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REVIEW

Anesthesia for ophthalmic surgery

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Abstract

Local and regional anesthesia are commonly employed methods in eye surgery, there are situations in which general anesthesia becomes necessary. Some patients may decline local or regional anesthesia, be unable to maintain a steady position, or lie flat during the procedure. This is particularly pertinent for pediatric patients and individuals with allergies to local anesthetics, who may require general anesthesia. In all cases, meticulous patient preparation is paramount in eye surgery. A thorough evaluation is essential before administering anesthesia, with the choice of anesthesia method dependent on factors such as the patient's overall health, the specific surgical procedure, and the surgeon's expertise. In this review, necessary anesthesia methods in ophthalmic surgeries and perioperative patient management will be discussed.

Keywords: Anesthesia; eye surgery; general anesthesia; ophthalmic; regional block.

The objectives of the anesthetic approach for elective ophthalmologic surgeries is to achieve painless surgical procedures, facilitate quick recovery, and minimize complications associated with anesthesia and surgery. The most commonly performed ophthalmologic surgeries include cataracts, glaucoma, strabismus, and vitreoretinal surgery.

In glaucoma surgery, it is crucial that intravenous and volatile anesthetics do not contribute to increased intraocular pressure (IOP). In vitreoretinal surgery, general anesthesia may be preferable to local anesthesia due to specific patient characteristics.[1-3]

This review evaluates analgesia, sedation, and anesthesia methods for cataracts, strabismus, glaucoma, and vitreoretinal surgery.

Anatomy and Physiology

Understanding the anatomical features of the orbit is critical to administering regional anesthesia and achieving ocular immobility. The ophthalmic nerve, which is a branch of the trigeminal nerve, provides sensory innervation to the eyeball. Conversely, the control of the extraocular muscles, responsible for the motor innervation of the eye, is carried out by the oculomotor, trochlear, and abducens nerves.[4] It is worth noting that, except for the trochlear nerve, all these nerves pass through the muscular cone of the eye. Therefore, injecting a local anesthetic into this region will induce akinesia of the eyeball by blocking both sensory and motor innervation. However, there is a risk of inadvertent puncture of the optic nerve and orbital vessels due to their close proximity during this procedure.[4]

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IOP refers to the pressure exerted by the contents of the eye on the surrounding structures. Elevated pressure can lead to a reduction in blood flow to critical ocular structures, including the retina, choroid, and optic nerve. Typically, normal IOP is in the range of 16±5 mmHg, with fluctuations of 2–3 mmHg observed throughout the day. Values greater than 24 mm Hg are considered pathologic. [5,6] Any disturbance in the outflow of aqueous humor can lead to a sudden increase in IOP.[2,7]

As one of the most metabolically active organs in the body, the retina depends on the retinal and choroidal circulation for its nutrition. Interestingly, the retinal circulation is an end-arterial system and is influenced by metabolic activity but does not receive autonomic innervation. In contrast, the choroidal circulation supplies a substantial 85% of the retina, providing vital nutrients to the retinal pigment and photoreceptors. The intricate interplay between IOP and mean arterial pressure is pivotal in governing the regulation of both choroidal and retinal circulation.[8]

The vitreous body makes up approximately two-thirds of the volume of the eyeball. It maintains a fixed volume and is primarily composed of water, which makes up approximately 98–99% of its composition. Remarkably, even a minute 0.5 mL injection into the intravitreal space can cause a significant increase in IOP, more than 150% higher compared to the pre-injection levels. Rapid pressure fluctuations like these can pose a significant risk to the perfusion of the retina and optic nerve following surgery, potentially resulting in visual impairment.[9,10] While performing local, regional, or general anesthesia, anesthesiologists or ophthalmologists should be masters of anatomy and physiology.

General Evaluation

Pre-operative Consultations

Perioperative decisions regarding comorbid conditions and chronic medications are included in the study. Surgery should not be postponed because of minor abnormalities in pre-operative tests.

Anesthesia Considerations

Most ophthalmic surgeries are performed using monitored anesthesia care (MAC), along with topical or regional anesthesia techniques. Many ophthalmic surgeons prefer to administer these anesthetic techniques themselves.

Evaluate Communication and Collaboration

When monitored anesthesia care with topical or regional anesthesia is planned, it is important that the patient be able to lie comfortably still during the procedure. Hence, it is crucial to evaluate whether the patient is capable of comprehending instructions and effectively communicating with the medical team to express any discomfort.[11]

Patient History

It is important to focus on issues such as the use of any anticoagulant or antithrombotic treatment, previous ophthalmic surgery, and suitability for outpatient procedures.[12] Although many cataract patients have comorbidities such as obesity, hypertension, diabetes, or chronic obstructive pulmonary disease, there are few reasons to delay surgery. Cataract surgery carries minimal risk because the physiological stress is minimal and there is little risk of bleeding or fluid accumulation. However, surgery should be postponed for the following conditions:[11-13]

a. Myocardial infarction within the last month
b. Recent percutaneous coronary intervention (within 14 days without stents or within 30 days with stents)
c. New onset of clinically significant arrhythmias
d. Decompensated heart failure
e. Presence of a serious pulmonary condition (e.g., upper respiratory tract infection, pneumonia, and pulmonary embolism) or worsening of a serious chronic condition (e.g. COPD)
f. New onset of neurological condition (e.g., stroke, transient ischemic attack, and mental status changes)
g. Malignant hypertension with recent organ damage (e.g., encephalopathy, myocardial ischemia, and acute kidney injury)
h. Recent episode of diabetic ketoacidosis or hyperglycemic hyperosmolar non-ketotic coma.

Physical Examination

A standard physical examination, including the airway, is performed to identify any abnormalities that may interfere with the patient's surgery.

Pre-Operative Tests

There is no benefit to routine testing before local anesthesia for cataract surgery. Tests should only be performed for newly developed or acutely worsened serious medical conditions.[14]

General anesthesia needs routine physical evaluations and tests: Pre-operative tests, including a hemogram, biochemistry panel, and clotting times, should be carefully chosen based

on the patient's medical history, existing health conditions determined through physical examination, and the nature of the planned surgical procedure. Coagulation tests should be specifically requested for surgeries anticipated to involve significant bleeding, although they may not be definitive indicators of clinical bleeding risk. For patients with a history of coronary heart disease, arrhythmia, peripheral artery disease, cerebrovascular disease, or any notable structural heart disease, an electrocardiogram should be performed. In addition, individuals with respiratory issues should undergo PA chest radiography. In cases involving women of childbearing age, it is advisable to consider pregnancy testing as part of the preoperative evaluation to ensure the safety of both the patient and the potential unborn child during surgery.[15]

Routine Medications and Ophthalmic Solutions

The anesthesiologist should be aware of the patient's chronic medications and the effects of chronic ocular solutions. Non-selective beta-adrenoceptor antagonists such as timolol and carteolol may decrease heart rate and increase systemic vascular resistance or decrease the forced expiratory volume in one second (FEV1). Muscarinic agonists such as pilocarpine cause an increase in heart rate or blood pressure. Phenylephrine increases blood pressure, alpha-2 adrenergic agonists (brimonidine or apraclonidine) decrease blood pressure, atropine may cause flushing or drowsiness, and pilocarpine or non-steroidal anti-inflammatory drugs (NSAIDs) may cause bronchospasm (Table 1).[16]

Pre-operative Fasting

Standard fasting periods should be followed for patients receiving general or deep sedation. Patients may consume clear liquids (water, pulp-free fruit juices, black coffee or tea, and carbohydrate-containing beverages) up to 1 h before elective procedures requiring anesthesia or sedation. Breast milk should be discontinued for 3 h, formula for 4 h, and solid foods for 6 h before surgery.

Ophthalmic Considerations

Anticoagulant and Antiplatelet Therapies

In patients at high risk for coagulation and embolic complications due to cardiac or vascular pathology, therapeutic doses of aspirin and warfarin are frequently continued throughout the pre-operative period in cataract surgery.[17]

Dual antiplatelet therapy, which typically includes medications such as aspirin and clopidogrel, is commonly prescribed following the placement of drug-eluting coronary stents. It is essential for patients to consult with a cardiologist before undergoing any surgical procedures. This is because there is a real risk of recurrent cardiac ischemia or stent thrombosis. In cases where non-urgent surgery is planned, it is advisable to delay the procedure for a minimum of 30 days after the placement of bare-metal stents and ideally for 6 months following drug-eluting stent placement. However, in situations where urgent surgery is necessary, and there is a significant risk of bleeding, it is recommended to continue aspirin therapy if feasible and discontinue clopidogrel before the surgery. Clopidogrel should then be resumed as soon as possible after the surgical intervention.[18]

There are no pharmacological agents that can reverse the antiplatelet effects of agents that irreversibly inhibit platelet function, such as aspirin, clopidogrel, or ticlopidine. Platelet transfusion can be administered to patients who require urgent surgical intervention and whose platelet functions need to be normalized.[19]

Warfarin's estimated half-life is 36 h, necessitating discontinuation 5 days before surgery. On the day of

Table 1. Common ophthalmologic medications and their side effects

Eye drop	Use	Systemic effects
Timolol, Betaxolol (Beta blockers)	Reduce IOP	Bradycardia, arrhythmia, bronchospasm
Acetazolamide, Brinzolamide (Carbonic anhydrase inhibitors)	Reduce IOP	Metabolic acidosis, electrolyte abnormalities, allergies, nausea
Cyclopentolate, Atropine (Antimuscarinics)	Mydriasis	Dry mucous membranes, tachycardia, nausea, and vomiting
Phenylephrine (Sympathomimetic)	Mydriasis	Tachycardia, hypertension
Diclofenac sodium, Ketorolac (NSAIDs)	Analgesia and anti-inflammatory	Gastrointestinal upset, bronchospasm
Tetracaine, Oxybuprocaine, Proxymetacaine (Local anesthetics)	Pain relief or prevention	Local anesthetic toxicity
Latanoprost (Prostaglandin analogues)	Reduce IOP	Bronchospasm, increase pigmentation iris/eyelashes/eyelids

surgery, the INR should be monitored to ensure proper hemostasis. Given that warfarin's effects onset gradually, if hemostasis is deemed satisfactory, it may be resumed either on the evening of surgery or the following day.[20] In patients receiving pre-operative bridging therapy with low molecular weight heparin, the last dose should be administered at least 24 h before surgery. It recommends halving the final dose if a high risk of bleeding is expected.[21] In patients undergoing high-bleeding-risk surgery, bridging is not initiated until at least 48 hours after surgery.[20,21] Indications for the administration of bridging anticoagulation are summarized in Table 2.[22]

There is apprehension regarding an elevated risk of bleeding in patients using newer oral anticoagulants such as apixaban, rivaroxaban, edoxaban, and dabigatran. However, it has been shown that the use of these agents in the pre-operative period does not lead to an increased incidence of bleeding complications in cataract surgery.[23] For these patients, the timing of surgery should be decided with the risk of bleeding and thrombosis in mind, involving the ophthalmologist, anesthesiologist, prescribing physician (often a cardiologist or neurologist), and the patient.[23] The perioperative management of ophthalmic patients on anticoagulants and antiplatelet agents is detailed in Table 3.

Axial Length of the Eye

The distance from the cornea to the retina, known as the axial length of the eye, is typically measured using ultrasound before cataract surgery. This measurement is used to determine the appropriate size of intraocular lens to be implanted. Increased risk of needle injury during retrobulbar block in patients with axial length >25 mm.[24] In such patients, peribulbar (extraconal) or sub-Tenon's block, topical anesthesia, or general anesthesia are preferred over retrobulbar block.

Position

During surgery, ensuring the patient's comfort and minimizing potential complications is a collaborative effort between the anesthesiologist and surgeon. For eye surgery, specific considerations are vital:[25]

- To avoid back and neck discomfort, position the patient's head at the upper end of the operating table.
- To minimize unintended movement, provide adequate support for the patient's head using a comfortable headrest.
- To reduce the risk of intraoperative bleeding and

Table 2. Indications for bridging anticoagulation*

Mechanical Heart Valves		
High risk	• Stroke or TIA within 6 months • All mitral and aortic valves	Bridging strongly recommended
Moderate risk	• Disc aortic valve and one/more stroke risk factors	Bridging should be considered
Low risk	• Disc aortic valve without risk	Bridging optional
Stroke risk factors: AF, previous stroke/TIA, congestive heart failure/reduced left ventricular ejection fraction, age >75 years, hypertension, diabetes mellitus		
Atrial Fibrillation		
High risk	• Recent stroke/TIA (within 3 months) • Rheumatic heart disease • CHADS 5 or 6	Bridging strongly recommended
Moderate risk	• CHADS 3 or 4	Bridging should be considered
Low risk	CHADS score 0-2 (and no prior stroke/TIA)	Bridging rarely necessary
CHADS score: Congestive heart failure/LV dysfunction (1), Hypertension (1), Age >75 years (1), Diabetes Mellitus (1), previous stroke/TIA (2)		
Venous Thromboembolism		
High risk	VTE (within 3 months) Severe thrombophilia	Bridging strongly recommended
Moderate risk	VTE within the past 3–12 months • Non-severe thrombophilic conditions • Recurrent VTE • Active cancer	Bridging should be considered
Low risk	Single VTE more than 12 months and no other risk factors	Bridging rarely necessary
High risk: >10% per year risk of arterial thromboembolism or > 10% per month risk of venous thromboembolism		
Moderate risk: 4–10% per year risk of arterial thromboembolism or 4–10% per month risk of venous thromboembolism		
Low risk: <4% per year risk of arterial thromboembolism or <4% per month risk of venous thromboembolism		

*The table is used with permission from Dr. Makuloluwa.

Table 3. Recommended pathway for perioperative management of ophthalmic patients using anticoagulants and antiplatelets agents***

Low-risk surgery			**High-risk surgery**		
• Sub-Tenon/topical cataract surgery • Corneal surgery • Oculoplastic: Chalazion, eyelid cyst/lesion removal • Strabismus			• Peri/retro-bulbar anesthesia • Glaucoma surgery • Vitreorenal surgery (PPV) • Vitreorenal surgery (oncology: endoresecon, a biopsy of intraocular tumors, plaques/markers • Oculoplastic: blepharoplasty, post-septal eyelid surgery • Temporal artery biopsy		
Antiplatelets	**Anticoagulants**		**Antiplatelets**	**Anticoagulants**	
	Warfarin	**DOACs****		**Warfarin**	**DOACs**
Continue	Check INR on day of surgery and continue if within therapeutic range.	Omit dose 2 days pre-operatively and re-start 1–2 days post operatively if adequate hemostasis achieved.	Aspirin/clopidogrel: stop 7 days preoperatively, continue in high risk. Prasugrel: stop 7 days preoperatively* Ticagrelor: stop 5 days preoperatively*	If low risk (e.g. non-valvular atrial fibrillation): stop 2 days pre-operatively, check INR on day of surgery, and continue if <2. Re-start on evening of surgery. If high risk: discuss with a physician.	Omit dose 2 days pre-operatively and re-start 1-2 days post operatively if adequate hemostasis achieved.

*only stop if after a high thrombosis risk period or liaise with a cardiologist if uncertain; >12 months after insertion of drug-eluting coronary stent; >1 month after insertion of bare metal coronary stent; **Depends on renal function; *** The table is used with permission from Dr. Makuloluwa.

elevated venous pressure within the eye, maintain the head at or above the heart level.

- For added stability and to prevent unexpected movements, securing the patient's head to the operating table with tape may be considered.
- Utilize arm boards or secure the patient's arms by their side to prevent sudden arm movements.
- Take precautions to minimize the accumulation of oxygen (O_2) beneath the surgical drapes.

Sedation

Sedation is carefully administered at the minimal effective dosage to ensure the patient's ability to cooperate during surgery is eliminated while minimizing the risk of potential side effects such as agitation, confusion, unresponsiveness, or airway obstruction. Maintaining the patient's co-operation throughout the procedure is crucial to prevent any unintended head movements.

In the event that the patient experiences post-operative pain, two options are available. First, additional local anesthesia may be administered to effectively manage discomfort. Alternatively, if necessary, transitioning to general anesthesia should be advised instead of deep sedation, prioritizing the patient's comfort and safety during the surgical procedure. The choice between these options should be determined by the individual patient's requirements and the specific surgical context.

Oxygen Therapy

During surgery, inspired oxygen may be administered below ≤30%. If a higher oxygen concentration is required, the surgeon should be advised that electrocautery cannot be used.

Post-operative Management

Patients are instructed not to drive, operate machinery, or consume alcohol until at least one day after surgery or until the effects of sedation have worn off, the eye patch has been removed, and vision has returned to or improved.

Anesthesia Techniques

Topical Anesthesia

Topical anesthesia is a good choice for short and uncomplicated cases that do not require complete akinesia or control of IOP. It can be achieved with eye drops (0.5% proparacaine, 0.5% tetracaine), gel application (3.5% lidocaine), or anesthetic-soaked

sponges. However, proper patient selection is critical because the patient must remain still throughout the procedure. Patients with low pain thresholds and high anxiety levels should be considered for regional or general anesthesia.[26]

Regional Anesthesia

Successful regional anesthesia provides deep anesthesia and akinesia of the eye. Standard monitoring should be used during the regional block, as rare complications such as oculocardiac reflex (OCR) (bradycardia or asystole), intravascular injection (systemic toxicity), or central nervous system injection (affecting the brainstem) may occur and require immediate intervention.[27]

Midazolam may be used for sedation, and low-dose remifentanil may be administered immediately before regional block to reduce anxiety and minimize or eliminate pain during needle insertion and local anesthetic injection. An alternative technique is to administer low doses of propofol to the patient during the block. Supplemental oxygen (O_2) is provided during sedation for the block because of the risk of hypoxemia. Long-acting agents should be avoided because the procedure requires the patient to be awake and cooperative.

The most commonly used combination is lidocaine (2%) and bupivacaine (0.75%). Some studies have reported that ropivacaine (0.75%) results in less pain during injection, excellent intraoperative akinesia, and effective postoperative pain control (Table 4).[28-31] Hyaluronidase enzyme can be added to local anesthetics at concentrations ranging from 1 to 7.5 units/mL as an adjuvant.[32]

The routinely used regional blocks in ophthalmic surgery are summarized below and in Figure 1.[33]

Table 4. Local anesthetic agents

Anesthetic agent	Maximum anesthetic per dose
Tetracaine	1–3 mg/kg
Tetracaine+Epinephrine	1.5 mg/kg
Lidocaine	4.5 mg/kg
Lidocaine+Epinephrine	7 mg/kg
Bupivacaine	2.5 mg/kg
Bupivacaine + Epinephrine	3 mg/kg
Levobupivacaine	2 mg/kg
Levobupivacaine+Epinephrine	3 mg/kg
Ropivacaine	2-3 mg/kg
Ropivacaine+Epinephrine	3-4 mg/kg
Articaine	7 mg/kg
Mepivacaine	4.5-5 mg/kg
Mepivacaine+Epinephrine	6.6 mg/kg

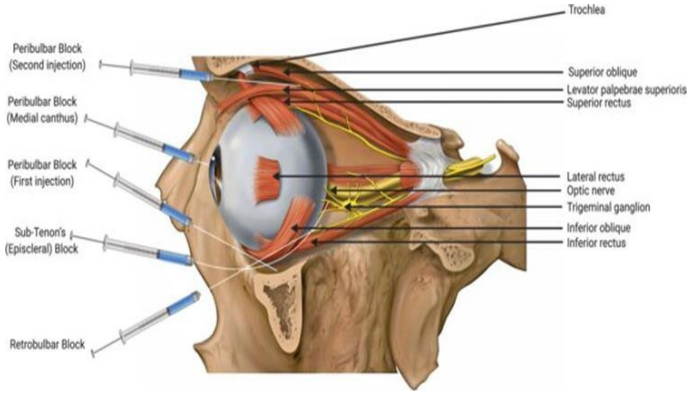

Fig. 1. Different types of regional blocks commonly used for ophthalmic surgery (The figure is used with permission from Dr. Singh).

Subconjunctival Anesthesia

In this technique, local anesthetic is injected under the conjunctiva. It can be used for various procedures such as intravitreal injections, cataract surgery, glaucoma surgery, and pterygium surgery. After applying topical anesthetic eye drops, a 27–30 gauge needle is used to inject the anesthetic solutions either superotemporally or inferotemporally 5–8 mm from the limbus. A cotton swab may be used to spread the anesthetic.[34]

Sub-Tenon's Block

The procedure requires creating a small incision in the sclera through which a cannula is carefully inserted. Lokal anesthetic is then injected under Tenon's fascia, surrounding the eye to provide both pain relief and immobilization of the eye. Although the complications are rare, they may include subconjunctival hemorrhage, chemosis, pain, and, in extremely rare cases, globe perforation.[35]

Intracameral Anesthesia

Intracameral anesthesia is a technique that requires the precise injection of a small volume of anesthetic, typically ranging from 0.1 to 0.5 mL, directly into the anterior chamber of the eye. Commonly used intracameral agents include preservative-free 1% lidocaine and 0.5% bupivacaine. This approach is often combined with topical, subconjunctival, or sub-Tenon's anesthesia, making it a highly effective and safe technique for cataract surgery and related procedures.[36]

Retrobulbar Block (Intraconal Block)

The retrobulbar block is a commonly employed method to induce anesthesia and akinesia before intraocular surgery, preferred by many surgeons for its rapid onset and prolonged duration of action. A comprehensive understanding of orbital anatomy and precise technique is important to prevent potential complications, including

retrobulbar hemorrhage, inadvertent injection into the globe, optic nerve, extraocular muscles, or unintended subarachnoid injection of local anesthetic. It is essential to exercise caution when considering this technique for patients with orbital pathology, high axial myopia, or coagulopathy. In general, mixtures containing epinephrine are avoided due to the potential risk of vasospasm and retinal ischemia.[37] To check the effectiveness of ocular globe akinesia, an assessment should be conducted approximately 5 min after infiltration.[37]

Peribulbar Block (Extraconal Block)

This block was developed as a safer alternative to the retrobulbar block for anesthetizing and numbing the eye. The needle used is typically shorter and is inserted less deeply and at a different angle than a retrobulbar block. A single injection of 6–12 mL of local anesthetic is administered into the inferolateral quadrant of the eye. Alternatively, 5–6 mL of local anesthetic can be injected into the inferolateral quadrant of the eye, with the option to administer an additional 3–5 mL in the medial peribulbar area if it is necessary.[38,39]

Supraorbital Block

The block is a method of anesthesia that covers a broad area, including the upper eyelid, eyebrow, forehead, and front part of the scalp. Using a smaller amount of anesthetic agent than local tissue infiltration provides the advantage of a larger coverage area.[31]

Infraorbital Block

This block is a nerve block that supplies sensory innervation to the lower eyelid, the side of the nose, the upper lip, and the maxillary teeth. It is useful for various procedures involving the lower eyelid and chin-face.[40]

Supratrochlear Block

This block is often used in conjunction with the supraorbital block to maximize the anesthetic effect on the forehead.[41]

Nasociliary Block

The anesthetic block is directed to the anterior and posterior ethmoidal foramina, which allows anesthetic delivery to the infratrochlear nerve.[42]

Facial Nerve Blocks

These blocks can be used either independently or in conjunction with general anesthesia or sedation for outpatient surgery. They specifically target the periocular branches of the facial nerve to reduce excessive blinking during the procedure.[43]

General Anesthesia Applications

A limited number of ophthalmic procedures are performed under general anesthesia. Surgical procedures are more commonly performed under monitored anesthesia (sedation). Midazolam is the most commonly used premedication for general anesthesia and has been shown to prevent blood pressure increases after peribulbar block.

In recent years, procedural sedation can be performed without complications using ultra-short-acting agents such as remimazolam and remifentanil.[44,45] The combination of propofol and remifentanil is particularly recommended for pediatric patients because of its advantages, including less airway irritation, fewer secretions, stable hemodynamics, fewer adverse effects, and rapid recovery.[46]

Sevoflurane and desflurane are commonly used inhalational anesthetics. Nonetheless, the use of sevoflurane, in particular, has been linked to postoperative delirium, which is a phenomenon more frequently reported and observed in children. The use of dexmedetomidine (an alpha-2 agonist) has been shown to reduce post-operative delirium in several studies.[47]

In the field of eye surgery, anesthesia can be administered through the use of a laryngeal mask in conjunction with inhalational anesthetics at 1.6–2.0 minimum alveolar concentration (MAC) values. This approach, which avoids the use of muscle relaxants, is likely to be just as safe as anesthesia techniques involving intubation and muscle relaxation. When opioids are incorporated into the anesthesia protocol, MAC values should be adjusted to 0.8–1.0 in accordance with vital parameters.[48] In our daily medical practice, we administer a neuromuscular blocker at a dosage of 0.3 mg/kg to patients who are fitted with a laryngeal mask. This effectively prevents patient movement during the procedure. The effects of anesthetic drugs on IOP are shown in Table 5.[49,50]

Special Surgery Considerations

Examination and IOP Measurement Under Anesthesia

In cases involving uncooperative children, general anesthesia is employed. Anesthesia induction can be achieved using a face mask. It is noteworthy, however, that most induction agents have the potential to lower IOP, which typically ranges from 10 to 20 mmHg. Given that children may require periodic IOP measurements, it is crucial to standardize the anesthetic technique.[49]

Table 5. Anesthetic agents and their effects on IOP

Anesthetic agent	Effect on intraocular pressure
Propofol, thiopental sodium	IOP reduced by 20–30% (3–7 mmHg)
Sevoflurane, desflurane	IOP reduced by 20–30% (3–7 mmHg)
Opioids (Remifentanyl, Fentanyl)	Minimal/No effect
Nitrous oxide (N_2O)	Minimal effect/Contraindicated in the presence of intraocular gas
Ketamine	A dose-dependent increase in IOP (minor)
Atropine	No effect
Non-depolarizing muscle relaxants	Minimal/No effect
Succinylcholine (depolarizing muscle relaxant)	Significant increase in IOP within 30 s of administration (approx.: 8 mmHg), effect lasts for 5–7 min.
Acetazolamide, mannitol, dextran	Used for acute reduction of IOP perioperatively
Ondansetron	No effect

Retinopathy of Prematurity (ROP)

The treatment of ROP encompasses cryotherapy, laser photocoagulation, and the use of anti-vascular endothelial growth factor monoclonal antibodies. These procedures are primarily performed at the bedside for premature infants under sedation or local anesthesia. When general anesthesia becomes necessary, meticulous attention must be paid to potential complications, including respiratory, cardiovascular, neurotoxicity, hypothermia, and hypoglycemia.

To prevent hypoglycemia during the intraoperative period, it is essential to maintain the administration of glucose-containing fluids. The operating room temperature should be maintained at a minimum of 25°C, and active warming measures should be employed.[51,52]

In cases involving cryotherapy, it is crucial to perform tracheal intubation and controlled ventilation to secure the airway and maintain a stable operative field. Short-acting opioids are administered for analgesia, and in many infants, extubation can be done safely. However, some neonates may still require respiratory support. The use of a sub-Tenon's block has been demonstrated to reduce the necessity for fentanyl and post-operative respiratory support in these cases.[53]

Cataract Surgery

In adults without comorbidities, topical anesthesia is the primary approach for cataract surgery. However, inadequate akinesia can be a challenge for the surgeon. The effectiveness of topical anesthesia can be improved by incorporating intracameral lidocaine. The choice between topical anesthesia, peribulbar/retrobulbar block, or general anesthesia can be made based on factors such as patient age, cataract complexity, comorbidities, and the surgeon's level of expertise.[54,55]

Surgery typically takes 15–30 min, but complications such as uveitis, glaucoma, endophthalmitis, iris damage or prolapse, retinal detachment, and retinal thickening may occur. Anesthetic management should focus on achieving akinesia with deep anesthesia or neuromuscular blockade, avoiding elevated IOP during induction and intubation, controlled ventilation to prevent hypercapnia, and the use of antiemetics.[49]

Glaucoma Surgery

Most glaucoma surgeries can be carried out using regional or topical anesthesia. Patients with glaucoma already exhibit optic nerve damage, and injections in the back of the eye for nerve blocks can potentially increase IOP by impeding blood flow to the optic nerve, potentially exacerbating the damage. Consequently, it is advisable to avoid injections at the back of the eye in this patient population. Other considerations include the appropriate selection of general anesthetics, monitoring the effects of topical glaucoma medications, and the control of IOP.[56,57]

Trabeculectomy can be performed under various forms of anesthesia, including local or general anesthesia. If a nerve block is preferred, the anterior sub-Tenon's block is recommended because it has a lower impact on the optic nerve. When opting for topical anesthesia for trabeculectomy, it should be noted that additional intravenous analgesics may be necessary for pain management.[57]

For non-penetrating surgeries such as deep sclerectomy and viscocanalostomy, all anesthesia options are applicable, but general anesthesia is typically not the preferred choice.[46] In the case of minimally invasive glaucoma procedures such as drainage devices and shunt placement, topical anesthesia emerges as the safest and most well-tolerated option.[58] In instances of closed-angle glaucoma requiring

peripheral iridotomy, topical anesthesia remains the sole viable choice.[59]

In situations where general anesthesia is employed, intubation or insertion laryngeal mask should be performed under deep anesthesia to prevent an elevation in IOP. Neuromuscular agents are administered to induce akinesia, while controlled ventilation is employed to avert hypercapnia. Analgesia with acetaminophen and NSAIDs is typically adequate, but opioids may be necessary if cyclocryotherapy is performed. Given the heightened risk of nausea and vomiting, the routine use of antiemetics is recommended.[49]

Strabismus Surgery

For strabismus surgery in children, general anesthesia is the preferred approach. Nevertheless, recent studies have indicated promising results in adult patients when using retrobulbar blocks or subconjunctival anesthesia in combination with topical agents.[60,61]

During strabismus surgery, it is common to observe the OCR, which involves a slowing of the heart rate when pressure is applied to the eye. The choice of anesthesia can influence the intensity of the OCR. Pediatric strabismus surgery performed with propofol or remifentanil anesthesia has been associated with a higher incidence of OCR compared to sevoflurane and desflurane anesthesia. However, there is no definitive method to completely eliminate OCR. One effective approach is to incorporate a sub-Tenon's block into general anesthesia, as it has been shown to reduce the incidence of OCR during surgery and alleviate post-operative nausea and vomiting.[62,63]

To help mitigate nausea and vomiting, ondansetron can be administered at a dose of 0.1 mg/kg, and dexamethasone can be given at a dosage ranging from 0.1 to 0.2 mg/kg. In addition, to further minimize the OCR, atropine can be used at a dose of 20 mcg/kg or glycopyrrolate at a dose of 10 mcg/kg. NSAIDs or acetaminophen should be utilized for post-operative pain management unless contraindicated.[49]

Vitreoretinal Surgery

Significant advancements in surgical instruments and increasingly sophisticated techniques have introduced vitreoretinal surgery into the field of regional anesthesia, allowing patients to remain awake during the procedure. Anesthetic approaches, such as topical anesthesia alone or in conjunction with subconjunctival anesthesia (referred to as two-stage anesthesia), have shown similar pain scores when compared to peribulbar and retrobulbar anesthesia techniques. It is important to note that relying solely on topical analgesia may not achieve ocular akinesia and requires special attention, particularly in macular surgery.[64,65]

In cases of general anesthesia, the use of nitrous oxide (N_2O) should be avoided. Given the potential for pain during the procedure, alternative analgesics, including opioids, should be considered. Extubation is typically carried out under deep anesthesia to prevent an elevation in IOP.[49]

Blocked Nasolacrimal Ducts

Opening obstructed nasolacrimal ducts usually requires general anesthesia. In simple cases, methylene blue is instilled through the duct under mask anesthesia while maintaining spontaneous breathing to visualize the nasopharynx. The patency of the duct is confirmed by inserting an aspiration catheter into the nasopharynx or nasal cavity. More complex cases may require the creation of a new canal (dacryocystorhinostomy, DCR). General anesthesia may be prefered for these complex surgeries. These patients should be monitored for bleeding, and opioids and local anesthetics may be used for analgesia.[66]

Orbital and Oculoplastic Surgery

The majority of oculoplastic procedures, including blepharoplasty and ptosis repair, are typically performed under local anesthesia. To alleviate the discomfort associated with local anesthesia for eyelid surgery, topical anesthetic gels, and drops are administered before the procedure. Epinephrine is frequently employed to prolong the effectiveness of agents such as lidocaine and bupivacaine. However, it is worth noting that some publications have suggested that adding epinephrine to local anesthetics may have a negative impact on the outcomes of surgery for aponeurotic blepharoptosis.[67] For external DCR and straightforward tumor excisions, sedatives can be combined with local anesthetics as an alternative to general anesthesia.[68]

Patients undergoing orbital decompression for thyroid disease with multiple comorbidities (e.g., autoimmune disease, diabetes), long-term corticosteroid-related side effects, or the presence of goiter should be approached cautiously, considering potential challenges with difficult airways.[69] Enucleation and evisceration procedures are generally performed under general anesthesia.

Utilizing local anesthetics for post-operative pain management not only guarantees effective pain control but also diminishes the occurrence of OCR and supports hemostasis.[70] Regional anesthesia, such as retro-upper peribulbar and subconjunctival anesthesia, combined with

sedation (utilizing drugs like midazolam and fentanyl), has been studied in a limited number of cases.[70,71]

Ocular Trauma

Managing patients with penetrating ocular injuries presents a primary challenge in anesthetic care, as it often involves an increase in IOP due to diminished intraocular contents. In addition, these patients may exhibit concomitant orbital or head trauma. To ensure complete akinesia for repair, general anesthesia is generally the preferred choice. However, it is important to note that the use of succinylcholine in general anesthesia should be avoided, as it may elevate IOP beyond 10 mmHg. Conversely, inhaled and intravenous anesthetics typically have the effect of lowering IOP. In cases involving smaller open corneal incisions, regional blocks may be employed in conjunction with intravenous sedation. Furthermore, in selected cases where fasting is not feasible, intracameral anesthesia can be considered as an adjunct to topical anesthesia.[72,73]

Anesthesia-related Complications

Complications related to regional blocks utilized in ophthalmic surgery can stem from the agents used or the block technique itself. These may include intravascular injection or anaphylaxis, making it crucial to have resuscitation equipment readily available.[74,75]

Retrobulbar Hemorrhage

Retrobulbar hemorrhage is characterized by a sudden increase in IOP, rapid corneal edema, pain, and proptosis, often necessitating surgery postponement. It typically occurs as a result of direct trauma to an artery or vein. This complication is exceptionally rare in retrobulbar or peribulbar blocks (0.07%). In cases of elevated IOP, lateral canthotomy may be performed for relief.

Subconjunctival Edema (Chemosis)

Slowing the injection rate can minimize subconjunctival edema, as it can interfere with suturing. The condition resolves rapidly when gentle pressure is applied to the closed eye.

Globe Perforation

Suspect globe perforation when patients experience pain, sudden vision loss, hypotony, or vitreous hemorrhage during block application (<0.1%). Risk factors include direct trauma, myopic eye, posterior staphyloma, or repeated injections.

Spread of Local Anesthesia to the Central Nervous System

Local anesthetics may inadvertently reach the central nervous system through direct injection into the dural sac or optic artery. Symptoms may include numbness, nausea, vomiting, contralateral blindness, convulsions, respiratory depression, neurological deficits, or even cardiac arrest. These symptoms typically manifest within approximately 5 min and require immediate intervention.

Optic Nerve Atrophy

It can develop due to various factors, including vascular occlusion, direct trauma to the optic nerve or artery, injection into the optic nerve sheath, or hemorrhage within the nerve sheath. These complications have the potential to lead to partial or complete vision loss.

OCR

The OCR manifests as bradycardia, nodal rhythm, ectopic beats, or sinus arrest and arises due to pressure on the eyeball or torsion/traction of the extraocular muscles. It is a trigeminovagal reflex most commonly observed in pediatric strabismus surgery. The OCR can be mitigated with local anesthetic blocks and the use of atropine. It is essential to avoid triggering a hypercarbia reflex in patients.

Oculo-respiratory Reflex

Characterized by reduced depth and rate of respiration, or even respiratory arrest, the oculorespiratory reflex operates on a mechanism similar to the OCR. It involves the pontine pneumotactic center and the medullary respiratory center. This reflex is common in strabismus surgery and is not affected by atropine. Patients should receive respiratory support if controlled mechanical ventilation is not utilized.

Oculoemetic Reflex

The oculoemetic reflex likely contributes to the relatively high incidence of vomiting following strabismus surgery, with rates ranging from 60 to 90%. This reflex is part of the trigeminovagal pathway and involves the stimulation of extraocular muscles. Although antiemetics can help reduce post-operative vomiting, regional block techniques remain the most effective prophylactic measure against this reflex.

Conclusion

The successful outcome of eye surgeries largely links to the administration of either topical or regional anesthesia, involving the use of local anesthetics. Hence, it is essential for both the anesthesiologist and the surgeon to possess a thorough understanding of potential complications stemming from the surgical procedure itself, as well as those arising from the use of local anesthetics. To address these complications effectively, it is crucial to have resuscitation

equipment readily available within the surgical area. In addition, the entire surgical team must be well-trained to promptly manage any unexpected issues that may arise.

For patients who are unsuitable candidates for topical or regional anesthesia, general anesthesia serves as a viable alternative. In such cases, achieving complete immobility becomes essential, often necessitating the use of neuromuscular blockers. Throughout the various phases of the procedure, such as induction, intubation, and extubation, it is imperative to take measures to prevent any increases in IOP, as this can have detrimental effects on the surgery's success.

When it comes to post-operative pain management, a range of options exist, including regional blocks, paracetamol, non-steroidal anti-inflammatory drugs, and opioids. The choice of analgesia should be tailored to the individual patient's needs and medical condition, with the goal of ensuring their comfort and facilitating a smooth recovery process.

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