Asian Spine Journal
Clinical Study
Asian Spine J 2023;17(6):1035-1042 • https://doi.org/10.31616/asj.2023.0093

Spinal Deformity, Surgery at the Cervicothoracic Junction, and American Society of Anesthesiologists Class Increase the Risk of Post-surgical Intensive Care Unit Treatment after Dorsal Spine Surgery: A Single-Center Multivariate Analysis of 962 Patients

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Study Design: This was a retrospective multivariate analysis of preoperative risk factors leading to intensive care unit (ICU) admissions in patients undergoing elective or acute dorsal spine surgery.

Purpose: Numerous studies have predicted a substantial increase in spine surgeries within the next decades, potentially overwhelming hospitals' resources, including ICU occupancy. Accurate estimates of whether patients need postsurgical ICU treatment are pivotal for both resource allocation and patient safety.

Overview of Literature: Risk factors leading to ICU admissions after dorsal spine surgery have been extensively examined for lumbar elective surgery. Studies including other anatomical segments of the spine and nonelective surgery regarding postsurgical ICU treatment probability are lacking.

Methods: This study was designed to be a single-center multivariate analysis of data retrospectively collected from a tertiary care university hospital. Patients undergoing dorsal spine surgery from 2009 to 2019 were included in this study. The patients' demographic data were analyzed to determine potential preoperative risk factors for ICU admission after surgery using multiple logistic regression.

Results: In our cohort, 962 patients with a mean age of 71.1±0.55 years were included. Surgeries involved 3.24±0.08 spinal levels on average. The incidence of ICU treatment after surgery was 30.4% (n=292). Multivariate logistic regression showed a markedly increased odds ratio (OR) for patients undergoing surgery of the cervicothoracic junction (OR, 8.86) and those undergoing surgery for spinal deformity treatment (OR, 7.7). Additionally, cervical procedures (OR, 3.29), American Society of Anesthesiologists (ASA) class 3–4 (OR, 2.74), spondylodiscitis (OR, 2.47), fusion of ≥3 levels (OR, 1.94), and age >75 years (OR, 1.33) were associated with an increased risk of postsurgical ICU admission.

Conclusions: The findings highlight the relevance of anatomical location, preoperative diagnosis, ASA class, and length of surgery regarding the predictability of postoperative ICU admission. Our data allowed for more sophisticated estimates regarding the need for ICU treatment after dorsal spine surgery, guiding the surgeon through patient selection, communication, and ICU admission predictability.

Keywords: Cervicothoracic junction; Spinal deformity; Spine surgery; Intensive care unit admission; Risk factors

Received Mar 23, 2023; Revised May 17, 2023; Accepted Jun 18, 2023
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Asian Spine Journal • pISSN 1976-1902 eISSN 1976-7846 • www.asianspinejournal.org

Introduction

Originating from tuberculosis treatment, dorsal spine surgery evolved from a narrow spectrum of indications, including unstable spinal stenosis or segmental instability. Today, it is an established treatment modality for a growing number of highly specialized procedures and indications [1,2]. In fact, over the past decades, a substantial increase in the number of performed dorsal fusions has been reported globally [3,4]. In particular, the number of spine surgeries for degenerative conditions, such as degenerative cervical myelopathy, being the most common nontraumatic spinal pathology, reflects this growth [5]. Because dorsal fusion has been proven to be effective in alleviating pain and improving functional outcomes, the development of new surgical techniques alongside the growing global life expectancy will amplify the demand for spine surgery in general and hence dorsal fusion [6,7]. A recently published study suggested future challenges for healthcare systems because of increasing case numbers of spine surgeries, advocating for a judicious use of the available financial and human resources [8].

The recent coronavirus disease 2019 (COVID-19) pandemic has highlighted the fragility of the capacity of healthcare systems regarding major elective surgical procedures, prompting calls for a triage system for spine surgery [9]. In particular, surgical procedures requiring postsurgical intensive care unit (ICU) treatment are prone to strain a hospital's resources. As of today, elective surgical procedures account for 13.4% of overall ICU admissions [10]. The considerable increase in age and concomitant age-related comorbidities among patients undergoing spine surgery implies a higher demand for postsurgical ICU treatment in the future. This affects not only the general occupancy of ICUs but also the associated budgeting and planning, particularly for elective dorsal spine surgery. Insufficient planning of the capacity of ICUs frequently leads to the cancelation or postponement of a surgical procedure which—besides the economically devastating potential standstill in the operation room—has been linked to a lower patient satisfaction and can deteriorate the patient's condition [11]. Considering the finite nature and significance of ICUs, particularly their capacity, conservative planning seems imperative. However, the economic incentives of progressive planning are undeniable. In particular, unnecessarily canceled surgeries carry other potential risks, once more highlighted by the COVID-19 pandemic [12]. Although postoperative ICU monitoring after spine surgery has not been attributed to be a main contributor to an increase in costs, the aging population and the continuous rise in costs of critical care medicine might alter that in the near future [13].

Several efforts have been made to predict postsurgical complications after elective spine surgery. Age, cardiovascular comorbidities, obesity, and surgical invasiveness have been described as the main contributors to postsurgical complications [14,15]. Although the potential need for postsurgical ICU treatment can indirectly be extrapolated, data analyzing the postsurgical ICU admission rate after dorsal fusion are scarce. To the best of our knowledge, only one study analyzing the effects of preoperative factors on the probability of postsurgical ICU admission has been published so far [16]. However, the authors only included patients with degenerative spine deformities of the lumbar spine and did not consider other preoperative parameters, such as diagnosis and the vertebral level.

This study aimed to identify predictive preoperative factors affecting the probability of patients requiring postsurgical ICU treatment after dorsal surgical procedures of the spine.

Materials and Methods

1. Patients

This study was a retrospective analysis of patient data collected between 2009 and 2019 at a university clinic. Patients aged >18 years undergoing dorsal spine surgery with dorsal instrumentation were included in this study. More precisely, we included both elective (i.e., degenerative and spinal deformity) and nonelective spine surgeries (i.e., trauma, malignancies, and spondylodiscitis). Surgical procedures without the implant of screws and rod constructs, that is, discectomies and surgical decompressions without dorsal instrumentation, were excluded. Data were obtained from the surgical and anesthesiologic databases and the corresponding digital patient charts. Demographic variables included age, sex, preoperative diagnoses, vertebral level, and the details of the procedure. Comorbidities were accounted for the use of the grading system of the American Society of Anesthesiologists (ASA) [17]. Additionally, we acquired hospitalization data based on previous spine surgeries, ICU treatment, and mortality depicted as categorical variables and the duration of both

ICU treatment and total inpatient stay.

Degenerative diagnoses included disk herniations, spinal canal stenosis, spondylolisthesis, and osteochondrosis. Spinal deformities included any deformity of the spine (idiopathic or degenerative scoliosis and sagittal malalignment). Postsurgical complications consisted of adjacent joint degeneration, material insufficiency or misplacement, and non-fusion after previous dorsal fusion. The procedures performed included dorsal instrumentation plus decompression, transforaminal/posterior lumbar interbody fusion (TLIF/PLIF), hybrid kyphoplasty, and simultaneous corpectomy.

Surgeries overlapping different segments of the spine were classified as surgeries of the respective junction (i.e., T10–L3 would be considered surgery at the thoracolumbar junction).

For the ICU data, any ICU or intermediate care unit treatment was included. The final decision on whether a patient required postsurgical ICU treatment was at the discretion of the attending anesthesiologist. Reasons included postsurgical hypotension requiring invasive blood pressure monitoring, prolonged weaning of catecholamines or ventilation, necessity for noninvasive ventilation, decompensated electrolyte imbalances, postsurgical delirium, and blood loss leading to hemodynamic instability. An extended length of surgery alone was not considered a criterion for ICU admission if the patient did not present symptoms of hemodynamic or respiratory instability. All surgeries were performed by the hospitals' group of experienced and specialized spine surgeons.

Data were pseudonymously collected according to national laws and the 1975 Declaration of Helsinki. In total, 962 patients matched the criteria to be included in our study group. The study was approved by the Institutional Review Board (IRB-07742). Informed consent from individual participants was omitted because of the retrospective design of this study.

2. Statistical analysis

Continuous variables are depicted as means±standard error of the mean or as the number of cases with percentages for categorical variables. Postoperative ICU treatment at any point after the procedure was recorded for each patient. Continuous variables were analyzed using Student *t*-test or the Mann-Whitney *U* test for nonnormally distributed variables. The chi-square test or Fisher's exact test was used to compare categorical parameters when appropriate. *p*-values <0.05 were used to denote statistical significance. All statistical calculations and analyses were performed using GraphPad Prism ver. 9.5.0 (GraphPad Software, Boston, MA, USA).

For the multivariate regression, the initial identification of potential risk factors was assessed using the chi-square test and Fisher's exact test. Because multiple tests of the same data can artificially inflate the alpha, thus causing type I errors, we opted for a multivariate model. To account for confounding effects, precisely covariances between explanatory variables, we included all parameters with a potential correlation, as reflected by a *p*-value <0.1 from our initial analysis, in the multiple logistic regression model [18].

Results

1. Patient population

The mean age of the 962 patients included in this study was 71.1±0.55 years on the day of surgery. Furthermore, 53.2% (n=512) of the patients were female (Table 1). The most frequently operated anatomic location (Table 2) was the lumbar spine (n=294, 30.5%), followed by the thora-

Table 1. Patient demographics and general surgical information

Characteristic	Value
Total no. of patients	962
Age (yr)	71.1±0.55
>75	505 (52.5)
Gender	
Male	450 (46.8)
Female	512 (53.2)
ASA class (n=933)	
1	73 (7.8)
2	394 (42.2)
3	423 (45.3)
4	43 (4.6)
Previous spine surgery	332 (34.5)
Operated levels	3.24±0.07
>3	464 (48.2)
>5	186 (19.4)
CSF leaks	42 (4.4)

Values are presented as number, mean±standard error of the mean, or number (%). ASA class was available for 933 patients.
ASA, American Society of Anesthesiologists; CSF, cerebrospinal fluid.

Table 2. Anatomical location of the performed surgical procedures and the respective length of fusion (n=962)

Variable	No. (%)	Mean length of fusion±SEM
Occipital-cervical	8 (0.8)	4.1±0.8
Cervical	39 (4.0)	1.8±0.2
Cervical-thoracic	36 (3.7)	5.8±0.5
Thoracic	143 (14.8)	4.1±0.2
Thoracic-lumbar	233 (24.2)	4.8±0.2
Lumbar	294 (30.5)	1.9±0.1
Lumbar-sacral	185 (19.2)	2.2±0.1
Thoracic-sacral	24 (2.5)	6.1±0.6

The first column includes the frequency distribution with fraction of total (%). The second column shows the average amount of operated spinal levels with SEM.
SEM, standard error of the mean.

Table 3. Preoperative indications for surgical procedures (n=962)

Variable	No. (%)
Trauma	324 (33.7)
Degeneration	282 (29.3)
Fusion related complications	144 (15.1)
Inflammation	107 (11.1)
Spinal deformity	61 (6.3)
Tumor	44 (4.6)

Table 4. Performed procedures and additional procedures (n=962)

Variable	No. (%)
Dorsal fusion only	350 (36.4)
+ PLIF/TLIF	324 (33.7)
+ Decompression	257 (26.7)
+ Kyphoplasty	21 (2.1)
+ Corpectomy	10 (1.0)

PLIF, posterior lumbar interbody fusion; TLIF, transforaminal interbody fusion.

columbar junction (n=233, 24.2%). The mean number of operated levels was 3.24±0.08. Moreover, 332 patients (34.5%) had undergone previous spine surgery. Trauma (n=324, 33.7%) was the most common indication for dorsal spine surgery (Table 3). The exact procedures performed are depicted in Table 4. In total, 42 (4.3%) cerebrospinal fluid leakages were reported. Furthermore, 30.4% (n=292) of the patients were admitted to the ICU postoperatively with a mean length of stay of 3.3±0.4 days (Table 5). The mean length of inpatient stay was 15.78±0.38 days.

Table 5. Hospital data, including the duration of the stay, mortality, and ICU admissions (n=962)

Variable	Value
Duration of stay	15.78±0.38
ICU admission	292 (30.4)
ICU days spent	3.3±0.4
Mortality	20 (2.1)

Values are presented as mean±standard error of the mean or number (%).
ICU, intensive care unit.

Patients requiring ICU treatment during hospitalization had a significantly longer length of stay than those who did not require ICU treatment (p<0.0001; 20.01±0.9 days versus 13.95±0.35 days). The patients' most frequent ASA classes were ASA II (42.2%, n=394) and ASA III (45.3%, n=423). ASA I accounted for 7.8% (n=73) of the patients. Meanwhile, ASA 4 accounted for 4.6% (n=43) of the patients.

2. Stepwise multiple logistic regression

Univariate analysis of demographic and surgical data yielded significant results for several parameters that were subsequently included in the stepwise multivariate logistic regression (Table 6). Regarding demographics, sex (p=0.0026), ASA class III–IV (p<0.0001), and age >75 years (p=0.027) were included in the multivariate analysis. Furthermore, surgery covering >3 vertebral levels (p<0.0001) and previous spine surgery (p=0.029) were found to be potential risk factors. Procedures including additional surgical decompression via laminectomy (p<0.0001), interbody fusion (p<0.0001), and surgeries for degenerative pathologies (p<0.0001), spinal deformities (p<0.0001), postsurgical complications (p=0.007), and spondylodiscitis were included in the multivariate regression model. Finally, the vertebral level showed interactions with surgeries of the cervical spine (p=0.016), the cervicothoracic junction (p<0.0001), and surgeries with a rostrocaudal expansion, including the thoracic and sacral spines, among others.

The results of the multiple logistic regression indicated that the probability of patients with ASA class 3 or 4 to require postsurgical ICU treatment was 2.74 folds higher than that of patients with ASA class 1 or 2 (odds ratio [OR]). Additionally, a fusion including ≥3 levels (OR, 1.94) and age >75 years (OR, 1.33) affected the probability of necessary ICU treatment.

Table 6. Results of the multivariate logistic regression

Variable	Univariate analysis *p*-value	Multivariate analysis OR (95% CI)
Gender	0.0026	0.78 (0.56–1.09)
ASA III–IV	<0.0001	**2.74* (1.93–3.93)**
Age >75 yr	0.027	1.33 (0.94–1.89)
>3 Levels	<0.0001	**1.94* (1.28–2.96)**
Revision surgery	0.029	1.05 (0.68–1.63)
Procedures		
PSIF only	0.0058	0.57 (0.26–1.32)
PSIF + decompression	<0.0001	0.63 (0.28–1.47)
PSIF + PLIF/TLIF	<0.0001	0.39 (0.16–0.94)
Reason for surgery		
Degenerative	<0.0001	1.02 (0.59–1.76)
Spinal deformity	<0.0001	**7.75 (3.85–16.06)**
Postsurgical complications	0.007	0.57 (0.29–1.09)
Spondylodiscitis	<0.0001	**2.47 (1.48–4.14)**
Vertebral level		
Cervical	0.016	**3.29 (1.49–7.24)**
Cervical-thoracic	<0.0001	**8.86 (3.57–25.45)**
Thoracic	0.0021	1.35 (0.83–2.19)
Lumbar	0.0001	0.76 (0.44–1.31)
Lumbar-sacral	0.0003	1.04 (0.57–1.91)
Thoracic-sacral	0.0004	**4.18 (1.37–13.31)**

The initial identification of potential risk factors was assessed using analysis with chi-square and Fisher's exact test. Afterwards, multivariate logistic regression was conducted for factors with $p<0.1$ (middle column) from the initial, univariate analysis. The multiple logistic regression was then performed to identify potential risk factors leading to an intensive care unit admission (right column). Statistically significant results are marked in bold.
OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists; PSIF, posterior spinal instrumentation and fusion; TLIF, transforaminal interbody fusion.

Patients undergoing surgery at the cervicothoracic junction had the highest risk of requiring postsurgical ICU treatment (OR, 8.86), followed by those undergoing surgery at the thoracosacral area (OR, 4.18) and those undergoing surgery at the cervical spine (OR, 3.29).

Spinal deformities (OR, 7.7) and spondylodiscitis (OR, 2.47) were associated with an increased risk of requiring ICU treatment. While spinal deformities showed a significantly higher number of operated levels (2.9±0.07 versus 7.7±0.47, $p<0.0001$) than other diagnoses, this was not the case for surgeries due to spondylodiscitis (2.9±0.16 versus 3.3±0.09, $p=0.09$).

Revision surgery (OR, 1.05) and sex (OR, 0.78) were not associated with higher probability of ICU admission.

Discussion

The aim of this retrospective analysis was to identify risk factors affecting the probability of ICU treatment after dorsal spine surgery. Furthermore, we strived to pay tribute to the broad range of diagnoses for dorsal spine surgery—past the exclusive evaluation of degenerative pathologies of the lumbar spine. Our results highlighted the relevance of the ASA classification as a pragmatic and accessible parameter for estimating whether a patient requires postsurgical ICU admission. Additionally, they revealed the vertebral level, as underscored by the markedly increased OR of the cervicothoracic junction, and the preoperative diagnoses, that is, spondylodiscitis and spinal deformities, as independent risk factors for postsurgical ICU treatment.

Throughout the decades, dorsal instrumentation of the spine has been established as a safe and efficient therapy. Today, it is a cornerstone of spine surgery. Starting from a narrow set of indications, the development of new techniques and equipment has broadened the spectrum of indications, from TLIF/PLIF with additive dorsal instrumentation, to percutaneous dorsal fusion, to complex corrective spondylodesis and hybrid treatments [19,20].

Owing to the increasing global life expectancy, a substantial growth in degenerative diseases of the spine necessitating dorsal spine surgery and a concomitant increase in comorbidities among patients have been predicted. In fact, models for Japan, which has the most pronounced aging population worldwide, predict a marked increase in comorbidities per capita within the next 2 decades [21]. These findings are supported by a longitudinal study on lumbar spine surgery indicating a rise in both patient age and ASA class within the last decade [22]. Both have been associated with higher mortality and higher incidence of complications for spine and surgical treatment in general [23,24]. Our results, associating higher ASA classes and age >75 years with higher probability of postsurgical ICU admission, align with these findings. Regarding demographic societal changes, these findings suggest higher ICU use attributed to spine surgery within the next decades, potentially challenging current ICU capacities. Furthermore, they might add an economic dimension because the costs for spine surgery have been surging over the past decades [25].

The results of our regression analysis revealed that the vertebral location of the surgery is an additional risk factor for postsurgical ICU admission. Patients undergoing dorsal fusion at the cervicothoracic junction showed an increased probability of postsurgical ICU admission, without showing a significant difference in the length of fusion compared with the thoracolumbar junction (p=0.09). The inclusion of the cervicothoracic junction has been associated with increased blood loss, longer time of surgery, and higher wound dehiscence rate, potentially explaining this marked increase in postsurgical ICU admissions [26,27]. The general length of fusion, which has been shown to be more invasive, might be a satisfactory explanation for the increased probability of ICU admissions for patients undergoing fusion from the thoracic spine to the pelvis (OR, 4.18; 6.1±0.6) or spinal deformities (OR, 7.7; 7.7±0.47) [28]. However, accepting it as the only associated factor was challenged by patients undergoing dorsal surgery of the cervical spine in our study group (OR, 3.29; 1.8±0.2). In fact, a recent study proposed re-evaluating the invasiveness index of surgeries for cervical spine deformities to reflect their complexity [29].

Lastly, our data suggest a higher probability (OR, 2.47) for patients with spondylodiscitis to require ICU treatment after surgery. This finding once again emphasizes the severity of this pathology with substantial short- and long-term mortality and underlines the critical conditions the patients are in [30].

This study has some limitations because of its retrospective design. In particular, a detailed assessment of comorbidities and a more detailed assessment of perioperative blood loss and surgery time would have allowed for a more in-depth analysis. However, we aimed to identify preoperative factors that affect the probability of ICU treatment after dorsal spine surgery. Furthermore, the decision on whether patients required ICU treatment presents a limitation because the anesthesiologists might have admitted patients with known risk factors (i.e., higher ASA classes and surgery >3 levels) as a safety measure. Despite these limitations, the study incorporated a large group of patients from a maximum care provider, allowing for a reliable multivariate analysis.

Because of its complex patient flow variability, ICU capacity is a bottleneck for larger elective spine surgery, and a limited ICU capacity can be a contributor for postponements and their impact on patient dissatisfaction and negative economic consequences for the hospital. Therefore, accurate predictions for the postoperative need for ICU treatment are pivotal. Although the multicausal decision for the predicted necessity must be reevaluated for each patient individually, the results from our multivariate analysis highlighted the relevance of the well-established ASA class as a preoperative risk evaluation tool for postsurgical ICU admission. Despite including nonelective spine surgeries and the vertebral location, the ASA class remained a reliable and independent predictor of postsurgical ICU admission. Although the comorbidities, patient age, and intended length of fusion represent the foundation of every presurgical risk assessment, we advocate considering other factors, that is, preoperative diagnoses and the vertebral location, as suitable and pragmatic parameters to estimate the postsurgical need for ICU treatment.

As of today, elective spine surgery does not substantially affect the ICU occupancy. However, because the demographic change toward an aging society and the growing demand for spine surgery are inevitable, optimization of resource efficiency is imperative. This necessity is highlighted by the potential relapse of COVID-19-associated lockdowns of elective surgeries. Simultaneously, frailty research should be intensified and multidisciplinary treatment options should be advanced to face the challenges of an aging society.

Conclusions

Our results emphasize the significance of preoperative ASA class assessment. Furthermore, our regression identified surgery involving the cervicothoracic junction, spinal deformities, and spondylodiscitis as independent risk factors. Our data allowed for more sophisticated predictions of the need for ICU treatment after dorsal spine surgery, aiding surgeons in patient selection, communication, and ICU occupancy predictability.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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References

1. Knoeller SM, Seifried C. Historical perspective: history of spinal surgery. Spine (Phila Pa 1976) 2000;25:2838-43.
2. Hanley EN Jr. The indications for lumbar spinal fusion with and without instrumentation. Spine (Phila Pa 1976) 1995;20(24 Suppl):143S-153S.
3. Grotle M, Smastuen MC, Fjeld O, et al. Lumbar spine surgery across 15 years: trends, complications and reoperations in a longitudinal observational study from Norway. BMJ Open 2019;9:e028743.
4. Reisener MJ, Pumberger M, Shue J, Girardi FP, Hughes AP. Trends in lumbar spinal fusion: a literature review. J Spine Surg 2020;6:752-61.
5. Carr DA, Abecassis IJ, Hofstetter CP. Full endoscopic unilateral laminotomy for bilateral decompression of the cervical spine: surgical technique and early experience. J Spine Surg 2020;6:447-56.
6. Heller C, Sperlich S, Tetzlaff F, et al. Living longer, working longer: analysing time trends in working life expectancy in Germany from a health perspective between 2002 and 2018. Eur J Ageing 2022;19:1263-76.
7. Kurra S, Lavelle WF, Silverstein MP, Savage JW, Orr RD. Long-term outcomes of transforaminal lumbar interbody fusion in patients with spinal stenosis and degenerative scoliosis. Spine J 2018;18:1014-21.
8. Heck VJ, Klug K, Prasse T, et al. Projections from surgical use models in Germany suggest a rising number of spinal fusions in patients 75 years and older will challenge healthcare systems worldwide. Clin Orthop Relat Res 2023 Feb 10 [Epub]. https://doi.org/10.1097/CORR.0000000000002576
9. Donnally CJ 3rd, Shenoy K, Vaccaro AR, Schroeder GD, Kepler CK. Triaging spine surgery in the COVID-19 era. Clin Spine Surg 2020;33:129-30.
10. Poeran J, Zhong H, Wilson L, Liu J, Memtsoudis SG. Cancellation of elective surgery and intensive care unit capacity in New York State: a retrospective cohort analysis. Anesth Analg 2020;131:1337-41.
11. Caesar U, Karlsson J, Olsson LE, Samuelsson K, Hansson-Olofsson E. Incidence and root causes of cancellations for elective orthopaedic procedures: a single center experience of 17,625 consecutive cases. Patient Saf Surg 2014;8:24.
12. Norris ZA, Sissman E, O'Connell BK, et al. COVID-19 pandemic and elective spinal surgery cancelations: what happens to the patients? Spine J 2021;21:2003-9.
13. Halpern NA. Can the costs of critical care be controlled? Curr Opin Crit Care 2009;15:591-6.
14. Lee MJ, Konodi MA, Cizik AM, Bransford RJ, Bellabarba C, Chapman JR. Risk factors for medical complication after spine surgery: a multivariate analysis of 1,591 patients. Spine J 2012;12:197-206.
15. Schoenfeld AJ, Ochoa LM, Bader JO, Belmont PJ Jr. Risk factors for immediate postoperative complications and mortality following spine surgery: a study of 3475 patients from the National Surgical Quality Improvement Program. J Bone Joint Surg Am 2011;93:1577-82.
16. Kay HF, Chotai S, Wick JB, Stonko DP, McGirt MJ, Devin CJ. Preoperative and surgical factors associated with postoperative intensive care unit admission following operative treatment for degenerative lumbar spine disease. Eur Spine J 2016;25:843-9.
17. Daabiss M. American Society of Anaesthesiologists physical status classification. Indian J Anaesth 2011;55:111-5.
18. Sperandei S. Understanding logistic regression analysis. Biochem Med (Zagreb) 2014;24:12-8.
19. Cho SK, Safir S, Lombardi JM, Kim JS. Cervical spine deformity: indications, considerations, and surgical outcomes. J Am Acad Orthop Surg 2019;27:e555-67.
20. Lenz M, Mohamud K, Bredow J, Oikonomidis S, Eysel P, Scheyerer MJ. Comparison of different approaches in lumbosacral spinal fusion surgery: a systematic review and meta-analysis. Asian Spine J 2022;16:141-9.
21. Chen BK, Jalal H, Hashimoto H, et al. Forecasting trends in disability in a super-aging society: adapting the future elderly model to Japan. J Econ Ageing 2016;8:42-51.

22. Oezel L, Okano I, Hughes AP, et al. Longitudinal trends of patient demographics and morbidity of different approaches in lumbar interbody fusion: an analysis using the American College of Surgeons National Surgical Quality Improvement Program Database. World Neurosurg 2022;164:e183-93.
23. Somani S, Capua JD, Kim JS, et al. ASA classification as a risk stratification tool in adult spinal deformity surgery: a study of 5805 patients. Global Spine J 2017;7:719-26.
24. Hackett NJ, De Oliveira GS, Jain UK, Kim JY. ASA class is a reliable independent predictor of medical complications and mortality following surgery. Int J Surg 2015;18:184-90.
25. Cortesi PA, Assietti R, Cuzzocrea F, et al. Epidemiologic and economic burden attributable to first spinal fusion surgery: analysis from an Italian Administrative Database. Spine (Phila Pa 1976) 2017;42:1398-404.
26. Charest-Morin R, Bailey CS, McIntosh G, et al. Does extending a posterior cervical fusion construct into the upper thoracic spine impact patient-reported outcomes as long as 2 years after surgery in patients with degenerative cervical myelopathy? J Neurosurg Spine 2022 May 6 [Epub]. https://doi.org/10.3171/2022.3.SPINE211529
27. Huang KT, Harary M, Abd-El-Barr MM, Chi JH. Crossing the cervicothoracic junction in posterior cervical decompression and fusion: a cohort analysis. World Neurosurg 2019;131:e514-20.
28. Mirza SK, Deyo RA, Heagerty PJ, et al. Development of an index to characterize the "invasiveness" of spine surgery: validation by comparison to blood loss and operative time. Spine (Phila Pa 1976) 2008;33:2651-62.
29. Passias PG, Horn SR, Soroceanu A, et al. Development of a novel cervical deformity surgical invasiveness index. Spine (Phila Pa 1976) 2020;45:116-23.
30. Kehrer M, Pedersen C, Jensen TG, Hallas J, Lassen AT. Increased short- and long-term mortality among patients with infectious spondylodiscitis compared with a reference population. Spine J 2015;15:1233-40.