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Original Article

Predictive factors for postoperative ıntensive care unit admission in pediatric patients undergoing scoliosis correction surgery

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Abstract: Objective: Postoperative intensive care unit (ICU) admission might be required in adolescent patients following posterior fusion and instrumentation surgery for the treatment of scoliosis. We aimed to evaluate the predictive factors for mechanical ventilation and the characteristics of the patients who required an ICU stay following spinal surgery. Methods: We retrospectively reviewed the records of 85 children undergoing primary scoliosis surgery at a university-affiliated general hospital from January 2010 and June 2020 by the same spinal surgeon. The demographic data, pre- and peritoperative variables were collected and recorded. All patients underwent surgery with a combined anesthesia protocol of fentanyl and remifentanil. Results: There were 31 males (36.5%) and 54 females (63.5%). In the postoperative period, 13 patients (15.3%) were admitted to the ICU, and six of them required mechanical ventilation. Among these, three patients (50%) were extubated within the postoperative 0-12 hours, two (33.3%) within postoperative 12-24 hours, and one (16.7) after postoperative 24 hours. The major complications included acidosis (4.7%), hemodynamic instability (1.2%), hypercapnia (1.2%), hypoxemia (1.2%), and delayed extubation (1.2%). Conclusions: A smaller bodyweight percentile, neuromuscular etiology, abnormal findings in preoperative chest X-ray, additional comorbidities, and preoperative estimated risk for postoperative mechanical ventilation were among the risk factors for postoperative ICU stay. The age, height, weight, degree of the curvature, and the number of operated segments did not have an association with the postoperative outcomes.

Keywords: Scoliosis surgery, ıntensive care unit, risk factors, posterior spinal surgery, adolescents

Introduction

Scoliosis is a lateral curvature of the spine of 10° or more, often with a rotational component. The severe cases with a higher curvature degree, which is defined with the Cobb angle, require surgical reduction [1]. With the increasing annual rate of recent cases in developing countries, scoliosis surgery including spinal fusion and instrumentation is one of the most frequently performed operations in the adolescent age group [2, 3].

The surgery for scoliosis includes the application of different types of instruments in order to provide spine alignment. Surgical treatment of scoliosis is related to a high level of blood loss and prolonged operation time which can be a cause of increased hospital stay, need for intensive care, rampant medical costs, and may lead to major complications. Thus, these patients may need admission to the intensive care unit (ICU) following surgery in order to decrease morbidity and mortality, and provide efficient recovery [4, 5].

The aim of this study is to define the demographic, structural, and systemic variables in the patients who required ICU stay following spinal surgery.

Materıals and methods

We conducted a retrospective chart review of 85 patients with scoliosis who underwent spinal fusion and instrumentation in the Orthopedics and Traumatology Clinic of Uludag University Medical, School between January 2010 and June 2020 by the same spine surgeon. The study was approved by the

Institutional Review Board (2020-11/3), and conducted in accordance with the Declaration of Helsinki. Informed consent was signed by all of the patients.

Inclusion criteria included a diagnosis of adolescent idiopathic scoliosis and a posterior spinal instrumentation and fusion surgery with either idiopathic, neuromuscular, or congenital etiology. Exclusion criteria included incomplete radiographic and clinical data, recurrent surgery, and an age of <10 and >18 years

The variables include age, gender, weight, height, preoperative Cobb angle, etiology of scoliosis, and comorbidities which were collected and recorded. Patient records were further scanned for additional pathological findings in the preoperative examinations including Gross Motor Function Test for neuromuscular scoliosis, chest X-ray, magnetic resonance imaging (MRI), electrocardiography (ECG), echocardiography, spirometric evaluations, and any anticonvulsive therapies. Intraoperative variables included the total number of instrumented spinal levels, the use of thoracoplasty, intraoperative neuromonitoring, and wake-up test.

All patients underwent surgery with a combined anesthesia protocol of 2 mcg/kg of fentanyl for induction, followed by a continuous infusion of 0.5 mcg/kg/min remifentanil. An intravenous 0.03 mg/kg morphine patient-controlled anesthesia (PCA) was started immediately before wound closure after the operation.

The patients were subgrouped in terms of a need for ICU admission following the surgery. Among them, patients who required admission to ICU were further classified into two groups for the need for mechanical ventilation. The study variables were compared between the groups, and the risk factors were evaluated. We also compared the study variables between the patients who developed a major complication in the postoperative course.

Statistical analysis

The statistical analyses of the study data were done using SPSS v.22.0 (IBM Corp, USA). The demographic variables were presented as number and percentages. The continuous variables for the comparison of study groups were presented as mean ± standard deviation. The normality of the variables was tested using a Kolmogorov-Smirnov test, and the difference between the study groups was calculated using the student's t-test. A *p*-value of <0.05 was accepted as statistically significant.

Results

The study population included 85 adolescent patients who underwent spinal instrumentation surgery for scoliosis by a single surgeon within a ten year period.

There were 31 males (36.5%) and 54 females (63.5%). Eighteen patients (21.2%) had an additional vertebral or spinal abnormality concomitant with the current condition. Forty patients (47.1%) exhibited abnormal chest X-ray findings, cardiology consultation revealed an aberrant ECG pattern in seven (8.2%), and preoperative echocardiography revealed abnormal results in 15 patients (17.6%). Eleven patients (12.9%) were under medical treatment with anticonvulsant agents due to their conditions, and the number of cases with an ASA class of III-IV was five (5.9%).

Forty-one patients (48.2%) had additional comorbidities including a forced vital capacity (FVC) of <79%, congenital heart disease, cardiomyopathy, arrhythmia, chronic renal failure, epilepsy, hemorrhagic disease, and coagulopathy. Demographic variables of the pediatric patients who underwent spinal fusion and instrumentation surgery for correction of scoliosis are presented in **Table 1**.

The preoperative evaluation estimated a postoperative ICU admission need for 60 patients (70.6%). The number of operated vertebral segments in the same session and the need for thoracoplasty were presented in **Table 2**. Seventy-three patients (85.9%) underwent intraoperative neuromonitoring during the surgery.

In the postoperative period, 13 patients (15.3%) were admitted to the ICU, and six of them required mechanical ventilation. Among these, three patients (50%) were extubated within the postoperative 0-12 hours, two (33.3%) within postoperative 12-24 hours, and one (16.7) after postoperative 24 hours (**Table 3**).

The characteristics of the patients who required an ICU stay are presented in **Table 4**. Eight cases (9.4%) experienced a major complication

Table 1. Demographic variables of the pediatric patients who underwent spinal fusion and instrumentation surgery for correction of scoliosis

	Number	%
Gender		
Male	31	36.5
Female	54	63.5
Etiology for scoliosis		
Idiopathic	64	75.3
Neuromuscular	20	23.5
Congenital	1	1.2
Additional vertebral/spinal abnormality		
Yes	18	21.2
No	67	78.8
Abnormal findings in chest X-ray		
Yes	40	47.1
No	45	52.9
Intraoperative opioid type		
Morphine	68	80.0
Remifentanyl	4	4.7
Fentanyl	13	15.3
Estimated postoperative need for ICU		
Yes	60	70.6
No	25	29.4
ASA		
I	55	64.7
II	25	29.4
III	4	4.7
IV	1	1.2
Abnormal result in spirometer testing		
Yes	1	1.2
No	4	4.7
Missing	80	94.1
Abnormal finding in ECG		
Yes	7	8.2
No	77	90.6
Missing	1	1.2
Abnormal finding in Echocardiography		
Yes	15	17.6
No	70	82.4
Anticolvulsant use		
Yes	11	12.9
No	74	87.1
Gross Motor Function Score		
1	63	74.1
2	6	7.1
3	5	5.9
4	5	5.9
5	5	5.9
Missing	1	1.2
Additional comorbidities		
Yes	41	48.2
No	44	51.8
Type of the spinal curve		
Kyphosis	10	11.8
Scoliosis	75	88.2

during the early postoperative period. The major complications included acidosis (4.7%), hemodynamic instability (1.2%), hypercapnia (1.2%), hypoxemia (1.2%), and delayed extubation (1.2%).

The comparison of variables between the patients with or without postoperative adverse events is presented in **Table 5**. The age, height, weight, preoperative Cobb angle, and the number of operated segments did not differ between the groups with or without major complications (P = 0.21, P = 0.42, P = 0.94, P = 0.75, P = 0.83, respectively), postoperative need for ICU (p = 0.72, P = 0.52, P = 0.81, P = 0.79, P = 0.89, respectively), postoperative need for mechanical ventilation (P = 0.60, P = 0.72, P = 0.92, P = 0.30, P = 0.06, respectively), and postoperative need for mechanical ventilation among ICU internalized patients (P = 0.88, P = 0.78, P = 0.38, P = 0.74, P = 0.83, respectively).

Although the number of operated segments was higher in the overall patient group who required a postoperative ICU stay, the difference did not reach statistical significance (13.17±2.79 vs 11.25± 2.82; P = 0.06).

ICU admission correlated significantly with lower body weight percentile [odds ratio (OR), 2.02 95%; confidence interval (CI) 1.96-2.04], neuromuscular etiology (OR, 1.21; 95% CI 1.10-1.32), an abnormal finding in chest X-ray (OR, 1.52; 95% CI 1.41-1.65), additional comorbidities (OR, 1.96; 95% CI 1.78-2.19), estimated postoperative need for ICU in the preoperative evaluation (OR, 2.74; 95% CI 2.38-3.06) (**Table 6**; **Figure 1**).

There were no deaths nor cases of readmission to the ICU in the studied patient group.

Discussion

Adolescent patients who undergo spinal fusion and instrumentation for scoliosis may experience high rates of postoperative complications which may require admission to an ICU and a need for mechanical ventilation. The recent data

Table 2. Intraoperative variables of the pediatric patients who underwent spinal fusion and instrumentation surgery for correction of scoliosis

Number of operated segments		
5	2	2.4
6	4	4.7
7	2	2.4
8	6	7.1
9	4	4.7
10	10	11.8
11	16	18.8
12	14	16.5
13	8	9.4
14	3	3.5
15	8	9.4
16	8	9.4
Thoracoplasty		
Yes	6	7.1
No	78	91.8
Missing data	1	1.2
Intraoperative Neuromonitoring		
Yes	73	85.9
No	12	14.1

Table 3. Postoperative variables of the pediatric patients who underwent spinal fusion and instrumentation surgery for correction of scoliosis

Postoperative need for ICU		
Yes	13	15.3
No	72	84.7
Postoperative need for mechanical ventilation		
Yes	6	46.2
No	7	53.8
Time for extubation		
0-12 hours	3	50
12-24 hours	2	33.3
>24 hours	1	16.7
Major complication		
Yes	69	81.2
No	16	18.8

available on the characteristics of patients who required an ICU admission following scoliosis surgery is limited.

A recent study by Chhabra et al reported that post-operative ventilation may be required in 20-35% of patients undergoing various correction procedures for the management of scoliosis [6]. However, as reported in our study, 15.3% of the patients admitted to the ICU, and 7.0% of them were intubated. All intubated patients except one with hypoxemia were extubated within postoperative 24 hours. Also, the ages of the patient groups in their cohort were younger than our patients, being 8.1±2.1 years for growth rod insertion, 12.9±1.7 years for anterior release procedures, and 14.2±2.2 years for posterior fusion and instrumentation. The mean age of our cases who required an ICU stay was 15.58±1.75 years in our study group. Furthermore, all cases in our cohort underwent posterior instrumentation and fusion for scoliosis treatment.

Among patient-related variables, we noted that a high ratio of the patients (10/13) who required a postoperative ICU stay had additional comorbidities including a decreased FVC, congenital heart disease, cardiomyopathy, arrhythmia, chronic renal failure, epileptic seizures, and hematological conditions. Furthermore, six out of thirteen ICU patients had an abnormal chest X-ray finding prior to the surgery. On the other hand, we found that the ASA score was not a predictive factor in our study group, and none of the patients with an ASA score of III-IV required an ICU stay following the surgery. Also, one out of seven patients, an epileptic male patient with regular use of anticonvulsants with an aberrant ECG pattern during the preoperative evaluation studies was followed-up in the ICU without extubation.

It is widely accepted that patients with developmental delay are more prone to ICU admission in the postoperative period [7]. Among our cases, six out of thirteen ICU patients had a body weight and height of less than the 5th percentile, and three of them were intubated. Noteworthy is that the common etiology for intubation was acidosis in these patients, and five had concomitant morbidity.

The patients with a neuromuscular etiology are in the high-risk group for ICU admission, the requirement of mechanical ventilation, delayed extubation, and postoperative complications, given the weakness of muscles in respiratory

Table 4. Characteristics of the cases that required ICU stay following the surgery

	Patient #1	Patient #2	Patient #3	Patient #4	Patient #5	Patient #6	Patient #7	Patient #8	Patient #9	Patient #10	Patient #11	Patient #12	Patient #13
Age	18	14	18	14	15	13	15	17	13	12	18	17	16
Gender	M	F	M	F	M	F	M	F	F	M	M	F	M
Body weight percentile	58	86	31	<1	<1	<1	58	9	<1	<1	96	2	61
ASA	2	2	1	1	1	1	2	3	3	2	2	2	2
Etiology of scoliosis	Congenital/ Structural	Idiopathic	Idiopathic	Idiopathic	Idiopathic	Idiopathic	Neuromuscular	Neuromuscular	Idiopathic	Neuromuscular	Neuromuscular	Neuromuscular	Idiopathic
Spinal cord abnormality	Yes	No	No	No	No	Yes	No	No	No	No	No	Yes	No
Preoperative Cobb angle	50	52	45	45	48	51	50	52	45	45	48	51	50
Abnormal finding in chest X-ray	Yes	No	No	No	No	Yes	No	No	Yes	Yes	Yes	Yes	No
Preoperative estimation for postoperative ICU stay	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
ICU condition	Extubated	Intubated	Intubated	Intubated	Intubated	Extubated	Extubated	Extubated	Intubated	Extubated	Intubated	Extubated	Extubated
Time of extubation	-	0-12 h	12-24 h	12-24 h	0-12 h	-	-	-	>24 h	-	0-12 h	-	-
Aberrant ECG pattern	Yes	No	No	No	No	No	No	No	No	No	No	No	No
Abnormal echocardiogram	Yes	N/A*	Yes	N/A	N/A	Yes	Yes	Yes	N/A	N/A	N/A	N/A	N/A
Anticonvulsant use	Yes	No	No	No	No	No	No	Yes	No	No	No	No	No
Gross Motor Function Score	1	1	1	4	1	2	1	1	1	3	1	1	1
Operated levels	T12-S1	T2-T12	T2-L3	T12-L3	T2-T12	T2-L3	T2-S1	T2-L5	T2-S1	T2-L4	T4-L5	T9-L4	T2-L3
IONM**	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Additional comorbidity	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Major complication	Implant failure	Hemodynamic instability	Acidosis	Acidosis	Acidosis	None	Hypercapnia	Delayed extubation	Hypoxemia	None	Hypotension	None	Acidosis

*N/A: Echocardiogram was not performed. **Intraoperative neuromonitoring.

Table 5. Comparison of variables between the patients with or without postoperative adverse events

		Yes	No	*p* value
Major complications	Age (years)	16.06±1.84	15.43±1.78	0.21
	Height (cm)	143.75±20.25	148±20.2	0.42
	Weight (kg)	40.81±14.86	42.33±17.66	0.94
	Preoperative Cobb angle (°)	46.13±8.80	44.9±7.28	0.75
	Number of operated segments	12.25±3.64	11.33±2.84	0.83
Postoperative need for ICU	Age (years)	15.58±1.75	15.38±2.10	0.72
	Height (cm)	147.6±20.68	145±17.56	0.52
	Weight (kg)	42.43±17.44	39.92±15.47	0.81
	Preoperative Cobb angle (°)	45.28±7.72	44.31±6.72	0.79
	Number of operated segments	12.92±3.68	11.25±2.82	0.89
Postoperative need for mechanical ventilation	Age (years)	15.5±1.75	15.33±2.16	0.60
	Height (cm)	147.6±20.68	145.6±16.7	0.72
	Weight (kg)	42.43±17.44	41±16.14	0.92
	Preoperative Cobb angle (°)	45.28±7.72	42.5±8.31	0.30
	Number of operated segments	13.17±2.79	11.25±2.82	0.06
Postoperative need for mechanical ventilation among ICU internalized patients	Age (years)	15.5±1.75	15.28±2.74	0.88
	Height (cm)	147.6±20.68	144.4±19.55	0.78
	Weight (kg)	42.43±17.44	39±16.10	0.38
	Preoperative Cobb angle (°)	45.28±7.72	45.86±5.18	0.74
	Number of operated segments	13.17±2.79	12.71±4.54	0.83

functions, and relevant pulmonary and systemic conditions [8-11]. A retrospective study of adolescent patients undergoing scoliosis surgery reported that the incidences of delayed intubation, pulmonary complications of both major and minor types, and major complications as 45%, 46.6%, and 45%, respectively in the neuromuscular disease group [12]. Of our patients, 25% (5/20) with a neuromuscular condition required an ICU stay, and only one of them was intubated due to hemodynamic instability and received inotropic agents. The ratio of patients who required an ICU stay in the early postoperative period is higher in the neuromuscular disease group compared to the subjects without the condition, similar to previously published worldwide data.

Pediatric patients are more prone to developing hypoventilation after scoliosis surgery, and patients with a neuromuscular disease require higher acuity care and advanced management of pulmonary functions [7]. Furthermore, due to the severe and progressive behavior of their condition, patients with neuromuscular disease may require a more aggressive treatment strategy of instrumentation of multiple spinal levels in one session [13].

Posterior fusion procedures are associated with a lower rate of pulmonary complications and a shorter duration of ICU stay. Previous global studies reported an ICU stay of 3.5-4.9 days in posterior-only procedures, and this period was longer in patients who underwent combined anteroposterior correction surgery [14, 15]. In our study group, the interval for ICU stay was 1.9-3.0 days including the time under mechanical ventilation for intubated cases.

According to our data, the predictive factors for an ICU admission after spinal instrumentation surgery are impaired physical development, neuromuscular etiology, abnormal result in chest X-ray, additional comorbidities, and an predicted ICU stay in the preoperative assessment by the anesthesiology team. Our findings did not support that a greater Cobb angle was associated with a postoperative ICU stay. A possible explanation is that the number of patients with a Cobb angle >60° was five in our study group, and this is lower than the previously published data [16-19]. In addition, since the total operation time has a major influence on the hospital length of stay and ICU admission, these variables are strongly correlated with the number of the operated segments in

Table 6. Cox regression analysis of variables associated with ICU stay in pediatric patients following scoliosis surgery

	ICU stay OR (95% CI)
Gender	
Female	1.00 (reference)
Male	1.67 (1.55-1.77)
Body weight percentile	
>35th percentile	1.00 (reference)
<35th percentile	2.02 (1.96-2.04)
Etiology of scoliosis	
Idiopathic	1.00 (reference)
Neuromuscular	1.21 (1.10-1.32)
Congenital	1.02 (0.97-1.08)
Additional vertebral/spinal abnormality	
No	1.00 (reference)
Yes	1.79 (1.69-1.89)
Abnormal findings in chest X-ray	
No	1.00 (reference)
Yes	1.52 (1.41-1.65)
Estimated postoperative need for ICU	
No	1.00 (reference)
Yes	2.74 (2.38-3.06)
Cobb angle	
>90°	1.00 (reference)
≤90°	1.32 (1.22-1.43)
Anticolvulsant use	
No	1.00 (reference)
Yes	1.67 (1.48-1.86)
Intraoperative opioid type	
Fentanyl/Remifentanyl	1.00 (reference)
Morphine	1.29 (1.12-1.46)
Additional comorbidities	
No	1.00 (reference)
Yes	1.96 (1.78-2.19)

CI, confidence interval; OR, odds ratio.

the scoliosis surgery. The number of the operated segments in the same session was similar between the groups, and we did not notice a higher incidence of ICU stay in the patients with a more extended operation area. However, our patient group consisted of adolescents who underwent primary surgery and were not previously operated on, and secondary cases with multiple previous procedures might yield different outcomes. On the other hand, preoperative evaluation by the anesthesiology team estimated an ICU stay for 60 cases with a neuromuscular etiology and a higher number of planned segments to be fused, and only 13 patients required admission to the ICU. This might be a consequence of the management of anesthesia procedures during the surgery which minimized the need for ICU internalization and mechanical ventilation.

Although remifentanil is a better-tolerated anesthetic agent with a favored potential for decreasing the incidence of ICU admission in comparison to opioids, the intraoperative anesthesia protocol was similar in our patient group, hence the effect of agents used for the induction and continuation of the sedation on ICU stay could not be further evaluated in our study group.

A recent study on the National Inpatient Sample (NIS) database of the United States revealed that intraoperative neuromonitoring (IONM) was utilized in only 18% of the pediatric spinal fusion surgeries, and the ratio of postoperative complications was higher in the patients IONM was not used. In addition, although there was not reported mortality among the patients in the IONM group, 0.2% of the patients in the non-INOM group died [20]. In our study, the ratio of the patients who had an IONM was 85.9%, and eight out of thirteen patients in the ICU group received an IONM. We did not experience death in our study group either for the IONM, or the non-IONM group within ten years duration. Since we measured Gross Motor Function Score in patients with a neuromuscular deficit, IONM was not further employed in this patient group with a higher neurological burden, since further iatrogenic damage during surgery was not expected.

Reports suggest that hypotension is a common postoperative incident after scoliosis surgery independent of the patient or surgery-related factors [21, 22]. However, we observed hypotension in only one of our patients and he was extubated within 0-12 hours of the intubation. Since the risk factors and management methods have advanced within the ten years of our study duration, we did not experience an incident of acute renal injury, rhabdomyolysis, cardiac or hemodynamic instability in our study group, which were previously reported by various articles in the literature.

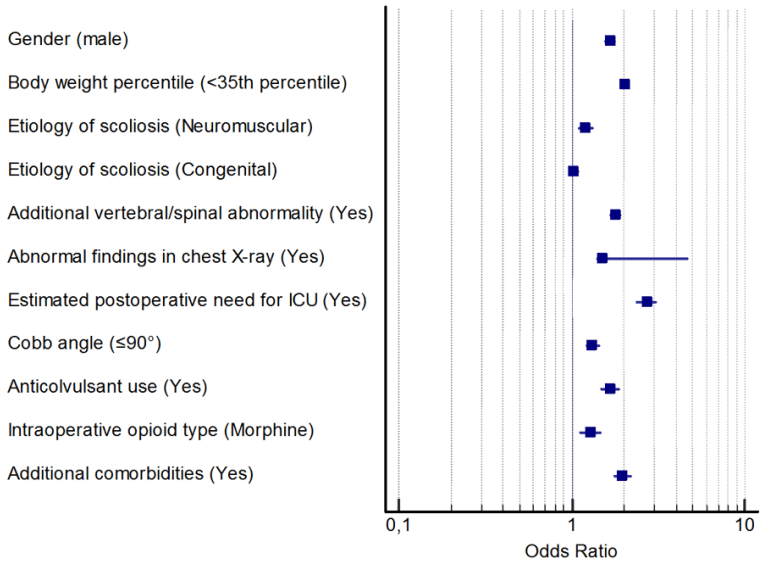

Figure 1. The odds ratio distribution of the variables, gender, body weight percentile, etiology of scoliosis, additional vertebral/spinal abnormality, abnormal findings in chest X-ray, estimated postoperative need for ICU, Cobb angle, anticonvulsant use, intraoperative opioid type, and additional comorbidities in the preoperative evaluation.

One limitation of our study is its retrospective nature and heterogeneous nature of the study population. In addition, we did not conclude the intraoperative variables including total blood loss, need for transfusion, and total operation time. However, those are the variables that were studied with large patient groups for decades, and we aimed to evaluate different variables in order to launch optimization strategies and define the risk groups depending on novel criteria. On the other hand, this is a relatively large cohort from a single surgeon during a decade, and the operative methods, technology, spinal instrumentation system equipment have been evolved over time alongside the experience of the operating surgeon. Hence, simultaneous developments in the area of intra- and postoperative care, as well as the preoperative identification of patients who would require an ICU stay allow the anesthesiologists to determine their postoperative care strategies tailored for each individual patient.

In conclusion, despite the limitations, this single-center study specifically considers the factors for an ICU admission and intubation following a spinal fusion and instrumentation surgery in a pediatric population from the perspective of the anesthesiology. Our data indicate that a smaller bodyweight percentile, neuromuscular disease, abnormal findings in chest X-ray, additional comorbidities, and estimated risk for postoperative mechanical ventilation in the preoperative anesthesiology visit are among the risk factors for admission to the ICU following a spinal fusion and instrumentation surgery. Further studies with stratified groups and homogenous populations would provide a better understanding of the at-risk populations for an ICU stay, and optimize the manageable conditions for these patients.

Disclosure of conflict of interest

None.

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