



The Prone Position During Surgery and its Complications: A Systematic Review and Evidence-Based Guidelines

Melissa M. Kwee¹, Yik-Hong Ho², Warren M. Rozen^{1,2}

¹*Department of Surgery, Monash University, Clayton 3168, Victoria, Australia*

²*Discipline of Surgery, School of Medicine, James Cook University, Townsville, Queensland, Australia*

Surgery in the prone position is often a necessity when access to posterior anatomic structures is required. However, many complications are known to be associated with this type of surgery, as physiologic changes occur with increased pressure to anterior structures. While several studies have discussed postoperative vision loss, much fewer studies with lower levels of evidence have addressed other complications. A systematic literature review was conducted using 2 different databases, and 53 papers were regarded as appropriate for inclusion. Qualitative and quantitative analysis was performed. Thirteen complications were identified. Postoperative vision loss and cardiovascular complications, including hypovolemia and cardiac arrest, had the most number of studies and highest level of evidence. Careful planning for optimal positioning, padding, timing, as well as increased vigilance are evidence-based recommendations where operative prone positioning is required.

Key words: Prone – Surgery – Trunk – Supine – Retinal – Complications – Evidence based medicine – Qualitative and quantitative methods

Prone positioning is a common position used for access to the posterior head, neck, and spine during spinal surgery, access to the retroperitoneum and upper urinary tracts and access to posterior structures when required during plastic surgery.^{1,2} Prone surgery is associated with a variety of

complications many of which are derived from increased pressure on anterior structures. Rates of pressure sores as an intraoperative complication have been reported to be between 5% and 66%. As such, pressure sores incur longer hospital stays and healthcare costs.³ Postoperative vision loss can

Corresponding author: Warren M. Rozen, MD, PhD, Discipline of Surgery, School of Medicine, James Cook University, Townsville, Queensland 4814, Australia.

Tel.: +61 747961417; E-mail: warrenrozen@hotmail.com

result from inappropriate orbital pressure and can also be a permanently debilitating condition. Lateral femoral cutaneous nerve neuropathy in 20% of spinal surgery cases causing pain and dysesthesia in the anterolateral thigh.⁴ Inappropriate pressure on vital structures of the abdomen can cause ischemia and organ failure, resulting in prolonged hospitalization, permanent disability, or death.⁵ Cardiovascular changes associated with prone surgery increase risk of intraoperative cardiac arrest. At the same time, prone surgery is also associated with airway management and CPR issues as access to anterior structures is limited.⁶

Materials and Methods

We conducted a systematic literature search using Medline and Scopus for literature using the MeSH terms “surgery,” and “prone position.” We limited the search to those in the English language and with a focus on humans. Articles were included or excluded based on the content of the article’s title and abstract, particularly if surgical complications were addressed, and if they were tied to prone positioning intraoperatively. Full text articles were reviewed for citations, which had appropriate content or those that could not be excluded indisputably based on abstract content (Table 1).

Type of complication and surgery were identified and articles were sorted accordingly. Guidelines for level of evidence from the Oxford Centre for Evidence-Based Medicine (OCEBM) were also applied (Table 2). Results were presented qualitatively and quantitatively.

Results

Fifty-three papers addressing complications during prone surgery were reviewed. In these, 13 complications were identified: increased intra-abdominal pressure and increased bleeding, abdominal compartment syndrome, limb compartment syndrome, nerve palsies, pressure sores, cardiovascular compromise, thrombosis and stroke, hepatic dysfunction, postoperative vision loss, oropharyngeal swelling, venous air embolism, and endotracheal tube dislodgement. The 2 complications with the highest number of studies had the highest level of evidence. Half of the papers found addressed postoperative vision loss despite its low rate of incidence. Cardiovascular complications including hypovolemia and cardiac

arrest were discussed in 13 studies. Many other complications had few studies with low levels of evidence. Several studies have discussed recommendations to reduce risk of complication, which will be discussed further.

Discussion

Several studies addressed physiologic changes associated with prone position.

Without proper padding and bolster placement, significant pressure is put on thorax and abdomen.⁷ Pelvic and abdominal compression results in increased intra-abdominal pressure causes direct pressure on inferior vena cava and venous pooling and decreased venous return.^{7,8} Increased thoracic pressure causes decreased left ventricular compliance and filling, resulting in reduced ventricular volume, stroke volume and cardiac index, while raising central venous pressure.^{7–11} Reduced stroke volume and cardiac index results in a drop in blood pressure often seen when a patient is turned from supine to prone.¹⁰

Respiratory changes include a 30% to 35% decrease in respiratory compliance and increase in peak airway pressure.⁷ This in turn decreases venous return and cardiac output.⁴

Increased intra-abdominal pressure may cause a decrease in renal perfusion and impair function, however, this is controversial.⁷

Prone position also increases intraocular pressure as the episcleral venous system is connected to the central venous system by valveless vessels.^{7,12–14} Thus an increase in central venous pressure will result in an increase in episcleral venous pressure and intraocular pressure.¹³

With proper supportive padding to alleviate pressure on abdomen and thorax there is minimal reduction in respiratory compliance.⁷ Lung volume and oxygenation increase due to improved ventilation/perfusion ratio in both adults and pediatric demographics.^{7,15}

Obese patients are at particular risk of increased abdominal pressure, increased venous pressure in the head, and decreased cardiac output and reduced end organ blood flow.^{1,16} However, with proper supportive padding, these patients have better oxygenation in supported prone position versus supine position, as mediastinal contents fall anteriorly facilitating ventilation.⁷

Table 1 Details of reviewed literature

Author	Title	Date	Surgery type	Complication
Akhavan <i>et al</i>	Complications associated with patient positioning in urologic surgery	2010	Urology	Compartment syndrome, neuropraxia
Akinci <i>et al</i>	Effect of prone and jackknife positioning on lumbar disc herniation surgery	2011	Spinal surgery	Intra-abdominal pressure and increased bleeding
Ali <i>et al</i>	Unusual presentation and complication of the prone position for spinal surgery	2003	Spinal surgery and orthopedic surgery	Shoulder dislocation, ischemia, compartment syndrome, rhabdomyolysis
Asok <i>et al</i>	Central retinal artery occlusion and ophthalmoplegia following spinal surgery in the prone position	2009	Spinal surgery	Postop vision loss
Bafus <i>et al</i>	Severe hypotension associated with the prone position in a child with scoliosis and pectus excavatum undergoing posterior spinal fusion	2008	Spinal surgery	Hypotension in prone position
Biais <i>et al</i>	Abilities of pulse pressure variations and stroke volume variations to predict fluid responsiveness in prone position during scoliosis surgery	2010	Spinal surgery	Cardiovascular and pulmonary changes in prone
Brodsky	Positioning the morbidly obese patient for anesthesia	2002		Cardiovascular and pulmonary changes in prone
Brown <i>et al</i>	cardiac arrest during surgery and ventilation in the prone position: a case report and systematic review	2001	Spinal surgery	Cardiac arrest and air embolism
Chang and Miller	The incidence of vision loss due to perioperative ischemic optic neuropathy associated with spine surgery	2005	Spinal	Postop vision loss
Demoitie <i>et al</i>	Acute bilateral submandibular swelling following surgery in prone position	2006	Neurosurgery	Submandibular swelling
Dharmavaram <i>et al</i>	Effect of prone positioning systems on hemodynamic and cardiac function during lumbar spine surgery: an echocardiographic study	2006	Spinal	Cardiac function
Dumont <i>et al</i>	Venous air embolism: an unusual complication of atlantoaxial arthrodesis	2010	Spinal	Venous air embolism
Goepfert <i>et al</i>	Ischemic optic neuropathy: are we any further	2010		Postop vision loss
Grisell <i>et al</i>	Face tissue pressure in prone positioning	2008	Spinal	Facial pressure sores
Ho <i>et al</i>	ischemic optic neuropathy following spine surgery	2004	Spinal surgery	Postop vision loss
Hoff <i>et al</i>	Acute visual loss after spinal surgery	2010	Spinal surgery	Postop vision loss
Hunt <i>et al</i>	Changes in intraocular pressure in anesthetized prone patients	2004	Spinal surgery	Postop vision loss
Jaral <i>et al</i>	Thoracoscopic esophagectomy in the prone position	2012	Esophagectomy	Bleeding, endotracheal tube displacement
Kamming and Clarke	Postoperative visual loss following prone surgery	2005	Spinal surgery	Postop vision loss
Koreckij <i>et al</i>	Vectored cranial-cervical traction limits facial contact pressure from prone positioning during posterior spinal deformity surgery	2011	Spinal	Facial pressure sores
Kumagai <i>et al</i>	Perioperative cardiopulmonary complications after cervical spine surgery in the prone position: the relationship between age and preoperative testing	2011	Spinal	Cardiovascular risks
Kumar <i>et al</i>	Blindness and rectus muscle damage following spinal surgery	2004	Spinal surgery	Postop vision loss - orbital compression
Lee <i>et al</i>	Postoperative ischemic optic neuropathy	2010	Spinal	Postop vision loss
Leibovitch <i>et al</i>	Ischemic orbital compartment syndrome as a complication of spinal surgery in the prone position	2006	Spine surgery	Postop vision loss - ischemic orbital compartment syndrome
Marks <i>et al</i>	Does the systolic pressure variation change in the prone position?	2009		Hypovolemia

Table 1 Continued

Author	Title	Date	Surgery type	Complication
Mimami <i>et al</i>	Case report: central venous catheterization via internal jugular vein with associated formation of perioperative venous thrombosis during surgery in prone position	2012	Spinal	CVC-related venous thrombosis
Nakra <i>et al</i>	Unilateral postoperative visual loss due to central retinal artery occlusion following cervical spine surgery in prone position	2007	Spinal surgery	POVL
Neira <i>et al</i>	A transesophageal echocardiography examination clarifies the cause of cardiovascular collapse during scoliosis surgery in a child	2011	Spinal surgery, pediatrics	Cardiovascular collapse
Nicol <i>et al</i>	Incidence of thromboembolic complications in lumbar spinal surgery in 1,111 patients	2009		Deep vein thrombosis, pulmonary embolism
Ozcan <i>et al</i>	The effect of body inclination during prone positioning on intraocular pressure in awake volunteers: a comparison of two operating tables	2004		Post op vision loss
Poon <i>et al</i>	Hemodynamic changes during spinal surgery in the prone position	2008	Spinal surgery	Cardiovascular and pulmonary changes in prone
Postoperative Vision Loss Study Group	Risk factors associated with ischemic optic neuropathy after spinal fusion surgery	2012	Spinal	Postop vision loss
Raphael <i>et al</i>	Emergency airway management with laryngeal mask airway in a patient placed in the prone position	2004	Spinal surgery	Accidental extubation
Reddy <i>et al</i>	Dilated superior ophthalmic veins and posterior ischemic optic neuropathy after prolonged spine surgery	2008	Spinal surgery	Postop vision loss
Rigamonti <i>et al</i>	Prone versus knee-chest position for microdiscectomy: a prospective randomized study of intra-abdominal pressure and intraoperative bleeding	2005	Spinal	Intra-abdominal pressure and increased bleeding
Roth	Perioperative visual loss: what do we know, what can we do?	2009		Post op vision loss
Schonauer <i>et al</i>	Positioning on surgical table	2004		Blood loss, increased abdominal pressure, decreased cardiac output
Shermak <i>et al</i>	Prone positioning precautions in plastic surgery	2006	Plastic surgery	Pressure complications, nerve compression, brachioplexopathy, shoulder impingement, thrombosis - vertebral artery occlusion and stroke
Sherman <i>et al</i>	Prospective assessment of patient morbidity from prone sacral positioning	2012		Chest pressure sores, nerve palsies
Shih <i>et al</i>	Abdominal complications following posterior spinal fusion	2011	Spinal	Abdominal compartment syndrome
Sinha <i>et al</i>	Oropharyngeal swelling and macroglossia after cervical spine surgery in the prone position	2001	Spinal	Oropharyngeal swelling and macroglossia
Singer and Salim	Bilateral acute angle-closure glaucoma as a complication of facedown spine surgery	2010	Spine surgery	Postop vision loss and glaucoma
Stambough <i>et al</i>	Ophthalmologic complications associated with prone positioning in spine surgery	2007	Spine surgery	Postop vision loss
Trethowan <i>et al</i>	A case report and brief review of the literature on bilateral retinal infarction following cardiopulmonary bypass for coronary artery bypass	2011		Postop vision loss

Table 1 Continued

Author	Title	Date	Surgery type	Complication
von Ungern-Sternberg <i>et al</i>	Prone equals prone? Impact of positioning technique on respiratory function in anesthetized and paralyzed healthy children	2007	Pediatric surgery	Cardiovascular and pulmonary changes in prone
Walick <i>et al</i>	Changes in Intraocular Pressure due to Surgical Positioning	2007		Post op vision loss
Wax <i>et al</i>	Prone positioning for head and neck reconstructive surgery	2007	Plastic surgery	Cardiovascular and pulmonary changes in prone
Woodruff <i>et al</i>	Postoperative visual loss after plastic surgery: case report and a novel continuous real-time video monitoring system for the eyes during prone surgery	2011	Plastic surgery	Post op vision loss
Yano <i>et al</i>	Lower intracuff pressure of laryngeal mask airway in the lateral and prone positions compared with that in the supine positions	2008	Orthopedic, plastic surgery	Anesthetic complication - LMA disengagement
Yu <i>et al</i>	An analysis of perioperative eye injuries after nonocular surgery	2010	Head and neck surgery	Post op vision loss
Yu <i>et al</i>	Ischemic orbital compartment syndrome after posterior spinal surgery	2008	Spinal	Post op vision loss. Orbital compartment syndrome
Yuen <i>et al</i>	Severe hypotension and hepatic dysfunction in a patient undergoing scoliosis surgery in the prone position	2005	Spine surgery	Cardiovascular instability and ischemic hepatitis
Zimmerer <i>et al</i>	Amaurosis after spine surgery: survey of the literature and discussion of one case	2011	Spinal surgery	Post op vision loss

Increased intra-abdominal pressure, abdominal compartment syndrome, and increased bleeding in spinal surgery

An increase of intra-abdominal pressure in the prone position of more than 12 mmHg is high risk for abdominal compartment syndrome, as visceral compression and intra-abdominal hypertension cause dropped perfusion pressure resulting in multi-organ failure.⁵ Patients with previous abdominal surgeries are at particularly high risk as tight abdominal closures can reduce abdominal compliance, increasing abdominal pressure. In addition, patients with previous abdominal surgeries are at risk for incisional hernia, particularly if the patient is also obese.⁵

Bleeding from vertebral veins during spinal surgery is increased in the prone position and can obscure the surgical field and prolong surgical time.¹⁷ Multiple thin-walled, low-pressure venous plexuses closely related to the vertebrae are connected to chest and abdominal venous supplies. Pressure on the chest and abdomen therefore increases pressure in the vertebral vessels resulting in increased bleeding in spinal surgery.^{4,17} Venous engorgement in combination with arterial hypoten-

sion, can lead to poor spinal cord perfusion and result in ischemia.¹⁸

Recommendations

Chest rolls provide sufficient supportive padding to the chest to allow the abdomen to hang freely.

Table 2 Complications and level of evidence

Complication	Number of manuscripts included	Highest CEBM Level of evidence
Increased abdominal pressure and increased bleeding	3	2
Abdominal compartment syndrome	1	4
Limb compartment syndrome	2	2
Shoulder dislocation	1	4
Nerve palsies	2	4
Pressure sores	3	2
Cardiovascular compromise	13	1
Thrombosis and stroke	3	3
Hepatic dysfunction	1	4
Postoperative vision loss	23	1
Oropharyngeal swelling	2	4
Venous air embolism	2	1
Endotracheal tube dislodgement	3	3

Similarly, the Jackson table also achieves a freely hanging abdomen, which decreases visceral congestion and pressure on the cardiac and respiratory systems.^{1,5,7}

A study by Akinci *et al*, showed a decrease in intra-abdominal pressure and bleeding when spinal surgery patients were placed in a jackknife position rather than the prone position, as it uses hip flexion to relax and decrease intra-abdominal pressure while supporting the chest.¹⁹

Monitoring intra-abdominal pressure by intra-vesicular transducer should be considered for high-risk patients or high risk procedures. Frequent checks for signs of multi-organ failure during surgery such as drop in blood pressure, rise in PCO₂, drop in oxygen saturation and PO₂, decrease in urine output, coagulopathy or abnormal base deficit is also suggested. If abdominal compartment syndrome is suspected, delay for emergency abdominal decompression should be avoided.⁵

Nerve palsies and neuropraxia

Surgery in prone position has increased risk of injury of cervical spine and brachial plexus due to focal pressure points or strain in flexion or extension, leading to increased intraneural venous pressure, local edema, and impaired axoplasmic transmission.^{1,7} Risk factors include hypotension, diabetes, hypothermia, anatomic variations, and malnutrition.¹

Recommendations

For prevention of brachial plexus injury, anterior positioning of the humerus to the thoracic cage along with supportive padding for the arms is recommended.^{1,7} Palpating the pectoralis major muscle tendon along the anterior axilla border can monitor tension on the brachial plexus.⁷ Appropriate supportive padding should be used at bony surfaces where known superficial nerves are known to travel to avoid nerve compression.²⁰ Neutral positioning is encouraged to avoid impingement and excessive stretch forces on nerves.^{7,20} Neuropraxia assessment should be done postoperatively. Evaluation for muscle weakness, impaired sensation, or myalgia can be done as soon as anesthesia has worn off. Electromyography can be used to pick up lesions 2–3 weeks after surgery. Treatment options include physiotherapy, pain management, and repair by nerve graft.¹

Head and neck pressure sores

During prone surgery, the rate of stage-1 pressure sores is said to be between 5% and 66%.^{3,21} The risk increases with longer duration and increased volume replacement causing increased facial edema.²¹ Pressure on the face in prone position is on average 30 mmHg, but can be higher than 50 mmHg in certain areas such as the chin and forehead above the supraorbital ridge.²² Prolonged pressure on ears, particularly on cartilaginous auricles can result in hematoma, chondritis, ischemia or necrosis.⁷

Recommendations

Supportive padded headrests and bed inclination to elevate the head can be used to minimize inappropriate pressure on the face.²¹ However, the latter is not always possible as lumbar flexion is sometimes required for adequate access during spinal surgery, thus increasing pressure on the face.¹ Koreckil *et al* proposed upward traction on the head to alleviate pressure off the face by way of Gardner-Wells tongs applying 15 lbs of traction at a 45° angle.²¹

Chest pressure injuries

Pressure sores on the chest are also associated with prolonged surgical procedures in the prone position. Large breasts are subject to greater direct pressure. In addition, patients with breast implants have a theoretical risk of rupture and risk of breast necrosis with the direct pressure applied in prone position.⁷

Recommendations

Patients with larger breasts should have medial placement of the breasts, as lateral placement can be painful.^{1,7}

Cardiovascular collapse, arrest

As mentioned above, prone position during surgery is associated with reduced stroke volume, cardiac index, raised central venous pressure and low blood pressure. This, when combined with other factors, is associated with an increased risk for cardiovascular collapse and arrest. Risk factors include massive blood loss, hypothermia, fluid shifts, cardiac comorbidities, venous air embolism, and anatomic deformities such as thoracic lordosis or pectus excavatum, which can aggravate hypotension.^{9,11,23,24}

Recommendations

It is important to maintain euvolemia and monitor fluid responsiveness by pulse pressure variation and stroke volume variation, both of which remain reliable indicators for fluid status monitoring, despite both increasing in the prone position.²⁵ Systolic pressure variation may also be used for fluid status monitoring as it increases during hypovolemia.²⁷ High-risk patients should be identified so that positioning can be optimized, and adhesive defibrillator pads can be applied prior to surgery.²⁴ Patients in prone position on the Jackson spine table showed the least change in cardiac function (relative to supine position) compared with other prone position types.⁸ In this position, the abdomen hangs free and the chest and pelvis are supported, with the legs supported at heart level.

An arterial line is also recommended as a means to monitor real-time blood pressure and to allow immediate access to arterial blood samples to detect acid-base and electrolyte abnormalities.^{11,24} Central venous pressure monitoring can be used to monitor for trends indicating changes in right ventricular preload and intravascular volume. As central venous pressure is raised in the prone position, trends should be monitored for indication of change, not absolute values.¹¹

For patients with significant chest deformity and scoliosis, transesophageal echocardiography can be used to detect flow abnormalities in the prone position and find optimal supportive padding configuration to minimize the impact on cardiovascular function.^{9,23} In certain cases, pectus excavatum may need surgical correction prior to prone surgery.²³

During cardiac arrest, cardiac compressions may need to be commenced while the patient is still in prone position as turning the patient to supine position in a timely manner may not be feasible due to open wounds, ongoing blood loss, protruding metal work, or exposed or unstable structures such as the spine.²⁴

Hepatic dysfunction

Also liver congestion can be a consequence of raised central venous pressure. This paired with hypotension could lead to hypoperfusion and ischemic hepatitis.¹¹

Thrombosis and stroke

Thrombosis risk increases with patient age, malignancy, obesity and recent major surgery.²⁶ Position

of the patient contributes significantly to risk of thrombosis, as position-related occlusion of blood flow results in stasis and clotting.²⁶ Increased risk of carotid and vertebro-basilar artery dissection is associated with non-neutral neck positioning and movements. Such movements can lead to kinking of blood vessels, intimal injury and thrombosis. The highest risk is at the atlanto-axial joint, which is the site of maximal head rotation.^{20,26} Significant neck flexion or rotation can also lead to reduced cerebral perfusion.^{1,7}

In addition, foreign bodies introduced into the blood stream such as central venous catheters can act as sites of thrombosis, as foreign materials can activate the clotting cascade.²⁶

Recommendations

Reduction of excessive pressure and stabilization of the head and neck are important to avoid changes in blood supply and thrombosis during prolonged surgeries.²⁰ Shermak *et al* suggests maintaining the neck in a neutral nonextended position to reduce pressure on neurovasculature.^{1,20} A subclavian venous catheter follows a less thrombogenic route than an internal jugular venous catheter.²⁶ Nicol *et al* recommends kneeling or seated position to prevent venous thromboembolism during spinal surgery, as this reduces venous kinking in the lower extremities.²⁸

Limb compartment syndrome

Lower limb compartment syndrome and rhabdomyolysis are common complications associated with positioning in nonsupine positions.^{29,30} Elevated intracompartmental pressure can result in reduced local perfusion.¹ Inadequate blood supply to the limbs can result in ischemia, which in turn can lead to edema and further increase in intracompartmental pressure.¹ Ischemia can lead to necrosis of local tissue leading to neuropathy, rhabdomyolysis, raised myoglobin, and renal failure. In severe cases, permanent injury, disability, and death can result.^{1,30}

Risk factors include obesity, increased muscularity, peripheral vascular disease, and surgeries with long duration.¹ In addition, the risk for anterior shoulder dislocation may be higher in the prone position, and may lead to ischemia and compartment syndrome.³⁰

Recommendations

Monitoring of arterial supply to the limb by way of pulse oximetry can be a useful in detecting poor

limb perfusion.³⁰ Further, neutral positioning and padding can reduce the risk of thrombosis and the risk of limb compartment syndrome.

Postoperative vision loss (POVL) and other ophthalmic injuries

Several studies have discussed postoperative vision loss due to prone position. The rate of this complication is estimated to be between 0.05% and 1%.^{3,21,22,31}

Ischemic optic neuropathy (ION) and orbital compartment syndrome (OCS)

Direct pressure on orbits can cause trauma resulting in conjunctival edema, hemorrhage, chemosis, pain, and vision loss.^{7,14}

ION is caused by damage to optic nerve by increased intraocular pressure and orbital venous pressure.³² ION can be classified as either anterior ION, anterior to lamina cribrosa, or posterior ION. Posterior ION is more common postoperatively and more severe than anterior.³³

Direct pressure on the orbits causes an increase in intraocular pressure. Raised intraocular pressure in combination with raised intra-abdominal pressure reduces venous return in the orbit increasing venous pressure and edema.^{14,22,35} Edema can be aggravated by high-volume fluid replacement aggravating intraocular pressure.¹⁴ Congestion at the orbital apex can result in OCS and an ischemic orbit.^{34,22} Decreased perfusion pressure on the optic nerve results in ION.^{22,35} ION and OCS are well-established risk even with sufficient supportive facial padding.

Central retinal artery occlusion (CRAO)

CRAO is caused by vasospasm, emboli, compression, or hypotension.^{31,33,36,37} In particular, it can be due to displacement of plaques from the carotid arteries and can obstruct the central retinal artery.³¹ CRAO is almost always irreversible.³¹

Cortical blindness

Cortical blindness can be a result of emboli to posterior cerebral artery territory or significant hypotension and bilateral watershed infarctions affecting the visual cortex.^{31,33} It can improve over first few weeks, but is not likely to completely recover sight.^{31,33}

Acute angle-closure glaucoma

The prone position can shift the lens-iris diaphragm forward, impinging on the drainage angle recess and obstructing the aqueous humor outflow and increased intraocular pressure and optic nerve injury.³⁹ Patients predisposed to acute angle-closure glaucoma are at high risk with even short surgical procedures.³⁹

Other ophthalmic and extraocular injuries

Orbital pressure can also result in extraocular muscle impingement leading to swelling and impaired function.³⁸ Corneal abrasion and scleral injuries are usually self-limiting. General anesthesia decreases tear production, and in combination with incomplete eye closure can be high risk for increased dryness, irritation, abrasion, laceration and subsequent inflammation and infection.³¹

Risk factors

Venous congestion of the head which can be exacerbated when the head is placed lower than the heart seen when patients are positioned in the Trendelenburg position or in a Wilson's frame.^{16,33,40,41}

Anemia, hemodilution, blood loss (>1000 mL) and hypotension, in combination with the increased ocular pressure in the prone position can reduce perfusion pressure to the optic nerve and cause ION.^{31,33–37,41–45} Surgical duration longer than 6 hours and small cup-to-disc ratio are associated with POVL.^{36,41,44}

Preoperative risk factors include obesity, peripheral vascular disease, hypertension, smoking, atherosclerosis, hyperlipidemia, diabetes hypercoagulability, sleep apnea, polycythemia, renal failure, male gender, and middle age group.^{13,35,37,41–43,46} Direct pressure from the head rest on orbits may be higher in patients with low nasal bridges or exophthalmos.^{22,31}

Narrow-angle glaucoma may be a risk factor for CRAO.³¹ Risk factors for cortical blindness include cardiac arrest, significant hypotension, air embolism, prolonged hypoxia, and cyanosis if intubation is difficult and prolonged.³¹

Acute angle-closure glaucoma may be associated with hyperopia, female gender, advanced age and thickened lenses, certain ethnicities, medications, personal history, or family history of acute angle-closure glaucoma.³⁹

Recommendations

Several studies advocate elevating the head above the heart in a neutral position will reduce the risk of venous stasis.^{7,14,16,35–37,46,47} The reverse Trendelenburg position at 10° has been suggested to ameliorate raised intraocular pressure in prone position.^{13,14,31,36,40,43,48} However, in surgeries involving the head or neck, this reverse Trendelenburg position should not be overdone, as this will increase the risk of venous air embolism.⁴⁹ If the Trendelenburg position is required during surgery, minimize time with the head below heart level.³⁵

Direct pressure on the orbits should be avoided and use of headrests that ensure pressure is off the orbits and ears is advised.^{7,31,38,48} Asok *et al* recommends the Mayfield head clamp to prevent external pressure on the orbit.⁵⁰ Roth *et al* suggests using a square foam headrest and avoiding using a horseshoe head rest during cervical spine surgery, as frequent movement of the head increases risk of position change and increased orbital pressure.³⁷ Sherman *et al* used skull traction to suspend the head and reducing direct orbital pressure from the headrest.⁴⁷

Frequent monitoring of eye position every 20 minutes with a mirror attachment to the headrest ensures that prolonged inappropriate external orbital pressure is avoided.³⁷ Woodruff *et al* has developed a computer video streaming system to monitor eye position throughout the prone procedure.⁵¹ Trethowan *et al* suggests using loose endotracheal tube ties, however, care should be taken to not increase risk of endotracheal tube dislodgement.¹³

Maintaining tight control of hemostasis, monitoring blood pressure by arterial line or central venous pressure line, and timely correction of anemia and hypotension is paramount.^{16,31,35,36,48} Lower transfusion threshold and maintaining hematocrit above 30% in high risk patients is recommended.^{36,48} A safe lower limit for hypotension for each patient should be established based on an assessment of risk-benefit ratio using the patient's pre-operative blood pressure.⁴³ However, generally, maintaining systolic pressure above 90 mmHg with mean arterial pressure above 70 mmHg has also been suggested.³¹ Colloids along with crystalloids should be used for fluid management as this may theoretically reduce edema as high volumes of crystalloids are avoided.^{16,37,48}

Changes in perfusion-related medications prior to surgery should be avoided and preoperatively

withholding medications that may reduce blood pressure or increase blood coagulability should be taken into consideration.⁴⁸

Ophthalmologic evaluation pre-operatively should be considered if the patient has personal or family history of acute angle-closure glaucoma.³⁹

Staging prone surgeries if duration is likely to be prolonged.^{16,31,36,37,48} However, risk of thromboembolism, infection and additional anesthetic risks increase with staging.³¹

Early postoperative assessment of vision and early ophthalmologic intervention if visual disturbance is present is essential after prolonged surgery in the prone position and can be vital to prognosis of POVL.^{31,34–36,48}

Oropharyngeal swelling, macroglossia, sublingual hematoma

Oropharyngeal swelling including macroglossia, sublingual hematoma, and salivary gland swelling is a complication that may be seen in prolonged prone surgery, particularly if the head and neck position are in non-neutral, full flexion. Kinking and stretching of the salivary ducts blood vessels and lymphatics when the neck is in full flexion may lead to obstruction, and if prolonged, leads to swelling of local structures.^{52,53} In addition, the endotracheal tube may cause increased compression in the fully flexed neck, affecting venous and lymphatic drainage of the oropharynx and tongue causing swelling. Venous thrombosis may also cause local swelling as a result of ischemia of the oropharynx, reperfusion hyperemia, and subsequent capillary leak.⁵³ Salivary gland swelling post operatively is a complication that may result from general or spinal anesthetic.⁵² Repeated laryngoscopy and certain medications, including angiotensin-converting enzyme inhibitors, can also contribute to oropharyngeal swelling.⁵³ Luxation of the temporomandibular joint during intubation, poor oral hygiene, dehydration, and malnutrition may also increase risk of salivary gland swelling.⁵²

Recommendations

Full neck flexion can be reduced with proper head and neck support. A chin bar can be used to reduce soft tissue compression, and a bite block prevents tongue compression. Also, oral airways can put increased pressure on the tongue, which should be taken into consideration.⁵³

Hourly monitoring of head neck and tongue is advocated if significant neck flexion is required during the surgical procedure. Visualization of the oral cavity with laryngoscope for swelling should be done prior to extubation. Lack of air leaking after deflation of the endotracheal tube cuff may be a sign of oropharyngeal swelling and should be checked on extubation. Extubation should be postponed if swelling is suspected and patients should be monitored in the first few hours for postextubation swelling.⁵³

Venous air embolism

Air embolisms can be a product of either air entrainment through the surgical wound or accumulation of gas when using hydrogen peroxide for wound irrigation.^{24,49} Risk of air entrainment into the venous system is higher if venous pressure is low, such as when the surgical site is elevated above the heart or hypotensive episodes, as is often the case in the prone position.²⁴

Recommendations

Capnography and transesophageal echocardiography can be used to detect gas embolisms, while flooding the surgical field with normal saline or closure of open veins can be used to prevent air embolism. Central venous catheter can be used to remove air from the right heart and should be placed in patients with high risk of blood loss and air embolism.²⁴

Endotracheal tube and LMA displacement

Patients in prone position may be at higher risk for endotracheal tube and LMA displacement due to gravitational effects on instruments designed for intubation and airway management in supine position.^{24,54,55} LMAs can be used to maintain the airway if the endotracheal tube becomes dislodged as it can be rapidly inserted without laryngoscopy.^{24,54} However, it should be taken into consideration that prone as well as lateral position causes dilation in the airway due to gravitational effects of local anatomic structures. Therefore there is a higher risk of LMA dislodgement in the prone position if intracuff pressure is too low.⁵⁶

Conclusions

Several issues arise when a patient is put in the prone position for surgical procedures. Increased

pressure on anterior structures results in complications associated with reduced abdominal and respiratory compliance, compression of the orbits and vital organs, and hemodynamic changes that require close monitoring. There is sufficient evidence in the literature to support several key interventions. Carefully planned positioning and supportive padding, which cater specifically to alleviating pressure off key structures, are essential for prone positioning. Shorter duration or staged surgeries aimed at shortening time in the prone position are also advised. Additionally, interventions that require access to anterior structures are further complicated when the patient is prone and so require increased vigilance.

Acknowledgments

The authors have no disclosures or conflicts of interest to report.

References

1. Akhavan A, Gainsburg DM, Stock JA. Complications associated with patient positioning in urologic surgery. *Urology* 2010; **76**(6):1309–1316
2. St-Arnaud A, Paquin MJ. Safe positioning for neurosurgical patients. *AORN J*. 2008;**87**(6):1156–1168
3. Grisell M, Place H. Face tissue pressure in prone positioning. *Spine*. 2008;**33**(26):2938–2941
4. Schonauer C, Bocchetti A, Barbagallo G, Albanese V, Moraci A. Positioning on surgical table. *Eur Spine J* 2004;**13**(Suppl 1): S50–55
5. Shih P, Slimack NP, Roy A, Fessler RG, Koski TR. Abdominal complications following posterior spinal fusion in patients with previous abdominal surgeries. *Neurosurg Focus* 2011; **31**(4):E16–21
6. Jumagai G, Takeuchi K, Aburakawa S, Yokoyama T, Ono A, Numasawa T *et al*. Perioperative cardiopulmonary complications after cervical spine surgery in the prone position: the relationship between age and preoperative testing. *Arch Orthop Trauma Surg* 2011;**131**(7):911–916
7. Wax MK. Prone positioning for head and neck reconstructive surgery. *Head Neck* 2007;**29**(11):1041–1045
8. Dharmavaram S, Jelish S, Nockels RP, Shea J, Mehmood R, Ghanayem A *et al*. Effect of prone positioning systems on hemodynamic and cardiac function during lumbar spine surgery: an echocardiographic study. *Spine* 2006;**31**(12):1388–1393
9. Neria VM, Gardin L, Ryan G, Jarvis J, Roy D, Splinter W. A transesophageal echocardiography examination clarifies the

- cause of cardiovascular collapse during scoliosis surgery in a child. *Can J Anesth* 2011;**58**(5):451–455
10. Poon K, Wu K, Chen C, Fung S, Lau AW, Huang C *et al.* *Acta Anaesthesiol Taiwan* 2008; **46**(2):57–60
 11. Yuen VMY, Chow BFM, Irwin MG. Severe hypotension and hepatic dysfunction in a patient undergoing scoliosis surgery in the prone position. *Anaesth Intensive Care* 2005;**33**(3):393–399
 12. Hunt K, Bajekal R, Calder I, Meacher R, Eliahoo J, Acheson JF. *J Neurosurg Anaesthesiol* 2004;**16**(4):287–290
 13. Trethowan BA, Gilliland H, Popov AF, Varadarajan B., Phillips SA, McWhirter L *et al.* A case report and brief review of the literature on bilateral retinal infarction following cardiopulmonary bypass for coronary artery bypass grafting. *J Cardiothorac Surg* 2011;**6**(1):154–160
 14. Yu Y, Chen W, Chen L, Chen W. Ischemic orbital compartment syndrome after posterior spinal surgery. *Spine* 2008;**33**(16):E569–72
 15. von Ungern-Sternberg BS, Hammer J, Frie FJ, Ritz EJ, Schibler A, Erb TO. Prone equals prone? Impact of positioning techniques on respiratory function in anesthetized and paralyzed healthy children. *Intensive Care Med* 2007;**33**(10):1771–1777.
 16. Postoperative Vision Loss Study Group. Risk factors associated with ischemic optic neuropathy after spinal fusion surgery. *Anesthesiology* 2012;**116**(1):15–24
 17. Rigamonti A, Gemma M, Rocca A, Messina M, Bignami E, Beretta L. Prone versus knee-chest position for microdiscectomy: a prospective randomized study of intra-abdominal pressure and intraoperative bleeding. *Spine* 2005;**30**(17):1918–1923
 18. Brodsky JB. Positioning the morbidly obese patient for anesthesia. *Obesity Surgery* 2002;**12**(6):751–758
 19. Akinci IO, Tunalı U, Aidarbak A, Guresti E, Sencer A, Karasu A *et al.* Effects of prone and jackknife positioning on lumbar disc herniation surgery. *J Neurosurg Anesthesiol* **23**(4):318–322
 20. Shermak M, Shoo B, Deune EG. Prone positioning precautions in plastic surgery. *Plast Reconstr Surg* 2006;**117**(5):1584–1588
 21. Koreckij J, Price N, Schwend RM. Vectored cranial-cervical traction limits facial contact pressure from prone positioning during posterior spinal deformity surgery. *Spine* 2011;**36**(15):E993–997
 22. Leibovitch I, Casson R, Laforest C, Selva D. Ischemic orbital compartment syndrome as complication of spinal surgery in the prone position. *Ophthalmology* 2006;**113**(1):105–108
 23. Bafus BT, Chiravuri, van der Velde ME, Chu BI, Hirchl R, Farley FA. Severe hypotension associated with the prone position in a child with scoliosis and pectus excavatum undergoing posterior spinal fusion. *J Spinal Disord Tech* 2008; **21**(6):451–454
 24. Brown J, Robers J, Soar J. Cardiac arrest during surgery and ventilation in the prone position: a case report and systemic review. *Resuscitation* 2001;**50**(2):233–238
 25. Biais M, Bernard O, Ha JC, Degryse C, Sztark F. Abilities of pulse pressure variations to predict fluid responsiveness in prone position during scoliosis surgery. *Br J Anaesth* 2010; **104**(4):407–413
 26. Mimami K, Iida M, Iida H. Case report: central venous catheterization via internal jugular vein with associated formation of perioperative venous thrombosis during surgery in the prone position. *J Anesth* 2012;**26**(3):464–466
 27. Marks R, Silverman R, Fernandez R, Candiotti KA, Fu E. Does the systolic pressure variation change in the prone position? *J Clin Monit and Comput* 2009;**23**(5):279–282
 28. Nicol M, Sun Y, Craig N, Wardlaw D. Incidence of thromboembolic complications in lumbar spinal surgery in 1,111 patients. *Eur Spine J* 2009;**18**(10):1548–1552
 29. Agro F, Cataldo R, Carassiti M, Gherardi S, Pedace C. Lower limb pulse-oximetry prevention of complications due to non-supine position under general anaesthesia. *Resuscitation* 1999; **41**(3):281–282
 30. Ali AA, Breslin DS, Hardman HD, Martin G. Unusual presentation and complication of the prone position for spinal surgery. *J Clin Anesth* 2003;**15**(6):471–473
 31. Stambough JL, Dolan D, Werner R, Godfrey E. Ophthalmologic complications associated with prone positioning in spine surgery. *J Am Acad Orthop Surg* 2007;**15**(3):156–165
 32. Reddy A, Foroozan R, Edmond JC, Hinckley LK. Dilated superior ophthalmic veins and posterior ischemic optic neuropathy after prolonged spine surgery. *J Neuroophthalmol* 2008;**28**(2):327–328
 33. Lee LA, Newman NJ, Wagner TA, Dettori JR, Dettori NJ. Postoperative ischemic optic neuropathy. *Spine* 2010;**35**(95):S105–116
 34. Hoff JM, Varhaug P, Midelfart A, Lund-Johansen M. Acute visual loss after spinal surgery. *Acta Ophthalmol* 2010;**88**(4):490–492
 35. Walick KS, Kragh JE, Ward JA, Crawford JJ. Changes in intraocular pressure due to surgical positioning. *Spine* 2007; **32**(23):2591–2595.
 36. Goepfert CE, Ifune C, Tempelhoff R. Ischemic optic neuropathy: are we any further? *Curr Opin Anesthesiol* 2010;**23**(5):582–587
 37. Roth S. Perioperative visual loss: what do you we know, what can we do? *Br J Anaesth* 2009;**103**(Suppl. 1):i31–i40
 38. Kumar N, Jivan S, Topping N, Morrell AJ. Blindness and rectus muscle damage following spinal surgery. *Am J Ophthalmol* 2004;**138**(5):889–891
 39. Singer MS, Salim S. Bilateral acute angle-closure glaucoma as a complication of facedown spine surgery. *Spine J* 2010;**10**(9):e7–e9
 40. Ozcan MS, Praetel C, Bhatti MT, Gravenstein N, Mahla ME, Seubert CN. The effect of body inclination during prone positioning on intraocular pressure in awake volunteers: a comparison of two operating tables. *Anesth Analg* 2004;**99**(4):1152–1158
 41. Tempelhoff R. An optic nerve at risk and a prolonged surgery in the prone position: time to reconsider? *Anesthesiology* 2008; **108**(5):775–776

42. Chang S, Miller NR. The incidence of vision loss due to perioperative ischemic optic neuropathy associated with spine surgery. *Spine* 2005;**30**(11):1299–1302
43. Kamming D, Clarke S. Postoperative visual loss following prone spinal surgery. *Br J Anaesth* 2005;**95**(2):257–269
44. Ho VTG, Newman NJ, Song S, Ksiazek S, Roth S. Ischemic optic neuropathy following spine surgery. *J Neurosurg Anesthesiol* 2005;**17**(1):38–44
45. Yu HD, Chou AH, Yang MW, Chang CJ. An analysis of perioperative eye injuries after nonocular surgery. *Acta Anaesthesiol Taiwan* 2010;**48**(3):122–129
46. Nakra D, Bala I, Pratap M, Kaur H. Unilateral postoperative visual loss due to central retinal artery occlusion following cervical spine surgery in prone position. *Pediatric Anesthesia* 2007;**17**(8):805–808
47. Sherman CE, Rose PS, Pierce LL, Yaszemski MJ, Sim FH. Prospective assessment of patient morbidity from prone sacral positioning. *J Neurosurg Spine* 2012;**16**(1):51–56
48. Zimmerer S, Kockler M, Turtzsch S, Palmowski-Wolfe A, Girard T. Amaurosis after spine surgery: survey of the literature discussion of one case. *Eur Spine J* 2011;**20**(2):171–176
49. Dumont TM, Stockwell DW, Horgan MA. Venous air embolism: an unusual complication of atlantoaxial arthrodesis. *Spine* 2010;**35**(22):E1238–1240
50. Asok T, Aziz S, Faisal HA, Tan AK, Mallika PS. Central retinal artery occlusion and ophthalmoplegia following spinal surgery in the prone position. *Med J Malaysia* 2009;**64**(4):323–324
51. Woodruff C, English M, Zoouter, Hemmerling TM. Postoperative visual loss after plastic surgery: case report and a novel continuous real-time video monitoring system for the eyes during prone surgery. *Br J Anaesth* 2011;**106**(1):149–151
52. Demoitie PHJ, Collignon L, Bex V, Bonbomme V. Acute bilateral submandibular swelling following surgery in prone position. *J Anaesthesiol* 2006;**23**(1):80–87
53. Sinha A, Agarwal A, Atul G, Pandey CK. Oropharyngeal swelling and macroglossia after cervical spine surgery in the prone position. *J Neurosurg Anesthesiol* 2001;**13**(3):237–239
54. Raphael J, Rosenthal-Ganon T, Gozal Y. Emergency airway management with a laryngeal mask airway in a patient placed in the prone position. *J Clin Anesth* 2004;**16**(7):560–561
55. Jarral OA, Purkayastha A, Athanasiou T, Darzi A, Hanna GB, Zacharakis E. Thoracoscopic esophagectomy in the prone position. *Surg Endoscopy* 2012;**26**(8):2095–2103
56. Yano T, Imaizumi T, Uneda C, Nakayama R. Lower intracuff pressure of laryngeal mask airway in the lateral and prone positions compared with that in the supine position. *J Anesth* 2008;**22**(3):312–316