Ischemic optic neuropathy: are we any further?

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Purpose of review

Postoperative vision loss (POVL) as related to spinal surgery and the prone position has garnered increasing attention in the US over the last 15 years, resulting in an increase of litigations submitted to the legal system. It might be associated with the development of new surgical techniques involving complex instrumentation of the spine. By 2000, the magnitude of this problem was such that the American Society of Anesthesiologists developed a Postoperative Visual Loss Registry in an effort to better understand and evaluate this devastating operative complication.

Recent findings

The cause of ischemic optic neuropathy (ION) as the most complex entity of POVL is still unclear. Retrospective studies show that although it can strike patients of any age, there is an increased incidence in patients less than 18 and more than 65 years of age. Significant risk factors include male sex, anemia, surgery lasting over 6 h, and intraoperative hypotension. Profound anatomical knowledge and new animal studies have helped to define possible mechanisms underlying ION.

Summary

ION is still poorly understood and risk factors remain speculative. Given that there is no known treatment, increased understanding should help to prevent this postoperative complication.

Keywords

ION, POVL, risk factors, spine surgery

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Introduction

Postoperative vision loss (POVL) is a term that encompasses many syndromes including central retina artery (or vascular) occlusion (CRAO), cortical blindness, ischemic optic neuropathy (ION) and rarely otherwise classified blindness.

Central retina artery occlusion and cortical blindness are caused by painless strokes, primarily embolic in nature. CRAO is second most common cause of POVL. With CRAO, a very distinctive pattern is seen on fundoscopic examination of the affected eye: retinal pallor combined with characteristic 'cherry red spots' at the macula [1]. Although usually an embolic phenomenon, CRAO can also be the result of direct external compression of the ocular globe.

Cortical blindness is a result of an infarct of certain visual areas in the occipital lobe and can be the result of embolic or thrombotic events. It has been described mostly after cardiothoracic surgery.

Ischemic optic neuropathy

Ischemic optic neuropathy is the most important and common diagnosis for POVL after lumbar spine surgery. It is an acute ischemic disorder of the optic nerve and two different forms are recognized distinguished by the distribution of optic nerve ischemia. Anterior ischemic optic neuropathy (AION) affects the anterior portion of the optic nerve in which it enters the ocular globe and posterior ischemic optic neuropathy (PION) involves the intraorbital segment of the nerve.

In AION, the onset of symptoms is accompanied by optic disc edema revealed by fundoscopy with or without hemorrhage. Symptoms of AION rarely occur upon awakening. The onset of blindness is usually delayed from 48 h up to more than 1 week after surgery. Binocular involvement is more frequent than in other forms of ION (60%) [2].

In PION, the optic disc appears normal at time of onset of symptoms. However, delayed disc edema may be

observed as nerve ischemia spreads anteriorly. PION affects men (70%) more than woman and has been described even in young children (12 years old). Although the incidence of PION has been reported most frequently with lumbar spine surgery, it has been described albeit less frequently in cervical and thoracic surgery. In contrast to AION, with PION the majority of the patients report symptoms upon awakening (59%) with an additional 29% reporting symptoms within 24 h [2].

Anatomy

It is difficult to understand the cause of ION without some knowledge of the ocular globe and optic nerve anatomy and physiology. An excellent overview has been published by Hayreh [3••].

The optic canal

The optic canal is virtually a closed cavity, limited anteriorly by the ocular globe, and laterally by bone structures of the frontal and maxillary sinuses. Cerebrospinal fluid (CSF) surrounds the neurovascular bundle up to the globe with varying thickness of this layer. The space between nerve and bone is only between 2 and 3 mm. The posterior part of the canal opens within the surrounding cerebral structures. The optic nerve transverses the optic canal in its prechiasma portion.

Of anatomical importance is the presence in some individuals of a relatively smaller optic canal opening at the sclera. Described as a small disc-to-cup ratio, this may represent the only objective sign of an 'optic nerve at risk' for an ischemic event [4].

Blood supply and blood flow of the optic nerve

The anterior portion of the optic nerve has a rich arterial supply which includes the left and right posterior ciliary arteries (PCAs) as well as peripapillary choroid arteries and short PCAs, also called the circle of Zinn and Haller (see Fig. 1). Their sectoral distribution might explain the occurrence of segmental vision loss.

The posterior portion of the optic nerve is supplied by multiple arteries. Branches from the central retinal artery (CRA) combine with vessels derived from the hypophyseal artery to provide the vascular supply.

In contrast to the richly supplied anterior and posterior portions of the nerve, the mid portion of the optic nerve within the optic canal is supplied only by the pial vascular plexus derived from arterial extensions of the anterior and posterior blood supplies and intraneural branches of the central retinal artery. The relative poverty in the vascular supply to the mid portion of the nerve places it at increased risk for ischemia and it is this portion of the nerve that is thought to be related to PION.

Figure 1 Blood supply of the optic nerve by the central retinal artery

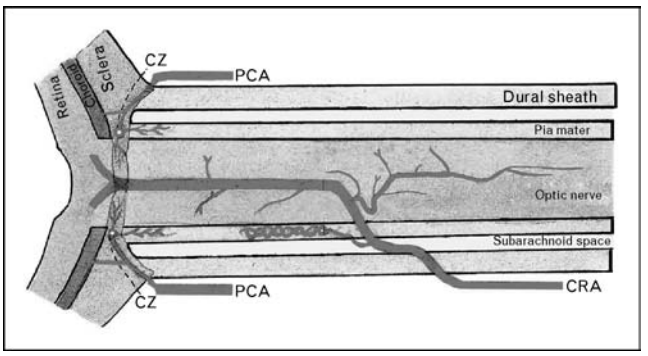

Diagram showing one of the intraneural branches of the central retinal artery running backward in the axial part of the optic nerve posterior to the central retinal artery. CZ, circle of Zinn and Haller. Reproduced with permission from [3••].

Venous drainage occurs primarily via the central retinal vein and to a lesser extent into a number of small orbital veins. In the prelaminar region, there are retinociliary collaterals to the peripapillary choroidal veins and drainage through these collaterals can become substantial in case of central retinal vein thrombosis.

There is substantial interindividual variability in the anatomical vasculature pattern and location of watershed zones between the PCAs. This variability exists even between the eyes of one individual.

Autoregulation in the optic nerve head and ocular perfusion pressure

Blood flow to the optic nerve depends on perfusion pressure, resistance to flow, presence of autoregulation and rheological properties of the blood. Our knowledge on possible pharmacological influences on ocular blood flow is extremely limited.

Autoregulation exists also in the human eye and resembles autoregulation in the brain. High IOP and systemic blood pressure (BP) might alter the mechanism of autoregulation by metabolic and myogenic factors not quite known yet.

Autoregulation allows maintenance of constant blood flow despite fluctuations in perfusion pressure (which is the pressure difference between arterial blood entering the eye and the venous blood leaving the eye). There is a pressure range in which autoregulation can exert its control. Above and below this pressure range, vasomotor

adjustments are exhausted and blood flow becomes more linearly related to perfusion pressure.

In the eye, the ocular perfusion pressure (OPP) is estimated as the difference between the mean arterial BP and intraocular pressure (IOP), because the IOP is close to the pressure in the veins leaving the eye. IOP and BP fluctuate widely within one individual.

A recent study in rhesus monkeys has examined the relationship between IOP changes, systemic BP and ocular blood flow [5••]. When IOP was increased, the decrease in blood flow in the optic nerve head was dependent on the systemic BP. At higher BPs, the ocular blood flow did not substantially change. At lower systemic BPs, there was a significant decrease in ocular blood flow. The lower level of autoregulation was determined at a mean BP of 35 mmHg, somewhat higher than the previously reported 30 mmHg [6]. Clinically, increasing the IOP in the setting of low systemic BP may significantly drop OPP beyond the point that autoregulatory mechanisms can compensate. Furthermore some individuals are shown not to be able to at all autoregulate the blood flow to the anterior part of the optic head [7].

Intraocular pressure

Intraocular pressure is normally about 27 mmHg. In patients in the prone position, the IOP can increase up to three times the baseline pressure thus putting susceptible patients at risk for inadequate ocular nerve perfusion [8]. Older findings showed that an increase in $PaCO_2$ increases IOP, suggesting an influence on IOP and blood flow through ventilation [9].

Despite numerous case reports, recent large-scale retrospective studies, and advances in knowledge in anatomy and physiology of the eye, scientific evidence remains fragmentary. The following is currently known about POVL.

Incidence

Those at highest risk are patients undergoing cardiac on bypass and spine surgery in the prone positioning. Exact incidence, however, is very difficult to determine. There have been recent publications of retrospective case-control studies involving extremely large numbers of patients and surgeries [10•,11••]. However, even in these studies, the accuracy of the incidence rates is not very convincing as the data used was derived from billing coders with no training in distinguishing between types of eye complications (e.g. eye injury). The results in the two most recent analyses estimate an incidence of ION between 0.13% overall, and 0.36% in spine surgery as well as 0.0235% overall and 0.0309%, respectively.

Cause

Patient-related factors comprise age, sex, concomitant risk factors, and the cup-to-disc ratio.

Age

One retrospective study shows that patients less than 18 years of age undergoing spinal but not other kinds of surgery experienced more POVL in the form of cortical blindness than older patients. In patients over the age of 50, ION was the predominant cause of POVL following spine surgery [11••].

Sex

Men are more often affected than women with a 1.3 times higher odds ratio (OR) for all POVL and twice as many for ION [11••].

Concomitant vascular risk factors

The Charlson index as an index for vascular risk factors does not appear predictive of ION in spinal surgery [11••].

Small cup-to-disk ratio

The individual disposition of a small cup-to-disk ratio seems to increase the incidence of ION [12].

Amongst surgery-related factors positioning of the patient, length of surgery and intraoperative blood loss are confirmed to be of importance. Direct compression, however, does not seem to increase specifically ION. Venous congestion, however, appears to contribute highly to the development of ION.

Type of surgery

Postoperative vision loss occurs at significantly higher rates in orthopedic surgery, spine fusion and cardiac surgery compared to abdominal and other surgery.

Within the category of spine surgery, those undergoing lumbar spine surgery are more likely to develop ION (especially AION) compared to those having cervical and thoracic spine procedures [2].

Surgical experience and surgical emergency

Surgical experience and discrimination between elective and nonelective surgery does not have an impact on POVL [11••].

Length of surgery

The ASA POVL registry, which is a voluntary report system, has demonstrated a correlation between duration of surgery and the development of ION. Most of the cases of ION reported were associated with surgeries lasting 6 h or more (94% of the cases reported [13]).

Positioning

During the prone position, IOP rises significantly with time [8]. This could potentially drop the perfusion pressure of the ciliary arteries to critical values.

Swelling of eyelids and periorbital swelling in prone positioning is common and not associated with POVL.

Thromboembolism through rotation of the head from the anterior carotid artery has been assumed to cause CRAO [14].

The use of different frames for positioning and pinning the head without any compression of the eyes does not seem to influence the incidence of POVL.

Direct compression

Direct compression of the eye will result in an increase of IOP. Increased IOP due to direct eye compression is implicated in POVL related to central retinal artery occlusion [14].

Increased venous pressure

Increased IOP can result from increased venous pressure within the eye [15]. Perioperative infusion of large quantities of fluids [16] combined with reduced venous return in the head-down position may lead to venous congestion in the eye, even with a central venous pressure within normal values [17]. IOP also rises if there is direct pressure on the abdomen. It is thought by some that increase in venous pressure is one of the main factors responsible for triggering ION in susceptible patients. It creates the equivalent of a compartment syndrome at the level of the optic canal, impeding the arterial blood flow to the optic nerve.

Blood loss and anemia

Anemia and acute blood loss have been the major suspects in causing POVL especially as related to CRAO [18]. The ASA POVL registry reports a blood loss of 1000 ml or greater as one of the two determinants for the appearance of POVL [13]. Anemia, although the limits of hematocrit/hemoglobin are not clearly specified in this study, increases the OR for POVL in spinal but not in cardiac or other surgeries. Blood transfusion did not show a significant influence [11••]. The lowest hematocrit or hemoglobin level in all reported cases has been 30%.

Anesthesia-related factors go hand in hand with surgical factors.

Arterial hypotension

In the majority of case reports, POVL has been associated with significant intraoperative arterial hypotension and prolonged drops in systolic pressure [19]. However, in one recent retrospective multivariate analysis, hypotension as an independent risk factor did not reach significance [11••].

Animal studies have shown that arterial hypotension results in significantly decreased blood flow to the optic nerve. Oxygen delivery to the optic nerve can be similarly decreased during hypotension alone or when hypotension was associated to anemia and venous congestion [20].

Blood transfusion

Among all reviewed surgeries, spine surgery seems to be the only one in which blood transfusions do not seem to be associated with POVL [11••].

Vasopressors

The use of direct-acting vasoconstrictors (e.g. phenylephrine) is controversial as it may lead to vasoconstriction of arterioles feeding the optic nerve. Probably norepinephrine may be a better choice to maintain an efficient arterial pressure.

The fact that endogenous vasoconstrictor agents can be released after blood loss can hypothetically also play a role in reducing ocular blood flow [21].

Anesthesia management

Knowing more about likely risk factors the anesthetic plan starts with the preoperative management.

Attentiveness

Reports of ION increased the attention of the surgeons and anesthesiologist markedly. Prior to surgery patients at risk should be educated and adequately warned about this potential anesthetic complication.

Planning of surgery

In an effort to decrease the amount of time the patients need to remain in the prone position, staging – when feasible – should be discussed with the surgical team, for example in anterior–posterior spinal fusion.

Intraoperative management needs to be especially meticulous in regards to positioning and hemodynamic management.

Positioning and surgical duration

Patients should not be positioned with their head below the level of the body. Compression of the abdomen needs to be minimized and any extrinsic direct pressure on the eyes eliminated. Consider a 10° reverse Trendelenburg position in an attempt to decrease the IOP while the patient is prone [22]. Venous congestion in conjunction with prolonged surgery longer than 5 h and blood loss of 1 or more liters emerge in a recent literature review to be associated with ION in over 85 and 83% of the described cases as the major culprits [23•].

Hemodynamics

To avoid anemia a high transfusion trigger should be chosen. We can only suggest to keep the hematocrit around 30%, and the hemoglobin around 10 mg/l, respectively.

Arterial hypotension should be avoided and the blood pressure maintained at approximately preoperative levels. A well tolerated lower limit for the perfusion pressure of the optic nerve remains unknown. It should be remembered that the posterior part of the optic nerve and the anterior part in some individuals [7] are incapable of autoregulation and dependent on the systemic blood pressure for adequate blood flow.

A balanced fluid management seems to be beneficial. Fluid overload with crystalloids with decreased serum osmolality should be avoided [24,25], as this will further contribute to an increase in compartmental pressures and venous congestion [23•].

Ventilation

Normoventilation and avoiding hypercapnia might prevent further increases in the IOP during surgery [9].

Patient care extends into the postoperative period.

Examination of the visual function should be included in the immediate postoperative assessment of patients with high risk. Follow-up visits are recommended as a substantial number of patients do not present with symptoms until hours or days after surgery. Indeed, the onset of AION has been reported up to 9 days after the procedure.

Treatment options

When a patient reports any visual symptoms, an ophthalmologist should be consulted without delay. Symptomatic treatment for ION should be started immediately and prior to the establishment of a definitive diagnosis. Treatment protocols, although not evidence-based, include the use of mannitol and intravenous steroids as well as head elevation in an effort to decrease any venous compression, elevation of the median arterial pressure and correction of the hematocrit. Unfortunately therapeutic options for ION are very limited. Surgical treatment with optic nerve fenestration has been almost abandoned due to its poor results. Many drugs, especially calcium antagonists, are currently under investigation, but most have not reached the stage beyond experimentation [26].

Conclusion

Ischemic optic neuropathy remains a rare, devastating condition following various surgeries, preferably lumbar fusions in prone position [27]. Even after large-scale retrospective studies and animal studies risk factors remain speculative and prospective studies are unfeasible due to the rarity of this condition.

Differences in the anatomy and physiology of the eye between individuals seem to be the key to our understanding of ION. Anemia, high blood loss, arterial hypotension below patient's baseline, long surgery and venous congestion due to prone positioning and unbalanced fluid management are still the assumed risk factors, as suggested by the American Society of Anesthesiologists Task Force on Perioperative Blindness in 2006 [28].

Our limited knowledge of pathophysiology restricts our treatment options. There is no prevention available outside of a reasonable hemodynamic management, for instance to keep the hematocrit above 30 and the arterial blood pressure maintained within the patient's normal limits. The major factor is still probably the duration of surgery and therefore the prone position, but this is out of our direct control.

References and recommended reading

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Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 673).

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