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Review of orbital anatomy, the nervous system and blood supply to the eye and its adnexa

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ABSTRACT

THE EYE IS A COMPLEX SENSORY ORGAN, intricately housed in a portion of the cranium known as the orbit. For the eye care practitioner, knowledge of the structures surrounding the eye is important in aiding one's clinical diagnosis. An understanding of ocular anatomy and the surrounding orbital structures and processes is necessary for an accurate diagnosis of oculomotor, ocular disease and neuro-ophthalmologic conditions affecting the eye. Practitioners are therefore advised to consider the anatomical relationship of the eye to its surrounding structures, including the orbit, vascular and nerve supply to the eye, when investigating any ocular problems or abnormalities of the visual system.

Introduction

The eye is a complex sensory organ, intricately housed in a portion of the cranium known as the orbit. For the eye care practitioner, knowledge of the structures surrounding the eye is important in aiding one's clinical diagnosis. This article presents a review of the orbital anatomy, nerves and blood vessels associated with the eye.

Orbital Anatomy

The orbit is a bony cavity occupied by the eyes and associated muscles, nerves, blood vessels, fat and much of the lacrimal apparatus[1]. It protects, supports, and maximizes the function of the eye. Its shape can be described as a four-sided pyramid, with its apex situated posteriorly and its base anteriorly. Seven bones conjoin to form the orbital structure as depicted in Fig 1. These include:

- The frontal bone
- The zygomatic bone
- The maxillary bone
- The sphenoid bone
- The ethmoid bone
- The lacrimal bone
- The palatine bone

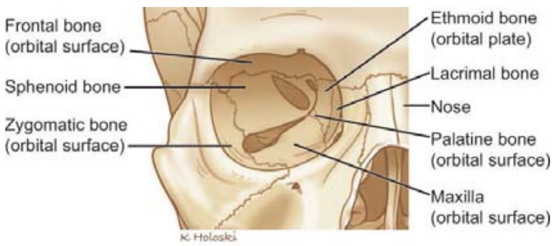

Fig 1: Bones of the orbit[2]

The orbit possesses four walls i.e. the roof, lateral wall, floor and medial wall. Structurally, the orbital process of the frontal bone and the lesser wing of the sphenoid form the orbital roof; the orbital plate of the maxilla joins the orbital plate of the zygomatic bone and the orbital plate of the palatine bones to form the orbital floor; and medially, the orbital wall consists of the frontal process of the maxilla, the lacrimal bone, the sphenoid, and the thin, smooth lamina papyracea of the ethmoid. The lateral wall is formed by the lesser and greater wings of the sphenoid, which is a wedge-like bone situated towards the middle of the skull (Fig. 2), and the zygoma.

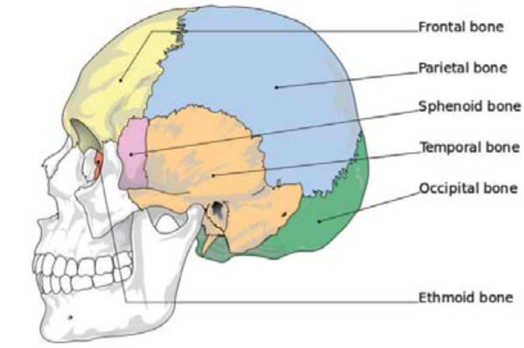

Fig 2: Sphenoid bone seen laterally[3]

The orbits are aligned so that the medial walls are parallel and the lateral walls are perpendicular, forming its pyramidal shape. The arc from medial to lateral wall in each orbit is 45°[5]. The average dimensions of the orbit are as follows:

- Height of orbital margin - 40 mm
- Width of orbital margin - 35 mm
- Depth of orbit - 40-50 mm
- Interorbital distance - 25 mm
- Volume of orbit - 30 cm^3

Orbital fissures and associated structures

The roof (frontal and sphenoid bones) presents the fossa for the lacrimal gland anterolaterally, and the trochlear pit for the cartilaginous pulley of the superior oblique muscle anteromedially. The optic canal lies in the posterior part of the roof and transmits the optic nerve and ophthalmic artery from the middle cranial fossa. The lateral walls of the two orbits are set at approximately a right angle from one another, whereas the medial walls are nearly parallel to each other (Figure 4).

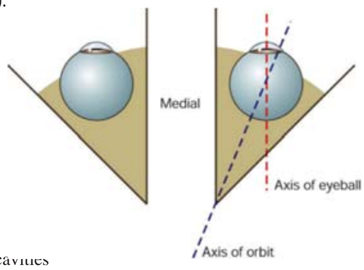

Fig. 3: Orbital cavities

The posterior aspect of the lateral wall (zygomatic and sphenoid bones) is demarcated by the superior and inferior orbital fissures (Figure 4). The superior orbital fissure lies between the greater and lesser wings of the sphenoid bone, communicating with the middle cranial fossa. It transmits cranial nerves III, IV, and VI, the three branches of the ophthalmic nerve, and the ophthalmic veins. The inferior orbital fissure communicates with the infratemporal and pterygopalatine fossae and transmits the zygomatic nerve.

The floor, consisting of the maxilla, zygomatic, and palatine bones, presents the infraorbital foramen (Figure 4) and canal for the infraorbital nerve and infraorbital artery. The inferior oblique muscle arises anteromedially, immediately lateral to the nasolacrimal canal. The medial orbital wall (ethmoid, lacrimal, and frontal bones) is very thin. Its main component, the orbital plate of the ethmoid, is paper-thin, hence the term 'papyraceous'. At the junction of the medial wall with the roof, the anterior and posterior ethmoidal foramina transmit the nerves and arteries of the same name.

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The orbit therefore communicates with the middle cranial fossa via the optic canal and superior orbital fissure, the infratemporal and pterygopalatine fossae (via the inferior orbital fissure), the inferior meatus of the nose (via the nasolacrimal canal), the nasal cavity (via the anterior ethmoidal foramen), and the face (via supraorbital and infraorbital foramina). Furthermore, it is related on its superior side to the anterior cranial fossa and usually to the frontal sinus, laterally to the temporal fossa in (anterior) and to the middle cranial fossa (posterior), on its inferior side to the maxillary sinus, and medially to the ethmoidal and the anterior extent of the sphenoidal sinuses[1]. The infraorbital sulcus crosses the floor of the orbit and carries the infraorbital artery, infraorbital vein, and infraorbital nerve from the inferior orbital fissure to the infraorbital foramen. Clinically, the infraorbital foramen provides a route of spread for infection or maxillary tumours to the orbit and the skull base. The supratrochlear notch is medial to the supraorbital notch. The supraorbital notch is within the supraorbital rim and is closed to form the supraorbital foramen in 25% of individuals.

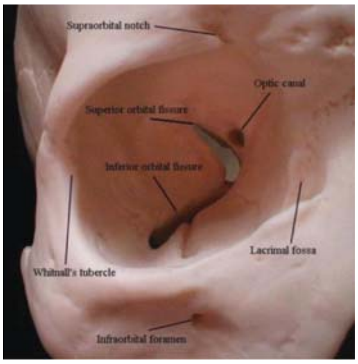

Fig. 4: Shows superficial landmarks, optic canal, and superior and inferior orbital fissures[5]

The major nerves and vessels to the orbit and globe therefore enter through three openings viz. the superior oribital fissure, the inferior orbital fissure and the optic canal. The structures entering through the superior orbital fissure are (Fig 5):

- Cranial nerves (CN) III, IV, and VI;
- Lacrimal nerve;
- Frontal nerve;
- Nasociliary nerve;
- Orbital branch of middle meningeal artery;
- Recurrent branch of lacrimal artery;
- Superior orbital vein; and
- Superior ophthalmic vein.

The structures entering through the inferior orbital fissure are:
- Infraorbital nerve;
- Zygomatic nerve;
- Parasympathetics to lacrimal gland;
- Infraorbital artery;
- Infraorbital vein; and
- Inferior ophthalmic vein branch to pterygoid plexus.

The structures entering through the optic canal are:
- Optic nerve,
- Ophthalmic artery, and
- Central retinal vein.

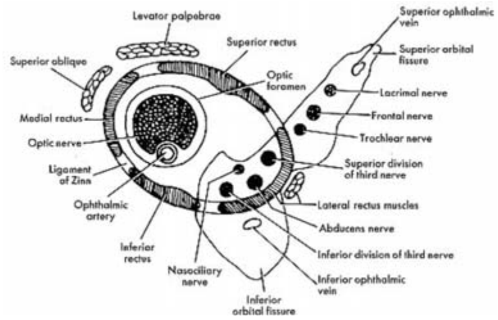

Fig. 5: Showing structures passing through the optic foramen, superior and inferior orbital fissures[7]

The trochlea, a cartilaginous ring that supports the superior oblique muscle, attaches to the periorbita along the superior-medial orbit.

THE NERVOUS SYSTEM

Two integrated organ systems i.e. the nervous system and the endocrine system serve to monitor and maintain a stable internal environment as well as respond to changes in the external environment.

Three basic functions are performed by the nervous system:

1. To receive sensory input from the internal and external environments;
2. To integrate the input received; and
3. To respond to stimuli.

Sensory input is facilitated by receptors which sense changes in the internal or external environment which may be in various forms including temperature, taste and light. These inputs are converted to signals and sent to the brain or spinal cord for interpretation and response. In the sensory centres of the brain or spinal cord, inputs are integrated and a motor response or output is generated. This motor output transmits a signal to relevant organ/s that then convert this into an action, such as reflex tearing, changes in heart rate, etc.

The nervous system comprises the central nervous system (CNS), consisting of the brain and spinal cord, and the peripheral nervous system (PNS) which consists of the cranial, spinal, and peripheral nerves together with their motor and sensory endings (Figure 6). The PNS connects the CNS to other parts of the body and is composed of millions of nerve and glial cells, blood vessels and connective tissue.

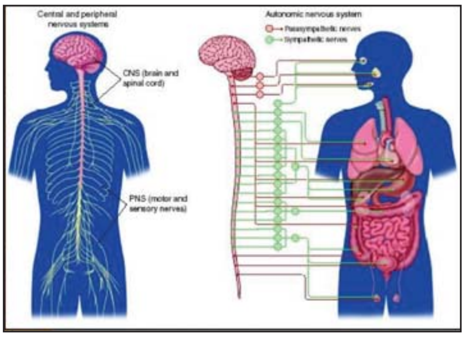

Fig. 6: Central and Peripheral nervous systems[4]

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Neurons are characterized by multiple processes and specialized for reception and transmission of signals. The glial cells (neuroglia) are characterized by short processes that have special relationships to neurons, blood vessels, and connective tissue, and provide physical support and protection for neurons.

The PNS contains only nerves and connects the brain and spinal cord (CNS) to the rest of the body. A nerve is a collection of multiple constituent fibres bound together by connective tissue possessing axons and dendrites. The axons and dendrites which transmit impulses are surrounded by a white myelin sheath. Myelin is an electrical insulator which facilitates conduction in axons[8].

The two main components of the PNS are:
1. Sensory or afferent pathways that provide input from the body into the CNS.
2. Motor or efferent pathways that carry signals to muscles and glands (effectors).

Peripheral nerve fibres may be classified according to the structures they supply, i.e. according to function. A fibre that stimulates or activates skeletal muscle is termed a motor (efferent) fibre. A fibre that carries impulses from a sensory ending is termed a sensory (afferent) fibre. Fibres that activate glands and smooth muscle are also motor fibres, and various kinds of sensory fibres arise from endings in viscera (internal organs of the body). Most nerves are mixed nerves made up of both sensory and motor elements. Furthermore, most sensory input carried in the PNS remains below the level of consciousness. Input that does reach the conscious level contributes to perception of our external environment[9].

There are two major subdivisions of the PNS motor pathways: the somatic and the autonomic systems.

a. Somatic Nervous System

The Somatic Nervous System (SNS) includes all nerves controlling the muscular system and external sensory receptors. External sense organs, including the skin, are receptors. Muscle fibres and glandular cells are effectors. The reflex arc is an automatic, involuntary reaction to a stimulus, with the CNS being informed, but not consciously controlling the response. Examples of reflex arcs include balance, the blinking reflex, and the stretch reflex.

Sensory input from the PNS is processed by the CNS and responses are sent by the PNS from the CNS to the organs of the body. Motor neurons of the somatic system are distinct from those of the autonomic system as inhibitory signals cannot be sent through the motor neurons of the somatic system[9].

b. Autonomic nervous system

The Autonomic Nervous System is that part of PNS consisting of motor neurons that control internal organs. It is also known as the visceral nervous system and has two subsystems: the parasympathetic nervous system and the sympathetic nervous systems. It acts as a subconscious control system for visceral organs and regulates functions such as heart rate, glandular activity (salivation) and diameter of pupils.

The sympathetic nervous system is involved in the fight or flight response. The parasympathetic nervous system is involved in relaxation. Each of these subsystems operates antagonistic to the other e.g. when you are afraid, the sympathetic system causes your heart to beat faster and the parasympathetic system reverses this effect. Both systems innervate the same organs and act to maintain homeostasis. Motor neurons in this system usually do not reach their targets directly but connect to secondary motor neurons which in turn innervate the target organs with inhibitory and excitatory synapses between neurons.

The autonomic system can be considered as a series of hierarchical levels, with the higher levels producing more widespread and general functions. The highest level is the cerebral cortex, certain areas of which control or regulate visceral functions.

These areas then send fibres to the hypothalamus which is a coordinating centre for the motor control of visceral activity. The hypothalamus also sends nerve fibres to lower centres in the brain stem that are concerned with more specific functions such as regulation of breathing, heart rate and circulation. These centres function through connections with still lower centres, which are collections of nerve cells in the brain stem and spinal cord that send their axons into certain cranial and spinal nerves. It is characteristic of these axons that they synapse with multipolar neurons located in ganglia outside the central nervous system before they reach the structure to be supplied. The axons that pass from the central nervous system to these ganglion cells are termed preganglionic fibres. The axons of ganglion cells are called postganglionic fibres.

Functions of the ANS

By its role in central integrating mechanisms, the autonomic system is involved in processes which keep the body's internal environment constant. The parasympathetic system is concerned with specific functions, such as digestion, metabolism, and excretion; and the sympathetic system is an important part of the mechanism of reaction to stress.

THE CRANIAL NERVES

Nerves in the human body control movement and carry sensory information from various areas of the body. Twelve nerves innervate parts of the cranial region and related structures, hence the term called Cranial Nerves. These 12 cranial nerves and their antero-posterior arrangement are depicted in the image below.

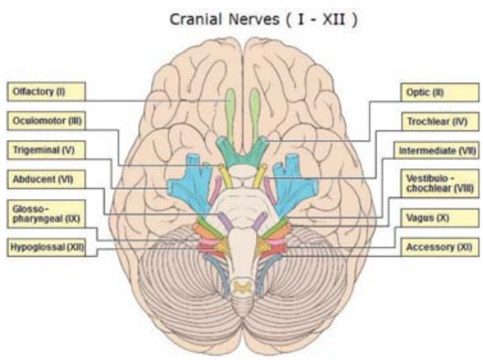

Figure: The 12 Cranial Nerves[11]

Most major nerves emerge from the spinal cord with the 12 pairs of cranial nerves projecting directly from the brain. All but 1 pair relay motor or sensory information (or both); the tenth (vagus nerve) affects visceral functions such as the heart rate, vasoconstriction and contraction of the smooth muscle found in the walls of the trachea, stomach, and intestine.

PERPHERAL NERVES

The branches of major peripheral nerves are usually muscular, cutaneous (or mucosal), vascular (adjacent to blood vessels) or terminal (including any of the foregoing types). Muscular branches are the most important: sectioning off even a small muscular branch of a peripheral nerve results in complete paralysis of all muscle fibres supplied by that branch and may be seriously disabling[1]. Adjacent nerves may communicate with each other and such communications sometimes account for residual sensation or movement even after damage to a nerve above the level of a communication.

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The optic nerve is actually a tract of the central nervous system rather than a peripheral nerve. Nerve supply to the eye is primarily by the ophthalmic nerve, which is one of the 3 branches of the trigeminal nerve (cranial nerve V) which branches off into multiple divisions (Figure 7). The oculomotor nerve (cranial nerve III) supplies all the extraocular muscles, except the superior oblique, which is supplied by cranial nerve IV, and the lateral rectus, which is supplied by cranial nerve VI. The third nerve also supplies the levator palpebrae superioris, and indirectly the iris and ciliary muscle of the eyeball, through the ciliary ganglion. A complete paralysis of the third nerve therefore causes ptosis, or drooping of the eyelid; external rotation of the eyeball, and consequent diplopia; fixation of the eyeball, save for down and outward movements; loss of power of accommodation (ciliary paralysis); and dilatation of pupil.

The fourth (trochlear) nerve is rarely affected alone, and when it is, causes a slight upward movement, with limitation of downward movement of the eyeball, possibly resulting in diplopia. When the sixth nerve is paralyzed there is convergent strabismus with consequent diplopia. The first or ophthalmic division of the fifth nerve supplies sensation by its three branches to the skin of the brow, upper eyelid, both canthi, and nose; eyeball and conjunctiva, except that of the lower lid; and also the nasal mucosa. Lesions of this branch are followed by loss of reflex blinking, and hence irritation and ulceration of the cornea are likely to follow.

Sensory fibres from the cornea and uvea reach the nasociliary nerve (of the ophthalmic nerve) by way of the short and long ciliary nerves. The sympathetic system supplies some fibres in the upper and Müller's muscle, as well as the radial or dilator fibres of the iris resulting in a dilated pupil and retraction of the upper lid in a high stress, fight or flight response.

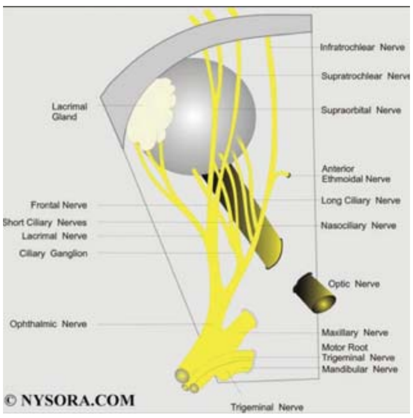

Fig 7: Sensory innervation of the eye and orbit[10]

BLOOD SUPPLY TO THE EYE

The eye receives its blood supply from the ophthalmic artery by way of the central artery of the retina, short and long posterior ciliary arteries and the anterior ciliary arteries. The ciliary arteries divide into 2 long posterior ciliary arteries and ~20 short posterior ciliary arteries that enter the eye immediately adjacent to and around the optic nerve. The short posterior ciliary arteries directly supply the choroid, and the long posterior ciliary arteries travel in the suprachoroidal space anteriorly, then supply the choroid anteriorly via recurrent branches. The internal part of the retina is supplied by the branches of the central retinal artery, which do not anastomose / communicate with each other. The short posterior ciliary arteries give rise to numerous capillaries that supply the external part of the retina. At the front of the eye, posterior conjunctival vessels become dilated during inflammation of the conjunctiva, whereas the anterior ciliary vessels become dilated in inflammation of more anterior structures of the cornea, iris or ciliary body.

Most of the veins from the eye accompany the arteries and drain into the cavernous sinus by way of the ophthalmic veins. The choroid is the most vascular structure in the eye, with blood in the choroid circulating through choriocapillaries and draining through 4-6 vortex veins which emerge just posterior to the equator in quadrants, draining into the superior and inferior ophthalmic veins. The vortex veins anastomose with the anterior ciliary veins which normally carry blood only from the anterior ciliary muscle, but may become quite dilated if the vortex veins are occluded. The anterior ciliary venous system joins the conjunctival and episcleral vessels at the junction of the limbus. These vessels eventually exit via the cavernous sinus.

Conclusion

An understanding of ocular anatomy and the surrounding orbital structure and processes is necessary for an accurate diagnosis of oculomotor, ocular disease and neuro-ophthalmologic conditions affecting the eye. Practitioners are advised to consider the anatomical relationship of the eye to its surrounding structures when investigating any abnormalities of the eye or visual system.

References:

1. O'Rahilley, Muller, Carpenter and Swenson. "The Orbit." In Basic Human Anatomy, by Muller, Carpenter and Swenson O'Rahilley. Darmouth Medical School, 2004.
2. Thanc Foundation, 2015. Orbital Tumours. Available from http://www.headandneck-cancerguide.org/teens/cancer-basics/explore-cancer-types/orbital-tumors/
3. Cranial bones. Available from https://commons.wikimedia.org/wiki/File:Cranial_bones_en.svg
4. Study Blue. Bones, Viscera, Fascia. University of Washington. Availabe from https://www.studyblue.com/notes/note/n/bones-viscera-fascia/deck/2604042
5. Petruzzelli, GJ. 2013. Orbit Anatomy. Available online from http://emedicine.med-scape.com/article/835021-overview. Accessed 23 September 2015.
6. Walker, C. Peripheral nervous system. Available online from http://www.biologyrefer-ence.com/Oc-Ph/Peripheral-Nervous-System.html Accessed 25 September 2015.
7. Cybersight. Surgical Anatomy. Available from http://www.cybersight.org/bins/volume_page.asp?cid=1-2161-2163-2175
8. Morell, P and Quarles, RH. 1999. The Myelin Sheath. Available online at http://www.ncbi.nlm.nih.gov/books/NBK27954/
9. Fridman, A and Friedman, G. 2012. Plasma medicine. Joh Wiley and Sons.
10. New York School of Regional Anaesthesia. 2013. Local and Regional Anaesthesia for eye surgery. Available from http://www.nysora.com/mobile/regional-anesthesia/sub-specialties/3029-local-regional-anesthesia-for-eye-surgery.html
11. The Twelve Cranial Nerves. Available form http://www.my-ms.org . Accessed 28 September 2015.
12. Surgical Anatomy. Available from http://bookdome.com/health/anatomy/Surgical-Anatomy/Nerve-Supply-to-the-Eye.html#.VgozpW5OWpD Accessed 29 September 2015.