Review Article

Regional anaesthesia for intraocular surgery

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The role of anaesthetists in providing local anaesthesia for intraocular surgery has changed over the past decade. No longer confined to the interested few, more and more anaesthetists are involved in monitored care and/or are performing eye block anaesthesia. This review summarizes the information related to eye block anaesthesia. The salient features of the orbital anatomy important for safe conduct of eye block anaesthesia are described. The techniques for retrobulbar and peribulbar anaesthesia, including facial nerve blocks, anaesthetic mixture, types of needles, and softening the eye are presented. Complications such as retrobulbar haemorrhage, globe penetration/perforation, visual impairment, brainstem anaesthesia, muscle injury, and oculocardiac reflex are explored. The implications of anticoagulant therapy are examined. The choice between retrobulbar and peribulbar blocks and the role of anaesthetists are discussed.

Le rôle de l'anesthésiste en anesthésie locale oculaire a changé au cours de la dernière décennie. L'anesthésie locale oculaire ne fait plus partie du domaine de quelques initiés mais intéresse de plus en plus d'anesthésistes qui veillent non seulement au monitoring mais exécutent souvent eux-mêmes les blocs. Cette revue résume l'information relative aux blocs oculaires. Les caractéristiques de l'anatomie orbitale pertinentes à l'exécution des blocs de l'oeil sont décrites. Les auteurs traitent des techniques de blocs rétrobulbaires et péribulbaires, incluant le bloc du nerf facial, les mélanges anesthésiques, les types d'aiguilles. Les complications comme l'hémorragie rétrobulbinaire, la

Key words

ANAESTHETIC TECHNIQUES: regional, retrobulbar, peribulbar, facial nerve;

COMPLICATIONS: haemorrhage, globe penetration, blindness, brainstem anaesthesia, oculocardiac reflex;

SURGERY: ophthalmic.

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pénétration et la perforation du globe, les atteintes visuelles, l'anesthésie du tronc cérébral, les blessures musculaires et le réflexe oculocardiaque sont abordés. Les conséquences de l'anticoagulothérapie sont décrites. On discute du choix à faire entre le bloc péribulbinaire et rétrobulbinaire ainsi que du rôle de l'anesthésiste.

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Role of anaesthetists

Since the discovery of cocaine as a local anaesthetic in 1884 by Koller, then an Austrian ophthalmology resident, eye surgery has been commonly performed under local anaesthesia. The retrobulbar anaesthesia technique was first described in the same year by Knapp,¹ but it was not until 50 yr later when better local anaesthetic agents were available that it became generally accepted. Today, more than one million retrobulbar anaesthetic blocks a year are performed in the United States.² The insertion of a needle within the muscle cone occasionally produces serious complications. This led to the introduction of peribulbar anaesthesia in which the needle is introduced outside the muscle cone.

Regional anaesthesia is suitable for a wide variety of eye operations, including cataract extraction, trabeculectomy, vitrectomy and strabismus repair. Cataract surgery constitutes by far the most common eye operation done under local anaesthesia. Almost all cataract surgery is performed under regional anaesthesia in the United States and India. General anaesthesia is still commonly used in other countries, but the pattern is changing. There is evidence that in elderly patients having cataract surgery, the endocrine and metabolic responses seen during general anaesthesia are inhibited by local anaesthesia.³ Regional anaesthesia should be considered as an alternative choice for eye surgery, and not just for those unfit for general anaesthesia.⁴ The reductions in health care funding and the recent trend towards day-care surgery will increase the demand on regional anaesthesia for eye surgery.

Today, most of the eye anaesthesia blocks world-wide are performed by ophthalmic surgeons and the bulk of information on regional anaesthesia for eye surgery is found in the ophthalmic literature. However, life-threatening complications, fortunately rare, are best managed by anaesthetists experienced in resuscitation.⁵ Furthermore, the care of patients having eye surgery with local anaesthesia can be improved by having anaesthetists involved in the perioperative management.⁶ Anaesthetists are also trained in nerve block techniques. Thus, it is natural that in many centres, anaesthetists have become more involved in local anaesthesia for ophthalmic surgery.

While many participate in monitored care, others are performing the eye blocks.

It is the purpose of this review to draw the attention of anaesthetists to this neglected area. A brief description of the anatomy of the orbit and its contents is presented first to serve as a base for performing safe eye blocks. This is followed by an analysis of the various ocular block techniques. The complications associated with ocular blocks are then presented for their awareness, prevention and management. The review will conclude with a discussion of the choice between retrobulbar and peribulbar approaches, and the role of anaesthetists in eye surgery under local anaesthesia.

Anatomy of the orbit

Regional blocks for eye surgery involve the insertion of a needle very close to many important structures. A knowledge of the anatomy of the orbit and its contents is essential for the safe conduct of eye block anaesthesia. Detailed functional orbital anatomy can be found in the excellent treatise by Doxanas and Anderson,⁷ and the works on orbital connective tissues by Koornneef.⁸⁻¹⁰

The orbit (Figure 1)

The orbit is 40 to 50 mm deep. The commonly used 38-mm (1.5 in) retrobulbar needle is long enough to penetrate the optic nerve in front of the optic foramen in about 10% of the population.¹¹ The medial wall of the orbit is parallel to the sagittal plane, and the lateral wall lies at 45° to the medial wall. The volume of the orbit is approximately 30 ml, and that of the globe is about 7 ml. The injection of five to ten ml of local anaesthetic solution will increase the orbital pressure.

Above the pear-shaped orbital cavity are the anterior cranial fossa and frontal sinus. The maxillary sinus lies beneath the orbital floor. The medial wall is separated from the ethmoid sinus by a very thin portion of the ethmoid bone called the lamina papyracea. Perforation of the medial wall by a block needle may result in orbital cellulitis or abscess. The lateral wall is bordered by the temporal fossa in front, and the middle cranial fossa at the back. The orbital septum forms its anterior boundary.

The supraorbital notch, an often used landmark in the medial third of the superior orbital rim, is totally enclosed to form a foramen in 25% of orbits. The sharp border lateral to it and the rounded margin medial to it may give a clue to its location if it is not felt easily. Nerves and vessels cross over the orbital rim medial to the supraorbital notch, and may be injured if the block needle is inserted too close to the periosteum in this area.

Eyelids

The eyelids are protracted by the orbicularis muscle

FIGURE 1 Volume, angle and relations of the orbit.

which is innervated by the facial nerve. This muscle may not be paralysed by anaesthetic solutions deposited behind the globe, enabling the patient to squeeze the eye and cause an increase in intraocular pressure (IOP). The upper eyelid is retracted by the levator palpebrae superioris which originates from the annulus of Zinn at the orbital apex and is innervated by the oculomotor nerve. The lower eyelid is retracted by the capsulopalpebral fascia which is a direct extension of the inferior rectus muscle.

Extraocular muscles

The globe is moved by four rectus (superior, medial, inferior, lateral) and two oblique (superior, inferior) muscles. The rectus muscles originate from the annulus of Zinn, a fibrous ring at the orbital apex, which encircles the optic foramen and the medial aspect of the superior orbital fissure. Together, the four rectus muscles form a "cone" with the point at the orbital apex and the base at the equator of the globe. Within this cone lie the optic nerve, artery, vein and the ciliary ganglion. When performing local anaesthesia blocks, the tip of the needle is inserted inside this muscle cone in retrobulbar blocks,

FIGURE 2 Position of the block needle in relation to the muscle cone in retrobulbar and peribulbar blocks.

and outside it in peribulbar blocks (Figure 2). In the anterior orbit, fibrous septa connect the adjacent muscles to form a well-defined "cone." These intermuscular fibrous septa are often poorly developed in the posterior orbit. Computerised tomography following retrobulbar and peribulbar anaesthesia demonstrated that the anaesthetic solution spread freely between the inside and outside of the cone irrespective of where it was deposited.¹²

The levator palpebrae muscle originates above the superior rectus at the orbital apex, and proceeds anteriorly as a functional unit with the superior rectus muscle. The superior oblique muscle originates superomedial to the annulus of Zinn, and runs forward at the junction of the medial wall and roof of the orbit. It becomes a tendon before reaching the anterior orbital margin, passes through the trochlea, a cartilaginous ring which redirects it so that it pulls in an anterior-medial direction, and inserts posteriorly on the sclera close to the optic nerve superotemporally. The trochlea may be traumatized by a needle inserted in the superomedial quadrant of the

orbit while performing eye blocks. The inferior oblique muscle arises in a shallow depression lateral to the origin of the nasolacrimal duct, runs obliquely along the inferior surface of the globe, and inserts to the sclera inferior to the macula. Inadvertent penetration of extraocular muscles by a block needle causing intramuscular haematoma, or intramuscular injection of a large volume of anaesthesia solution may cause ischaemia, leading to fibrosis and contracture of the muscle.

The globe is enclosed by Tenon's capsule which is a dense fibrous layer of connective tissue. The rectus muscles penetrate Tenon's capsule posterior to the equator of the globe, while the oblique muscles penetrate anterior to the equator of the globe. In the recently described sub-Tenon block, anaesthetic solutions are deposited in the retrobulbar space with an irrigating cannula through an incision made in the Tenon's capsule.

Nerves and vessels

Nerves and vessels coming through the optic foramen and medial portion of the superior orbital fissure go through the annulus of Zinn to supply the structures within the muscle cone. The optic nerve, ophthalmic artery and ocular sympathetics pass through the optic canal and foramen. The dura is adherent to the optic canal and the optic nerve itself. Inadvertent needle penetration of the optic nerve sheath may result in depositing the local anaesthetic directly in the subarachnoid space.

The abducens nerve, divisions of the oculomotor and trigeminal nerves, sensory root of the ciliary ganglion, and superior ophthalmic vein come into the orbit through the medial portion of the superior orbital fissure. The inferior orbital fissure transmits the maxillary division of the trigeminal nerve and permits venous drainage from the inferior ophthalmic vein to the pterygoid plexus. These vessels and nerves are at risk of being traumatized by injections in the retrobulbar space.¹³

Three cranial nerves serve the motor functions of the extraocular muscles: the oculomotor nerve supplies the medial, superior and inferior rectus, the inferior oblique, and the levator palpebrae superioris muscles; the trochlea nerve supplies the superior oblique muscle; the abducens nerve supplies the lateral rectus muscle. The motor nerves to the superior, medial and inferior recti enter the muscles from within the muscle cone at approximately the junction of the middle and posterior thirds, and to the lateral rectus at just posterior to the middle. Deposition of anaesthetic solution inside the muscle "cone" or in the posterior orbit would thus produce akinesia of the rectus muscles more readily. The inferior oblique is supplied at about the middle of its posterior border. The trochlear nerve enters the orbit outside the annulus of Zinn, and supplies the superior oblique in several branches that enter

FIGURE 3 Somatosensory innervation of the eye and surrounding tissues from the ophthalmic division of the trigeminal nerve.

the anterior half of the posterior third of the muscle on its orbital surface. This may explain why this muscle often continues to function after a low volume retrobulbar block.

Somatosensory innervation

All somatosensory inputs from the eye are transmitted mainly through the ophthalmic nerve and, to a much less extent, the maxillary nerve, to the sensory root of the trigeminal nerve.

The ophthalmic nerve divides into three branches, the frontal, lacrimal, and nasociliary nerves. These branches enter the orbit through the superior orbital fissure, and provide the innervation of the eye and surrounding tissues (Figure 3).

The frontal nerve enters the orbit supero-lateral to the annulus of Zinn and runs forward above the recti and levator palpebrae superioris muscles just below the periosteum. It divides into a medial supratrochlear nerve

and a large lateral supraorbital nerve midway through the orbit. The supratrochlear nerve passes above the pulley of the superior oblique muscle, and supplies the medial part of the upper eyelid. The supraorbital nerve exits the orbit via the supraorbital notch and supplies the middle two-thirds of the upper eyelid and superior conjunctiva.

The lacrimal nerve follows the upper border of the lateral rectus muscle close to the junction of the roof and lateral wall of the orbit. It supplies sensory innervation to the lacrimal gland and the lateral part of the upper eyelid and conjunctiva.

The nasociliary nerve conveys the principal somatosensory inputs from the eye. It passes through the annulus of Zinn and between the two divisions of the oculomotor nerve, and crosses the orbit obliquely below the superior rectus muscle, deeper than the other branches of the ophthalmic nerve. As it crosses above the optic nerve it sends a sensory root to the ciliary ganglion from which the short ciliary nerves continue to the eyeball. The ciliary ganglion, lying between the optic nerve and the lateral rectus muscle about 10 mm from the orbital apex, receives a parasympathetic root from the oculomotor branch to the inferior oblique muscle, and a sympathetic root from the internal carotid plexus. On the medial side of the optic nerve, the nasociliary nerve gives rise to two or three slender long ciliary nerves which course to the eye together with the optic nerve. They penetrate the sclera near the attachment of the optic nerve, and supply the cornea, iris, ciliary body, and sclera. On the medial side of the orbit the nasociliary nerve divides into the infratrochlear and anterior ethmoidal nerves close to the superior oblique muscle. The infratrochlear nerve runs close to the orbital wall, passes under the pulley of the superior oblique muscle, and supplies the skin at the medial angle of the eye, medial eyelid and conjunctiva, and lacrimal apparatus.

Only two branches of the maxillary nerve, both entering the orbit through the inferior orbital fissure, are related directly to sensory input from the eye. The zygomaticotemporal nerve from the zygomatic nerve supplies the lacrimal gland. The infraorbital nerve supplies the lower eyelid and inferior conjunctiva.

The sensations arising from the cornea, iris, conjunctiva, and sclera, unlike other parts of the body, are principally pain or irritation. The retina and optic nerve, like the rest of the brain tissue, lack direct sensitivity to somatosensory stimuli. However, the optic nerve dural sheaths are densely innervated with free nerve endings, and a needle puncture of the optic nerve will be painful. The sensory supply to the globe is by the nasociliary nerve and ganglion which are readily blocked by anaesthetics deposited within the muscle cone, or spreading from out-

side the cone. The sensory supply to the conjunctiva includes the supraorbital, lacrimal, infratrochlear, and infraorbital nerves, most of which run outside the muscle cone and may not be totally blocked. Despite an otherwise satisfactory block, the patient may feel pinching at the beginning or antibiotic injection at the end of surgery. However, this can be managed easily with topical anaesthetic placed directly on the conjunctiva. The sensory supply to the eyelids and conjunctiva arise from the lacrimal, supraorbital, supratrochlear, infratrochlear, and infraorbital nerves. The plexus formed by these nerves lies deep to the palpebral fibres of the orbicularis oculi muscle. Anaesthetics must be deposited deep into the orbicularis muscle in order to anaesthetize the eyelids.

Ocular blocks

Retrobulbar block

Retrobulbar anaesthesia was first described by Knapp of New York in 1884 for enucleation of an eyeball.¹ "The conjunctiva was first anaesthetized by instilling the solution (cocaine). Then the globe was strongly drawn toward the nose by means of a forceps, and six minims of a 4% solution (painlessly) injected into the orbital tissue close to the posterior part of the globe."

Atkinson described the classic technique of retrobulbar injection using a blunt-tipped 35-mm needle inserted through the skin at the inferotemporal margin of the orbit. "The needle is first directed straight back, well away from the eyeball, until the point is beyond the globe. It is then pointed upward toward the apex of the orbit and inserted to a depth of 2.5 to 3.5 cm. and the injection made in the muscle cone. The eye is turned upward and nasally so the inferior oblique muscle and fascia between the lateral and inferior rectus muscles are forward and upward, out of the way."¹⁴

Using computerized tomography in cadavers, Unsöld *et al.* demonstrated that when the globe was in the Atkinson "up and in" position, the optic nerve was displaced downward and outward, and a 35-mm needle inserted through the lower eyelid would be in immediate proximity to the optic nerve, and would pass near the ophthalmic artery, superior ophthalmic vein, and the posterior pole of the globe.¹⁵ When the globe was placed in a slightly downward position, however, the optic nerve remained mobile and displaced away from the needle. A recent study using orbital magnetic resonance imaging in a normal subject also confirmed that Atkinson's position is hazardous.¹⁶ Indeed, most of the reported cases of inadvertent trauma to the optic nerve and vessels, globe perforation, and brain stem anaesthesia involved retrobulbar injections with the globe in the Atkinson "up and in" position. To minimize complications, the globe should

be positioned "down and out" or in primary gaze, and a needle no longer than 35 mm passed to a depth just enough to enter the muscle cone, and not crossing the midsagittal plane.¹⁷

Many modifications to the classical retrobulbar anaesthetic injection have been described, such as: transconjunctival,^{18,19} through the lateral canthal region,²⁰ through the superomedial quadrant,²¹ directing the needle to a point behind the macula and not toward the apex of the orbit,²² retrobulbar injection followed by injection in eyelid during withdrawal of needle,²³ using a specially curved needle inserted through the inferior conjunctival sac,²⁴ and small volume retrobulbar injection coupled with superior rectus muscle injection.²⁵ These modifications were made either to minimize complications or to eliminate the need for separate injections for the facial nerve block.

SUB-TENON'S ANAESTHESIA

The direct sub-Tenon's approach to retrobulbar anaesthesia has drawn much attention in recent ophthalmic surgical literature. This block is administered by ophthalmic surgeons. After topical anaesthesia with tetracaine, a small incision is made in the conjunctiva and through the Tenon's fascia, down to bare sclera. A blunt irrigation cannula is then inserted through this incision into the posterior sub-Tenon's space to deposit 4–5 ml of anaesthetic solution. Rapid anaesthesia and akinesia are achieved without the risks associated with the classical retrobulbar injection techniques. Additional injections can be made at any time if the block is inadequate.

The technique of sub-Tenon's anaesthesia varies with the type of surgical procedure for which it is intended, and it is used with or without facial nerve block. Sub-Tenon's approach to retrobulbar anaesthesia has been described for cataract surgery,^{26–28} vitreoretinal surgery,^{29,30} panretinal photocoagulation,³¹ trabeculectomy,³² and strabismus surgery.^{33,34} A curved cannula has also been designed for sub-Tenon injections.³⁵

However, concern has been expressed that this technique does not provide a secure means of controlling the position of the globe should intraoperative complications occur, and therefore it should be used only with a good deal of caution.³⁶ Occasionally, incomplete anaesthesia despite repeated supplementations in the sub-Tenon's space would be most distressing for both the surgeon and the patient.³⁷

Peribulbar block

The use of peribulbar anaesthesia was first reported by Davis and Mandel in 1986.³⁸ By introducing the needle outside the muscle cone, the risks of traumatizing orbital structures are much reduced. Peribulbar anaesthesia is

obtained by bulk spread. To produce akinesia, a larger volume of anaesthetic solution is required to spread inside the orbit. It takes longer to produce adequate anaesthesia for surgery, and also causes a greater increase in orbital pressure.

The most popular peribulbar anaesthetic technique involves dual injections above and below the globe. The needle is first inserted either through the conjunctiva or lid at a point between the lateral third and medial two-thirds of the lower orbital margin. It is then advanced in a superomedial direction for a distance of 25 mm to the equator of the globe. Four ml of anaesthetic solution are injected here outside the muscle cone. The needle is then introduced through the upper lid at about 2 mm medial and inferior to the supraorbital notch. It is advanced in a sagittal plane under the roof of the orbit for a maximal depth of 25 mm. Three ml of anaesthetic solution are deposited here. Conjunctival oedema is often seen after the peribulbar injections. An orbital compression device is then applied. A facial nerve block is performed only if orbicularis akinesis is not achieved.^{19,39,40}

There are many modifications to the technique. Bloomberg described a technique where the anaesthetic solution is deposited more superficially outside the muscle cone, approximately 18 mm from the skin surface (anterior peribulbar block). Five ml of anaesthetic agent is injected into the superonasal orbit and a further 5 ml inferotemporally.⁴¹ A small volume peribulbar injection together with block of the facial nerve at the lateral orbital rim has been advocated to minimize chemosis of the surface tissues.⁴² Some authors have found a single peribulbar injection either through the lower lid^{43,44} or the upper lid⁴⁵ just as effective and safe.

SUBCONJUNCTIVAL BLOCK

Subconjunctival anaesthesia has been advocated for intraocular surgery of the anterior segment of the eye, as an alternative to retrobulbar and peribulbar techniques. A small volume of 0.5 to 1 ml of anaesthetic is injected beneath the superior bulbar conjunctiva, raising a bleb that extends from the superior limbus to beyond the insertion of the superior rectus tendon.^{46–48} The advantage of this technique is that the small volume of anaesthetic used hardly increases the orbital pressure. However, anaesthesia of the iris may be incomplete, akinesia often is inadequate, and the chemosis caused by the injection sometimes interferes with surgery.^{49,50} Many surgeons find this technique uncomfortable.⁵¹

Facial nerve blocks

If the orbicularis muscle is not immobilized, the patient may squeeze the eyelids, which interferes with surgery and increases IOP. The orbicularis muscle is supplied by

the facial nerve. Orbicularis akinesia can be achieved by blocking the facial nerve at its terminal branches (van Lint block), superior branches (Atkinson block), or proximal trunk (O'Brien or Nadbath block).

van Lint block

Blocking the facial nerve to paralyse the orbicularis muscle was first advocated by van Lint in 1914. "Introduce the needle one cm. back of the intersection of a horizontal line extending from the lowest part of the inferior margin of the orbit and a vertical line from the most temporal part of the lateral margin of the orbit. The needle is introduced as far as the bone and directed inward and slightly downward into the deep tissues just below the orbital margin. The injection is given as the needle is withdrawn. Through the same opening in the skin, the needle is again inserted as far as the bone and directed upward and inward near the orbital margin close to the bone."⁵² The van Lint facial nerve block is still commonly used in the original or modified form. It sometimes causes eyelid oedema and lid haemorrhage, which may contribute to postoperative ptosis.

O'Brien block

O'Brien advocated blocking the facial nerve near the condyloid process. Only two ml of anaesthetic solution are required. Due to anatomical variations, occasionally the facial nerve is not successfully blocked. The block can be painful both at the time of injection and for several days after the operation, in spite of care taken to avoid pricking the periosteum of the condyloid process.¹⁴ The lower branches of the facial nerve supplying the lips and face are frequently blocked, leading to facial paralysis which on at least one occasion was prolonged for months.⁵³

Atkinson block

Atkinson prefers to block the superior branches of the facial nerve by inserting the needle at the inferior margin of the zygomatic bone below the lateral margin of the orbit, and injecting 3–4 ml of anaesthetic solution as it is advanced upward and temporally across the bone at 30° from the vertical. Firm pressure is then applied over the site of the injection. With the technique, one rarely fails to obtain complete akinesia of the orbicularis.⁵² However, this block can be painful.¹⁹

Nadbath block

The Nadbath facial nerve block selectively blocks the facial nerve as it leaves the skull through the stylomastoid foramen.⁵⁴ The needle is inserted approximately 2 mm anterior to the antero-superior border of the mastoid process, immediately below the external auditory meatus,

and advanced perpendicular to the skin. In the original description, a 12-mm, 16-gauge needle was used to deliver 3 ml of 1% carbocaine solution. This block is painful. Prolonged paralysis of the facial nerve,^{19,55} and sudden onset of respiratory obstruction and cord paralysis have been reported as complications.^{56–59} When long needles and large volumes of anaesthetic solution containing hyaluronidase are used in thin patients, inadvertent injection of anaesthetic solution into the jugular foramen, which lies approximately 10 mm medial to the stylomastoid foramen, has resulted in paralysis of the vagus, glossopharyngeal and spinal accessory nerves causing dysphagia, hoarseness, dysphonia, coughing, unilateral vocal cord paralysis and respiratory distress from pooling of oropharyngeal secretions and laryngospasm.^{60,61}

Many ophthalmologists routinely perform a facial nerve block before the retrobulbar block, assuming that the retrobulbar block would not provide orbicularis akinesia.^{29,30,53,60,61} However, it has been shown that a standard 3 ml retrobulbar injection of local anaesthetic does give adequate orbicularis akinesia in 88% of patients.⁶² This may have resulted from the spread of anaesthetic solution along the needle tract, or through the tissues planes of the orbit during ocular massage.

Orbicularis akinesia can also be achieved by injecting 0.5 to 1 ml of local anaesthetic in the inferior fornix, in the lower lid near the lateral canthus, or in the subcutaneous space of the lower or upper lid when withdrawing the retrobulbar needle, making a separate facial nerve block unnecessary.^{18,21,23,63,64}

Anaesthetic mixture

Anaesthetic agents

Cocaine was the first anaesthetic used for retrobulbar anaesthesia by Knapp in 1884. Procaine, etidocaine, mepivacaine, lidocaine, bupivacaine and other local anaesthetic agents, alone or in combination, have been used for ocular anaesthesia.

Etidocaine has high lipid solubility and protein binding capacity, and provides a prolonged duration of action and good postoperative analgesia. The exact location of etidocaine injection seems to be critical, and supplemental injections were required more often after etidocaine blocks than after lidocaine blocks.^{65,66} Bupivacaine also produces prolonged retrobulbar block, but the onset is slow.^{67,68} Mepivacaine or lidocaine have been added to bupivacaine to provide a rapid onset of anaesthesia while retaining the prolonged duration of block achieved with bupivacaine.

A mixture of lidocaine and bupivacaine is the most popular preparation used (Table I).^{19,23,39,40,42–44,63,64,69–84} Lidocaine has good penetrating properties and produces

TABLE I Anaesthetic mixtures used for ocular blocks in randomly selected papers

Author	Volume (ml)	Final concentrations in mixture			Hyaluronidase (units · ml ⁻¹)	Epinephrine
		Lidocaine	Bupivacaine	Etidocaine		
<i>Retrolbulbar block</i>						
Follette (1985) ⁶⁹	1.5	1%	0.375%	–	No	No
Murphy (1985) ⁶³	4	1%	0.25%	–	Yes (?)	No
Kobet (1987) ⁷⁰	4	1%	0.375%	–	No	Yes
Kimbrough (1987) ²³	7–10	–	0.75%	–	Yes (15)	No
Witteman (1987) ⁶⁴	4–4.75	2%	–	–	Yes (?)	Yes
Rodman (1987) ⁷¹	8	–	0.75%	–	Yes (7.5)	No
Hamilton (1988) ¹⁹	3–7	1%	0.375%	–	Yes (5)	Yes
Rao (1988) ⁷²	2	2%	–	–	No	Yes
Cowley (1988) ⁷³	3	2%	–	–	No	No
Brod (1989) ⁷⁴	5	1%	0.375%	–	No	No
Hersch (1989) ⁷⁵	4	–	0.75%	–	Yes (37.5)	No
Abelson (1989) ⁷⁶	5	2%	0.375%	–	Yes (60)	No
Davis (1989) ⁴²	6	1%	0.25%	–	Yes (15)	No
Verma (1990) ⁷⁷	2.5	2%	–	–	No	No
Mieler (1990) ⁷⁸	3.5	1%	0.375%	–	Yes (?)	No
Wood (1990) ⁷⁹	5	1%	0.25%	–	Yes (3)	No
Brent (1991) ⁸⁰	?	1%	0.375%	–	Yes (15)	No
<i>Peribulbar block</i>						
Hamilton (1988) ¹⁹	7–9	1%	0.375%	–	Yes (5)	Yes
Pannu (1990) ⁸¹	8–10	2%	0.375%	–	Yes (18.75)	No
Kishore (1990) ⁴³	5	1.2%	0.2%	–	Yes (30)	Yes
Fry (1990) ³⁹	8–20	1%	0.25%	–	Yes (42)	No
Apel (1991) ⁴⁴	10	0.8%	0.3%	–	Yes (12.5)	Yes
Ropo (1992) ⁸²	4	–	–	1.5%	Yes (7.5)	No
Puustjärvi (1992) ⁴⁰	7	–	–	1.5%	Yes (15)	No
Arora (1992) ⁸³	8	1%	0.375%	–	Yes (18.75)	No
Nicholson (1992) ⁸⁴	9	–	0.5%	–	Yes (25)	No

a fast onset, while bupivacaine provides the prolonged duration for surgery and for postoperative analgesia. In randomized, double-blinded studies, this combination has been demonstrated to produce a faster onset and longer duration of action than bupivacaine alone⁸⁵ or in combination with etidocaine.⁸⁶

Carbonated lidocaine, which has been shown to be more effective than lidocaine hydrochloride for brachial plexus and caudal anaesthesia, does not have any advantage over lidocaine hydrochloride and bupivacaine mixture in achieving peribulbar block of the orbit.⁴² The local pH changes provided by the carbonation of lidocaine do not have as great an effect when the anaesthetic solution is placed remote from the nerves outside the muscle cone. Chloroprocaine is a useful agent for retrolbulbar anaesthesia for strabismus surgery with adjustable sutures. Its short duration of action permits earlier adjustment of sutures.⁸⁷

Hyaluronidase

Hyaluronidase hydrolyses the C₁–C₄ bonds between glucosamine and glucuronic acid in ground substance,

thus promoting a diffusion of the anaesthetic through the tissue. It is commonly added to local anaesthetic solutions for ocular anaesthesia in varying concentrations (Table I). In randomized, double-blinded studies, the addition of hyaluronidase into local anaesthetic solutions for retrolbulbar blocks was shown to enhance akinesia,^{76,88,89} speed the onset of surgical anaesthesia,^{79,90} and reduce the requirements for supplemental injections prior to surgery than if it was not used.^{79,91} A concentration of 7.5 IU · ml⁻¹ hyaluronidase seems to be sufficient, and doubling the dose does not have any further beneficial effects, at least when used with 1.5% etidocaine.⁸⁹ Indeed, when hyaluronidase was not available, there was a delay in onset of surgical analgesia, more frequent reinforcement of blocks, and the local anaesthetic did not dissipate throughout the orbit properly, causing more marked proptosis, requiring longer application of pressure-reducing device, and producing positive vitreous pressure intraoperatively.⁹²

Epinephrine

Epinephrine is sometimes added to delay anaesthetic reab-

TABLE II Block needles used in reported complications associated with ocular blocks

<i>Authors</i>	<i>Block</i>	<i>Gauge</i>	<i>Tip</i>	<i>Length</i>
<i>Globe penetration</i>				
Joseph (1991) ⁹⁹	PB	25	blunt	37 mm
Rinkoff (1991) ¹⁰⁰	RB	25	10 sharp 1 blunt	?
Duker (1991) ²	RB	25	sharp	?
Grizzard (1991) ¹⁰¹	5 RB 4 PB	23–27	7 sharp 5 blunt	?
Hay (1991) ¹⁰²	3 Superior 12 RB 11 PB	23,25	16 sharp 7 blunt	35–38 mm
<i>Retrobulbar haemorrhage</i>				
Cionni (1991) ¹⁰³	RB	25	?	38 mm
Puustjärvi (1992) ⁴⁰	PB	24	sharp	25 mm
<i>Optic nerve injury</i>				
Paulter (1986) ²²	RB	27	sharp	38 mm
Jindra (1989) ¹⁰⁴	RB	25	dull	?
Brod (1989) ⁷⁴	RB	25	blunt	38 mm
Hersch (1989) ⁷⁵	RB	23	rounded	?
Mieler (1990) ⁷⁸	RB	23	rounded	38 mm
<i>Respiratory arrest</i>				
Rodman (1987) ⁷¹	RB	25	?	38 mm
Ruusuvuura (1988) ¹⁰⁵	RB	?	sharp	35 mm
Rigg (1989) ¹⁰⁶	RB	25	?	40 mm

sorption for prolonging operative and postoperative analgesia. The addition of epinephrine to bupivacaine, however, does not extend the already prolonged anaesthesia and akinesia induced by bupivacaine.⁹³ Its use does not appear to contribute to the quality or effectiveness of the block in blinded studies.⁹¹ Furthermore, the addition of epinephrine to lidocaine for retrobulbar anaesthesia was observed to cause a 50% reduction in ophthalmic artery pressure, suggesting that epinephrine should be omitted in patients with compromised circulation.⁹⁴ The use of epinephrine in ocular anaesthesia, however, is not universal (Table I).

pH adjustment with sodium bicarbonate

Although the active structure of the local anaesthetic molecule is the cationic form, the noncationic form can penetrate nerve membranes more readily. Local anaesthetic preparations, particularly those with added epinephrine, are supplied at a low pH. Adjusting the pH of a local anaesthetic towards neutrality can increase its noncationic form, and thus should promote neural membrane penetration, especially for bupivacaine and peribulbar blocks which generally have a delayed onset of anaesthesia. Randomized, double-blinded studies of pH adjustment with sodium bicarbonate have shown that the onset of peribulbar anaesthesia is reduced when using bupivacaine-hyaluronidase,^{95,96} lidocaine-bupivacaine-

hyaluronidase or commercially prepared lidocaine with epinephrine-bupivacaine-hyaluronidase⁹⁷ solutions. However, pH-adjustment may be associated with loss of bupivacaine from solution and an increased failure rate of the block.⁹⁶ Precipitation may occur if too much bicarbonate is added.

Block needles

The type of needle used may influence the complication rate associated with eye blocks. Fine-gauge needles cause less pain and are more comfortable for patients. Since a blunt needle may show some increase in resistance and a sharp needle may not show any appreciable change of resistance should the globe or optic nerve be penetrated, it is generally believed that using blunt needles may reduce these complications.^{13,14,98} However, blunt needles are not immune to producing complications, and there is no statistical difference between sharp and blunt needles in causing globe penetration and optic nerve injury (Table II).^{2,22,40,71,74,75,78,99–106} In the series reported by Hay *et al.* the severity of injury or visual outcome was not related to whether a sharp or a blunt needle was responsible for the globe penetration.¹⁰² Grizzard *et al.*, on the other hand, reported that, unless there were multiple exit wounds, the visual acuity was better preserved in cases where sharp needles had penetrated the globe compared to those cases where blunt needles had been

responsible.¹⁰¹ It is interesting that, in a rat sciatic nerve model, lesions induced by short bevelled needles are more severe, more frequent and take longer to repair than those induced by long bevelled needles.¹⁰⁷

The length of the block needle is important. Optic nerve penetration and brainstem anaesthesia are usually associated with needles 35 mm or longer. Specially curved needles have been designed to decrease the risk of complications associated with retrobulbar injections and to improve the success of reaching the muscle cone.^{24,108} However, doubt has been expressed regarding its effectiveness to prevent ocular penetration, as it is the tip of the needle, and not the barrel, that penetrates.¹⁰¹

Softening the globe

The intraocular pressure is increased after local anaesthetic injections. This may lead to vitreous loss during intraocular surgery. Many techniques and devices have been used to soften the eye prior to ocular surgery, including intermittent digital pressure,¹⁰⁹ Super Pinky ball,¹⁹ Honan balloon,^{110,111} Storz Autopressor,^{40,112} Nerf ball,¹¹³ mercury bag,⁴⁴ and lead shot-filled balloon.¹¹⁴ In addition to softening the globe, compression also helps to spread the anaesthetic solution and promote akinesia of the periorbital muscles.

Palay and Stulting found that the injection of four ml of retrobulbar anaesthetic caused an immediate increase in IOP averaging 6.2 mmHg (range 1 to 17 mmHg) in 30 patients.¹¹⁵ Digital pressure or the Honan IOP reducer was then applied to the orbit. There was an initial decrease of IOP to slightly less than the baseline level in the first 2.5 min, which was believed to be due to a combination of relaxation of the intraocular muscles, reduction of aqueous production from blockade of the ciliary ganglion, and dispersal of the anaesthetic volume in the retrobulbar space. Continual application of compression caused gradual reduction of IOP, due to a decrease in vitreous volume, at about $0.35 \text{ mmHg} \cdot \text{min}^{-1}$ for ten minutes (the maximal duration in the study) by both techniques.

In a prospective double-blind controlled study using healthy volunteers not given an ocular anaesthetic, the application of 30 mmHg pressure using the Honan intraocular pressure reducer produced a mean IOP decrease of 8.8 mmHg when applied for five minutes and 14.3 mmHg when applied for 40 min.¹¹⁶ The reduction in IOP was transient, persisting for only 15 min after the pressure reducer was removed. No rebound elevation in IOP was observed. There was no change in visual acuity or colour vision after the tests.

The blood flow to the retina, choroid, and optic nerve depends on the balance between IOP and the mean local pressure. Ocular compression theoretically can produce

retinal and choroidal ischaemia leading to visual loss. However, in a retrospective review of 1000 unselected cases, Martin *et al.* found no cases of ocular ischaemia attributable to the Honan IOP reducer.¹¹⁷ On the other hand, following retrobulbar injection of anaesthetic, external ocular compression will produce an increase in IOP that may be sufficient to compromise ocular perfusion in patients with high IOP.¹¹⁸ Thus, for patients with glaucoma or advanced carotid occlusive disease, ocular compression preceding retrobulbar anaesthesia has been recommended to maintain ocular perfusion better.¹¹⁹

Complications of ocular blocks

The insertion of a needle into the orbit can traumatize orbital contents, and the injection of local anaesthetic mixtures may cause local or systemic complications. Any unusual symptoms such as extreme pain or a sudden decrease in visual acuity should be attended to immediately. Dilating the pupil before inserting the block needle may facilitate examination of the eye by indirect ophthalmoscopy.¹³

Complications such as retrobulbar haemorrhage, globe perforation, blindness, brainstem anaesthesia, and muscle damage will be discussed in detail. In addition, the question of whether retrobulbar or peribulbar block protects against cardiac arrhythmias due to oculocardiac reflex will be explored.

Retrobulbar haemorrhage

The incidence of haemorrhage from retrobulbar injections is estimated to be about 1%.¹⁷ Atkinson reported no retrobulbar haemorrhages in 20 yr of practice using a blunted 35 mm needle.¹⁴ Hamilton *et al.* reported five (0.14%) moderate retrobulbar haemorrhages in 3595 retrobulbar blocks.¹⁹ Cionni and Osher collected 60 cases over a three-year, ten-month period, which represented an incidence of retrobulbar haemorrhage associated with retrobulbar blocks in their institution of 1.7%.¹⁰³ Retrobulbar haemorrhage has also been reported following posterior peribulbar block.⁴⁰

Haemorrhages may be venous or arterial. Venous haemorrhage spreads slowly, and will probably not cause long-term visual problems. Severe arterial haemorrhage produces rapid orbital swelling, marked proptosis with immobility of the globe, and swollen and blood-stained eyelids.⁴⁰ The increased pressure may cause closure of the central retinal artery and late optic atrophy, leading to visual loss.^{120,121}

If retrobulbar haemorrhage occurs, ophthalmoscopic examination should be performed to rule out ischaemic damage to the optic nerve or retina. Measurement of IOP is helpful in assessing the severity of the haemorrhage

and the risk to the circulation of the eye. If the IOP is high, or if the nerve becomes pale, a lateral canthotomy should be performed to relieve the orbital pressure.^{40,103}

Should one proceed to perform the cataract surgery in the presence of retrobulbar haemorrhage? Many surgeons would cancel the procedure because increased orbital and intraocular pressure can lead to iris prolapse and vitreous loss. Cionni and Osher, however, showed that if the orbital pressure could be reduced by digital massage, one could proceed with small incision phacoemulsification and intraocular lens implantation with successful outcome.¹⁰³

ANTICOAGULANT THERAPY

Patients taking anticoagulant therapy may have an increased risk of haemorrhagic complications. On the other hand, discontinuation of anticoagulant therapy may result in serious cardiovascular complications, including cerebral vascular accident, peripheral thrombosis and death.

In a retrospective study of ocular surgery, Gainey *et al.* reported six (12%) perioperative haemorrhagic complications in 50 patients receiving long-term warfarin therapy, compared with none in 50 patients not taking anticoagulant drugs.¹²² These complications, however, did not impair the long-term visual acuity. The study found no difference in haemorrhagic complications between patients in whom warfarin was continued and those in whom it was discontinued. However, preoperative prothrombin time check was inconsistent, and the type of anaesthesia was not clear from the report.

Two questionnaire surveys showed that the majority of cataract surgeons withheld warfarin, and many stopped aspirin before cataract surgery.^{123,124} Although no adverse effects occurred in most patients in whom anticoagulant therapy was allowed to be continued, surgery was occasionally complicated by bleeding.¹²⁵

Hall *et al.* reported that continuing warfarin therapy on the day of surgery in 42 patients having 49 cataract operations under local anaesthesia did not result in more operative bleeding, and no cardiovascular complications occurred in the operative period.¹²⁶ Robinson and Nylander reported three hyphaema complications in ten cataract extractions on eight patients for whom warfarin was not discontinued prior to surgery.¹²⁷ In this report, four cases were performed under local anaesthesia in patients with BCR/INR (British comparative ratio/international normalized ratio) of 1.5 to 3.1, and there were no retrobulbar haemorrhages. Based on these data, continuation of anticoagulant therapy and the use of aspirin were recommended.^{124,126,127}

The absence of serious bleeding complications as described in these surveys and reports of small series of cases does not prove that it is safe to administer ocular

blocks in patients taking anticoagulant therapy. The risks of administering regional anaesthesia to patients taking anticoagulants have been explored mainly for epidural and spinal techniques.¹²⁸ The risks involved in eye blocks have not been fully evaluated. In the study reported by Cionni and Osher, 18 (30%) of 60 cases of retrobulbar haemorrhages occurred in patients taking anticoagulants which included Coumadin, aspirin and/or nonsteroidal anti-inflammatory drugs.¹⁰³ The authors stated that all patients discontinued anticoagulant therapy two weeks before surgery unless contraindicated as determined by their internist. It is not clear how many patients were still taking anticoagulants on the day of surgery.

Until data are available regarding risks of ocular blocks in a large series of patients taking anticoagulant therapy, certain basic principles may apply. Patients who are at high risks of thrombo-embolic complications should not have their anticoagulant therapy discontinued. The coagulation profile should be checked before surgery, and should be within the appropriate therapeutic range. Although the incidence of retrobulbar or peribulbar haemorrhage associated with ocular block is low, general anaesthesia should be considered as the first choice. If local anaesthesia is deemed necessary, a peribulbar block is preferable to a retrobulbar block. By avoiding insertion of the needle within the muscle cone, the risk of trauma to blood vessels is much reduced.

Globe penetration/perforation

Inadvertent globe penetration (single entry) or perforation (entry and exit wounds) can complicate both retrobulbar^{2,100,102,129} and peribulbar blocks.^{2,99,102,130} Interestingly, this can also happen during subconjunctival block,¹³¹ upper eyelid anaesthesia injection^{20,132} and periocular steroid injections to treat ocular inflammatory conditions.¹³³ Both ophthalmologists and anaesthetists who perform ocular blocks have contributed to this complication.

Based on large reported series involving from 1000 to 4200 cases, the incidence of globe penetration secondary to ocular anaesthetic blocks is less than 0.1%.^{38,130,134} The risk of globe penetration is increased in highly myopic eyes,^{2,99,134} after a previous scleral buckling procedure, and with retrobulbar blocks, multiple injections, or the use of long sharp needles.^{2,100} However, the absence of these factors does not eliminate the risk. Duker *et al.* estimated the incidence of penetration in eyes with axial length greater than or equal to 26 mm to be one in 140 injections.²

Penetration or perforation of the globe is often not apparent at the time of block administration, and the initially planned procedure, usually cataract removal, is completed. To avoid missing this complication, Feibel recommends checking the fundus with an indirect ophthal-

moscope to be sure the sclera has not been penetrated and that the retinal vessels are patent after every retrobulbar or peribulbar injection.¹³⁵ In some cases, a possible penetrating injury may be noted by the surgeon at the time of surgery because of hypotony (intraocular pressure 8 mmHg or lower) or the presence of a dark red reflex.¹⁰⁰ If globe penetration is suspected, cancellation of the cataract surgery should be considered since the hypotony associated with cataract surgery could exacerbate retinal vascular and choroidal haemorrhage. If the cataract allows visualization of the penetration site with indirect ophthalmoscopy, cataract surgery should be cancelled and arrangements made for retinopexy to the perforation site. If the cataract prevents adequate visualization of the posterior segment, some surgeons recommend that it be removed to allow the retinal surgeon to perform photocoagulation or retinal repair, provided adequate anaesthesia and akinesia are present and the eye is not hypotonous.¹⁷ However, proceeding with surgery in the presence of hypotony would impair possible future visual improvement because of the increased risk of vitreous haemorrhage and subsequent retinal detachment.¹⁰¹

Many patients with penetrated globes are referred to retinal surgeons because of vitreous or subretinal haemorrhage, and/or retinal detachment. The management depends on the extent of injury, and may include transscleral cryotherapy, laser retinopexy, vitrectomy, silicone oil tamponade and scleral buckling. Improvement of visual acuity can usually be achieved unless recurrent retinal detachment or proliferative vitreoretinopathy develops.² However, poor vision and blindness can result from globe penetration or perforation.⁹⁹

The long-term effect of needle penetration of the globe appears to be related to the physical trauma. In the series reported by Grizzard *et al.*, blunt needle penetrations generally caused more damage with subretinal and vitreous haemorrhage, requiring vitrectomies, and resulted in poorer vision. On the other hand, laser therapy, cryopexy therapy or observation was sufficient to achieve good vision in sharp needle penetrations.¹⁰¹ Multiple penetrations or multiple exit wounds, and penetration of the optic nerve or macula would result in poor vision.

The effects of lidocaine and hyaluronidase injected into the eyeball are temporary and produce no detectable histologic damage to the retina. Intraocular injection of lidocaine causes immediate dilatation and paralysis of the pupil and diminished visual acuity lasting a few hours.¹³⁶

Visual complications

VISUAL EFFECTS OF OCULAR ANAESTHESIA

Visual function is affected by eye block anaesthesia. With

serial measurements of visual acuity and visual fields, Carroll and de Roeth found that retrobulbar injections of 2% to 8% procaine produced loss of vision.¹³⁷ Although retrobulbar anaesthesia results in a marked reduction in visual acuity, total blindness does not occur, and most patients claim that they can see with the operated eye during intraocular surgery.¹⁰⁹ Brent and Singh demonstrated impairment of visual acuity ten minutes after retrobulbar injections of 2–3 ml of a lidocaine, bupivacaine and hyaluronidase mixture.⁸⁰ In general, the longer the globe axial length, the greater the decrease in visual acuity following retrobulbar block. There was no correlation between postinjection acuity changes and the age of patients or the volume of anaesthetic injected. The decrease in visual acuity may be due to conduction blockade of the optic nerve by the local anaesthetic agents, or relative ischaemia produced by orbital compression. Verma *et al.* found that in three patients who were given retrobulbar injections of 2.5 ml of 2% lidocaine with a blunt 22-gauge needle, there was a consistent decrease in visual acuity, and an increase in the latency and a decrease in the amplitude of visual evoked potentials. The conduction block of the optic nerve, though profound, was temporary since these measurements returned to normal within 45 to 75 min.⁷⁷

VISUAL COMPLICATIONS

Apart from the temporary visual blockade by local anaesthetic agents, severe impairment of visual acuity and even blindness may result from penetration of the globe during ocular blocks. Retrobulbar anaesthesia can be complicated by permanent blindness due to trauma to the optic nerve or the central retinal artery.^{22,75,78,104} Furthermore, the compressive effect of the injected solution can cause occlusion of the central retinal artery leading to visual loss.¹³⁸

Trauma to the optic nerve in most reported cases was associated with retrobulbar injections while the patient looked up and in, making the nerve taut. Sharp needles may cause piercing injury of the nerve, and even rounded needles may result in tearing of neural tissues. There is often nothing unusual during the insertion of the needle or injection of anaesthetic. The loss of vision may have been attributed to the effect of local anaesthetic blockade, and the possibility of blindness is often noticed only when this is prolonged. Fundus examination reveals optic disc oedema, retinal oedema and vitreous haemorrhage, and later, signs of optic nerve atrophy. CT scan and ultrasonographic examination may demonstrate dilation of the optic nerve either from haemorrhage or injection of anaesthetic.^{75,104}

Cowley *et al.* reported a case of retinal vascular occlusion immediately following a retrobulbar lidocaine in-

jection in a patient with diabetic retinopathy.⁷³ This was believed to be due to vasospasm because of absence of retrobulbar haemorrhage, presence of a normal optic nerve on CT scanning, and reversibility by paracentesis, nitroglycerine and CO₂ rebreathing. An alternative explanation was that the increase in volume in the orbit resulted in decreased perfusion of the central retinal and/or ophthalmic arteries, which were already severely compromised by diabetes. Purtscher-like retinopathy has been reported after retrobulbar anaesthesia, with marked decrease in visual acuity lasting 12 weeks.¹³⁹ This could have been due to a sudden increase of pressure in the orbit leading to increased intravenous hydrostatic pressure and diminished arteriolar flow, or to an infarction of the pericapillary arterioles produced by embolization of residual air bubbles in the syringe or of orbital fat embolus mobilized by the needle.

Peribulbar injections are not immune to serious visual complications. Permanent blindness with optic nerve atrophy following retrobulbar haemorrhage from posterior peribulbar anaesthetic injection has been reported.⁴⁰

Contralateral or bilateral amaurosis may complicate either retrobulbar^{69,74,140-142} or peribulbar¹⁴³ anaesthetic injections. The most probable mechanism is inadvertent injection into the optic nerve sheath with spread of anaesthetic to the optic chiasma, and thus blocking the opposite eye.^{74,141} Ahn and Stanley reported eight cases of apparent subarachnoid injection of local anaesthetic through the optic nerve sheath and subsequent spread to the parabrainsstem cisterns and the contralateral optic nerve sheath.¹⁴⁴ Their patients experience bilateral decrease in vision and ophthalmoplegia, and variable degrees of central nervous system symptoms and respiratory depression. All injections were given with the patients' gaze directed up and towards the contralateral side, as described by Atkinson. Sharp needles were used in six of the eight cases.

Brainstem anaesthesia

Brainstem anaesthesia is a potentially life-threatening complication of retrobulbar anaesthesia. The estimated incidence of brainstem anaesthesia complicating eye block anaesthesia is one in 350 to 500 patients.¹⁴⁵ The symptoms include various combinations of agitation, confusion, unconsciousness, difficulty in breathing or apnoea, cyanosis, numb throat, dysphagia, impaired hearing, hypertension, tachycardia, amaurosis in the contralateral eye, and severe shivering.¹⁴⁶⁻¹⁵¹ In most cases, the symptoms appear within two minutes, but may be delayed for a few minutes. Management is mainly supportive, and surgery can usually proceed with no further problems in most cases. If it is not recognised and managed properly, however, serious sequelae could result.

Respiratory arrest is a frequent presentation of brainstem anaesthesia complicating retrobulbar blocks.^{70,71,105,106,146,147,152} David and Mandel had no episode of respiratory depression in a series of 1600 consecutive peribulbar blocks.³⁸ In a prospective study, Wittenpenn *et al.* reported nine cases of respiratory arrest following 3123 retrobulbar anaesthesia, an overall incidence of 0.29%.¹⁵² A 50:50 mixture of 4% or 2% lidocaine and 0.75% bupivacaine was used together with hyaluronidase. The higher concentration of lidocaine gave a higher incidence of respiratory arrest (0.79% versus 0.09%). Rodman *et al.*, on the other hand, reported a 1.5% incidence of respiratory depressive episodes in 200 retrobulbar blocks using 0.75% bupivacaine as the sole anaesthetic agent, and no further episodes occurred after discontinuation of 0.75% bupivacaine as the sole agent.⁷¹ These authors believe the high lipid solubility of bupivacaine was responsible for the relatively high complication rate. Although systemic absorption of local anaesthetic occurs soon after retrobulbar anaesthesia injections, the serum concentrations are well below the levels of toxicity.^{152,153}

Most case reports claimed that neither cerebrospinal fluid nor blood was aspirated before the anaesthetic was injected. The onset of symptoms may be immediate as a result of intra-arterial injection,¹⁵⁴ or delayed up to ten minutes after completion of retrobulbar block.¹⁰⁶ Unconsciousness frequently accompanies apnoea. Heart rate and blood pressure changes are variable. The apnoea is usually self-limiting lasting a few minutes. Ventilatory support is essential before the patient regains adequate spontaneous breathing. There are usually no long-term residual effects when managed properly.

Most cases of reported brainstem anaesthesia were associated with retrobulbar injections with sharp needles while the patient's eye was positioned in the traditional Atkinson position. Two mechanisms have been proposed by which toxic concentrations of local anaesthetic agents gain access to the brain. Occasionally, inadvertent intra-arterial injection produces a retrograde flow through the ophthalmic artery and antegrade flow through the internal carotid artery to the thalamus and other midbrain structures.¹⁵⁴ Very high levels of local anaesthetic agents can reach the brain this way, and central nervous symptoms including respiratory arrest appear immediately. In most cases, the access route to the brain is by direct injection into the subarachnoid space.¹⁵⁵ This was demonstrated in a cadaver in which radiological examination showed contrast material injected into the dural sheath of the optic nerve could diffuse posteriorly along the subdural space to the brain stem surrounding the respiratory centre.¹⁵⁶ Furthermore, local anaesthetics were recovered from the cerebrospinal fluid in a patient who suffered

respiratory arrest after retrobulbar block.⁷⁰ Most of the reported cases of brainstem anaesthesia with respiratory arrest presenting two or more minutes after injection appeared to be due to entry of local anaesthetic into the brain stem via the CSF route. The presence of personnel trained in ventilatory support while performing ocular blocks cannot be over-emphasised.^{152,157}

Muscle complications

Ptosis, entropion and diplopia may occur after cataract surgery. Many, but not all, cases are due to needle insertion or anaesthetic injection.

LEVATOR APONEUROSIS DEHISCENCE: PTOSIS

Ptosis may be present in 6% to 13% of patients after cataract surgery, and is more common after local than general anaesthesia.¹⁵⁸⁻¹⁶⁰ Ropo *et al.* studied the incidence and duration of postoperative ptosis in 64 patients undergoing cataract surgery, one half having a 2-point peribulbar block and the other half having general anaesthesia.⁸² About 50% of patients in both groups demonstrated ptosis on the first postoperative day. The levator function returned to preoperative levels within four days in most patients irrespective of the type of anaesthesia.

The proposed mechanisms of postoperative ptosis include dehiscence or disinsertion of the levator aponeurosis,¹⁵⁸ trauma to the superior rectus muscle complex caused by bridle suture,¹⁶¹ trauma to the eyelid by rigid speculum,¹⁶² and myotoxicity of local anaesthetic agents.¹⁶³ The volume of the local anaesthetic mixture injected may also play a part.

CAPSULOPALPEBRAL FASCIA DEHISCENCE: ENTROPION

Permanent spastic entropion after cataract surgery as a result of dehiscence of the capsulopalpebral fascia may be caused by injection of anaesthetic and/or antibiotic or corticosteroid solutions into the eyelid and inferior cul-de-sac.¹⁶⁴

EXTRAOCULAR MUSCLE INJURY: DIPLOPIA

Transient diplopia after cataract surgery is common, asymptomatic sensory deviation having been unmasked by the optic correction.¹⁶⁵ Rainin and Carlson in 1985 drew attention to the association of diplopia and retrobulbar anaesthesia.¹⁶³ Subsequently, many cases of vertical diplopia due to inferior rectus muscle restriction following cataract surgery with retrobulbar anaesthesia were reported.¹⁶⁶⁻¹⁶⁸ In addition, superior rectus muscle overaction can result from transient postoperative weakness of the inferior rectus muscle, and presents as hypertropia which is worse in upgaze.¹⁶⁹ In these patients, a temporary paralysis or weakening of an extraocular muscle

led to a contracture or strengthening of the antagonist muscle.

Peribulbar injections have also resulted in extraocular muscle injury. Acquired Brown's syndrome with impaired superior oblique function from scarring within the trochlea and tendon sheath,¹⁷⁰ and superior rectus muscle overaction¹⁶⁹ have both been reported to follow peribulbar anaesthesia. Kushner described a patient who developed progressive vertical diplopia several weeks after peribulbar anaesthesia for cataract surgery, believed to be due to inferior rectus muscle inflammation from subconjunctival gentamicin injection.¹⁷¹

Based on the clinical data of 63 patients with strabismus presenting after cataract surgery, Hamed classified the aetiology into four categories: pre-existing disorders, disorders precipitated by prolonged occlusion by a cataract, disorders resulting from surgical or anaesthetic trauma, and disorders related to optical aberrations.¹⁶⁸ Surgical trauma was the presumed cause in 17 of the 63 patients. Seven patients who had undergone cataract surgery under retrobulbar anaesthesia presented with inferior rectus restrictive syndrome. Injury to the inferior rectus muscle during retrobulbar anaesthesia administration was the likely cause of this syndrome, and pain or persistent pressure was often elucidated during injection of the anaesthetic.¹⁶⁷ This syndrome is not seen in patients undergoing surgery with general anaesthesia.

Many mechanisms of injury to the extraocular muscles associated with cataract surgery and anaesthesia have been proposed. A popular one is the ocular myotoxic effect of the local anaesthetics.^{72,163} The absence of gross muscle dysfunction in the majority of cases is believed to be because only the superficial layers of muscle fibres of the extraocular muscles are involved. Symptoms of muscle damage occur when local anaesthetics are directly injected into the muscles. This hypothesis was based on the observation of severe pathological changes in rat extraocular muscles induced by lidocaine and bupivacaine. However, only mild morphological changes are seen in similar experiments on monkeys with extraocular muscles identical to those of humans.^{172,173} Other possible causes of muscle injury include trauma from bridle sutures, traction on neurovascular bundles, and inflammatory reaction to subconjunctival antibiotic injections. It is also likely that the injury is the result of direct penetration by the needle. Elevated tissue pressure leading to ischaemia, fibrosis and contracture may occur as a result of intramuscular haematoma from laceration of the anterior ciliary vessels, or from a large volume of anaesthetic solution injected inside the muscle. These changes are similar to those leading to Volkmann's ischaemic contracture.^{168,174} Muscle recession surgery may be required to correct the contracture.

Oculocardiac reflex

Oculocardiac reflex is a frequent complication during eye surgery with general anaesthesia. Traction on the extraocular muscles (especially the medial rectus) or conjunctiva, or pressure on the globe can trigger cardiac arrhythmias (most commonly sinus bradycardia) and hypotension. Asystole can occur.¹⁷⁵ The afferent fibres of this reflex run with the short or long ciliary nerves to the ciliary ganglion and then with the ophthalmic division of the trigeminal nerve to the gasserian (trigeminal) ganglion. The efferent fibres run with the vagus nerve. The incidence of cardiac arrhythmias due to oculocardiac reflex during eye surgery is as high as 58% to 82%.^{176,177} Strabismus surgery in children tends to be associated with a high incidence of this complication. Anticholinergic drugs such as atropine or glycopyrrrolate are commonly used as prophylaxis against this complication, but have not been consistently effective.

The oculocardiac reflex is rare during eye surgery with regional anaesthesia. Since the afferent pathway can be blocked by local anaesthesia, retrobulbar and peribulbar blocks have been used during general anaesthesia to prevent the oculocardiac reflex.¹⁷⁸ Early studies demonstrated that retrobulbar block could abolish severe ECG changes caused by the oculocardiac reflex.^{179,180} In one patient who developed severe bradycardia from the slightest pressure on the eyeball during general anaesthesia despite intravenous atropine, retrobulbar block was effective in preventing further episodes of bradycardia.¹⁸¹

However, the relationship between the oculocardiac reflex and regional anaesthesia is not clear. Meyers, with no supporting data, stated that the most common complication of retrobulbar block is the oculocardiac reflex,¹⁸² while most authors do not list this as a complication.^{19,183} The few authors who mentioned oculocardiac reflex as a complication of retrobulbar blocks quoted the paper by Berler.¹⁸⁰ In this paper, the reflex was induced by the block itself in one case, and was also evoked by pressure on the globe before or immediately after the block. It is unlikely that the reflex is a common complication of retrobulbar block. However, several theoretical mechanisms may account for its rare occurrence. The injection of local anaesthetics can stretch the orbital contents and thus stimulate the oculocardiac arc. The use of dull needles and fast injection may play a role. Another possibility is that vasovagal activity is mislabelled as oculocardiac reflex. When patients are prepared for eye blocks in the sitting position, vasovagal activity is frequently seen during the insertion of intravenous catheters or at the sight of a needle. Hamilton *et al.* reported no oculocardiac reflex during the blocks, after application of the orbital compression device or intraoperatively, and a 0.5 to 0.85% incidence of vasovagal activity in 12,000 procedures.¹⁹ At

the Vancouver General Hospital Eye Care Centre (VGH-ECC), we have experienced no oculocardiac reflex complications and a 0.75% incidence of vasovagal activity in 8,480 retrobulbar and peribulbar blocks over a five-year period from 1988 to 1992.

Retrobulbar and peribulbar blocks, however, are not totally reliable as prophylaxis against oculocardiac reflex. The blocks take a minute or two to block the reflex arc, and thus pressure on the globe immediately after blocking can stimulate the reflex. Inadequate blocks do not abolish the reflex.¹⁸⁰ In one study, peribulbar anaesthesia with eight to ten ml of 2% lidocaine without hyaluronidase was not effective protection against the reflex in patients, under general anaesthesia, whose medial rectus muscles were subjected to a one kg pull for 20 sec.¹⁷⁸ Cardiac rhythm changes secondary to the oculocardiac reflex can still occur.^{176,178,184} Two patients have been reported to be suffering from sinus arrest during traction of the extraocular muscles despite retrobulbar block and intravenous atropine.¹⁸⁵

Although cardiac rhythm changes resulting from the oculocardiac reflex are much less common during retrobulbar or peribulbar blocks than during general anaesthesia, they may not be totally abolished. Thus, cardiac rhythm monitoring is essential during local anaesthesia for eye surgery.

Retrobulbar versus peribulbar block

The choice of whether to use retrobulbar or peribulbar block is based on safety and effectiveness.

Safety

Serious complications of eye blocks are generally related to inadvertent penetration of the globe, the optic nerve or blood vessels. Although they may occur with either retrobulbar or peribulbar block, the intraconal placement of the needle in retrobulbar blocks increases the risks of such complications. However, their overall incidence is low.

As discussed previously, perforation of the globe occurs in less than 0.1% of ocular blocks. Although this complication occurs more often after retrobulbar injections, it can also occur with peribulbar injections.

Nicoll *et al.* reported a 0.27% incidence of complications attributable to direct spread of anaesthetic solution into the central nervous system in 6000 consecutive retrobulbar injections.¹⁸⁶ Davis and Mandel had no central nervous system complications in over 1600 peribulbar injections.³⁸ Hamilton *et al.* reported brainstem anaesthesia in eight patients (0.15%) and five (0.1%) moderate retrobulbar haemorrhages in 5235 retrobulbar blocks, and none in 5704 peribulbar blocks.¹⁹ On the other hand, computed tomography after peribulbar injection into ca-

daver orbits revealed intraconal and intracranial spread of radiopaque dye which was seen tracking along the optic nerve sheath in one case.¹⁸⁷ Respiratory arrest soon after peribulbar injections has occurred in experienced hands.⁸¹

Effectiveness

Effectiveness is judged by the ability of the block to provide analgesia, akinesia and optimal orbital pressure with the least discomfort to the patient and minimal delay for the surgeon.

Classical retrobulbar anaesthesia has a high rate of complete block, and is the standard with which other techniques are compared. Ocular analgesia is easy to obtain within a short time after both retrobulbar and peribulbar injections. However, akinesia takes a longer time and is more frequently inadequate after peribulbar injections. As the motor nerves enter the extraocular muscles from the inside, akinesia can be achieved sooner and with smaller volume after retrobulbar injection than peribulbar injection. Despite the computerised tomographic demonstration that anaesthetic solutions diffuse freely across the muscle "cone" irrespective of retrobulbar or peribulbar injection,¹² there are more failures in akinesia with extraconal injections than with classical intraconal injections.^{19,188} Since residual extraocular muscle function causes movement of the globe and increases IOP, supplemental injections are required, which mean additional risk to the patient.

Peribulbar anaesthesia produces adequate orbicularis akinesia, while retrobulbar anaesthesia often requires a separate facial nerve block which adds to the discomfort to the patient. The dual injection in the peribulbar technique does not necessarily increase the discomfort to the patient, as the globe should be numb after a couple of minutes, well before the second injection.

Generally, the smaller volume of anaesthetic used in retrobulbar anaesthesia requires only brief orbital compression. The larger volume injected in peribulbar anaesthesia produces a higher orbital pressure which requires a longer orbital compression time before the globe is ready for surgery.

In a prospective study of local anaesthesia in 99 patients for cataract surgery, peribulbar was shown to be better than retrobulbar anaesthesia in terms of pain during administration, perioperative discomfort, and perioperative complications.¹⁸⁹

Operators' Preference

The choice between retrobulbar and peribulbar anaesthesia is an issue of great controversy which at times may be quite emotional.¹⁹⁰⁻¹⁹³ A recent survey among the members of the American Society of Cataract and Refractive Surgery showed that retrobulbar is still pre-

ferred by a ratio of approximately 3 to 1.¹⁸⁸ In England and Wales, retrobulbar anaesthesia was used in 54%, peribulbar in 33%, and other techniques in 13% of cataract surgery done under local anaesthesia.¹⁹⁴ In Australia, 73% of 165 surgeons surveyed preferred retrobulbar injection, 22% preferred peribulbar injection and 5% used both.¹⁹⁵ In Calgary, Hamilton *et al.* over a period of four years, have gone full circle from retrobulbar to peribulbar and then to a customized block in which a retrobulbar injection is made if the initial peribulbar injection does not produce akinesia. Retrobulbar injection was required in nearly half of their cases. However, the block supplementation rate was only 1.6% compared with 24% when dual peribulbar block was used.¹⁹ A combined retrobulbar and peribulbar approach using a large volume of local anaesthetic has been shown to have an exceptionally high efficacy rate, as judged by akinesia and vitreous scores.¹⁹⁶

Variation of techniques

The terms retrobulbar and peribulbar indicate the location where the anaesthetic solution is deposited: either inside or outside the muscle cone. There are many variations in the techniques with which this is achieved. The variations include the position of the patient's eye; the gauge, sharpness and length of the needle; the location of entry, direction of advancement, and depth of penetration by the needle; and the type and volume of the anaesthetic mixture. To add to these are the care and experience of the operator. To compare the pros and cons of retrobulbar and peribulbar anaesthesia without taking into account these variations is being over-simplistic.¹⁹⁷ Sometimes, it may not even be clear whether or not an operator gives the type of block that he or she believes was being given – is it truly peribulbar or is it retrobulbar?⁶ Furthermore, a technique used may be assumed wrongly to be what another author has described.¹⁵⁷

Suggested approach

Peribulbar anaesthesia generally carries a lower risk of serious complications, and is the preferred technique in operating suites where anaesthetists are available to administer the blocks ahead of the scheduled surgical time. A longer time is required for orbital compression, and perhaps more frequent supplemental injections are needed. It may not be the ideal technique to use for the high volume, quick turn-over surgeons who administer the blocks themselves. Most surgeons still prefer the classical retrobulbar anaesthesia. In either situation, the anaesthetist is invaluable for monitoring the patient and for resuscitation when complications do occur.

Complications do occur in spite of meticulous care. However, they can be kept to the minimum if proper

techniques based on a clear understanding of the orbital anatomy and physiology are applied.

The role of anaesthetists

The constraints of medicare funding over the last few years have resulted in a shift from performing most ophthalmic surgery in the hospital with general anaesthesia, to day-care facilities with local anaesthesia. To some surgeons, this implies the end of involvement in patient care by anaesthetists.¹⁹⁸ Others, however, see the value and importance of anaesthetists' contribution to the overall care, including preoperative assessment, adjustment of medications, intravenous sedation, monitoring and management of life-threatening complications associated with eye blocks.^{5,6} It has been well documented that the incidences of systemic illness, such as hypertension, diabetes mellitus and drug allergy, are very high among cataract patients.^{199,200} Anaesthetists are best qualified to manage these problems in the perioperative period. Their contribution would reduce the potential postoperative complications and hospital admissions, with savings to the patient and insurer, both in cost as well as in time and convenience to the patient.⁶

In a recent editorial, Lichter argues that retrobulbar anaesthesia should be performed by ophthalmologists.²⁰¹ This argument was based on the reported higher incidence of globe perforations when retrobulbar injections were administered by anaesthetists or nurse anaesthetists.¹⁰¹⁻¹⁰³ Concerns were also raised regarding the knowledge of non-ophthalmologists of the orbital anatomy and physiology, and their ability to recognize and manage complications of globe penetration and haemorrhage. An examination of the three papers cited by Lichter reveals an interesting pattern. All 60 cases of retrobulbar haemorrhage, representing 1.7% of all retrobulbar injections, reported by Cionni and Osher,¹⁰³ were from a single nurse anaesthetist. In the report by Hay *et al.*¹⁰² one anaesthetist, who usually was involved in stand-by anaesthesia, was responsible for seven of the eleven globe penetrations, and ophthalmologists were responsible for the other four. In the paper by Grizzard *et al.*,¹⁰¹ 11 different anaesthesia persons were involved in the 12 ocular penetrations. Five different ophthalmologists were involved, and one ophthalmologist had six ocular penetrating injuries to his patients caused by five different anaesthetists. None of the anaesthetists had taken a formal course in eye block techniques. All had learned from the attending ophthalmologists, although some did augment this by watching videotapes and reading, and from other anaesthetists. It is interesting to note that Rinkoff *et al.* found that surgeons were responsible for 60% and nonophthalmologists for 40% of 50 reported cases of ocular penetration or perforation.¹⁰⁰ Since the number

of injections administered by ophthalmologists and non-ophthalmologists is not available, no conclusions can be made on who has the higher complication rate.

Kimble, from Birmingham, Alabama, reported one globe perforation associated with peribulbar injection administered by an anaesthetist who had performed over 4,000 retrobulbar injections and over 200 peribulbar injections without previous globe perforation.¹³⁰ Hamilton, an ophthalmic-anaesthetist from Calgary, reported only one globe perforation in a series of 12,000 cases, and this complication occurred during the early phase consisting of 3,595 retrobulbar blocks.¹⁹ Other serious complications were also low, with 0.07% brainstem anaesthesia, and 0.04% retrobulbar haemorrhage. At the VGH-ECC, there was no documented case of globe perforation in 8,480 retrobulbar and peribulbar blocks. There were eight cases (0.09%) of brainstem anaesthesia. Major neurological manifestations occurred in three, and minor neurological symptoms, consisting of sedation, agitation, confusion, or shivering in the other five. Surgery was cancelled in only one case because of brainstem anaesthesia. Retrobulbar or peribulbar haemorrhage occurred in 0.35%, all managed successfully with orbital pressure.

The low incidence of major complications in these series, with all ocular blocks performed by anaesthetists, demonstrates that anaesthetists can also acquire expertise in this area. The importance of the detail knowledge of orbital anatomy and physiology and meticulous care cannot be over-emphasized. The serious nature of potential complications must be stressed. To this end, cadaver dissection would be of great value for anyone learning eye block techniques.

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