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Corresponding Author
Seok Woo Kim
https://orcid.org/0000-0003-2882-4477

Spine Center, Hallym University Sacred Heart Hospital, Hallym University College of Medicine, 22 Gwanpyeong-ro 170beon-gil, Dongann-gu, Anyang 14068, Korea
Email: spinedrk@gmail.com

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Analysis of the Incidence and Risk Factors of Postoperative Delirium in Patients With Degenerative Cervical Myelopathy

Namhoo Kim, Tae-Hwan Kim, Jae Keun Oh, Jeongsup Lim, Kang Uk Lee, Seok Woo Kim

Spine Center, Hallym University Sacred Heart Hospital, Hallym University College of Medicine, Anyang, Korea

Objective: The purpose of this study is to analyze various risk factors that can cause postoperative delirium (POD) in degenerative cervical myelopathy (DCM) patients, which may affect normal recovery and outcomes after surgery, and to help deal with them in advance and to take a medical approach.
Methods: A total of 148 patients aged 60 years or older who underwent laminoplasty or anterior cervical discectomy and fusion (ACDF) for DCM from 2008 to 2015 were included in this study. Incidence and multiple risk factors for development of POD were analyzed.
Results: POD occurred in 24 patients (16.2%). Among the 148 patients, 78 received laminoplasty, of whom 19 patients (24%) experienced delirium; the other 70 patients underwent ACDF, of whom 5 patients (7.1%) experienced delirium. History of Parkinson disease (odds ratio [OR], 178.242; p = 0.015), potassium level (OR, 3.764; p = 0.031), and surgical approach of laminoplasty over ACDF (OR, 8.538; p = 0.008) were found to be significant risk factors in a multivariate analysis. Age (OR, 1.056; p = 0.04) and potassium level (OR, 3.217; p = 0.04) were significant risk factors in the laminoplasty group.
Conclusion: The findings of this study suggest that the incidence and risk factors for POD may vary in patients with DCM. It is necessary to understand multiple factors that affect the development of POD.

Keywords: Delirium, Postoperative care, Cervical myelopathy, Laminoplasty

INTRODUCTION

Postoperative delirium (POD) refers to any acute change in cognition, including fluctuating awareness, deficit attention, memory impairment, disorientation, or other behavioral disorders that occur within 30 days after surgery.[1,2] The overall complication rate was reported at 13% in patients with posterior lumbar fusion according to the data of National Inpatient Sample.[3] Delirium is one of the most common postoperative complications (10%–77%) and occurs after various surgical treatments including orthopedic, pelvic, and aortic surgeries.[4,5] POD worsens surgical outcomes, increases hospitalization period, raises the medical cost, and increases postoperative morbidity and mortality.[6] There are many causes of delirium. Preoperative cognitive impairment, drug abuse or alcoholism, diabetes, hearing or vision impairment, various types of surgery, excessive bleeding, and acute anemia are known as factors of POD. Older age is the most common cause in relation to orthopedic and cardiac surgeries, as well as anesthesia.[7,8]

A few studies on POD after spinal surgery have been conducted and identified various associated factors, including age, baseline comorbidities, preoperative cognition, neurological diseases, and operation duration.[9-12] However, these studies included all spinal surgery patients with no consideration for factors related to the prevalence of delirium, whose occurrence varies according to the type and method of spinal surgery. Thus, these studies provide no descriptions of whether the degree of delirium would vary according to the severity of the disease, the surgical levels, or the specific surgical method.[13,14]

Early surgical treatment is usually recommended at degenerative cervical myelopathy because it not only causes clinical manifestations such as clumsiness of hands, abnormal gait, and bowel or bladder dysfunctions, but also can cause irreversible neurological damage to the spinal cord as the lesion progresses.[15,16] Surgical methods for DCM can vary according to the extent and location of the lesion.[17,18] Anterior cervical discectomy and fusion (ACDF) or anterior corpectomy and fusion (ACF) can be performed in the anterior approach, and posterior cervical laminoplasty or posterior laminectomy and fusion can be performed in the posterior approach to relieve the compressed spinal cord, improve blood flow in the spinal cord, and prevent nerve damage. Typically, in the presence of lesions extending over 3 or more segments and in cases where lordosis of the cervical spine is well maintained in myelopathy with cervical stenosis, posterior laminoplasty or posterior laminectomy and fusion are usually recommended.[17,18]

As far as the authors know, no study has yet provided any data on the incidence and risk factors of POD in patients with DCM. Furthermore, active rehabilitation after surgery is extremely important because DCM patients may have poor outcomes when they have POD.

Laminoplasty is known as one of the most performed surgical procedures in Asia for DCM. Thus, this study is aimed to investigate whether the incidence of delirium is higher after laminoplasty than ACDF, which is known as the most common surgical method for the cervical spine, evaluated for comparison with the results of the study.

MATERIALS AND METHODS

1. Study Population

This study included 148 patients aged 60 years or older who underwent surgery ACDF or laminoplasty surgeries for DCM or myelo-radiculopathy at our clinic from 2008 to 2015. Of these 148 patients who underwent surgery, 78 patients underwent laminoplasty, and 70 patients underwent ACDF. In the patient group who underwent laminoplasty, all had symptoms and signs associated with myelopathy, and the causes of myelopathy were ossification of the posterior longitudinal ligament (OPLL) (n = 62), cervical spinal stenosis (n = 10), and herniated nucleus pulposus (HNP) (n = 6). Among patients who underwent ACDF, 57 patients had symptoms and signs associated with myeloradiculopathy. The causes of them were HNP (n = 48), spinal stenosis (n = 3), HNP with spinal stenosis (n = 3), and HNP with OPLL (n = 3). Thirteen patients who underwent ACDF had only myelopathy and were diagnosed with HNP (n = 6), spinal stenosis (n = 2), HNP with spinal stenosis (n = 2), and HNP with OPLL (n = 3) (Table 1).

Table 1. The etiologies of myelopathy

Etiology	Laminoplasty (n = 78)	ACDF (n = 70)
Myelopathy		
OPLL	62	-
HNP	6	6
HNP with OPLL	-	3
HNP with cervical spinal stenosis	-	2
Cervical spinal stenosis	10	2
Myeloradiculopathy		
HNP	-	48
HNP with OPLL	-	3
HNP with cervical spinal stenosis	-	3
Cervical spinal stenosis	-	3

ACDF, anterior cervical discectomy and fusion; OPLL, ossification of the posterior longitudinal ligament; HNP, herniated nucleus pulposus.

An inclusion criterion was patients who underwent laminoplasty or ACDF aged 60 years or older due to DCM at our institution. Exclusion criteria were patients who have had previous cervical spine surgery, patients who were received a combination of surgery with laminoplasty and ACDF, patients who underwent laminoplasty or ACDF due to myelopathy caused by trauma, tumors and congenital stenosis, patients who received laminoplasty or ACDF under age 60 years old, and extension of surgical levels to C2 or T1. The criteria for ACDF were soft disc herniation, instability of a degenerative nature, concomitant severe axial neck pain, and cervical kyphosis. ACF is an alternative to multilevel ACDF, but ACF was not included in our study because of small number of cases. The criteria of laminoplasty were multilevel cervical stenosis, patients with advanced multilevel spondylosis, OPLL, and patients with at least 10° of cervical lordosis to allow posterior shift or the spinal cord for indirect compression.

The mean age was 66.7 years (56.5–76.9) in the laminoplasty group and 67.2 years (60.9–73.4) in the ACDF group, with no statistical difference between these 2 groups ($p = 0.747$). The male to female ratio was 60:18 in the laminoplasty group and 36:34 in the ACDF group, with a statistically significant differ-

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Table 2. Demographics of participants according to surgical method

Variable	Laminoplasty (n = 78)	ACDF (n = 70)	p-value
Age (yr)	66.74 ± 10.22	67.2 ± 6.25	0.747
Sex, male:female	60:18	36:34	0.02*
Operated level	3.13 ± 0.85	1.93 ± 0.80	< 0.01*
mJOA score (preoperative)	12.43 ± 3.61	15.16 ± 2.26	< 0.01*
mJOA score (postoperative)	14.04 ± 3.53	16.24 ± 2.31	< 0.01*
Operation time (min)	258.31 ± 80.83	230.07 ± 94.63	0.052
EBL (mL)	774.36 ± 440.90	562.71 ± 327.67	0.001*
Hospital stay (day)	15.15 ± 10.92	11.50 ± 4.85	0.009*

Values are presented as mean ± standard deviation.
ACDF, anterior cervical discectomy and fusion; mJOA, modified Japanese Orthopedic Association score; EBL, estimated blood loss.
Chi-square test for categorical variables, independent t-test for continuous variables.
*p < 0.05, statistically significant differences.

Table 3. The criteria for diagnosis of postoperative delirium

DSM-5 (Diagnostic and Statistical Manual of Mental disorders, 5th version)
The presence of delirium requires all the criteria to be met:
Disturbance in attention and awareness
Disturbance develops acutely and tends to fluctuate in severity
At least one additional disturbance in cognition
Disturbances are not better explained by a pre-existing dementia
Disturbances do not occur in the context of a severely reduced level of arousal or coma
Evidence of an underlying organic cause or causes
CAM (Confusion Assessment Method)
The presence of delirium requires features 1 and 2 and either 3 or 4:
Acute change in mental status with a fluctuating course (feature 1)
Inattention (feature 2)
Disorganized thinking (feature 3)
Altered level of consciousness (feature 4)

ence in the chi-square test (p = 0.02). The extent of surgery was 3.13 levels (2.87–3.39) in the laminoplasty group and 1.93 levels (1.74–2.12) in the ADCF group on average, showing a statistically significant difference (p < 0.01). The preoperative modified Japanese Orthopedic Association (mJOA) score for laminoplasty patients was 12.43/18 (8.82–16.04) and that for ACDF patients was 15.16/18 (12.90–17.42), which also showed a statistically significant difference (p < 0.01). The postoperative mJOA score for laminoplasty patietnts was 14.04/18 (10.51–17.57) and that for ACDF patients was 16.24 (13.93–18.55), showed a statistical difference (p < 0.01) (Table 2).

2. Diagnosis of POD

Based on the medical records of patients receiving replies after consulting a specialist in the neurology or psychiatry department and the medical records that evaluated the patient's condition after surgery, POD were analyzed retrospectively, and the diagnosis of POD was made in the following way.

The surgeons who performed the surgeries and 2 attending physicians evaluated the cognitive status of patients every day during the period after the surgery until discharge. The evaluation included disturbance in attention and disturbance in awareness. Based on the Diagnostic and Statistical Manual of Mental Disorders-V criteria (Table 3), delirium was determined: disturbance occurrence within a few hours or days after the surgery, a change in baseline attention and awareness, and a fluctuation in severity was assessed by asking patients about orientation such as time, place and person and evaluating whether hallucinations or other psychiatric symptoms occurred every 8 hours after surgery.[19,20] Besides, patients who did not associate with a pre-existing established neurocognitive disorder were diagnosed with having delirium and underwent consultation with a neurologist or psychiatrist.[2,21-23]

Since the surgeons who performed the surgeries and 2 attending physicians evaluated the cognitive status of patients were not a neurologists or psychiatrists, authors tried to reduce the error of diagnosis by consulting in a specialized field, and thus seek advice from neurologists or psychiatrists. The neurologist or psychiatrist reevaluated suspected patients who received consultations and ultimately diagnosed them with delirium. All of the patients described in the paper included only those identified and confirmed as delirium through neurology or psychiatric consultation. The delirium diagnosis was finally determined based on the confusion assessment method (CAM).

3. Anesthesia and Drug Regimen

All patients underwent cervical spine surgery under general anesthesia, and anesthesia was induced and maintained according to our clinic's standard regimen. Anesthesia was induced with IV propofol and maintained with sevoflurane and remifentanil (0.25–0.5 μg/kg per min). At the end of the surgery, neostigmine (0.05 mg/kg), and glycopyrrolate (0.01 mg/kg) were used to recover from neuromuscular block during extuba-

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tions. They were used once in the process of removing the tube.

4. Risk Factor

The following known risk factors were compared. Age, sex, baseline comorbidities, osteoporosis, bone mineral density (BMD) score, hemoglobin and hematocrit, sodium, chloride, potassium, hypotension (systolic blood pressure < 80 mmHg) immediately after the surgery or during surgery. Patients' height, weight, body mass index (BMI), smoking status, American Society of Anesthesiologists (ASA) physical status classification above II, intraoperative blood loss, blood transfusion, transfusion volume, drugs used to control pain such as opioids, nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophens, and other pain killers, duration of hospitalization, days to wait for hospitalization from admission to surgery, operation time, intensive care unit (ICU) care, and duration of ICU care were reviewed. Postoperative complications comprised of patients' medical conditions requiring consults from other specialists, including acute kidney injury, pneumonia, pulmonary edema, urinary tract infection, atrial fibrillation, insomnia, vertigo, and anxiety were also compared. However, these complications were heterogeneous and lacked in number for individual analysis.[4,5,7,13,14,24,25]

5. Statistical Analysis

The cross-tabulation analysis was performed by using Pearson chi-square test for the incidence of POD after laminoplasty and ACDF. In analyzing the risk factors, Pearson chi-square test (parametric test), Fisher exact test (nonparametric test), and cross-tabulation analysis were conducted for categorical variables. An independent t-test (parametric test) and Mann-Whitney U-test (nonparametric test) were performed for continuous variables. Multivariate logistic regression test was conducted on factors with p-values lower than 0.05 in univariate analysis. Statistical analysis was performed using IBM SPSS Statistics ver. 22.0 (IBM Co., Armonk, NY, USA). Statistical significance was set at a significance probability (p-value) < 0.05.

6. Ethics

This study was approved by the Institutional Review Board of Hallym University Sacred Heart Hospital (Ref. No. 720127) and performed in accordance with the guidelines and regulations.

RESULTS

1. Incidence of POD

Delirium occurred in 24 patients out of 148 patients with DCM aged 60 years or older who underwent laminoplasty or ACDF. The incidence of POD was 16.2%. Among those 148 patients who underwent surgery, 78 patients received laminoplasty, and 19 (24%) of them experienced delirium. Seventy patients underwent ACDF and 5 (7.1%) of them experienced delirium. The odds ratio (OR) for POD in the laminoplasty and ACDF groups was 4.18 (95% confidence interval [CI], 1.47–11.9) (Table 4).

Table 4. Incidence and odds ratio of postoperative delirium in patients with DCM

POD	Laminoplasty	ACDF	Odds ratio (95% CI)	p-value
(+)	19/78 (24.3)	5/70 (7.1)	4.18 (1.47–11.9)	0.005*
(-)	59/78 (75.7)	65/70 (92.9)		
Total	78	70		

Values are presented as number (%).
DCM, degenerative cervical myelopathy; ACDF, anterior cervical discectomy and fusion; CI, confidence interval; POD, postoperative delirium.
*p < 0.05, statistically significant differences.

2. Risk Factors for POD

The risk factors for developing POD that were found to be statistically significant were age, neurologic disease, dementia, Parkinson disease, stroke history, hyponatremia, hyperkalemia, and ASA physical status classification > II, blood transfusion, transfusion volume, and ICU care. (age, p < 0.001; neurologic disease, p = 0.009; dementia, p = 0.001; Parkinson disease, p = 0.001; stroke history, p = 0.001; hyponatremia, p = 0.012; hyperkalemia, p = 0.048; ASA physical status classification > II, p = 0.002; transfusion volume, p = 0.013; blood transfusion, p = 0.001; ICU care, p = 0.003) (Table 5).

Multivariate logistic regression analysis was performed on the above factors including surgical method. Parkinson disease (OR, 178.242; p = 0.015), potassium level (OR, 3.764; p = 0.031), and surgical method (laminoplasty over ACDF) (OR, 8.538; p = 0.008) were statistically significant for the development of POD (Table 6).

In the patient group who underwent laminoplasty, the risk factors for POD that were found to be statistically significant were the patient's age (p = 0.008), Parkinson disease (p = 0.012), sodium level (p = 0.023), potassium level (p = 0.047), and ICU care (p = 0.033) (Table 7).

Multivariate logistic regression analysis was performed on the above factors. Age (OR, 1.056; p = 0.04), and potassium level (OR, 3.217; p = 0.04) were statistically significant for the de-

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Table 5. Analysis of risk factors for postoperative delirium in patients with DCM

Variable	POD (-) (n = 124)	POD (+) (n = 24)	p-value
Sex			0.503
Male	79 (63.7)	17 (70.8)	
Female	45 (36.2)	7 (29.1)	
Age (yr)	73.2 ± 10.2	65.7 ± 7.66	0.000*
Smoking	22 (17.7)	5 (20.8)	0.720
Cardiovascular disease	41 (33.0)	6 (25)	0.437
Pulmonary disease	9 (7.25)	1 (4.16)	0.581
Endocrinal disease	30 (24.1)	8 (33.3)	0.348
Diabetes mellitus	27 (21.7)	7 (29.1)	0.431
Renal disease	4 (3.22)	2 (8.33)	0.246
Neurologic disease	12 (9.67)	7 (29.1)	0.009*
Dementia	0 (0)	2 (8.33)	0.001*
Parkinson disease	1 (0.80)	3 (12.5)	0.001*
Liver disease	5 (4.03)	1 (4.16)	0.976
Hypertension	52 (41.9)	13 (54.1)	0.269
Stroke	3 (2.41)	3 (12.5)	0.022*
MDD	6 (4.83)	0 (0)	0.271
Osteoporosis	5 (4.03)	1 (4.16)	0.976
BMD score	-1.1 ± 1.74	-0.7 ± 1.56	0.427
Hemoglobin	13.0 ± 1.97	13.7 ± 1.47	0.350
Hematocrit	36.5 ± 3.18	37.7 ± 3.91	0.201
Sodium	138. ± 4.78	140. ± 3.62	0.012*
Chloride	102. ± 3.80	103. ± 3.15	0.077
Potassium	4.47 ± 0.54	4.28 ± 0.41	0.048*
Intraoperative hypotension	5 (4.03)	1 (4.16)	0.976
Height (cm)	161.97 ± 8.50	160.90 ± 8.22	0.804
Weight (kg)	62.7 ± 13.0	65.1 ± 11.1	0.350
Body mass index	24.1 ± 3.99	24.8 ± 3.59	0.420
ASA PS classification > II	37 (29.8)	15 (62.5)	0.002*
Intraoperative blood loss (mL)	787.5 ± 550.3	652.3 ± 368.4	0.134
Blood transfusion	22 (17.7)	12 (50)	0.001*
Transfusion volume (mL)	363.3 ± 423.9	144.5 ± 383.5	0.013*
Postoperative opioid use	17 (13.7)	4 (16.6)	0.704
Postoperative NSAIDs use	77 (62.0)	16 (66.6)	0.672
Postoperative acetaminophen use	50 (40.3)	13 (54.1)	0.209
Postoperative other pain killer use	58 (46.7)	8 (33.3)	0.225
Postoperative complications	19 (15.3)	7 (29.1)	0.103
Duration of admission (day)	18.3 ± 11.2	19.9 ± 11.1	0.580
Duration of preoperative period (day)	3.9 ± 7.2	2.3 ± 1.7	0.337
Operation time (min)	245.75 ± 89.98	240.83 ± 81.79	0.804
ICU care	19 (15.3)	10 (41.6)	0.003*
Duration of ICU care period (day)	0.87 ± 2.04	0.67 ± 3.71	0.801

Values are presented as number (%) or mean ± standard deviation.
DCM, degenerative cervical myelopathy; POD, postoperative delirium; MDD, manic depressive disorders; BMD, bone mineral density; ASA PS, American Society of Anesthesiologists physical status; NSAIDs, nonsteroidal anti-inflammatory drugs; ICU, intensive care unit.
*p < 0.05, statistically significant differences.

Table 6. Multivariate analysis of risk factors of postoperative delirium in patients with DCM

Variable	Odds ratio	95% CI	p-value
Age	1.078	0.998–1.164	0.056
Neurologic disease	0.329	0.020–5.319	0.434
Dementia	14,582,368,637.117		0.999
Parkinson disease	178.242	2.686–11,827.268	0.015*
Stroke	33.308	0.993–1,117.692	0.050
Sodium	0.881	0.770–1.009	0.067
Potassium	3.764	1.131–12.525	0.031*
ASA PS classification > II	0.730	0.183–2.919	0.657
Blood transfusion	2.889	0.352–23.711	0.323
Transfusion volume	1.000	0.998–1.002	0.993
ICU	3.260	0.850–12.507	0.085
Surgical method (laminoplasty over ACDF)	8.538	1.729–42.149	0.008*

DCM, degenerative cervical myelopathy; CI, confidence interval; ASA PS, American Society of Anesthesiologists physical status; ICU, intensive care unit; ACDF, anterior cervical discectomy and fusion.
*$p < 0.05$, statistically significant differences.

velopment of POD in the patients who underwent laminoplasty (Table 8). This was not analyzed in ACDF due to the low (n = 5).

DISCUSSION

Several studies on POD have been conducted on patients that underwent spinal surgery, investigating the incidence and risk factors. According to the literature, the incidence of the delirium after spinal surgery is reported at 11%–61%.[12-14,25] Various risk factors have also been reported.[12,22,25,26] According to a retrospective study, which analyzed data from more than 500,000 patients with various degenerative diseases of the lumbar spine including herniated lumbar discs, spondylolisthesis, and lumbar spinal stenosis, the risk factors of POD were identified as age (≥ 65 years), sex (female), alcohol/drug abuse, depression, psychotic disorders, and neurological disorders.[13]

However, previous studies on spinal surgery have covered on a wide range of spinal disorders including HNP, spinal stenosis, myelopathy, tumors, and trauma across a variety of regions treated with various surgical methods, they did not characterize the POD associated with certain specific disorders.[22,26,27] Furthermore, although not many, some of meta-analysis were conducted by extracting data from other studies, the methods for determining POD were heterogeneous.[12]

1. Incidence of POD

In the study, delirium occurred in 24 out of 148 elderly patients (16.2%) aged 60 years or older who underwent cervical spine surgery, similar to the results of previous studies, which reported an incidence of 11%–61% (Table 4).[12-14,25]

There was difference of incidence rates of POD between surgical methods and multivariate analysis demonstrated higher risk of POD in laminoplasty patients according to our results. This shows that there is a difference in the development of POD depending on the surgical method even for the same disease. This finding deviates substantially from those of previous similar studies. As a result, the studies overlooked the characteristics present in the incidence of delirium. This approach could make medical professionals overly cautious about the incidence of delirium for surgeries with a low frequency of delirium, while making them erroneously comfortable with surgeries with a high risk of delirium incidence. Thus, it should be noted that POD after spinal surgery can vary depending on the type and selection of surgical methods. This is particularly related to the fact that spinal surgery, unlike surgery in any other parts, has been performed through various methods depending on the surgical levels and the characteristics of the disease, despite surgery for a similar disease in the same area.

2. Risk Factors of the POD

According to this study, the risk factors that affect the incidence of POD following cervical spine surgery were age, neurologic disease, dementia, Parkinson disease, stroke history, hemoglobin, hyponatremia, hyperkalemia, and ASA physical sta-

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Table 7. Analysis of risk factors for postoperative delirium following laminoplasty

Variable	POD (-) (n = 59)	POD (+) (n = 19)	p-value
Sex			0.386
Male	44 (74.6)	16 (84.2)	
Female	15 (25.4)	3 (15.8)	
Age (yr)	65.2 ± 9.5	72.1 ± 10.5	0.008*
Smoking	7 (11.8)	5 (26.3)	0.107
Cardiovascular disease	8 (13.6)	2 (10.5)	0.731
Pulmonary disease	4 (6.8)	1 (5.3)	0.814
Endocrinal disease	11 (18.6)	5 (26.3)	0.471
Diabetes mellitus	11 (18.6)	5 (26.3)	0.471
Renal disease	3 (5.1)	1 (5.3)	0.976
Neurologic disease	5 (8.5)	3 (15.8)	0.361
Dementia	0 (0)	1 (5.3)	0.076
Parkinson disease	0 (0)	2 (10.5)	0.012*
Liver disease	2 (3.4)	0 (0)	0.416
Hypertension	25 (42.4)	9 (47.4)	0.703
Stroke	1 (1.7)	2 (10.5)	0.082
MDD	2 (3.4)	1 (5.3)	0.416
Osteoporosis	5 (8.5)	1 (5.3)	0.648
BMD score	-1.0 ± 1.4	-1.2 ± 1.9	0.746
Hemoglobin	12.5 ± 1.4	12.8 ± 1.4	0.548
Hematocrit	37.2 ± 3.7	37.4 ± 3.8	0.914
Sodium	140.1 ± 3.6	137.6 ± 4.9	0.023*
Chloride	103.6 ± 3.3	102.2 ± 3.7	0.138
Potassium	4.2 ± 0.4	4.4 ± 0.5	0.047*
Intraoperative hypotension	11 (18.6)	6 (31.6)	0.744
Height (cm)	162.7 ± 8.5	162.6 ± 7.2	0.119
Weight (kg)	65.8 ± 9.8	62.3 ± 11.0	0.160
Body mass index	24.8 ± 2.5	23.5 ± 3.1	0.201
ASA PS classification > II	24 (40.7)	11 (57.9)	0.189
Intraoperative blood loss (mL)	683.9 ± 297.9	828.6 ± 342.9	0.558
Blood transfusion	13 (22.0)	8 (42.1)	0.086
Transfusion volume (mL)	180.4 ± 439.5	290.5 ± 395.7	0.335
Postoperative opioid use	12 (20.3)	3 (15.7)	0.662
Postoperative NSAIDs use	38 (64.4)	13 (68.4)	0.749
Postoperative acetaminophen use	30 (50.8)	11 (57.9)	0.593
Postoperative other pain killer use	28 (47.4)	6 (31.6)	0.225
Postoperative complications	4 (6.8)	2 (10.5)	0.311
Duration of admission (day)	18.3 ± 11.2	19.9 ± 11.1	0.580
Duration of preoperative period (day)	3.9 ± 7.2	2.3 ± 1.7	0.337
Operation time (min)	253.2 ± 57.9	253.2 ± 62.2	0.715
Duration of postoperative period (day)	14.3 ± 10.7	17.6 ± 11.2	0.580
ICU care	13 (22.0)	9 (47.4)	0.033*
Duration of ICU care period (day)	1.2 ± 5.3	1.0 ± 2.2	0.918

Values are presented as number (%) or mean ± standard deviation.
POD, postoperative delirium; MDD, manic depressive disorders; BMD, bone mineral density; ASA PS, American Society of Anesthesiologists physical status; NSAIDs, nonsteroidal anti-inflammatory drugs; ICU, intensive care unit.
*$p < 0.05$, statistically significant differences.

Table 8. Multivariate analysis of risk factors of postoperative delirium following laminoplasty

Variable	Odds ratio	95% CI	p-value
Age	1.056	1.004–1.124	0.04*
Parkinson disease	154	0.000–154.000	0.99
ICU care	2.457	0.658–7.037	0.17
Sodium	0.879	0.762–1.013	0.75
Potassium	3.217	1.456–11.174	0.04*

CI, confidence interval; ICU, Intensive care unit.
*$p < 0.05$, statistically significant differences.

tus classification >II, transfusion volume, blood transfusion, and ICU care (Table 5). Among these factors, Parkinson disease, potassium, and surgical method (laminoplasty over ACDF) were statistically significant for the development of POD in multiple regression analysis (Table 6). When we looked at the factors involved in the occurrence of the POD for each surgery, the factors that found to be statistically significant were patient's age, Parkinson disease, low sodium level, high potassium level, ICU care in patients who underwent laminoplasty (Table 7). A multivariate logistic regression test conducted on the above factors and revealed that age and high potassium level alone were significant factors in the development of POD (Table 8). Thus, if any patient who receives laminoplasty due to DCM is old or has an electrolyte imbalance (high potassium level), he or she will require more caution due to a higher probability of POD. However, the factors affect ACDF were not analyzed in the study, because the incidence of POD unexpectedly lowers in ACDF (n = 5), making it difficult to statistically analyze the associated factors and have a statistical significance with it.

In this study, we tried to investigate factors that are known to affect spinal surgery, and examined the relations between these factors and the development of POD.

The smoking status is a known factor that can affect surgical outcomes.[28] The toxic agents in cigarette smoke induce atherosclerotic and microvascular changes, which build up gradually with time and remain even years after quitting. Especially in older smokers, these changes are linked to cognitive decline and dementia, as well as vascular disease, which increase the risk of developing delirium.[9] In our study, however, smoking was not found to increase the risk of POD (Tables 5, 7). Dementia and delirium (an acute confused state) are also known to be associated with drug toxicity.[29] Especially, elderly people are more likely than young people to develop cognitive impairments associated with medication use because renal and liver functions are often impaired in elderly people. Anticholinergic medications are common causes of both acute and chronic cognitive impairment. Psychoactive drugs, antidepressants and anticonvulsants can cause dementia and delirium.[30] The use of NSAIDs, opioids, and other pain killers did not affect the development of POD in this study. However, there are reports of drug-induced cognitive impairment by these agents, so care should be taken when using painkillers after surgery.[30] Other factors associated with surgery including blood transfusion, operation, blood loss, operation time, postoperative complications, ICU care, and duration of admission were not found to be significant. This is a finding that is different from other studies.[12,13] We assume that this was due to our study being a single-center study where surgeries and postoperative care were performed under uniform protocols. More heterogeneous cohort might lead to different results in future studies.

In addition, patient with existing neurological disorders such as dementia or Parkinson disease have been reported to develop POD, and authors included them as one of the causes of the delirium in the study. Our results demonstrated that patients with Parkinson disease had higher risk for development of POD. This is a similar result of a recent systematic review, which suggested that people with Parkinson disease may be at increased risk of delirium.[11] According to a study of Caplan[10] diagnosing delirium in the presence of pre-existing dementia is difficult and gets harder as either progresses because their symptoms are intertwined. Prolonged delirium becomes permanent cognitive impairment, and severe dementia is often manifested by multiple symptoms that are similar to those of delirium. As the neuro-inflammatory mechanism in delirium is actually mediated by the effect of glucose, and not the inflammatory changes in the brain, they suggest that glucose could be the link between dementia and delirium pathophysiology, given that dementia is characterized by insulin resistance and impairments in glucose metabolism and delirium may be working likewise.[31,32] As if to support this hypothesis, recent studies of F-fluorodeoxyglucose positron emission tomography in delirium reveal a novel and unique pattern of glucose hypometabolism that correlates with neuropsychological functions.[33] Parkinson disease, dementia and neurologic disease were found to be meaningful factor in the occurrence of POD in cervical spine surgery, and Parkinson disease was also a meaningful factor in our results. Therefore, patients with neurological disorders such as Parkinson disease and dementia need to take special care of the occurrence of POD if they operate on cervical spine surgery.

Preoperative comorbidities such as liver disease, renal disease, cardiovascular disease, pulmonary disease, hypertension,

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endocrine disease, diabetes mellitus, BMI, BMD, and osteoporosis were also analyzed but they were not found to be meaningful factors associated with POD in the study. There is little research on whether gender affects the occurrence of the POD. According to a study of age- and sex-related peculiarities of patients with delirium in the cardiac ICU,[34] it was shown that delirium is a severe complication that more often affects men amongst patients <65 years old and more frequently affects women in the age group of ≥ 85 years. Male patients <65 years old, who develop delirium, should be treated with more caution because they tend to have more serious forms of disorder and a poorer prognosis.[34] Age was also found to a meaningful factor to develop the POD in our study, however, sex was not found to be a meaningful risk factor of POD (Tables 5, 7).

3. Reasons for a Difference in POD

Based on our observations, there was a difference in the occurrence of delirium between ACDF and laminoplasty in the study. We potentially suggest the reason why the incidence of POD was higher following laminoplasty than ACDF as follows.

The preoperative mJOA score was 12.43/18 in the laminoplasty group and that of the ACDF group was 15.16/18. The preoperative mJOA score was statistically significantly lower in the laminoplasty group ($p<0.001$; 95% CI, -3.726 to -1.735) (Table 2), suggesting the preoperative neurological status in the patients who underwent laminoplasty was worse and this status might influence the development of POD. In addition, the operation levels were 1.93 levels in the ACDF group and 3.13 levels in the laminoplasty group on average. This indicates wider and more extensive surgical area in the patient group that underwent laminoplasty. These patients would have considered the operation to be more dangerous and this might have affected the results. Furthermore, 74 patients underwent laminoplasty mainly due to the symptoms of myelopathy, characterized by hand clumsiness, gait disturbance, and bowel or bladder dysfunctions, while the other group of patients underwent ACDF mainly due to symptoms of myeloradiculopathy (77%) accompanied by radiculopathy and mild myelopathy. For these reasons, we inferred that the incidence of POD was relatively higher in the laminoplasty group than in the ACDF group, which was commonly performed in cervical spine surgery. Further studies are required to determine whether these reasons actually contributed to the incidence of POD.

4. Diagnosis and Treatment of the POD

In this study, we tried to diagnose POD using the diagnostic criteria and methods currently in practice at the clinical site (Diagnostic and Statistical Manual of Mental disorders, 5th version, DSM-5),[35,36] and tried to double-check it through consultation with neurology or psychiatry, the specialty of the disease.

According to the guidance of the specialists, various treatments, ranging from drug treatment to supportive therapy, were carried out depending on the degree of the patient's symptoms. The treatment of POD combines drug therapy and supportive treatment for the situation.[9,37] First of all, it is necessary to secure hemodynamic stability and correct electrolyte imbalance after surgery. If the symptoms are not severe, and in the early stages, it continuously provides information on time, place, and person, and creates an environment where patients can sleep without interruption during bedtime. Early ambulation and movement can also help treat patients, and it is also necessary to create an environment to help patients recover by using the items needed for each patient.

5. Limitations

This study has some limitations as follows. First, this study, as a retrospective study, has a limitation in that the sample size was not sufficiently large because the study was conducted at a single institution. Also, the retrospective nature limited acquisition of standardized data on postoperative pain, which can be a risk factor of POD. Second, as in this study, as far as authors know, there are very few research methods that objectively evaluate the preoperative cognitive function of patients. All of the patients who participated in this study showed no cognitive dysfunction in the preoperative evaluation according to the criteria of DSM-5 and CAM. However, objectively assessing the cognitive status of patients before surgery, along with objectively assessing the cognitive function of patients after surgery, can be one of the key factors in determining the results of the study associated with POD. Third, although we intended to compare and analyze factors affecting the POD according to the method of surgery in DCM, we'd like to emphasize that we can create a bias in the interpretation of the results by not including all factors that may be related to the occurrence of POD. Moreover, we concede that although patients had same diagnosis, underlying etiologies and baseline characteristics such as severity of preoperative symptoms, levels requiring treatment were insufficiently standardized for analysis and this can create bias. In future studies, there should be stricter conditioning for confounders, such as matching or weighting in larger numbers. In addition, in the course of analyzing the factors affecting the occurrence of POD between surgical methods, the incidence of

POD unexpectedly lowers in ACDF (n = 5), making it difficult to statistically analyze the associated factors and have a statistical meaning with it. We look forward to further research on this. Lastly, this study also did not include other surgical methods for DCM, such as posterior laminectomy and fusion or ACF, due to the small number of cases. As it is not easy to review the characteristics depending on all surgical methods for DCM, this study was focused on laminoplasty, which is regarded as one of the most common surgical procedures in Asia for DCM.

CONCLUSION

It is important for surgeons to understand various factors that can affect the development of POD in patients with DCM, which can help to potentially prevent its occurrence.

NOTES

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ORCID

Seok Woo Kim: 0000-0003-2882-4477
Jeongseob lim: 0000-0002-1995-0749

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