Predictors associated with neurological recovery after anterior decompression with fusion for degenerative cervical myelopathy

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Abstract

Background

Anterior decompression with fusion (ADF) has often been performed for degenerative cervical myelopathy (DCM) in patients with poor cervical spine alignment and/or anterior cord compression. However, it is difficult to preoperatively predict the extent to which patients will experience postoperative neurological improvement. We aimed to identify predictors associated with neurological recovery after ADF in a retrospective study of prospectively collected data.

Methods

We prospectively enrolled patients who were scheduled for ADF for DCM. The associations of baseline variables with recovery rate were investigated using a multiple linear regression model.

Results

In total, 36 patients completed the 1-year follow-up. Regarding clinical outcomes, the Japanese Orthopedic Association score for the assessment of cervical myelopathy, European Quality of Life Five Dimensions Scale, Neck Disability Index, and Physical Component Summary of the SF-36 (PCS) scores improved postoperatively. The recovery rate was significantly correlated with the sagittal vertical axis (SVA) and T1 pelvic angle. Univariate regression analyses showed that the SVA and PCS score were significantly associated with recovery rate. Lastly, multiple regression analysis identified the independent predictors of recovery rate after ADF as thoracic kyphosis (TK), PCS, and SVA. According to this prediction model, the following equation was obtained: recovery rate = − 8.26 + 1.17 × (TK) − 0.45 × (SVA) + 0.85 × (PCS).

Conclusion

Patients with lower TK, lower PCS score, and higher SVA were more likely to have poor neurological recovery after ADF. Therefore, DCM patients with these predictors who undergo ADF might be cautioned about poor recovery and be required to provide adequate informed consent.

Background

With age, degeneration of the cervical spine progresses [1]. Accordingly, with the advent and progression of an aging society, the number of patients with degenerative cervical myelopathy (DCM) will increase. Surgery is considered to be a treatment for advanced DCM that is resistant to conservative therapy and interferes with daily life. Anterior decompression with fusion (ADF) has often been performed for patients with poor cervical spine alignment and/or anterior cord compression [2]. Although the results of ADF are usually satisfactory, sometimes they are not. To date, it has been difficult to preoperatively predict the extent of neurological improvement a patient will experience after ADF. The aim of this study was to identify predictors which are associated with neurological recovery after ADF.

To date, research regarding preoperative predictors for the success of ADF has been limited. A prospective randomized study showed that preoperative predictive factors of good outcome 10–13 years after ADF included initial high neck-related pain intensity, nonsmoking status at the time of surgery, and male sex [3]. A retrospective study showed that advanced age, longer duration of symptoms, and bigger kyphotic angle at final follow-up were associated with poor outcome in DCM patients after anterior surgery [4]. Thus, there is little about the analysis of how whole spinal parameters play a role in surgical outcomes after ADF.

This study correlates measurable preoperative variables to the likelihood of neurological improvement after ADF. We found that sagittal vertical axis (SVA), thoracic kyphosis (TK), and Physical Component Summary of the SF-36 (PCS) score were independent predictors for level of recovery after ADF. To the best of our knowledge, this study is the first to investigate the predictive value of global spinal parameters and PCS score for recovery rate after ADF.

Methods

Study population

This multicenter study, initiated by the Japanese Organization of the Study for Ossification of the Spinal Ligament, prospectively recruited patients with cervical myelopathy who were scheduled for surgical treatment at eight participating institutes from October 2016 through December 2017. Institutional review board approval was obtained before initiation of the study. At the time of enrollment, written informed consent was obtained from all participants. Demographic data, including age, sex, body mass index, and etiology of myelopathy were collected. The exclusion criteria were comorbidities impairing physical functions (e.g., cerebral infarction, cerebral palsy, or severe rheumatoid arthritis), bedridden status or full dependence on a wheelchair before surgery due to severe cervical myelopathy, and difficulty completing a questionnaire because of cognitive impairment.

Radiologic findings

Cervical lordosis (CL) of the spine was defined by the Cobb angle between C2 and C7 on a lateral radiograph in the neutral position. C2-7 range of motion was measured on flexion–extension lateral radiographs. The C7 slope was calculated by measuring the angle formed by the horizontal line to the C7 vertebra and the line parallel to the superior endplate of the C7 vertebra [5]. Thoracic kyphosis (TK) was defined by the Cobb angle between the superior endplate and the inferior endplate of T1-T12 [6]. The C2-7 sagittal vertical axis (SVA) was defined as the sagittal distance between a plumb line dropped from the center of C2 and the posterior superior corner of C7 [7]. Lumbar lordosis was defined as the angle between the superior endplate of L1 to the inferior endplate of L5 [8]. Sacral slope was measured between the tangent line to the superior endplate of S1 and the horizontal plane [9]. The SVA was defined as the sagittal distance between the C7 plumb line and the vertical line through the posterosuperior corner of the S1 endplate on standing whole-spine lateral radiographs [10]. Pelvic tilt was measured as the angle between the vertical reference line from the center of the femoral head and the line from the center of the femoral head to the midpoint of the sacral endplate [11]. The T1 pelvic angle (TPA) was defined as the angle between the line from the femoral head axis to the centroid of T1 and the line from the femoral head axis to the middle of the S1 endplate [12].

Outcome measures

Outcomes were assessed before surgery and 1 year after surgery using the Japanese Orthopedic Association score for the assessment of cervical myelopathy (C-JOA score, which ranges from 0 to 17, with higher scores indicating better neurological function) [13], the European Quality of Life Five Dimensions Scale (EQ-5D, which ranges from − 0.111 to 1, with higher scores indicating better quality of life) [14], the Neck Disability Index (NDI) score (which ranges from 0 to 100, with higher percentages indicating more severe disability) [15], and the SF-36 Physical Component Summary (PCS) and Mental Component Summary (MCS) (which range from 0 to 100, with higher scores indicating better health and functioning) [16]. The recovery rate, based on the C-JOA score, was calculated according to Hirabayashi's method using the following formula: recovery rate (%) = (postoperative C-JOA score − preoperative C-JOA score) × 100 / (17 − preoperative C-JOA score) [17].

Statistical analysis

We performed a paired *t*-test to identify differences in scores before surgery and 1 year after surgery. Spearman correlation coefficient was used to evaluate the relationships between the recovery rate and the preoperative radiographic factors. The associations between baseline variables with recovery rate were investigated with a multiple linear regression model. First, predictors associated with the dependent variable at a p-value < 0.25 in univariate regression analyses were carried forward to the second step of the analysis [18]. Second, the remaining predictors were included in a backward multiple regression analysis. Predictors with a p value > 0.05 were removed. For all statistical analyses, JMP version 12 (SAS Institute, Cary, NC, USA) was used, and a p-value of < 0.05 was considered statistically significant.

Results

Patient demographics and surgical outcomes

A total of 36 patients with 48 weeks of postoperative follow-up were included in this study. The baseline characteristics of the patients are shown in Table 1. The mean age of the patients was 60.8 years. The average cervical lordosis was 10.0° before surgery.

Table 1
Demographic data of patients

Number of cases	36
Age (year)	60.8 ± 11.1
Female sex [no. (%)]	14 (39)
BMI	25.6 ± 4.6
OPLL [no.(%)]	15 (42)
CL (degree)	10.0 ± 12.1
ROM (degree)	32.4 ± 18.1
C7 slope (degree)	22.6 ± 10.7
C2-7 SVA (mm)	20.3 ± 13.8
TK (degree)	34.1 ± 13.0
LL (degree)	35.1 ± 12.4
SS (degree)	29.0 ± 7.7
SVA (mm)	24.6 ± 26.4
PT (degree)	18.9 ± 6.3
TPA (degree)	15.3 ± 6.0
BMI, body mass index; OPLL, ossification of posterior longitudinal ligament; CL, cervical lordosis; ROM, range of motion; SVA sagittal vertical axis; TK, thoracic kyphosis; LL, Lumbar lordosis; SS, sacral slope; PT, pelvic tilt; TPA, t1 pelvic angle;	
*p < 0.05	
Data are given as mean ± SD.	

Table 2 shows the surgical outcomes. The mean recovery rate was 44.2%. While C-JOA, EQ-5D, NDI, and PCS scores were improved postoperatively, there was no significant difference between the preoperative and 1-year postoperative MCS scores (Table 2).

Table 2
Surgical outcomes

Characteristic	pre	1 year after surgery	p
C-JOA	10.9 ± 2.3	13.5 ± 2.4	< 0.001*
Recovery rate	44.2 ± 30.8		
EQ-5D	0.55 ± 0.17	0.68 ± 0.18	< 0.001*
NDI	42.8 ± 19.5	28.8 ± 19.5	< 0.001*
PCS	26.0 ± 15.9	35.5 ± 16.5	< 0.001*
MCS	47.8 ± 9.2	50.4 ± 8.8	0.08
C-JOA, Japanese Orthopedic Association score for the assessment of cervical myelopathy; EQ-5D, European Quality of Life-5 Dimensions; NDI, neck disability index; PCS, Physical component summary of SF36; MCS, Mental component summary of SF36			
*p < 0.05			
Data are given as mean ± SD.			

Correlations between recovery rate and preoperative radiographic factors

We then investigated whether the recovery rate correlated with the preoperative factors (Table 3). The results showed that the recovery rate significantly negatively correlated with the preoperative SVA (ρ = -0.545, p = 0.001) and TPA (ρ = -0.422, p = 0.04); however, no correlations were observed between the recovery rate and other radiographic parameters.

Table 3
Correlations between recovery rate and preoperative radiographic parameters

	ρ	p-value
Recovery rate versus		
CL	-0.02	0.92
ROM	-0.11	0.53
C7 slope	-0.06	0.71
C2-7 SVA	-0.04	0.82
TK	0.18	0.30
LL	0.05	0.77
SS	0.04	0.82
SVA	-0.52	0.002*
PT	-0.17	0.35
TPA	-0.40	0.02*

CL, cervical lordosis; ROM, range of motion; SVA, sagittal vertical axis; TK, thoracic kyphosis; LL, Lumbar lordosis; SS, sacral slope; PT, pelvic tilt; TPA, t1 pelvic angle,

*$p < 0.05$

Independent predictors of recovery rate after ADF

The association between the baseline variables and the recovery rate was investigated in a univariate regression model (Table 4). Univariate regression analysis showed that SVA and PCS score were significantly associated with the recovery rate after ADF (p = 0.01 and 0.03).

Table 4
Univariate regression analysis. Association of baseline variables with recovery rate

Characteristic	Regression coefficient	95% CI	*P*
Age (year)	-0.76	-1.69 to 0.18	0.11
Female sex [no. (%)]	4.95	-5.76 to 15.66	0.35
BMI	0.97	-1.32 to 3.26	0.39
OPLL	6.04	-4.48 to 16.56	0.25
CL	-0.30	-1.18 to 0.58	0.50
ROM	-0.24	-0.85 to 0.35	0.41
C7 slope	-0.05	-1.05 to 0.95	0.92
C2-7 SVA	0.09	-0.68 to 0.87	0.81
TK	0.57	-0.28 to 1.42	0.18
LL	-0.08	-0.99 to 0.83	0.86
SS	0.12	-1.35 to 1.60	0.86
SVA	-0.52	-0.90 to -0.13	0.01*
PT	0.09	-1.67 to 1.85	0.92
TPA	-1.17	-2.97 to 0.63	0.19
C-JOA	1.38	-3.27 to 6.04	0.55
EQ-5D	34.46	-33.49 to 102.40	0.31
NDI	-0.30	-0.91 to 0.30	0.32
PCS	0.80	0.10 to 1.49	0.03*
MCS	-0.30	-1.61 to 1.00	0.64

CI, confidence interval; BMI, body mass index; OPLL, ossification of posterior longitudinal ligament; CL, cervical lordosis; ROM, range of motion; SVA sagittal vertical axis; TK, thoracic kyphosis; LL, Lumbar lordosis; SS, sacral slope; PT, pelvic tilt; TPA, t1 pelvic angle; C-JOA, Japanese Orthopedic Association score for the assessment of cervical myelopathy; NDI, neck disability index; EQ-5D, European Quality of Life-5 Dimensions; PCS, Physical component summary of SF36; MCS, Mental component summary of SF36

*p < 0.05

Then, the independent predictors for recovery rate were investigated using a multiple regression analysis. Based on the univariate analysis, the dependent variable was defined as the recovery rate, and the independent variables were age, TK, SVA, TPA, and PCS. As a result, the independent baseline predictors were identified as TK (Regression coefficient = 1.17, p = 0.01), PCS (Regression coefficient = 0.85, p =

0.03), and SVA (Regression coefficient = -0.45, p = 0.03) (Table 5). According to this prediction model, the following equation was obtained: recovery rate = − 8.26 + 1.17 × (TK) − 0.45 × (SVA) + 0.85 × (SF-36’s PCS) (Fig. 1).

Table 5
Multiple regression analysis: independent predictors of recovery rate

Factor	Regression coefficient	95% CI	*P*
TK	1.17	0.27 to 2.06	0.01*
PCS	0.85	0.11 to 1.58	0.03*
SVA	-0.45	-0.85 to -0.05	0.03*
CI, confidence interval; TK, thoracic kyphosis; PCS, Physical component summary of SF36; SVA, sagittal vertical axis			
*p < 0.05			

Discussion

This study investigated the predictors of recovery rate after ADF. C-JOA, EQ-5D, NDI, and PCS scores were improved postoperatively. The recovery rate was significantly correlated with the SVA and TPA. Univariate regression analyses showed that the SVA and PCS scores were significantly associated with the recovery rate. Lastly, multiple regression analysis showed that the independent predictors of recovery rate after ADF were identified as TK, PCS, and SVA. To the best of our knowledge, this study is the first to investigate the predictive value of global spinal parameters and PCS score for recovery rate after ADF.

In this study, we found that the SVA and TPA were significantly negatively correlated with the recovery rate after ADF. This is the first time, to the best of our knowledge, that these correlations have been identified. The TPA is a radiographic measure of sagittal spinal alignment, and a low TPA indicates good thoracic-lumbar alignment [19]. Accordingly, attention might also be paid to the TPA when performing ADF on DCM patients. One other advantage of the TPA is that it is less affected by patient posture, as the TPA can also be measured in a seated position [19]. Therefore, in the case of patients who have difficulty standing due to severe myelopathy, measuring the TPA may be substituted for the SVA to predict neurological recovery after ADF. We also found that CL was not correlated with the recovery rate. This result confirmed the notion that even in patients with poor cervical spine alignment, ADF can be expected to produce good neurological recovery.

We also found that the independent radiographic predictors of recovery rate after ADF were identified as TK and SVA. These results indicate that patients with higher TK and lower SVA were more likely to improve their C-JOA scores. A recently established concept is that good SVA can be predicted by pelvic incidence, LL, and TK [20]. In general, as thoracic kyphosis increases, lumbar lordosis increases to maintain the C7 in the correct position. Conversely, as lumbar lordosis decreases, thoracic kyphosis decreases [21]. Therefore, these results may mean that in patients with better global spinal alignment, the postoperative outcome of ADF is likely to be better. However, it is important to note that when the compensation mechanism for spinal kyphosis is surpassed, spinal kyphosis continues to progress. In such a condition, even if lumbar lordosis decreases, thoracic kyphosis may increase.

We also found that the independent predictor of recovery rate after ADF was identified as PCS score. A cohort study that investigated the surgical results of cervical spondylotic myelopathy showed that the recovery rate improvements correlated with SF-36's physical component domains [22], although both anterior and posterior surgery scores were included for the analysis. Collectively, when performing ADF, it may be important to have a thorough understanding of the patient's physical functioning prior to surgery to accurately predict the postoperative neurological recovery.

There are some limitations in this study. First, although our study is based on prospectively collected data, the primary limitation of this study is the retrospective design. Second, sample size may have been small. Further prospective studies are needed to address these limitations and validate the results of this study.

Conclusions

We found that the recovery rate following ADF was negatively correlated with the preoperative SVA and TPA. A preoperatively higher SVA, lower TK, and lower PCS score were independent predictors for poor recovery after ADF. Therefore, patients who undergo ADF with these predictors might be cautioned about poor recovery and be required to provide adequate informed consent.

Abbreviations

ADF
anterior decompression with fusion
DCM
degenerative cervical myelopathy
PCS
Physical Component Summary of the SF-36
SVA
sagittal vertical axis
TK
thoracic kyphosis
CL
cervical lordosis
TPA
T1 pelvic angle
C-JOA score

Japanese Orthopedic Association score for the assessment of cervical myelopathy
EQ-5D
European Quality of Life Five Dimensions Scale
NDI
Neck Disability Index
MCS
Mental Component Summary of the SF-36

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Helsinki Declaration and approved by the Ethics Committee of Tokyo Medical and Dental University (M2016-017) and written informed consent was obtained from all participants.

Consent for publication

Not applicable

Availability of data and materials

Not applicable

Competing interests

Hiroyuki Inose is an associate editor of BMC surgery.

There are no other conflicts of interest.

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Authors' contributions

HI, TH, TY, AK, KT, HInoue, AM, KE, TF, AN, KM, SK, SI, SS, SM, and AO (1) provided substantial contributions to the conception or design of the study or the acquisition, analysis, or interpretation of data; (2) drafted the paper, read it, and revised it critically for important intellectual content; (3) provided final approval of the version to be published; and (4) agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Figures

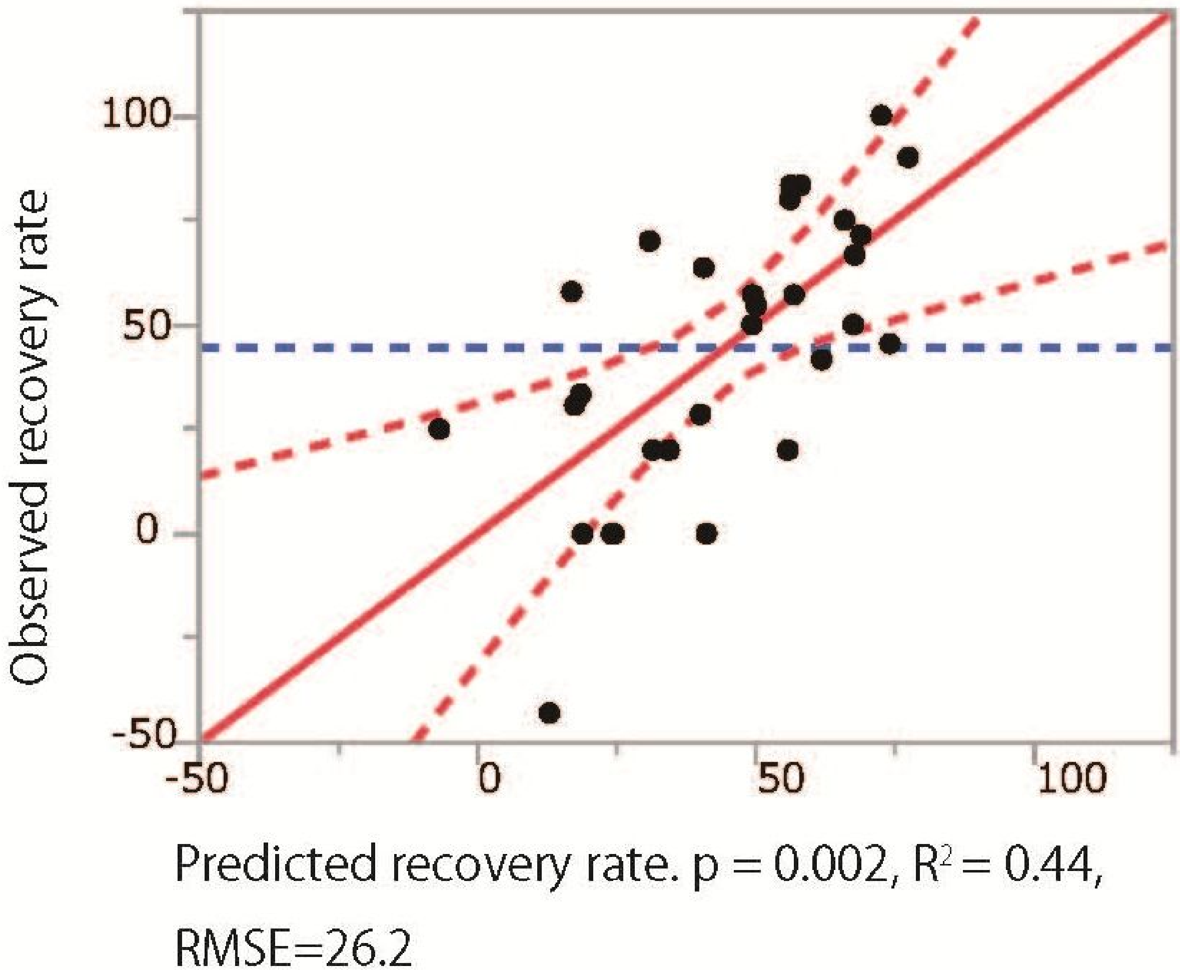

Figure 1

Observed versus predicted plots of the multiple linear regression model for recovery rate.