outcomes and with moderate/poor outcomes in WORST-outcomes.
*Results:* We included 244 patients. Fifty-four percent had 3-, 39% 4-level and 7% had 5-level fusion. At mean follow-up of 26 months, 41% of patients achieved BEST-outcome and 23% WORST-outcome. Complications and reoperation rates did not significantly differ. Non-union significantly influenced outcomes. The number of patients with non-union was significantly higher in patients with a preoperative cSVA>4cm (OR 13.1 (95%CI:1.8-96.8). Our model, based on the multivariable analysis with WORST-outcome as outcome variable showed a high accuracy (NPV=73%, PPV=77%, specificity=79%, sensitivity=71%).
*Discussion and Conclusion:* In 3-5-level AMCS, improvement of FA and cSVA were independent predictors of clinical outcome. Improvement of CL positively influenced clinical outcomes and rates of non-union.

## 1. Introduction

In degenerative cervical disease satisfactory outcomes can be achieved using anterior-only multilevel cervical fusion surgery (AMCS) (Burkhardt et al., 2019; De la Garza-Ramos et al., 2016; Traynelis, 2010). Several studies report favorable influence of anterior compared to posterior-only decompression on neurological outcome in patients with cervical spondylotic myelopathy (CSM) (Ames et al., 2013; Liu et al., 2011). Nevertheless, AMCS is associated with risk of non-union (Fountas et al., 2007; Fraser and Härtl, 2007), implant loosening and difficulties realigning the spine in patients with cervical kyphosis (CK) of the whole cervical spine (Fountas et al., 2007; Fraser and Härtl, 2007), especially if corpectomy is needed (Koller et al., 2009; Liu et al., 2012). Surgical destabilization can warrant additional posterior instrumentation to prevent construct failure (Koller et al., 2015; Steinmetz et al., 2002).

Correction of CK and sagittal imbalance in anterior displaced cervical sagittal vertical axis C2-7 (cSVA) has previously been associated with improved biomechanics, health-related quality of life (HRQOL) metrics and neurological outcomes in patients with moderate to severe cervical deformity (Ames et al., 2013; Patwardhan et al., 2015; Shamji et al., 2016). However, data regarding the outcomes after AMCS in patients undergoing 3-level, 4-level or 5-level instrumentation is sparse (Lau et al., 2020). Influence of radiographic parameters on outcome after AMCS for patients with degenerative disease and mild to moderate

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deformity or patients with previously failed surgery is still unclear (Lau et al., 2020).

We aimed to identify patients who benefit from AMCS by a detailed analysis of radiographic, surgical and outcome data, in patients undergoing 3-5-level AMCS. We hypothesize that analyzing factors influencing clinical outcome dichotomized into BEST- and WORST-outcome can identify influence of cervical alignment.

## 2. Material and methods

We retrospectively analyzed a consecutive series of adult patients with mild to moderate cervical kyphosis undergoing plated AMCS of 3-5-levels using intervertebral cages in a single-center between 2010 and 2016. We recorded patient demographics (including body mass index [BMI]), evidence of thoracolumbar (TL) fusion, history of chronic lumbar pain syndrome, previous cervical anterior surgery with or without non-union indicating reoperation. Minimum follow-up was six months. We included patients aged 18–80 years undergoing surgery for degenerative cervical disease with stenosis and symptomatic cervical myelopathy (CSM) and/or severe axial neck pain (visual analogue scale, VAS >6) due to degenerative changes such as disc degeneration and spondylosis and/or non-union. We excluded patients with missing data in the following variables: clinical course, complications and outcomes. We also excluded patients with cervical scoliosis >10°, trauma, neoplastic or neuromuscular disease, multilevel thoracolumbar fusion between index surgery and follow-up, history of spinal infection, multilevel corpectomies or additional posterior surgery. Patients with a severe and rigid kyphosis were all operated by a 360° approach or posterior-only approach using a 3-column osteotomy. These patients were therefore excluded from this study as no ACMS was used.

## 3. Surgical techniques

Patients were operated using a right-sided anterior retropharyngeal approach unless left recurrent laryngeal nerve (RLN) injury was present. Anterior decompression included removal of posterior longitudinal ligament (PLL) and enclosed fusion material in case of revision surgery. Decompression is shown in Fig. 1. Decompression was performed on all levels affected by degeneration, not only symptomatic ones. Anterior-only reconstruction was achieved with segmental titanium cages or a hybrid construct with 1-level corpectomy. For interbody segmental reconstruction we used three types of titanium cages: Harms-cages (HMC), trabecular mesh cages (TMC), and titanium-coated Peek mesh-cages (TCP). In the early period of the study, iliac crest graft (ICG) was harvested. Later, we used tricalciumphosphate and local bone graft to fill cages. Corpectomies were reconstructed using lordotic TMC. A titanium locking cervical plate was used in all patients (Skyline, DepuySynthes, Rayham/USA). Fusions was stopped at the C7 level if no sign of degeneration was present at the C7/T1 level.

## 4. Radiographic assessment

Patients underwent preoperative, postoperative and at final follow-up standing cervical radiographs (in upright and standing position). Upper and lower instrumented vertebra (UIV and LIV) was recorded. We studied CL on serial radiographs according to the Harrison method, Cobb angle of fused levels (fusion angle [FA]), C7-Slope (C7S) as well as cSVA (Fig. 1) (Harrison et al., 2000). C7S was the angle between the upper endplate of the C7 vertebra and the horizontal accessory line. Patients were stratified into cSVA>4 cm or cSVA≤4 cm. Using the Harrison tangent method, we measured the angle of the next-adjacent segment to the fused levels cephalad (UIV-angle) and caudal (LIV-angle). Positive values in CL, UIV-angle and LIV-angle measurement indicate kyphotic and negative values lordotic angle. Cervical fusion was assessed routinely on radiographs and only on CT if in doubt.

## 5. Clinical outcome

Clinical outcomes at latest follow-up were defined according to Odom's criteria and stratified into excellent, good, satisfactory and poor. They show substantial interrater reliability, almost perfect test-retest reliability (Broekema AEH et al., 2019) and strong correlations with disease-specific and generic health-related quality of life (HRQOL) metrics (Koller et al., 2009). Patients with excellent outcome were grouped in BEST- and with either satisfactory or poor outcomes in WORST-outcomes.

## 6. Surgical results, complications and reoperation

Major complications were recorded according to Glassmann (Glassman et al., 2005). A descriptive analysis of all complications as well as indications and techniques used for revision surgery was conducted.

Patients with revision surgery and those refusing one (n = 4), were stratified in +REV-group and compared to the –REV-group. In patients with revision surgery for construct related issues and non-union, the last radiographic and clinical follow-up before the revision surgery was defined as final follow-up.

**Fig. 1.** Surgical technique of 4-level anterior fusion and circumferential decompression by anterior approach. A) 54-year-old patient with cervical spondylotic myelopathy and both anterior and posterior spinal cord compression B) by ligamentum flavum hypertrophy and loss of height C5-6. C) Decompression of circumferential stenosis by anterior spurring and posterior intrusion of non-ossified flavum ligament achieved by combined anterior direct decompression and posterior indirect decompression via restoration of intersegmental height. D) Uneventful clinical course, satisfied patient at 12 months postoperative.

## 7. Statistical analysis

Data was checked for consistency and normality. We used Fisher's Exact test, Kruskal-Wallis-Test for singly ordered crosstabs and Wilcoxon-Mann-Whitney test for cross tabulations based on Monte Carlo methods. ANOVAs and Kruskal-Wallis ANOVAs were used for continuous variables and LSD-tests were used for pairwise comparisons.

A multivariable logistic regression analysis was conducted to evaluate independent radiographic predictors of WORST-outcomes. Negative and positive predictive power, sensitivity, specificity and total corrected cases were computed and normalized to patients with a prediction. All reported tests were two-sided, and a p-value of $< .05$ was considered statistically significant.

## Ethical approval

This study was conducted according to the World Medical Association Declaration of Helsinki. The institutional review board approved this retrospective study. As this was a retrospective analysis and none of the included data harbors the possibility of being tracked back to a specific patient, the review board deemed our study exempt for retrospective informed consent for the included patients.

## 8. Data availability agreement

Our data will be shared with other authors upon reasonable request.

## 9. Results

### 9.1. Sample characteristics

We included 244 patients, mean age was 55 years, mean number of fused levels was 3.5. Follow-up information including clinical and radiographic outcomes was available in all patients. Digital pre- and postoperative radiographs in order to evaluate imaging variables were available in a subgroup of 126 patients. Mean clinical follow-up was 26 months and did not differ between 3-5-level AMCS. Baseline characteristics are summarized in Table 1. Distribution of UIV and LIV is illustrated in Fig. 2.

**Table 1**
Characteristics, demographics, surgical variables and techniques in 244 patients with anterior cervical fusion.

| Variable | Results |
|---|---|
| Patient age (yrs) | 55.2 ± 10.1 (Range 18–79) |
| Radiographic follow-up (mt) | 25.6 ± 18.5 |
| Clinical follow-up (mt) | 26 ± 22.2 |
| BMI* | 36.9 ± 13.4 |
| | **N (%)** |
| Female sex | 144 (59) |
| Any TL-fusion | 71 (29.1) |
| TL-fusion >3 levels | 31 (12.7) |
| TL fusion ≤3 levels | 40 (16.4) |
| History of prior surgery | 93 (38.1) |
| Chronic Lumbar Pain | 95 (38.9) |
| Tobacco use | 42 (17.2) |
| 3-level fusion | 131 (53.7) |
| 4-level fusion | 96 (39.3) |
| 5-level fusion | 17 (7) |
| Corpectomy | 31 (12.7) |
| Non-union repair | 68 (27.9) |
| Use of ICG | 202 (82.8) |
| Intervertebral cages: | |
| TMC | 22 (9) |
| TCP | 20 (8.2) |
| HMC | 202 (82.8) |

Legend: BMI = body mass index; ICG = iliac crest graft; HMC = Harms mesh cage, mt = months; TCP = titanium coated Peek-cage; TL = thoracolumbar fusion; TMC = trabecular mesh cage; * = valids n = 70.

### 9.2. Comparing 3-, 4-, and 5-level fusion

The number of fusion levels increased with age (Fig. 3) and the number of patients with TL-fusion >3 levels was significantly different ($p = .02$) between 3- (8%), 4- (17%) and 5-level fusion (24%). The number of patients additionally receiving 1-level corpectomy significantly differed between 3- (10%), 4- (13%) and 5-level (35%) fusion. Clinical examples are summarized in Figure E1.

### 9.3. Radiographic results

Radiographic results are summarized in Table 2. Mean FA was corrected from pre- 7° to postoperative 15° ($p < .001$). cSVA>4 cm occurred in 5% of patients preoperatively, 12% postoperatively and 11% at follow-up. The continuum of cSVA in patients exhibiting similar postoperative CL but different cSVA is highlighted in Fig. 4. Fusion rate after index surgery was 95%. CT-scan to assess fusion was done in 22%. Thirteen patients had non-union following AMCS with 10 undergoing revision surgery and fusion and 3 refusing.

Changes of UIV- and LIV-angle show weak correlation with FA-change ($r \leq 0.2$, $p < .001$). However, the main predictor of postoperative UIV- and LIV-alignment was preoperative UIV- and LIV-alignment ($r = 0.04$, $p < .001$).

### 9.4. Clinical outcomes

Forty-one percent of patients reported BEST- and 23% WORST-outcomes (Table 3). In the univariable analysis (Table E1), absence of non-union repair at index surgery, absence of revision surgery, non-smoking status, and postoperative cSVA≤4 cm was significantly associated with achieving BEST-outcomes.

Results of correlation analysis for radiographic and outcome variables (Table E2**)** showed that BEST-outcomes had better postoperative alignment in terms of postoperative cSVA as well as greater improvement of FA and CL compared to other patients.

The multivariable model predicting WORST-outcome included following radiographic variables: pre-to postoperative correction of FA and change of cSVA. It showed high accuracy (NPV = 73%, PPV = 77%, specificity = 79%, sensitivity = 71%, total correct predicted results in 75%). Both, change of FA and cSVA were independent predictors of clinical outcome.

### 9.5. Surgical results, complications and reoperations

Sixteen percent had a complication and 7% needed revision surgery (Table 3). There was no difference regarding complication, fusion rate nor clinical outcome in patients with LIV at T1 or LIV cephalad to T1.

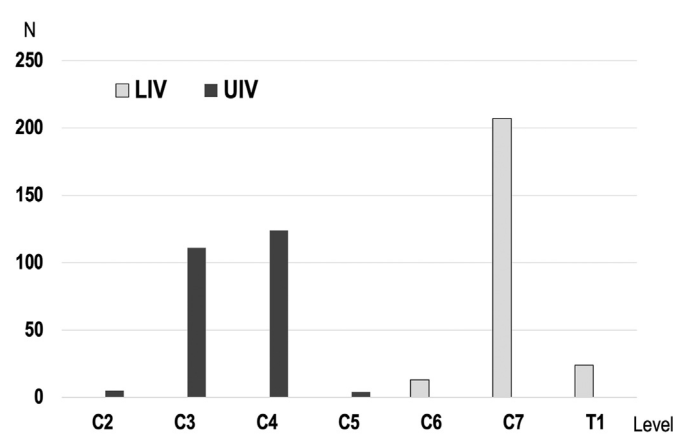


**Fig. 2.** Distribution of UIV and LIV. UIV = Upper instrumented vertebra, LIV = Lowest instrumented vertebra.

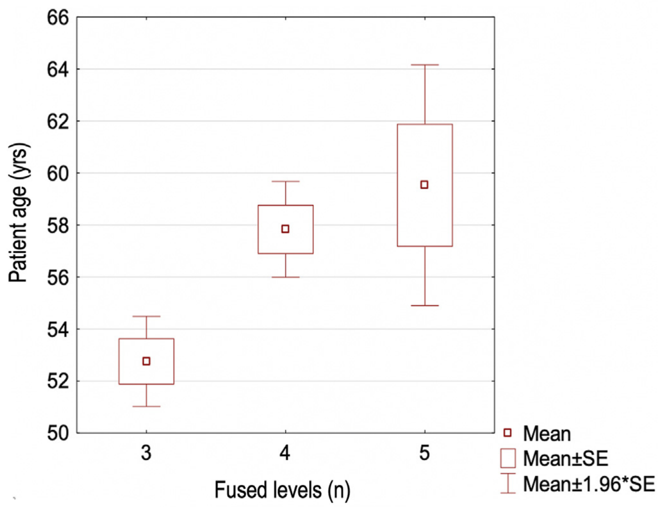


**Fig. 3.** Patient age distribution among 3-, 4- and 5-level anterior cervical fusions. SE = standard error.

Non-union occurred more frequently in patients with preoperative cSVA>4 cm compared cSVA≤4 cm (40% vs. 3%, p = .002; OR13.1; 1.8–96.8 95%CI, Table E1). Patients with non-union had a higher postoperative C7S (34° vs. 28°, p = .04) and CL (27° vs. 21°, p = .04) but a larger mismatch between C7 slope and CL as indicated by a larger postoperative anterior translation in the non-union group (cSVA: 27.6 mm vs. 23 mm, p > .05) indicating cervical imbalance although this difference was not statistically significant.

Five patients reported chronic dysphagia at follow-up including two 3-level and 4-level AMCS each and one patient with a 5-level AMCS. No patient required invasive treatment. The most common complications were non-union, symptomatic adjacent segment disease and dysphagia. Three patients developed postoperative C5 palsy, of whom all improved on follow-up.

## 10. Discussion

We created a prediction model for WORST-outcomes and established risk factors for cervical non-union. This study represents one of the largest samples of AMCS for 3-5-level with analysis of radiographic and clinical outcomes including complications.

### *10.1. Clinical outcome and cervical alignment*

De la Garza-Ramos et al. (De la Garza-Ramos et al., 2016) reported on 3-level and 4-level ACDF. Outcomes according to Odom's criteria was fair or poor in 42% and 31%, respectively. In other series surgical success was achieved in 81% and 87% (Burkhardt et al., 2019; Traynelis, 2010). In our cohort, 41% had excellent clinical outcome in the BEST-outcome group, 36% good, 7% moderate and 16% poor outcome meaning 77% of patients reported good or excellent outcome at 26 months. Mean change of FA was substantial but average cSVA change only mild (20 mm pre-vs. 22 mm postoperative). While some kyphotic patients achieved decent correction, others might only have improved clinically due to the decompression, fusion and correction of some loss of CL due to the degenerative processes. Lau et al. (2020) reported overall good outcomes in ACDF for degenerative disease with no to mild sagittal deformity although they did not stratify outcome into BEST- and WORST-outcomes. The cSVA changed little from 24.9 mm to 24.8 mm and CL from 10° to 12°. 10% had 3-level fusions. Radiographic correction did not correlate with clinical outcome. The average preoperative CL, however, was higher than in our cohort. In contrast another study (Horn et al., 2019) reporting on patients with moderate to severe cervical deformity, showed a clear association between worse alignment (cSVA) and poor clinical outcome. Other studies had similar weak to moderate correlation between cervical alignment and outcome measures (Hyun et al., 2016; Roguski et al., 2014). We established a prediction model for AMCS patients to assess sagittal alignment parameters, such as FA and cSVA, and their influence on clinical outcome stratified into BEST- and WORST-outcome. While FA-change can be planned based on the surgeon's technique, cSVA-change is more difficult to predict. FA-changes induces cSVA-change and cSVA-worsening can occur by postoperative

**Table 2**
Main radiographic results in 3-, 4- and 5-level anterior only fusions.

| Variable (unit) | Preop | Postop | Final | ΔPreop vs. Postop | ΔPreop vs. Final | ΔPostop vs. Final |
|---|---|---|---|---|---|---|
| | ***Mean ± SE (95% CI)*** | ***Mean ± SE (95% CI)*** | ***Mean ± SE (95% CI)*** | *P* | *P* | *P* |
| CL (°) | 13.2 ± 1.0 (11.1–15.2) | 21.5 ± 0.7 (20.0–23.9) | 20.6 ± .0.8 (18.9–22.3) | <.001 | <.001 | ns |
| cSVA (mm) | 19.7 ± 1.2 (17.3–22.1) | 23.8 ± 1.2 (21.-26.4) | 21.8 ± 1.4 (19.0–24.5) | .006 | ns | ns |
| C7S (°) | 24.4 ± 0.9 (22.7–26.1) | 28.3 ± 0.8 (26.8–29.8) | 28.0 ± 0.8 (26.4–29.6) | <.001 | <.001 | ns |
| Fusion-angle (°) | 7.2 ± 0.7 (5.7–8.6) | 15.0 ± 0.6 (13.7–16.2) | 13.3 ± 0.6 (12.0–14.5) | <.001 | <.001 | 0.01 |
| UIV-angle (°) | 3.6 ± 0.5 (2.6–4.7) | 2.7 ± 0.4 (1.9–3.4) | 3.1 ± 0.4 (2.3–3.9) | ns | ns | ns |
| LIV-angle (°) | 4.0 ± 0.3 (3.4–4.7) | 3.3 ± 0.2 (2.8–3.8) | 3.6 ± 0.3 (3.0–4.1) | ns | ns | ns |

Legend: CL = Cervical lordosis according to Harrison tangent angle C2–C7; cSVA = sagittal vertical axis; C7S = C7-slope; LIV = lowest instrumented vertebra; SE = Standard error of measurement; UIV = upper instrumented vertebra.

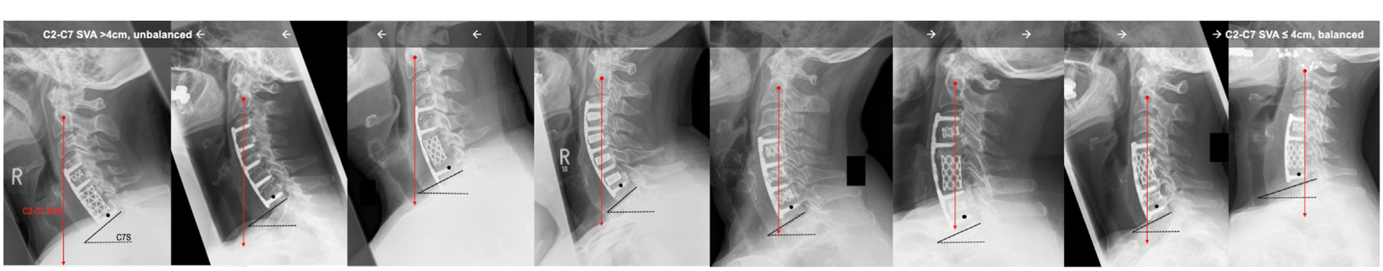


**Fig. 4.** Sagittal cervical balance in terms of sagittal translation and SVA. The images show various states of sagittal cervical balance and position of the SVA from a physiologically aligned spine with the SVA touching the C7 vertebra (right image) to an anterior imbalanced cervical spine with SVA >4 cm (left image). Notably, in the current study we measured the cSVA with the deviation of the C2-plumbline off the centre of the C7 vertebra. Comparing our results to prior studies using the cSVA with the posterior superior corner of C7 as landmark, one has to add about 1 cm to our results. In the authors' perspective, using the centre of C7, particularly postoperative, is a more reliable method to accurately define cSVA.

**Table 3**
Major complications, symptomatic adjacent segment disease and need for revision surgery in 244 patients with multilevel anterior cervical fusion.

| Variable | N (%) |
|---|---|
| **Patients with complications** | 39 (16) |
| **Total number of complications** | 42 |
| **Surgical** | **23 (9.4%)** |
| Non-union (Pseudoarthrosis)* | 13 (5.3) |
| Cervical haematoma | 4 (1.6) |
| C5-palsy with recovery | 3 (1.2) |
| CSF-leakage | 1 (0.4) |
| Severe postoperative delirium | 1 (0.4) |
| Celoid scarring | 1 (0.4) |
| Symptomatic screw loosening with retraction | 1 (0.4) |
| **ICG-harvesting** | **9 (3.6)** |
| Dysesthesia at ICG-site | 4 (1.6) |
| Haematoma at ICG-site | 2 (0.8) |
| Delayed wound-healing at ICG-site | 2 (0.8) |
| Stable fracture of iliac wing a ICG-site | 1 (0.4) |
| **Otolarnygeal** | **10 (4.1)** |
| Chronic dysphagia | 5 (2) |
| RLN palsy with persistent hoarseness | 2 (0.8) |
| RLN palsy with recovery | 3 (1.2) |
| **Patients with reoperation** | **18 (7.4)** |
| **Reoperations** | **19 (7.8)** |
| PSF and extension of fusion for non-union with/without sASD | 10 (4.1) |
| Ant/Post extension of fusion for ASD | 6 (2.5%) |
| Anterior haematoma evacuation | 4 (1.6) |
| Re-ACDFP (1x for non-union repair, 1x for ASD) | 2 (0.8) |
| Haematoma revision at ICG-site | 1 (0.4) |
| Repair of CSF-leak | 1 (0.4) |
| Early re-decompression C4-6 for severe C5-palsy | 1 (0.4) |
| Change of loosened anterior screw of C3 | 1 (0.4) |
| Early revision (<1 mt) | 8 (3.3) |
| Late revision (>1 mt) | 10 (4.1) |
| Revision recommended | 4 (1.6) |

Legend: CSF = cerebrospinal fluid; ICG = iliac crest graft; PSF = posterior instrumented spinal fusion; RLN = recurrent laryngeal nerve; sASD = symptomatic adjacent segment disease; * = including 4 patients with mild screw loosening.

reduction of a compensatory thoracic alignment increasing C7S (Patwardhan et al., 2018). Changes in C7S, however, were small in our cohort. Low FA-correction and related small cSVA-change were the main drivers of WORST-outcomes in our model.

### 10.2. Postoperative non-union

A previous study on plated 3-5-level AMCS and maximum of 1-level corpectomy reported fusion rates between 58% and 96% for 3-level, 46–87% for 4-level fusions and about 78% for 5-level fusions (Shen et al., 2010). Reoperation rate for non-union was reported in 7–18% (Guppy et al., 2015; Teton et al., 2020). Improved fusion rates in AMCS occurred in plated AMCS (Wang et al., 2001) and in non-smokers (Lu et al., 2013). In our series, non-union was relatively low at 5%, most likely due to the described surgical technique. Non-union more likely occurred in WORST-outcome patients (5.6% vs. 0.5%, $p = .09$). But it might also be influenced by alignment factors. The number of patients experiencing a non-union was significantly increased in patients if preoperative cSVA was>4 cm. Non-union patients had higher postoperative C7S and CL, but larger mismatch between C7S and CL indicated by a larger postoperative cSVA, indicating cervical imbalance. Findings imply that although CL was larger in the non-union-group, it did not cause better sagittal cervical balance. Patients with non-union displayed more anterior translation and shear stress on their fusion construct, a risk factor for non-union (Patwardhan et al., 2018).

### 10.3. Limitations of anterior multilevel cervical fusion

Our low rate of serious complications might be related to the selection of patients for AMCS. With modern techniques and adding posterior instrumentation to biomechanically challenging indications such as multilevel corpectomies, mechanical failure rates and non-union rates can be decreased. Compared to multilevel corpectomy procedures, the hybrid technique increases mechanical stability and facilitates reduction of CK.

## 11. Limitations

The study was a retrospective study resulting in the inadvertent biases that this design introduces including absent multidimensional evaluation measurements as outcome variable. Nevertheless, the strength of this study lies in its sample size with it being one of the largest single-center series on AMCS. Detailed analysis of radiographs and clinical outcomes enabled the creation of a useful prediction model and identification of risk factors for unfavorable outcomes.

## 12. Conclusion

Anterior plated 3-5-level cervical decompression and fusion can lead to good results with high fusion rates when using standardized techniques. Clinical outcome was better in patients with better alignment and fusion. Restoration of CL and balance improves clinical outcomes and can reduce non-union rates. In patients with maintained cervical balance, we recommend AMCS. In patients with advanced anterior translation (e.g., a cSVA>4–5 cm), a combined AP-approach might be superior to AMCS in order to increase correction, add construct stability and facilitating early fusion. These findings and our proposed model need to be validated in a separate, independent cohort.


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The authors did not receive any funding for this study.


## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bas.2023.101716.

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