

# MICROANATOMY OF THE TRIGEMINAL CAVUM: MECKEL'S CAVE

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## ABSTRACT

The anatomy of the trigeminal cavum also known as Meckel's cave is still poorly understood despite the number of various descriptions available in the literature. The new concept of parasellar compartment means that Meckel's cave and the cavernous sinus constitute a unique entity. We sought to understand anatomic organization of the trigeminal cavum through dissection of 5 previously frozen, formalin-fixed human heads under operating microscope and to gain further knowledge about pathological processes developed in this intracranial region. Meckel's cave appeared as an invaginated fingered-glove structure tightly attached to the lateral wall of the cavernous sinus and is located in the ventro-lateral quadrant delineated by petro-clinoid folds. The trigeminal porus was observed to be located halfway between the back of the dorsum sellae and the porus of the internal auditory meatus. The trigeminal nerve is the main constituent of Meckel's cave. The microanatomy of Meckel's cave is described and the trigeminal cavum can be involved in pathological processes such tumors, meningiomas and trigeminal neuralgia.

**Keywords:** Microanatomy, parasellar compartment, trigeminal cavum, cavernous sinus

## INTRODUCTION

Meckel's cave is a perfect site where pathological processes such as trigeminal neuralgia and tumours arise (Du et al, 2001). Although conventional MRI with T1 and T2 sequences may be sufficient in diagnosing these processes, it is paramount however to acquire high resolution gradient echo T2-weighted imaging with 3D construction in steady state (3D Ciss) and 3D fast inflow with steady-state precession (3-D-FISP) (Akimoto et al, 2002; Held et al, 2001; Seitz. et al, 2002.). During an anterior petrectomy via a petroclival approach for tumour removal (neuronoma, meningioma), the trigeminal cavum represents the anterior limit when drilling the petrous apex (Velut S and Jan M. 1988). It is wedged between the meningeal and periosteal sheets of the dura and contains the trigeminal ganglion, the trigeminal cistern and

postganglionic trigeminal rootlets. The aim of the present study was to understand anatomic organization of the Meckel's cave and to gain further knowledge about pathological processes developed in this intracranial region. The microanatomy is described and photograph of stepwise dissection taken using an Olympus box attached to the operating microscope are included.

Meckel's cave is wedged between the meningeal and periosteal sheets of the dura and contains the trigeminal ganglion, the trigeminal cistern and postganglionic trigeminal rootlets. The periosteal layer stretches forward to that of the cavernous sinus lining the temporal bone and the meningeal layer is in contact with the arachnoid. Meckel's cave extends forward to

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the cavernous sinus and together, they form a single entity. It sits tightly on the petrous apex at the middle cranial fossa and opens medially in the posterior cranial fossa through the trigeminal porus. The roof of the cavum forms part of the medial floor of the middle cranial fossa. It extends rostrally to the lateral wall of the cavernous sinus and dorsally to the tentorium cerebelli.

The trigeminal cavum appears as a 3-fingered-glove structure where the hand represents the trigeminal ganglion extended by terminal branches of the trigeminal nerve. Its marking on the petrous apex constitutes rostrally the trigeminal fossa which Princeteau tubercle overhangs caudally. The trigeminal porus is located halfway between the back of the dorsum sellae and the porus of the internal auditory meatus. It opens medially into the cerebellopontine cistern. The two layers of the dura of the petrous bone are either bound together or dehiscent and in this case, they form venous sinuses. The trigeminal nerve is sheathed by a meningeal layer of the dura which invaginates in a fingered-glove fashion between the meningeal layer of the dura of the temporal base on top and the periosteal layer of the dura of the middle cranial fossa below. This meningeal layer sheathes the ganglion, the plexus of the trigeminal nerve and its branches; and is interrupted before the penetration of the maxillary and the mandibular branches in their respective foramina. The floor of Meckel's cave consists of the meningeal and periosteal sheets of the dura. The meningeal layer is in contact with the trigeminal nerve and the periosteal layer

extends through foramina ovale and rotundum by the peripheral sheath of the maxillary and the mandibular nerves. The roof of the trigeminal cavum consists of two meningeal layers of the dura. The superficial layer stretches with the superficial layer of the middle cranial fossa medially, and rostrally, it extends to the lateral wall of the cavernous sinus. The deeper layer also known as the peri-trigeminal sheath extends above the trigeminal nerve to the tentorium cerebelli; and this extension is under and beyond the anterior petroclinoid fold.

The trigeminal cavum contains the triangular plexus, the trigeminal ganglion, the trigeminal cistern and postganglionic trigeminal rootlets. The trigeminal cistern which communicates with the cerebellopontine cistern ( Soeira et al,1994 ) represents the subarachnoid invagination accompanying the nerve in the peri-trigeminal sheath. The trigeminal ganglion occupies the most rostral part of the cavum and is located 45° to the sagittal plane. At its rostral end, the ganglion receives its three peripheral branches.

The posterior aspect of Meckel's cave rests on the inferior surface of the temporal lobe and the anterior part is located between the medial part of petrous portion of the carotid artery and the lateral aspect of the greater petrosal nerve, which courses from the geniculate ganglion to the hiatus under the cave before exiting the skull base through the foramen lacerum. The medial aspect of the cave is located below and lateral to the posterior part of the cavernous sinus. The middle meningeal artery supplies the trigeminal and geniculate ganglions.

### **MATERIAL AND METHODS**

Five cadaveric adult heads were dissected regardless of gender. Specimens were taken 24 hours after death and fixed with 10, 15 or 20% formalin solution. Latex Neoprene (DUPONT) liquid coloured with cyan acrylic ink (for venous network) or magenta acrylic ink (for arterial network) was used for injection of

venous and arterial systems. Dissections were performed using an operating microscope Zeiss OPMI 9FC Germany mounted with a Zeiss cold light source. Photographs of stepwise dissection were taken using an Olympus box attached to the microscope by a Zeiss adapter.

Films used were slides films for artificial light (Kodak Etachrome160T).

Twelve fresh head specimen were obtained after beheading cadaveric adult human 24 hours after their death. The first step was to catheterize the internal jugular veins following by the common carotid and vertebral arteries. The specimen were left to settle for 24 hours in order to allow satisfactory fixation. Injections of arterial and venous network with a mixture of one-quarter of ink with three-quarter of Latex Neoprene were done before dissecting the skull. Catheterisation started by the clamping of the right jugular vein followed by progressive flushing of the left internal jugular vein with a fully charged 50 mL syringe until resistance is felt. The same procedure was repeated for the contralateral vein by swapping clamping and injection from right to left and left to right respectively. Catheterisation of the arterial system was performed with a 10 mL syringe in order to reduce the flushing pressure. The quality of arterial injection was regularly checked against a background of satisfactory skin and conjunctival mucosa pinkish colouring. Catheters were clamped to allow latex polymerization and avoid deterioration of anatomic specimen. A circular craniotomy (approximately 9 cm above the zygomatic arch) was performed using a band

saw. Specimen were soaked in a 20% formalin solution for 5 to 7 days to allow good impregnation and help brain extraction. When the desired consistency was achieved; extraction proceeded with extreme care after excision of the most rostral and caudal parts of the brain by lowering the circular craniotomy 2-4 cm below the first craniotomy line. The frontal lobes were elevated and optic nerves were severed with internal carotid arteries to the brim of anterior clinoid processes. Likewise the III, IV, V and VI cranial nerves were severed. The temporal lobes were elevated and the tentorium was stripped off to the brim of the superior edges of the petrous bone. Cranial nerves VII and VIII were severed with vertebral arteries to the most proximal level possible. The brain stem was last to be excised and the extraction of the brain from the skull was made possible. The extracted specimen was soaked in a 15% formalin solution for 5 more days to allow fixation of deeper diencephalic structures. Between dissections, the specimens were stored in a 10% formalin solution. When dissections were finished, specimen were stored back in a 10% formalin solution to which 10% hydrogen peroxide solution was added to bleach brain structures and improve "vessels / parenchyma" contrast in photographs. This process lasted 3-5 days depending on brain parts.

## RESULTS

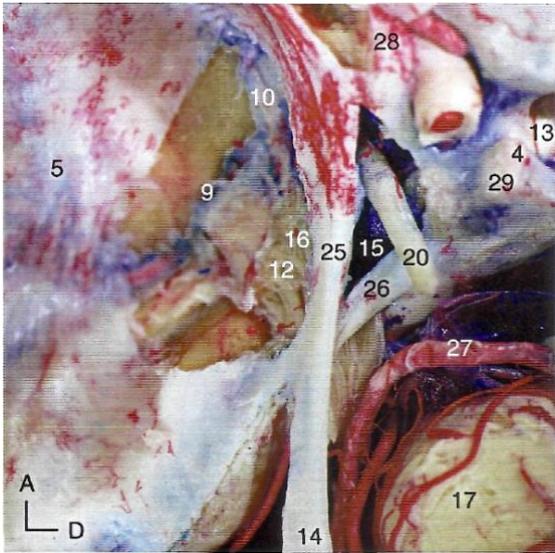
The trigeminal porus was observed to be located halfway between the back of the dorsum sellae and the porus of the internal auditory meatus. The trigeminal nerve was sheathed by the peri-trigeminal sheath made of the meningeal layer of the dura of the temporal base on top and the periosteal layer of the dura of the middle cranial fossa below. The peri-meningeal sheath was interrupted before the penetration of the maxillary and the mandibular branches in their respective foramina. The floor of Meckel's cave was made of the meningeal and periosteal sheets of the dura. The roof was made of two meningeal layers of the dura. The superficial layer stretched with the superficial layer of the middle cranial fossa medially (figure 3). The

peri-trigeminal sheath could course a venous sinus (figure 2). The petrous sinus coursed between the two dural sheets of the floor, crossed over the trigeminal ganglion posteriorly before joining the cavernous sinus. The petroclinoid folds delineated four quadrants (figure 1). The anterior petroclinoid fold bordered Meckel's cave and the cavernous sinus. Basal sinuses of the clivus would empty into the inferior petrosal sinus laterally (figure 2). The medial wall of the parasellar compartment constituted the dural envelop of the pituitary gland.

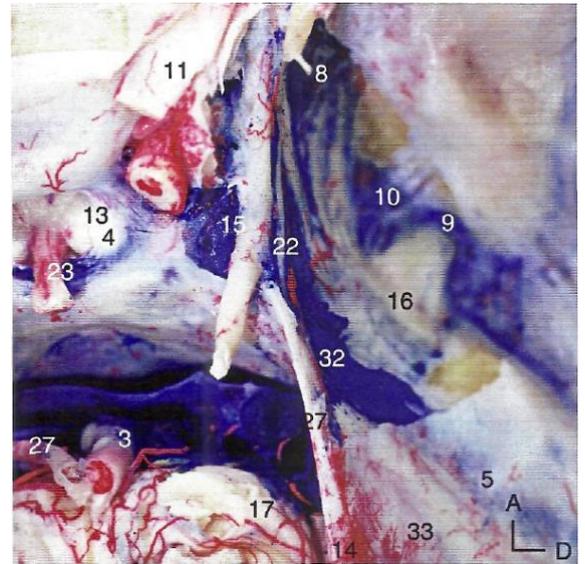
The triangular plexus owes its name from the pattern of its fibres distribution (figure 4). The ophthalmic nerve coursed along the cavernous portion of ICA in its horizontal portion and the

abducens nerve. The trigeminal ganglion sprung into ophthalmic, maxillary and mandibular branches which penetrated the

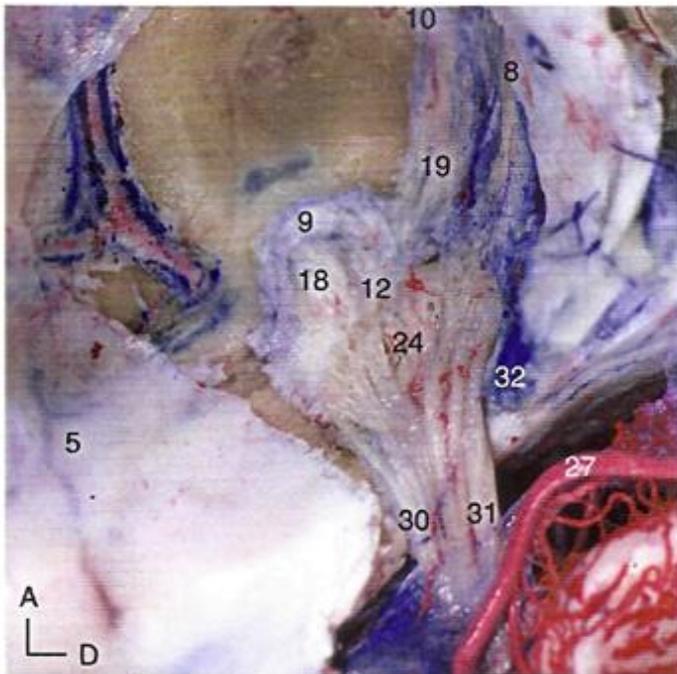
skull through the superior orbital fissure, foramina rotundum and ovale respectively.



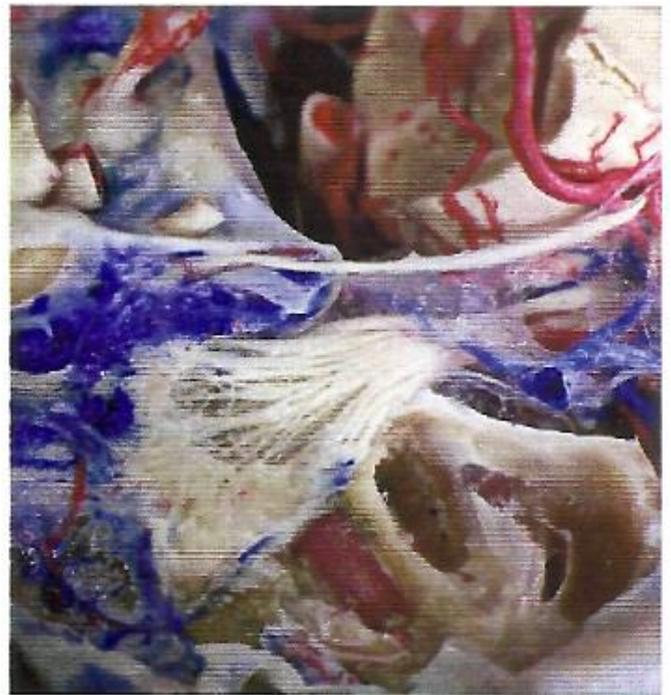
**Figure 1:** Superior view of the left petroclinoid folds and Meckel's cave



**Figure 2 :** Superior view of the right parasellar compartment after removal of the roof.



**Figure 3:** Superior view of the right Meckel's cave



**Figure 4:** Anterior view of the right Meckel's cave



**Figure 5:** Anterior and coronal view of the right parasellar compartment

1= Cavernous portion of the ICA, 2= Petrous portion of the ICA, 3= Basilar artery, 4= Diaphragma sellae, 5= Temporal base dura, 6= Meningeal dura, 7= Periosteal dura, 8= Superior orbital fissure, 9= Foramen ovale, 10= Foramen rotundum, 11= Optic nerve, 12= Trigeminal ganglion, 13= Pituitary gland, 14= Tentorial notch, 15= Parasellar compartment, 16. Meckel's cave, 17= Mesencephalon, 18= Mandibular nerve, 19= Maxillary nerve, 20= Oculomotor nerve, 21= Ophthalmic nerve, 22= Trochlear nerve, 23= Pituitary stalk, 24= Triangular plexus, 25= Anterior petroclinoid fold, 27. Posterior petroclinoid fold, 28. Cerebellar artery, 29= Anterior clinoid process, 30= Posterior clinoid process, 31= Trigeminal motor nerve root, 32= Trigeminal posterior nerve root, 33= Superior petrous sinus, 34= Tentorium cerebelli, 35= Facial and cochleo-vestibular nerve bundles, A= Front, D= Right, G= Left, H= Top

## DISCUSSION

Petroclinoid folds are important landmarks delineating four quadrants and Meckel's cave is located in the ventro-lateral quadrant. This study focused on a small number of anatomical specimen and has been helpful in cross-checking data in the literature. Meckel's cave appears as an invaginated fingered-glove structure tightly attached to the lateral wall of the cavernous sinus. It extends to the cavernous sinus and together, they form the parasellar compartment (Kehrli et al, 1997). The concept of parasellar compartment is best understood through an embryological study of this region. The parasellar compartment appears during the 10<sup>th</sup> and the 12<sup>th</sup> week of gestation following condensation and bending of the middle cranial fossa mesenchyme. This mesenchymal condensation deep in the meningeal lining sheet is thought to give rise to the definitive dural envelop. It extends to the mesenchyme surrounding the trigeminal

ganglion which has no clear sheath at this stage (Kehrli. et al, 1997). The trigeminal nerve is the main constituent of Meckel's cave and is formed of two portions (Danial et al, 1986). The retro-gasserian portion which is located in the cerebellopontine cistern stretches between the rostrolateral surface of the pons and Meckel's cave. High resolution T2-weighted imaging best explore this portion of the nerve [Akimoto 2002]. Given the fact that Meckel's cave and the cavernous sinus constitute together a unique entity known as the parasellar compartment, they could be imaged at the same time. Imaging the parasellar compartment requires high field imaging techniques for high quality acquisition of fine slices. It includes T1-weighted imaging with or without contrast enhancement which provides high quality neural and venous study [ Akimoto et al,2002]. Pathological processes such as trigeminal neuralgia may develop in Meckel's cave

[Du et al,2001]. Although conventional MRI with T1 and T2 sequences may be sufficient in diagnosing these processes, it is paramount however to acquire high resolution gradient echo T2-weighted imaging with 3D construction in steady state (3D Ciss) and 3D fast inflow with steady-state precession ( 3-D-FISP) (Akimoto et al,2002; Held et al,2001; Seitz et al,2002).

In conclusion this study is helpful in cross-checking data in the literature which is consistent

with our observation that Meckel's cave anatomy is still very poorly understood. Good knowledge of such anatomy is paramount when approaching this intracranial region and complex neurovascular anatomy of neighbouring structures.

**Conflict of interest:** The authors declare that there is no conflict of interests regarding the publication of this paper.

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