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Preoperative Variables Associated With Respiratory Complications After Pediatric Neuromuscular Spine Deformity Surgery

Scott J. Luhmann, MD*, Ryan Furdock, BS

Pediatric Orthopaedic Surgery, Washington University School of Medicine, St. Louis, MO 63110, USA

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Abstract

Objective: The objective of this study is to identify preoperative laboratory values and patient factors that are associated with postoperative respiratory complications in pediatric neuromuscular scoliosis (NMS) populations undergoing posterior spinal fusion (PSF) with instrumentation.

Summary of Background Data: PSF in NMS patients are high-risk surgeries. Respiratory complications are the most common postoperative event, with rates up to 28.2% following surgery.

Methods: A single-surgeon, two-hospital pediatric spine surgery database was reviewed to identify all patients who underwent PSF for NMS. Diagnoses included cerebral palsy (n=83), myelomeningocele (n=13), spinal muscular atrophy (n=4), and other (n=11). This study defined respiratory complications as postoperative pneumonia, pleural effusion, pneumothorax, need for reintubation, respiratory status requiring a return to the pediatric intensive care unit (PICU), or prolonged (>4-day) need for mechanical ventilation. Preoperative laboratory values for transferrin, prealbumin, hemoglobin/hematocrit, total protein, albumin, and total lymphocyte count were collected.

Results: There were 50 males and 61 females with a mean age of 14 years 2.5 months (8−20 years). Seventeen patients (15.3%) experienced postoperative respiratory complications. On univariate analysis, any history of pneumonia, the presence of gastrostomy tube, and low transferrin levels were associated with postoperative respiratory complications, and a strong trend (p=.06) was observed for tracheostomy. On multivariate analysis, the presence of gastrostomy tube and history of pneumonia remained as clinically significant predictors of postoperative respiratory complications.

Conclusion: Pediatric NMS patients undergoing PSF that have history of pneumonia or gastrostomy tube present at time of surgery are at increased risk for postoperative respiratory complications. The univariate associations of tracheostomy presence and low transferrin levels with postoperative respiratory complications deserve further examination.

Level of Evidence: Level II.

Keywords: Respiratory complications; Spinal fusion; Neuromuscular; Spine deformity

Introduction

Posterior spinal fusion (PSF) surgery is associated with high morbidity in children with neuromuscular scoliosis [1-6]. Respiratory complications following PSF are common, and have been reported in 15.6% to 28.2% of operative cases [1-3,7]. Respiratory impairment is common in pediatric scoliosis surgery; in a cohort that included scoliosis patients of multiple etiologies, patients averaged only 50% of baseline respiratory function one week after surgery [5]. Postoperative complications following PSF may cause further impairment of respiratory function, leading to prolonged intubation time, need for reintubation, and longer inpatient hospital stay. These factors contribute to significantly greater consumption of health care resources [8,9].

The risk of postoperative respiratory complication following PSF can be reduced. In a cohort of 13 pediatric neuromuscular scoliosis (NMS) patients who were preoperatively trained for use of noninvasive positive pressure ventilation and mechanical insufflation-exsufflation, there

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*Corresponding author. St Louis Children's Hospital, 1 Children's Place, Suite 4S60, St Louis, MO 63110, USA. Tel.: (314) 747-4705; fax: (314) 454-4562.

E-mail address: luhmanns@wustl.edu (S.J. Luhmann).

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were zero respiratory complications observed [10]. Identification of patients at highest risk for postoperative respiratory complications allows for appropriate conversations with family and permits initiation of interventions aimed at reducing postoperative morbidity. The purpose of this study was to identify preoperative variables in pediatric NMS patients that are associated with postoperative respiratory complication following PSF.

Methods

Following IRB approval, a single-surgeon, two-hospital database was queried to identify all patients from July 2006 to May 2016 who underwent PSF for NMS. One hundred seventeen consecutive patients were identified; 6 were excluded because of incomplete medical records. Patient diagnoses included cerebral palsy (n=83), myelomeningocele (n=13), spinal muscular atrophy (n=4), Duchenne muscular dystrophy (n=2), neurogenic scoliosis due to syrinx (n=2), disseminated encephalomyelitis (n=1), hydromyelia (n=1), centronuclear myopathy (n=1), Krabbe syndrome (n=1), Leigh's syndrome (n=1), Dandy-Walker syndrome (n=1), and Dwayne's syndrome (n=1). Preoperative information including history of pneumonia, presence of gastrostomy tube, and presence of tracheostomy were determined by chart review. Preoperative lab values for transferrin, prealbumin, folate, hemoglobin/hematocrit, total lymphocyte count, total protein, and albumin were also collected. Preoperative pulmonary function tests were not part of the preoperative protocol for this patient population because of cognitive impairment and the inability to follow commands to achieve meaningful tests. For the duration of the study, all patients were evaluated, treated, and counseled in a similar manner about the risks of pulmonary complications. Preoperative optimization was similar for all patients and there was no stratification according to their history of pulmonary problems.

Spine reconstruction for all patients included intraoperatively applied traction. This was achieved proximally with a 4 or 6-pin halo or Gardner-Wells tongs, and distally with a distal femoral traction pin applied to the side with the elevated hemipelvis. All surgeries were posterior-only approaches with pedicle screw constructs (a small minority of patients had upper instrumented vertebral fixation with hooks). Surgeries were performed by a single attending surgeon with the assistance of a fellow or upper level orthopedic resident. Posterior column osteotomies (Ponte-type) were used to improve three-dimensional alignment if intraoperative traction was unable to achieve adequate correction. The upper instrumented vertebra was either T2, T3, or T4; this was dependent on the degree of kyphosis and the coronal plane deformity. Iliac fixation was achieved with bilateral iliac screws placed through a traditional approach at the posterior inferior iliac spine. Various rod diameters from 4.75 to 6.0 mm and rod metal types (titanium alloy, stainless steel, and cobalt chrome) were used depending on patient size and quality of spinal fixation.

In line with previous literature, respiratory complications were defined as postoperative pneumonia, pleural effusion, pneumothorax, need for reintubation, respiratory status requiring a return to the PICU, or prolonged (>4-day) need for mechanical ventilation [6,9]. Patients were considered to have a positive history of pneumonia if they had experienced a pneumonia at any point in their past, from infancy onwards. The presence of a pleural effusion was operationally defined as a complication, regardless of the need for treatment. Gastrostomy tubes and tracheostomies were considered present only when in place at the time of surgery. For analysis of preoperative laboratory test results, institutional normalized values were used. Length of anesthesia was defined as the time elapsed from the patient's entry into the operating room until the patient was taken out of the operating room following surgery.

Two-tailed, unpaired *t* tests were used to compare means of demographic, preoperative, and operative variables between patients who did and did not develop a respiratory complication. Fisher exact test was used in univariate analysis to compare proportions of respiratory complications between groups in all categorical analyses. Multivariate logistic regression was then used to identify variables that remained significant independent risk factors for development of respiratory complications. Statistical significance was reached when $p < .05$.

Results

A total of 50 males and 61 females with a mean age of 14.2 years were included in the study (range 8–20 years). Of this 111-person cohort, 17 experienced postoperative respiratory complications (15.3%). Of these 17 patients with respiratory complications, 13 had cerebral palsy (76%), 2 had myelomeningocele (12%), 1 had spinal muscular atrophy (6%), and 1 had Leigh's syndrome (6%). No diagnosis was found to be associated with increased incidence of respiratory complications ($p > .05$). Ten patients who developed respiratory complications (58%) required intraoperative blood transfusion, and 46 patients who did not develop respiratory complications (49%) required transfusion; no significant difference was observed ($p = .60$). The frequencies of respiratory complications for patients with a tracheostomy, gastrostomy tube, or history of pneumonia compared with patients without those factors are outlined in Table 1.

On univariate analysis, patients with a history of pneumonia were found to develop postoperative respiratory complications 2.8 times more frequently ($p = .03$), and had an absolute risk increase of 18.9% (95% confidence interval [CI]= 0.004%, 37.4%). Similarly, patients with a gastrostomy tube at the time of surgery developed postoperative respiratory complications 3.1 times more frequently ($p = .01$), and had an absolute risk increase of 18.3% (95% CI= 3.1%, 33.3%). The presence of a tracheostomy and the

Table 1
Frequency of respiratory complications.

	No respiratory complication, % (n/n)	Respiratory complication, % (n/n)	p value	Relative risk	Absolute risk increase, % (95% confidence interval)
Tracheostomy	63.6 (7/11)	36.4 (4/11)	.064	2.79	23.4 (−5.3, 52.5)
No tracheostomy	87.0 (87/100)	13.0 (13/100)			
Gastrostomy tube	73.2 (30/41)	26.8 (11/41)	**.01**	3.12	18.3 (3.2, 33.3)
No gastrostomy tube	91.4 (64/70)	8.6 (6/70)			
History of pneumonia	70.4 (19/27)	29.6 (8/27)	**.029**	2.77	18.9 (0.5, 39.0)
No history of pneumonia	89.3 (75/84)	10.7 (9/84)			

Table 2
Univariate analysis of preoperative laboratory values and respiratory complications following PSF.

	Normal/high lab value, % (n)		Low lab value, % (n)		p value	Absolute risk increase, % (95% confidence interval)
	No respiratory complication	Respiratory complication	No respiratory complication	Respiratory complication		
Transferrin (<200 mg/dL)	86 (43)	14 (7)	0 (0)	100 (2)	**.03**	86 (76.3, 95.6)
Prealbumin (<20 mg/dL)	77.5 (31)	22.5 (9)	100 (11)	0 (0)	.18	−22.5 (−35.4, −9.6)
Hemoglobulin (<13.8%)	82.1 (55)	17.9 (12)	87.8 (36)	12.2 (5)	.59	−5.7 (−19.3, 7.9)
Hematocrit (<40.7%)	82.9 (58)	17.1 (12)	86.8 (33)	13.2 (5)	.78	−3.9 (−17.8, 9.9)
White blood cell (<3.8k/mm^3)	85 (91)	15 (16)	0 (0)	100 (1)	.16	85 (78.2, 91)
Total protein (<6.5 g/dL)	83.2 (84)	16.8 (17)	100 (7)	0 (0)	.24	−16.8 (−24.1, −9.5)
Albumin (<3.5 g/dL)	84 (89)	16 (17)	100 (2)	0 (0)	1.00	−16 (−23.3, −9.1)
Total lymphocyte count (<1.0k/mm^3)	84.4 (81)	15.6 (15)	0 (0)	0 (0)	1.00	N/A

Table 3
Effects of preoperative and intraoperative variables on postoperative respiratory complications.

	No respiratory complication, mean	Respiratory complication, mean	p value	*t* statistic	Degree of freedom
Age at surgery (years)	14.3	13.8	.48	0.7	109
Height (cm)	143.8	137.4	.11	1.6	87
Weight (kg)	39.0	33.4	.06	1.95	30
Body mass index	18.4	18.0	.77	0.43	89
Estimated blood loss (mL)	566.0	558.8	.90	0.08	109
Length of anesthesia (min)	467.8	483.3	.38	−0.88	105
Preoperative coronal Cobb (degrees)	73.8	80.7	.31	−1.03	108
Preoperative coronal balance (mm)	37.3	46.5	.30	−1.04	107
Preoperative sagittal Cobb angle (degrees)	60.5	67.3	.43	−0.8	86

development of a postoperative respiratory complication trended toward significance on univariate analysis (p=.06, relative risk=3.4). In patients with a tracheostomy, an absolute risk increase of 23.4% was observed (95% CI= −5.8%, 52.5%).

Univariate analysis of preoperative laboratory test results demonstrated that patients with low transferrin levels experience postoperative respiratory complications following PSF 7.1 times more frequently. The absolute risk increase associated with low transferrin levels was found to be 86% (95% CI= 76.3%, 95.6%). Low values for all other preoperative laboratory test results were not associated with increased incidence of postoperative respiratory complications; the results from these comparisons can be observed in Table 2. Additionally, no difference in means of preoperative laboratory test results was identified between patients who developed postoperative respiratory complications and those who did not. No significant differences were observed between patients who did and did not develop respiratory complications with respect to mean age, height, weight, body mass index, magnitude of spinal deformity, and intraoperative characteristics (Table 3).

On multivariate analysis, the presence of a gastrostomy tube was identified as an independent risk factor for development of a respiratory complication following PSF, and a strong trend toward significance (p=.056) was observed for history of pneumonia (Table 4).

Table 4
Multivariate analysis of preoperative variables and respiratory complications following PSF.

	p value	Odds ratio (95% CI)
Gastrostomy tube	**.031**	3.38 (1.16, 10.29)
History of pneumonia	.059	2.92 (0.96, 8.90)

Discussion

Morbidity following PSF surgery for NMS is high [1-6], in large part due to the high frequency of respiratory complications. Efforts to optimize respiratory function perioperatively are thus critical in improving surgical outcomes. Based on this study, for a patient with a tracheostomy or history of pneumonia, our perioperative protocol for optimizing respiratory function is rigorous. Preoperatively, the patient's pulmonary physician is contacted, and the patient is started on a regimen that includes percussion vest therapy, cough assist, an increase in nebulizer treatments, and frequent suctioning. Postoperatively, these patients receive both a formal consult with a pulmonologist and a formal respiratory therapy consult. In patients without a tracheostomy or history of pneumonia, no preoperative treatment targeted at improving respiratory function is given. Postoperatively, these patients follow a respiratory therapy clearance protocol that includes humidified oxygen and nebulized albuterol treatment four times per day. In this study, univariate analysis indicated that NMS patients with tracheostomies were more likely to experience respiratory complications following PSF, despite implementation of this more aggressive, preventative approach preoperatively and postoperatively. Specific complications for this population included two returns to PICU, one pneumonia, and one pleural effusion necessitating an additional surgery.

Tracheostomy presence has been implicated with negative outcomes following treatment of a variety of medical conditions [11,12]. The presence of a tracheostomy indicates a preexisting problem with pulmonary dysfunction, and its presence may be more of an indicator of the level of the neurologic involvement of underlying disease rather than a PSF-specific risk factor.

History of pneumonia

Analogous to patients with tracheostomy, patients with history of pneumonia had an increased complication rate, despite receiving more comprehensive respiratory therapy preoperatively and postoperatively. Multivariate analysis indicated that history of pneumonia is a clinically significant independent predictor of increased risk for respiratory complications. The complications observed in this population include three returns to PICU, two required reintubations, one postoperative pneumonia, one return to the operation theater for pleural effusion, and one case of extended ventilator support (>4 days). There is a close association between tracheostomy presence and history of pneumonia in this study: 28.9% of patients with a history of pneumonia also had a tracheostomy at time of surgery. In other surgical fields, an association between tracheostomy presence and postoperative pneumonia has often been observed [12,13]. History of pneumonia and presence of tracheostomy may be two manifestations of underlying respiratory and neurologic impairment that leads to worsened surgical outcomes.

Excluding patients with tracheostomy from analysis, history of pneumonia was associated with an absolute risk increase of 13.7% for development of postoperative respiratory complication ($p=.1392$, 95% CI= −5.7%, 33.1%). In line with these results, Caputo et al. found an association between history of pneumonia and surgical site infection following general spine surgery [14].

Transferrin

The optimization of preoperative nutrition has shown promise in improving outcomes in pediatric scoliosis populations, including minimization of the need for allogenic blood transfusion [3,15]. To our knowledge, no recent literature has been published regarding the effect of preoperative nutritional and hepatic protein laboratory test results on postoperative respiratory outcomes in pediatric NMS populations [1].

Transferrin has been identified as a perioperative marker of serum protein and iron status useful in stratification of patient illness and future morbidity and mortality [16,17]. In this study, the mean transferrin of the respiratory complication group was 253 mg/dL, versus 286 mg/dL in the no complication group. Both patients with low transferrin laboratory test results (<200 mg/dL) experienced postoperative respiratory complications; one case of reintubation and one case of postoperative pneumonia was observed. Despite a statistically significant result, the observed effect of low transferrin may not be important because of sample size limitations. The role of transferrin in outcomes following PSF in NMS patients deserves further investigation.

Gastrostomy tube

Sponseller et al. reported a relationship between gastrostomy tube presence and surgical site infection after spinal fusion, but no literature has been published regarding the association of gastrostomy tube and respiratory complications [16]. In this study, presence of a gastrostomy tube was identified as an independent predictor of respiratory complications on multivariate analysis. The following complications were observed in patients with gastrostomy tubes: three cases of pneumonia, three returns to the PICU, three cases of extended ventilator support, one return to the operation theater, and one reintubation. As may be the case for tracheostomy presence, history of pneumonia, and low transferrin status, the presence of a gastrostomy tube may simply be a proxy for underlying depth of disease. Still, it is a useful tool for quick identification of NMS patients who are at higher risk for respiratory complications following PSF.

The main weakness of this study is its retrospective collection of information in the medical records. This increases the risk of error by omission; hence, a data point was more likely to be counted a negative because of the lack of a notation in the records. This may impact the frequency of preoperative factors (ie, history of pneumonia)

and postoperative findings (minor pleural effusion or pneumothorax that did not impact clinical care).

Conclusion

Overall 15.3% of the pediatric NMS patients undergoing PSF in this study developed a postoperative pulmonary complication. NMS patients with a history of pneumonia or a gastrostomy tube present at the time of surgery are at significantly increased risk for postoperative respiratory complications. Further investigation into the univariate analysis associations of tracheostomy and low transferrin with increased risk of postoperative respiratory complications is necessary. Based on these findings, preoperative identification of patients with one of these ''at-risk'' factors, at our institution, permits initiation of a proactive pulmonary therapy protocol in the perioperative time period aimed at minimizing the frequency of postoperative pulmonary complications.

Key points

1. Respiratory complications are common (15.3% in this study) following posterior spinal fusion in neuromuscular scoliosis (NMS) patients.
2. Preoperative assessment for presence of gastrostomy tube and history of pneumonia is a clinically useful means of identification of NMS patients at heightened risk for respiratory complications.
3. On univariate analysis, presence of tracheostomy was identified as a clinically significant risk factor for development of postoperative respiratory complication.
4. With the possible exception of transferrin, nutritional and hepatic protein laboratory test results are not useful in identification of NMS patients at high risk of respiratory complications.

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