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Nervous system

Topographical and surgical anatomy of third cranial nerve. A review

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Abstract

Knowledge of the neuroanatomy of the third cranial nerve, oculomotor nerve, which provides motor innervation to four of the six extraocular muscles and the levator palpebrae superioris, and parasympathetic innervation to the sphincter pupillae and ciliary muscles, is critical for neurosurgical management of lesions located in the cavernous sinus or orbit. The oculomotor nerve itself has a complex anatomy regarding anatomical landmarks for its localization, considering the characteristics of the arachnoidal sleeve and cisterns that accompany the oculomotor nerve especially through the cavernous sinus. The aim of this review was to underline anatomical landmarks for localization of the ocumolotor nerve.

Keywords

Oculomotor nerve, neuroanatomy, surgical anatomy, neurosurgery.

Introduction

Knowledge of the neuroanatomy of the III cranial nerve, oculomotor nerve, which provides motor innervation to four of the six extraocular muscles and the levator palpebrae superioris, and parasympathetic innervation to the sphincter pupillae and ciliary muscles, is critical for neurosurgical management of lesions located in the cavernous sinus or orbit.

The aim of this review is to underline anatomical landmarks for localization of the ocumolotor nerve, considering the characteristics of the arachnoidal sleeve and cisterns that accompany the oculomotor nerve especially through the cavernous sinus.

Material and methods

A systematic literature review of English articles since 1965 was performed using search terms pertaining to oculomotor nerve topography, surgical triangles, cisterns and cavernous sinus anatomy.

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Results

The nuclei of origin of cranial nerve III, the triangular-shaped oculomotor nuclear complex, is located in the mesencephalon. Edinger (Edinger, 1885) and Westphal (Westphal, 1887) described the small-cell nuclei which still commemorate them, and in 1889 Perlia (Perlia, 1889) combined these and his own topographic findings to produce his well-known diagram of the oculomotor nucleous. He added another paired, small-cell group, the anteromedian nucleus, situated cranially and in the midline, and caudal to this his better known "central" nucleus. The oculomotor nucleus consists of an elongated mass of cells lying ventral to the periaqueductal gray matter adjoins the trochlear nucleus rostrally at the ventral border of the periaqueductal gray matter and extends rostrally to the level of the posterior commissure (Büttner-Ennever, 2006).

Unlike the troclear and abducens nuclei, the oculomotor nucleus has both midline unpaired and lateral paired portions. It consists of several cell groups: the symmetrically paired lateral nuclei, which provide the innervation of the extrinsic ocular muscles, and the symmetrically paired parasympathetic nuclei, situated above, medial to and in front of the preceding nuclei, which provide the innervation of the intrinsic ocular muscles.

Fascicles of the oculomotor nerve originate from the entire rostral-caudal extent of the nucleus and pass ventrally through the medial longitudinal fasciculus, red nucleus, substantia nigra, and medial part of the cerebral peduncle. As they pass through the red nucleus, the fascicles fan out, and converge again before exiting the midbrain in the interpeduncular fossa. Based on clinicoradiologic and clinicopathological findings, it is proposed that, from lateral to medial, the order of fascicles is inferior oblique, superior rectus, medial rectus and levator palpebrae, inferior rectus, and pupil (Gauntt et al., 1995).

The apparent origin of the oculomotor nerve is from the anterior aspect of the brainstem, at the medial border of the base of the cerebral peduncle. After leaving the cerebral peduncle and the posterior perforate substance the nerve courses between the posterior cerebral artery and superior cerebellar artery and passes forward, downward, and laterally via the basal cistern (Adler and Milhorat, 2002).

The nerve passes inferolateral to the posterior communicating artery, above the superior cerebellar artery, below the temporal lobe uncus, where it runs over the petroclinoid ligament, medial to the trochlear nerve and just lateral to the posterior clinoid process. An arachnoidal reinforcement is there where the posterior communicating artery penetrates the interpenducular cistern and the oculomotor nerve with its own arachnoid sheath, leaves the cistern to enter the dura of the cavernous sinus. Dense arachnoid trabeculae often bind the artery and nerve to each other at this point (Yasargil et al., 1984). The nerve glides under the posterior clinoid process, producing a more or less marked sulcus on the lateral margin of the dorsum sellae, and then enters the transverse plate of the cavernous sinus at the "pore" for the oculomotor nerve. The anterolateral margin of the oculomotor pore is sharp. A pocket of dura and arachnoid accompanies the nerve for a distance of 6-8 mm into the cavernous sinus (Lang, 1983). During the subarachnoid course, parasympathetic pupillary fibers lay peripherally in the dorsomedial part of the nerve (Sunderland and Hughes, 1946).

Within the wall of the cavernous sinus, the third cranial nerve lies initially above the trochlear nerve, where it receives sympathetic fibers from the carotid artery. It does not become incorporated into the fibrous dural cavernous sinus wall until it reaches the lower margin of the anterior clinoid process. The lower cavernous sinus is an interperiosteo-dural space limited laterally by a meningeal layer. The medial wall is composed of 2 parts: the sphenoidal part, which corresponds to the endosteal layer, and the hypophyseal part, which corresponds to the encephalic (meningeal) layer. (François et al., 2010).

After leaving the cavernous sinus, the oculomotor nerve is crossed superiorly by the trochlear and abducens nerves and divides into superior and inferior rami, which pass through the superior orbital fissure (Natori and Rhoton, 1995), and enter the orbit within the annulus of Zinn. The superior oculomotor division runs lateral to the optic nerve and ophthalmic artery, to supply the superior rectus and levator palpebrae muscles from their global sides. The larger inferior oculomotor division branches in the posterior orbit, to supply the medial rectus, inferior rectus and inferior oblique muscles and the ciliary ganglion (Sacks, 1983).

Crucial to the surgeons understanding of the relevant surgical anatomy of the cavernous sinus is a working knowledge of the multiple triangular shaped entry corridors into the region (Fukushima, 2011).

The oculomotor nerve delineates three of the cavernous sinus surgical triangles: clinoidal (anteromedial), oculomotor (medial or Hakuba's) and supratrochlear (paramedian or Fukushima's) triangles

The clinoidal triangle is bounded by the optic neve, oculomotor nerve before entering the superior orbital fissure and from the dural fold between dural entries of optic and oculomotor nerves. The clinoidal triangle is visible after removing the anterior clinoid process. It is limited laterally by the oculomotor nerve and medially by the lateral margin of the optic nerve. It is in close relationships with the clinoid segment of the internal carotid artery.

The oculomotor triangle is where the oculomotor nerve enters the roof of the cavernous sinus. The corners of this space are the anterior and posterior clinoid processes and the petrous apex. These points are connected by the anterior and posterior petroclinoid folds and the interclinoid dural fold. The space bounded by this triangle exposes the distal intracavernous carotid artery and is an important access corridor for tumors involving the medial cavernous sinus and for approaches to the interpeduncular fossa.

The supratroclear triangle is bounded by the III and IV cranial nerves with its posterior margin being the crest of dura at the transition from medial to posterior fossa. This triangle is the most suitable for exposure of the carotid cavernous segment-clinoid segment junction (Fukushima, 2011). The supratroclear triangle is defined by the oculomotor (located above) and trochlear (located bellow) nerves, it is called medial triangle by some authors and has the following corners: subclinoidal carotid segment, posterior clinoid process, and the oculomotor porus.

The oculomotor cistern courses from the oculomotor porus to the inferior surface of the anterior clinoid process. The segment of the nerve inside the oculomotor cistern is interposed between its free portion in the interpeduncular cistern and the part of its course where it is incorporated into the fibrous lateral wall of the cavernous sinus. This small dura-arachnoid cuff is filled with cerebrospinal fluid and is an important surgical and imaging landmark. The nerve in its proximal intracisternal portion averages a diameter 2.5-3.0 mm, is round. Progressively the nerve towards and downwards the cavernous sinus becomes flattened. Its intracisternal cross section area is on the right 2.90 - 4.55 mm^2 and on the left 2.90 - 4.22 mm^2 (Thorsteinsdottir, 1982).

In its cisternal course after emergence from the brain stem the oculomotor nerve receives arterial supply from branches of the vertebrobasilar system, may receive arterial supply in the vicinity of the posterior perforating substance from the basilar artery or from the posterior cerebral artery. The blood supply of the intracranial portion of the oculomotor nerve from its emergence from the brainstem until it passes over the posterior cerebral artery originates from thalamic perforating branches. The middle intracranial part of the nerve does not receive nutrient arterioles from adiacent arteries (Fukushima, 2011).

Dural arteries contribute to the supply of the nerve in its distal dural and transosseous course. On the roof of the cavernous sinus blood is supplied by the marginal artery of the cerebellar tentorium which usually is a branch of the meningohypophyseal trunk. The marginal artery of the tentorium is an arcade between orbital vessels and branches of the carotid siphon. Many anatomic variations may be observed in this region (Lasjaunias, 2001).

Discussion

Cranial nerve III injury most likely occurs during cavernous sinus surgery or during surgery in the region of the interpeduncular fossa. Injury is one of the leading postoperative ophthalmological morbidities following cavernous sinus surgery and may occur during some of the steps in approaching benign cavernous sinus tumors after splitting the Sylvian fissure: (a) resection of the dura and underling anterior clinoid and lateral cavernous sinus wall; (b) resection of the optic strut and exposure of the orbital apex; (c) piecemeal resection of the tumor to expose cranial nerve V and its branches, cranial nerve III and cranial nerve IV (Sekhar et al., 1987). Due to its short intracavernous course, its anatomical continuity can often be preserved. However, it is very fragile and temporary functional impairment can occur with minimal manipulation. Success of third nerve regeneration after operative repair appears to be limited due to its highly differentiated functions. Aberrant regeneration of the oculomotor nerve following surgical intervention is likely more common than current literature would suggest (Weber and Newman, 2007).

The evolution of technology promote new studies as the use of two and three dimensional educational materials for accurate study of the triangles and nearby structures trying to analyse further the surgical anatomy of the cavernous sinus (Beom Sun Chung et al., 2016)

All these points support the usefulness of continuous anatomical knowledge improvement through theoretical and practical preparation for neurosurgeons to obtain the best preservation of oculomotor nerve.

Conclusion

The oculomotor nerve itself has a complex anatomy regarding anatomical landmarks for localization of the nerve, considering the characteristics of the arachnoidal sleeve and cisterns that accompany it especially through the cavernous sinus. This makes consistent landmarks difficult to identify, therefore it is necessary that neurosurgeons have the most complete knowledge of the surgical and functional anatomy of this nerve to obtain the best preservation during neurosurgical operations.

Advanced section images that allow identification of almost all structures in the entire courses of III, IV, and VI cranial nerves from the central to the peripheral nervous system can inform on the potential ability of such images for the construction of sophisticated three-dimensional models of those nerves from the brainstem to the orbit (Park et al., 2015). Technologically advanced cadaveric dissections supported by high resolution images (7 Tesla magnetic resonance imaging) and appropriate neurosurgical procedures could improve the already available knowledge regarding the surgical anatomy of the III cranial nerve (Fukushima, 2011).

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