Anatomy for ophthalmic anaesthesia

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Study of the anatomy of the orbit, its contents and surrounding structures allows the anaesthetist to understand how to insert needles within the orbit. Local anaesthetics may thereby be deposited in sites where they may spread to block sensory and motor nerves to provide anaesthesia and akinesia, without damaging the globe, blood vessels, lacrimal apparatus, muscles or the optic nerve and its coverings.

Traditional techniques of dissection fail to show structural relationships as they exist in the living. Newer methods of cadaveric orbital fixing and thick section examination, and CT and MRI scanning techniques have added to the ease of understanding the system of connective tissue septa supporting the globe within the orbit. These tissues allow extensive mobility and also divide the orbit into functional adipose compartments allowing distribution of injected local anaesthetic solutions to gain access to neural tissue.

In this review, the anatomy is described with reference to relevant drawings and diagrams and with the economical use of descriptive text. Excellent detailed texts are available for further study.

The bony orbit

Direct observation of the human skull provides the most valuable information on the pathway that a straight needle must follow, and the depth to which it may be inserted, to achieve a desired result. Each subject differs and observation of individual soft tissue and bony characteristics is essential. The dimension of the globe also varies (e.g. a large, short-sighted eye) and ultrasound biometry, performed routinely before cataract surgery, provides this dimension. The axial length (usually marked AL) is the dimension from the external corneal surface to the retina. Axial length of 26 mm or more denotes a large eye, dictating that great caution should be exercised to avoid globe puncture.

Each orbit is an irregular pyramid in shape with its base forming the orbital opening. Its axis is directed postero-medially towards the apex. The triangular roof is composed of the orbital plate of the frontal bone with a small portion of the lesser wing of the sphenoid bone posteriorly. At the posterior end is the optic foramen, which is the orbital opening of the optic canal (fig. 1).

The lateral wall is formed from the zygomatic bone and the greater wing of the sphenoid. The sphenoid portion of the lateral wall is separated from the roof by the superior orbital fissure, and from the floor by the inferior orbital fissure. The thin floor is composed mainly of the orbital plate of the maxilla, the zygomatic bone anteriorly and the palatine bone posteriorly. The medial wall is quadrangular in shape and is composed of the ethmoid centrally, surrounded by the frontal bone superiorly and anteriorly, the lacrimal bone inferiorly and anteriorly, and the sphenoid bone posteriorly. Of particular importance from the point of view of injection into the medial compartment are the positions of the anterior and posterior lacrimal crests between which lies the fossa containing the lacrimal sac.

The average adult orbital height measured at the entrance is 35 mm and the width 40 mm. The orbital depth measured from the hind surface of the eyeball to the apex is approximately 25 mm (range 12–35 mm). When considering the position of the needle point in relation to the apex, the relative angulations of the medial and lateral walls must be taken into account. If the length of the needle and axial length of the eyeball are known, and accepting that orbital wall angles are reasonably constant, accuracy of needle placement is achievable (fig. 2).

The angle between the lateral walls of both orbits is approximately 90° and the angle between the lateral and medial walls of one side is approximately 45°. It follows that the medial walls of the orbit are nearly perpendicular to the frontal plane. The orbital axis and visual axis (the position of the eye when in straight, or primary, gaze) do not coincide and the anaesthetist must be quite clear as to which one he or she is referring to when describing angles for insertion of needles.

Orbital openings and their contents

The optic canal transmits the optic nerve and the ophthalmic artery from the middle cranial fossa to the orbit. The superior orbital fissure carries the lacrimal, frontal, trochlear, oculomotor, nasociliary

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and abducent nerves, in addition to the superior ophthalmic vein. The annulus of Zinn divides the superior orbital fissure. The trochlear, frontal and lacrimal nerves enter the orbit above (outside) the muscle cone. The area within the annulus is termed the oculomotor foramen. The inferior orbital fissure contains the foramen rotundum transmitting the maxillary branch of the trigeminal nerve from the middle cranial fossa to the pterygopalatine fossa (fig. 3).

**Relations**

Above the roof are the frontal air sinuses anteriorly and the meninges and frontal lobe of the cerebral hemisphere. Inferior to the floor is the maxillary air sinus. The infraorbital nerve and blood vessels lie within the infraorbital canal. Laterally the orbit is related to the temporal fossa in its anterior portion and the middle cranial fossa containing the temporal lobe of the cerebral hemisphere and its investing meninges posteriorly. Medially, the orbital wall is related to the nasal cavity anteriorly, the ethmoid sinuses in the middle part and the sphenoid sinus posteriorly. The bony walls may be very thin in some individuals and needle penetration is possible.

**The globe**

The eyeball is situated in the anterior part of the orbital cavity closer to the roof than the floor and nearer the lateral than the medial wall. The position of the globe in relation to the orbital opening varies in normal individuals and with pathology (e.g. tumours or thyroid disease). The cornea has a radius of curvature of approximately 8 mm and the main portion of the globe has a radius of curvature of between 10 and 15 mm. The myopic eye is longer (see biometry above). Highly myopic eyes may develop staphylomata when the posterior globe is enlarged with thinning of the sclera. A staphyloma is a bulge in the wall of the globe posteriorly which includes choroid tissue. Other types and positions of staphylomata may occur. Eyes with posterior staphylomata are more susceptible to needle trauma.

The sclera is the fibrous layer of the eyeball and is present everywhere except in the cornea. In the adult it is about 1 mm thick posteriorly and thins to 0.6 mm at the equator and 0.3 mm adjacent to the insertions of the rectus muscles. The optic nerve penetrates the sclera posteriorly 1 or 2 mm medial to and above the posterior pole. The central retinal artery and vein accompany the optic nerve. Anterior, middle and posterior apertures transmit the anterior ciliary arteries, the vortex veins and the long and short ciliary nerves and vessels, respectively. The sclera is relatively tough but is pierced easily by sharp or blunt needles. The limbus forms the corneoscleral junction (fig. 4).

The uveal tract consists of the choroid, ciliary body and iris. The choroid is a thin coating deep to the sclera and has a rich vascular supply. Its
function is largely as a vascular nutritional source for the retina. Its circulation is also important in the control of intraocular pressure (IOP). This layer offers no significant resistance to penetration by a needle.

The retina is a thin transparent membrane lining the eyeball from the optic nerve to the ciliary body. The “visual” part of the retina extends anteriorly to approximately the points of insertion of the medial and lateral rectus muscles. The neural retina is attached firmly to the pigment epithelium at the optic disc and ora serrata but elsewhere attachment is weak. The layers normally remain attached because of negative pressure created by absorption of fluid between the two layers, the presence of viscous mucopolysaccharides and possibly an electrostatic force between the two layers. Separation may occur after trauma or degenerative changes. Penetration of the globe by a needle is likely to result in such detachment.

Support of the eyeball within the orbit

Normal dissection techniques destroy the fine structure of the orbital connective tissue. This supports the eyeball within the orbit while permitting smooth and extensive movement. Koornneef developed a technique of fixation of cadaveric orbits and thick sectioning to allow three-dimensional reconstruction to study the septa, their relationship to other orbital structures and to adipose tissue compartments. His accounts of the technique and findings are important reading for those concerned with orbital nerve block techniques (see recommended reading list).

Quoting Koornneef: “The study of serial thick (60 microns) histological sections reveals a highly complicated but orderly constructed connective tissue system within the orbit. Between this system adipose tissue compartments were present, built up in a comparable orderly fashion. In this intraorbital continuum, to which Tenon’s capsule, the so-called check ligaments, the fascial sheaths of the muscles and the periorbital membrane belong, other different areas of characteristic connective tissue septa originating from the fascial sheaths of the eye muscles are recognizable.” In the mid and posterior orbits, fatty tissue predominates whereas in the anterior orbit (from the equator to the hind surface of the globe) the septa are more dense. The cone is the space contained within the rectus muscles between the annulus posteriorly and the hind surface of the eye anteriorly. Septa exist inside the cone which support vascular structures. At no time did Koornneef demonstrate complete septal barriers between the extraocular muscles separating the space within the cone from that without. This is highly significant when considering spread of local anaesthetic solutions. Of equal importance is the division of the orbit into compartments of loose fatty tissue within which solutions will spread freely. Sections also demonstrate the spacial anatomy of the orbit (confirmed by CT and MRI scanning) and routes for access to the compartments which are relatively devoid of structures at risk from needle puncture (fig. 5).

Extraocular muscles

The combined actions of the four rectus and two oblique muscles on each eyeball allow elevation, depression, adduction and abduction. Intortion is otherwise termed inward or medial rotation, and
extortion may be termed external or lateral rotation. Under normal circumstances unmodified activity of one muscle is rare but testing individual muscle function becomes necessary after neural block to identify the unblocked nerve when akinesia is incomplete (fig. 6).

The superior rectus muscle arises from the annulus of Zinn passing forwards and laterally to be inserted into the sclera about 7.7 mm behind the corneoscleral junction. The muscle is innervated by the superior division of the oculomotor nerve which enters the inferior (intraconal) surface of the muscle. The inferior rectus muscle arises from the annulus below the optic foramen and passes forward and laterally to insert into the sclera approximately 6.5 mm from the corneoscleral junction. It is innervated by the inferior division of the oculomotor nerve entering the muscle on its superior (intraconal) aspect. The lateral rectus muscle runs from the lateral part of the tendinous ring (there is a smaller head arising from the sphenoid a little laterally) and inserts into the sclera about 6.9 mm from the corneoscleral junction. It is innervated by the abducent nerve on its intraconal aspect. The medial rectus passes from the medial aspect of the annulus along the medial orbital wall inserting into the sclera about 5.5 mm from the limbus with innervation from the inferior division of the oculomotor nerve entering its intraconal surface.
The superior oblique muscle is long and slender, arising from the body of the sphenoid bone superomedial to the optic canal. It runs forward and its long tendon passes through the trochlea attached to the trochlear fossa of the frontal bone. The tendon then passes downwards, backwards and laterally, passing inferior to the superior rectus muscle to be inserted posterior to the equator of the eyeball. It is innervated by the trochlear nerve which enters the muscle superiorly (outside the cone). The inferior oblique muscle originates, uniquely, from the front of the orbit, arising from the floor posterior to the orbital margin and just lateral to the nasolacrimal duct. It passes laterally, posteriorly and superiorly, to pass inferiorly to the inferior rectus muscle to insert into the sclera at the posterolateral aspect of the eyeball. The inferior oblique is innervated by the inferior division of the oculomotor nerve.

If the trochlear nerve is unblocked, superior oblique action is spared and intorsion of the eyeball occurs if the patient is asked to look downwards, as the motion is not balanced by inferior rectus activity. The spatial anatomy of the extraocular muscles and their relationship to the orbital walls in the anterior, mid and posterior orbits are shown in figure 7.

Nerves

Figure 8 shows the origins and passage of the principal nerves of the orbit. The motor supply has been discussed. A simple aide-mémoire is by the pseudo-formula \( \text{LR}_6(\text{SO}_4)_3 \) — lateral rectus by the sixth (abducent) cranial nerve, superior oblique by the fourth cranial nerve (trochlear) and the remainder by branches of the third (oculomotor) nerve (table 1).

Injection of local anaesthetic solution into the lateral adipose compartment from inferotemporal needle insertion normally blocks the nasociliary, lacrimal, frontal, supraorbital and supratrochlear branches of the ophthalmic division of the trigeminal nerve and the infraorbital branch of the maxillary division.

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<tr>
<th>Table 1</th>
<th>Summary of sensory nerve supply</th>
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<td>Short ciliary nerves</td>
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<td>Supraorbital nerve</td>
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<td>Lateral</td>
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<td>Lacrimal nerve (with contribution from zygomaticofacial nerve)</td>
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<td>Circumcorneal</td>
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<td>Long ciliary nerves</td>
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<td>Lacrimal</td>
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**Figure 8**  
A: Nerves within the right orbit viewed from above—muscle cone intact.  
B: Nerves within the right orbit viewed from above with the levator, superior rectus and part of the superior oblique muscles removed.  
C: Nerves within the right orbit—lateral aspect.
Injection into the medial compartment through a needle placed between the caruncle and the medial canthal angle usually blocks the medial branches of the nasociliary nerve, the long ciliary nerves, the infratrochlear nerve and the medial components of the supraorbital and supratrochlear nerves.

If a supplementary injection is required superiorly, it is important to note that the superomedial approach almost inevitably brings the needle into contact with a path congested with nerves, blood vessels and muscles. A superolateral approach avoids this but must be made through the skin of the upper lid as the relevant area of conjunctiva is inaccessible.

**Blood vessels**

The main arterial supply to the globe and orbital contents is from the ophthalmic artery which is a branch of the internal carotid artery and passes into the orbit through the optic canal inferolateral to the optic nerve and within the meningeal sheath of that nerve. The artery pierces the sheath to lie outside it as soon as it enters the orbit. Its course within the orbit is shown diagrammatically, as are its major branches. The early intraorbital course of the ophthalmic artery takes it superior to the optic nerve and inferior to the superior rectus muscle towards the medial wall of the orbit from whence it runs anteriorly above the medial rectus muscle. In the elderly and hypertensive patient it is tortuous and vulnerable to needle trauma when it bleeds profusely (fig. 9).

Venous drainage is via the superior and inferior ophthalmic veins. The superior vein arises deep to the medial part of the upper eyelid from the confluence of the supraorbital and facial veins. It passes posteriorly within the orbit receiving branches corresponding to those of the ophthalmic artery. It leaves the orbit through the superior orbital fissure within the annulus fibrosus. The inferior ophthalmic vein arises from a venous plexus on the anterior part of the floor orbit: it passes posteriorly on the inferior rectus muscle passing through the inferior part of the superior orbital fissure draining into the cavernous sinus.

**Eyelids, levator palpebrae superioris and orbicularis muscles**

The eyelids protect the eye from injury and excess light and distribute tear fluid over the anterior surface of the eyeball. It is necessary to maintain proper closure of the unoperated eye during general anaesthesia and to block sensory and motor function of the operated eye during local anaesthesia.

It may be seen from figure 10 that from the external surface inwards, the tissue layers encountered are skin, subcutaneous tissue, striated muscle bundles of orbicularis oculi, orbital septum and tarsal plate, and conjunctiva. The upper lid contains the insertion of the levator palpebrae superioris muscle.

Skin texture usually permits easy passage of sharp injection needles but in elderly patients elastic tissue is degenerate and blood vessels are fragile, explaining the unsightly and embarrassing haematomata that occasionally follow. Sensory innervation is described above.

The orbicularis oculi muscle is a flat elliptical muscle surrounding the orbital margin and extending into the lids and onto the temporal region and cheek. It is composed of voluntary (striated) muscle. Fibres arise from the medial palpebral ligament and adjacent bone and pass laterally through the lids in front of the orbital septa—in other words, they are very superficial. Innervation is from the temporal and zygomatic branches of the facial nerve which enter the deep surface of the muscle from the lateral side. Although the orbital part of the muscle is under voluntary control, it may act reflexly when threat to the eye demands its protective activity. The palpebral part effects reflex blinking. The muscle is also important in dilating the lacrimal sacs and providing a pumping action for tear drainage which also promotes passage of topically applied drugs towards the nasal mucosa hastening systemic absorption. Prolonged paralysis from local anaesthesia leaves the eye vulnerable to drying and trauma.
Levator palpebrae superioris is a strong striated muscle inserted as an aponeurosis, much wider than the muscle belly, into the upper lid deep to the orbital septum. The muscle arises from the inferior surface of the lesser wing of the sphenoid above the optic canal. The superior tarsal muscle is a thin sheet of smooth muscle inserted into the tarsal plate arising from the inferior surface of the aponeurosis of levator. The main striated muscle is innervated by the superior branch of the oculomotor nerve; the smooth muscle component receives sympathetic nerves from the superior cervical ganglion.

Levator raises the upper lid; sympathetically stimulating experiences result in contraction of the smooth muscle element. It is observed clinically that in a patient under general anaesthesia, the lid of an eye that has been instilled with sympathomimetic drugs (such as phenylephrine) demonstrates lid elevation relative to its untreated partner; this results from pharmacologically induced contraction of the smooth muscle element.

The orbital septum and tarsal plates are important structures in respect of needle insertion. The orbital septum is a membranous sheet and is thin, especially in the elderly, and is almost vestigial in some individuals. It is incomplete, as may be seen during dissection; areas of fat herniate from the deep surface into the preseptal space. Local anaesthetic solutions placed deep to the septum flow through the deficiencies to block the orbicularis muscle. The septum is attached to the orbital margins and is continuous with the periosteum and periorbita. Within the lids the septa are thickened to form the dense fibrous tarsal plates which afford the eyelids their shape and firmness.

Lacrimal apparatus

The lacrimal gland has orbital and palpebral components. The orbital part lies in the lacrimal fossa on the anterolateral aspect of the orbital roof, and the palpebral part is situated below the levator palpebrae superioris aponeurosis and extends into the upper eyelid secreting tear fluid into the superior conjunctival fornix. It is innervated by autonomic and sensory nerves via the zygomaticotemporal and lacrimal nerves.

Lacrimal drainage occurs through superior and inferior lacrimal puncta near the medial ends of both lid margins which form entrances to the 10-mm long lacrimal canaliculi medially passing through the lacrimal fascia to enter the lacrimal sac (fig. 11), situated in the lacrimal fossa in the anterior part of the medial wall of the orbit. The sac is enclosed in the lacrimal fascia which is attached posteriorly to the posterior lacrimal crest and anteriorly to the anterior lacrimal crest. The nasolacrimal duct connects the inferior end of the lacrimal sac to the inferior meatus of the nose.

A needle placed in the cul-de-sac between the caruncle, the small pinkish body in the triangular lacus lacrimalis at the medial angle of the eye, and the canthal angle and directed 45° posteriorly is both lateral and posterior to the lacrimal sac and between the canaliculi, avoiding damage to either structure.

Summary and clinical significance

The anatomical features of the orbit permit the passage of needles into fibre-adipose compartments in the mid orbit avoiding close contact with the globe, major blood vessels, extraocular muscles and the lacrimal apparatus. From these compartments, local anaesthetic solution usually spreads to block sensory nerves to all structures within the orbit and the lids, and motor nerves to the extraocular muscles, orbicularis and levator palpebrae superioris.

In summary, there are no complete septa between the extraocular muscles behind the eyeball in the mid orbit to separate physically an intraconal space from an extraconal space. Orbital and globe dimensions vary in health and disease and careful observation is required before every block. The superomedial part of the orbit contains vessels, nerves and muscles with little available space for safe needle passage.

Acknowledgement

Illustrations drawn by Alexander James are from Johnson RW, Forrest FC. Local and General Anaesthesia for Ophthalmic Surgery. Oxford: Butterworth-Heinemann, 1994, with permission from the publisher and authors.
Recommended reading
