Increased Height of Fused Segments Contributes to Early-Phase Strut Subsidence after Anterior Cervical Corpectomy with Fusion for Multilevel Ossification of the Posterior Longitudinal Ligament

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Abstract:

Introduction: Anterior decompression and fusion have shown favorable neurologic outcomes in patients with cervical myelopathy. However, implant migration sometimes occurs immediately after multilevel anterior cervical corpectomy with fusion (ACCF). Risk factors associated with early bone graft migration have not been precisely documented. The study aimed to investigate how frequently bone graft subsidence occurs after ACCF and to determine the factors affecting implant migration.

Methods: Forty-seven consecutive patients who underwent ACCF for ossification of the posterior longitudinal ligament at our hospital between 2007 and 2015 and were able to complete 1 year of follow-up were enrolled. Patients treated with hybrid fixation were excluded. Data on demographics and radiographic findings, namely, fused segment angle and fused segment height (FSH), were collected. Implant migration was defined as subsidence of >3 mm. The patients were divided into 2-segment (2F), 3-segment (3F), and ≥4-segment (4F) groups. Results were compared between the groups using one-way analysis of variance, the Mann-Whitney *U* test, and the chi-square test.

Results: Mean age was 61.6 years in the 2F group (n = 17), 62.1 years in the 3F group (n = 21), and 69 years in the 4F group (n = 9). There were no significant between-group differences in demographics or clinical characteristics. Implant subsidence occurred in 3 cases (17.6%) in the 2F group, 4 (19%) in the 3F group, and 3 (33.3%) in the 4F group. Revision surgery was required in 2 cases (1 patient each in the 3F and 4F groups). Logistic regression analysis showed a significant association of increased FSH and increased risk of postoperative implant subsidence.

Conclusions: A postoperative increase in FSH may affect graft stability and lead to early implant migration.

Keywords:

Anterior cervical corpectomy with fusion, ossification of posterior longitudinal ligament, implant failure, over-distraction, dislodgement, graft subsidence

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Introduction

Anterior cervical corpectomy with fusion (ACCF) is a crucial strategy for adequate decompression of cervical ossification of the posterior longitudinal ligament (OPLL). We have previously demonstrated that outcomes were more favorable after ACCF than after posterior procedures in patients who had severe OPLL with kyphotic alignment[1,2]. However, it has been reported that patients treated using the anterior cervical method have a relatively high rate of complications, including respiratory distress, dysphagia, and graft dislodgement. Higher intraoperative and perioperative complication rates and greater invasiveness have been demonstrated for ACCF compared with anterior cervical discectomy and fusion (ACDF)[3]. Notably, early reconstruction failure after ACCF often requires anterior revision surgery or additional posterior fixation, so some spine surgeons prefer to perform posterior surgery even in patients with severe

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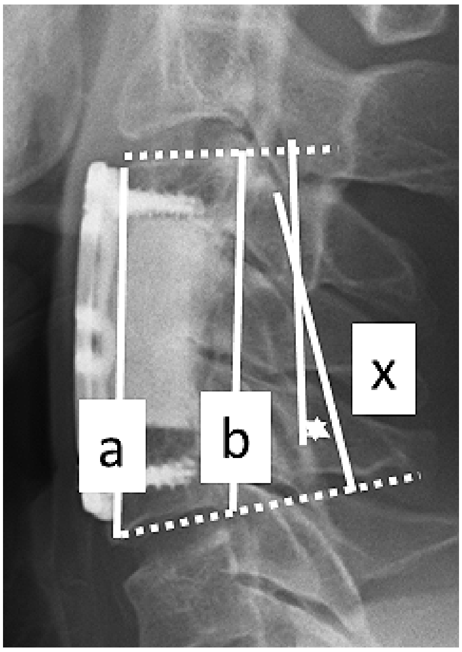

Figure 1. Postoperative radiograph showing the fused segment angle and fused segment height. Fused segment angle is the angle between lines drawn parallel to the cranial endplate of the cranial vertebra of the fused segment and the caudal endplate of the caudal vertebra of the fused segment (x). Fused segment height is the mean value of the anterior and posterior vertebral body heights at the fused segments ((a+b)/2).

OPLL or excessive kyphotic sagittal alignment. Therefore, it is important to recognize risk factors for implant migration in order to avoid the need for a second operation. This study aimed to review patients undergoing ACCF for multilevel OPLL and to investigate the clinical and radiographic parameters associated with implant migration.

Materials and Methods

Patients and methods

This single-center retrospective cohort study investigated the anterior procedure for the treatment of patients with OPLL. Patients with a history of previous cervical spine surgery or injury were excluded. The study was approved by our Institutional Ethics Committee.

Operative technique

Anterior decompression with fusion procedure consisted of corpectomy with a strut graft[4] that was performed by removing the disks and vertebral bodies. Operative segments were selected based on preoperative radiographic findings. The length of the bone graft was measured preoperatively on lateral cervical radiographs taken in a neutral position and again intraoperatively using X-calipers between the upper and lower endplates with the head in a neutral position. A strut graft from the iliac crest or artificial bone made from hydroxyapatite (Boneceram®; Olympus Corporation, Tokyo, Japan) was inserted for <2 levels of fixation, and fibula strut grafts were inserted for >3 levels. We inserted a semi-rigid plate in all cases. Essentially, variable screws were inserted for the proximal vertebrae and fixed screws for the distal vertebrae. Patients were instructed to wear a neck collar for 2-3 months after surgery until bony union was confirmed.

Evaluation

Clinical outcomes

All patients completed 1 year of follow-up at our hospital. The Japanese Orthopaedic Association (JOA) scoring system[5] was used to evaluate cervical myelopathy before and after surgery.

Radiographic evaluation

Cervical sagittal alignment (C2-7 lordotic angle) was measured by tangential lines drawn on the posterior edge of the C2 and C7 vertebral bodies on lateral radiographs taken in a neutral position. Preoperative center of gravity of the head-C7 sagittal vertical axis (C-SVA)[6] and T1 slope[7] were also measured. Fused segment angle (FSA) was defined as the angle between the lines drawn parallel to the cranial endplate of the cranial vertebrae of the fused segment and the caudal endplate of the caudal vertebrae of the fused segment. Fused segment height (FSH) was determined as the mean value of the anterior and posterior vertebral body heights at the fused segments (Fig. 1). Changes in FSA (ΔFSA) and FSH (ΔFSH) between before and immediately after surgery were also calculated[8]. Subsidence of >3 mm was defined as implant migration.

Forty-seven consecutive patients were divided according to the number of fused segments into 2-segment (2F), 3-segment (3F), and ≥4-segment (4F) groups. The patients were also divided into groups according to whether implant migration occurred postoperatively.

Statistical analysis

Between-group differences were assessed by one-way analysis of variance, the Mann-Whitney *U* test, or the chi-square test. Risk factor analysis was performed using multivariate logistic regression with a forward stepwise procedure to identify the most crucial risk factors for postoperative implant migration ($p < 0.1$ for entry) The dependent variable was occurrence of implant migration and the independent variables were age, sex, and the radiographic parameters. All statistical analyses were performed using SPSS for Windows (version 20.0; IBM Corp., Armonk, NY). A *p*-value < 0.05 was considered statistically significant.

Table 1. Demographic and Clinical Characteristics of Patients Treated with ACCF.

	2F group (n=17)	3F group (n=21)	4F group (n=9)
Age (years)	61.8±11.6	62.1±8.0	63.0±10.2
Male:female	11:6	16:5	8:1
Preoperative JOA score	11.0±2.7	11.1±3.8	11.3±3.8
Postoperative JOA score	14.6±2.3	15.1±1.7	14.1±1.2
Implant migration, n (%)	3 (17.6)	4 (19)	3 (33.3)
Revision surgery, n (%)	-	1 (4.8)	1 (11.1)

Data are shown as the mean±standard deviation or as the number and percentage as appropriate. ACCF, anterior cervical corpectomy with fusion; JOA, Japanese Orthopaedic Association

Table 2. Changes in Radiographic Parameters in the Three Groups.

	2F group (n=17)	3F group (n=21)	4F group (n=9)
C2-7 lordotic angle			
Preoperatively	13.3±8.6	10.1±11.7	12.3±10.0
Immediately after surgery	12.4±8.0	12.4±10.8	13.0±7.8
3 months	13.9±8.9	12.4±10.8	10.5±5.4
6 months	14.4±8.9	11.5±11.2	10.5±5.4
1 year	13.5±9.4	11.9±9.7	10.2±8.3
C-SVA			
Preoperatively	25.1±18.0	24.4±14.6	22.6±15.7
Immediately after surgery	29.4±15.2	28.5±15.8	26.3±17.7
3 months	24.3±15.2	27.3±20.0	16.2±6.6
6 months	19.7±13.1	25.5±18.0	20.6±6.7
1 year	20.2±13.0	23.6±17.4	19.9±9.2
T1 slope			
Preoperatively	26.8±7.4	21.0±6.6	22.3±5.2
Immediately after surgery	28.2±8.2	23.1±8.7	23.7±5.8
3 months	28.5±8.7	22.8±8.0	21.3±5.7
6 months	27.1±5.4	22.7±7.3	22.4±5.1
1 year	26.6±6.4	22.1±6.9	21.7±5.8
FSA			
Preoperatively	1.9±7.0	1.4±12.6	7.9±7.4
Immediately after surgery	3.4±7.3	4.6±10.8	8.7±7.1
3 months	3.2±7.8	3.9±9.8	6.3±7.1
6 months	3.4±7.1	4.6±10.3	5.5±6.8
1 year	2.2±6.8	4.5±10.3	4.7±6.3
FSH			
Preoperatively	53.7±5.3	68.0±9.3	93.0±6.9
Immediately after surgery	53.5±4.9	71.7±10.2	94.1±13.4
3 months	52.7±5.1	68.5±8.0	90.3±10.1
6 months	52.7±4.0	67.7±7.5	86.9±6.4
1 year	52.6±5.2	67.8±7.7	86.9±10.2
Fusion rate, n (%)	17 (100)	17 (81.0)	6 (66.7)

Data are shown as the mean±standard deviation. C-SVA, cervical sagittal vertical axis; FSA, fused segment angle; FSH, fused segment height

Results

Demographics and clinical outcomes

Patients (35 men, 12 women; follow-up rate, 100%) were tracked for at least 1 year (Table 1). There were 17 patients in the 2F group, 21 in the 3F group, and 9 in the 4F group; mean preoperative/postoperative JOA scores were 11.0/14.6 points, 11.1/15.1 points, and 11.3/14.1 points, respectively. The rate of implant subsidence by >3 mm was 17.6% (3 cases) in the 2F group, 19% (4 cases) in the 3F group, and 33.3% (3 cases) in the 4F group. Of these 11 cases, 2 had deteriorating neurologic status. Therefore, revision surgery for implant failure was performed in 1 case (4.8%) in the 3F group and 1 (11.1%) in the 4F group. No patient in the 2F group underwent a second operation. Of the remaining 9 patients in whom graft subsidence occurred, 7 had pseudoarthrosis in the distal end of the bone graft with no pain or neurologic dysfunction. All the patients declined secondary surgery because there was no deterioration.

Radiographic outcomes

Radiographic parameters are shown in Table 2. Mean C2-7 angle was preserved in the 2F and 3F groups but had decreased in the 4F group by 3 months postoperatively. C-SVA was increased immediately after surgery but had decreased by 6 months postoperatively in all groups. T1 slope remained unchanged during the follow-up period. Mean FSA was increased immediately after surgery in all 3 groups. Lordotic change was maintained in the 2F and 3F groups but there was a gradual decrease in FSA, with loss of 4 degrees at 1 year postoperatively in the 4F group. Mean FSH was unchanged postoperatively in the 2F and 3F groups. However, there was a 3 mm decrease in FSH in the 4F group at 1 year postoperatively. Fusion rate was 100% for the 2F group, 81% for the 3F group, and 66.7% for the 4F group.

Comparison between patients with and without implant subsidence

Radiographic parameters immediately after surgery were compared between patients with implant migration (the M+ group) and those without implant migration (the M− group) to identify factors associated with implant dislodgment. There were no significant between-group differences in demographic data or preoperative radiographic parameters, including C2-7 angle, C-SVA, T1 slope, FSA, and FSH (Table 3). However, mean ΔFSH was significantly greater in the M+ group than in the M− group. Similarly, mean ΔFSA tended to be greater in the M+ group than in the M− group; however, the trend did not reach statistical significance (Table 4). The preoperative and immediate postoperative values for each of the radiographic parameters were compared to determine whether any were associated with dislodgement of the implant. As seen in Fig. 2, the greater the postoperative increase in FSH, the greater the likelihood of implant failure after surgery.

Table 3. Comparison between Patients with and without Implant Migration.

	M+ group (n=10)	M− group (n=37)	*p*-value
Age (years)	58.3±13.2	64.1±8.6	0.15
Male:female	7:3	28:9	0.85
Preoperative JOA score	10.9±4.1	11.2±2.5	0.79
Postoperative JOA score	14.6±1.9	14.8±1.9	0.77
No. of fusion segments	3.1±1.5	2.9±1.6	0.74
Preoperative C2-7 angle	10.8±9.0	11.9±10.6	0.76
Preoperative C-SVA	24.2±16.5	24.4±15.8	0.97
Preoperative T1 slope	24.0±6.7	23.2±7.2	0.77
FSA (°)	3.9±8.5	2.3±10.6	0.67
FSH (mm)	71.6±17.3	65.8±15.1	0.30
ΔC2-7 angle	3.8±8.5	0±7.1	0.08
ΔFSA (°)	5.1±7.3	3.7±8.5	0.13
ΔFSH (mm)	6.1±9.9*	0.6±4.6	0.02

C-SVA, cervical sagittal vertical axis; FSA, fused segment angle; FSH fused segment height; M+, implant migration; M−, no implant migration; JOA, Japanese Orthopaedic Association. *$p<0.05$, M+ group vs. M− group, Mann-Whitney *U* test

Table 4. Analysis of Factors Influencing the Risk of Graft Dislodgement.

Factor	Standardized β	t	*p*-value	Exp (B)	95% CI
ΔFSH	0.132	0.065	0.043	1.141	1.00-1.296

ΔFSH, FSH immediately after anterior cervical discectomy and fusion-preoperative FSH. CI, confidence interval; FSH, fused segment height

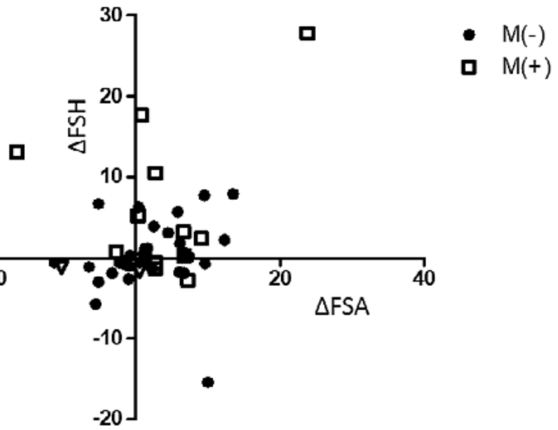

Figure 2. Plot showing changes in FSA and FSH (ΔFSA and ΔFSH). A large ΔFSH is more closely associated with implant migration than ΔFSA. M+, implant migration; M−, no implant migration.

Analysis of factors potentially affecting the risk of implant subsidence

Univariate logistic regression showed that both ΔFSA and ΔFSH were likely associated with postoperative implant subsidence. However, in forward stepwise logistic regression, only ΔFSH (odds ratio 1.141, 95% confidence interval 1.004-1.29; $p = 0.04$) was a crucial risk factor for postoperative implant subsidence.

Case presentation

A 66-year-old man underwent ACCF at C2-6 for cervical OPLL (Fig. 3A). Plate fixation was extended to C7 because of ankylosis from C6 to the middle of the thoracic spine (Fig. 3B). The C2-7 lordotic angle changed from 8.3 degrees preoperatively to 34.3 degrees postoperatively. Furthermore, there was a 27.8 mm increase in FSH immediately after surgery. The fibular strut was found to be dislodged 2 weeks after ACCF (Fig. 3C). Posterior fixation was added to stabilize the entire length of the cervical spine (Fig. 3D).

Discussion

Surgical procedures have now been performed for cervical OPLL for nearly half a century. Although controversy remains about whether anterior or posterior surgery is better, several studies have reported that anterior surgery is superior to a posterior procedure. However, anterior surgery is well-known to be associated with some risks, including dysphagia, dysphonia, airway obstruction, and implant failure, with morbidity rates in the range of 9%-20%[9-12]. Anterior surgery is also associated with a high rate of implant dislodgement, even when a plate is used. Early failure of anterior cervical reconstruction surgery requires a second operation, resulting in a prolonged hospital stay and increased medical costs. Long strut grafts and plate fixation in an ACCF create long lever arms that result in graft subsidence and in instrumentation failure, especially for multilevel reconstructions. Graft dislodgement is most likely to occur in the first 6 weeks after surgery[13]. Vaccaro et al.[14] observed dislodgement of a graft/plate construct in 9% of patients with 2-level ACCF and in up to 50% of those with 3-level ACCF. Okawa et al.[15] also found early strut migration in 30% of those who underwent ACCF involving an average of 3.8 segments. In the present study, early graft migration occurred in 10 of 47 patients treated with ACCF (21%, average 3.1 segments) and revision surgery was required in 2 cases (4.3%) within 1 year postoperatively. Casper et al.[16] reported that revision surgery was required in 3 (2.1%) of 146 patients treated with anterior decompression and fusion. This reoperation rate was still not very low despite the use of the plating technique to reduce extrusion during instrumentation. Therefore, it is important for spine surgeons to evaluate the implant status after ACCF chronologically, especially if ≥4 levels are involved.

Several factors have been reported to be associated with postoperative implant subsidence in patients treated with ACCF. We had previously demonstrated that postoperative cervical hyperlordosis impairs graft stability in the early period after ACCF surgery. Similarly, in the present study, the increase in C2-7 lordotic angle was relatively greater, albeit not significantly, in patients with implant subsidence. Our

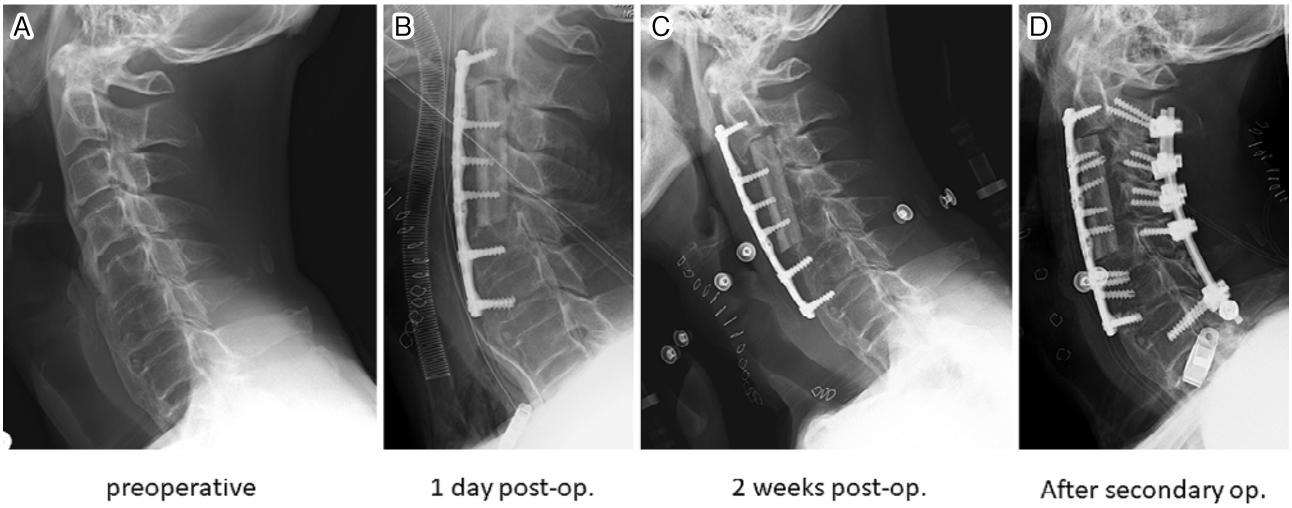

Figure 3. A. Preoperative lateral radiograph showing a C2-7 angle of 8.3 degrees, FSA of 6 degrees, and FSH of 72.4 mm. B. Lateral radiograph taken immediately after surgery showing that the C2-7 angle increased to 34.3 degrees, FSA to 29.8 degrees, and FSH to 96.1 mm. C. Graft dislodgement at 2 weeks after the index surgery. D. A second anterior procedure was performed to optimize the graft placement. Posterior fixation was added to stabilize the structure.

findings suggest that there may be high shear stress at the distal vertebra of the fused segment because of hyperlordosis of the cervical spine. Therefore, it is important to make the FSA almost parallel to the sagittal angle when setting a plate to stabilize the grafted strut.

We found that a postoperative increase in FSH affected the incidence of implant subsidence following ACCF. We speculate that over-distraction during grafting could have been one of the causes of reconstruction failure. Over-distraction probably causes surgeons to overestimate the length of a bone graft, which sometimes leads to an inadvertent increase in FSH. Oh et al.[17] reported that the change in FSH immediately after ACCF was significantly smaller than that after ACDF for a 2-level lesion. FSH has also been reported to increase significantly immediately after the procedure and then decrease slowly over time. These findings indicate that a change in FSH could occur depending on neck alignment during surgery and that the fused segment would be more likely to undergo a kyphotic change after ACCF than after ACDF. A biomechanical study that used finite element modeling reported that the stress at the interface of the bone and distal screws was greatest after ACCF[18]. Rupture can occur if the axial load is not perpendicular to the distal end plate and contribute to settling or telescoping of the graft and failure of the construct. The results of our studies, combined with those of other researchers, suggest that we should set the proximal and distal endplate at the fused segment as parallel as possible and place a bone graft of appropriate length.

Smith et al.[5] demonstrated that implant failure was more likely after an anterior corpectomy involving the cervicothoracic junction. Furthermore, Wang et al.[19] reported that implant migration occurred in 87.5% of patients who underwent C6 corpectomy with fusion extending to the C7 vertebral body. However, in the present investigation, implant migration occurred in 3 of 10 patients (30%) who underwent ACCF extending to C7, which does not suggest a significant trend in the incidence of implant failure. In many cases, the cervicothoracic junction represents a unique segment of the spine with an abrupt transition between kyphosis and lordosis. Therefore, biomechanical failure of ACCF can easily occur at the transition zone where shear stresses on the construct may have been underestimated. Supplementary posterior instrumentation should be considered in cases of multilevel corpectomy to provide extra resistance against extension and offset loading of the graft leading to failure, especially when the reconstruction involves the cervicothoracic junction.

This study has several limitations, including its retrospective design, the relatively small number of patients, and heterogeneity in the type of plate and graft. Moreover, although we preserved the endplates of the cephalic and caudal vertebral body as much as possible, the degree of preservation was not consistent in our series. Finally, we could not evaluate factors related to location of the graft or screw angle and length. However, despite these limitations, we suggest that the FSH should not be increased after graft placement and plating to prevent postoperative implant failure.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Ethical Approval: This study was approved by Institutional Ethics Committee of Tokyo Medical and Dental university (M2017-118).

Author Contributions:
Takashi Hirai; study design, data acquisition, data analysis, and drafting the manuscript
Toshitaka Yoshii: data acquisition, data interpretation, and

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Kenichiro Sakai: data analysis and critical revision of the manuscript

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Osamu Nakai: data interpretation and critical revision of the manuscript

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