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Regional Anesthesia and Eye Surgery

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THE vast majority of ophthalmic surgeries are performed under regional anesthesia only. However, its use is also described in association with general anesthesia for pediatric cases and for postoperative analgesia. Eye blocks have long been limited to retrobulbar anesthesia (RBA) as performed by surgeons. Surgical technique changes and research on improving patient safety during eye blocks has resulted in the development of alternative techniques, such as peribulbar anesthesia (PBA), followed by low-volume sub-Tenon block (STA) or topical anesthesia (TA).

In this review, we present the general requirements necessary for an eye block and then briefly describe each technique, discussing their respective advantages and inconveniences. Although cataract surgery is the most frequent ophthalmic surgical procedure and a large number of articles we cite refer to studies concerning this procedure, implications to regional anesthesia are not limited to cataract surgery; much of the data we review can be extrapolated and reinterpreted for other ophthalmic applications.

General Requirements

Anatomic Considerations

The orbit is filled mainly by adipose tissue, and the globe is suspended in its anterior part. Four rectus muscles delimit the retrobulbar cone, which is not sealed by an intermuscular membrane.[1] Sensory innervation of the globe is supplied by the ophthalmic nerve, the first branch of the trigeminal nerve, which passes through the muscular cone. Motor extraocular nerves pass through the muscular cone, except the trochlear nerve. Therefore, injecting local anesthetics inside the cone can logically be expected to provide anesthesia and akinesia of the globe and of the extraocular muscles. Only the motor command of the orbicularis muscle of the eyelids has an extraorbital course because it arises from the superior branch of the facial nerve. Many major structures are located in the muscular conus and are therefore vulnerable to the risk of needle injury, including the optic nerve with its meningeal sheaths; most of the arteries of the orbit; and the autonomic, sensory, and motor innervation of the globe (fig. 1).

The fascial sheath of the eyeball—also called the Tenon capsule—is a fibroelastic layer that surrounds the entire scleral portion of the globe. It delimits the episcleral space or sub-Tenon space, a potential space with no actual volume, although fluid can be injected into it. Some experts assimilate it into the articular capsule of the globe. Near the equator, the tendons of the oblique and rectus muscles perforate the Tenon capsule before they insert into the sclera. At this point, there is continuity between the Tenon capsule and the fascial sheath of the muscles. Anteriorly, the Tenon capsule merges with the bulbar conjunctiva before both insert together into the corneal limbus.

Patient Management

Ophthalmic surgical procedures have little systemic impact and are associated with a very low rate of general morbidity or mortality. As a result, in some countries, standard safety measures, such as fasting, are sometimes circumvented for eye blocks.[2] However, when taking into account potential complications, as described in Complications of Injection Blocks, we believe that standard safety measures (preoperative evaluation, fasting, and monitoring) should be applied.

The most debated problem concerning usual patient treatment is whether to continue anticoagulant/antiplatelet therapy. Totally “bloodless” superficial procedures, such as cataract sur-

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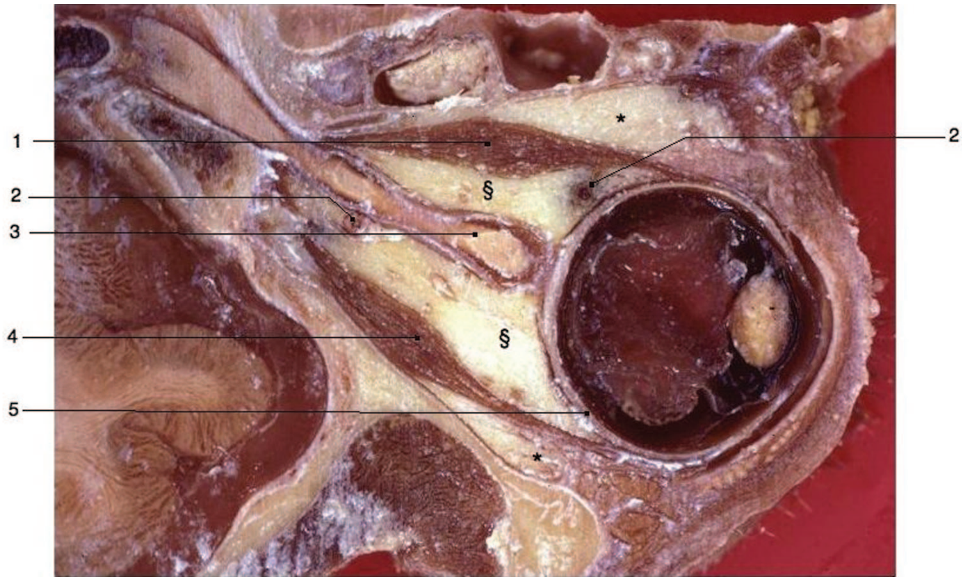

Fig. 1. Horizontal cadaver section of the orbit: (*1*) medial rectus muscle, (*2*) vessels, (*3*) optic nerve and its meningeal sheath, (*4*) lateral rectus muscle, (*5*) sclera. * Extraconal space. § Intraconal space.

gery, can be performed in the presence of any anticoagulant/antiplatelet agent. A meta-analysis[3] demonstrated that patients who have a cataract surgery without warfarin interruption (international normalized ratio = 2–3) have a greater risk for bleeding but that such bleeds are not clinically relevant. The bleeds consisted of dot hyphemaeand subconjunctival hemorrhage involving a limited segment of the eye with no impact on postoperative acuity.[3] Similar results were found in a recent large cohort of more than 2,000 patients taking warfarin.[4] This study also showed that aspirin use was not associated with bleeding. However, clopidogrel use was associated with a significant increase in observations of posterior capsule rupture, with or without vitreous loss.

For those patients, choosing the eye block must take into account TA as a possible option. All injection techniques carry a risk for retrobulbar hemorrhage (very infrequent) or subconjunctival hematoma (short-term esthetic consequences). Benzimra *et al.*[4] demonstrated that there was no significant increase in the overall recording of complications involving sharp needles and sub-Tenon cannula local anesthesia in patients using aspirin or dipyridamole. Similar results were found for those on aspirin used in combination with clopidogrel, warfarin, or dipyridamole.[4] As concerns hemorrhagic complications, subconjunctival hemorrhaging was significantly increased among patients on clopidogrel or warfarin alone, as well as those on a combination of aspirin and warfarin. No significant increases in the potentially sight-threatening hemorrhagic complications of retrobulbar/peribulbar were found in any of the anticoagulant or antiplatelet groups. Therefore, discontinuation of anticoagulant/antiplatelet therapy for an injection technique is no longer routinely recommended by British and French guidelines.‡ The only drugs for which there are no current recommendations are clopidogrel and the newer antiplatelet agents. In this case, a decision must be made on an individual basis.

Requests from the Surgeon

Requests from the surgeon vary with the procedure. During an open eye surgery, the request from the surgeon is analgesia, akinesia, and hypotonia of the eyeball. Because the eyeball is open, the concept of intraocular pressure cannot exist. However, a "positive vitreous pressure" is commonly caused by the pressure on the outside of the scleral wall (extraocular muscle tension) or a mass (choroidal effusion, hematoma), causing a reduction in scleral cavity volume. Increased positive vitreous pressure is manifested by repeated iris prolapse and can lead to a posterior capsule rupture, vitreous loss, choroidal effusion, or hemorrhage. This increased pressure can be prevented by akinesia of oculorotatory or orbicularis muscle.[5]

Closed intraocular surgery (*i.e.*, phacoemulsification and anterior vitrectomy) is characterized by some degree of pressurization of the globe. This result is achieved using self-sealing or small incisions while an infusion line pressurizes the eye. Moreover, operating times using this procedure are short, and manipulations of ocular tissues are limited. They do not require the same degree of akinesia as open eye surgery, only anesthesia.

The surgeon may also require that other general conditions be prevented. Acute peak arterial hypertension, for instance, may cause catastrophic choroidal expulsive hemorrhage. Tremor and/or restlessness due to anxiety may impair the procedure for obvious reasons. Coughing must be prevented because it results in head movement that increases intraocular pressure to very acute and high peak, which can impair surgery. Sedation may help to obtain optimal "akinesia of the head" but

‡ The Royal College of Anaesthetists and the Royal College of Ophthalmologists. Local anaesthesia for intraocular surgery, London: Royal College of Anaesthetists, 2001 [online]. Available at: http://www.rcoa.ac.uk/docs/RCARCOGuidelines.pdf. Accessed March 23, 2010.

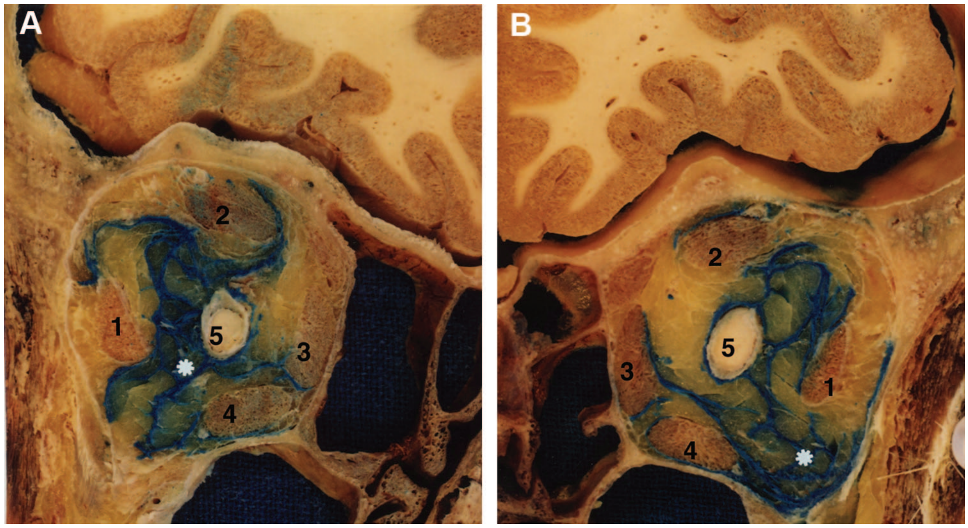

Fig. 2. A human cadaver head was injected with blue latex into intraconal or extraconal space (coronal section passing just to the posterior pole of the eyeball). (*A*) Right orbit injected into the intraconal space *via* an inferotemporal approach (retrobulbar anesthesia). (*B*) Left orbit injected into the inferotemporal quadrant of the extraconal space (peribulbar anesthesia). * Approximate injection site: 1, lateral rectus muscle; 2, superior rectus muscle–levator palpebrae superioris muscle complex; 3, medial rectus; 4, muscle inferior rectus muscle; 5, optic nerve. Note the spread of latex from one space to the other, through the supposed intermuscular membrane, resulting in a very similar picture after each injection. Reprinted from Ripart J, Lefrant JY, de La Coussaye JE, Prat-Pradal D, Vivien B, Eledjam JJ: Peribulbar *versus* retrobulbar anesthesia for ophthalmic surgery: An anatomical comparison of extraconal and intraconal injections. ANESTHESIOLOGY 2001; 94:56–62 Copyright © 2001 Lippincott Williams & Wilkins. Used with permission.

should be used cautiously because of the potential risk of ventilatory depression in a context with no airway accessibility.[6]

Injection Techniques

Techniques are usually named according to the site at which the needle tip is localized at the time of injection.

Retrobulbar Anesthesia

RBA was the "gold standard" for eye blocks from the beginning of the 20th century until the formalization of PBA and STA in the 1990s. RBA is achieved by injecting a small volume of local anesthetic agent (3–5 ml) inside the muscular cone. The main hazard of RBA is the risk of injury to the globe, the rectus muscles, or one of the many vulnerable elements located in the muscular cone. Near the apex, these structures are packed in a very small volume and are fixed by the tendon of Zinn, which prevents them from moving away from the needle. Currently, RBA is used less frequently because of these potential complications.

Peribulbar Anesthesia

The long-used technique of PBA was highlighted by the work of Bloomberg *et al*[7,8] in 1986. PBA has a tendency to replace RBA on the theoretical principal of better security. It consists of introducing the needle into the extraconal space to avoid risk of injury to major structures in the intraconal space. See video, Supplemental Digital Content 1, which demonstrates an inferotemporal injection for peribulbar anesthesia, http://links.lww.com/ALN/A653. As much as 12 ml local anesthetic is injected and spreads into the entire corpus adiposum of the orbit, including the intraconal space (figs. 2 and 3).[1,9] In addition, this large volume allows an anterior spread to the eyelids, providing a block of the orbicularis muscle of the eyelids. The most classic PBA technique involves two injections, one inferiorly and temporally, and the second superiorly and nasally.

Alternative techniques have been described but cannot be extensively reported here. However, advances in PBA techniques may be summarized in terms of a few guidelines:

Using a Single Injection Technique. Comparative studies have confirmed that, provided the injected volume is sufficient, the single injection technique is as effective as the double injection technique. A second injection should be performed only as a supplement when the first injection has failed.

Limiting the Depth of Needle Insertion (Usually 25 mm). Posterior to the globe, the rectus muscles are in contact with the orbital walls, so that the extraconal space becomes virtual. Increasing the depth of needle insertion is expected to change a PBA into an RBA.[10]

Avoiding the Superior and Nasal Site of Puncture. At this level, the distance between the orbital roof and the globe is reduced, theoretically increasing the risk of globe perforation. In addition, the needle may injure the superior oblique muscle. Inferior and temporal puncture remains the "gold standard." An alternative site of puncture for PBA is the medial canthus.[11] The needle is introduced at the medial junction of the eyelids, nasally to the lacrimalcaruncle in a strictly posterior direction at a depth *limited to 15 mm*. At this level, the space between the orbital wall and the globe is large and free from blood vessels.

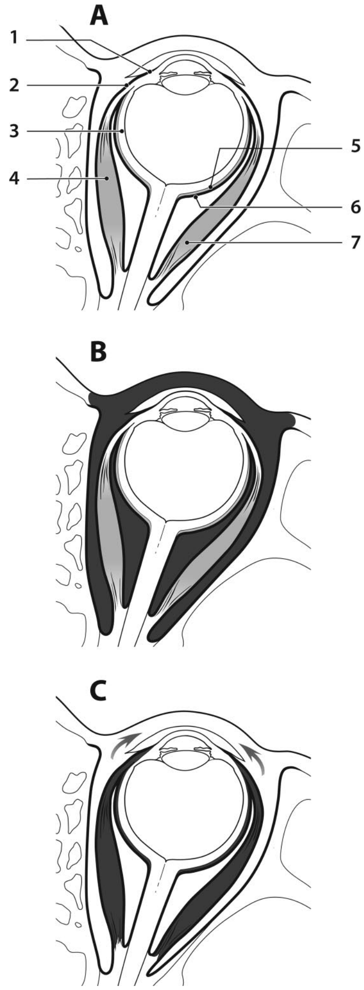

Fig. 3. (*A*) Semischematic view of a horizontal section of the orbit: 1, Common insertion of bulbar conjunctiva and Tenon capsule on the eyeball, near the sclerocorneal limbus; 2, anterior fascial sheath of the eyeball (the Tenon capsule); 3, sclera; 4, medial rectus muscle; 5, episcleral space (sub-Tenon); 6, posterior fascial sheath of the eyeball; 7, lateral rectus muscle. Note the continuity between the Tenon capsule and the sheaths of the rectus muscles. (*B*) Figurated spread of a local anesthetic injected into the peribulbar space, with subsequent spread into the muscular cone. Because the space for spreading is the adipose tissue of the orbit, including the small septas network, this spread may be incomplete or heterogeneous, thus accounting for imperfect blocks. (*C*) Figurated spread of a local anesthetic injected into the episcleral (sub-Tenon) space. Note the spreading into the whole episcleral space and into the sheaths of the rectus muscles, thus accounting for good akinesia. Because the episcleral space is adherence-free and septum-free, this spread is more constant, thus accounting for more constant akinesia. In addition, because the anterior Tenon is not tightly sealed, part of the local anesthetic flows to the lids, accounting for akinesia of the orbicularis muscle.[9] Reprinted from Lopatka CW, Magnante DO, Sharvelle DJ, Kowalski PV: Ophthalmic blocks at the medial canthus. ANESTHESIOLOGY 2001; 95:1533–5. Copyright © 2001 Lippincott Williams & Wilkins. Used with permission.

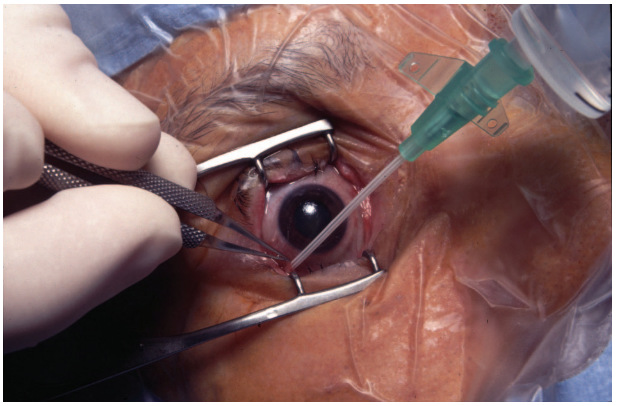

Fig. 4. Sub-Tenon's anesthesia using an intravenous catheter as cannula.

Using Compression to Decrease Intraocular Pressure after Injection. Compression has not been clearly shown to enhance the quality of the block. A 30 mmHg pressure applied for 10–15 min is sufficient.

In all cases, the spread of local anesthetics in the corpus adiposum of the orbit remains somewhat unpredictable, leading to the common need to increase the injected volume to prevent an imperfect block. Depending on the surgeon's request for akinesia, an additional injection is required in as many as 50% of cases.[7,8,12] This poor reproducibility in block efficacy is the main disadvantage of PBA.

Sub-Tenon Block

Initially this technique was proposed as an intraoperative complement to RBA. STA is achieved by injecting local anesthetic in the sub-Tenon (or episcleral) space[9] (fig. 3). Two techniques have been described.

Blunt Cannula Technique. Under TA, a buttonhole is opened into the conjunctiva and Tenon capsule 5–10 mm from the limbus. A blunt cannula is then inserted in the episcleral space (fig. 4).[13] This is the most popular STA, the main advantage being avoidance of a sharp needle technique, which theoretically increases safety. Most articles on STA safety refer to blunt cannula techniques.

Needle Technique. The needle is introduced between the semilunaris fold of the conjunctiva and the globe, tangentially to the globe. After it has encroached on the conjunctiva, the needle is shifted slightly medially and advanced strictly posteriorly, thereby pulling the globe, which results in directing the gaze medially. See video, Supplemental Digital Content 2, which demonstrates an STA needle technique, http://links.lww.com/ALN/A654. At a 10–15 mm depth, after a small loss of resistance (a "click" is perceived), the globe returns to its primary gaze position.[14] This technique has not gained a large popularity most likely because it does not avoid the use of a sharp needle.

Injecting into the sub-Tenon space allows the local anesthetic to spread circularly around the scleral portion of the globe, thereby achieving high-quality analgesia of the whole globe with the injection of relatively low volumes (2–5 ml).

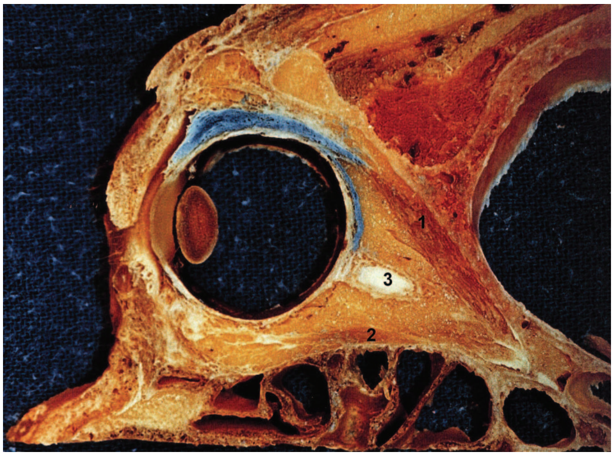

Fig. 5. A human cadaver head was injected with blue latex using a needle technique sub-Tenon anesthesia (horizontal section): 1, lateral rectus muscle; 2, medial rectus muscle; 3, optic nerve. Dye can be seen in the lateral part of the episcleral space. Note the subconjunctival spread of the dye and laterally a spread to the lateral rectus muscle sheath.

In addition, use of a larger volume (up to 11 ml) means the local anesthetic will spread to the extraocular muscle sheaths (fig. 5), producing an effective and reproducible akinesia.[12] Chemosis (subconjunctival spread of the local anesthetic) occurs frequently after injection of large volumes. Its occurrence confirms the sub-Tenon location of the injection and may require compression to be resolved.

When small volumes are used, STA carries the same limitations as TA. Another limitation of this technique is the relatively high rate of minor complications, which were estimated at 2.5-fold higher using STA compared with RBA or PBA.[15] Guise[16] reported that 6% of 6,000 cases had chemosis and 7% had subconjunctival hematoma, with only one case requiring surgery cancellation. However, Kumar *et al.*[13] reported a greater incidence of chemosis and conjunctival hemorrhage, ranging from 25 to 60% and from 20 to 100%, respectively. STA efficacy is excellent for globe analgesia. Guise[16] reported that 96% of blocks were scored as perfect or good. STA leads to better perioperative analgesia compared with TA. One study reported improved patient and surgeon satisfaction in favor of STA compared with PBA[17]; however, these results remain somewhat controversial.[18,19] Finally, safety is the main advantage of the cannula technique, because it avoids the blind introduction of a needle into the orbit.[14] Some major complications associated with STA, although rare, have been described.[20]

Complications of Injection Blocks

The most common cause of needle block complications is needle (or cannula) misplacement (*e.g.*, optic nerve damage during RBA). Although some anatomical features may increase the risk of complications, the main risk factor is poor physician training and limited experience using the procedure.

Life Threatening Complications Arise from the Spread of the Anesthesia into the Central Nervous System. First, an inadvertent intra-arterial injection may reverse blood flow in the ophthalmic artery up to the anterior cerebral or the internal carotid artery, such that an injected volume as small as 4 ml can produce seizures. Second, an inadvertent injection under the dura mater sheath of the optic nerve, or directly through the optic foramen, may result in subarachnoid spread of the local anesthetic. This error causes partial or total, progressive, brainstem anesthesia. Symptomatic treatment should result in total recovery.

Inadvertent Globe Perforation and Rupture Is the Most Devastating Complication of Eye Blocks. This complication has a poor prognosis, particularly in cases of delayed diagnosis. Perforation incidence was evaluated as 0.9 in 10,000 with RBA and as 1 in 16,000 and 1.4 in 10,000 with PBA.[21,22] Classic risk factors include physician inexperience and a highly myopic eye (*i.e.*, long eyeball). In a series of 50,000 cases, Edge and Navon[23] observed that myopic staphyloma was the most important risk factor for scleral perforation. This finding suggests that isolated high myopia may not be a risk factor *per se* but acts as a confounding factor because myopic staphyloma occurs only in myopic eyes. The probability of staphyloma is greater in highly myopic, compared with slightly myopic, eyes.[24] Moreover, staphyloma is more frequently located at the posterior pole of the globe (accounting for perforations after RBA) or in the inferior area of the globe (accounting for perforations after inferior and temporal punctures, both PBA and RBA). As a result, ultrasound measurements of the axial length of the globe (biometry) should be available, at least in myopic patients. A highly myopic eye (axial length more than 26 mm) remains the classic contraindication for eye block. However, this contraindication may be circumvented if B-mode ultrasound is conducted to assess the presence and location of a staphyloma.

Injury to an Extraocular Muscle May Cause Diplopia and Ptosis. Several mechanisms can be involved: direct injury by the needle resulting in intramuscular hematoma, high pressure as a result of injection into the muscle sheath, or myotoxicity from the local anesthetic.

Retrobulbar Hemorrhage Results from an Inadvertent Arterial Puncture. This complication may lead to a compressive hematoma, which can threaten retinal perfusion. The main risk factor is arterial fragility (diabetes, atheroma) rather than clotting disorders. Venous puncture leads to noncompressive hematoma, the consequences of which are much less severe, and in most cases surgery can be continued.

Direct Optic Nerve Trauma by the Needle Is Very Rare but Causes Blindness. Computed tomography usually shows optic nerve enlargement that is the result of intraneural hematoma.

Topical and Intracameral Anesthesia

TA consists of the instillation of local anesthetic eye drops on the cornea. The procedure is quick and easy to perform as well as extremely cost-effective. The main advantage of this technique is the avoidance of all potential hazards of injection techniques. TA has thus gained in popularity over the last decade for cataract surgery *via* phacoemulsification. In the United States, TA use has been documented as occurring in 61% of cataract surgery cases, increasing to 76% among surgeons who perform more than 75 procedures per month.[25]

The use of TA has been reported for many ophthalmic procedures (*e.g.*, keratoplasty, glaucoma surgery). However, it has its own limitations, chiefly limited duration, limited extension to cornea, and total mobility of the eyeball and lids. First, however, is that analgesia may be incomplete. Despite small differences, less comfort and increased pain are reported when TA is compared with injection blocks.[6,26–27] Second, the lack of akinesia and pressure (intraocular pressure or positive vitreous pressure) control associated with the short duration of the procedure theoretically makes surgery more hazardous. These operative conditions are not optimal and may lead to perioperative patient movement.[26] Moreover, a closed claim analysis showed that such movements were associated with 11 of 117 eye injuries.[28] Acceptably low rates of surgical complications in cataract surgery performed under TA have been described.[29] One study observed an advantage for TA in terms of surgical complication rates. In a randomized, nonblind, comparative study of unselected patients, Jacobi *et al.*[30] observed only one significant difference between TA and RBA, namely a surprising decrease in vitreous loss rate in the TA group (0.4 *vs.* 2.5%, $P = 0.41$). Inversely, in a case-control study, a protective effect of PBA or STA *versus* TA was identified for displacement of nuclear fragments into vitreous (OR = 0.18 [0.10–0.34]).[31] However, these data were not confirmed by Srinivasan *et al.*,[32] who compared STA with TA. In their study, TA was associated with a twofold increase in posterior capsule rupture requiring anterior vitrectomy (4.3 *vs.* 2.1%) but with a nonsignificant difference ($P = 0.39$). Therefore, TA should be limited to planned, easy procedures performed by experienced surgeons in selected patients. Current research must define criteria for patient selection and surgeon experience. For procedures other than phacoemulsification, such as manual extracapsular cataract extraction, akinesia is still required and the use of TA is questionable.[5]

Efforts have been made to improve TA efficacy in many ways. Use of long-acting local anesthetics such as levobupivacaine or ropivacaine seems more efficient than lidocaine (lignocaine). Intracameral injection of local anesthetics has been proposed to enhance analgesia. This option entails injecting small volumes (0.1 ml) of local anesthetic into the anterior chamber at the beginning of surgery. The safety of this technique in relation to local anesthetic toxicity for corneal endothelium seems to be acceptable but any significant analgesic benefit of intracameral injection *versus* simple TA is very limited if present.[33] This result is not surprising because analgesia is not correlated with intracameral local anesthetic concentration. For these reasons, intracameral injection is still debated and cannot be clearly recommended.[34] The efficacy of sponges soaked with local anesthetic inserted into the conjunctival fornix and soluble local anesthetic inserts needs further documentation. Instilling lidocaine jelly instead of eye drops seems to enhance the quality of analgesia of the anterior segment and is being increasingly used.

TA may also be associated with an increased risk for endophthalmitis. One study reported the independent risk for endophthalmitis to be sixfold higher with TA compared with RBA.[35] The most plausible explanation for this observation is that if the jelly was applied on the eye first, it could have acted as a barrier, preventing disinfectant applied later from reaching the conjunctiva, thereby resulting in insufficient eye disinfection. As a result, the problem is probably related to the wrong sequence of application rather than the jelly itself.

Summary

Three eye block techniques, PBA, STA, and TA, are widely used. The main disadvantages of PBA are needle-related complications and a lack of reproducibility with a high rate of reinjection. The cannula technique, which gains access to the sub-Tenon space, avoids needle block but does not totally prevent complications. Research is needed to assess the potential benefits of ultrasound guidance for injection techniques to prevent these complications. Using TA, needle-related complications are avoided but at the expense of imperfect surgical conditions. Specific local anesthetic jelly mixtures for topical anesthesia should be developed to ameliorate TA analgesia.

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