Perioperative visual loss and anesthetic management

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Purpose of review
Perioperative visual loss (POVL) is an uncommon complication primarily associated with cardiac, spine, and head and neck surgery that can have a potentially severe impact on quality of life. The largest multicenter case control study to date on POVL recently identified risk factors associated with ischemic optic neuropathy and prone spinal fusion surgery. This review will summarize these findings and the updated American Society of Anesthesiologists practice advisory on POVL to provide guidance on identification and management of high-risk patients undergoing prone spine surgery. Epidemiology data on POVL from national databases, POVL in robotic surgery, and posterior reversible encephalopathy syndrome as a newer cause of POVL will also be discussed.

Recent findings
Risk factors associated with prone spinal fusion surgery and ischemic optic neuropathy identified in a large multicenter case–control study include male sex, obesity, use of the Wilson spinal frame, longer anesthetic duration, greater blood loss, and a lower percentage of colloid in the nonblood fluid administration.

Summary
Strategies aimed at modifying risk factors for ischemic optic neuropathy associated with prone spinal fusion surgery that are extrinsic to the patient may decrease its incidence. Further research is needed to validate this concept.

Keywords
American Society of Anesthesiologists practice advisory, anesthesia, colloid, estimated blood loss, ischemic optic neuropathy, obesity, perioperative or postoperative visual loss, posterior reversible encephalopathy syndrome, prone, robotic surgery, spine surgery, surgical duration, Wilson frame

INTRODUCTION

Perioperative visual loss (POVL) is a dreaded complication for patients and healthcare providers because the most common causes of POVL have no proven treatment and are associated with poor recovery. The disability and impact on quality of life for patients can be devastating. Research on this topic has barely progressed beyond the infancy stage because of its low incidence, lack of animal models, and technological deficiencies in monitoring the visual pathways under anesthesia. This review will provide an update of research and publications on POVL including the recent multicenter case–control study identifying risk factors associated with ischemic optic neuropathy (ION) and spinal fusion surgery, the updated American Society of Anesthesiologists (ASA) practice advisory on this topic, epidemiology data from the Nationwide Inpatient Sample database, emergence of POVL in robotic procedures, and introduction of an additional cause of visual loss in the hospital setting known as posterior reversible encephalopathy syndrome (PRES).

EPIDEMIOLOGY

The major causes of POVL include anterior ischemic optic neuropathy (AION) and posterior ischemic optic neuropathy (PION), central retinal artery occlusion (CRAO)/retinal vascular occlusion (RVO), and cortical blindness. Detailed features of the fundoscopic and ophthalmologic exam and course

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KEY POINTS

- POVL is most common after cardiac, spinal fusion, and orthopedic procedures on the hip and femur.
- Risk factors for ION associated with prone spinal fusion surgery include male sex, obesity, use of the Wilson frame, longer anesthetic duration, greater estimated blood loss, and a lower percentage of colloid in the nonblood replacement.
- Risk modification strategies for ION and prone spine surgery are aimed at minimizing the operative duration, estimated blood loss, and venous congestion and interstitial edema formation in the head, and should be evaluated for benefit and harm.
- Prolonged robotic and laparoscopic procedures in the head down position may be at increased risk for developing ION, but reported numbers are currently small.
- Posterior reversible encephalopathy syndrome (PRES) is another rare cause of POVL in the perioperative setting associated with a wide variety of disease states that requires prompt expert consultation, evaluation, imaging and treatment to avoid irreversible injury to the brain.

progression can be found in previous review articles or chapters [1]. AION is most commonly seen in cardiac bypass procedures, major vascular surgery, and spine surgery. Early fundoscopic exam reveals attenuated vessels, edema at the optic disc, and frequently peripapillary flame-shaped hemorrhages (Fig. 1). PION is associated with procedures with elevated venous pressures in the head such as prone spine surgery and bilateral radical neck surgery. Early fundoscopic exam demonstrates a normal-appearing fundus (Fig. 2). Several weeks to months after the onset of symptoms, the edema subsides and the heme is reabsorbed in AION; optic disc pallor occurs in both AION and PION; and the two appear identical on fundoscopic exam [2] (Fig. 3). These two types of ION will be considered together for purposes of this chapter because of diagnostic limitations from both clinicians and national databases and other issues discussed elsewhere. CRAO/RVO is most commonly associated with procedures in which large emboli may be injected near facial vessels or in which the risk of direct globe compression is high such as prone operations. Cortical blindness is most commonly seen in cases with high embolic loads such as cardiac bypass or in cases with profound hypotension.

National databases such as the Nationwide Inpatient Sample (NIS) contain useful demographic and procedural information that are reported for most patients, but data are not entered by physicians and are not verifiable. Nevertheless, these data do provide useful estimates of the prevalence of many complications. Shen *et al.* [3] utilized NIS data on POVL between 1996 and 2005 and demonstrated the highest rates of POVL occurred in cardiac (8.64/10 000) and spinal fusion (3.09/10 000) surgeries. They were the first to report that POVL was also significantly increased in hip and femur operations (1.86/10 000) compared with abdominal procedures

FIGURE 1. Acute (nonarteritc) anterior ischemic optic neuropathy. Blurring of the optic disc margin is from edema. Peripheral hemorrhage is noted superiorly and to the right of the disc.

FIGURE 2. Normal optic nerve, retina and macula. (Fundoscopic exam of posterior ischemic optic neuropathy is normal.)

FIGURE 3. Resolving (nonarteritic) anterior ischemic optic neuropathy. Note the optic nerve pallor with attenuation of retinal arterioles. Both anterior and posterior ischemic optic neuropathy demonstrate a normal retina with optic nerve pallor several weeks to months after the injury. Figures 1–3 are courtesy of Dr Raghu Mudumbai, University of Washington, Seattle, WA and reprinted with permission from [2].

such as appendectomy and cholecystectomy (0.12–0.66/10 000) [3]. These three different types of procedures with an increased risk for POVL share many common factors such as high embolic loads, large blood loss with subsequent resuscitation, anemia, hemodynamic derangements, and inflammation that may contribute to the development of the different types of POVL.

Another notable finding from Shen's study was that children below 18 years had the highest risk of POVL for all procedures [odds ratio (OR) 6.91, confidence interval (CI) 4.30–11.1, $P < 0.001$] primarily related to cortical blindness (OR 64, CI 35.9–114, $P < 0.001$), and had an especially high risk in spinal fusion surgery (OR 18.3, CI 9.81–34.0, $P < 0.00001$) [3]. It is unclear if this high OR is related to anatomic or developmental vulnerabilities in children or to specific procedural or perioperative management practices. Patients 50–64 years had an increased risk of ischemic optic neuropathy (OR 1.75, CI 1.13–2.71, $P = 0.04$) for all procedures. Prone position for spinal fusion operations had a four-fold increased risk of POVL compared with supine ($P < 0.0001$). Men had a higher risk of POVL in spinal fusion operations (OR 1.75, CI 1.06–2.59, $P < 0.002$) compared with women [3]. Overall, there was a trend for a decreasing incidence of POVL in this 10-year time period primarily related to cardiac surgery.

Review of the literature for incidence of POVL from single institutions or small groups of institutions provides estimates from 0 to 1 in 500 operations for spine surgery. Based on these data and the NIS data above, there appears to be wide variation in the occurrence of this complication from institution to institution which may be related to the types of procedures performed and examined, or alternatively to unidentified unique perioperative practices.

RISK FACTORS ASSOCIATED WITH ISCHEMIC OPTIC NEUROPATHY AND SPINAL FUSION SURGERY

In early 2012, the Postoperative Visual Loss Study Group published their findings on the largest multicenter case–control study to date examining risk factors for ION after spinal fusion surgery [4▪▪]. Prior to this study, most publications related to POVL were case reports or case series. Studies attempting to determine risk factors for different types of POVL were well carried out, but limited by inclusion of all types of POVL in the cases (e.g., ION, CRAO, and cortical blindness) before it was widely recognized that these different types of POVL are thought to have different causes [5]; use of national databases without verifiable data or pertinent intraoperative data (e.g., no data on estimated blood loss, operative/anesthetic duration, fluids administered, or type of surgical frame used) [4▪▪,6]; or single institution databases with a limited number of cases ($n = 17$) from a variety of different procedures with markedly different physiologic perturbations (e.g., prone spine surgery, knee surgery, cardiac bypass surgery, femoral artery aneurysm repair) [7]. The biggest challenge to performing a case–control study on this topic was obtaining a database with detailed perioperative data on a large number of cases of a single type of POVL associated with a single type of surgery.

This dilemma prompted examination of cases from the ASA POVL Registry that was established in 1999 by the ASA Committee on Professional Liability to collect POVL cases occurring within 2 weeks of nonocular surgery with details of submission previously provided [4▪▪]. ION cases from the ASA POVL Registry meeting inclusion/exclusion critieria were selected for the study and matched to controls by year. Inclusion criteria were age at least 18 years, spinal fusion surgery in the prone position for at least a portion of the time; anesthetic duration at least 4 h, noncervical spinal fusion surgery as the first or only spine surgery on the index admission, and surgery performed between 1991 and 2006 [4▪▪]. Exclusion criteria were perioperative cardiopulmonary resuscitation, perioperative stroke, incomplete medical records, and multiple staged procedures on the admission index preceding ION. For controls,

inclusion and exclusion criteria were the same in addition to no evidence of POVL. ION cases associated with spine surgery that met inclusion/exclusion criteria were matched 1 : 4 to controls from 17 academic institutions. After final analysis, 80 ION cases were matched to 315 controls [4▪▪].

Perioperative factors examined included patient characteristics (age, sex, ASA Physical Status 1 and 2 vs. 3 and 4, obesity, hypertension, tobacco history, atherosclerosis, diabetes, and preoperative blood pressure), predetermined procedural factors (number of levels of fusion, type of spine frame, and type of headrest), potentially modifiable intraoperative procedural factors (estimated blood loss and anesthetic duration as a surrogate marker for surgical duration), and potentially modifiable intraoperative management factors (lowest hematocrit, blood pressure $>$ 40% below baseline for $\geq$ 30 min, use of vasopressors, total volume replacement, total volume replacement: estimated blood loss ratio, crystalloid as % of total volume replacement, total nonblood replacement, and colloid as % of nonblood replacement) [4▪▪].

The statistical analysis was performed using univariate analysis with logistic regression followed by a stepwise multivariate analysis. Factors that were independently and significantly associated with the development of ION after prone spinal fusion surgery were male sex, obesity, use of the Wilson frame, longer anesthetic duration (as a surrogate for operative duration), greater estimated blood loss, and a lower percentage of colloid used in the nonblood replacement [4▪▪].

Theoretical pathophysiologic mechanism for ischemic optic neuropathy after prone spine surgery

With the exception of male sex, these factors could be explained by the leading theoretical pathophysiologic mechanism at this time that focuses on the elevated venous pressure in the head leading to interstitial edema that somehow damages the optic nerve via direct mechanical compression, venous infarction, or compression of the thread-like pial vessels that feed the optic nerve [4▪▪]. Obesity is usually associated with increased abdominal girth, which elevates the central venous pressure in the prone position as well as reducing venous return and cardiac output. The Wilson frame places the patient's head significantly lower than the heart leading to increased venous pressure in the head. Greater estimated blood loss leads to inflammation, capillary leak, and lower oncotic pressure, which favor interstitial edema formation. Less colloid in the volume resuscitation will also result in lower oncotic pressure and favor interstitial edema formation. Increased duration is relevant because the longer unfavorable pathophysiologic conditions exist, the worse the injury. However, it is important to remember that this concept is an unproven theory, and that this case–control study is only the beginning of the research that will be required to untangle the complex physiologic processes that occur during prone spinal fusion operations.

Limitations of the multicenter case–control study

Several limitations of this study should be noted including anonymous submission of cases without the ability to verify data; derivation of controls from a different set of institutions than the cases and with more rigorous data collection; and inability to retrospectively assess factors such as degree of table tilt, other details of positioning, and volume status. Concurrency of some risk factors such as lowest hematocrit and blood pressure more than 40% below baseline for at least 30 min were not examined. Additionally, AION and PION cases were combined in this study because they were all associated with the same type of procedure and because there were no significant differences in the perioperative variables examined between these groups [4▪▪]. Though this model had a very good fit for 85% of the ION cases, the factors associated with the other 15% of cases remain unknown. Undetectable or unknown patient factors such as anatomy, autoregulatory capacity of the optic nerve vasculature, or other genetic vulnerabilities are likely to contribute to this complication.

Study limitations impacting clinical practice

Factors that were significant in the univariate analysis ($P < 0.05$) such as lowest hematocrit and blood pressure more than 40% below baseline for at least 30 min, but did not reach statistical significance in the multivariate analysis, cannot be definitively eliminated as having an effect on the development of ION. Clinicians are cautioned to avoid extremes of physiologic perturbations based on these data until more is known about the pathophysiology of perioperative ION.

THE UPDATED AMERICAN SOCIETY OF ANESTHESIOLOGISTS PRACTICE ADVISORY

If one makes the assumption that the six risk factors identified in the multicenter study described earlier are not just associated with ION, but are somehow

causal, strategies aimed at modifying some of these risk factors may impact the development of this injury. No substantial changes in recommendations were made in the updated ASA practice advisory for perioperative visual loss associated with spine surgery [8▪] from 2006, as results of the multicenter study were not available for inclusion. However, many strategies in this advisory pertain to these risk factors including elevating the head of the bed to keep the head neutral with the heart or above it, keeping the head in a neutral position, using colloids along with crystalloids for volume replacement, and consider staging procedures in high risk patients [8▪]. Other recommendations from this practice advisory include identifying patients at high risk for POVL associated with spine surgery based on expected prolonged duration and/or substantial blood loss, consider informing these high-risk patients that there is a low, but unpredictable risk of POVL, continually monitor systemic blood pressure, periodically check hemoglobin or hematocrit values, avoid direct pressure on the globe to avoid CRAO injuries, assess the patient's vision postoperatively as soon as the patient is alert, obtain an urgent ophthalmologic consultation if there is concern for POVL. If POVL is suspected, additional management may include optimizing hemoglobin/hematocrit values, hemodynamic status, and oxygenation [8▪]. The full list of recommendations can be found in the reference provided.

The ASA practice advisory did not find any literature to support the association of deliberate hypotension or a particular transfusion threshold with POVL, and advocated determining practice on a case-by-case basis. Interestingly, consultants to the advisory and specialty society members surveyed in 2006 varied widely in their definition of deliberate hypotension, with the average response at 24% below baseline mean arterial pressure with a range of 0–40% below baseline. Similarly, the mean response for the lowest acceptable hemoglobin was 9.4 g/dl (range 6–13 g/ dl) and the lowest acceptable hematocrit was 28% (range 18–37%) [8▪].

Other potentially preventive strategies

When incorporating other risk factors identified in the multicenter study that were not considered in the updated ASA practice advisory, other potentially preventive strategies for high-risk patients could include choosing more conservative treatments for the spinal disease when possible and using alternative surgical frames to the Wilson frame that do not keep the head lower than the heart. The impact of antifibrinolytics on the development of ION is unstudied; and therefore, recommendations on its use cannot be made. Its use in this study was less than 5% of cases and controls; and consequently was not examined as a risk factor. Implementation of any potentially preventive interventions should be critically evaluated to assess effect and to ensure that other unintended consequences do not arise.

PERIOPERATIVE VISUAL LOSS IN ROBOTIC SURGERY

The rapid adoption of robotic surgery in hospitals around the country has brought new challenges to the anesthesia community. Robotic surgical times are significantly greater than the open surgical approach when surgeons are first learning this technique, and expansion into longer procedures than prostatectomies is now occurring. Prolonged durations in the head-down position cause venous congestion in the head resulting in facial edema and elevated intraocular pressures similar to prolonged prone spine operations [9]. Recognizing the potential for a recurring pattern of injury as seen in the prone spine operations, concern was raised that robotic and laparoscopic cases in steep Trendelenburg position may also be associated with an increased risk of ION. Several case reports of POVL associated with robotic and laparoscopic surgery have been published as well as the report of three robotic prostatectomy cases with ION from the ASA POVL registry with a mean duration of approximately 9 h [10–15]. The relatively low number of case reports with POVL from these procedures at this point may be a result of the relatively shorter durations of these procedures and the lower estimated blood loss compared with spinal fusion surgery, resulting in less inflammation and interstitial edema formation. However, as more complex procedures convert to robotic techniques with very prolonged operative times, the number of these cases may increase. It is unclear if the same risk factors will apply to robotic and laparoscopic cases in the head down position as for prone spine surgery, but efforts aimed at reducing the venous congestion and interstitial edema formation in the head would seem prudent.

POSTERIOR REVERSIBLE ENCEPHALOPATHY SYNDROME

Posterior reversible encephalopathy syndrome (PRES) is a constellation of neurologic findings which in one series of 25 patients [16] included seizures (88%); visual changes (60%) in the form of cortical blindness, homonymous hemianopia, or blurred vision; decreased level of consciousness (56%); headaches (52%); nausea and vomiting

(28%); brainstem symptoms (12%); and hemiplegia (12%) that occurs in the setting of acute medical illness with hypertensive episodes, autoimmune disease, malignancy, immunosuppressant therapy, chemotherapy, infection, acute and chronic renal disease, vasculitis, preeclampsia, and eclampsia, and a variety of other miscellaneous diseases. In this same series of 25 patients, symptoms resolved in 25% of patients in 1 day and in 75% of patients in 10.5 days with a mean resolution time of 7.5 days [16]. Three patients had no improvement in symptoms during their hospital admission.

PRES displays characteristic high-signal intensity on T2-weighted and fluid-attenuated inversion recovery (FLAIR) MRI consistent with edema, typically in a symmetric pattern in the occipital and parieto-occipital cortex and subcortical white matter, and occasionally the posterior frontal lobes. Diffusion-weighted imaging is crucial to detect ischemia and will display vasogenic edema in the setting of PRES [17]. Though PRES was initially described in 1996, and is better known in the obstetric literature, it is included in this review because more than half of the cases have visual involvement and several cases have recently been reported after nonobstetric surgery such as a video-assisted thoracoscopic wedge resection [17], hysterectomy [18], and lumbar fusion [19].

The pathophysiology of PRES is still debated but the two leading theories are that hypertensive episodes surpass the autoregulatory capacity of the cerebral vasculature causing breakthrough brain edema, or that cytotoxic drugs or diseases cause endothelial injury with subsequent edema formation. Neither has been proven, and many of the cases reported do not involve hypertensive episodes. Anticonvulsants for seizures and judicious use of antihypertensive drugs to control the blood pressure and prevent worsening cerebral edema should be instituted promptly. Treating any potential causative factors such as stopping suspected chemotherapeutic or immunosuppressant drugs or treating any infections is also recommended. Cerebral infarction, hemorrhage and death have been described with PRES; and therefore, any potential treatment and appropriate imaging should be instituted without delay. Fortunately, PRES has a very good recovery pattern for POVL, unlike ION and CRAO.

CONCLUSION

One of the biggest advances in POVL research was the recent multicenter case–control study that identified six risk factors associated with ION after spinal fusion surgery including male sex, obesity, use of the Wilson frame, longer anesthetic duration (surrogate for surgical duration), greater estimated blood loss, and decreased percentage of colloid in the nonblood replacement. Utilizing this study and the updated ASA practice advisory on perioperative visual loss associated with spine surgery, potential preventive strategies for ION in high-risk patients include choosing more conservative treatment for spinal disease, using frames other than the Wilson frame so that the head is not dependent to the heart, elevating the head of the bed to keep the head neutral with the heart or above the heart, keeping the head in a neutral position, using a higher percentage of colloid in the nonblood replacement, and consider staging prolonged procedures with substantial blood loss in high-risk patients. Any interventions should be carefully studied to assess the benefit as well as potential harm. The robotic and laparoscopic procedures performed in the head down position for prolonged durations may also be at increased risk for developing ION. Currently, the reported number of POVL cases in this field is small, possibly related to the fact that most of these procedures are less than 4 h with estimated blood loss less than 500 ml. PRES is another potential cause of POVL in the nonobstetric perioperative setting that has an excellent recovery profile when evaluated and treated promptly. This newer cause of POVL in the nonobstetric perioperative setting highlights the need for prompt evaluation of POVL by an expert ophthalmological, or preferably neuro-ophthalmological, consultant with appropriate imaging and treatment.

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Conflicts of interest

L.A.L. has provided expert witness review and testimony in medicolegal cases involving perioperative visual loss.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:
- ■ of special interest
- ■■ of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (pp. 400–401).

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