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Anatomy of the Orbit and its Surgical Approach

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With 16 Figures

Contents

Abstract

A micro anatomical and surgical study of the orbit was conducted on cadaver specimens. First of all we reviewed the anatomy of the orbit with special emphasis on microanatomical structures. Three neurosurgical approches are then described with all structures encountered along these routes. The superior approach which provides a good access to the superior part of the orbit is the only route which can explore all parts of the optic nerve even in the optic canal. The lateral compartment of the orbit could be exposed by the lateral approach above or below the lateral rectus muscle. It is the only route that could give access to the inferior part of the orbit. The supero lateral approach is the largest route and has advantages of the two preceding routes. It gives access to the superior part of the orbit but not the optic canal and gives also a good exposition to the lateral part of the orbit but less than the lateral route in the inferior part. These approaches could be used to remove all intra orbital lesions apart from those located in the infero medial part of the orbit.

Keywords: Anatomy; orbit; orbital anatomy; orbital approach; orbital tumor; surgical approach.

Introduction

Even though it represents a confined space, the orbit is amenable to a variety of exploratory surgical techniques. The diversity of possible techniques is due to its location at the juncture of various different anatomical regions. Containing the eyeball and located between the face and the cranium, the orbit is the meeting place of tissues and organs that are the focus of a range of different specialties, including ophthalmology, otorhinolaryngology and neurosurgery. The difficulties associated with approaching the orbit are related to its relatively small volume, its irregular, four-sided pyramid shape and to its situation embeded in the craniofacial structures.

It is essential to be intimately familiar with the microanatomy of the orbit before undertaking surgery in this region. In this chapter we have undertaken detailed study of the microsurgical anatomy of the orbit in cadaver specimens. After a literature review, we have described three neurosurgical approaches to the orbit on the basis of this anatomical study with emphasis on microanatomical structures that could be encountered along these routes.

Anatomy of the Orbit

The Orbital Cavity (Fig. 1)

The orbits are two cavities located symmetrically on either side of the sagittal plane at the root of the nose. The shape of each is that of a four-sided pyramid with its axis set off from the sagittal plane by an angle of 20°.

The roof is thin and concave in a downward direction. It can be separated into two laminae by the frontal sinus: there is the lacrimal fossa in the anterolateral part, and the anteromedial part houses the fovea into which the trochlea of the superior oblique muscle is inserted.

The floor separates the orbital cavity from the maxillary sinus. It is

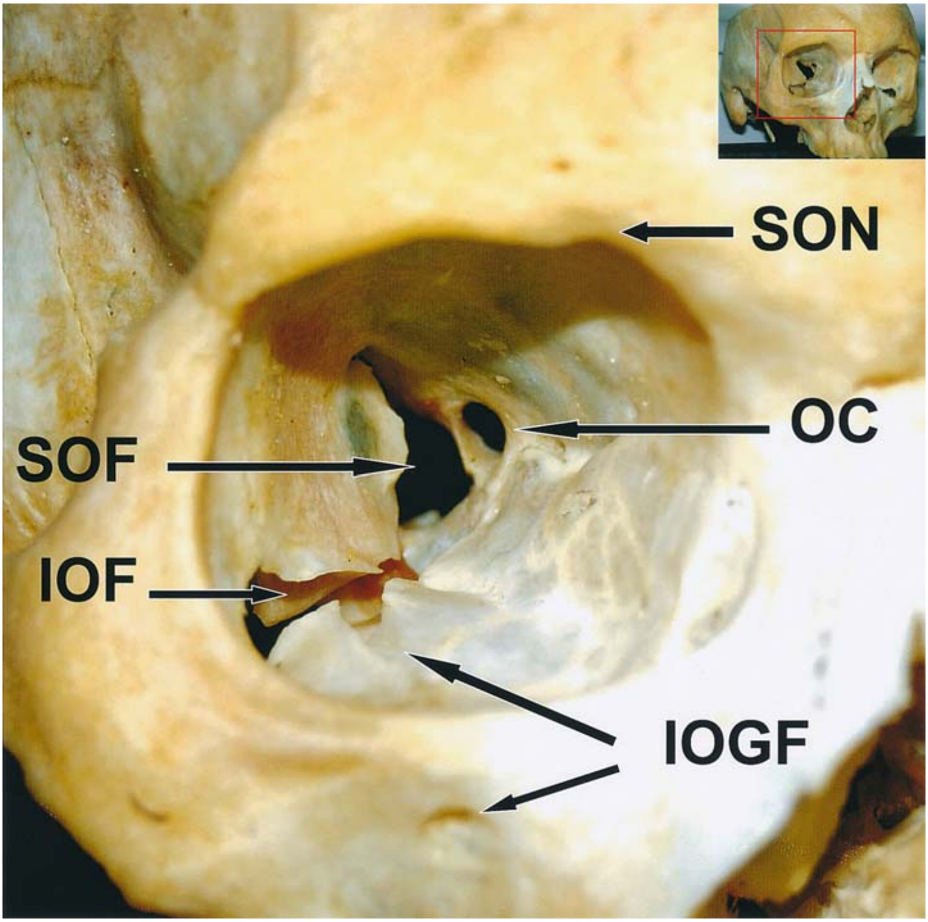

Fig. 1. Photograph of anterior aspect of the right orbital cavity showing optic canal (*OC*), superior orbital fissure (*SOF*), inferior orbital fissure (*IOF*), infra orbital groove and foramen (*IOGF*) and supra orbital notch (*SON*)

traversed by the infraorbital groove that runs from the back towards the front until it changes into a canal for the maxillary nerve.

The lateral wall is oblique outside and in front. The posterior two-thirds is formed by the greater wing of sphenoid with the superior orbital fissure at the top and the inferior fissure at the bottom. This wall is very thick, especially at the front (the lateral pillar), and it separates the orbit from the cerebral temporal fossa behind and from the temporal fossa (which houses the temporal muscle) in front.

The thinnest of the walls of the orbit is the slightly sagittal medial wall that has, in its forward portion, the lacrimal groove that subsequently turns into the nasal canal.

The superolateral angle of the orbit corresponds in front (1/3) to the lacrimal fossa and behind (2/3) to the superior orbital fissure. This is a dehiscence between the two wings of the sphenoid bone in the shape of a comma, with an inferomedial bulge and a superolateral taper. The bulging end matches the lateral face of the body of the sphenoid bone between the origin of the roots of the wings, and the tapered part extends as far as the frontal bone between the two wings. This fissure represents a line of communication between the middle cerebral fossa and the orbit, providing a passage for the orbital nerves (but not the optic nerve) and corresponding to the anterior wall of the cavernous sinus. At the junction between the two parts, there is a small bony protruberance on the lower lip to which the common tendinous ring (Zinn's tendon) is attached.

The superomedial angle is perforated by the anterior and posterior ethmoid canals. The posterior end is continuous with the medial wall of the optic canal.

The posterior two-thirds of the inferolateral angle correspond to the inferior orbital fissure, which provides a communication between the orbit and the pterygomaxillary (or pterygopalatine) fossa; this is covered by the periosteum.

On the superior orbital rim at the junction (1/3 medial and 2/3 lateral) is the supraorbital foramen for the supraorbital nerve and vessels.

The summit or apex of the orbit precisely coincides with the bulging portion of the superior orbital fissure. A little above and inside is the exocranial foramen of the optic canal. This canal, of 6–12 millimeters in length, forms a hollow at the origin of the small wing (between its two roots) on the body of the sphenoid bone. This canal is a site of communication between orbit and the anterior fossa of the cranium. It gives passage to the optic nerve with its meningeal sheath and for the ophthalmic artery traversing below this nerve from the inside to the outside.

The Orbital Fascia or Periorbita (Fig. 2)

This corresponds to the orbital periosteum. Its bone attachment is very loose apart from at points around the optic canal and the superior orbital fissure where it is continuous with the dura mater. In front, it continues into the cranial periosteum on the orbital rim to which it is very strongly attached. Here it sends out extensions towards the peripheral tarsal rim to form the orbital septum, which delineates the orbit in front and separates the intraorbital fatty tissue from the orbicular muscle of the eye. Inside, it is attached to the posterior lacrimal crest and on top, it is traversed by the levator palpebrae superior muscle. The periorbita thus surrounds the contents of the orbit, forms a bridge over the top, and closes the inferior orbital fissure. It is perforated by the various vessels and nerves of the orbit.

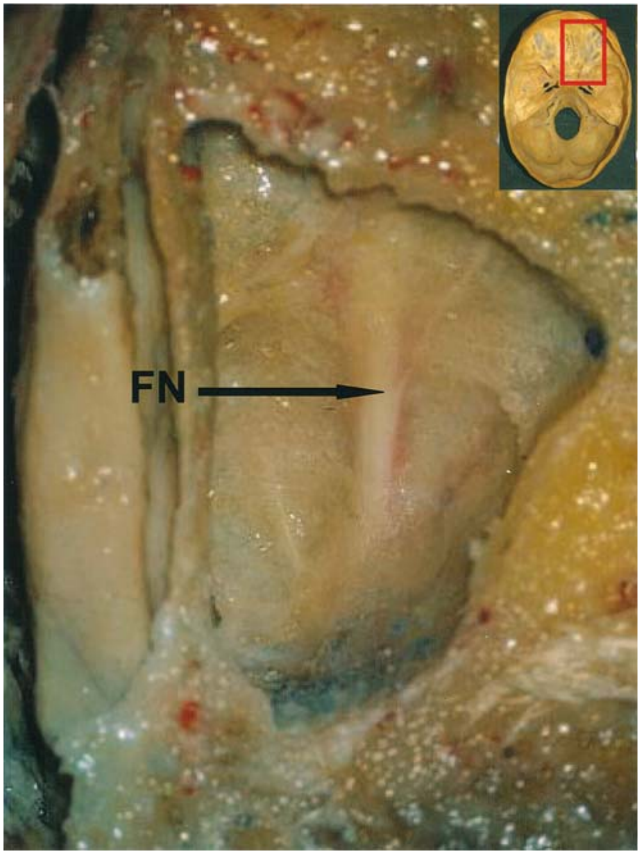

Fig. 2. Photograph of superior aspect of the right orbit after roof removal showing the transparent orbital fascia (periorbita) and underneath the frontal nerve

Orbital Contents

The orbit can be split into two parts, an anterior part containing the eyeball and a posterior compartment containing the muscles, the vessels and the nerves supplying the eyeball, all supported in a cellular, fatty matrix, the so-called adipose body of the orbit.

The eyeball does not touch any of the walls but is suspended at a distance of 6 mm outside and 11 mm inside. Its anterior pole is at a tangent to a straight line joining the upper and lower rims of the orbit, and it projects out beyond a line joining the medial and lateral edges, especially towards the outside. Finally, the anteroposterior axis of the eyeball (which is precisely sagittal) forms an angle of 20° with the axis of the orbit, oblique in front and outside.

From the optic nerve as far as the sclero-corneal junction, the eyeball is covered by a two-layer fascia (Tenon's capsule) with parietal and visceral sheets separating it from the orbital fatty tissue. There is a virtual space between the two sheets (the episcleral space) which forms a sort of lubricated joint system to facilitate the movements of the eye. The fascia is fused behind with the capsule of the optic nerve and in front with the sclera where it joins the cornea. In its anterior part, it is perforated by the muscles of the eye. The fascia turns back over these muscles to create their aponeurotic sheath.

Orbital Muscles (Fig. 3)

The orbit contains seven muscles, the first being the levator palpebrae superior muscle and the other six controlling the eye movements: four rectus muscles (superior, inferior, lateral and medial) and two oblique muscles (superior and inferior).

The levator palpebrae superior is a fine, triangular muscle, which originates above and in front of the optic canal at which point it is fine and tendinous although it sharply broadens out and assumes a more muscular character. It runs along the upper wall of the orbit just above the superior rectus muscle (covering its medial edge). It terminates in an anterior tendon that spreads out in the form of a large fascia, which extends out to the eyelid. The edges of this fascia form extensions, including a lateral one which traverses the lacrimal gland between its palpebral and orbital parts and goes on to attach to the fronto-zygomatic suture.

Rectus muscles: these four muscles form a conical space that is closed in front by the eyeball. They arise in the common annular tendon (Zinn's tendon); this tendon is located on the body of sphenoid near the infraoptic tubercle, and it surrounds the superior, medial and inferior edges of the optic canal, and then continues across the inferomedial part of the superior orbital fissure before inserting on a tubercle of the greater wing. It subsequently splits into four lamellae arranged at right angles to one another, from which the four rectus muscles arise respectively. The superolateral and inferomedial ligaments are solid but the other two are perforated: the one in the superomedial band lets the optic nerve and the ophthalmic artery through, and the other, which is larger, stretches between the inferomedial and superolateral bands passing through the inferolateral band. This opening called the common tendinous ring (Zinn's ring) or the oculomotor foramen corresponds to the bulging end of the superior orbital fissure and provides a passage for the nasociliary nerve, both branches of the oculomotor nerve, the abductor nerve and the sympathetic root of the ciliary ganglion. The superior ophthalmic vein can also pass through or above this opening, and the inferior ophthalmic vein may pass inside or below it.

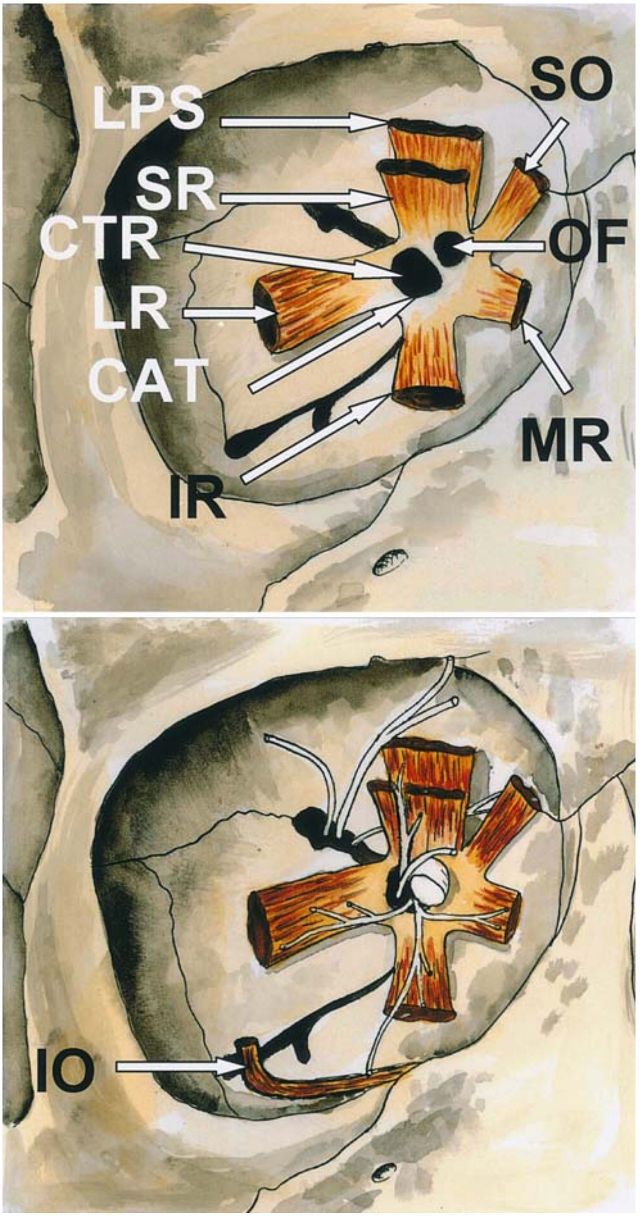

Fig. 3. Artist's drawing of right orbital cavity with extra ocular muscles showing common annular tendon (*CAT*), common tendinous ring (*CTR*), optic foramen (*OF*), levator palpebrae superior muscle (*LPS*), the four recti muscles: superior (*SR*), medial (*MR*), inferior (*IR*), lateral (*LR*), superior oblique muscle (*SO*) and inferior oblique muscle (*IO*)

The rectus muscles then continue for four centimeters in a forward direction to terminate in tendons, which are attached to the anterior part of the sclera near the limbus.

The oblique muscles, of which there are two.

The superior oblique muscle arises as a short tendon attached inside and above the optic foramen. It runs along the superomedial angle of the orbit and then becomes tendinous again when it turns back at an acute angle over the trochlea. It then becomes once more muscular and turns backwards in a lateral direction, skirts the upper part of the eyeball passing under the superior rectus muscle to terminate on the superolateral side of the posterior hemisphere of the eye. The inferior oblique muscle, shorter than the superior, is located on the anterior edge of the floor of the orbit and arises outside the orbital opening of the lacrimal canal before passing outside, behind and upwards. It skirts the lower surface of the eyeball, passing under the inferior rectus muscle to terminate on the inferior, lateral side of the posterior hemisphere of the eye.

All these muscles are attached to each other, to orbital fascia or to Tenon's capsule by a complex fibrous septa system that could contain vessels, nerves or smooth muscle cells. These septa can be considered as an important accessory locomotor system contributing to the motility of eye and explaining some motility disturbances in blow out fractures of the orbit (24).

The Arteries of the Orbit (Figs. 4–6)

The arteries of the orbit correspond essentially to the ophthalmic artery and its branches, although the orbit is also supplied by the infraorbital artery, a branch of the maxillary artery which is itself the terminal branch of the external carotid artery.

The ophthalmic artery, with a diameter of 1.5 mm, is a branch of the internal carotid artery, arising anteriorly where it emerges from the cavernous sinus medial to the anterior clinoid process. This artery makes its way through the subarachnoid space below the optic nerve and then continues on into the optic canal, carrying on laterally to perforate the sheath at the exit of the canal.

In the orbital cavity, it is initially lateral to the optic nerve and medial to the ciliary ganglion. Next, obliquely and accompanied by the nasociliary nerve, it crosses the top side of the optic nerve below the superior rectus muscle, ultimately reaching the medial orbital wall. From there it makes its way forward between the superior oblique and the medial rectus muscles, passes under the trochlea and then climbs back up again to pass between the orbital rim and the medial palpebral ligament. It terminates by splitting into two different arteries, the supratrochlear artery and the angular artery

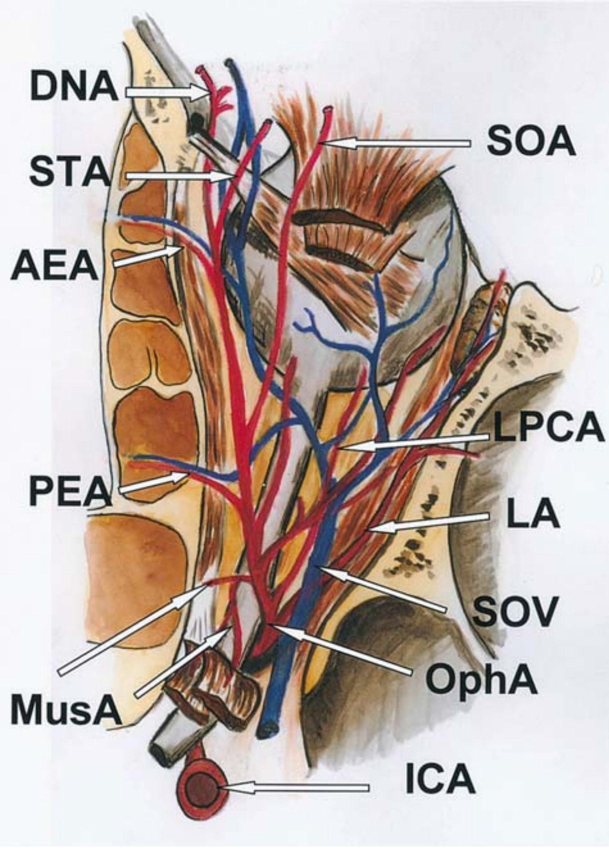

Fig. 4. Artist's drawing of superior view of right orbit showing ophthalmic artery and its branches. *ICA* Internal carotid artery, *OphA* ophthalmic artery, *SOV* superior ophthalmic vein, *LA* lacrymal artery, *PEA* posterior ethmoidal artery, *AEA* anterior ethmoidal artery, *LPCA* long posterior ciliary artery, *SOA* supra orbital artery, *STA* supra trochlear artery, *DNA* dorsal nasal artery, *MusA* muscle artery

(which forms an anastomosis with the dorsal artery of the nose). It should be noted that in about 15% of subjects, the ophthalmic artery passes underneath optic nerve.

Collateral branches of the ophthalmic artery
Variable in number from 10 to 19, most of these arise in the intraorbital segment of the artery. Anatomical variations are very common.

The central artery of the retina (Fig. 7)—one of the smallest—is present in all cases. It arises from the ophthalmic artery in 50% of subjects, and from one of its branches (the posterior long ciliary artery) in the other 50%. It often arises below and outside the optic nerve and then skirts over its lower side before penetrating at a distance of 10–15 mm from the poste-

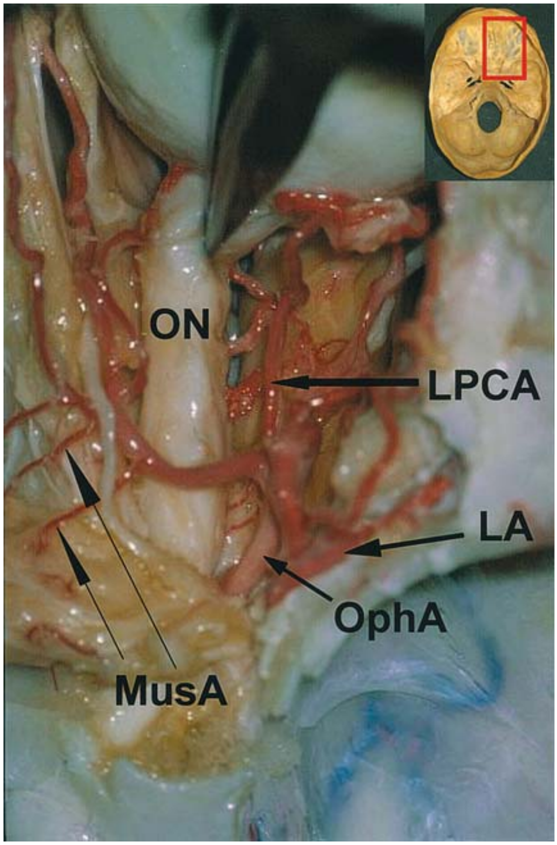

Fig. 5. Photograph of superior view of the right orbit, the roof and orbital fat have been removed and superior muscles were sectioned to show the optic nerve (*ON*) surrounded by ophthalmic artery (*OphA*) and some of its branches: lacrimal artery (*LA*), long posterior ciliary artery (*LPCA*) and muscles arteries (*MusA*)

rior pole of the eyeball. It then continues as far as the papilla where it splits to form its terminal branches.

The lacrimal artery, one of the largest branches, arises near the exit of the optic canal above and outside the optic nerve. It passes forwards, upwards and in a lateral direction, coming out of the cone to continue to the lateral wall of the orbit where it carries on with the lacrimal nerve above the lateral rectus muscle as far as the lacrimal gland. This artery gives rise to one or two zygomatic branches. One of these passes across the zygomatico-temporal foramen and forms an anastomosis with the deep temporal arteries. The lacrimal artery gives a recurrent anastomotic branch that passes through the lateral part of the superior orbital fissure to rejoin a branch of the middle meningeal artery.

Muscular branches are numerous. These often arise from one or two

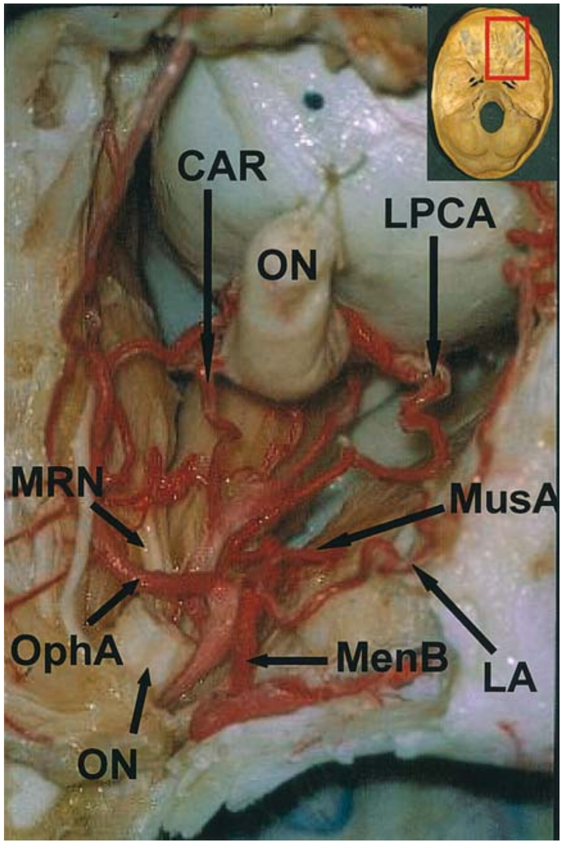

Fig. 6. Superior view of the right orbit, the roof and orbital fat have been removed and superior muscles with optic nerve were sectioned to show branches of the ophthalmic artery (*OphA*) situated under the optic nerve: *CAR* central artery of retina, *LPCA* long posterior ciliary artery, *MusA* muscle artery, *LA* lacrimal artery, *MenB* meningial branch. In this view we can also see the nerve of the medial rectus muscle (*MRN*)

arterial trunks. The inferior muscular artery—one of the largest of the branches of the ophthalmic artery—is the most commonly found. Other muscular branches exist, arising in the ophthalmic artery or one of its branches.

The ciliary arteries can be divided into three different groups:

The posterior long ciliary arteries, commonly two in number, arise in the ophthalmic artery at the point at which it crosses over the optic nerve. These enter the sclera not far from where the optic nerve enters it.

The posterior short ciliary arteries, seven in number, pass in a forward direction around the optic nerve.

The anterior ciliary arteries arise from muscular branches and pass in front, over the tendons of the rectus muscles.

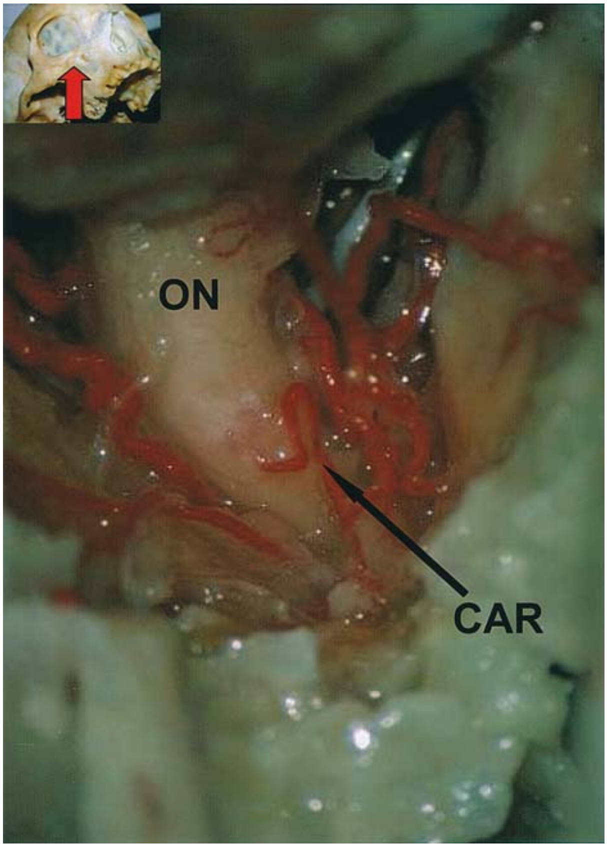

Fig. 7. Photograph of inferior aspect of the right orbit that was opened by removing its floor to show the central artery of retina (*CAR*) penetrating optic nerve (*ON*)

The supraorbital artery (which is absent in 12% of subjects) arises from the ophthalmic artery, often in its medio-optic part. It passes up and forwards, comes out of the cone between the levator palpebrae superior muscle and the superior oblique muscle, and then meets the supraorbital nerve, which it accompanies between the levator muscle and the periorbita until the supraorbital incisure or foramen. Inside the orbit, it gives rise to muscular branches and, in some cases, the supratrochlear artery.

The posterior ethmoidal artery arises within the muscular cone medial and above the optic nerve then leaves the cone between the superior oblique muscle underneath and the levator muscle above to carry on over the trochlear nerve towards the posterior ethmoid canal.

The anterior ethmoidal artery, which is present more often than the preceding vessel, arises near the anterior ethmoid canal: when it enters this canal, it is accompanied by the nerve of the same name.

The meningeal branch is a small branch that passes behind, across the superior orbital fissure, into the middle cerebral fossa to form an anastomosis with the middle and accessory meningeal arteries.

The medial palpebral arteries, two in number (the superior and the inferior), arise from the ophthalmic artery below the trochlea.

The supratrochlear artery, a terminal branch of the ophthalmic artery, leaves the orbit in the superomedial part together with the nerve of the same name.

The dorsal artery of the nose, another terminal branch of the ophthalmic artery, emerges from the orbit between the trochlea and the medial palpebral ligament.

Veins of the Orbit

There is a very dense venous network in the orbit, organized around the two ophthalmic veins that drain into the cavernous sinus. These veins are valve-less. Periorbital drainage also occurs towards the facial system via the angular vein. Thus, for the venous system, as with the arterial system, the orbit is a site of anastomosis between the endocranial and exocranial systems.

The superior ophthalmic vein (Fig. 8), a large-caliber vein present in all subjects, constitutes the orbit's main venous axis. It is formed by the union behind the trochlea of two rami, the first from the frontal veins and the other from the angular vein. This vessel then crosses the orbit from the front towards the back accompanying the artery and passing under the superior rectus muscle. Throughout its path, it receives a great number of collateral tributaries, including ethmoidal, muscular, ciliary, vorticose (from the choroid), lacrimal, palpebral, conjunctival and episcleral rami, and the central vein of the retina. This last, the caliber of which is very small, first traverses the optic nerve behind the lamina cribrosa sclerae then carries on into the subarachnoid space before piercing the dura mater and either rejoining the superior ophthalmic vein or passing directly into the cavernous sinus.

When it reaches the apex of the orbital pyramid, the superior ophthalmic vein insinuates itself between insertions of the lateral and superior rectus muscles and leaves the orbit via the enlarged portion of the superior orbital fissure outside the common tendinous ring. It terminates at the face of the cavernous sinus.

The inferior ophthalmic vein (Fig. 9) that is not present in all subjects, is the result of a venous anastomosis in the anterior inferomedial part of the orbit. It receives rami from muscles, the lacrimal sac and the eyelids. It carries on behind, above the inferior rectus muscle, whence it often rejoins the superior ophthalmic vein, although in some subjects, it carries on to the

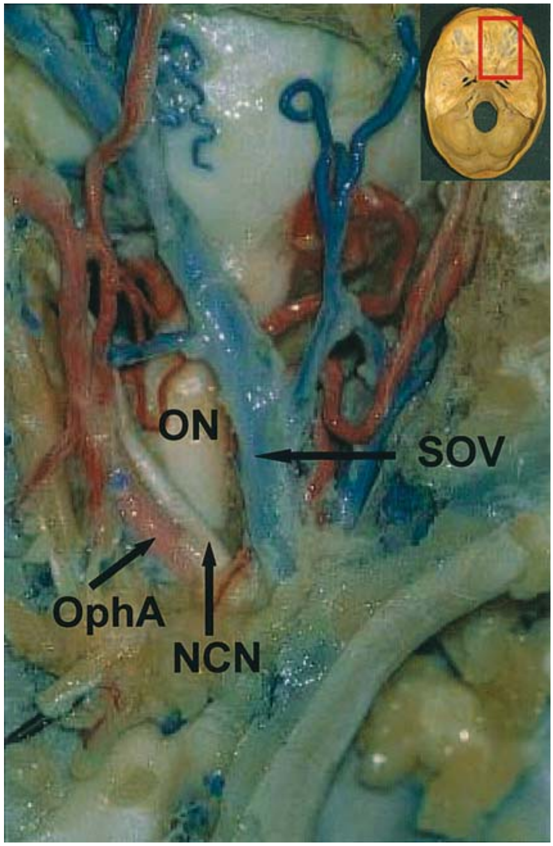

Fig. 8. Superior view of the right orbit after section of superior muscles to see structures passing between these muscles and optic nerve (*ON*): superior optic veine (*SOV*), naso ciliary nerve (*NCN*) and ophthalmic artery (*OphA*)

cavernous sinus as a distinct vessel. It communicates with the pterygoid plexus by small veins crossing the walls of the orbit.

Nerves of the Orbit (Figs. 10, 11)

The orbit contains a huge number of nervous structures of various types (as defined by physiological function).

There include:

– a component of the central nervous system: the optic nerve;
– three motor nerves: the third, fourth and sixth cranial nerves;
– a sensitive nerve: the ophthalmic nerve, a branch of the fifth cranial nerve
– an autonomic center: the ciliary ganglion.

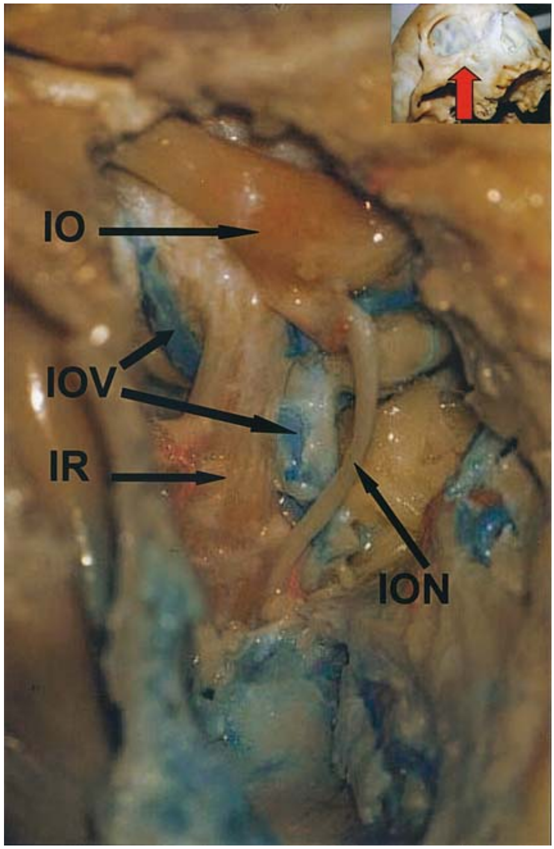

Fig. 9. Inferior view of the right orbit after opening of its floor and fascia showing inferior oblique muscle (*IO*), inferior rectus muscle (*IR*), nerve of the inferior oblique muscle (*ION*) and inferior ophthalmic vein (*IOV*)

The optic nerve (Fig. 12), about 4.5 cm in length and with a diameter of 3 mm, leaves the eyeball inside and below its posterior pole and carries on behind and inside. It is conventionally divided into three different parts, namely intraorbital, intracanicular and intracranial segments.

The intraorbital segment is about 30 mm long and follows a sinuous trajectory, which provides reserve length so that the eyeball can be moved without damaging the nerve. In this segment, relationships are made with:

– the muscles of the orbit, firstly at a distance from the nerve and separated from it by a mass of fatty tissue (through which the ciliary nerves and vessels), then coming closer nearer the point of entry of the optic canal where the nervous sheath is attached to the tendinous fibers of the superior oblique muscle, the medial rectus muscle and the superior rectus muscle;

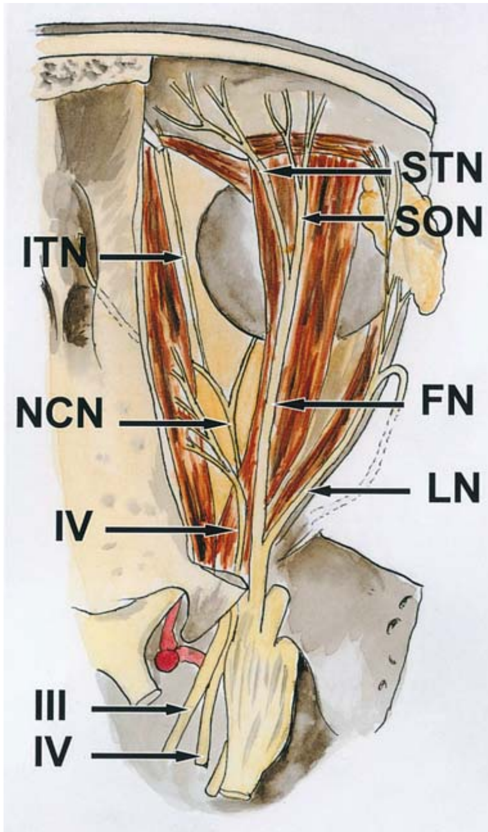

Fig. 10. Artist's drawing of superior view of the right orbit showing orbital nerves. *ITN* Infra trochlear nerve, *NCN* naso ciliary nerve, *IV* trochlear nerve, *III* oculomotor nerve, *LN* lacrymal nerve, *FN* frontal nerve, *STN* supra trochlear nerve, *SON* supra orbital nerve

– the ophthalmic artery which crosses over the nerve;
– the ciliary ganglion, juxtaposed with its lateral surface at the union of the anterior 2/3 and the posterior 1/3, and located between it and the lateral rectus muscle.

The intracanicular segment is 5 mm long and the nerve is here accompanied underneath and outside by the ophthalmic artery. Just in front of the canal, the ophthalmic artery and the nasociliary nerve carry on medially and in a forward direction above the optic nerve; in contrast, the nerve supplying the medial rectus muscle (which comes from the inferior branch of the third cranial nerve) passes below the optic nerve in a medial direction (Fig. 6). In this canal, the optic nerve is separated on the inside from

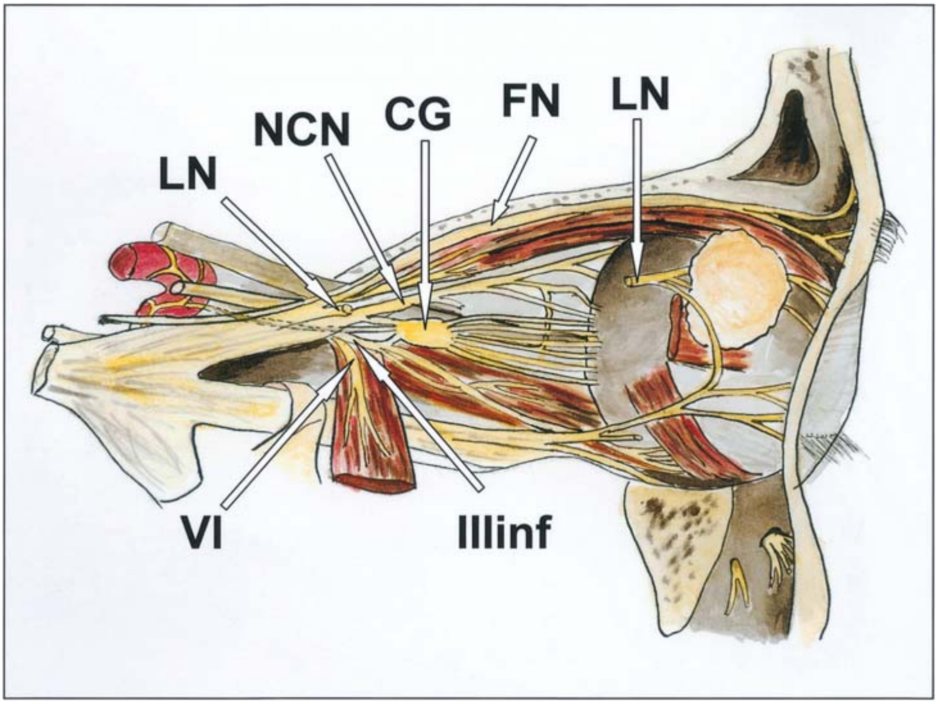

Fig. 11. Artist's drawing of lateral view of the right orbit showing orbital nerves. *LN* Lacrymal nerve, *NCN* naso ciliary nerve, *CG* ciliary ganglion, *FN* frontal nerve, *VI* abductor nerve, *IIIinf* inferior division of oculomotor nerve

the sphenoidal sinus and the posterior ethmoidal cells by a very thin lamella of bone.

The intracranial segment is 10 mm long, and passes behind and inside as far as the optic chiasm.

Blood is supplied to the intracanalicular segment of the optic nerve by recurrent branches of the ophthalmic artery. The intraorbital segment is supplied by the posterior ciliary arteries and the central artery of the retina, and drainage is via the central vein of the retina.

The oculomotor nerve supplies all the extraocular muscles apart from the superior oblique muscle and the lateral rectus muscle; its parasympathetic motor contingent also innervates—via the ciliary ganglion—the intraocular muscles (sphincter of the iris and the ciliary muscle).

Before entering the orbit, this nerve splits to form two terminal rami (superior and inferior) which penetrate the orbit across the bulging medial part of the superior orbital fissure inside the common tendinous ring. At this point, the nasociliary nerve is located between them on the inside with

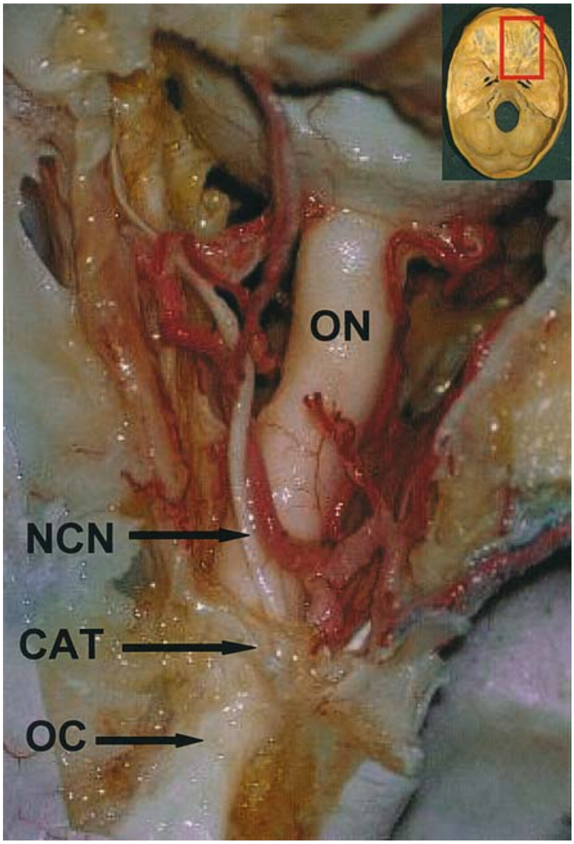

Fig. 12. Photograph of superior view of the right orbit, the roof and orbital fat have been removed, optic canal (*OC*) was opened, and superior muscles were sectioned to show the optic nerve (*ON*) in all its pathway: *CAT* common annular tendon, *NCN* naso ciliary nerve

the abductor nerve on the outside. The two branches then enter the muscular cone and diverge away from one another.

The superior, smaller-caliber branch climbs up the lateral side of the optic nerve and splits to form four or five rami that innervate the superior rectus muscle and, via a perforating ramus, the levator palpebrae superior.

The inferior branch is initially located below and outside the optic nerve and then spreads out over the upper surface of the inferior rectus muscle, splitting to form three branches. The first of these passes below the optic nerve on its way to the medial rectus muscle; the second travels outside towards the inferior rectus muscle; and the third (the longest), carries on in front between the inferior rectus muscle and the lateral rectus muscle on its way to the inferior oblique muscle (Fig. 9). From this branch

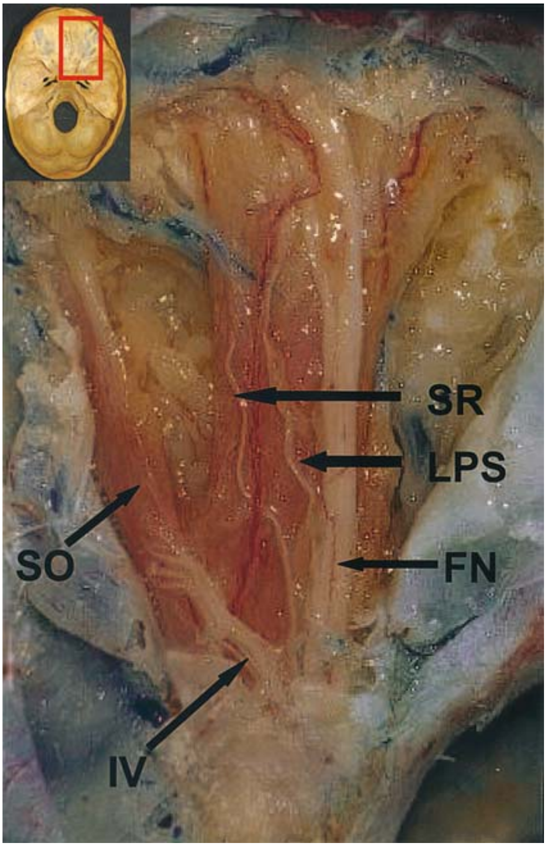

Fig. 13. Photograph of superior view of the right orbit after removal of the roof and opening of periorbita to see superior muscles and superficial nerves: *IV* trochlear nerve, *FN* frontal nerve, *SO* superior oblique muscle, *SR* superior rectus muscle, *LPS* levator palpebrae superior muscle

arises a short branch (sometimes actually composed of two or three distinct branches) to the ciliary ganglion to form its parasympathetic or motor root. After a synapse at this ganglion, fibers of the third cranial nerve intertwine with sympathetic and sensitive fibers to constitute the short ciliary nerves, which travel to the ciliary muscle and the sphincter of the iris.

The trochlear nerve (Fig. 13) enters the orbit across superior orbital fissure where its tapered and bulging portions come together. It passes outside the common tendinous ring above the orbital muscles and inside the frontal nerve (which is far more bulky). Inside the orbit, it carries on medially above the origin of the levator palpebrae superior, to reach the superior oblique muscle on its orbital side.

The abductor nerve starts in the medial part of the superior orbital fissure inside the common tendinous ring outside the branches of the oculomotor nerve. It then spreads out over the lateral rectus muscle and splits to form four or five branches, which carry on into the muscle.

The ophthalmic nerve, a superior branch of the trigeminal nerve, is exclusively sensitive. It innervates the eyeball, the lacrimal gland, the conjunctiva, part of the mucosa of the nasal cavity, and the skin of the nose, forehead and scalp. This nerve is the smallest of the three branches of the trigeminal nerve. After its passage into the lateral wall of the cavernous sinus but before it enters the orbit, it splits to form three branches, namely (going from the outside to the inside) the lacrimal nerve, the frontal nerve and the nasociliary nerve.

– *The lacrimal nerve*, the branch with the smallest caliber, enters the orbit via the lateral part of the superior orbital fissure and remains outside the cone. Then, together with the lacrimal artery, it travels along the superolateral edge of the orbit above the lateral rectus muscle and, from the zygomaticotemporal nerve (a branch of the maxillary nerve), it receives a branch which contains parasympathetic secretomotor fibers coming from the pterygopalatine ganglion on their way to the lacrimal gland. As the nerve crosses the gland, it sends out numerous branches to ensure its nervous supply, and then it perforates the orbital septum and terminates in the skin of the upper eyelid. In some subjects, the lacrimal nerve is missing, in which case its role is fulfilled by the zygomaticotemporal nerve.

– *The frontal nerve*, the largest of the branches of the ophthalmic nerve, enters the orbit through the tapered part of the superior orbital fissure, above the muscles, between the lacrimal nerve outside and the trochlear nerve inside. Outside the cone, it insinuates between the levator palpebrae superior muscle and the periorbita. Halfway along, it splits to form a small medial branch called the supratrochlear nerve, and a large lateral branch called the supraorbital nerve. The first passes above the trochlea of the superior oblique muscle and distributes to the medial 1/3 of the upper eyelid and the conjunctiva. The second passes into the supraorbital incisure and innervates the middle 1/3 of the upper eyelid and the conjunctiva.

– *The nasociliary nerve*, the most medial of the branches of the ophthalmic nerve, is intermediate in size to the frontal and lacrimal nerves, and is the only one to reach the eyeball. It is also the only one to pass through the common tendinous ring, which it does inside the two branches of the oculomotor nerve, just above the sympathetic root of the ciliary ganglion. Afterwards, together with the ophthalmic artery, it crosses the optic nerve before travelling obliquely between the medial rectus muscle below and the superior rectus and superior oblique muscles above, as far as the medial wall of the orbit. At the level of the anterior ethmoidal foramen, it splits to form two branches:

– the anterior ethmoidal nerve, medial, which crosses the canal of the same name with the corresponding artery, and then passes over the cribriform plate of the ethmoid bone.
– the infratrochlear nerve, lateral, continues in the direction of the common trunk. Under the trochlea of the superior oblique muscle, it splits to form rami going to the mucosae (the medial part of the conjunctiva and the lacrimal ducts) and the skin (the medial part of the eyelid and the root of the nose).

Along its route, the nasociliary nerve sends out three major collateral branches, from behind forwards:
– the communicating branch of the ciliary ganglion which leaves the nasociliary nerve at the point at which it enters the orbit; it contains the fibers for corneal sensitivity as well as the sympathetic fibers responsible for dilatation of the iris which are supplied to the trigeminal nerve from the cervico-trigeminal anastomosis;
– the long ciliary nerves, of which there may be either two or three, leave the nasociliary nerve where it crosses the optic nerve; they join up with the short ciliary nerves (from the ciliary ganglion), perforate the sclera and terminate in the ciliary body, the iris and the cornea; they usually contain the sympathetic fibers responsible for dilatation of the pupil;
– the posterior ethmoidal nerve crosses the canal of the same name and distributes to the sphenoidal sinus and posterior ethmoidal cells.
The ciliary ganglion, is a reddish-gray, pinhead-sized (2 mm $\times$ 1 mm) structure which is somewhat flattened out along its major horizontal axis. It is located near the apex of the orbit (at the junction of the anterior 2/3 and the posterior 1/3) in loose fatty tissue between the optic nerve and the lateral rectus muscle, usually lateral to the ophthalmic artery.

There are three roots:
– the motor or parasympathetic root which comes from the inferior branch of the third cranial nerve (by the inferior oblique branch). Its fibers mainly innervate the ciliary muscle and, to a lesser extent, the sphincter of the iris;
– the sympathetic root, a branch of the carotid plexus which enters the orbit via the common tendinous ring;
– the sensitive root, a long and fine fiber which rejoins the nasociliary nerve where it enters the orbit. This supplies the eye and the cornea.

The 8–10 filamentous branches of the ganglion are called the short ciliary nerves and these make their way in a forward direction around the optic nerve, together with ciliary arteries and the long ciliary nerves.

Lacrimal Gland

This comprises two different, laterally continuous parts: the upper, broader orbital part, and the lower, smaller palpebral part. The orbital part is accommodated in the lacrimal fossa of the zygomatic process of the frontal bone. It is located above the levator muscle (and laterally, above the lateral rectus muscle). Its lower surface is attached to the sheath of the levator muscle and its upper surface to the orbital periosteum; its anterior edge is in contact with the orbital septum and its posterior edge is attached to the orbital fatty tissue.

The palpebral part, which is in the form of two or three lobules, extends out below the fascia of the levator muscle in the lateral part of the upper eyelid. It is attached to the superior conjunctival fornix.

Approach Routes to the Orbit

Orbit's pyramidal shape affords five possible anatomical approach routes, namely the anterior, superior, inferior, lateral and medial faces [22, 23]. The neurosurgeon does not need to be familiar with either the anterior approaches (which tend to be restricted to ophthalmologic applications, essentially to access small, anterior neoplasms) nor, as a rule, the medial and inferior approaches (which are the domain of the Ear, Nose and Throat specialist working in collaboration with the ophthalmologist). On the other hand, the neurosurgeon is often called upon to collaborate on techniques based on an approach via either the lateral or the superior routes [9, 19].

The huge number of monographs about the various techniques tends to lead to confusion, even though they generally differ in only relatively minor details. The goal must always be to obtain optimum access while inflicting as little damage as possible, with damage considered in both functional and esthetic terms. It is beyond debate now that no single method is ideal for exploration of the orbit in all cases: the technique to be used has to be chosen in the light of the nature, the location and the size of the lesion.

In neurosurgery, three possible approach routes should be considered namely the lateral approach, the superior approach and a hybrid superolateral approach.

Incision

The type of incision to be made will depend on the approach route chosen although a temporofrontal incision is suitable for all three alternatives. For a lateral approach, certain experts prefer an incision in the shape of an elongated S starting at the eyebrow and descending along the lateral edge of the orbit before curving behind along the upper edge of the zygomatic arch. This option is shorter but tends to be more disfiguring. It is important to go no further than 4 centimeters beyond the canthus to preclude damage to the frontotemporal branch of the facial nerve [26]. Both the fascia and the temporal muscle are eventually detached to expose the lateral wall of the orbit.

The temporofrontal incision begins just in front of the tragus at the level of the upper edge of the zygomatic arch and is then carried on in an upward direction. At the level of the temporal line, the incision curves around towards the hair line past the median line. Some experts even prefer bilateral incision [1, 12, 20]. Subsequent detachment of the scalp should preserve the temporofrontal branch of the facial nerve (located between the galea aponeurotica and the temporal fascia) and should avoid in front the bulky temporal muscle mass in order to obtain full access. The detachment procedure starts under the galea and then, 4 cm from the edge of the orbit, an incision is made in the superficial layer of the temporal fascia (which is at this point divided into two layers) in order to pass dissection between the two layers [33]. This leaves the superficial layer in contact with the scalp, and the nerve branch between the two intact. In order to make absolutely sure that this branch is not damaged, it is even better to leave the two layers in contact with the galea, and make dissection between the fascia and the muscle [2]. The fascia and the periosteum are then released from the edge of the orbit and the zygomatic arch. After the fascia and the muscle have been incised at a point 1 cm from the superior temporal line, this muscle can be detached (using a raspatory in order to protect its vasculature [32]) and laid under and behind in order to expose the whole pterional region and the entire lateral wall of the orbit.

The Lateral Approach Route

Exploration of the orbit via this approach is safe in terms of both functional and esthetic parameters. This special anatomical situation led the earliest surgeons to choose this route. From an anatomical point of view, it should be remembered that the anterior quarter of the lateral wall is thick, and that it only thins out over a length of about one centimeter up to the bottom of the temporal fossa. Then, it becomes thicker again forming the angle at the meeting point between the orbit, the middle cerebral fossa and the temporal fossa. This bony junction has to be disrupted before the apex of the orbit can be accessed.

The essential differences between the many variants of this technique that have been described correspond to whether or not the anterior edge of the orbit has to be sectioned and whether the corner junction has to be disrupted or not.

In general, distinction can be made between two different types of lateral approach [8, 9]: the first (Krönlein's operation and its derivatives) involves deliberate section of the edge of the orbit so that, at the end of the operation, the original architecture has to be meticulously reconstructed (osteoplastic techniques); in the second type, the edge of the orbit is not encroached upon but the posterior corner is disrupted (non-osteoplastic techniques).

Osteoplastic Techniques

In 1888, Krönlein [25] was the first to describe this approach route which was subsequently modified to a greater or lesser extent by a number of surgeons [5, 6, 26, 29]. Once the periorbita has been detached from the internal surface of the orbit, the bone flap is trimmed in the lateral wall by making two straight cuts at the edge of the orbit, one above the frontozygomatic suture and the other at the level of the upper edge of the zygomatic arch. These cuts can be made using an oscillating saw, shears, a craniotome or a very fine drill. They are taken as far back as possible and then the flap is fractured at the rearmost point. This flap exposes the anterior part of the orbit. In order to expose the posterior part, it is necessary to disrupt the junction corner using a drill to expose the anterior aspect of the temporal and frontal dura mater, and open up the superior orbital fissure. This approach can also be extended downwards as far as the inferior orbital fissure.

Non-Osteoplastic Techniques

These techniques are first and foremost designed for the relief of orbital hyperpressure but they can also be used for tumors (located laterally in the middle or posterior part of the orbit) to which access could be hindered by the presence of the rim of the orbit. The best way to proceed is to make the key hole behind the zygomatic process of the frontal bone. Starting from this hole and using a drill, the thick orbito-cranial corner of the greater wing of sphenoid is resectioned to expose the frontotemporal dura mater and open the lateral end of the superior orbital fissure. In addition, the lateral wall of the orbit is resectioned as far in the forward direction as possible. Here again, resection can be continued into the greater wing of sphenoid as far as the inferior orbital fissure.

After bony opening in the two techniques, the periorbita is opened with a T-shaped incision (Fig. 14) with one branch parallel to the orbital axis and the other parallel to the rim of the orbit. This permits upward and forward exposure of the lacrimal gland and the orbital fatty tissue. The first feature to be distinguished is the lateral rectus muscle that is most obvious in the posterior part of the orbit where there is no fatty tissue. Once this has been identified, two microsurgical routes are possible [3], a superior route above the muscle, and an inferior one below it. The orbital fatty tissue is dissected as far as the lesion and then kept apart using self retaining retractor. The lateral rectus muscle can be kept out of the way with a suture but traumatic retraction can result in paralysis of this muscle.

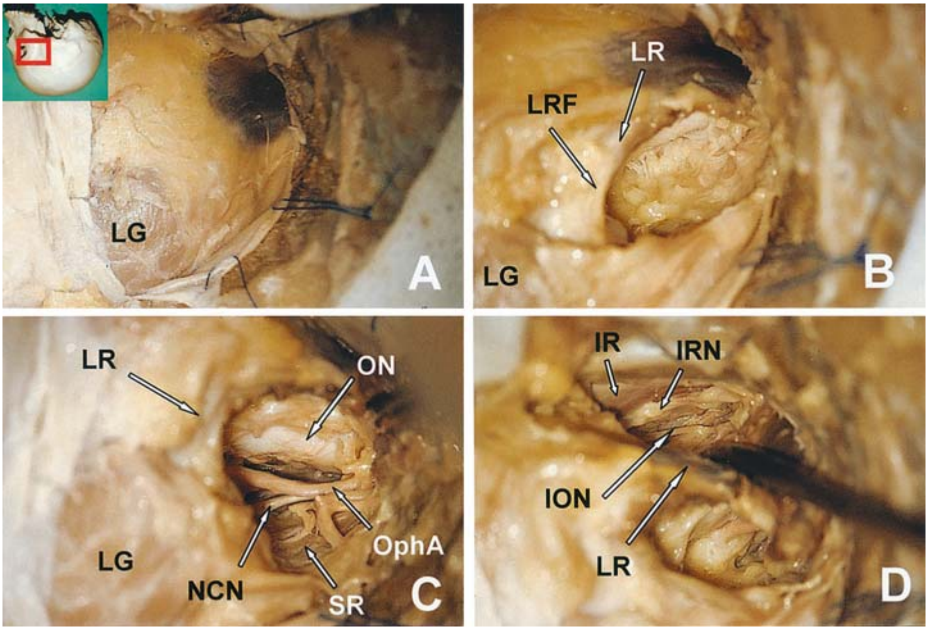

Fig. 14. Cadaver dissection showing anatomic structures encountered through a lateral approach to the right orbit in the surgical position. (A) View after the lateral wall has been removed and the periorbita opened showing lacrymal gland (*LG*) in front and above with orbital fat. (B) Microscopic view after fat has been lacerated showing lateral rectus muscle (*LR*) and its fascia reflecting on the eyeball (*LRF*). (C) Fat has been removed in the posterior part of the cone to show the optic nerve (*ON*) with ophthalmic artery (*OphA*) and nasociliary nerve (*NCN*) crossing over optic nerve from outside to inside below superior rectus muscle (*SR*). (D) the inferior route, the lateral rectus muscle has been superioly retracted showing under the optic nerve the origine of inferior rectus muscle (*IR*) with its nerve (*IRN*) and nerve of the inferior oblique muscle (*ION*)

Passing above the lateral rectus muscle, the first structures encountered are the lacrimal artery and nerve, which follow the upper edge of the muscle before they reach the lacrimal gland. In the anterior part of the muscular cone, no other features are encountered before arriving near the optic nerve to find the posterolateral ciliary artery and the short ciliary nerves coming from the ciliary ganglion located on the lateral side of the optic nerve. Behind as one approaches the apex, there is the superior branch of the third cranial nerve which gives off a branch to the superior rectus muscle that it encroaches upon at the meeting point of the middle third and the posterior third. It also sends out a branch to the levator palpebrae superior muscle that traverses the superior rectus muscle. Any attempt to approach the apex of the muscular cone via this route will be hindered by the presence of the superior ophthalmic vein which traverses the upper surface of the optic nerve and carries on behind to leave the muscular cone between the superior rectus muscle and the lateral rectus muscle in contact with the common annular tendon outside of Zinn's ring, to reach the cavernous sinus.

Passing below the lateral rectus muscle in the anterior part of the cone, there are no large structures before the posterolateral ciliary artery and the ciliary ganglion with the short ciliary nerves close to the optic nerve. These nervous elements are usually submerged in the orbital fatty tissue and may be damaged in the course of surgery. Behind, towards the apex, there is the inferior branch of the third cranial nerve which sends out three branches: one of these travels down towards the medial rectus muscle after passing under the optic nerve; the second is for the inferior rectus muscle which it joins at the meeting point of the middle third and the posterior third; and the third branch carries on in front along the inferior rectus muscle, ultimately reaching the inferior oblique muscle. This last branch being so long can easily be damaged when lesions, which extend downwards are being excised, although such damage is usually without any obvious clinical symptoms. Finally, the inferior ophthalmic vein leaves the muscular cone between the lateral and inferior rectus muscles outside Zinn's ring.

A central route in the lateral approach has also been described [16] but lateral rectus muscle must to be disinserted.

The Superior Approach Route

Use of the frontal route to access the orbit was systematically employed by Dandy [14] and Naffziger [30]. This approach was then used by other surgeons as reported in a number of articles.

More recently, use of this route has become more widespread as a result of the work of Bachs [4] (a single flap technique) and Karagjozow [21] (a double flap technique). Both of these techniques afford excellent exposure but they are difficult to perform and take a long time. In practice, in the Bach's operation [4], frontal orbital rim and the roof are sectioned without being able to see the dura mater, which is blindly declined, across the frontal hole. In the Karagjozow technique [21], the passage of the Gigli saws across the orbital fissures is blind and there is a significant risk of trauma [12]. Finally, it should be noted that there is the possibility of a limited superior approach across a frontal sinus of large size [11].

Our technique involves creating an initial frontal flap then detaching the dura mater from the roof of the orbit. The orbital periosteum is then detached passing under orbital rim and as far as possible under the roof. The supraorbital neuro vascular bundle should be entirely released and when it is embedded in a canal, the canal has to be converted into a groove by means of two sagittal cuts made with a gouge. A flexible sheet slid into the orbit will protect orbital structures and it is sometimes necessary to displace the frontal lobe using a self-retaining retractor. The second flap is then created from two cuts, one medial and the other lateral, in the upper orbital rim. These can be made using an oscillating saw, shears, a craniotome or a minidrill. These cuts are carried on as far back as possible into the roof before it is broken and folded down. The rest of the roof can then be resected using a gouge forceps and, if necessary, the optic canal can be opened using a diamond drill. In this case, attention must be paid to keeping the region cool enough to prevent thermal damage to the optic nerve. If the optic canal is opened, the optic nerve can be seen at the summit of the orbit penetrating into the orbit through the common annular tendon (Zinn's tendon). The periorbita is found in the shape of a T with one branch parallel to the orbit's axis and the other to the edge of the orbit. The two flaps are detached and then suspended laterally. The orbital structures that can be seen at this stage (Fig. 15A) are located at the level of the apex (the rest being covered by the fatty tissue). In front of the optic nerve can be seen the origins of the levator palpebrae superior muscle and the superior rectus muscle. Still in front of this nerve but a little further in is the superior oblique muscle. Outside the optic nerve, there is the broad,

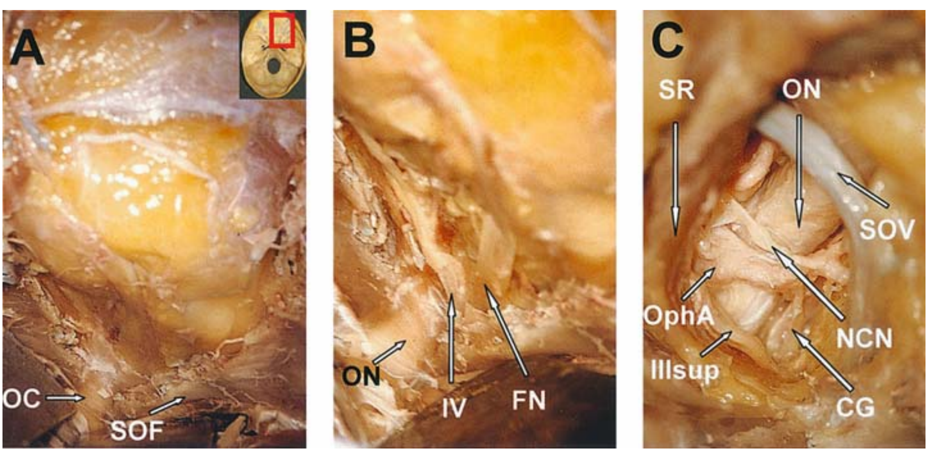

Fig. 15. Cadaver dissection showing anatomic structures encountered through a superior approach to the right orbit in the surgical position. (A) view after roof removal and opening of the optic canal (*OC*) and the superior orbital fissure (*SOF*). (B) Periorbita has been opened thereby it could be seen optic nerve (*ON*), frontal nerve (*FN*) and trochlear nerve (*IV*). (C) The lateral route with superior muscles retracted medially and fat has been removed to see the three structures crossing above the optic nerve (*ON*): superior ophthalmic vein (*SOV*), nasociliary nerve (*NCN*) and ophthalmic artery (*OphA*). We can also see at the apex the superior division of the oculomotor nerve (*IIIsup*) and on the lateral side of optic nerve the ciliary ganglion (*CG*)

flat frontal nerve making its way forwards (Fig. 15B); this is often readily perceived through the periorbita and it represents a useful anatomical landmark which is easy to find. It enters the orbit via the tapered part of the superior orbital fissure. Between this nerve and the optic nerve, as observed from this perspective, is the trochlear nerve. This extremely fine nerve carries on in front and medially making a angle of 45° with the frontal nerve and crossing over the optic nerve at the point at which it traverses the common annular tendon. It soon rejoins the upper edge of the superior oblique muscle. It is for this reason that opening the common annular tendon is associated with the risk of sectioning this nerve unless it has been identified and dissected out at the time of the opening procedure.

Throughout its path, the frontal nerve is above the lateral edge of the superior muscles (the levator palpebrae superior and the superior rectus muscles). In the anterior part of the orbit, it is less visible since it descends into the fatty tissue. This tissue can be dissected out to follow its path and discover the point at which it divides to form the supraorbital nerve (which follows the same path as the frontal nerve) and the supratrochlear nerve (which follows a medially concave curve and carries on towards the anteromedial part, passing above the superior oblique). At the same time, the whole path of the superior muscles is exposed; the levator which covers the medial edge of the rectus.

To approach an intraconical lesion, two possibilities exist: either the medial route, between the superior oblique muscle and the superior muscles or a lateral approach between these muscles and the lateral rectus muscle. The cone may also be approached between the levator and the superior rectus muscle [7, 31] but this passage is very narrow. The muscles can be put aside but this must be done gently to prevent postoperative complications.

Medially, retracting the superior muscles outside, access can be gained to the medial part of the cone although the fourth cranial nerve behind represents a major obstacle. It is important to recognize three elements which traverse this part of the orbit close to the optic nerve passing above the nerve from its lateral side as far as the medial region. These elements are (moving from the back towards the front) (Fig. 15C): the ophthalmic artery, the nasociliary nerve and the ophthalmic vein. In this medial part, it is possible to go right down as far as the level of medial rectus muscle. Beyond this point, the obstacle is this muscle's nerve which comes from the third cranial nerve passing under the optic nerve. If necessary, this exploration can be continued by opening the annular tendon along with the dura mater to completely expose the optic nerve. As has already been pointed out, this extension ought to be undertaken with care to avoid section of the trochlear nerve that passes just above in contact with the tendon.

Laterally, it is possible via this route to reach the lateral rectus muscle without any problem. Nevertheless, it is important to take care with the abductor nerve which is located on the internal side of the posterior half of this muscle. In this lateral part of the muscular cone, the lacrimal artery can be seen, climbing up from the ophthalmic artery to rejoin, a little way above the upper edge of the lateral rectus muscle, the lacrimal nerve which comes from the completely lateral part of the superior orbital fissure. These two elements (artery and nerve) carry on in front towards the lacrimal gland. In the posterior part of the cone and towards its apex, the surgeon may be hindered by the superior ophthalmic vein that comes from the medial region, traverses above the optic nerve and carries on towards the lateral part of the superior orbital fissure. It can be dissected medially and pushed towards the outside but this is associated with a risk of damage to the ciliary nerves and arteries.

An approach between the two superior muscles is achieved by pushing the muscles aside, the levator palpebrae to the medial side, and the superior rectus to the lateral side. The frontal nerve can be pushed out medially together with the levator but this will hinder access to the apex. Only the middle third of the upper part of the cone can be exposed [7, 31]. To approach the apex, the frontal nerve has to be pushed aside laterally which means that it has to be dissected, which inevitably entails a risk of damaging it. In addition, pushing these muscles aside may lead to resection of the branch supplying the levator muscle (coming from the superior branch of the third cranial nerve) which traverses the superior rectus muscle. The structures exposed by this approach are the superior ophthalmic vein, the ciliary nerves and arteries, the nasociliary nerve and the ophthalmic artery with its branches supplying the superior muscles. All these structures mean that this route is particularly difficult and fraught with risk, even if it is the most direct to the middle third of the upper part of the cone [31].

The Hybrid Lateral/Superior Approach

This hybrid approach involves the roof and the lateral wall of the orbit. It was, in effect, first envisaged by Karagjozov [21] when he extended the superior approach to encroach into the lateral wall and then other surgeons operated using the same route with some minor modifications [1]. As with the superior route it could be based on either a double flap or a single flap encroaching on the edge of the orbit. Single-flap methods are difficult to perform and the dura mater cannot be under control. In consequence, we prefer a double-flap technique. The first flap is fronto-pteriono-temporal and after detachment of the dura mater from the smaller wing of the sphenoid bone, the roof of the orbit and the middle cerebral fossa, we resect the thick orbito-cranial part of the greater wing of the sphenoid bone as far as the opening of the lateral end of the superior orbital fissure. From there, we resect a small part of the roof and the lateral wall of the orbit. The frontal and temporal lobes are reclined using an autostatic retractor and the orbital structures are protected with a flexible sheet. It is then possible, using an oscillating saw, a craniotome or a mini drill to create a second flap encroaching on the superolateral edge of the orbit including as much as possible of the roof and lateral wall. The rest of these walls is resected using a gouge forceps.

In practice, as with the lateral approach, it is not necessary to create a genuine craniotomy—a simple key hole behind the zygomatic process of the frontal bone suffices. From this hole, using a drill, the thick orbito-cranial part of the greater wing of the sphenoid bone is resected to expose the frontotemporal dura mater and open up the lateral end of the superior orbital fissure. Resection is then extended forwards into the lateral wall of the orbit, and upwards into the roof as far as possible in the medial direction. The edge of the orbit is then laterally cut at the level of the upper edge of the zygomatic arch then as far inside as possible. The saw cuts should join the preceding openings in the lateral and upper walls.

For certain lesions, and as with the lateral approaches which preserve the edge of the orbit, it is not even necessary to section orbital rim (pterional route [18] or postero lateral approach [10, 13]). The value of this route is that it preserves the orbital arch without the surgeon's access to the anterior part of the muscular cone being hindered. On the other hand, the overhanging edge of the orbit may block access to the apex.

Using a microscope, two anatomical markers can be identified (Fig. 16A): in front, in the superolateral part, the lacrimal gland (located from the perspective of this route, in the middle of the anterior edge of orbital structures) and behind, the distal tapered part of the superior orbital fissure. The periorbita is cut into between these two landmarks passing inside the lacrimal gland. A second incision is then made perpendicular to the first and parallel to orbital rim. The two flaps of the periorbita are then detached and suspended.

Along the first incision can be seen the lacrimal neurovascular bundle (Fig. 16B) going from the superior orbital fissure towards the lacrimal gland. Near and inside the superior orbital fissure, the large frontal nerve is easily seen. Outside and underneath the lacrimal bundle, the lateral rectus muscle can be seen. Finally, under the frontal nerve are found the levator and superior rectus muscles (Fig. 16C).

An incision is made into the fatty tissue and laceration is performed above and inside the lacrimal bundle. In front (inside the lacrimal gland), the eyeball is soon reached (Fig. 16D). Passing downward on the surface leads to the optic nerve, which is surrounded by the ciliary nerves and vessels. As with the superior route, in the posterior part of the cone there are three structures which cross over the optic nerve, namely (moving from the front towards the back) the superior ophthalmic vein, the nasociliary nerve

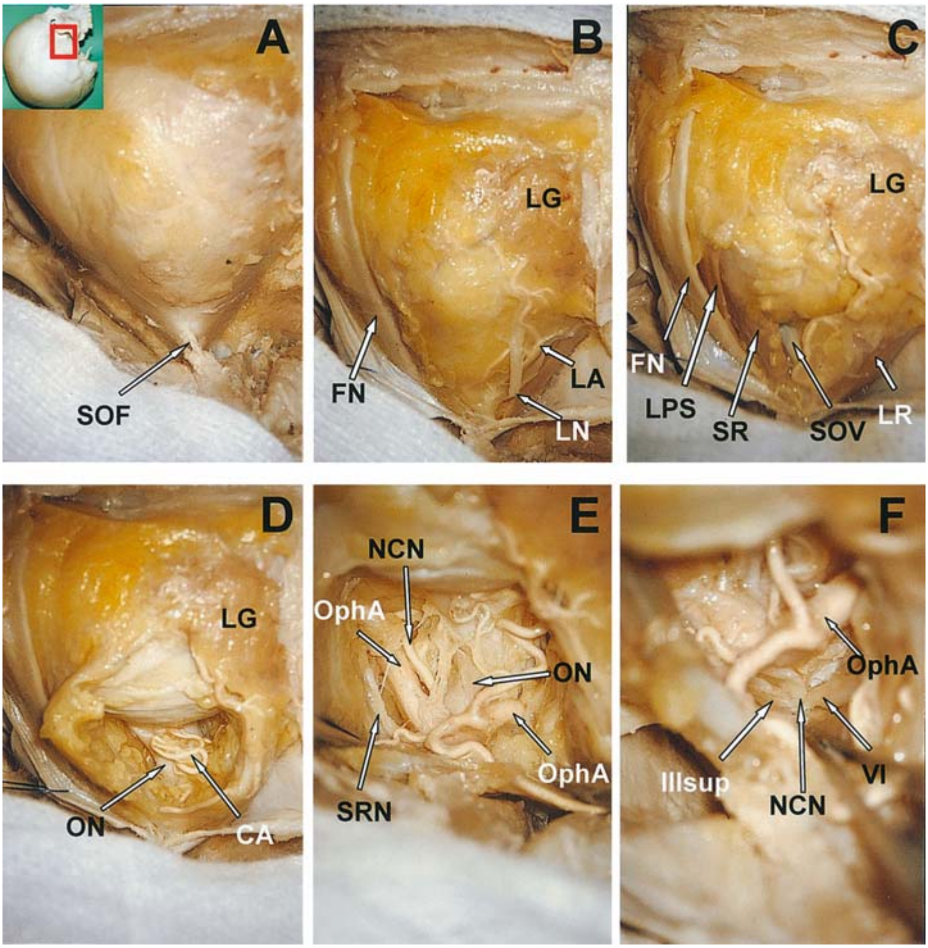

Fig. 16. Cadaver dissection showing anatomic structures encountered through a supero lateral approach to the right orbit in the surgical position. (A) Photograph after bony opening showing back the lateral extremity of the superior orbital fissure (*SOF*). (B) Periorbita has been opened and we can see the landmarks: medially frontal nerve (*FN*), laterally the lacrimal nerve (*LN*) and artery (*LA*) and in the front the lacrimal gland (*LG*). (C) Fat has been dissected to show under the frontal nerve (*FN*) the levator palpebrae superior muscle (*LPS*) and underneath the superior rectus muscle (*SR*); lateraly we can see the lateral rectus muscle (*LR*) and between these two rectus muscles the superior ophthalmic vein (*SOV*). (D) Medially and just below the lacrimal gland (*LG*) the eyeball is discovered with the optic nerve (*ON*) surrounded by ciliary arteries (*CA*). (E) Toward the apex we can see the ophthalmic artery (*OphA*) with its branches crossing over the optic nerve (*ON*) with the naso ciliary nerve (*NCN*). We can also see the nerve of superior rectus muscle (*SRN*). (F) Behind the ophthalmic artery (*OphA*) at the apex we can see the nerves which enter the orbit via the common tendinous ring: abductor nerve (*VI*), naso ciliary nerve (*NCN*) and the superior division of the oculomotor nerve (*IIIsup*), the inferior division being hidden by the ophthalmic artery

and the ophthalmic artery (Fig. 16E). Behind this, the apex is reached. Between this artery in front and the origin of the muscles can be seen the nerves which enter the orbit via the common tendinous ring (Fig. 16F). The most lateral of these is the abductor nerve which is applied against the internal face of the lateral rectus muscle; above and inside the superior branch of the third cranial nerve passes upwards, inside and forwards, juxtaposing against the superior rectus muscle where it splits giving a branch to the levator palpebrae superior muscle; medially, the extremely fine nasociliary nerve crosses over the optic nerve to accompany the ophthalmic artery and ultimately (below) the inferior branch of the third cranial nerve which is hidden by the ophthalmic artery.

Below the proximal part of the ophthalmic artery, is found the ciliary ganglion applied to the inferolateral side of the optic nerve. The nerve of the inferior oblique muscle passes outside and lower than this ganglion, carrying on forwards to reach its muscle.

As in the case of the superior route, this superolateral approach makes it possible to explore most of the regions inside the orbit other than the medial part below the optic nerve. It makes it possible to explore the apex but not the opening of the optic canal (or at least only with great difficulty).

Discussion

The choice between these alternative approach routes must be made on the basis of the location of the lesion. It is important to choose the route, which is the most direct, the least disruptive, and the one that entails the least esthetic compromise. The various neurosurgical approach routes afford access to all areas of the orbit except the inferomedial part. It could be approached by an infero lateral approach [17] but it is more accessible via a medial ENT-type approach.

If it can be avoided, the orbital edges should not be systematically resectioned for esthetic reasons. In contrast, there should be no hesitation when it comes to opening this edge if it is a question of better exposure or to prevent inopportune displacements.

The intraorbital fatty tissue can hinder access to orbital lesions but even if it is in the way, it must not be damaged. It can be lacerated and retracted by self-retained retractor [22, 23, 27] but it should not be excised (at the risk of postoperative enophthalmos). The surgeon should be aware that this fatty tissue is more abundant in the front where it is both extra- and intra-conical. It then steadily thins out as it approaches the apex where it is exclusively intraconical. It is not always easy to pinpoint the various anatomical structures because of the presence of this fatty tissue, and even the eyeball itself can sometimes be confused with a pathological mass. During installation, it is therefore useful to leave access to the eye; pressure thereon can help define its location.

We will mention a few anatomical markers, which might be useful. The lacrimal gland is easy to locate because of its relatively firm texture and pinkish color. It is not covered by the fatty tissue and lies directly on top of the eyeball so it can be followed as far as the eyeball to return back into the cone. This gland receives the neurovascular lacrimal bundle that can thus be located and which runs along the upper edge of the lateral rectus muscle. The muscles that form the orbital cone are easier to detect behind than in front since the fatty tissue is entirely intraconical at this point. Finally, the frontal nerve is very easily identified in the posterior half since it is located immediately below the periorbita, and it can be followed out in front by dissecting it out of the fatty matrix. It passes immediately over the levator palpebrae muscle.

Familiarity with the microanatomy of the orbit is essential if the various complications that this type of surgery can entail are to be avoided. The most serious of these is blindness which can only result from major and direct damage to either the optic nerve or the vessels supplying the retina. The nerve can be damaged as a result of either rough displacement or during its dissection when operating on lesions located nearby. The central artery of the retina enters into the dura mater on the nerve's medial side at a distance of 8–15 mm behind the eyeball. Therefore, when operating on posterior and medial lesions, special attention must be paid to this artery [28]. Impaired oculomotor function is the second type of complication that can be temporary or definitive, depending on the cause. The etiology may be muscular, due to damage inflicted when dissecting a lesion very close or actually involving the muscle tissue, or following traumatic displacement of the muscle. Impaired oculomotor function may also be due to nervous damage. All the branches of the oculomotor nerve (apart from that going to the inferior oblique muscle) have fairly short paths between the tendinous ring and their respective muscles (junction of the posterior third and the middle third). They can be damaged individually during surgery to remove lesions at the apex or in the posterior third of the cone. Similarly for the abductor nerve which rejoins the lateral rectus muscle in the middle of the internal side. In contrast, the branch of the inferior oblique muscle can be damaged in surgery on the anterior two-thirds if it involves the inferolateral part of the muscular cone. Such involvement rarely has any clinical repercussions. Finally, the path of the trochlear nerve is fairly short. It enters the orbit via the medial end of the tapered part of the superior orbital fissure and then passes above and in contact with the annular tendon before immediately rejoining the upper edge of the superior oblique muscle near the apex. It can be sectioned if the tendinous ring is opened which is why it should be located and dissected out beforehand. However, even when this is done as carefully as possible, damage to this nerve is almost inevitable when this type of dissection is attempted [28]. Otherwise, dissection close to the optic nerve (especially via the inferior lateral route) entails a risk of damage to the ciliary ganglion or nerves, resulting in Bernard-Horner syndrome.

The advantage of the lateral approach is that it is less invasive because opening of the cranial cavity is avoided although in this case, access is limited to the anterior part of the orbit. For posterior lesions, the orbito-temporal junction will have to be resected. Even after enlargement, it is difficult to explore the apical region via this route, and quite impossible to access the optic canal. On the other hand, it is the only approach that affords access to the inferolateral region of the cone.

A lateral approach can therefore be used for lesions located in the lateral orbit, and possibly for those in the lateral part of the apex, but not for lesions which extend into the superior orbital fissure or the optic canal [3].

A superior approach is usually indicated for orbital tumors invading into the cranial region, cranial tumors which encroach on the orbit, and lesions in the medial part of the apex or the optic canal. For lesions located in the superomedial part of the cone or if the particularities of the case mean that the entire optic nerve has to be exposed, it will be necessary to pass medially between the superior muscles and the superior oblique muscle. The angle of vision afforded by this route is restricted by the medial edge of the craniotomy, which terminates at the median line.

Passage between the superior muscles and the lateral rectus muscle is the broadest one in the superior route with as broad an angle of view. It exposes the apical region, the superior orbital fissure and the part adjacent to the cavernous sinus. The only structure that can hinder access is the superior ophthalmic vein which can be displaced either medially (which restricts access to the apex) or—to better expose this region—it can be displaced laterally although there is a risk of damaging those neurological components that pass through the superior orbital fissure and the ciliary ganglion. In this case, the common tendon can be opened between the origin of the lateral and superior rectus muscles. This passage is equivalent to the superolateral route passing over the lateral rectus muscle.

The value of the passage between the levator muscle and the superior rectus muscle is somewhat limited because the space is so confined, meaning that displacement of the various structures or dissection procedures entail a significant risk of damage to nervous components. It can be used with care for certain lesions located in the middle third of the upper part of the cone although the superolateral approach is to be preferred.

In the superior approach the anterosuperior part can be hidden by the superior muscles. These can be put aside but if this displacement is to be avoided, the superolateral approach is preferable.

The superolateral approach is a hybrid of the preceding two routes which combines many of the advantages of each. Passage between the lateral rectus muscle and the superior muscles is the broadest and the least dangerous. It affords access to all regions of the orbit apart from the inferomedial region and the optic canal. In practice, the latter can only be opened via a superior approach route with extensive retraction of the frontal lobe.

In orbital surgery, it is better to reconstruct the orbital walls at the end of the operation, whenever possible [15]. This can be done using bone fragments or plastic surgery based on acrylic material. The advantage is primarily esthetic but it is also to prevent enophthalmos or transmission of beats from the brain to the eye. Plastic surgery will also make dissection easier in the event of the need to reoperate.

Conclusion

Intimate familiarity with the microanatomy of the region is indispensable before surgery is undertaken in the orbit. This type of surgery has become routine with the development of multiple approach routes. These can be divided into three groups, namely the superior, the lateral and the superolateral approaches. The superior approach which entails craniotomy and frontal displacement is the only one which allows opening of the optic canal and affords access to lesions which encroach into the cranial region. The lateral approach is supposed to be less disfiguring and does not involve craniotomy; however, it only affords access to the lateral lesions (including those in the apex, if the broader alternative is used). The superolateral approach that we have described is the broadest route that affords access to all regions of the orbit apart from the inferomedial region. The optic canal cannot be opened from this approach unless frontal craniotomy is performed with frontal displacement. It is the most suitable approach route to the region of the superior orbital fissure.

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