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REPORTS OF ORIGINAL INVESTIGATIONS

Ocular injury during spine surgery
Lésion oculaire pendant une chirurgie du rachis

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Abstract

Purpose *Ocular injury and vision loss are rare complications of surgery. Spine surgery has been identified as particularly high risk for postoperative vision loss; nevertheless, ocular injuries have not been comprehensively assessed in this patient population.*

Methods *This historical cohort study assessed incidence, cause, and risk factors of perioperative ocular injury after spine surgery at a tertiary care medical centre from January 1, 2006 through January 31, 2018. Patients were included who had ocular injury identified during an ophthalmology consultation in the first seven postoperative days. Differences in demographic, laboratory, intraoperative, and postoperative characteristics between those experiencing or not experiencing ocular injury were assessed with Fisher exact and Wilcoxon signed-rank tests for categorical and continuous variables, respectively.*

Results *Of 20,128 qualifying spine surgeries, 39 cases of perioperative ocular injuries were identified (39/20,128; 0.19% [95% confidence interval (CI), 0.14 to 0.26]). The most common ocular injury was blurry vision of unknown cause (13/39; 33%; 95% CI, 18.6 to 46.4), followed by ischemic optic neuropathy (9/39; 23%; 95% CI, 12.6 to 38.3) and corneal abrasion (7/39; 18%; 95% CI, 9.0 to 32.7). All cases of blurry vision of unknown cause were diagnosed via ophthalmology consultation and resolved within several days. Patients with perioperative ocular injury were more likely to have baseline anemia, have undergone fusion and instrumentation procedures, and had longer operative times with greater crystalloid, colloid, and transfusion requirements and more blood loss.*

Conclusions *Although not representing a causal relationship, these data suggest that surgical factors may have a greater role than demographic characteristics or other clinical factors in the development of perioperative ocular injury. Surgeons, anesthesiologists, and patients should be aware of the increased risk of ocular injury that accompanies longer, more extensive spine operations.*

Résumé

Objectif *Les lésions oculaires et la perte de vision sont des complications chirurgicales rares. La chirurgie du rachis a été identifiée comme une intervention entraînant un risque particulièrement élevé de perte de vision postopératoire; cependant, les lésions oculaires n'ont pas été évaluées de manière exhaustive chez cette population de patients.*

Méthode *Cette étude de cohorte historique a évalué l'incidence, la cause et les facteurs de risque de lésion oculaire périopératoire après une chirurgie du rachis dans un centre médical de soins tertiaires entre le 1er janvier 2005 et le 31 janvier 2018. Les patients ayant subi une lésion oculaire diagnostiquée lors d'une consultation en ophtalmologie au cours des sept premiers jours postopératoires ont été inclus. Les différences de caractéristiques démographiques, de laboratoire, peropératoires et postopératoires entre les patients ayant subi ou non une lésion oculaire ont été évaluées à l'aide du test exact de Fisher et du test des rangs signés de Wilcoxon pour les variables catégoriques et continues, respectivement.*

Résultats *Parmi les 20 128 chirurgies du rachis éligibles, 39 cas de lésions oculaires périopératoires ont été identifiés (39/20,128; 0,19 % [intervalle de confiance (IC) 95 %, 0,14 à 0,26]). La lésion oculaire la plus fréquente était une vision floue de cause inconnue (13/39; 33 %; IC 95 %, 18,6 à 46,4), suivie d'une neuropathie optique ischémique (9/39; 23 %; IC 95 %, 12,6 à 38,3) et d'une abrasion cornéenne (7/39; 18 %; IC 95 %, 9,0 à*

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32,7). Tous les cas de vision floue de cause inconnue ont été diagnostiqués lors d'une consultation en ophtalmologie et se sont résolus après plusieurs jours. Les patients ayant subi une lésion oculaire périopératoire étaient plus susceptibles de présenter une anémie de départ, d'avoir subi des interventions de fusion et instrumentation rachidiennes, et d'avoir subi une chirurgie plus longue nécessitant davantage de cristalloïdes, de colloïdes et de transfusions, ainsi que d'avoir subi des pertes sanguines plus importantes.

Conclusion *Bien que n'établissant pas de relation causale, ces données suggèrent que les facteurs chirurgicaux pourraient jouer un rôle plus important que les caractéristiques démographiques ou les autres facteurs cliniques dans l'apparition d'une lésion oculaire périopératoire. Chirurgiens, anesthésiologistes et patients devraient être conscients du risque accru de lésion oculaire qui accompagne les opérations du rachis plus longues et plus importantes.*

Ocular injury and vision loss are relatively rare complications of surgery, with data from two large reviews reporting an overall incidence of 0.02–0.06% for perioperative ocular injury after nonocular surgery.[1,2] Nevertheless, in a survey of patients undergoing outpatient surgery, an "eye problem" was reported with a frequency of 0.1–0.6%, suggesting that ocular injuries may be underdiagnosed.[3] The most common ocular injury occurring after nonocular surgery is corneal abrasion, with an incidence ranging from 0.01–44% as assessed by clinical complaint or fluorescein staining.[1,2,4,5] Other injuries include conjunctivitis, direct chemical injury, direct trauma, and blurry vision.[1,2] Previously identified risk factors for perioperative eye injury include increased operative time, lateral or prone positioning, head or neck surgery, fibreoptic intubation, anemia, and deliberate hypotension.[1,2] More often than not, a direct cause of injury is not discovered and permanent sequelae are rarely seen.[2] A closed claims analysis by the American Society of Anesthesiologists showed that ocular injuries constituted only 3% of claims, but the frequency of payment was higher than for claims not involving the eye.[6]

Vision loss is one of the most feared ocular complications, and patients undergoing cardiac surgery and spine surgery have the highest rates of postoperative vision loss.[7,8] Complete blindness after spine surgery has been estimated at one to 20 of 10,000 operations.[7-10] The most common cause, ischemic optic neuropathy (ION), appears to be decreasing in incidence.[10] Previously identified risk factors for ION include age, transfusion, male sex, increased anesthetic duration, greater estimated blood loss, use of a Wilson frame, anemia, diabetes mellitus, prolonged operative times, and obesity.[10-12] The most recent data derived from the Nationwide Inpatient Sample from 1998 to 2012 identified age, male sex, transfusion, and obesity as risk factors.[10]

Although our understanding of risk factors associated with frank vision loss after spine surgery has improved substantially in the last 20 years, far less is known about perioperative ocular injuries not associated with vision loss. To our knowledge, no study has provided a complete characterization of ocular injuries in this population. Hence, the goal of this study was to determine the incidence, causes, and risk factors for all types of perioperative ocular injuries in a large cohort of patients who underwent spine surgery.

Methods

This historical cohort study was approved by the Mayo Clinic Institutional Review Board in March 2018 (#18-001505). The requirement for written informed consent was waived for this minimal risk study; nevertheless, patients who had previously denied authorization to use their medical records in research activities were excluded. We used Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) as the reporting guideline for the study, although not all items were applicable.[13]

The inclusion criteria were all spine operations performed between January 1, 2006 and December 31, 2017, for patients aged 18 yr or older at a single tertiary care academic medical centre that performs approximately 1,700 spine operations each year. Both neurosurgeons and orthopedic spine surgeons performed the procedures.

Study patients were identified using Perioperative Data Mart, an institutional data warehouse that contains demographic, surgical, transfusion, and laboratory characteristics of all patients who have undergone surgery at the study institution.[14] Additional characteristics not available in the Perioperative Data Mart were obtained from Advanced Cohort Explorer, a second institutional database.[15] Both data sources undergo extensive validation at regular intervals, and data accuracy exceeds that obtained by manual extraction.[16,17]

Multiple perioperative variables were extracted from the electronic health record (EHR), including demographic characteristics (age, sex, and body mass index), severity of illness profiles (American Society of Anesthesiologists physical status score, Charlson comorbidity index score, and comorbid conditions), surgical characteristics (surgery

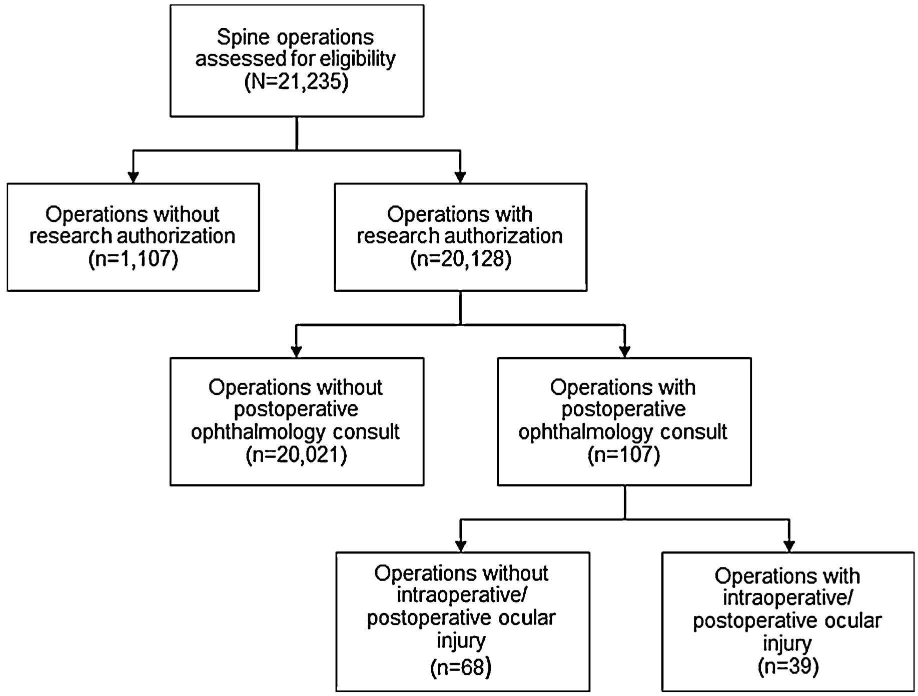

Figure Flowchart of exclusion. To obtain research authorization, institutional forms were mailed to patients indicating that their medical records would be used in clinical research unless they explicitly marked that they did not wish for their records to be used (Minnesota Statute 144.295)

type, total operative time, surgical positioning, estimated blood loss, and urinary output), resuscitative features (intraoperative crystalloid and colloid volumes, transfusion requirements), and postoperative characteristics (need for postoperative mechanical ventilation, intensive care unit [ICU] admission and length of stay, and hospital length of stay).

The primary outcome of interest was the presence of a postoperative ophthalmology consult within the first seven days after the index surgery. An electronic search algorithm was used to identify all patients receiving a postoperative ophthalmology consult. Health records for this subgroup were then manually reviewed for the presence or absence of ophthalmologic injury and type. As a predefined secondary analysis, EHRs for all patients were also searched for the presence of proparacaine eye drop administration in the first seven days after the surgical procedure to identify cases of potential corneal abrasion that were not evaluated as part of an ophthalmology consultation.

Statistical analysis

Continuous data were summarized with median [interquartile range (IQR); 25^{th}–75^{th} percentile], and categorical variables were summarized using frequency with proportion. Point estimates with 95% confidence intervals (CI) were used to assess the frequency of outcomes. We used univariable methods to compare risk factors (without adjustment) for injury between patients with and without ocular injury. Fisher exact tests (categorical variables) and Wilcoxon rank-sum tests (continuous variables) were used to assess factors for association with perioperative ocular injury. P values < 0.05 were considered statistically significant. Because of the anticipated low frequency of serious ocular injuries and the corresponding lack of statistical power, we did not perform multivariable regression to determine independent risk factors of ocular injury. JMP software (SAS Institute Inc., Cary, NC, USA) was used for statistical analyses.

Results

A total of 20,128 qualifying spine operations for 17,771 unique patients were included over the study period (Figure). Of those, 107 patients (107/20,128; 0.53%; 95% CI, 0.44 to 0.64) received a postoperative ophthalmology consultation. A manual review of the records for these patients resulted in 39 unique spine operations associated with a new perioperative ocular injury, corresponding to an incidence of 0.19% (39/20,128; 95% CI, 0.14 to 0.26). The most common ocular injury was blurry vision (13/39; 33%; 95% CI, 18.6 to 46.4) followed by ION (9/39; 23%; 95% CI, 12.6 to 38.3) and corneal abrasion (7/39; 18%; 95% CI, 9.0 to 32.7). Although ION uniformly resulted in permanent vision loss, all cases of blurry vision of unknown cause and corneal abrasion were resolved, most within two days. All ocular injuries are listed in Table 1. Notably, no cases of retinal arterial occlusion occurred. An

Table 1 Perioperative ocular injuries in the study cohort

Injury	No. (%) (n = 39)[a]
Blurry vision of unknown cause	13 (33.3)
Ischemic optic neuropathy	9 (23.1)
Corneal abrasion	7 (17.9)
Diplopia	3 (7.7)
Exposure keratopathy	3 (7.7)
Subconjunctival hemorrhage	2 (5.1)
Conjunctival abrasion	1 (2.6)
Visual field defect (tunnel vision)	1 (2.6)
Floaters	1 (2.6)

[a] One patient with both corneal abrasion and subconjunctival hemorrhage

additional 33 cases (33/20,128; 0.16%; 95% CI, 0.12 to 0.23) of potential corneal abrasion were identified (secondary analysis) by the presence of proparacaine eye drop administration postoperatively.

No significant differences in demographic characteristics were found between patients with an ocular injury and those without (Table 2), although differences were found in some comorbid conditions, laboratory values, and surgical characteristics. Patients with perioperative ocular injury were more likely to have anemia and asthma. Patients with perioperative ocular injury had lower hemoglobin levels than patients without ocular injury, both preoperatively and intraoperatively. Surgical procedures associated with ocular injury were more likely to be performed in the right lateral position. Ocular injury was also more likely to occur after surgery that included fusion and instrumentation.

All intraoperative and postoperative data are summarized in Table 3. Patients with ocular injury were more likely to have had a longer operative time, received higher volumes of crystalloid solution and colloid solution, and had greater estimated intraoperative blood loss. Patients with ocular injury were also more likely to have received transfusions of allogeneic red blood cells (RBC), plasma, and platelets, although the volumes transfused were not significantly different. Postoperatively, patients suffering a perioperative ocular injury had a longer hospital stay (median, 7.2 d *vs* 2.4 d; $P < 0.001$) and were more likely to require admission to the ICU and mechanical ventilation.

Nine cases of ION were diagnosed postoperatively (9/20,128; 0.05%; 95% CI, 0.02 to 0.09) (Table 4). Compared with patients without ION, patients with ION were older, had longer operative times, received more crystalloid solution, and lost more blood. Although there was no significant difference in the lowest level of intraoperative hemoglobin, patients diagnosed with ION were more likely to have received an RBC transfusion. Postoperatively, the patients with ION had longer hospital stays and were more likely to require ICU admission, although there was no difference in the need for mechanical ventilation. In a post hoc analysis, we explored how variation in surgical time frame may have impacted the rates of ocular injury. Specifically, we divided the surgical procedures into three unique time frames that would create approximately equal sample sizes. These included 2006–2010 (n =7,177), 2011–2014 (n = 6,348), and 2015–2017 (n = 6,603). There was no significant difference in the rate of any ocular injury (P = 0.09) or ION (P = 0.09) between the three groups.

Discussion

Our aim was to quantify the incidence and to identify potential risk factors of perioperative ocular injury after spine surgery. To that end, we found an incidence of 0.19% of new perioperative ocular injury, with the most common reason for ophthalmology consultation being blurry vision of unknown cause followed by ION and corneal abrasion. This rate is higher than previously reported rates for patients undergoing any type of nonocular surgery.[1,2] If cases of postoperative blurry vision of unknown cause were eliminated, the adjusted rate of ocular injury would be 0.13% (26/20,128), which is higher than previous estimates for nonocular surgery. This is the largest study describing perioperative ocular injury specifically after spine surgery.

There are several potential reasons for a higher incidence of ocular injury in this cohort than in others previously described.[1,2] First, there were differences in data acquisition. Our study used a robust electronic search algorithm and manual verification of results, which may have more efficiently identified cases of ocular injury than systems used in previous studies. Second, spine surgery is associated with a greater incidence of ION compared with other types of noncardiac surgery,[10] which certainly contributed to the increased incidence of ocular injury in our study population. Additionally, major spine surgery almost uniformly requires prone positioning (97% of cases). The manipulation required for optimal patient positioning or the prone position itself may put the patient at heightened risk for ocular injury that would not occur for a heterogeneous group of patients placed in various surgical positions. Interestingly, in this study, the incidence of prone positioning did not differ significantly for patients with or without ocular injury. Nevertheless, ocular injury was more likely to occur when patients were in the right lateral position, which is consistent with previous reports for other surgical populations.[1,2] The lateral position likely places the patient at risk during both the positioning process and during surgery, with effects

Table 2 Demographic, clinical, laboratory, and surgical characteristics of the cohort

Characteristic	Perioperative ocular injury (n = 39)[a]	No perioperative ocular injury (n = 20,089)[a]	P value
Demographic information			
Age (yr)	58 [43–71]	60 [47–71]	0.71
Male sex	21 (53.8)	11,459 (57.0)	0.75
Weight, kg	78 [66–103]	85 [71–99]	0.32
Obesity, BMI ≥ 30 kg·m^{-2}	14 (36.8)	8,462 (42.3)	0.52
ASA physical status	2 [2–3]	2 [2–3]	0.42
Comorbid conditions			
Charlson comorbidity index score	3 [1–5]	3 [2–5]	0.76
Myocardial infarction	1 (2.6)	676 (3.4)	1.00
Congestive heart failure	0 (0)	298 (1.5)	1.00
Peripheral vascular disease	0 (0)	203 (1.0)	1.00
Dementia	0 (0)	106 (0.5)	1.00
Cerebrovascular accident	1 (2.6)	611 (3.0)	1.00
Chronic pulmonary disease	7 (17.9)	1,878 (9.3)	0.09
Asthma	6 (15.4)	1,346 (6.7)	0.04
Interstitial lung disease	0 (0)	85 (0.4)	1.00
Connective tissue disease	0 (0)	583 (2.9)	0.63
Diabetes mellitus w/o complications	8 (20.5)	2,513 (12.5)	0.14
Diabetes mellitus with complications	3 (7.7)	556 (2.8)	0.09
Peptic ulcer disease	0 (0)	401 (2.0)	1.00
Liver disease			
Mild	0 (0)	136 (0.7)	1.00
Moderate to severe	0 (0)	35 (0.2)	1.00
Hemiplegia	0 (0)	79 (0.4)	1.00
Moderate to severe kidney disease	1 (2.6)	726 (3.6)	1.00
Cancerous tumours	6 (15.4)	3,185 (15.9)	1.00
Leukemia	1 (2.6)	102 (0.5)	0.18
Lymphoma	2 (5.1)	290 (1.4)	0.11
AIDS	0 (0)	3 (0.02)	1.00
Carotid stenosis	1 (2.6)	641 (3.2)	1.00
Hypertension	19 (48.7)	7,517 (37.4)	0.18
Coronary artery disease	5 (12.8)	1,950 (9.7)	0.42
Atrial fibrillation/flutter	3 (7.7)	1,281 (6.4)	0.74
Ophthalmologic disease	4 (10.3)	2,508 (12.5)	0.81
Current or history of smoking	3 (7.7)	2,370 (11.8)	0.62
Anemia[b]	11 (40.7)	3,237 (22.8)	0.04
Laboratory values			
Hgb level, closest preoperative, g·dL^{-1}	13.0 [11.9–14.2]	13.8 [12.7–14.9]	0.02
Creatinine level, closest preoperative, mg·dL^{-1}	0.9 [0.8–1.1]	0.9 [0.8–1.1]	0.37
Surgical characteristics			
Position[c]			
Supine	0 (0)	70 (0.3)	1.00
Prone	29 (74.4)	16,244 (80.8)	0.31
Right lateral	5 (12.8)	266 (1.3)	< 0.001
Left lateral	0 (0)	168 (0.8)	1.00
Surgery level			
Cervical	5 (12.8)	3,219 (16.0)	0.83

Table 2 continued

Characteristic	Perioperative ocular injury (n = 39)[a]	No perioperative ocular injury(n = 20,089)[a]	P value
Thoracic	0 (0)	869 (4.3)	0.42
Lumbar	4 (10.3)	5,924 (29.5)	0.01
Not specified	30 (76.9)	10,077 (50.2)	0.001
Procedure			
Discectomy	3 (7.7)	2,705 (13.5)	0.48
Decompression	24 (61.5)	15,534 (77.3)	0.03
Fusion	11 (28.2)	3,029 (15.1)	0.04
Instrumentation	13 (33.3)	2,285 (11.4)	< 0.001
Other	0 (0)	776 (3.9)	0.41
Emergent surgery	0 (0)	298 (1.5)	1.00

ASA = American Society of Anesthesiologists; BMI = body mass index; Hgb = hemoglobin; w/o = without

[a] Continuous variables are presented as median [interquartile range] and categorical variables as No. (%). Comparisons between continuous variables were assessed with the Wilcoxon rank-sum test and categorical/nominal comparisons with the Fisher exact test

[b] Anemia was defined as < 13.0 g·dL^{-1} for males and as < 12.0 g·dL^{-1} for females. Data were available for 27 patients with ocular injury and 14,174 patients without ocular injury

[c] Position was not specified in 3,346 (16.6%) cases

Table 3 Intraoperative and postoperative characteristics of patients with and without perioperative ocular injury

Characteristic	Perioperative ocular injury[a] (n = 39)	No perioperative ocular injury[a] (n = 20,089)	P value
Intraoperative			
Operative time, min	365 [213–526]	171 [117–270]	< 0.001
Crystalloid solution, mL	3,903 [2,831–5,738]	2,193 [1,394–3,293]	< 0.001
Colloid solution, mL	1,235 [620–2,527]	1,000 [500–1,386]	0.02
Estimated blood loss, mL	450 [250–1,218]	198 [75–475]	< 0.001
Urine output, mL, total	1,250 [674–2,219]	900 [500–2,647]	0.01
Lowest intraoperative Hgb level, g·dL^{-1}	9.5 [8.6–10.7]	12.1 [10.6–12.1]	0.01
Intraoperative Hgb level < 7 g·dL^{-1}	1 (3.3)	94 (1.3)	0.32
Any RBC transfusion	11 (28.2)	1,823 (9.1)	< 0.001
RBC, total, mL	660 [330–792]	660 [330–990]	0.70
Any FFP transfusion	3 (7.7)	247 (1.2)	0.01
FFP, total, mL	2,072 [567–2,831]	569 [511–1,072]	0.07
Any platelet transfusion	3 (7.7)	234 (1.2)	0.01
Platelets, total, mL	457 [411–768]	290 [238–478]	0.09
Postoperative			
Hospital length of stay, days	7.2 [4.3–17.3]	2.4 [1.3–5.0]	< 0.001
ICU admission	21 (53.8)	3,985 (19.8)	< 0.001
ICU length of stay, days	1.0 [0.8–3.9]	1.0 [0.8–1.7]	0.32
Postoperative mechanical ventilation	5 (12.8)	348 (1.7)	< 0.001
Postoperative mechanical ventilation, days	0 [0–0]	0 [0–0]	< 0.001

FFP = fresh frozen plasma; Hgb = hemoglobin; ICU = intensive care unit; RBC = red blood cells

[a] Continuous variables are presented as median [interquartile range] and categorical variables as No. (%). Comparisons between continuous variables were assessed with the Wilcoxon rank-sum test and categorical/nominal comparisons with the Fisher exact test

Table 4 Baseline and intraoperative characteristics for patients with and without ischemic optic neuropathy

Baseline characteristics	ION[a] (n = 9)	No ION[a] (n = 20,119)	P value
Age (yr)	68 [62–81]	60 [47–71]	0.01
Male sex	7 (77.8)	11,473 (57.0)	0.32
Weight, kg	84 [77–103]	85 [71–99]	0.74
Obesity, BMI $\geq$ 30 kg·m^{-2}	3 (33.3)	8,473 (42.3)	0.74
Hgb level, closest preoperative, g·dL^{-1}	12.8 [11.9–14.4]	13.8 [12.7–14.9]	0.27
Anemia[b]	4 (57.1)	3,244 (22.9)	0.03
ASA physical status	3 [2–3]	2 [2–3]	0.25
Intraoperative characteristics			
Operative time, min	445 [279–598]	171 [117–270]	< 0.001
Crystalloid solution, mL	4,701 [3,564–6,320]	2,194 [1,394–3,296]	< 0.001
Colloid solution, mL	1,000 [771–2,549]	1,000 [500–1,394]	0.27
Estimated blood loss, mL	500 [374–1,475]	198 [75–494]	0.002
Total urine output, mL	828 [648–1,572]	900 [500–1,600]	0.59
Lowest intraoperative Hgb level, g·dL^{-1}	9.6 [8.0–10.2]	10.6 [9.2–12.1]	0.07
Intraoperative Hgb level < 7 g·dL^{-1}	0 (0)	95 (0.47)	1.00
Any RBC transfusion	3 (33.3)	1,831 (9.1)	0.04
RBC, total, mL	788 [660–2,450]	660 [330–990]	0.17
Any FFP transfusion	1 (11.1)	249 (1.1)	0.11
FFP, total, mL	2,072 [2,072–2,072]	569 [513–1,073]	0.12
Any platelet transfusion	1 (11.1)	236 (1.2)	0.10
Platelets, total, mL	768 [768–768]	290 [239–475]	0.15
Postoperative characteristics			
Hospital length of stay, day	16.1 [6.75–24.2]	2.4 [1.3–5.1]	< 0.001
ICU admission	5 (55.6)	4,001 (19.9)	0.02
ICU length of stay, day	1.8 [0.9–6.4]	1.0 [0.8–1.7]	0.15
Postoperative mechanical ventilation	1 (11.1)	352 (1.8)	0.15
Ventilation in ICU, day	0 [0–0]	0 [0–0]	0.03

ASA = American Society of Anesthesiologists; BMI = body mass index;; FFP = fresh frozen plasma; Hgb = hemoglobin; ICU = intensive care unit; ION = ischemic optic neuropathy; RBC = red blood cells

[a] Continuous variables are presented as median [interquartile range] and categorical variables as No. (%). Comparisons between continuous variables were assessed with the Wilcoxon rank-sum test and categorical/nominal comparisons with the Fisher exact test

[b] Anemia was defined as < 13.0 g·dL^{-1} for males and as < 12.0 g·dL^{-1}for females. Data were available for seven patients with ocular injury and 14,174 patients without ocular injury

potentially related to direct ocular compression. There was no consistency regarding which eye was affected (dependent *vs* nondependent), and the same eye coverings were used regardless of patient positioning.

Our results show that many commonly considered patient factors have little influence on the risk of perioperative ocular injury after spine surgery. There were minimal differences in demographic or comorbid conditions between those with ocular injury and those without. Nevertheless, those with preoperative anemia were more likely to have an ocular injury. Mechanistically, this suggests that the risk of some ocular injuries (e.g., ION) may increase in the presence of decreased tissue oxygen delivery, although future studies will be necessary to further define the relationship between anemia and perioperative ocular injury. Conceivably, preoperative optimization of anemia may be a potentially modifiable risk factor in this high-risk patient population.

Intraoperative factors likely play a greater role than patient-specific factors in the development of ocular injury. In this study, patients experiencing ocular injury underwent more extensive procedures. They had longer operative times, higher crystalloid and colloid requirements, increased intraoperative blood loss, and lower intraoperative hemoglobin values. These findings are consistent with previously identified risk factors for ophthalmologic complications.[1,2] Moreover, patients with ocular injury were more likely to experience postoperative complications including longer hospital lengths of stay and increased requirements for ICU-level care and mechanical ventilation. Nevertheless, these findings are probably attributable to greater intraoperative insults than to the ocular injury itself.

The rate of ION in this study (0.05%; 95% CI, 0.02 to 0.09) is consistent with that of previous reports.[9,10] Lengthier surgery, higher crystalloid volumes, and greater estimated blood loss were all associated with ION. These findings confirm those of prior studies.[8,10,11] Additionally, the incidence of RBC transfusion was greater for patients with ION. The only difference in patient demographic characteristics for those with ION was age: patients with ION were older than those without ION (68.4 yr *vs* 60.3 yr; $P = 0.02$).

The rate of corneal abrasion was lower than has been previously reported, which was an unexpected finding.[1,2] Nevertheless, this was probably due to institutional practice. At our institution, corneal abrasions are commonly recognized and managed in the postanesthesia care unit by anesthesiology personnel; ophthalmology personnel are seldom involved in a straightforward occurrence. Because our study was designed to search for patients with ophthalmology consults, the accuracy of our results for corneal abrasions was certainly limited. We found an additional 33 cases of corneal abrasion by identifying patients who received proparacaine eye drops. Nevertheless, using this parameter still likely grossly underestimates the true incidence, and many cases of corneal abrasion probably go undocumented in the EHR or unrecognized by medical personnel.

This study has several limitations. First, this is a historical cohort study and contains all the inherent limitations of such a study design. Data were limited to what was available in the EHR. Many cases of minor perioperative ocular injury may not have been identified or adequately documented—especially for corneal abrasions, as mentioned previously. Additionally, given the relatively low incidence of ocular injury, multivariable analyses were not performed because of the inevitable concerns with model overfitting. Therefore, the effects of residual confounding remain highly relevant. Finally, this study was designed to identify patient and procedural factors associated with perioperative ocular injury. In no way do these results imply causal relationships with any identified factor.

In conclusion, perioperative ocular injury in spine surgery can be a devastating complication after an otherwise successful operation. The incidence is rare but greater than that encountered in other types of nonocular surgery. Although ION is one of the primary types of ocular injury in this population, various other ocular injuries occur that are not associated with permanent vision loss. Risk for ocular injury appears to be related primarily to surgical factors, with relatively limited influence from patient-specific factors apart from baseline anemia. Surgeons, anesthesiologists, and patients should be aware of the increased risk of ocular injury that accompanies longer, more extensive spine operations associated with nonsupine positioning.

Conflicts of interest None declared.

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