


Factors Affecting Length of Stay Following 3-Column Spinal Osteotomies in Pediatric Patients

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Abstract

Study Design: A retrospective analysis.

Objectives: Length of stay (LOS) is one of the important indicators for the quality of patient care. Although perioperative complications are known to be associated with longer LOS in general, little has been understood regarding LOS after 3-column spinal osteotomy for the rigid spinal deformity in pediatric population. The main objective of the article is to identify factors affecting the LOS in pediatric patients undergoing 3-column posterior spinal osteotomies.

Methods: Following research ethics approval, a retrospective review was performed of 35 consecutive posterior 3-column spinal osteotomies performed on pediatric patients in a single academic institution. Patients' demographic data, preoperative comorbidities, details of operative procedures, intraoperative complications, and postoperative complications were investigated, and LOS was compared among the groups.

Results: The mean LOS was 9.0 days, and the median LOS was 7 days (range = 4-23 days). Low body weight and syndromic deformity were associated with longer LOS. Operation time ≥ 6 hours and total perioperative fluid administration greater than or equal to twice the estimated blood volume were associated with longer LOS. Among postoperative complications, those with respiratory complication had prolonged stay.

Conclusions: Preoperative low body weight and syndromic scoliosis had longer LOS after 3-column osteotomies. Excessive fluid administration and respiratory complications were associated with longer LOS.

Keywords

spinal deformity, osteotomy, pediatric, length of stay, complication, adverse event, outcome

Introduction

Length of hospital stay (LOS) is an important aspect of patient care for both economic and clinical reasons. It directly indicates the performance of hospital bed utilization, and therefore it is one of the key outcomes to analyze the economic property of a certain treatment. The increase in LOS has significant implications, for example, in Canada, an average cost was reported to be \$7000 per day.¹ Extended LOS directly results in increased in-hospital costs and may be associated with nosocomial infections that can further prolong discharge from hospital.

Several factors have been known to affect LOS after spinal surgeries, including age, preoperative comorbidities, and perioperative complications.²⁻⁶ McAleese and Odling-Smee found that patients who experienced complications during surgery had

an increased hospital stay between 3.3 and 4.4 times the expected.⁷ On the other hand, different adverse events during surgery have been shown to have different impacts on LOS. Rampersaud et al proposed a system for grading adverse events based on the medical attention they require as well as their effect on a patient's LOS.^{8,9} Adverse events such as deep wound

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infections, myocardial infarction, spinal cord complications, and hematoma were classified as having the largest impact on LOS.

Three-column osteotomies (3CO) have been used more frequently in severe pediatric spinal deformities. Major complications have been reported to occur in up to 40% of cases of 3COs^{10,11}; however, little is known about the effect of these complications on LOS in the pediatric population. Understanding the specific factors affecting LOS in these patients can help better manage medical resources and patients' expectations, and provide surgeons information on the impact of specific complications.

Materials and Methods

A retrospective review was performed of the charts and radiographs of a consecutive series of 35 three-column spinal osteotomies in 27 patients from 2005 to 2012 in a single academic institution. Patients' demographic data (age, sex, and body weight [percentile for age]) was obtained. Estimated blood volume (EBV) was determined by sex and body weight. Preoperative comorbidities (intellectual disability, ambulatory status, pulmonary dysfunction, and cardiovascular comorbidities) were investigated. Pulmonary dysfunction was judged according to the results of spirometer and/or the clinical presentations (ie, recurrent episodes of respiratory infections). The etiologies of the deformity were categorized into 4 types: idiopathic (idiopathic scoliosis or Scheuermann's disease), syndromic, congenital, and iatrogenic (post-laminectomy kyphosis).

All patients underwent thoracic level posterior 3COs with neuromonitoring for the correction of rigid spinal deformity by the senior author. The procedures were classified as pedicle subtraction osteotomy (PSO), partial vertebral column resection (PVCR), or vertebral column resection (VCR). Osteotomies were performed at the apex of rigid spinal deformity. The detailed information of operative procedures investigated included previous surgical history, number of levels fused, osteotomy level, operation time, estimated blood loss, intraoperative fluid volume administered, and transfusion volume as well as intraoperative complications (neurophysiological change on monitoring, dural tear, and pleural tear). All dural tears were repaired by sutures, and chest tubes were placed for pleural tears. Information regarding postoperative management included the complications and the length of intensive care unit (ICU) stay. Postoperative complications investigated included neurological complication (paralysis or paraparesis), respiratory complication (delayed extubation, atelectasis, or pleural effusion), and surgical site infection.

LOS was defined as the days from admission to discharge. All patients were admitted to hospital the same day as the procedure. Discharge decision was made by the responsible surgeon depending on the patient's condition. A nonambulatory 16-year-old male patient who underwent VCR for kyphoscoliosis associated with severe Ehlers-Danlos syndrome and marked cardiopulmonary dysfunction died from an acute pulmonary arrest in the ICU on postoperative day 10. Excluding this patient, further analyses were performed for the remaining 34

Table 1. Demographic Data.

	n = 34
Age (years)	14.4 ± 2.5
Sex (female)	22 (65%)
Weight-for-age (percentile)	
<5	16 (47%)
5-95	13 (38%)
>95	5 (15%)
Comorbidities	
Pulmonary dysfunction	12 (35%)
Intellectual disability	4 (12%)
Nonambulatory	2 (6%)
Cardiovascular	1 (3%)
Numbers of comorbidities	
0	18 (53%)
1-2	16 (47%)
ASA	
1	5 (15%)
2	7 (21%)
3	22 (65%)
Deformity type	
Syndromic	13 (38%)
Congenital	12 (35%)
Idiopathic	7 (21%)
Iatrogenic	2 (6%)
Procedure	
PSO	7 (21%)
PVCR	17 (50%)
VCR	10 (29%)
Revision surgery	20 (59%)
Levels fused	11.7 ± 2.4

Abbreviations: ASA, American Society of Anesthesiologists; PSO, pedicle subtraction osteotomy; PVCR, partial vertebral column resection; VCR, vertebral column resection.

osteotomies. The LOS was compared between the groups divided by demographic data in the univariate analyses. When the groups were divided according to the continuous variables, the cutoff points were set to extract approximately one third of the cohort as outliers. Since the number of patients included in the present study is limited, multivariate analysis was not performed. To understand the trend, the patient cohort was stratified based on the preoperative risk factors and the key perioperative data was compared between the groups.

All statistical analyses were carried out using the IBM SPSS Statistics software program Version 19 (SPSS, Inc, Somers, NY). For the comparisons of the parameters between the groups, Mann-Whitney *U* test or Student's *t* test was used for continuous variables, and the χ^2 test or Fisher's exact test was used for categorical data. For all statistical tests, *P* values <.05 were considered to be significant.

Results

Demographics

Demographic data is summarized in Table 1. Twelve males and 22 females were identified. Five patients underwent 2

Table 2. Comparisons of Length of Hospital Stay According to Preoperative Factors.

	n	Length of Stay (Days)	P
Weight-for-age (percentile)			
<5	16	9.9 ± 5.0	.03
≥5	18	8.2 ± 5.6	
Pulmonary dysfunction			
Yes	12	10.2 ± 5.7	.19
No	22	8.4 ± 5.2	
Number of comorbidities			
0	18	7.1 ± 2.2	.14
1-2	16	11.1 ± 7.0	
ASA			.11
1-2	12	8.5 ± 6.2	
3	22	9.3 ± 5.0	
Syndromic scoliosis	13	10.9 ± 5.7	.007
Other types of deformity	21	7.8 ± 4.9	
PSO	7	8.9 ± 6.4	.90
PVCR or VCR	27	9.0 ± 5.2	
Revision surgery	20	9.2 ± 4.8	.52
Primary surgery	14	8.7 ± 6.2	

Abbreviations: ASA, American Society of Anesthesiologists; PSO, pedicle subtraction osteotomy; PVCR, partial vertebral column resection; VCR, vertebral column resection.

osteotomies and 1 patient underwent 4 osteotomies as separate operations, which were at least 6 months apart from the previous procedures (interval: 6-37 months), but their demographics were not changed at each stage. The mean age at surgery was 14.4 ± 2.5 years (mean \pm standard deviation, range: 8.1-17.4). The mean body weight was 46.5 ± 23.1 kg (range: 14.5-110.6). Sixteen patients (47%) were less than 5th percentile of weight-for-age and 5 patients (15%) exceeded 95th percentile of weight-for-age.¹² Pulmonary dysfunction was detected preoperatively in 12 patients (35%). Almost half of the patients (16 of 34, 47%) had at least one comorbidity, of which 3 patients were associated with 2 comorbidities. The most common etiology of the spinal deformity was syndromic scoliosis (13 patients, 38%), followed by congenital deformity and/or kyphosis (12 patients, 35%). Seven PSOs, 17 PVCRs, and 10 VCRs, all in thoracic spine, were performed. Six osteotomies (18%) were made at high thoracic level at T7 and above. Twenty surgeries (59%) were revision procedures. The mean construct length was 11.7 ± 2.4 levels.

Predictors of LOS

The mean LOS was 9.0 ± 5.3 days, and the median was 7 days (range 4-23 days). All except 2 patients were discharged home and the others needed in-hospital rehabilitation program. The comparisons of LOS according to the demographic data are summarized in Table 2. LOS was significantly longer in those with low body weight (less than 5th percentile for age) than the others (9.9 vs 8.2 days, $P = .03$), and in those with syndromic scoliosis than the other types of spinal deformity (10.9 vs 7.8 days, $P = .007$). Comorbidities, osteotomy procedure, and

Table 3. Comparisons of Length of Hospital Stay According to Perioperative Factors.

	n	Length of Stay (Days)	P
Operation time			
≥6 hours	23	10.5 ± 5.9	.003
<6 hours	11	5.9 ± 1.2	
Estimated blood loss			.11
≥1 EBV	8	11.4 ± 5.5	
<1 EBV	25	8.4 ± 5.3	
Total fluid volume			.02
≥2 EBV	13	10.9 ± 5.2	
<2 EBV	21	7.8 ± 5.2	
Intraoperative transfusion			.25
≥1 EBV	8	10.8 ± 5.5	
<1 EBV	26	8.4 ± 5.3	
Neurophysiological change			.38
Yes	7	10.4 ± 6.6	
No	27	8.6 ± 5.1	
Dural tear			.32
Yes	5	10.4 ± 7.1	
No	29	8.8 ± 5.1	
Pleural tear			.31
Yes	16	9.4 ± 5.3	
No	18	8.7 ± 5.5	

Abbreviation: EBV, estimated blood volume.

Table 4. Comparisons of Length of Hospital Stay According to Postoperative Complications.

	n	Length of Stay (Days)	P
Neurological complication			.38
Yes	7	10.4 ± 6.6	
No	27	8.6 ± 5.1	
Respiratory complication			.04
Yes	10	10.8 ± 4.8	
No	24	8.3 ± 5.5	
ICU stay			.06
≥2 days	10	10.7 ± 5.0	
0-1 day	24	8.3 ± 5.4	

Abbreviation: ICU, intensive care unit.

revision procedure were not associated with prolonged hospital stay.

Perioperative Data

The mean operation time was 6.9 ± 1.8 hours, and the estimated blood loss averaged 2.3 ± 2.2 L. The mean total fluid volume administered was 5.8 ± 2.8 L, and the mean intraoperative transfusion volume was 2.1 ± 2.6 L. Neurophysiological change on neuromonitoring was noted in 7 patients (21%) and dural tear and pleural tear occurred in 5 patients (15%) and 16 patients (47%), respectively. The comparisons of LOS according to the perioperative data are summarized in Table 3. Those with operation time of 6 hours or longer (10.5 vs 5.9 days, $P = .003$) and those who received the total fluid volume more than twice of EBV (10.9 vs 7.8 days, $P = .02$)

Table 5. Perioperative and Postoperative Characteristics in High-Risk Groups.

	Deformity Type		P	Weight-for-Age (Percentile)		P
	Syndromic (n = 13)	Other (n = 21)		<5 (n = 16)	≥5 (n = 18)	
Operation time (hours)	7.9 ± 1.7	6.2 ± 1.5	.01	7.1 ± 2.0	6.7 ± 1.6	.59
Estimated blood loss (%EBV)	194 ± 200	50 ± 43	.02	185 ± 178	33 ± 26	<.001
Total perioperative fluid volume (%EBV)	342 ± 214	155 ± 79	.005	321 ± 192	142 ± 87	<.001
Respiratory complications	62%	10%	.002	44%	17%	.09
ICU stay (days)	3.0 ± 2.6	1.2 ± 1.0	.02	2.7 ± 2.5	1.2 ± 1.0	.02

Abbreviations: EBV, estimated blood volume; ICU, intensive care unit.

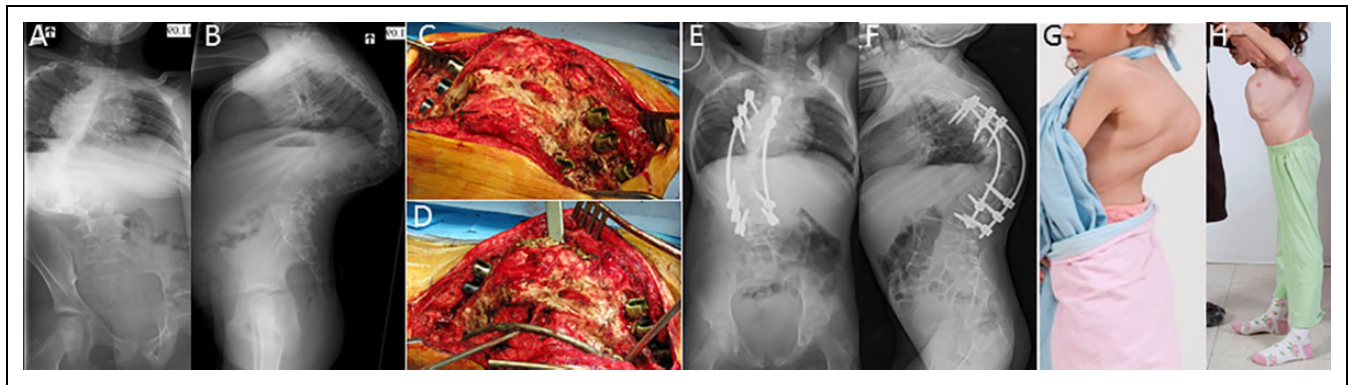


Figure 1. An 8-year-old female patient with VACTERL syndrome and previous anterior and posterior noninstrumented fusion 3 years prior presented with worsening kyphoscoliosis as depicted in the standing anteroposterior (A) and lateral (B) radiographs. She weighed 16.6 kg, which was less than the 5th percentile for age. She had no other comorbidities. Revision posterior spinal fusion from T4 to L3 with VCR at T10 and I1 was performed. Intraoperative image (C) following placement of the implants demonstrates the apical fusion. A loss of motor evoked potentials (MEP) occurred during the decompression portion of the procedure (D). The surgery was completed, as demonstrated in the postoperative AP (E) and lateral radiographs (F) with some return of MEP signal following osteotomy closure. Total time in the operating room was 11 hours and she lost 800 cc of blood (69% of EBV) and received 2400 cc of fluid (207% of EBV). Unfortunately her surgery was complicated by postoperative neurological deficit (ASIA D, Brown-Sequard deficit) but she managed to be discharged home with a walker on day 8 postoperative. A complete neurological recovery was made by 2 weeks postoperatively. Clinical sagittal image (G) demonstrates the patient's large deformity that has been corrected and her ability to stand with assistance at 5 days following the procedure (H).

stayed longer than the others. Of note, none of the intraoperative complications investigated were associated with longer LOS.

Postoperative Management

Respiratory complications occurred in 29% (delayed extubation in 8, atelectasis in 2, and pleural effusion in 1 patient). Those complications tended to happen more in those with preoperative pulmonary dysfunction (42% vs 23%, $P = .22$), and occurred significantly more frequently in high thoracic osteotomy group (67% vs 21%, $P = .03$). Neurological complications occurred in 21% (ASIA B in 1, C in 3, and D in 3 patients at discharge). All of these neurological deficits eventually recovered at the latest follow-up. One patient (3%) experienced superficial surgical site infection. The mean ICU stay was 1.9 ± 2.0 days, with 10 patients (29%) staying in the ICU for more than 1 day. Among them, 8 patients (80%) were associated with respiratory complications. The comparisons of LOS according to the postoperative data are summarized in Table 4.

Those with respiratory complications stayed longer than those without (10.8 days vs 8.3 days, $P = .04$). Neurological complication did not affect the LOS.

Perioperative and Postoperative Characteristics in High-Risk Groups

Although we were not able to perform the multivariate risk factor analysis in perioperative and postoperative data or to elucidate the causative relationships between these factors associated with longer LOS, the comparisons were made between those with and without syndromic scoliosis and low body weight in order to understand the trend (Table 5). In summary, most of the important factors including perioperative fluid balance and respiratory complications were associated with preoperative diagnosis or condition. It emphasizes both of these factors (syndromic scoliosis and low body weight) can result in challenging perioperative management and the importance of skilled postoperative respiratory function control.

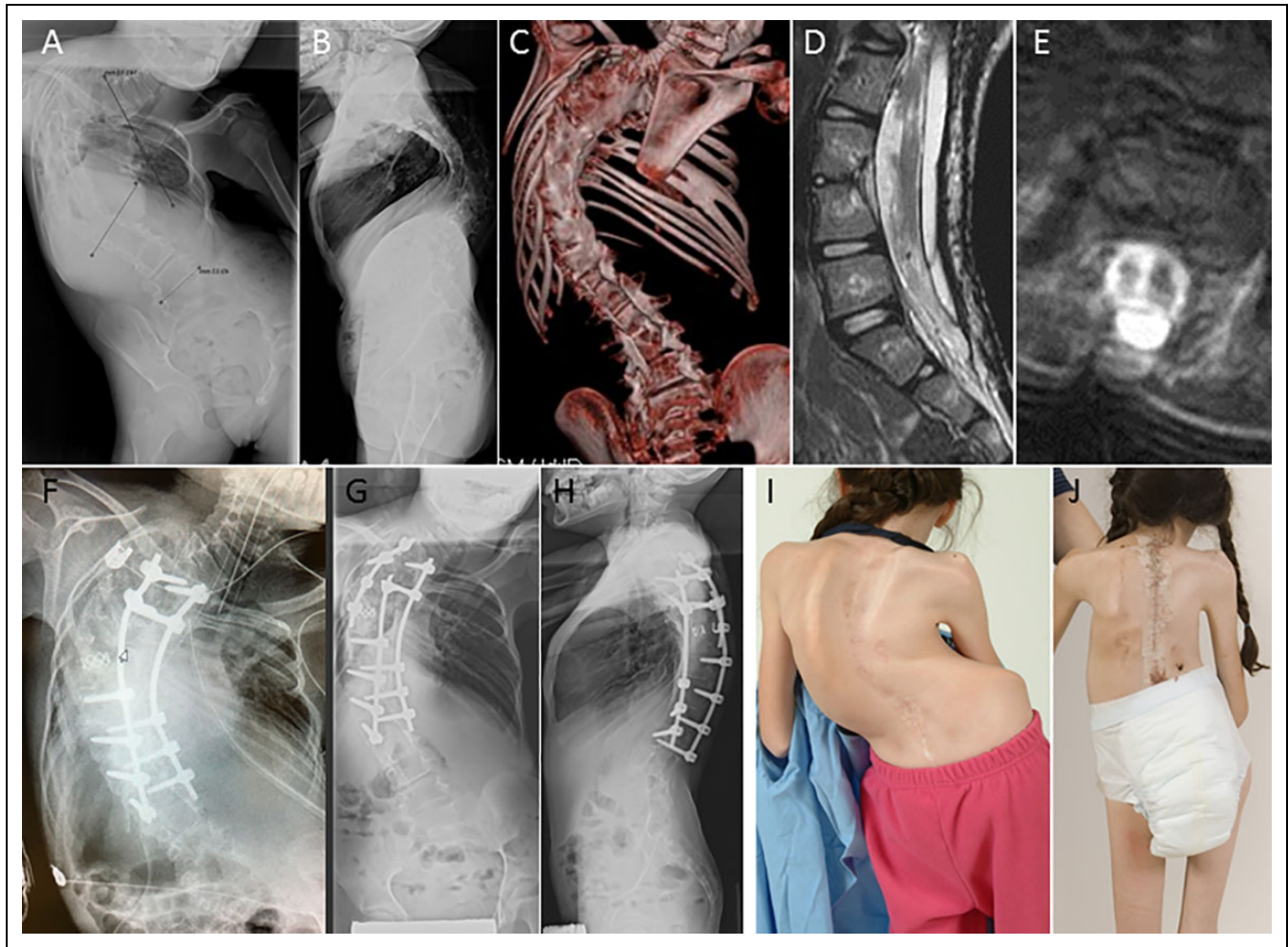


Figure 2. An 11-year-old female patient with undiagnosed syndrome with severe leg length discrepancy and spinal anomalies presented with worsening kyphoscoliosis 5 years after unsuccessful spinal fusion, as demonstrated in the anteroposterior (A) and lateral (B) standing radiographs. Three-dimensional CT scan (C) demonstrates a previous anterior and posterior fusion with a previous L1 to S1 decompression. Sagittal MRI (D) demonstrates a tethered cord and the axial (E) confirms a diastomyelia. She weighed 17.6 kg, which was less than 5th percentile for age. She had the history of frequent upper respiratory infections suggestive of pulmonary dysfunction. Revision posterior spinal fusion from T3 to L1 with vertebral column resection at T5 was performed. Operation time was 7 hours and she lost 6 L of blood (493% of EBV) and received 7500 cc of fluid (607% of EBV). She was extubated immediately after the operation but suffered respiratory distress (F) and required reintubated in the ICU. She was in the ICU for 7 days and LOS was 21 days. Postoperative anteroposterior (G) and lateral (H) radiographs and standing preoperative (I) and early postoperative photographs (J) demonstrate the correction achieved.

Case Presentations

Case 1

An 8-year-old female patient with VACTERL syndrome presented with worsening kyphoscoliosis despite the previous history of spinal fusion. She weighed 16.6 kg, which was less than 5th percentile for age. She had no other comorbidities. Revision posterior spinal fusion from T4 to L3 with VCR at T10 and 11 was performed. Operation time was 11 hours, and she lost 800 cc of blood (69% of EBV) and received 2400 cc of fluid (207% of EBV). Unfortunately, her surgery was complicated by postoperative neurological deficit (ASIA D) but she managed to be discharged home with a walker on postoperative day 8 (Figure 1).

Case 2

An 11-year-old female patient with undiagnosed syndrome associated with diastematomyelia presented with worsening kyphoscoliosis after the unsuccessful spinal fusion. She weighed 17.6 kg, which was less than 5th percentile for age. She had the history of frequent upper respiratory infections suggestive of pulmonary dysfunction. Revision posterior spinal fusion from T3 to L1 with PVCR at T5 was performed. Operation time was 7 hours, and she lost 6 L of blood (493% of EBV) and received 7500 cc of fluid (607% of EBV). She was extubated immediately after the operation but suffered respiratory distress and reintubated in ICU. She was in the ICU for 7 days and LOS was 21 days (Figure 2).

Discussion

Following 3COs for severe pediatric spinal deformities, preoperative low body weight, syndromic scoliosis, longer operation time, larger perioperative fluid administration, and patients with pulmonary complications necessitating prolonged ICU stays had associated increased hospital LOS. Neurological complication did not affect the LOS. Focusing on aggressive pulmonary treatments and limiting fluid administration in the perioperative setting may improve LOS.

There are only a few studies that have been specifically reported LOS after 3-column spinal osteotomy. Lenke et al reported that the mean LOS after VCR was 10 days in their case series of pediatric and adult spinal deformity,¹³ and Zhang et al reported the LOS after VCR for posttuberculous kyphosis was 20 days.¹⁴ We reported the mean LOS for pediatric spinal deformity to be 9 days, which was comparable to the previous studies. Sponseller et al reported in their multicenter study that the mean ICU stay was 6 days and the mean LOS was 14 days in neuromuscular scoliosis,¹⁵ and Murphy et al reported that LOS was longer and respiratory complications were more commonly experienced in neuromuscular scoliosis than in idiopathic scoliosis.¹⁶ In the present study, the patients with syndromic scoliosis stayed longer after 3-column spinal osteotomies. Management of syndromic scoliosis patients is particularly challenging because of medical comorbidities and their frailty. Perioperative risks in this subset of patients have been classically advocated,¹⁷⁻¹⁹ but our current results supported these knowledge by adding the possibility of prolonged hospital stay.

Understanding the relationships between postoperative complications and LOS is also important. The rates of neurological deficits, respiratory complication, and surgical site infection reported in the multicenter study by Bianco et al were 18.6%, 2.6%, and 7.6%, respectively.¹¹ Despite their various impacts on LOS,⁸ which complications can actually be the drivers to lengthen the hospital stay remains unclear. In the present study, respiratory complications including prolonged ventilator usage were shown to be associated with longer LOS, whereas neurological complications were not. Gruskay et al also reported that pneumonia was one of the postoperative events that caused longer LOS, but that none of the demographic data was predictive of developing postoperative pneumonia.⁵ Large intraoperative fluid administration has negative impact on pulmonary function, increasing the frequency of respiratory complications and lengthens LOS.²⁰ Indeed, total perioperative fluid volume was significantly higher in the long LOS group. Given it was not necessarily associated with preoperative diagnosis as syndromic scoliosis, rigorous volume management with limited fluid administration strategy may be universally imperative in pediatric high-risk spine surgeries.

Neurological dysfunction was not associated with increased LOS. Of those with postoperative deficits, 6 of 7 improved within a few days and were discharged home with walking aids or wheelchair. The parents of the one patient with persistent deficits were keen on returning home and homecare

arrangements were put in place to facilitate this process. In this population, neurological complication did not seem to affect the LOS on condition that sufficient preoperative planning in regard to postoperative destination and familial, social, and institutional support will be provided.

Limitations of the present study include the small sample size. We might have been unable to detect the other factors that affect LOS. Furthermore, the retrospective design of the study prevented us from obtaining information of potential factors including preoperative renal functions and medication usage. Further studies are warranted to prove controlling the perioperative fluid balance and preventing respiratory complications can actually shorten LOS.

Conclusion

In the 3-column spinal osteotomy patients, syndromic scoliosis and low body weight were the significant preoperative risk factors for longer LOS. Longer operation time, larger perioperative fluid administration, and respiratory complications were associated with increased LOS; however, neurological dysfunction was not. The postoperative management of those with syndromic scoliosis or low body weight were more likely to be more challenging, and attention to aggressive perioperative pulmonary care is recommended in these cases.


Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: SJL: Consulting: Stryker, Medtronic. Receives payment for lectures and travel for meetings from Medtronic, Stryker, and AO. SK and TD have no conflicts of interest to disclose.

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