Anesthesia for Glaucoma Surgery

VV Jaichandran
Consultant Anesthesiologists, Department of Anesthesia, Sankara Nethralaya, Chennai, Tamil Nadu, India

Correspondence: VV Jaichandran, Postgraduate Diploma in Biostatistics, Consultant Anesthesiologists, Medical Research Foundation, Sankara Nethralaya, 41/18, College Road, Nungambakkam, Chennai-600006, Tamil Nadu, India
Phone: +91-44-28271616, Fax: +91-44-28254180, e-mail: jaichand1971@yahoo.com

ABSTRACT
In this review article, the anesthetic challenges and management of patient posted for glaucoma surgery are discussed. The various physiological and pharmacological factors that influence the level of intraocular pressure in the perioperative period are highlighted. The syndromes of anesthetic implications in childhood glaucoma, the systemic effects of topical antiglaucoma medications, preparation of the patient for surgery beginning from the history taking to investigations required, different techniques practiced for regional and topical anesthesia with their pros and cons, the effect of general anesthetic drugs and maneuvers on intraocular pressure and the postoperative pain management strategies were reviewed in detail in this article.

Keywords: Anesthesia, General, Glaucoma, Regional anesthesia, Intraocular pressure.

INTRODUCTION
Patients in whom the medical management fails to control glaucoma, are planned for surgery. Peroperatively in such cases, it is important to prevent any pressure rise before a surgical incision is made. It is the role of the anesthetist to ensure that IOP is maintained at a low-normal level before a surgical incision is made. Adverse anesthetic practice or inappropriate administration of anesthetic drugs may cause deleterious rise in IOP, which can cause permanent damage to the eye. Hence, it is vital for clinician to know about the physiological and pharmacological factors that influence the IOP during a perioperative period.

FACTORS INFLUENCING INTRAOCULAR PRESSURE
The three main physiological factors affecting IOP during surgery are:1

Aqueous Humor Fluid Dynamics
The major controlling influence on IOP is the dynamic balance between aqueous humor production and its drainage from the eye.

The physiological factor and pharmacological agents, which influence IOP through aqueous humor production mechanism are:

a. Drugs: Acetazolamide (by inhibiting carbonic anhydrase), drugs with sympathetic and parasympathetic effects, beta blockers, anesthetic drugs (Thiopental sodium),2 etc.

b. Systemic arterial pressure: It is speculated that increased blood pressure leads to increased ciliary artery pressure, increasing the ultrafiltration component of aqueous humor formation and thus increasing IOP and vice versa occurs with decreased arterial pressure.3

The physiological factor and pharmacological agents, which influence IOP through aqueous humor drainage mechanism are:

a. Drugs: Miotics, mydriatics, glaucoma medications and anesthetic drugs like thiopental sodium.

b. External compression: Digital ocular compression decreases IOP by increasing aqueous outflow facility.2

Blood Volume in the Eye
The choroidal blood volume depends on a balance between the rate of arterial blood inflow to and the rate of venous blood outflow from the eye. Apart from this, the baseline intraocular blood volume depends on the tone of the intraocular blood vessels.

a. Effect of change of systemic arterial pressure on IOP: The choiociapillaries has the ability to locally autoregulate and thus only a poor correlation exists between changes in systemic arterial pressure and IOP. The choroidal blood flow remains constant through a range of perfusion pressures. A sudden increase in systolic blood pressure produces a transient acute rise in IOP. Moderate decrease in arterial pressure has little effect on IOP, but below mean pressure of 90 mmHg marked reductions in IOP occur.

b. Effect of change in venous pressure on IOP: Normally, the aqueous venous pressure (15 mmHg) inside the globe is higher than the episcleral venous pressure (10 mmHg) outside the globe. This pressure gradient helps in draining the choroidal venous plexuses in the eye. If episcleral venous pressure increases due to obstruction of the central venous return occurs then the above pressure gradient falls and blood pools within the orbit.


49
Causes for Increased Central Venous Pressure

The following factors can cause an increase in central venous pressure:

- Anxiety
- Bladder fullness
- Cough
- Vomiting
- Straining
- Restlessness.

Under local anesthesia (remember the mnemonics “ABC VSR”).

- Airway obstruction
- Bucking on ETT
- Cough
- ETT secured with tape too tightly
- Face mask held during preoxygenation
- Retching.

Under general anesthesia (Remember the mnemonics “ABC EFR”).

- Airway obstruction
- Bucking on ETT
- Cough
- ETT secured with tape too tightly
- Face mask held during preoxygenation
- Retching.

c. Intraocular vascular tone and IOP: Intraocular vascular tone is predominantly affected by PaCO₂, PaO₂, metabolic pH and body temperature (Table 1).¹

<table>
<thead>
<tr>
<th>Syndromes</th>
<th>Anesthetic problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apert’s</td>
<td>Difficult intubation, cardiac anomalies</td>
</tr>
<tr>
<td>Goldenhar’s</td>
<td>Difficult intubation, congenital heart disease</td>
</tr>
<tr>
<td>Homocystinuria</td>
<td>Skeletal and cardiac anomalies, coagulation defects, hypoglycemia</td>
</tr>
<tr>
<td>Lowe’s</td>
<td>Severe mental retardation, hypotonia, renal tubular dysfunction</td>
</tr>
<tr>
<td>Marfan’s</td>
<td>Skeletal anomalies, cardiac anomalies</td>
</tr>
<tr>
<td>Sturge-Weber</td>
<td>Mental retardation, seizures, airway angiomata</td>
</tr>
</tbody>
</table>

Extraocular Muscle Tone and Vitreous Volume

The central nervous system was found to influence IOP directly through neurogenic control of extraocular muscle tone from central diencephalic control centers and indirectly through hormonal and hemodynamic effects. IOP increased markedly following contraction of the extraocular muscle. General anesthetic drugs decreased IOP partly by depressing the neurogenic centers.

The vitreous is an unstable gel consisting mainly of water, whose volume can be radically altered by changing the osmolarity of the blood reaching it. Thus, acute reduction in IOP can be achieved by infusing 20% Mannitol 1.5 gm/kg IV.

PREOPERATIVE ASSESSMENT AND PREPARATION

Eighty percent of cases of congenital glaucoma are inherited in an autosomal recessive pattern and 75% are bilateral. Infantile glaucoma occurs at any time from birth to 5 years and the juvenile type from 6 to 30 years. Childhood glaucoma may also be associated with various syndromes involving other systems in the body and it is important for the anesthetist to be aware of these conditions and, hence examine the child accordingly (Table 2).

History and Examination

It is important to identify medical problems that significantly increase the risk of anesthesia by taking a complete history and thorough clinical examination of the patient. A specific enquiry about bleeding disorders or the use of anticoagulant medication is mandatory. Also, the anesthetist has to know or find out from the patient, his/her current drug regimen followed for glaucoma, since most of these topical drugs have adverse systemic effects (Table 3).

### Table 1: Effect of PaCO₂, PaO₂, metabolic pH and body temperature on IOP

<table>
<thead>
<tr>
<th>Intraocular pressure</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increases</td>
<td>Respiratory acidosis, metabolic alkalosis, hypoxemia, and hyperthermia</td>
</tr>
<tr>
<td>Decreases</td>
<td>Respiratory alkalosis, metabolic acidosis, hyperbaric oxygen and hyperthermia</td>
</tr>
</tbody>
</table>

### Table 2: Glaucoma and associated conditions: Anesthetic implications

<table>
<thead>
<tr>
<th>Syndromes</th>
<th>Anesthetic problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apert’s</td>
<td>Difficult intubation, cardiac anomalies</td>
</tr>
<tr>
<td>Goldenhar’s</td>
<td>Difficult intubation, congenital heart disease</td>
</tr>
<tr>
<td>Homocystinuria</td>
<td>Skeletal and cardiac anomalies, coagulation defects, hypoglycemia</td>
</tr>
<tr>
<td>Lowe’s</td>
<td>Severe mental retardation, hypotonia, renal tubular dysfunction</td>
</tr>
<tr>
<td>Marfan’s</td>
<td>Skeletal anomalies, cardiac anomalies</td>
</tr>
<tr>
<td>Sturge-Weber</td>
<td>Mental retardation, seizures, airway angiomata</td>
</tr>
</tbody>
</table>

### Table 3: Systemic effects of topical antiglaucoma medications used by patients regularly

<table>
<thead>
<tr>
<th>Topical drugs</th>
<th>Systemic effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>β-adrenergic antagonists</td>
<td>CNS: Light headedness, fatigue, disorientation and may show a general depression of central function</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>CVS: Hypertension, tachycardia, dysrhythmias and fainting</td>
</tr>
<tr>
<td>Apraclonidine α₂-adrenoceptor agonists</td>
<td>Significant sedation and drowsiness, hypotension is a possible complication, however acute withdrawal may result in rebound hypertension</td>
</tr>
<tr>
<td>Echotothiopate Iodide</td>
<td>Prolonged action of neuromuscular junction blockers broken down by pseudocholinesterases Example: Succinylcholine</td>
</tr>
<tr>
<td>Acetazolamide</td>
<td>Metabolic acidosis with depletion of sodium and potassium, dyspepsia may produce acute decrease in blood pressure</td>
</tr>
</tbody>
</table>
Investigations

Certain basic investigations should be carried out as a routine on all patients and to let clinical judgement guide the need for more extensive investigations. Blood sugar estimation and routine urine examination will help to identify most of the patients having an undiagnosed systemic condition requiring attention prior to surgery. More specific investigations may be required in patients, who have a positive risk factor identified in the history or when general anesthesia is being contemplated.

Preparation of Patients

Preoperative optimization of medical conditions (control of blood sugar, blood pressure, etc.) is required before patients could be taken up for planned surgery. Drug treatment should be continued in most patient especially cardiac drugs, antihypertensives, bronchodilators and corticosteroids.

Patients on Anticoagulants and Antiplatelet Medications

In a previous retrospective study, increased incidence of hyphema was found in patients taking aspirin but it did not appeared to affect surgical outcome. Perioperative anticoagulation and high preoperative intraocular pressure are potential risk factors for hemorrhagic complications in patients undergoing glaucoma surgery. Warfarinised patients were found to be at risk of serious hemorrhagic complications compromising surgical success. Thus, it is safe to continue aspirin but those on warfarin international normalized ratio (INR) must be checked close to the time of surgery, ideally on the same day and the level should be within the recommended therapeutic ratio, which is determined by the condition for which the patient is being anticoagulated.

Perioperative Reduction of IOP

20% Mannitol 1 to 2 gm/kg IV. Its onset of action is within 20 to 60 minutes. It acts by reducing the volume of vitreous. The mechanism of vitreous shrinkage is commonly considered to result from an osmotic gradient between the blood and ocular tissues, which initially pull fluid from the eye. The other hypothesis is that the osmotic agents exert their influence on IOP through the central nervous system, possibly originating in the hypothalamus and mediated by efferent fibers in the optic nerve. A suggested mechanism of action is by reducing the production of aqueous humor.

Adverse effects of Mannitol: Fluid and electrolyte imbalances are the most severe adverse effects generally encountered during mannitol therapy. Other adverse effects that may be encountered include GI (nausea, vomiting), cardiovascular (pulmonary edema, CHF, tachycardia), and CNS effects (dizziness, headache, etc.).

Scope of Surgery and Implications

Measurement of IOP under GA Examination using Face Masks

Reliable and accurate IOP measurements are needed for the diagnosis and management of glaucoma and in the determination of optimum treatment. In pediatric age group and mentally challenged patients, IOP measurement is usually done under general anesthesia with face mask using oxygen, nitrous oxide and volatile agent (Sevoflurane). The anesthetist must be familiar with the factors that influence intraocular pressure under these conditions. The facemask may produce pressure on the eye when tightly applied and may increase IOP and also limits the access to the eye. The anesthetic agents influence intraocular pressure as does the level of anesthesia. The best time point to measure IOP in children receiving sevoflurane is just before arousal, when the child is still quiet, sevoflurane is almost fully eliminated and the BIS is reading light anesthesia.

Regional Anesthesia for Glaucoma Surgery

For glaucomatous patients, anesthetic technique that has a low risk of causing further damage to the optic nerve must be chosen as a technique of choice for surgery. In regional anesthesia as soon as the local anesthetic is injected into the space outside the muscle cone confined by the bony walls of the orbit, the intraorbital pressure increases. This pressure rise is in turn transmitted to the globe and thus IOP tends to increase. The degree of IOP elevation depends on the following: volume of local anesthetic injected, tightness of the orbital septae and type of local anesthetic used. Lowest IOP elevation induced by bupivacaine, more marked effect with lidocaine and highest elevation after mepivacaine injection.

In peribulbar anesthesia much larger volume of local anesthetic is required, as it has to diffuse through the orbital connective tissue septa and the muscle cone to block the motor and sensory nerves in the eye. Larger drug volume in turn raises the IOP to a greater extent compared with retrobulbar technique, where relatively less volume of the drug is required, as they were injected directly inside the muscle cone. There is a large and individual variable rise in IOP following peribulbar block.

Glaucma patients may be at increased risk of sight-threatening complications from orbital injections because the optic nerve is already compromised and vulnerable to pressure ischemic damage. This damage could occur as a result of direct trauma from a retrobulbar needle or peribulbar needle, pressure on the nerve, or ischemia. For patients, whose optic nerve is already damaged by glaucoma, this could result in further loss of vision. The phenomenon of severe visual loss after surgery, with no obvious cause, is known as “wipe-out” or “snuff syndrome.” The problems described above could potentially occur with retrobulbar, peribulbar or posterior sub-Tenon’s regional block. Surgery for glaucoma is done on the anterior part of the globe and of late, many surgeons prefer to avoid putting any local anesthetic near to the optic nerve and they tend to prefer subconjunctival, sub-Tenon’s or topical anesthesia as in these techniques only the surgical area is anesthetized.

Ritch and Liebmann were among the earliest to describe sub-Tenon’s technique using 1 ml of 2% lidocaine or 2%...
mepivacaine for glaucoma surgery. Also on prospective randomized comparison of sub-Tenon’s versus retrobulbar and peribulbar anesthesia, it was found that sub-Tenon’s technique was well-tolerated and no significant differences in pain score were obtained both during and after surgery among these groups. Sub-Tenon’s block does not cause significant increase in IOP. Reduction in IOP was found to occur three minutes after sub-Tenon’s injection, possibly due to reduction in muscle tone. However, sub-Tenon’s/sub-conjunctival anesthesia is still a form of ‘injection anesthesia’ with chemosis and undesirable subconjunctival hemorrhage, which could hinder surgery and is a potential risk factor for filtration failure. A potential advantage of sub-Tenon’s anesthesia, in the cases of reoperation, where the infiltration of anesthetic fluid separates Tenon’s capsule and conjunctiva from episclera, thus allowing the surgeon to check for conjunctival mobility when choosing a site for surgery. Sub-Tenon’s block might not be feasible or sometimes impossible due to scarring, especially following multiple repeat surgeries and in such cases topical anesthesia might be a better and safer choice to proceed.

Topical techniques include local anesthesia (LA) drops alone, application of LA gel, or via an applicator made of sponge like material soaked in 2% lidocaine solution. Ahmed and colleagues conducted randomized trial of topical bupivacaine drops vs retrobulbar anesthesia for glaucoma surgery. They felt that both techniques were similarly well tolerated by patients. Among LA gel technique, topical 2% lidocaine gel was found to be as effective as the sub-Tenon’s technique. A recent retrospective result of a long-term (4-year period) follow up of trabeculectomy surgery with subconjunctival anesthesia vs topical lidocaine 2% jelly, has shown that both these techniques do not seem to influence the outcome of surgery. Pablo and colleagues described a modified technique of topical anesthesia (i.e. contact anesthesia) for trabeculectomy. A cellulose sponge soaked in 2% lidocaine was inserted into the superior fornix for 5 minutes before surgery and this technique was compared with peribulbar anesthesia in a randomized trial of 100 cases. Pain scores and the use of sedation were similarly low in both groups.

Lidocaine 2% gel has also been used for implantation of glaucoma drainage devices. This technique compared with retrobulbar anesthesia was found to offer a reasonably safe and comfortable surgical environment for experienced surgeons and selected patients. In an prospective randomized trial, technique referred to as “blitz” anesthesia, involved topical bupivacaine or mepivacaine, 1% lidocaine and a sub-Tenon’s injection of 1% lidocaine was found to be “a safe and effective alternative to retrobulbar anesthesia” for glaucoma surgery.

Though different modalities of anesthesia have been described for glaucoma, each technique has its own advantages and disadvantages (Table 4). The choice among them has to be done according to various parameters based on both patient and surgeon point of view. A close link between surgeon and anesthesiologist is of utmost importance to ensure the most efficient, comfortable, and appropriate anesthesia for each individual patient.

**General Anesthesia for Glaucoma Surgery**

General anesthesia is indicated for glaucoma surgery in the following patients:

**Indications for General Anesthesia**

Decreasing order of significance:

- All pediatric age group patients
- Patient refusal for LA
- Allergy to local anesthetic agent
- Mentally challenged patients
- Patients with behavioral or psychiatric disorder, agitated or phobic patient
- Constant head movements due to parkinson’s disease, dystonia, tremors, etc
- Very anxious and uncooperative patients
- Senile dementia
- Coagulation defect
- Intractable cough
- Communication difficulties due to language barrier or deafness
- High myopic eye
- Blind in the nonoperated eye.

**Effect of Drugs used in General Anesthesia**

- Drugs used for premedication
- No changes in IOP
- Induction agents
- All induction agents (except ketamine), opioids and volatile agents cause a decrease in IOP.

**Neuromuscular Blocking Agents**

Depolarizing muscle relaxant: Succinylcholine was found to increase IOP within 1 minute after IV administration, reached a peak at 2 to 4 minutes and subsided within the sixth minute. The cause for the rise in IOP has been ascribed to the “tonic” contraction of the extraocular muscles. Section of the recti muscles failed to prevent the rise in IOP following succinylcholine administration. The other possible mechanism postulated for the increase in IOP was contraction of the orbital smooth muscle, effect on choroidal blood volume or influence on aqueous humor formation or drainage.

Nondeparising muscle relaxants: Atracurium and vecuronium have been shown to produce little change or to reduce IOP, principally due to their paralyzing effect of extraocular muscles.

**Effect of Anesthetic Maneuvers on IOP**

Laryngoscopy and intubation: IOP has been found to increase following laryngoscopy and tracheal intubation secondary to
increased sympathetic activity. Adrenergic stimulation by causing vaso and venoconstriction increases central venous pressure and also increases the resistance to outflow of aqueous humor in the trabecular meshwork.

Laryngeal mask insertion: Insertion of LMA provokes less sympathetic response and catecholamine release because it requires neither the visualization of cords nor the penetration into the larynx. Due to this diminished stress response, the mean maximum increase in IOP was significantly higher in patients after endotracheal intubation compared with LMA insertion.

Spontaneous or controlled ventilation: A deep level of anesthesia is needed during spontaneous ventilation to prevent the patient form bucking on the ETT. The subsequent hypotension and hypercapnia, which can occur in turn can produce adverse effects on visual outcome following eye surgery. Though IPPV produces a small increase in venous pressure secondary to increase in the mean intrathoracic pressure, it is generally preferred to control ventilation because of the better control of PaCO₂.

Exsufflation: Emergence from general anesthesia is often associated with straining/bucking on an ETT, coughing, restlessness and breath holding. Tracheal extubation, thus causes a marked rise in IOP. Cough could increase the IOP upto 50 mmHg. The Valsalva effect produced by coughing can lead to vessel wall rupture due to a sudden increase in venous pressure resulting in suprachoroidal hemorrhage (SCH), a serious complication following eye surgery. Cases of delayed nonexpulsive type of SCH have been reported after trabeculectomy following straining and bucking at the time of extubation.

Intravenous and prior topical administration of lidocaine have been used to help diminish cough during emergence from general anesthesia. Recently, studies have shown that smooth emergence from general anesthesia can be obtained by filling the ETT cuff with buffered lidocaine. The cough receptors in the tracheal mucosa are blocked by the nonionized form of the drug, which diffuses across the hydrophobic polyvinyl chloride walls of the ETT cuff.

POSTOPERATIVE CARE

**Postoperative Nausea and Vomiting (PONV)**

Adverse ocular effects of PONV are rupture of suture, loss of vitreous, iris prolapse and intraocular hemorrhage. PONV is managed by use of Inj.ondansteron 0.1 to 0.15 mg/kg (maximum 8 mg) and dexamethasone 200 to 300 µg/kg (maximum 8 mg) IV before the end of surgery. Local infiltration of the surgical site with 0.5% Bupivacaine helps to decrease PONV as well as postoperative pain. It is important to stress that a patient with persistent vomiting along with severe eye pain and headache, then a raise in the IOP level must be excluded by the surgeon.
settled with simple analgesics like Paracetamol and NSAID. But following laser and cyclophotocoagulation procedures moderate—severe intensity of pain could occur in the eye. NSAID as a sole analgesic agent may not be effective and it should be combined with an opioid (multimodal approach). It is always a good clinical practice to give a sub-Tenon’s injection with local anesthetic just before the closure of conjunctiva is preceded. Pre-emptive analgesia with Inj. Ketorolac IM helps in decreasing not only the pain in the eye following surgery but also the incidence and severity of postoperative nausea and vomiting (PONV). Ketorolac, a potent NSAID, 30 mg of which is equivalent to 10 mg morphine, if given by intramuscular injection. It has relatively slow onset of action, taking over 30 minutes to take effect, but has a long duration of action with a half-life of over 7 hours. In children, it can be administered at a dose of 0.5 to 0.75 mg/kg IV or IM.

**SUMMARY**

The main intent of this article was to shed light on important issues in anesthesia for patients planned for glaucoma surgery. A timely and detailed history and physical examination, identifying associated comorbidities and syndromes with indicated diagnostic tests generally ensures a safe anesthetic course.

We reviewed the systemic effects of topical antiglaucoma medications, preparation of the patient for surgery, different techniques practiced for regional anesthesia with their pros and cons, the effect of general anesthetic drugs and maneuvers on IOP and the postoperative pain management strategies.

Though there are many physiological and pharmacological factors that influence the IOP during anesthesia and surgery, it is the technique, and experience of the anesthesiologist practicing ophthalmic anesthesia, the skill of ophthalmologists and team work that determine the visual outcome of surgery for glaucoma.

**REFERENCES**

3. Harry Murgatroyd, Jane Bembridge. Intraocular pressure. Continuing Education in Anaesthesia, Critical Care and Pain 2008(3);100-03.