possible that the antibacterial properties of liquor amnii may be decreased in the presence of poor maternal nutrition, resulting in a greater susceptibility to infection. Maternal nutritional status assessed by height, weight and weight/height ratio was not significantly different between the normal and infected mothers; however, nor was fetal nutrition, assessed by birth weight, significantly different. The high incidence of amniotic fluid infection with no apparent ill effects on the fetus at term has been documented in the study population, but the causative organism, predisposing factors and ability of the fetus to prevent systemic infection remain to be elucidated.

We wish to thank Professor D. A. Davey for allowing access to the antenatal records.

REFERENCES

The Orbital Muscle of Müllер

M. J. TOERIEN, A. E. F. GOUS

SUMMARY

The orbital muscle consists of smooth muscle fibres interspersed with blood lacunae and is therefore both contractile and erectile. Contraction is under sympathetic control, whereas erection appears to be under parasympathetic (pterygopalatine) influence. Apart from its possible effect on the position of the eyeball in the orbit, the muscle seems to be mainly concerned with directing facial venous blood to or away from the cavernous sinus which acts as a heat exchanger for internal carotid blood.


Three smooth muscles in the orbit are associated with the name of Heinrich Müllér, the Würzburg anatomist of the last century. Perhaps the best known of the three is the orbital muscle, which spans the inferior orbital fissure and is pierced by vessels connecting the ophthalmic veins to the pterygoid plexus. The function of this extensive muscle which reaches the cavernous sinus posteriorly is unknown in man, but in other mammals it is described as a protractor (propulsor) of the eyeball.

What else is known about this muscle? It was shown many years ago that embryologically it forms part of the masticatory musculature, that it contains lacunae lined by endothelium and connected to arterioles and venules, and that a number of orbital nerves from the pterygopalatine ganglion pass through and around the muscle. Müllér,

Duke-Elder and Wybar and Wolff are of the opinion that these nerves innervating the muscle are of sympathetic origin, but Ehinger also found cholinergic nerve endings in the muscle.

MATERIALS AND METHODS

The heads of two human embryos of 80 mm crown-rump (C-R) length were serially sectioned (20 µm) and stained with haematoxylin and chromotrope 2R. The contents of the orbit and surrounding structures were graphically reconstructed. All nerves visible at a magnification of 400 were depicted.

Description

The muscle has been described so often that very little can be added. At this stage of development, however, the inferior orbital fissure is incompletely formed and the orbit is inferiory continuous with the infratemporal fossa. Through this deficiency the orbital muscle is in close contact — virtually continuous (Fig. 1) — with the temporal muscle. Posteriorly the muscle supports the ophthalmic veins as they enter the cavernous sinus. Anteriorly the muscle reaches the posterior part of the eyeball. Laterally it is continuous with the periosteum and perichondrium of the orbital walls. Apart from the orbital branches of the pterygopalatine ganglion passing round the muscle, at least six fibre bundles enter it (Fig. 2). Many of these fibres carry ganglia which seem to be associated with the pterygopalatine ganglion. Lacunae containing blood cells are found throughout the spongy muscle, but the detailed anatomy could not be studied in the thick sections.

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DISCUSSION

At first glance it seems strange that striated (temporalis) and smooth (orbital) muscles could have the same origin. However, one should bear in mind that the muscles of mastication have secondarily become voluntary (and striated) and they therefore should have the same embryological (i.e. visceral) origin as the orbital muscle.

The large number of ganglion-carrying orbital branches of the pterygopalatine ganglion innervating the muscle (first observed by Vitalii) indicate that the cholinergic nerve endings, found by Ehinger among a preponderance of sympathetic fibres, are almost certainly of parasympathetic origin.

The development of exophthalmos in humans was ascribed to stimulation of the sympathetic nerves, contraction of the orbital muscle fibres and consequently a blocking of the veins passing through the muscle, which in turn results in the accumulation of venous blood behind the eyeball. More recently the occlusion of the large vessels passing through the muscle (to produce exophthalmos) was also thought to be caused by the congestion and dilatation of the blood spaces. These views were not very seriously considered since there are so many alternative pathways for venous blood to leave the orbit, for instance anteriorly along the large angular vein.\textsuperscript{5,6} Vermeij-Keers\textsuperscript{7} recently returned to this aspect of venous occlusion and suggested that because of the extensive contact between the orbital muscle and the cavernous sinus, contraction of the muscle could at least cause changes in the venous blood flow.

It seems to us that previous workers have missed the point. A study of the muscle reveals that it consists mainly of a body of erectile tissue and any function ascribed to it should therefore also be related to its ability to become erect.

The relationship between smooth (and striated) muscle and erectile tissue is not unexpected. The muscles (propulsors and retractors) of the penes of lower vertebrates have developed into the corpora cavernosa and corpus spongiosum of mammals and are supplied by pelvic parasympathetic nerves. The walls of the organ of Jacobson (vomeronasal organ) of many mammals contain smooth muscle which is both contractile and erectile and functions as a pump to suck in or dispel buccal and/or nasal fluid into or from this hollow organ, which is innervated by the parasympathetic terminal nerve\textsuperscript{8} and which was found to mediate sexual behaviour.

Since there are four retractors of the eyeball to only two protractors (oblique muscles) the orbital muscle of Müller could conceivably be regarded as an additional protractor to counteract the stronger action of the four recti. The tone of the orbital muscle is maintained by the sympathetic nerves and with a lesion of the orbital sympathetic nerves the muscle is relaxed and the eyeball sinks into the orbit. Coupled with the drooping of the upper eyelid and contraction of the pupil, these signs constitute features of Horner's syndrome.

![Diagram](image-url)

**Fig. 1.** Semidiagrammatic section through the orbit of 80 mm C-R length human fetus to show the relationship of the orbital muscle to the temporal muscle.

**Fig. 2.** Semidiagrammatic reconstruction of orbital muscle of 80 mm C-R length human fetus to show its parasympathetic innervation and its relationship to surrounding structures. Vertical dimensions not to scale.
Active contraction of the saucer-shaped muscle causes it to become flattened; under conditions of apprehension or fright (sympathetic stimulation) the eye will tend to be pushed out of the socket (although this is denied by some). This action is enhanced or magnified by the wider opening of the palpebral fissure partly caused by the contraction of the other smooth muscle in the upper eyelid named after Müller. The reflex popping of the eyes following the interruption of a light stimulus, noticed by Perez in infants, seems to be caused by the contraction of the levator palpebrae superioris (and other eye muscles) and does not seem to have a sympathetic base.

The observation of Vermeij-Keers that contraction of the muscle can influence the direction of the orbital venous blood flow deserves closer scrutiny. The function of the cavernous sinus is to cool the blood in the internal carotid artery passing through it to the brain. It is therefore conceivable that when the temperature of the arterial blood reaching the sinus is too high (e.g. during strenuous exercise), venous blood flowing from the face through the orbit to the sinus will tend to reduce the temperature of the internal carotid blood passing through it. Under more normal conditions contraction (or erection), or possibly relaxation of the orbital muscle, will enable the facial or orbital blood to bypass the cavernous sinus.

However, it also seems possible that sexual parasympathetic stimulation will cause not only erection of the external sex organs and in some people of the erectile nasal mucoperiosteum, but also of the orbital muscle. Fright is therefore not the only emotion capable of causing the eyes to at least theoretically, to literally pop out of their sockets.

**CONCLUSION**

The orbital muscle develops as part of the muscles of mastication (visceral musculature) and in the 80-mm human fetus it is still in very intimate contact with the temporal muscle through the large inferior orbital fissure. The temporal muscle develops into a striated voluntary muscle, whereas the fibres of the orbital muscle remain smooth, but become interspersed with blood lacunae. The muscle is innervated by both sympathetic and parasympathetic nerves, the latter derived from the pterygopalatine ganglion.

Previous work on the muscle in man centred around its ability to block venous return from the orbit and consequently on its role in the possible development of exophthalmos. However, the function of the muscle should be considered in terms of its contractile and erectile aspects. Contraction and tone are assumed to be under sympathetic control, whereas erection is controlled by the large complement of parasympathetic orbital branches.

Apart from the theoretical possibility of causing protrusion of the eyeball (contraction or erection of the muscle) with sympathetic (fright) or parasympathetic (sexual) stimulation, it seems to act as a regulator of facial venous blood flow to or away from the cavernous sinus which acts as a heat exchanger for arterial blood passing to the brain.

The dual function of contraction and erection of the orbital muscle is similar to that found in the smooth muscles in the walls of the vomeronasal organs of many mammals.

**REFERENCES**