

# A Clinical Review of Orbital Anatomy and Its Relevance to Retrobulbar Anaesthesia

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## Abstract

Knowledge of the anatomy of the body is essential when carrying out invasive procedures. The orbital anatomy is particularly interesting as it allows some neurovascular structures to be subjected to the effects of local anaesthetic while sparing others. There are also serious potential complications from retrobulbar injections. This review takes an in depth look at the anatomy of the orbit, the technique of retrobulbar injections, complications, and management of retrobulbar haemorrhage.

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**Categories:** Anesthesiology, Ophthalmology, Neurosurgery

**Keywords:** orbit, anatomy, anaesthesia, retrobulbar haemorrhage, retrobulbar anaesthesia

## Introduction And Background

The aim of retrobulbar anaesthesia is to provide safe, painless, efficient, and effective local anaesthesia by infiltrating the intraconal space [1-4]. The advantages of the technique is rapid onset of analgesia and akinesia with the use of relatively small volumes of anaesthetic [3, 5].

Because the needle is inserted blindly, adverse events, including scleral perforation, haemorrhage, and injection of anaesthetic agent into the perioptic meningeal space, may occur [3]. As a result, knowledge of the anatomy of the intraorbital structures is important when carrying out such an invasive procedure.

## Review

### The anatomy of the orbit

The orbit is shaped as a four-sided pyramid that has three sides near the posterior apex directed medially and upwards to the superior orbital fissure. The eye sits in the anterior orbit closer to the roof and lateral wall. The lateral orbital rim is approximately at the level of the eye's equator, with its maximum dimension 1cm behind the orbital rim corresponding to the widest point of the orbital cavity. The orbit cavity volume is approximately 30ml, and the dimensions of the orbital rim are 40mm horizontally, 35mm vertically, 45 to 50mm from the anterior lacrimal crest, and 40mm from the lateral rim to the superior orbital fissure [2, 6]. The globe has a volume of 7ml, occupying 1/5 of the cavity. The diameters of the globe are 24mm anterior-posterior, 23mm vertical and 23.5mm horizontal [6-8].

The seven bones forming the orbit include the maxilla, palatine, zygomatic, sphenoid, frontal, ethmoid, and lacrimal bones. They develop from neural crest cells and are present by the third month of gestation. Ossification is completed by birth, except at the orbital apex [8]. The lesser wing of sphenoid is initially cartilaginous, whereas the other bones develop by intramembranous ossification and enlargement of the orbit relies on the growth of the eyeball [8].

The apex of the orbit communicates with the intracranial cavity via the optic foramen and superior orbital fissure, and the pterygopalatine fossa and ganglion via the posterior part of the inferior orbital fissure. In this small space, many important neurovascular structures pass into the orbital cavity and are acutely susceptible to compression [6].

The periorbita is the periosteum of the bones and is derived from the mesodermal layer of the embryonic eyelid, continuous with the orbital septum via the arcus marginalis of the eyelids. It receives its sensation from the trigeminal nerve branches in the orbit. It is loosely attached to the bones allowing the accumulation of blood, pus and tumour. At the foramina, sutures, arcus marginalis, trochlear fossa, lateral tubercle, anterior lacrimal crest, and the dural sheath of the optic nerve, it is firmly attached [8]. The periorbita is continuous with the endosteal layer of the dura mater at the superior orbital fissure, optic and anterior ethmoidal canal and splits at the lacrimal groove to enclose the sac and forms the periosteum of the canal. It also encloses the lacrimal gland in the lateral orbital roof [8].

At the optic canal and medial end of the superior orbital fissure, the periorbita forms the annulus of Zinn, to surround and form the origin of the four rectus muscles (Figure 1) [2, 8]. This fibrous ring separates the

Review began 11/05/2012

Published 02/21/2013

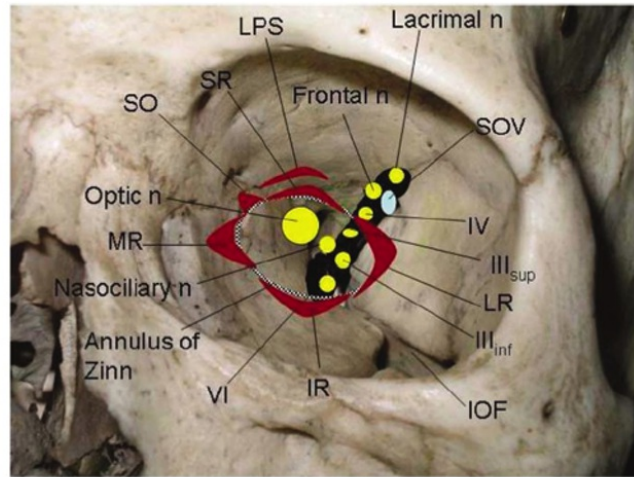
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### How to cite this article

McAllister A S (February 21, 2013) A Clinical Review of Orbital Anatomy and Its Relevance to Retrobulbar Anaesthesia. Cureus 5(2): e97. DOI 10.7759/cureus.97

fissure into intraconal and extraconal spaces. The lacrimal, frontal and trochlear nerves from the ophthalmic division of the trigeminal nerve pass outside of the annulus of Zinn in the fissure's superior narrower portion. The nerves passing within the annulus of Zinn and susceptible to retrobulbar anaesthesia include the optic nerve, superior and inferior divisions of the oculomotor nerve, the abducens nerve, and nasociliary branch of the ophthalmic trigeminal nerve. The orbital fat cushions these structures, aids in movement, and complex fibrous septae from Tenon's capsule around the globe to the periorbita divides the orbital fat [8].



Anatomy of the left orbital apex, highlighting the extraocular muscle origins and the contents of the superior orbital fissure. Key: LPS, levator muscle; SR, superior rectus; LR, lateral rectus; IR, inferior rectus; MR, medial rectus; SO, superior oblique; SOV, superior ophthalmic vein; III<sub>sup</sub>, superior division of oculomotor nerve; III<sub>inf</sub>, inferior division of oculomotor nerve; IOF, inferior orbital fissure.

### FIGURE 1: The left orbital space describing the extent of the annulus of Zinn and surrounding structures

The inferior orbital fissure in the lateral orbital wall and floor is extraconal and contains the maxillary division of the trigeminal nerve, its branch the zygomatic nerve, branches from the pterygopalatine ganglion, and branches of the inferior ophthalmic vein leading to the pterygoid plexus. The maxillary trigeminal nerve and terminal branch of the internal maxillary artery continue in the infraorbital groove 3cm posterior to the orbital rim through the canal to exit at the infraorbital foramen as the infraorbital nerve and artery [8]. The zygomatic branch divides into the zygomaticotemporal and zygomaticofacial nerves, and with their vessels pass through their foramina in the lateral orbit to terminate in the cheek and temporal region respectively; the former carries the parasympathetic fibres from the sphenopalatine ganglion to the lacrimal gland [8].

The optic nerve and ophthalmic artery enter the orbit at 45° medially and 15° upwards through the optic foramen in the lesser wing of the sphenoid [6, 8]. The optic nerve is surrounded by cerebrospinal fluid within the dural layers and is continuous with the posterior periorbita at the optic foramen. From the optic foramen to the orbit is 18mm, with the nerve having a convex curve between the two structures and measuring 25mm in total length. The residual 7mm allows freedom of eye movement and reduces damage to the nerve in proptosis [8].

The nerves innervating the extraocular muscles enter on the ocular surface at the junction of the posterior third and anterior two-thirds of the muscle. The medial, inferior recti and inferior oblique are innervated by the inferior division of the oculomotor nerve; the superior rectus and levator palpebrae superioris are innervated by the superior oculomotor division; the superior oblique is innervated by the trochlear nerve; and the lateral rectus is innervated by the abducens nerve [8].

Separation of the oculomotor nerve into the superior and inferior divisions occurs in the anterior cavernous sinus posterior to the annulus of Zinn. The superior division innervates the inferior surface of the superior rectus and then terminates in the levator palpebrae superioris. The inferior division innervates the medial and inferior rectus, and a terminal branch runs laterally along the inferior rectus to the inferior oblique as it crosses the rectus where it is susceptible to iatrogenic injury [6]. This nerve supplies a parasympathetic branch to the ciliary ganglion to innervate the ciliary body and iris sphincter [8]. The short ciliary nerves carry these fibres, with sympathetic and sensory branches, from the ciliary ganglion to the globe. The ganglion is often adhered to the lateral aspect of the optic nerve and is 15mm posterior to the globe [8]. The trochlear nerve is extraconal and supplies the superior oblique, crossing the orbital cavity lateral to medial, entering the muscle laterally. The abducens nerve is intraconal and travels along the medial surface of the

lateral rectus before entering the muscle [6].

The sensory ophthalmic division of the trigeminal nerve divides in the lateral wall of the cavernous sinus and enters the orbit via the superior orbital fissure as the lacrimal, frontal and nasociliary nerves. The lacrimal nerve joins the lacrimal artery and travels to the lacrimal gland to divide into superior and inferior branches. The gland, conjunctiva and lateral upper eyelid are supplied by the superior branch. The inferior branch joins with the zygomaticotemporal branch of the maxillary trigeminal nerve where it receives parasympathetic fibres to supply the lacrimal gland [8]. The frontal branch divides anteriorly to become the supratrochlear and larger supraorbital nerves that provide sensation to the medial canthus, upper eyelid, brow, and forehead [8]. These two branches are not affected by retrobulbar anaesthesia, whereas the nasociliary branch is within the annulus of Zinn, passing from lateral to medial over the optic nerve with the ophthalmic artery to go between the superior oblique and medial rectus. The nerve branches into the long and short ciliary nerves to supply sensation to the globe, the latter passing through the ciliary ganglion; and the anterior and posterior ethmoidal nerves supplying the mucosa of the nasal passages via their respective ethmoidal foramina at the frontoethmoidal suture along with their arterial branches from the ophthalmic artery. The terminal infratrochlear branch from the anterior ethmoid nerve supplies the tip of the nose and can be involved in herpes zoster ophthalmicus, called Hutchinson's sign [8].

The path of the sympathetic supply through the orbit is not clear, entering through the superior orbital fissure and into the ciliary ganglion for pupillary dilation, smooth tarsal muscles of the eyelids, and vasoconstriction [8].

All the muscles, except the inferior oblique, arise from the orbital apex at the annulus of Zinn. The levator palpebrae superioris and superior oblique muscles are more superomedial and originate from the lesser wing of sphenoid [6].

The extraocular muscles are covered by a muscular fascia which forms check ligaments anteriorly, enter tunnel-like openings through Tenon's fascia to attach to the sclera on the anterior globe in a configuration called the spiral of Tilleux. The medial rectus inserts the closest to the limbus, 5.5mm posteriorly [6].

The lateral rectus is separated from the lateral orbital wall by fat. Between it and the optic nerve is the site of deposition of a retrobulbar injection where the ciliary ganglion the nerves entering the orbit lie [6]. The lateral rectus check ligament is the strongest and inserts on Whitnall's lateral orbital tubercle located 4-5 mm behind the lateral orbital rim and 1 cm inferior to the frontozygomatic suture. Here, the lateral canthal tendon, lateral rectus check ligament, lateral horn of the levator aponeurosis, the suspensory ligament of the lower lid (Lockwood's ligament), the orbital septum, and the lacrimal gland fascia attach. The medial rectus check ligament mainly inserts behind the posterior lacrimal crest [8].

The superior oblique courses from the annulus of Zinn anteriorly along the superomedial orbital wall. Between it and the medial rectus are the ethmoidal branches of the nasociliary nerve and ophthalmic artery [8]. The superior oblique forms its tendon before it reaches the trochlear in the anteromedial orbital roof, 5-10mm behind the orbital rim in a shallow fossa, formed from cartilage from the periorbita. Here, it makes a 54° angle to pass under the superior rectus posterolaterally and insert on the globe [9]. Its action is to depress, intort, and abduct the eye.

The inferior oblique originates from periorbita at the anteromedial orbital floor lateral to the lacrimal fossa, passing between the central and medial fat pads of the lower eyelid with its arcuate expansion of fascia dividing the lateral and central fat pads. It enters the orbit under the inferior rectus muscle posterolaterally which radiates fibrous septae to the inferior periorbita. The fascia of the two muscles forms the suspensory ligament of Lockwood before it continues as the capsulopalpebral fascia and lower lid retractor complex. With the check ligament of the lateral rectus and lateral horn of the levator aponeurosis, they fuse with the lateral canthal tendon [8].

The ophthalmic artery is the first large branch from the internal carotid artery as it emerges from the cavernous sinus. It passes within the optic canal into the intraconal space inferolateral to the optic nerve within the dural sheath, supplying the nerve with pial branches. In 90% of orbits, it crosses the nerve to course medially, 80% of which are above the nerve. There is significant variability in the order in which the artery gives off its branches. The central retinal artery branches from the ophthalmic artery approximately 10mm from posterior surface of the globe and enters the optic nerve ventrally. The other branches of the ophthalmic artery include the lacrimal, supraorbital, ethmoidal, posterior ciliary arteries, two long posterior ciliary arteries, and the muscular arteries to the extraocular muscles. Terminal branches of the ophthalmic artery leave the medial orbit as the supratrochlear, dorsal nasal, and medial palpebral arteries [8].

Blood supply to the extraocular muscles is from the medial and lateral muscular branches of the ophthalmic artery, lacrimal artery and the infraorbital artery. The rectus muscles receive two anterior ciliary arteries, except the lateral rectus which has one, that communicate with the major arteriole circle of the ciliary body [2, 8]. The lateral rectus also receives blood supply from the lacrimal artery.

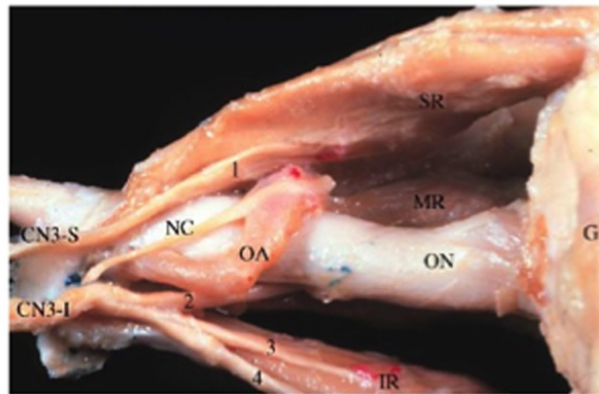
There are significant anastomoses between the external carotid system and the internal carotid system. The recurrent meningeal branch of the middle meningeal artery may enter a foramen at the suture between the frontal and sphenoid bones and join lacrimal branch of the ophthalmic artery. Likewise, the maxillary artery has branches to the orbital fat and communicates with the muscular arterial branches of the inferior rectus and inferior oblique [6, 8].

Venous drainage via valveless superior and inferior ophthalmic veins, which receive tributaries from the muscular, vortex, medial, and lateral collateral veins, are variable and lie in the connective septa of the orbit. The superior ophthalmic vein is the largest, forming superomedially near the trochlear from the angular, supraorbital, and supratrochlear veins to exit at the superior orbital fissure into the cavernous sinus via three parts. In order, it passes along the medial border of the superior rectus, posterolateral under the superior rectus into the muscle cone, and posteriorly along the lateral border of the superior rectus to enter the upper part of the superior orbital fissure outside the annulus of Zinn [6]. The inferior ophthalmic vein is more variable and starts anteriorly in the inferomedial orbital fat, along the inferior rectus and usually into the superior ophthalmic vein. It also communicates with the pterygoid plexus via the inferior orbital fissure [6].

The orbit is traditionally thought to have no lymphatic drainage in the extraocular muscles or orbital fat. A superficial preorbicularis muscle and deep pretarsal plexus is present and does not interconnect with the upper and lower eyelids [8].

### Structures most at risk of trauma from retrobulbar anaesthesia

Retrobulbar injections involve a 35mm 25-gauge needle with 2-3ml of anaesthetic passing through the facial skin or conjunctiva at the inferolateral orbit between the globe and lateral wall. It pierces the orbital septum, the lateral rectus muscle, and at full depth lies behind the globe between the lateral rectus muscle and optic nerve in the intraconal space (Figure 2) [2-3, 5, 10-15].



Lateral view of the right retrobulbar orbit. The superior division of the oculomotor nerve (CN3-S) supplies a branch (1) to the superior rectus and levator palpebrae superioris muscles, whereas the inferior division of the oculomotor nerve (CN3-I) supplies branches to the medial rectus (2), inferior rectus (3), and inferior oblique muscles (4). The nasociliary branch of the ophthalmic trigeminal nerve (NC) and the ophthalmic artery (OA) cross over the optic nerve (ON) from lateral to medial to subsequently course the medial orbit. G, globe; IR, inferior rectus; MR, medial rectus; SR, superior rectus muscle.

**FIGURE 2: Lateral view of the right orbit and the structures at risk of trauma from retrobulbar injections**

The Atkinson technique [16] has the patient looking up, backward and slightly inward to move the inferior oblique muscle and fascia between the lateral and inferior rectus muscles out of the way to direct the needle toward the apex of the orbit. Trauma occurs mostly to the optic nerve, which is stretched and more easily punctured, the ophthalmic artery, superior ophthalmic vein, and posterior portion of the globe [15]. A safer technique is for the patient to be in primary gaze or look down to direct the needle toward the inferior part of the superior orbital fissure [17].

Serious local and systemic complications are very rare with no statistical differences in the efficacy and safety between retrobulbar and peribulbar injections. In the literature, retrobulbar haemorrhage after injection has been described once in 1,438 participants over six trials [3, 18]. Retrobulbar and subperiosteal haemorrhage causes proptosis, firmness of the globe, subconjunctival haemorrhage, and discolouration of

the conjunctiva, usually in the lower fornix [2, 19]. Pain is not a feature as the eye is anaesthetised. The resulting increased orbital and intraocular pressure result in ischaemia to the anterior optic nerve over the watershed zones of the paraoptic short posterior ciliary arteries, angle-closure glaucoma, compression of the optic nerve, and central retinal artery. This causes permanent visual loss if surgical decompression does not occur within 90 minutes [13, 19-21].

Bleeding from the extraocular muscles and palsies can occur and is increased if the needle is reinserted [2, 19]. The risk of conjunctival chemosis is 7.1%, and the risk of lid haematoma is 7.3% [3]. The possibility of persistent ptosis is 1.3% with no difference compared to peribulbar injections, which are delivered outside of the muscle cone, requires a larger volume of anaesthetic (average 8.3ml) and has a slower onset [3].

Perforation of the globe and scleral rupture, as well as damage to the optic nerve causing atrophy, has been recorded [19]. Puncture of the meningeal sheath around the optic nerve and injection of anaesthetic into the subdural or subarachnoid space can cause contralateral blindness and extraocular muscle paralysis, hearing loss, throat numbness, swallowing difficulty, diaphragmatic paralysis, hypertension, and tachycardia from vagus and glossopharyngeal nerve inhibition, drowsiness, general paresis, apnoea, sensory loss, and unconsciousness as the anaesthetic spreads to the chiasm, mid-brain and encephalic bridge [2, 10, 14]. Apnoea and unconsciousness was described in three patients from a series of 1,500 retrobulbar injections lasting for up to 20 minutes [14]. Injection into the ophthalmic artery and entry of anaesthetic to the CNS via the carotid artery may also occur [10].

### Structures subject to therapeutic effect

A successful block paralyses the intraconal nerves including the oculomotor and abducent nerves. Thus, all extraocular muscles, except the superior orbital oblique supplied by the trochlear nerve, are anaesthetised resulting in the eye becoming depressed, intorted and abducted. The ciliary ganglion is also affected, causing the pupil to dilate as the constrictor pupillae is supplied by the parasympathetic fibres in the ciliary ganglion and short ciliary nerves. The globe will be anaesthetised due to blocking of the nasociliary nerve. The effect on the optic nerve is variable due to its meningeal coverings, with vision maintained or substantially affected [2].

Fibrous septae in the orbital fat can inhibit diffusion of anaesthetic, which can be overcome using hyaluronidase in the solution to hydrolyse connective tissue mucopolysaccharides [2]. Adrenaline can be added to the solution to reduce systemic absorption of the anaesthetic, constrict the blood vessels and said to reduce the risk of retrobulbar haemorrhage [14]. After injection, gentle massage of the globe allows spread of the anaesthetic [2].

### Management of vascular injury

Management of retrobulbar haemorrhage is through decompression of the orbit by lateral canthotomy and inferior cantholysis [19, 22]. This is followed by septolysis, which opens the orbital septum at the base of the cantholysis with a pair of surgical scissors [22]. Using all three steps reduces ocular pressure by 70% and intraocular pressure by 58.7%; however, this effect is short-lived if bleeding and intraocular hypertension continues [22]. In this case, an anterior orbitotomy and drainage is necessary and is the definitive treatment to evacuate haematoma (particularly, if subperiosteal) and to ligate or cauterise bleeding vessels [19, 22].

If surgical decompression cannot be immediately carried out, initial medical treatment of intravenous mannitol 20% 2g/kg six hourly, acetazolamide 250 mg six hourly and methylprednisolone 250 mg six hourly is recommended [20].

## Conclusions

Knowledge of the anatomy of the orbit is important to understand the technique and risks of retrobulbar anaesthesia, as well as structures that are subject to therapeutic effect. The rates of severe local and systemic complications from retrobulbar anaesthesia are very rare [3]. Direct ocular trauma and vascular and neurological insult have been described, resulting in localised mass effect compromising the orbital structures or causing central anaesthesia, respectively. It is therefore necessary to know how to manage these complications if they arise.

## Additional Information

### Disclosures

**Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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