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Clinical Study

Visual loss after corrective surgery for pediatric scoliosis: incidence and risk factors from a nationwide database

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Abstract

BACKGROUND CONTEXT: Perioperative visual loss (POVL) after spinal deformity surgery is an uncommon but severe complication. Data on the incidence and risk factors of this complication after corrective surgery in the pediatric population are limited.

PURPOSE: The present study aimed to investigate nationwide estimates of POVL after corrective surgery for pediatric scoliosis.

STUDY DESIGN: This is a retrospective study that uses a nationwide database.

PATIENT SAMPLE: The sample includes 42,339 patients under the age of 18 who underwent surgery for idiopathic scoliosis.

OUTCOME MEASURES: The outcome measures were incidence of POVL and risk factors.

METHODS: Patients under the age of 18 who underwent elective surgery for idiopathic scoliosis between 2002 and 2011 were identified using the Nationwide Inpatient Sample database. The incidence of POVL (ischemic optic neuropathy, central retinal artery occlusion, or cortical blindness) was estimated after application of discharge weights. Demographics, comorbidities, and operative parameters were compared between patients with and without visual loss. A multivariate logistic regression was performed to identify significant risk factors for POVL development. No funds were received in support of this work.

RESULTS: The incidence of POVL was 1.6 per 1,000 procedures (0.16%). Patients with visual loss were significantly more likely to be younger and male, have Medicaid as insurance, and undergo fusion of eight or more spinal levels compared with patients without visual loss. Following multivariate analysis, older patients (odds ratio [OR]: 0.84; 95% confidence interval [CI]: 0.77–0.91) and female patients (OR: 0.08; 95% CI: 0.04–0.14) were significantly less likely to develop POVL compared with younger and male patients. On the other hand, having Medicaid as insurance (OR: 2.13;

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95% CI: 1.32–3.45), history of deficiency anemia (OR: 8.64; 95% CI: 5.46–14.31), and fusion of eight or more spinal levels (OR: 2.40; 95% CI: 1.34–4.30) were all independently associated with POVL.

CONCLUSIONS: In this nationwide study, the incidence of POVL after scoliosis surgery in patients under the age of 18 was estimated at 0.16%, similar to the rate reported in adult patients. Cortical blindness accounted for all cases of POVL in the present study. Younger patients, patients with history of deficiency anemia, and patients undergoing long-segment fusions may be at increased risk of POVL after corrective surgery for pediatric scoliosis.

Keywords: Adolescent idiopathic scoliosis; Cortical blindness; Infantile scoliosis; Juvenile idiopathic scoliosis; Nationwide Inpatient Sample; Visual loss

Introduction

First described by Slocum et al. in 1948, perioperative visual loss (POVL) after spine surgery is a severe and devastating complication [1]. This complication is estimated to occur in 0.03% to 0.2% of patients who undergo spinal surgery [2], and several etiologies for its development have been identified [2–5]. These include external ocular injury (corneal abrasion), cortical blindness, central retinal artery occlusion, and ischemic optic neuropathy [6]. The risk factors for POVL include patients younger than 18 years (compared with adult patients), obesity, male gender, history of peripheral vascular disease or hypertension, need for blood transfusion, intraoperative hypotension, deformity surgery, and others [2,6].

Although POVL has been well described in patients undergoing surgery for degenerative spine disease and adult spinal deformity [6], few studies have specifically investigated this complication in the younger population [2], specifically pediatric patients who undergo surgery for scoliosis. The purpose of the present study was to estimate the risk of POVL after surgery for spinal deformity in patients younger than 18 years and to identify potential risk factors for its occurrence.

Materials and methods

Study design and data source

This is a retrospective review of the Nationwide Inpatient Sample (NIS) database from 2002 to 2011, the largest inpatient database in the United States. The NIS contains inpatient information from a 20% sample of non-federal hospitals across the country, which corresponds to over 8 million admissions per year (http://www.hcup-us.ahrq.gov/nisoverview.jsp). It uses the International Classification of Diseases, Ninth Edition codes to characterize diagnoses, procedures, and complications.

Patients with a discharge diagnosis of idiopathic scoliosis (737.30) or progressive infantile idiopathic scoliosis (737.32) were identified. Patients over 18 years, who are not undergoing spinal fusion (codes 81.04–81.09), and who have non-elective admissions were excluded (Figure). Perioperative visual loss was identified using the following codes: unspecified sudden visual loss (368.11), ischemic optic neuropathy (377.41), cortical blindness (377.75), and retinal vascular occlusion (362.3, 362.30, 363.31, and 362.35). Other gathered data included patient's age, gender, race, insurance status, operative parameters, length of stay, and inpatient mortality.

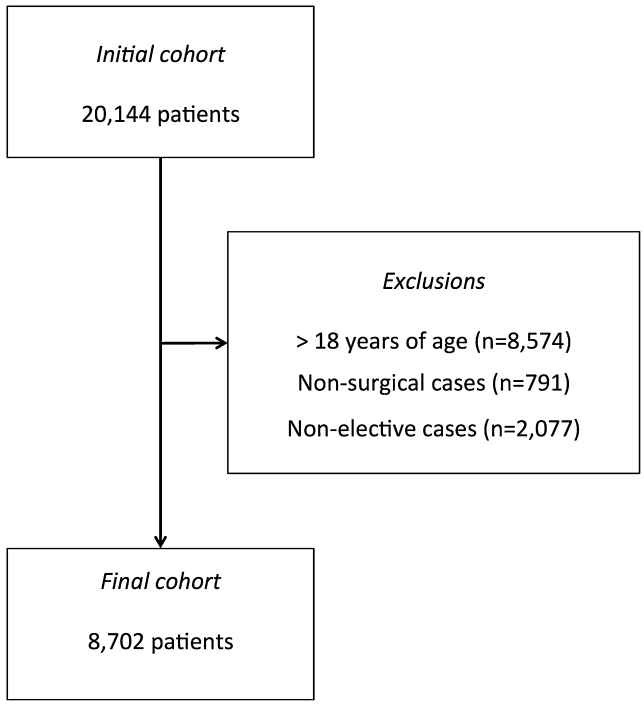

Figure. Patient selection algorithm. The initial cohort included all patients with a discharge diagnosis of idiopathic scoliosis or progressive infantile scoliosis admitted between 2002 and 2011. Discharge weights (supplied by the Nationwide Inpatient Sample [NIS]) were applied to each admission, which roughly correspond to a fivefold multiplication (given that the NIS is a 20% sample database of all admissions for a given year); this yielded a total of 42,339 estimated cases.

Statistical analysis

Discharge weights supplied by the NIS were used to produce national discharge estimates. Given that the NIS is a 20% sample database of all discharges in the United States

EVIDENCE & METHODS

Context

The authors present results following an analysis of the Nationwide Inpatient Sample (NIS; 2002–2011) evaluating risk factors for perioperative visual loss (POVL) following spinal deformity surgery in pediatric patients.

Contribution

The study included more than 42,000 patients. Only 70 experienced the outcome of interest (POVL). Several risk factors, including gender, age, history of iron deficiency anemia and number of levels fused were considered risk factors for POVL.

Implications

These findings provide important information that may be used for preoperative counseling and possible risk management, especially in the setting of extensive surgical intervention and patients with a history of anemia. Given the rarity of this condition, it is appropriate to use a study set such as the NIS to assemble enough patients to allow for robust statistical testing. That said, readers should be aware that given the low number of POVL cases in this series, the number of statistical comparisons and variables included may mean that the model is overfit. Thus, findings may not be translatable to other populations. Additionally, due to the design of the NIS, findings for rare conditions such as POVL after pediatric deformity surgery may not necessarily be nationally representative.

—The Editors

for any given year, roughly a fivefold multiplication gives the total number of estimated cases per year. Thus, the initial search yielded 8,702 admissions, which corresponds to an estimated 42,339 total patients after application of discharge weights. General patient characteristics were compared between cases (patients with visual loss) and controls (no visual loss). Select parameters and comorbidities were compared between groups and assessed by logistic regression to identify potential associations to POVL. These factors included gender (male vs. female), patient-reported race (Caucasian vs. African American vs. Hispanic vs. other), insurance status (Medicare vs. Medicaid vs. private insurance vs. other), diagnosis (juvenile or adolescent idiopathic scoliosis vs. progressive infantile scoliosis), history of iron deficiency anemia (no vs. yes), number of spinal levels fused (less than 8 vs. 8 or more), hypotension (no vs. yes), and transfusion (no vs. yes) [2,6]. Any factors with a p-value <.05 on univariate analyses were then included in a multivariate model and backward stepwise regression was performed. Results are reported as odds ratios (OR) with 95% confidence intervals (CI). Statistical significance was set at .05. All analyses were done in Stata SE 12 (StataCorp LP, College Station, TX, USA).

Table 1
Characteristics of patients with no visual loss and visual loss after surgery for pediatric and adolescent scoliosis

Variable	No visual loss	Visual loss	p-Value
Total	42,269	70	
Age (average years)	13.9±2.3	13.1±2.6	.014*
Female gender (%)	75.2	21.4	<.001*
Race			
Caucasian (%)	65.7	90.0	.013*
African American (%)	17.8	10.0	
Hispanic (%)	8.2	0.0	
Other (%)	8.3	0.0	
Primary payer			
Medicare (%)	0.2	0.0	<.001*
Medicaid (%)	24.2	50.0	
Private insurance (%)	69.1	50.0	
Other (%)	6.5	0.0	
Fusion of 8 or more levels† (%)	57.3	78.6	<.001*
Length of stay (%)	5.6±4.1	8.6±6.2	<.001*
Mortality (%)	0.1	0.0	.776

* Indicates statistical significance.

† Identification of eight-level or more fusion procedures was done via procedural code 81.64.

Results

A total of 42,339 patients under the age of 18 who underwent surgery for scoliosis between 2002 and 2011 and met our inclusion criteria were identified. There were 70 patients who experienced POVL (0.16% or 1.6 per 1,000 procedures). General demographics and operative parameters between groups are summarized and compared in Table 1. There were significant differences in terms of age, gender, race, insurance status, and length of constructs between groups. Patients who experienced POVL were younger (13.1 vs.13.9 years, p<.001) and less likely to be female (21.4% vs. 75.1%, p<.001). The majority of patients who experienced POVL were Caucasian (90%) compared with controls (65.7%, p=.013). A significantly higher proportion of patients in the POVL group underwent fusion of eight or more spinal levels (78.6%) compared with controls (57.3%, p<.001). The rate of POVL for patients with a primary diagnosis of juvenile or adolescent idiopathic scoliosis was 0.16%, compared with 0.19% for infantile idiopathic scoliosis (p=.543).

All patients with POVL were diagnosed with cortical blindness; there were no documented cases of retinal vascular occlusion or ischemic optic neuropathy. Factors significantly associated with POVL on univariate analysis are shown in Table 2. Following multivariate analysis (Table 3), older patients (OR: 0.84; 95% CI: 0.77–0.91) and female patients (OR: 0.08; 95% CI: 0.04–0.14) were significantly less likely to develop POVL compared with younger and male patients. On the other hand, having Medicaid as insurance (OR: 2.13; 95% CI: 1.32–3.45), history of anemia (OR: 8.64; 95% CI: 5.46–14.31), and fusion of eight or more spinal levels (OR:

Table 2
Univariate analysis of factors associated with perioperative visual loss

Parameter	Odds ratio	95% confidence interval	p-Value
Increasing age	0.88	0.80–0.96	.004*
Gender			
Male	Reference		
Female	0.09	0.05–0.16	<.001*
Race			
Caucasian	Reference		
African American	0.40	0.16–1.03	.058
Hispanic	—	—	—
Other	—	—	—
Insurance status			
Medicare	Reference		
Medicaid	2.86	1.78–4.56	<.001*
Private insurance	—	—	—
Other	—	—	—
Diagnosis			
Juvenile or adolescent scoliosis	Reference		
Infantile scoliosis	1.23	0.62–2.40	.543
History of iron deficiency anemia			
No	Reference		
Yes	8.62	5.36–13.85	<.001*
Number of levels fused†			
Less than 8	Reference		
8 or more	2.73	1.54–4.83	.001*
Hypotension			
No	Reference		
Yes	2.13	0.85–5.30	.103
Transfusion			
No	Reference		
Yes	1.54	0.96–2.47	.073

* Indicates statistical significance.
† Identification of eight-level or more fusion procedures was done via procedural code 81.64.

Table 3
Multivariate analysis of factors associated with perioperative visual loss

Parameter	Odds ratio	95% confidence interval	p-Value
Increasing age	0.84	0.77–0.91	<.001*
Gender			
Male	Reference		
Female	0.08	0.04–0.14	<.001*
Insurance status			
Medicare	Reference		
Medicaid	2.13	1.32–3.45	.002*
Private insurance	—	—	—
Other	—	—	—
History of iron deficiency anemia			
No	Reference		
Yes	8.64	5.46–14.31	<.001*
Number of levels fused†			
Less than 8	Reference		
8 or more	2.40	1.34–4.30	.003*

* Indicates statistical significance.
† Identification of eight-level or more fusion procedures was done via procedural code 81.64.

2.40; 95% CI: 1.34–4.30) were all independently associated with POVL.

Discussion

Visual loss after any surgical procedure is an uncommon but severe complication. Slocum et al. and Hollenhorst et al. were among the first to describe POVL after spinal surgery in adults. The patients they described had central retinal artery occlusions, which they attributed to improper head positioning in the prone position, leading to ocular compression by the hard rubber horseshoe headrests previously used in prone-position spine surgery [1,7]. The use of soft headrests has largely eliminated this complication, leaving posterior ischemic optic neuropathy as the most common cause of permanent POVL.

Given its rarity, an accurate determination of the true incidence of POVL after spine surgery is challenging. In a retrospective review of 14,102 spine surgeries performed at a tertiary care institution, the authors reported four cases of POVL (0.03%) [8]. Although two occurred in children, the authors did not specify the proportion of pediatric patients from the overall cohort [8]. In a review of the NIS database that included pediatric and adult patients, the authors found an overall POVL incidence of 0.09%. The incidence for patients younger than 18 years was 0.32% [2]; however, that study included only patients with idiopathic scoliosis and not patients with progressive infantile scoliosis [2]. Other differences from the present study were that Patil et al. examined cases from 1993 to 2002, and included patients with laminectomy, discectomy, or spinal fusion [2]. Stevens et al. reported a higher POVL incidence of 0.2% in 3,450 adult patients from three tertiary care institutions [5]. In line with these previous estimates, we sought to identify the incidence of POVL in the younger population, finding an incidence of 0.16% for patients undergoing corrective surgery for pediatric scoliosis.

Pathophysiology of POVL

As mentioned previously, POVL may result from ischemic optic neuropathy, central retinal artery occlusion, or cortical blindness [2]. Ischemic optic neuropathy develops secondary to "decreased perfusion pressure of the optic nerve head" [2]. The optic nerves receive blood supply from many sources, including branches from the internal carotid arteries, anterior cerebral and anterior communicating arteries, short posterior ciliary arteries, and perhaps most importantly pial vessels that originate from the ophthalmic artery and that lack autoregulatory control, making them particularly susceptible to damage from decreased blood pressure [9].

In patients undergoing prone-position spine surgery, central retinal artery occlusion results most often from direct pressure on the globe and presents as unilateral vision loss with or without signs of periorbital swelling [10]. The use of soft

headrests and the practice of constant (every 15 min) checks of head position on the headrest during the case have largely eliminated this complication.

Lastly, cortical blindness occurs from injury of the striate cortex. It has been suggested that given the watershed blood supply to the visual cortex, this region "is more likely to be susceptible to hypo-perfusion and ischemic injuries" [11]. Factors associated with this event include cardiac or vascular thromboembolism or hypoperfusion secondary to hypotension or arrhythmia [3]. Clinical findings include visual field impairment, normal retinal examination, normal pupillary reflexes, confusion, or visual hallucinations [3,12,13]. Although rare, cortical blindness (in most cases transient) has been reported after urological [11], spinal [14], and cardiac surgery [15] in children. Nathan et al. described a case of transient postoperative cortical blindness in an 11-year-old with muscular dystrophy who underwent posterior spinopelvic fixation. The procedure lasted for 675 minutes and blood loss was 1,300 mL; the lowest intraoperative blood pressure was 55/28 mm Hg and the lowest mean arterial pressure was 37 mm Hg. The authors concluded that "the combination of hypotension, excessive estimated blood loss, and increased fluid administration may have exposed our patient to longer periods of physiological alterations resulting in cerebral underperfusion of the posterior border zone and subsequent transient cortical blindness" [14]. Although hypotensive anesthesia is used in an attempt to prevent excessive blood loss during spine surgery, anecdotal cases have suggested that it may be an important risk factor for POVL. Thus, future research into the optimum blood pressure range during spinal surgery is warranted, and the benefits and risks of such a strategy should be evaluated and recognized by patients and clinicians.

In a review of 105 cases of POVL in adults, the authors reported cortical blindness in 49% of cases, compared with 28% with ischemic optic neuropathy and 22% with vascular occlusion [6]. In another study of POVL in both children and adults, the authors found that children were much more likely to present with non-ischemic optic neuropathy and non-artery occlusion visual loss compared with adults [2]. Commensurate with these findings, we found that all cases of POVL in our study were caused by cortical blindness.

Risk factors

Numerous parameters have been suggested as potential risk factors for POVL in the setting of spinal surgery. These include prone positioning, intraoperative hypotension, excessive blood loss, prolonged surgery time, deformity surgery, excessive use of crystalloids instead of colloids, preexisting iron deficiency anemia, intraoperative anemia, facial or orbital edema, history of peripheral vascular disease, hypertension, and diabetes mellitus with end-organ damage, among others [2,3,6,16,17].

In the present study, we identified younger age, male gender, preexisting iron deficiency anemia, having Medicaid as primary insurance, and fusion of eight or more spinal levels as independent risk factors for POVL. A study using the American Society of Anesthesiologists Postoperative Visual Loss Registry found that 72% of POVL patients were also male, supporting this as a potential risk factor [18]. Although the NIS does not record operative time or blood loss, anemia has also been found to be a risk factor for POVL. In a study of over 4 million spinal procedures, investigators found that preoperative deficiency anemia increased the risk of POVL by a factor of 5.9 compared with patients without anemia [2].

Fusion of multiple spinal segments has also been identified as a risk factor for POVL. Nandyala et al. found that among 105 cases of visual loss after spinal surgery, 46.8% involved fusion of eight or more levels, compared with 2.4% in patients without visual loss ($p<.001$) [6]. The rationale behind this as a potential risk factor is perhaps more related to intraoperative blood loss and prolonged operative time, both associated with long-segment fusion, than to the actual number of segments that are fused [6]. Patients with Medicaid were also at increased risk of POVL; studies have suggested that patients with suboptimal insurance are at an increased risk for poor outcomes, perhaps because they typically represent a sicker population [19]. Although other studies have suggested that perivascular disease, hypertension, and diabetes are potential risk factors for POVL in patients undergoing spine surgery [2,6], pediatric patients rarely have these comorbidities.

Preventive strategies and treatment

Recommendations to potentially decrease the incidence of POVL after spine surgery include avoiding direct pressure on the globe, avoiding perioperative hypotension, avoiding perioperative anemia, considering 10° of reverse Trendelenburg positioning during prone-position surgery, maintaining hematocrit above 30 in high-risk patients, avoiding excess crystalloid solutions, staging procedures (if they are to be greater than 8 h), maintaining a mean arterial pressure at patient's baseline, and performing a visual examination as early as possible in higher risk patients with postoperative visual complaints [2]. Additionally, the use of devices to protect the eyes during prone operations (such as the Opti-Gard eye protector, ROHO neoprene pillow, and ProneView Protective Helmet System) may potentially help prevent this complication [17].

Given that long-segment fusion procedures and anemia are potential risk factors for POVL in the pediatric population, optimization of fluid balance is a recommended preventive strategy. Chang and Miller recommend that fluid deficits be replaced (maintenance fluids × hours nil per os (NPO)) preoperatively, and an additional liter of fluids given to account for venous pooling in the lower extremities and changes in hemodynamics secondary to positioning [8]. Replacement of fluid losses ranges from 2 mL/kg per hour to 10 mL/g per hour, depending on several factors such as incision size, length of

Table 4
Summary of recommendations in the Practice Advisory for Perioperative Visual Loss Associated with Spine Surgery, published by the American Society of Anesthesiologists [21]

Recommendation
"High-risk" patients for POVL include patients who undergo prolonged procedures or have substantial blood loss.
Continuous blood pressure and central venous pressure monitoring should be considered in high-risk patients.
High-risk patients should be advised of the potential risk of POVL.
Use of hypotensive techniques has not been shown to be associated with POVL.
Both colloids and crystalloids should be used to maintain intravascular volume in patients with excessive blood loss.
The transfusion threshold that would decrease the risk of POVL is unknown at this time.
Staged procedures should be considered for high-risk patients.
Positioning for high-risk patients includes placing the head at the same level (or above) than the heart when possible. The patient's head should also be maintained in a neutral position when possible.

construct, and operative time [8]. Although there is no universal transfusion trigger in spine surgery, we recommend maintaining hemoglobin levels in pediatric patients above 8 g/dL, particularly during the active bleeding phases of surgery. Blood losses are usually replaced in a 3:1 blood-to-crystalloid or 1:1 blood-to-whole blood ratio [8]. It may be also reasonable to optimize hemoglobin levels before anemic pediatric patients undergo major spinal surgery. van Popta et al. recommend a minimum preoperative hemoglobin level of 5 g/dL higher than the established transfusion trigger value at any given institution (which is typically 7 g/dL) [20]. The use of antifibrinolytics, such as tranexamic acid or epsilon-aminocaproic acid, may be considered in carefully selected patients.

In 2012, a "practice advisory" for POVL associated with spine surgery was updated and published by the American Society of Anesthesiologists; findings are summarized in Table 4. However, it is important to note that these recommendations do not apply for cortical blindness, which was the cause of POVL in our study. Although some groups have suggested the use of corticosteroids, mannitol, and antiplatelet agents to treat POVL, there is insufficient current evidence to support their use [5,21–24]. If POVL is suspected after spine surgery, immediate consultation with an ophthalmologist is recommended.

Limitations

Although the present study represents one of the largest to date to examine POVL in patients younger than 18 years, it has several limitations. Identification of POVL was done using the International Classification of Diseases, Ninth Edition codes, which carries the risk of information or coding bias. Certain patients with neuromuscular scoliosis are known to have coexisting cortical blindness, and it may be possible that some of the patients in our series were diagnosed incorrectly as having idiopathic or progressive scoliosis. Nonetheless, neuromuscular scoliosis has a different diagnostic code, and it was not included in the initial database search. Another limitation is that the NIS database does not include radiographic data such as scoliosis curves, or other operative parameters such as surgery duration or estimated blood loss, which may have contributed to this complication. Lastly, given that it is an inpatient database, it is unclear if the POVL in these cases was permanent or resolved, as no information outside the inpatient stay is captured. Nonetheless, the main objective of the present study was to estimate the nationwide incidence of visual loss after corrective surgery for idiopathic scoliosis in the pediatric population and to identify potential risk factors for its occurrence. Although we acknowledge that this study design may not be the best to identify such a rare complication, the present findings were relatively consistent with previous clinical and national database publications, particularly in terms of the incidence of POVL and associated risk factors.

Conclusions

In the present study, POVL after scoliosis surgery in patients younger than 18 years old had an estimated incidence of 1.6 cases per 1,000 procedures (0.16%) and was caused exclusively by cortical damage rather than by either retinal vascular occlusion or ischemic optic neuropathy. Younger patients, patients with a history of preexisting iron deficiency anemia, and patients undergoing long-segment fusions appear to be at increased risk of POVL after spinal surgery.

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