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Perioperative visual loss following prone spinal surgery: A review

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Abstract

Background: Postoperative visual loss (POVL) following prone spine surgery occurs in from 0.013% to 1% of cases and is variously attributed to ischemic optic neuropathy (ION: anterior ION or posterior ION [reported in 1.9/10,000 cases: constitutes 89% of all POVL cases], central retinal artery occlusion [CRAO], central retinal vein occlusion [CRVO], cortical blindness [CB], direct compression [horseshoe, prone pillows, and eye protectors Dupaco Opti-Gard]), and acute angle closure glaucoma (AACG).

Methods: Risk factors for ION include prolonged operative times, long-segment spinal instrumentation, anemia, intraoperative hypotension, diabetes, obesity, male sex, using the Wilson frame, microvascular pathology, decreased the percent of colloid administration, and extensive intraoperative blood loss. Risk factors for CRAO more typically include improper positioning during the surgery (e.g., cervical rotation), while those for CB included prone positioning and obesity.

Results: POVL may be avoided by greater utilization of crystalloids versus colloids, administration of α-2 agonists (e.g., decreases intraocular pressure), avoidance of catecholamines (e.g., avoid vasoconstrictors), avoiding intraoperative hypotension, and averting anemia. Patients with glaucoma or glaucoma suspects may undergo preoperative evaluation by ophthalmologists to determine whether they require prophylactic treatment prior to prone spinal surgery and whether and if prophylactic treatment is warranted.

Conclusions: The best way to avoid POVL is to recognize its multiple etiologies and limit the various risk factors that contribute to this devastating complication of prone spinal surgery. Furthermore, routinely utilizing a 3-pin head holder will completely avoid ophthalmic compression, while maintaining the neck in a neutral posture, largely avoiding the risk of jugular vein and/or carotid artery compromise and thus avoiding increasing IOP.

Key Words: Blindness, central retinal artery occlusion, cortical blindness, eye diseases, glaucoma, ischemic optic neuropathy, prone position, spinal surgery, visual loss

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INTRODUCTION

Postoperative visual loss (POVL) following prone spine surgery occurs in from 0.013% to 1% of cases, and the most frequently quoted risk is 0.2% [Tables 1-4].[14,40] POVL is variously attributed to ischemic optic neuropathy (ION: Anterior ION [AION] or posterior ION [PION reported in 1.9/10,000 cases: constitutes 89% of all POVL cases]), central retinal artery occlusion [CRAO], central retinal vein occlusion [CRVO], cortical blindness [CB], direct compression [horseshoe, prone pillows, and eye protectors Dupaco Opti-Gard]), acute angle closure glaucoma (AACG), rarely epidural spine injections, and occasional other factors (e.g., right-left atrial shunt with microvascular embolization).

The preoperative recognition of risk factors may protect against the development of POVL. The multiple factors contributing to ION may include; prolonged operative times, long-segment spinal instrumentation, anemia, intraoperative hypotension, diabetes, obesity, male sex, the Wilson frame, greater estimated blood loss (EBL), microvascular pathology, and decreased percent colloid administration. Risk factors for CRAO typically include improper positioning during the surgery (e.g., cervical rotation), while those for CB included prone positioning and obesity.

Limiting the risk of POVL may warrant greater utilization of crystalloids versus colloids, administration of α-2 agonists (e.g., decreases intraocular pressure [IOP]), avoidance of catecholamines (e.g., avoid vasoconstrictors), and avoiding excessive intraoperative blood loss/anemia, hypotension, and hypovolemia. Patients at risk for AACG may undergo preoperative ophthalmologic evaluation and prophylactic treatment where indicated. Most critically, routinely utilizing a 3-pin head holder for prone positioning completely avoids ophthalmic compression, and maintains the neck in a neutral posture, avoiding the potential for jugular venous congestion or carotid artery occlusion/embolization/compromise.

SUMMARY OF CASE STUDIES OF POSTOPERATIVE VISUAL LOSS

Of the 21 single case studies reviewed, the etiology of the POVL included: AACG (three patients), ION (three patients) CB (three patients), CRAO (four patients), ischemic orbital compartment syndrome/compression (one patients), CRA branch occlusion (one patient), or general POVL/unspecified etiology (six patients) [Tables 1 and 4].[1,4,9,10,12,14-16,18,21,23,26,29,30,31,34,36,37,39,40] They variously cited a 0.28–0.2% versus 0.01–1% frequency of POVL following prone surgery, most commonly noting that hypotension was the major contributor.[14,40] However, other risk factors for POVL included; prolonged spine surgery, extensive instrumentation, increased intraoperative blood loss, anemia, cancer, use of catecholamines or nefopam, patent foramen ovale (right to left shunt), use of a prone view pillow, and application of Dupaco Opti-Gard eye goggles.

Acute angle closure glaucoma after lumbar spine surgery

Five days following lumbar surgery performed in the prone position, Stewart *et al.* (2016) presented a patient who developed AACG due to an acute increase in IOP that had occurred intraoperatively [Tables 1 and 4].[36] POVL with prone spinal surgery was usually attributed to ION although prior cases of bilateral AACG had rarely been reported. The authors noted how critical it was to recognize postoperative AACG and to immediately treat it with laser iridotomy. They recommended targeted preoperative screening and treatment for those with significant risk factors for AACG with prone spinal surgery.

Postoperative visual loss in prone orthopedic spine surgery

Pin-On and Boonsri in 2015 reported on a patient with POVL due to ION occurring during prone spinal surgery [Tables 1 and 4].[29] They reviewed the pathophysiology and risk factors predisposing to POVL/ION as described by the American Association of Anesthesiology task force.

Cortical blindness following posterior lumbar decompression fusion

Agarwal *et al.* in 2014 noted that a 60-year-old paraparetic female developed POVL following an L2–L4 laminectomy for partial resection of a metastatic adenocarcinoma [Tables 1 and 4].[1] Intraoperatively, the patient had become severely anemic, and the resultant severe intraoperative hypotension had led to bilateral occipital lobe infarcts (posterior cerebral artery thromboembolism) leading to permanent cortical blindness.

Transient cortical blindness attributed to posterior spinal surgery in a child

Nathan *et al.* in 2013 noted the multiple factors that contribute to POVL following prone spine surgery; these vary from direct ocular ischemia (compression/venous occlusion) to CRAO, ION, or occipital cortical ischemia (infarction) [Table 1].[23] They presented an 11-year-old female who developed transient CB following posterior spinal fusion for scoliosis performed under hypotensive anesthesia.

Unilateral visual loss after excision of an extradural hematoma in the prone position

Ooi *et al.* in 2013 presented a patient who developed blindness attributed to CRAO following excision of an epidural spinal hematoma performed in the prone position [Tables 1 and 4].[26] This deficit was attributed to poor positioning of the head, leading to direct mechanical compression of the eyes. They recommended

Table 1: Case studies: Summary literature of blindness with spine surgery

Author Reference, year	Number of patients (age sex) disease	Diagnosis disease Type of blindness risks	Type of spine surgery Prone risks	Time of onset risks	Treatment outcome
Stewart *et al*.[36] Spine 2015	1	AACG Averted	Lumbar revision surgery (prone)	AACG postoperative day 5	Treatment Laser iridotomy Intact
Pin-On and Boonsri[29] J Med Assoc Thailand 2015	1	ION	Prone spine surgery	Visual loss postoperatively	Permanent deficit (complete)
Agarwal *et al*.[1] J Clin Neurosci 2014	1	POVL (CB occipital stroke)	Lumbar tumor Laminectomy L2-L4 (prone)	Risk factors Cancer Anemia PCA block	Risks Stroke Anemia Hypotension
Nathan *et al*.[23] J Pediatr Orthop B 2013	1 (11 female)	POVL	Posterior spinal instrumentation	Muscular dystrophy	Avoid Hypotensive anesthesia
Ooi *et al*.[26] BMJ Case Rep 2013	1	CRAO	Excision epidural hematoma/prone Malposition prone	Head rotation Eye compression	Best eye protection-3-pin head holder
Goni *et al*.[10] Asian Spine J 2012	1 (38 male)	CB Bilateral	Posterior spinal fusion L2 fracture Risks; 12 h surgery	CB: Bilateral occipital lobe infarcts	Permanent deficit
Quraishi *et al*.[30] Eur Spine J 2012	1	POVL Bilaterally	Prone lumbar spine surgery	Spontaneous resolution	Resolved within 48 h
Gayat *et al*.[9] Anesth Analg 2011	1	Bilateral AACG	Delayed-blindness Prone spine surgery	Risks; hypotension ephedrine	Other risks; nefopam Prone surgery
Zimmerer *et al*.[40] Eur Spine J 2011	1 (73 male)	Unilateral POVL 3 h postoperative	Lumbar disc Comorbidities HTN, ASCVD DM, high lipids Prostate Cancer (CA)	POVL 0.28–0.2% Prone spine Surgery hypotension	Risks Hypotension HTN Catecholamine in surgery
Visser *et al*.[37] Anesthesiology 2010	1	CB	Thoracic epidural catheter (lung OR)	One test dose bupivacaine epidurally	CB permanent
Hoff *et al*.[12] Acta Ophthalmol 2010	1	POVL/ION CT/OCT	56-year-old male Cervical prone surgery	OCT: Marked reduction of retinal nerve fiber layer thickness at optic nerve head	Minimal recovery 6 months
Singer and Salim[34] Spine J 2010	1 (68 female)	Bilateral AACG	Lumbar spine decompression and fusion (multilevel) Prone	Prone test: AACG	Narrowed angle > greater risk > IOP
Yu *et al*.[39] Spine 2008	1	Ischemic orbital compartment syndrome	Urgent treatment	Remained blind	Permanent blindness
Nakra *et al*.[21] Paediatr Anaesth 2007	1	Bilateral CRAO	Prolonged cervical spine surgery prone		Permanent blindness
Roth *et al*.[31] Anesth Analg 2007	1	CRAO Prone spine surgery	Prone foam headrest; eye goggles Dupaco Opti-Gard	CRAO permanent	Permanent Blindness Foam headrest goggles Contraindicated
Chung and Son[4] Korean J Ophthalmol 2006	1 (60 male)	CRAO (POVL)	Prone cervical surgery	Deficit Ptosis/ROM blindness	Permanent blindness Recovery ROM
Kasodekar and Chen[15] Singapore Med J 2006	1 (62 male)	POVL	Cervical myelopathy; C3-C6 laminectomy lateral mass plating (prone)	Blind in right eye postoperatively	Factors lead to POVL Prone cervical surgery
Kamming and Clarke[14] Br J Anesth 2005	1	Prone spine surgery	Unilateral blindness	POVL nonocular surgery 0.01-1% review	0.01-1% POVL prone spine surgery

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Table 1: Contd...

Author Reference, year	Number of patients (age sex) disease	Diagnosis disease Type of blindness risks	Type of spine surgery Prone risks	Time of onset risks	Treatment outcome
Katz and Karlin[16] Spine 2005	1	Branch occlusion CRA	Scoliosis surgery Right to left atrial shunt	Quadrantic defect Literature review	POVL risks compression Hypotension excess EBL anemia
Kumar *et al*.[18] Am J Ophthalmol 2004	1 (16 female)	Right eye POVL (unilateral blindness) Rectus muscle damage	Compression Prone scoliosis surgery	Swollen medial rectus muscle on right	Compression of globe against medial wall of orbit Permanent POVL

AACG: Acute angle closed glaucoma, POVL: Postoperative visual loss, CRAO: Central retinal artery occlusion, CRA: Central retinal artery, ION: Ischemic optic neuropathy, HTN: Hypertension, DM: Diabetes mellitus, IOP: Intraocular pressure, PCA: Posterior cerebral artery, CB: Cortical blindness, ASCVD: Atherosclerotic cardiovascular disease, OR: Operation/surgery, CT: Computed tomography, OCT: Ocular coherence tomography, ROM: Range of motion, EBL: Estimated blood loss

Table 2: Case series: Summary literature of blindness with spine surgery

Author Reference, year	Number of patients (age/sex)	Diagnosis type of blindness	Type of spine surgery prone	Time of onset risks disease	Treatment outcome
Kueper *et al*.[17] Am J Orthop 2015	2 (78 male, day 7) (51 male, day 15)	POVL PRES	Prone surgery Scoliosis T10-pelvis Scoliosis T3-pelvis	Medical management of PRES	Full recovery Blood pressure controlled electrolytes managed
Emery *et al*.[7] J Bone Joint Surg Am 2015	55 study versus controls prone surgery	Spine surgery; impact head position on IOP and ION	Two groups Neutral 55 elevated HOB 10 up degrees	Ages 18-80 Elevation HOP << IOP	>> Perfusion decreased risks blindness/ION
Li *et al*.[20] World Neurosurg 2015	19 ION 3 CRAO 5 CB	POVL Prone spine surgery Risks ION: longer surgery anemia, hypotension transfusion	CRAO: Improper positioning CB: Prone position and obesity	Recommend: Use 3-pin head holder for head positioning	Recommend Reduce surgical time Avoid hypotension Limit anemia Limit transfusions Check position Obesity >> risk POVL
Kaeser and Borruat[13] J Arthroplasty 2011	6	2 femur fractures 3 hip procedures 1 bilateral TKR	ION (all 6 with POVL) Bilateral in 5	Three partial improvement	Treatment rapid reversal of; anemia Hypotension Hypovolemia
Delattre *et al*.[5] J Spinal Disord Tech 2007	17 CRAO	Prone spine surgery CRAO due to ocular compression (9 cases) ION carotid embolism (head rotation-4 cases)	Review 13/15 case reports ocular complications: Compression	66 cases/4 series Compression cited in only 10 of 66 cases)	Risks Preoperative periorbital edema/conjunctiva edema Intraoperative Head position Recommendation: Use 3-pin head holder

POVL: Postoperative visual loss, CRAO: Central retinal artery occlusion, ION: Ischemic optic neuropathy, HOB: Head of bed, CB: Cortical blindness, IOP: Intraocular pressure, PRES: Posterior reversible encephalopathy syndrome

that future precautions be taken to provide adequate eye protection when patients undergo prone spinal surgery. This should include using a 3-pin head holder to eliminate focal mechanical eye compression while also limiting the potential for carotid or jugular compromise (e.g., avoid rotation).

Cortical blindness following spinal surgery

In Goni *et al*. study in 2012, a 38-year-old male undergoing a laminectomy with pedicle screw instrumentation for an L2 fracture developed bilateral CB attributed to occipital lobe infarcts (computed tomography and magnetic resonance confirmed) within

Table 3: Review articles: Summary of literature of blindness with spine surgery

Author Reference year	Number of patients Type of blindness	Diagnosis Prone	Type of spine surgery Disease	Time of onset risks Treatment outcome
DePasse *et al*.[6] World J Orthop 2015	Etiologies of POVL with prone surgery	AACG ION CRAO CB	Most common risk factors: Ischemia optic nerve retina or cortex	Rare AACG	Rare amaurosis
Nickels *et al*.[25] World J Orthop 2014	89% of POVL due to ION	AION PION Due to: >> Venous pressure >> Edema >> Pressure	Pathology Retinal ischemia CB PRES (venous or arterial infarct)	Risks for ION Obesity, male, Wilson frame, prolonged surgery, increased EBL, decreased colloid use	Avoid ION Use more crystalloids Use α-2 agonists
Nandyala *et al*.[22] Spine J 2014	541,485 NIS	Frequency 1.9/10,000 cases POVL 56.2% spinal deformity surgery POVL patients	Average age 37.6 (vs. 52.4) Doubled LOS and costs for POVL	Risk factors POVL Deformity surgery DM (end organ damage) Paralysis	Risk factors Prone DM Paralysis Younger Long scoliosis surgery
Özkiris *et al*.[27] J Craniofac Surg 2014	POVL 0.0.13% all surgery	POVL 0.2% prone spine surgery 1 carotid body tumor	Most often; POVL ION including AION and PION	Risks Prolonged prone spine surgery << Ocular perfusion pressure	Risks >> EBL/anemia >> Volumes crystalloid
Pandey *et al*.[28] Indian J Ophthalmol 2014	POVL nonocular surgery	CRAO ION CB	Risk factors: Microvascular pathology Hypotension	Case study POVL following C-section	CRAO and CRVO
Epstein[8] Surg Neurol Int 2013	ESI TFESI	POVL due to epidural injections	Complications Meningitis CB	Risks Stroke, paralysis CSF leak with intravascular injections	Risks ESI and TFESI CB/other
Lee[19] Curr Opin Anaesthesiol 2013	ION mostly cause POVL	Prone spine surgery	Risks Male Obesity Wilson frame	Risk factors Longer surgery Greater EBL lower % colloid	Advise Avoid Hypotension Anemia
Grover and Jangra[11] J Anaesthesiol Clin Pharm 2012	POVL	ION CRAO CB	Etiology Microvascular disease Hypotension	Risk factors reviewed	Avoid Hypotension Anemia
Berg *et al*.[3] Clin Ophthalmol 2010	POVL nonocular surgery 0.013%	Prone spine surgery 0.2% POVL AION 111 (more cardiac) PION 165 (most spine) 526 AION/PION	Spine surgery (most PION) Other; 933 CRAO 33 pituitary apoplexy 245 CB	Ocular surgery Trauma 5 AION 47 PION 5	Conclusion: More POVL after nonocular surgery
Roth[32] Br J Anaesth 2009	CRVO CRAO ION	Various etiologies	Reviews Risks Frequency	Diagnosis and treatment	Outcomes
Shen[33] Anesth Analg 2009	10 years US data 1996-2005 NIS >5.6 million people	POVL ION CB CRVO	Eight common nonocular OR Knee, GB, CABG/valves Joint surgery, spine, appendix Colorectal	Risk factors Male, anemia, >comorbidities transfusions (blood) Highest POVL Cardiac 8.64/10,000	Spinal fusion POVL 3.09/10,000 > Risk <18-year-old CB > Risk RVOION over age 50

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Table 3: Contd...

Author Reference year	Number of patients	Diagnosis Type of blindness	Type of spine surgery Prone	Time of onset risks Disease	Treatment outcome
Newman[24] Am J Ophthalmol 2008	Rate POVL 0.002%-0.2% mostly due to ION	Nonocular surgery ages 5-81-year-old	AION - cardiac surgery PION - spine surgery/ cervical included	Risk factors: Prolonged surgery prone spine surgery Excessive blood loss Hypotension Anemia Hypoxia Reduce IOP with head positioning	Resolution Transfuse crystalloid or blood Avoid anemia Avoid vasoconstrictive agents
Baig *et al*.[2] Neurosurg Focus 2007	0.028-0.2% POVL	Prone spine surgery more frequent	More complex instrumented spine operations	Higher incidence of POVL	Reduce time extent of OR
Stambough *et al*.[35] J Am Acad Orthop Surg 2007	Corneal abrasion	Most common injury prone spine surgery	Risk for ION Surgery >7 h Acute EBL anemia Hypotension Hypoxia	Risk for CB Hypoxia Embolism/infarct to occipital lobes	Risks CRAO Direct compression Increased IOP
Williams[38] Anesthestiol Clin North America 2002	Risks of POVL	Cardiac and spine surgery prone 0.05-1%	Direct compression ION CRAO CRVO CB	Recommendation to anesthesia for cardiac or spine procedures	Avoid Hypotension Hypoxia Anemia Prolonged surgery Other

AACG: Acute angle closed glaucoma, POVL: Postoperative visual loss, CRAO: Central retinal artery occlusion, ION: Ischemic optic neuropathy, AION: Anterior ischemic optic neuropathy, PION: Posterior ischemic optic neuropathy, PRES: Posterior reversible encephalopathy syndrome, DM: Diabetes mellitus, IOP: Intraocular pressure, CB: Cortical blindness, OR: Operation/surgery, EBL: Estimated blood loss, NIS: Nationwide inpatient sample, LOS: Length of stay, CRVO: Central retinal vein occlusion, ESI: Epidural steroid injection: TFESI: Transforaminal epidural steroid injection, GB: Gallbladder, CABG: Cardiac bypass, CSF: Cerebrospinal fluid

12 h of surgery [Tables 1 and 4].[10] The patient was followed for 3 postoperative years, during which time the deficit remained permanent and irreversible.

Transient bilateral postoperative visual loss following spinal surgery

Quraishi *et al*. in 2012 reviewed the general incidence and etiology of POVL following prone spinal surgery while also presenting one case of bilateral POVL that resolved within 48 postoperative hours [Tables 1 and 4].[30]

Bilateral angle closure glaucoma after general anesthesia

Gayat *et al*. in 2011 discussed a patient who developed POVL attributed to bilateral postoperative AACG following prone cervical spine surgery [Tables 1 and 4].[9] AACG was variously attributed to the use of ephedrine, nefopam, and/or the prone surgical position.

Amaurosis after prone spine surgery

Zimmerer *et al*. in 2011 discussed the 0.028–0.2% frequency of POVL following prone spine surgery [Tables 1 and 4].[40] They noted two major risk factors prolonged procedures and the performance of complex spinal fusions They presented 73-year-old male who developed POVL following prone surgery for a lumbar disc herniation. His comorbid factors included hypertension (HTN), arterial sclerosis, diabetes, elevated blood lipids, and a history of prostate cancer. Intraoperatively, the patient had developed acute hypotension treated with catecholamines and using the Trendelenburg positioning; 3 h later, he developed POVL in the right eye (e.g., complete amaurosis).

Persistent cortical blindness after a thoracic epidural test dose of bupivacaine

Visser *et al*. in 2010 observed that following administration of a test dose of bupivacaine for thoracic epidural anesthesia (e.g., administered through an epidural catheter) in a patient about to undergo lung surgery, the patient developed persistent CB [Tables 1 and 4].[37]

Acute visual loss after prone spinal surgery

Hoff *et al*. in 2010 reported acute left-eye ION in a 56-year-old male undergoing prone cervical spine surgery [Tables 1 and 4].[12] At 6 postoperative weeks, there was only partial recovery; at 6 postoperative months, the ocular coherence tomography showed a marked reduction of the "retinal nerve fiber layer thickness around the optic nerve head." The authors emphasized the preventive

Table 4: Summary of articles

Title	Summary
Summary of case studies of POVL	
AACG After lumbar spine surgery	The article by Stewart *et al*. (2016) emphasizes that patients undergoing prone lumbar spine surgery may develop postoperative AACG.[36] Therefore, prior to such surgery, patients at significant risk for POVL/AACG should be presumptively screened and appropriately treated
POVL in prone orthopedic spine surgery	In 2015, Pin-On and Boonsri reported a case of POVL attributed to ION following spine surgery performed in the prone position.[29] Furthermore, they identified the pathophysiology and risk factors that may lead to presumptive preoperative treatment in susceptible patients
CB following posterior lumbar decompression fusion	Agarwal *et al*. in 2014 observed that 6-year-old female undergoing an L2-L4 laminectomy for adenocarcinoma developed severe intraoperative anemia and hypotension leading to bilateral occipital lobe infarcts and blindness[1]
Transient CB attributed to posterior spinal surgery in a child	Nathan *et al*. in 2013 reported that an 11-year-old female undergoing prone-instrumented scoliosis surgery utilizing hypotensive anesthesia developed transient CB[23]
Unilateral visual loss after excision of an extradural hematoma in the prone position	This case report by Ooi *et al*. in 2013 focuses on the development of CRAO due to pressure on the eyes for a patient undergoing prone spinal surgery for an epidural hematoma.[26] This complication would be best avoided by routinely use a 3-pin head holder to keep the eyes free of mechanical compromise while also ensuring the lack of carotid or jugular compression (avoiding rotation)
CB following spinal surgery	In 2012, Goni *et al*. presented a 38-year-old male who, 12 h following a lumbar laminectomy/pedicle screw instrumentation addressing an L2 fracture, developed permanent CB.[10] This was attributed to bilateral occipital lobe infarcts confirmed on both MR and CT studies
Transient bilateral POVL following spinal surgery	Quraishi *et al*. in 2012 reviewed the incidence and etiology of POVL following prone spinal surgery and noted a single case in which bilateral POVL resolved within 48 postoperative hours[10]
Bilateral angle closure glaucoma after general anesthesia	Gayat *et al*. in 2011 discussed the various etiologies of bilateral AACG in a patient who developed bilateral POVL (blindness) following prone cervical surgery.[10] Risk factors included the use of ephedrine, nefopam, and/or the prone position
Amaurosis after prone spine surgery	Zimmerer *et al*. in 2011 observed a 0.028-0.2%, frequency of POVL for patients undergoing prone spine surgery; two major risk factors included prolonged surgery and more complex procedures.[40] They presented a 73-year-old male who underwent a lumbar diskectomy in the prone position, who developed POVL 3 h postoperatively. Multiple comorbid risk factors included; HTN, DM, atherosclerosis, elevated lipids, a history of prostate cancer, and severe intraoperative hypotension requiring the administration of catecholamine and the Trendelenburg position
Persistent CB after a thoracic epidural test dose of bupivacaine	Visser *et al*. in 2010 presented a patient who developed persistent CB following administration of a test dose of bupivacaine given through an epidural thoracic epidural catheter placed prior to lung surgery[37]
Acute visual loss after prone spinal surgery	Hoff *et al*. in 2010 reported ION developing acutely in the left eye of a 56-year-old male undergoing prone cervical spine surgery[12]
Bilateral acute angle-closure glaucoma as a complication of facedown spine surgery	Singer and Salim in 2010 noted that a 68-year-old Caucasian female developed bilateral AACG following a multilevel prone lumbar decompression with fusion; postoperatively, she required emergent bilateral laser iridotomies.[34] Patients at risk for AACG should be screened with "prone tests" by ophthalmologists prior to prone spine surgery to determine whether prophylactic treatment is warranted
Ischemic orbital compartment syndrome after prone spinal surgery	Yu *et al*. in 2008 presented a patient whose POVL was attributed to an "ischemic orbital compartment syndrome" (e.g., due to mechanical compression) that warranted urgent surgical intervention[39]
Unilateral POVL due to CRAO following prone cervical spine surgery	Nakra *et al*. (Paediatr Anaesth 2007) in 2007 report a patient who developed unilateral POVL due to CRAO following prolonged prone spinal surgery [Table 1][21]
Visual loss after prone spine surgery patient using a foam headrest and eye goggles	Roth *et al*. in 2007 described a patient with CRAO following prone spine surgery utilizing a foam headrest and goggles to protect the eyes (the Dupaco Opti-Gard) [Table 1].[31] These two devices contributed to direct compression and increased IOP resulting in irreversible PVOL due to CRAO. Notably, these risks may be completely avoided using a 3-pin head holder for head immobilization in the prone position
Prone spinal surgery leads to CRAO and unilateral visual loss	Chung and Son in 2006 reported on a 60-year-old male who developed CRAO after prone spine surgery [Table 1].[4] The authors emphasize that prolonged prone spinal surgery may contribute to sufficient mechanical eye compression to result in CRAO
Monocular blindness due to prone cervical spine surgery	Kasodekar and Chen in 2006 reviewed the incidence of POVL following cardiac and prone spine surgery as varying from 0.05% to 1%.[15] They also presented a 62-year-old male with cervical myelopathy who following a C3-C6 laminectomy with lateral mass plating, developed blindness in the right eye

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Table 4: Contd...

Title	Summary
POVL following prone spinal surgery	Kamming and Clarke in 2005 reviewed the incidence of POVL during nonocular surgery as ranging from 0.0% to 1%.[14] They also presented a patient who following a lengthy, prone spine operation was blind in one eye
Visual field defect/POVL after posterior spine fusion	Katz and Karlin in 2005 discussed the literature and presented a case in which POVL developed following prone scoliosis surgery; the patient had a right-to-left atrial shunt resulting in a paradoxical micro-embolus and CRA branch occlusion (quadrant defect)[16]
Blindness and rectus muscle damage following prone spinal surgery	Kumar *et al*. in 2004 presented a 16-year-old female undergoing prone surgery for scoliosis who developed unilateral POVL due to direct "compression of the globe against the medial wall of the orbit;" this resulted in retinal/optic nerve ischemia, with a permanent loss of vision[18]
Case series and literature review	
Temporary POVL/PRES following spinal deformity surgery	Kueper *et al*. in 2015 presented two patients (ages 78-51) undergoing extensive thoracolumbar-instrumented fusions who developed PRES 7-15 days postoperatively.[17] After adequate medical management of hypokalemia and HTN, both patients fully recovered. Notably, avoiding such extensive instrumented fusions, particularly in older patients (e.g., the 78-year-old), would have eliminated this complication entirely
Effect of head position on IOP during lumbar spine fusion	Emery *et al*. in 2015 compared IOP changes in 55 patients undergoing lumbar fusion in the prone position with the head elevated 10° versus control patients undergoing comparable surgery but with their heads positioned parallel to the floor/no elevation.[7] Head elevation 10° significantly reduced the mean IOP, increased optic nerve perfusion, and thus would reduce the risk of perioperative blindness
POVL following lumbar spine surgery: A review of risk factors by diagnosis	Li *et al*. in 2015 also noted that POVL after lumbar surgery performed in the prone position was attributed to three main causes.[20] ION (19 cases) was largely due to prolonged operative time, anemia, intraoperative hypotension, and the need for transfusion. CRAO (3 cases) was usually attributed to improper positioning, while CB (5 cases) was due to both prone positioning and obesity. Notably, POVL could be largely avoided through the routine use of an arterial line and the 3-pin head holder
Visual loss after orthopedic procedures	Kaeser and Borruat in 2011 discussed six patients who underwent orthopedic procedures (joint/fracture surgery), who developed postoperative ION (bilateral blindness in 5 of 6 cases); some only partially recovered.[13] They emphasized the need for immediate ophthalmic consults when ION arises and discussed how intraoperative anemia, systemic hypotension, or hypovolemia should be avoided
Spinal surgery and ophthalmic complications: A review of 17 cases	Delattre *et al*. in 2007 noted that in 13 of 15 case reports, POVL due to prone spine surgery was attributed to direct ophthalmic compression. However, for 66 patients with POVL culled from 4 review articles involving prone spine surgery, only 10 cited compression as the cause of blindness.[17] In this study, the authors noted that POVL was due to direct ocular compression in 9 cases (unilateral blindness due to CRAO), while four patients developed ION. Notably, the authors suggested modifying the horseshoe-shaped headrest and paying more attention to head positioning
Review articles on POVL with prone spine surgery	
Complications associated with prone positioning in elective spinal surgery	DePasse *et al*. noted in 2015 that POVL following prone spinal surgery was most frequently attributed to ischemia of the optic nerve, retina, or cerebral cortex, and even more rarely to acute closed-angle glaucoma and amaurosis[6]
Perioperative visual loss after spine surgery	Nickels *et al*. in 2014 noted that POVL following prone spine surgery was most commonly due to PION (e.g., comprised 89% of cases).[25] In PION, increased venous pressure and interstitial edema resulted in direct mechanical compression or venous infarction. Risks factors correlating with PION included "obesity, male sex, Wilson frame use, longer anesthetic duration, greater estimated blood loss, and decreased percent colloid administration." Measures to avoid ION included greater use of crystalloids versus colloids, and administration of α-2 agonists (e.g., decreases IOP)
Incidence and risk factors for perioperative visual loss after spinal fusion	Nandyala *et al*. in 2014 found that of 541,485 patients identified from the NIS database, for those undergoing spinal fusions, there were 1.9 instances of POVL per 10,000 cases; 56.2% were related to long-segment spinal deformity surgery.[22] POVL increased hospital costs and LOS 2-fold. Studies like this should also ask why so many and such extensive spinal fusions are being performed in the first place
ION after carotid body tumor resection	Özkiris *et al*. in 2014 noted that POVL arises from 0.013% for all operations (excluding those on the eye), and up to 0.2% for prone spine surgery.[27] The most common cause of POVL was anterior or posterior ION which typically resulted from; prolonged surgery, excessive blood loss, anemia/hemodilution, and infusion of large volumes of crystalloid versus colloid

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Table 4: Contd...

Title	Summary
POVL in nonocular surgery	Summary; Pandey *et al*. discussed in 2014 various etiologies of POVL following spine surgery as including ION, CRAO, and CB largely due to microvascular pathology and intraoperative hypotension[28]
The risks of epidural and transforaminal steroid injections in the spine	Epstein discussed in 2013 how epidural/translaminar/transforaminal and/or facet injections are increasingly performed in multiples of 3 by pain management specialists (radiologists, physiatrists, and anesthesiologists); however these injections have no documented long-term efficacy.[8] Furthermore, they are not approved by the FDA, and are associated with multiple complications including stroke/blindness (e.g., occipital strokes associated with cervical injections typically inadvertently penetrating the vertebral artery)
Perioperative visual loss and anesthetic management	Lee in their 2013 review discussed the frequency and etiology of ION/POVL associated with prone spine surgery.[19] Risk factors included: "Male sex, obesity, the Wilson spinal frame, longer anesthetic duration, greater blood loss, and a lower percentage of colloid in the nonblood fluid administration"
Perioperative vision loss	Grover and Jangra in 2012 noted POVL (e.g., ION, CRAO, CB, and occasionally, eye trauma) occurred secondary to two major factors; microvascular diseases, and intraoperative hypotension[11]
Perioperative visual loss in ocular and nonocular surgery	Berg *et al*. in 2010 discussed the frequency of POVL following spine surgery as ranging up to 0.2% and noted a much higher incidence of POVL following nonocular versus ocular operations.[3] They observed 111 cases of AION injuries mostly due to cardiac procedures, 165 cases of PION due to prone spine surgery, and 526 mixed AION/PION cases
Perioperative visual loss: What do we know, what can we do?	Roth in 2009 noted risks factors contributing to POVL (ION, CRAO) following nonocular surgery, and discussed the frequency, diagnosis, and treatment of POVL[32]
POVL; 10 years study attributed to spinal, orthopedic, cardiac, and general surgery	Shen *et al*. in 2009 studied POVL over a 10 year period (1996-2005) in the US following eight nonocular operations performed on >5.6 million patients in the NIS.[33] POVL, including ION, CB, or RVO were most commonly attributed to cardiac (8.64/10,000), followed by spine fusions (3.09/10,000), and orthopedic surgery. Risk factors for POVL in patients over age 50 included male gender, a higher Charlson comorbidity index, anemia, and blood transfusions
Perioperative visual loss after nonocular surgeries	Newman in 2008 discussed the risk of POVL in patients ages 5-81 undergoing monocular surgery as varying from 0.002% to 0.2%, with the majority occurring in cardiac and spine surgeries.[25] The most common cause of POVL was typically bilateral ION: AION with cardiac surgery and PION with prone spine surgery. Risk factors included: Long prone procedures, excessive blood loss, hypotension, anemia, hypoxia, high volume fluid replacement, use of vasoconstrictors, high venous pressure, head positioning, and other physiological factors
Vision loss after spine surgery: Review of the literature and recommendations	Baig *et al*. in 2007 reviewed the higher incidence of POVL (0.028-0.2%) due to the more frequent and complex instrumented spine versus cardiac operations[2]
Ophthalmologic complications associated with prone positioning in spine surgery	Stambough *et al*. in 2007 discussed the risk factors contributing to the three most common causes of POVL after spine surgery performed in the prone position.[35] Risk factors for ION included; surgery over 7 h, acute anemia, hypotension, and hypoxia. The major risk for CRAO was direct compression that raised IOP. CB was largely due to hypoxia/cerebral embolism (occipital cortical infarct)
Postoperative blindness	Williams in 2002 reviewed the various etiologies and risks for developing POVL (range: 0.05-1%) following cardiac or spine surgery.[38] Although direct compression may cause POVL other major etiologies included; ION, CRAO, CRVO, and CB

AACG: Acute angle closure glaucoma, CRVO: Central retinal vein occlusion, CB: Cortical blindness, POVL: Postoperative visual loss, CRAO: Central retinal artery occlusion, ION: Ischemic optic neuropathy, IOP: Intraocular pressure, PION: Posterior ischemic optic neuropathy, AION: Anterior ischemic optic neuropathy, RVO: Retinal vascular occlusion, NIS: Nationwide inpatient sample, FDA: Food and Drug Administration, LOS: Length of stay, PRES: Posterior reversible encephalopathy syndrome, MR: Magnetic resonance, CT: Computed tomography, HTN: Hypertension, DM: Diabetes mellitus

steps that may be taken during prone spinal surgery to avoid ION.

Bilateral acute angle closure glaucoma as a complication of facedown spine surgery

Singer and Salim in 2010 reported that prone spine surgery increased IOP "in individuals susceptible to AACG" [Tables 1 and 4].[34] They noted that ophthalmologists could perform provocative "prone tests" to determine whether glaucoma patients were at increased risk for AACG. The authors presented a 68-year-old Caucasian female who developed bilateral AACG while undergoing a multilevel lumbar decompression with fusion; postoperatively, she required bilateral laser iridotomies. The authors emphasized that ophthalmologists prior to prone spine surgery could screen patients with glaucoma or others at risk for AACG.

Ischemic orbital compartment syndrome after prone spinal surgery

Yu *et al*. in 2008 presented a patient undergoing prone spine surgery who developed "ischemic orbital compartment syndrome (e.g., due to compression)" warranting urgent intervention [Tables 1 and 4].[39]

Unfortunately, 3 months later, the patients remained blind.

Unilateral postoperative visual loss due to the central retinal artery occlusion following prone cervical spine surgery

Nakra *et al*. in 2007 reported a patient who developed unilateral POVL due to CRAO following prolonged spine surgery performed in the prone position [Tables 1 and 4].[21]

Visual loss after prone spine surgery in patient using a foam headrest and eye goggles

Roth *et al*. 2007 described a patient who developed CRAO following prone spine surgery utilizing a foam headrest and goggles to protect the eyes (the Dupaco Opti-Gard) [Tables 1 and 4].[31] Together the two devices resulted in direct eye compression; the increase in IOP resulted in CRAO/irreversible blindness. This report highlighted the need to avoid both of these devices. Notably, these risks may be completely avoided using a 3-pin head holder for head immobilization in the prone position.

Prone spinal surgery leads to central retinal retinal artery occlusion and unilateral visual loss

Chung and Son in 2006 reported on a 60-year-old male who developed CRAO after prone spine surgery [Tables 1 and 4].[4] Postoperative medical treatment did not resolve his unilateral blindness. The authors emphasized that prolonged prone spinal surgery may contribute to sufficient mechanical eye compression to result in CRAO.

Monocular blindness due to prone cervical spine surgery

Kasodekar and Chen in 2006 documented a 0.05–1% risk of POVL with cardiac or prone spine (including prone cervical spine) surgery [Tables 1 and 4].[15] The authors presented a 62-year-old male with cervical myelopathy who following a C3–C6 laminectomy with lateral mass plating, developed unilateral blindness (POVL: Right eye).

Postoperative visual loss following prone spinal surgery

Kamming and Clarke in 2005 identified the incidence of POVL during nonocular surgery as ranging from 0.01% to 1% [Tables 1 and 4].[14] They also presented a patient who following a lengthy, prone spine operation was blind in one eye. The authors discussed the multiple etiologies of POVL following prone spine surgery and also discussed methods for avoiding this complication.

Visual field defect/postoperative visual loss after posterior spine fusion

Katz and Karlin in 2005 reviewed the literature and presented a case in which POVL followed prone scoliosis surgery [Tables 1 and 4].[16] This patient had a right-to-left atrial shunt responsible for a paradoxical micro-embolus that resulted in branch CRAO (quadrant defect). The authors reviewed this and multiple other etiologies of POVL occurring during prone spine surgery; they included ophthalmic compression, hypotension, excessive blood loss, and anemia.

Blindness and rectus muscle damage following prone spinal surgery

Kumar *et al*. in 2004 discussed a 16-year-old female who following prone surgery for scoliosis, developed ocular compression responsible for both POVL and rectus muscle damage [Tables 1 and 4].[18] The loss of vision in the right eye was attributed to direct "compression of the globe against the medial wall of the orbit;" this resulted in retinal/optic nerve ischemia, with a permanent loss of vision."

CASE SERIES AND LITERATURE REVIEW

The five case series involving between 2 and 55 patients per study, and recounted the multiple etiologies of POVL attributed to prone spine surgery [Tables 2 and 4].[5,7,13,17,20] In three series, the etiology of POVL included posterior reversible encephalopathy syndrome (PRES: 2 patients), ION (55 patients), and CRAO (17 patients).[5,7,17] In the fourth study, POVL was due to ION alone (six patients), while in the fifth study, there were multiple etiologies of POVL: ION (19 patients), CRAO (three patients), and CB (five patients).[13,20] Risk factors for POVL attributed to prone spinal surgery included; prolonged instrumented spinal fusions, improper positioning (e.g., compressive complications of the eyes, jugular vein, and carotids), anemia, hypotension, and transfusions. Remedies included rapid reversal of anemia, hypotension, and hypovolemia. In addition, Emery *et al*. study recommended elevating the head 10° to decrease intraoperative IOP during prone procedures.[7] Furthermore, placement of a 3-pin head holder would avoid direct pressure on the eyes, along with jugular/carotid compression (avoid neck rotation).

Temporary postoperative visual loss/posterior reversible encephalopathy syndrome following spinal deformity surgery

Kueper *et al*. in 2015 evaluated two patients presenting with PRES contributing to temporary POVL following prone spinal deformity surgery [Tables 2 and 4].[17] A 78-year-old female underwent a posterior T10 to pelvis fusion with transpsoas lumbar interbody fusion (L1–L4); on postoperative day 7, she developed confusion and bilateral visual loss. A second 51-year-old female following a posterior T3 to pelvis fusion with interbody L4–S1 (fusions; presacral interbody) device placement also developed bilateral POVL on postoperative day 15. Fortunately, both patients fully recovered after successful medical management of PRES (e.g. treatment of

hypokalemia and HTN). Notably, avoiding such extensive instrumented fusions, particularly in older patients (e.g., the 78-year-old), would have eliminated this complication entirely.

Effect of head position on intraocular pressure during lumbar spine fusion

Emery *et al*. in 2015 noted that ION resulted from decreased perfusion attributed to increased IOP and/or hypotension occurring during prone spinal surgery [Tables 2 and 4].[7] In this randomized prospective trial, the authors studied the impact on IOP of elevating the head of bed 10 degrees in 55 patients (ages 18–80) undergoing prone lumbar fusions; results were compared with comparable control patients whose heads were positioned neutral/parallel to the ground. The multiple variables studied included; IOP, blood pressure, PCO_2, and changes in IOP. Elevating the head significantly lowered the mean IOP, improved optic nerve perfusion, and reduced the risk of perioperative blindness.

Postoperative visual loss following lumbar spine surgery: A review of risk factors by diagnosis

Li *et al*. in 2015 also noted that POVL rarely occurs following lumbar spine surgery performed in the prone position [Tables 2 and 4].[20] They evaluated the multiple perioperative risk factors likely contributing to the three main types of POVL; ION (19 cases), CRAO (three cases), and CB (five cases). Utilizing PubMed and Google literature searches, they identified the following risk factors in four large-scale studies; prolonged operative times, anemia, hypotension, and blood transfusion. Risks factors for CRAO mostly included improper positioning, while those for CB included both prone positioning and obesity. Notably, different types of POVL could be largely avoided through the routine use of an arterial line (e.g., avoidance of intraoperative hypotension/anemia/hypovolemia), and the 3-pin head holder (e.g. avoid direct eye compresssion and cervical spine rotation).

Visual loss after orthopedic procedures

Kaeser and Borruat in 2011 discussed six patients who developed ION (five of six cases bilateral blindness) following various orthopedic procedures (joint/fracture surgery); for some patients, deficits only partially recovered [Tables 2 and 4].[13] The authors emphasized the importance of rapidly diagnosing ION and its immediate treatment. Risk factors for ION included; intraoperative anemia, systemic hypotension, or hypovolemia.

Spinal surgery and ophthalmic complications: A review of 17 cases

Delattre *et al*. in 2007 noted that in 13 of 15 case reports, POVL due to prone spine surgery were due to ophthalmic compression [Tables 2 and 4].[17] However, in four review articles involving 66 cases of POVL following prone spine surgery, only 10 cited compression as the cause. Here, the authors utilized a 2-page survey of 28 French spine orthopedic centers asking about their incidence of POVL with prone spine surgery. They identified the following preoperative risk factors; "eyelid/conjunctival edema, periorbital numbness, or paresthesias;" intraoperative risks largely included head position. The etiology of 13 of 17 cases of POVL included ocular compression (nine cases-unilateral blindness due to CRAO), and internal carotid thromboembolism (four cases-head rotation toward the ipsilateral side leading to ION). The authors suggested modifying the horseshoe headrest and avoiding lateral rotation of the head, especially in patients with known carotid atheromata as this would effectively reduce/eliminate POVL. Rather than using a headrest at all, I would recommend using a 3-pin head holder; it completely eliminates all eye compression, and maintains the neck in a neutral posture.

REVIEW ARTICLES ON POSTOPERATIVE VISUAL LOSS WITH PRONE SPINE SURGERY

The 15 review articles from 2004 to 2015 cited the various types of POVL; ION (AION/PION), CRAO (including CRA-branch occlusion), CRVO, AACG, and CB (occipital lobe infarcts) [Tables 3 and 4]. The etiologies of POVL included direct compression (head rest/eye goggles), hypotension, excessive blood loss, anemia, glaucoma, HTN, use of catecholamines/ephedrine during surgery, prolonged prone spine surgery/deformity surgery, use of colloid rather than crystalloid fluid replacement intraoperatively, diabetes mellitus (DM), extensive use of instrumentation, obesity, history of multiple comorbidities, hypoxia, and male gender. Recommendations for avoiding POVL included; ophthalmological evaluation for patients with significant glaucoma histories, elevation of the head of the bed 10° to reduce IOP, avoidance of hypotension, hypovolemia, anemia, and greater use of colloids. In addition, the routine use of an arterial line would avoid hypotension/anemia/hypovolemia, while the 3-pin head holder would eliminate direct pressure on the eyes and avoid cervical rotation (e.g., jugular/carotid compression/manipulation).

Complications associated with prone positioning in elective spinal surgery

DePasse *et al*. in 2015 noted that POVL following prone spinal surgery was most frequently attributed to ischemia of the optic nerve, retina, or cerebral cortex, and rarely, AACG and amaurosis [Tables 3 and 4].[6] This article looked at ways in which spine surgeons could limit this complication.

Perioperative visual loss after spine surgery

Nickels *et al*. in 2014 evaluated POVL attributed to either prone spine or cardiac surgery [Tables 3 and 4].[25] The American Society of Anesthesiologists (ASA) POVL

Registry noted that POVL following prone spine surgery was most commonly due to PION (e.g., comprised 89% of cases involving blindness). Other pathologies of POVL with prone spine surgery included retinal ischemia (CRAO, CRVO), CB, and PRES. Risk factors contributing to ION for patients undergoing prone spinal fusions included; "obesity, male sex, Wilson frame use, longer anesthetic duration, greater EBL, and decreased percent colloid administration." Factors contributing to ION included; increased venous pressure/interstitial edema resulting in direct mechanical compression or venous infarction. As POVL is typically permanent/irreversible, it should be avoided by controlling the associated risks factors (e.g., greater utilization of crystalloids versus colloids) and α-2 agonists (e.g., decreases IOP).

Incidence and risk factors for perioperative visual loss after spinal fusion

Nandyala *et al*. in 2014 found that POVL was a rare complication of prone spine fusion surgery [Tables 3 and 4].[22] Utilizing the nationwide inpatient sample (NIS) database, the authors studied 541,485 patients undergoing spinal fusions, along with their preoperative risk factors and postoperative outcomes (e.g., length of stay [LOS], hospital costs, and mortality). POVL occurred in 1.9/10,000 cases; 56.2% of these patients underwent spinal deformity surgery, and LOS and hospital costs doubled. Risk factors contributing to POVL included; deformity surgery, DM with end organ damage, and paralysis. Studies like this should also ask why so many and such extensive spinal fusions are being performed in the first place.

Ischemic optic neuropathy after carotid body tumor resection

Özkiris *et al*. in 2014 noted that POVL followed any surgery in 0.013% of cases, but up to 0.2% of spine operations performed in the prone position [Tables 3 and 4].[27] The most frequent etiologies of POVL included AION or PION. ION was variously attributed to long prone operations, increased blood loss, anemia/hemodilution, and infusion of large volumes of crystalloid versus colloids. This study focused additionally on a single case of ION after resection of a carotid body tumor.

Postoperative visual loss in nonocular surgery

Pandey *et al*. discussed in 2014 various etiologies of POVL following prone spine surgery; this included ION, CRAO or branch retinal artery occlusion, and CB largely due to microvascular pathology and/or intraoperative hypotension [Tables 3 and 4].[28] This study uniquely presented POVL following a cesarean section.

The risks of epidural and transforaminal steroid injections in the spine

Epstein discussed in 2013 how the various types of spinal injections (e.g., epidural/translaminar, transforaminal, or facet injections) are increasingly and typically unnecessarily being performed in multiples of three by pain management specialists (radiologists, physiatrists, and anesthesiologists) [Tables 3 and 4].[8] Nevertheless, they are not approved by the Food and Drug Administration and expose patients to major risks/complications that are typically underreported; meningitis, stroke, paralysis, death, spinal fluid leaks (0.4–6%), positional headaches (28%), adhesive arachnoiditis (6–16%), hydrocephalus, air embolism, urinary retention, allergic reactions, intravascular injections (7.9–11.6%), stroke, blindness (occipital strokes associated with cervical injections typically inadvertently penetrating the vertebral artery), neurological deficits/paralysis, hematomas, seizures, and death. Furthermore, they have no documented long-term efficacy in the treatment of spinal pathology.

Perioperative visual loss and anesthetic management

Lee in their 2013 review discussed the frequency of ION/POVL due to prone spine surgery [Tables 3 and 4].[19] They reviewed the ASA recommendations regarding how to manage patients at increased risk for ION. They identified the following risk factors; "male sex, obesity, the Wilson spinal frame, longer anesthetic duration, greater blood loss, and a lower percentage of colloid in the nonblood fluid administration."

Perioperative vision loss

Grover and Jangra in 2012 noted POVL occurred following prone spine surgery and cardiothoracic surgical procedures; it was variously attributed to ION, CRAO, CB, and occasionally, compressive ocular trauma [Tables 3 and 4].[11] Additional etiologies of these injuries included microvascular diseases and intraoperative hypotension.

Perioperative visual loss in ocular and nonocular surgery

Berg *et al*. in 2010 discussed the frequency of POVL following nonocular surgery as ranging from 0.013% for all operations, but up to 0.2% following spine surgery [Tables 3 and 4].[3] After nonocular surgery, the authors identified 111 cases of AION (most due to cardiac surgery), 165 cases of PION (most due to prone spine surgery or radical neck dissection), and another 526 cases of either AION or PION. Other etiologies of POVL included 933 cases of CRAO, 33 cases of pituitary apoplexy, and 245 cases of CB. The frequency of POVL was much lower with ocular surgery; five cases of optic nerve trauma, 47 cases of AION, and five cases of PION.

Perioperative visual loss: What do we know, what can we do?

Roth in 2009 noted that POVL rarely occurred following nonocular surgery. Its various etiologies included; retinal vascular occlusion (RVO) and ION [Tables 3 and 4].[32]

This study discussed the frequency, risks, diagnosis, and treatment of POVL.

Postoperative visual loss; 10-year study attributed to spinal, orthopedic, cardiac, and general surgery

Shen *et al*. in 2009 studied POVL over a 10-year period (1996–2005) in the US following eight nonocular operations performed on >5.6 million patients in the NIS [Tables 3 and 4].[33] Surgery included: knee, gall bladder, hip/femur, laminectomy (no fusion), spinal fusion, appendectomy, colorectal, coronary artery bypass grafting, and cardiac valve procedures (1996–2005). POVL postoperatively was variously attributed to: ION, CB, or RVO. The highest rates of POVL occurred in cardiac (8.64/10,000) procedures, followed by spinal fusions (3.09/10,000), and orthopedic surgery. Those under 18 years of age showed a higher rate of CB, while those over 50-years-old exhibited more ION and RVO. Risk factors for POVL included; male gender, a higher Charlson comorbidity index, anemia, and the need for blood transfusion.

Perioperative visual loss after nonocular surgeries

Newman in 2008 discussed the risk of POVL in patients ages 5–81 undergoing nonocular surgery as varying from 0.002% to 0.2%; the majority occurred in cardiac and spine surgeries [Tables 3 and 4].[24] Most commonly, AION was seen bilaterally with cardiac surgery, while PION correlated with prone spine surgery. Risk factors included; long prone spine surgery, excessive blood loss, hypotension, anemia, hypoxia, high volume fluid replacement, use of vasoconstrictors, high venous pressure, and poor head positioning (rotation, orbital compression). Although the authors recommended urgent postoperative evaluation by ophthalmology for establishing the diagnosis of ION, most treatment modalities appeared to be largely ineffective.

Vision loss after spine surgery: review of the literature and recommendations

Baig *et al*. in 2007 reviewed the higher incidence of POVL (0.028–0.2%) due to the more frequent and complex instrumented spine versus cardiac operations [Tables 3 and 4].[2]

Ophthalmologic complications associated with prone positioning in spine surgery

Stambough *et al*. in 2007 discussed the most common eye injury occurring during prone spine surgery: a corneal abrasion [Tables 3 and 4].[35] Risk factors for ION included; surgery over 7 h, acute anemia, hypotension, and hypoxia. Other factors resulting in CRAO included; direct compression raising IOP. CB was attributed to hypoxia and cerebral embolism (e.g. occipital cortical infarct). Outcomes for ION and CRAO were poor, whereas those for CB may improve. The authors suggested multiple prophylactic measures to avoid these complications.

Postoperative blindness

Williams in 2002 looked at the various etiologies and of POVL (frequency 0.05–1%) that followed anesthesia for largely cardiac bypass or spine surgery [Tables 3 and 4].[38] Although direct compression may cause POVL, more frequent etiologies included ION, CRAO, CRVO, and CB.

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