Acta Neurochir (2014) 156:217–220
DOI 10.1007/s00701-013-1916-5

HOW I DO IT - NEUROSURGICAL TECHNIQUES

The epidural approach to the Meckel's cave: a how I do it

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Received: 4 June 2013 / Accepted: 7 October 2013 / Published online: 6 November 2013

Abstract
Background Meckel's cave (MC) is a meningeal cleft lying in the middle fossa laterally to the cavernous sinus. Tumours that develop inside the MC may require a surgical resection. The authors describe the surgical technique of the intracranial epidural approach to the MC.
Methods Based upon anatomical dissection showing the relevant surgical anatomy, and illustrated by the video of an operated case, the authors detail the surgical procedure. The key point is to shave the floor of the middle fossa and skeletonize the superior orbital fissure, rotundum and ovale foramen in order to delineate the plane of dural elevation and expose the lateral wall of the MC. The rules of exposure and resection of the tumour are then shown. Variations and limitations of the approach are discussed.
Conclusion Conducted in a stepwise manner and following relevant landmarks, the epidural anterolateral approach offers a safe and reliable exposure to the diseases that develop within the MC.

Keywords Dolenc's approach · Meckel's cave · Meningiomas · Neurosurgery · Schwannomas · Skull base surgery · Trigeminal nerve

Electronic supplementary material The online version of this article (doi:10.1007/s00701-013-1916-5) contains supplementary material, which is available to authorized users.

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Introduction

Meckel's cave (MC) lies at the floor of the middle fossa and is part of the parasellar space. The diseases involving this cisternal compartment are mainly meningiomas and schwannomas. They can extend backward toward the petroclival and cerebellopontine angle (CPA) areas through the porus trigeminus. In selected cases, these tumours may require a surgical resection that can be challenging if a proper stepwise procedure is not carried out. Despite the use of various techniques, the epidural approach modified from Dolenc's [1] offers an extensive window to the MC. We describe herein the surgical technique and its limitations.

Relevant anatomy (Figs. 1 & 2)

The MC lies in a concave depression at the superior petrous surface, medially to the ovale foramen and laterally to the petroclival suture. The dural cleft that delineates the MC describes a triangular shape [3]. Its superolateral wall is made of a double layer of dura, while its medial wall is formed by a thin layer of reticular tissue that corresponds to the posterolateral part of the cavernous sinus (CS). The floor of MC is formed by the petrolingual ligament that covers the horizontal segment of the internal carotid artery from the lacerum foramen to its entry point under the cavernous sinus. Posteriorly, the MC is opened toward the posterior fossa through a dural annulus named the porus trigeminus. Backward, the roof of the MC is covered by the anterior portion of the superior petrosal sinus that straddles the porus trigeminus to drain into the posterior compartment of the CS. Laterally, the dural sheath of the mandibullary division (V3) is connected with the pterygoid plexus through the foramen ovale. Several interdural venous channels may be found between the ophthalmic division (V1) and the maxillary division (V2) or between V2 and V3. The MC harbours the pars

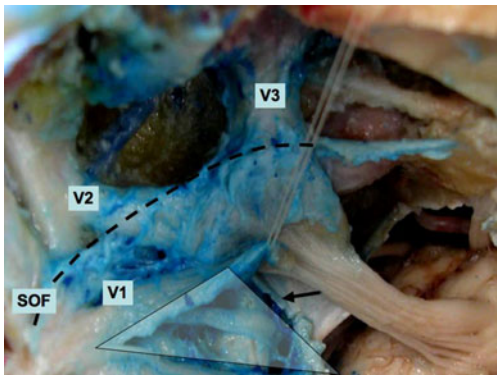

Fig. 1 Dissection of a parasellar space on the right side of an injected specimen. The floor of the middle fossa has been drilled. The *dotted line* corresponds to the plan of elevation of the dura propria. The *triangle* indicates the posterior compartment of the intracavernous space that is usually not opened. The *arrow* shows the dural sheath that delineates the medial limit of the Meckel's cave. *SOF* superior orbital fissure, V1: Ophthalmic division of the trigeminal nerve, V2: Maxillary division of the trigeminal nerve, V3: Mandibullary division of the trigeminal nerve

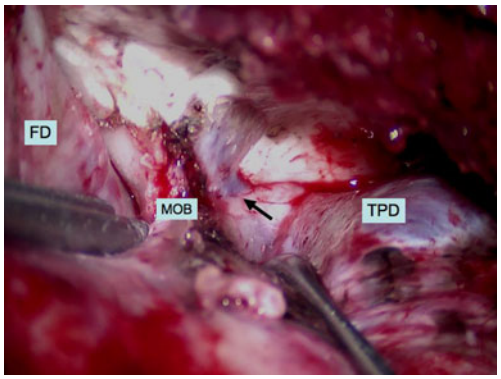

Fig. 3 View of the operated case on the right side once the bone flap has been removed (see video). The frontal dura (FD) is elevated from the roof of the orbit and the meningoorbital band (MOB) is exposed while the dura that covers the temporal pole (TPD) is pulled with a dissector to identify the superior orbital fissure from which the outer layer of the dura will be peeled

triangularis and the Gasserian ganglion of the trigeminal nerve and is filled by the CSF that comes from an expansion of the cerebellopontine cistern.

Methods (see Figs. 3, 4 and video)

Positioning & preparation

The patient is positioned supine with the head cautiously rotated toward the opposite side, around 60° or more in case of added anterior petrosectomy. Care is taken to avoid any jugular vein compression when head is rotated. Monitoring of the oculomotor nerves and facial nerve are proposed in case of intracavernous and CPA involvement respectively. Monitoring of the motor branch of the trigeminal nerve (put an electrode in the temporal or masseter muscle) can be helpful if a delicate dissection of V3 is anticipated. Head fixation with a three-pins holder & neuronavigation are optional. Antibiotic prophylaxis is administrated 30 min before the skin incision.

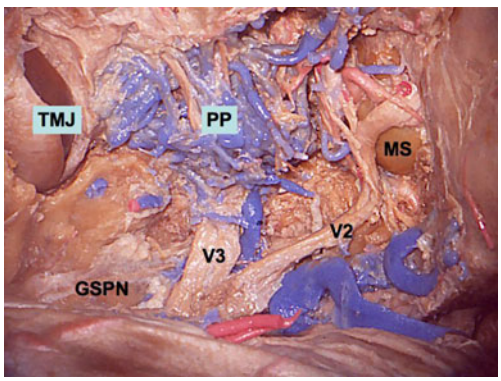

Fig. 2 Dissection of the trigeminal divisions (V2 & V3) and related structures on the right side of an injected specimen. The floor of the middle fossa as been drilled extensively to expose the upper part of the infratemporal fossa from the maxillary sinus (MS) that delineates the pterygopalatine fossa anteriorly, to the temporomandibular joint (TMJ) posteriorly. The great superficial petrosal nerve (GSPN) covers the petrous apex. Note the close relationship between V3 and the venous network of the pterygoid plexus (PP)

Superficial step

Skin incision is conducted from the preauricular pretragal point to the frontal area in a curved shape design. Soft tissues are elevated in two layers. The skin, the galea and the subgaleal tissues including the periosteum are elevated and divided from the superficial temporal fascia. The temporal fascia and muscle are reflected anteriorly and downward; root of the zygoma is exposed and is a relevant landmark that corresponds to the floor of the middle fossa.

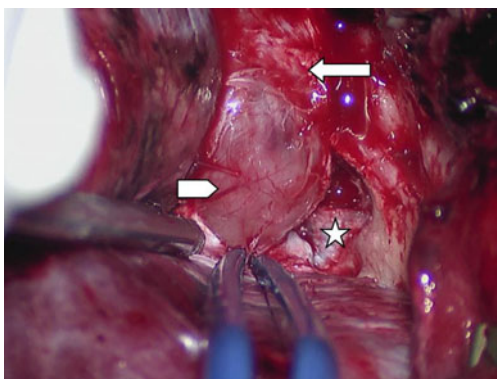

Fig. 4 Once Meckel's cave has been exposed, the tumour mass bulks in the operative field (*arrow head*) while the trigeminal nerve (*white arrow*) is shifted laterally by the tumour capsule. Since the tumour extended backward through the porus trigeminus, a limited resection of the petrous apex (*star*) has been added to the approach

Bony resection

One burr hole is performed at the level of the McCarthy point and another one just above the root of the zygoma. The dura is detached and a regular temporo-pterional bone flap is shaped. Care is taken not to violate the dura while elevating the bone flap in order to keep the bony landmarks and avoid any brain damage. The avoidance of CSF release may contribute to protect the temporal lobe during the retraction of the dura.

The initial drilling (use preferentially a 4- to 6-mm diamond drill) focuses on the pterion as far as the outer limit of the superior orbital fissure (SOF) is identified. At this point, the meningoorbital fold is divided with sharp micro-scissors, allowing a better retraction of the temporopolar dura in order to expose the medial part of the SOF where the line of dura elevation is identified (Fig. 3).

Then, the anterior part of the floor of the middle fossa (horizontal part of the great sphenoid wing) is flattened using the high-speed drill and under continuous irrigation. Rotundum, ovale and spinosum foramen are consecutively skeletonized on their outer 180°. For better retraction of the dura, the middle meningeal artery is coagulated and divided 3 mm above its intracranial entry point in order to preserve a tiny branch that reaches the geniculate ganglion.

Management of the dura mater

The outer layer of the dura is incised under high magnification using an eleven blade or a sharp and thin dissector, starting from the SOF toward the lateral border of V2 and V3 (Figs. 1 and 3). This step is carried out without damaging the underlying nerve fibers. Then, using a rigid sharp dissector, the outer layer of the dura is elevated from the inner layer of the lateral wall of the MC. This "interdural" dissection allows now the identification of the trigeminal nerve fibers and external part of the tumour mass (Fig. 2). This peeling step may be responsible of a certain amount of blood oozing from the veins that run between the two layers of the dura. Hemostasis is usually obtained by targeted application of small pieces of oxycellulose (Surgicel®).

Tumor removal

The identification of the appropriate working window is selected between the trigeminal nerve's fibers which are usually stretched by the tumour mass. The tumour capsule is opened parallel to the nerve fibers. Debulking of the tumour is started to reduce the tumour volume and allow the dissection and the devascularization of the capsule. Hemostasis inside the MC is achieved using oxycellulose or fibrin glue. Overpacking of the MC and prolonged bipolar coagulation should be avoided in order to spare the nerve fibers. The trigeminal nerve fibers can usually be separated from the tumour in schwannomas [6] and epidermoid cysts while strong adhesion can be encountered in meningiomas depending of the texture of the tumour. Another issue is the prediction of nerve shifting due to the tumour origin and growth.

Closure

The dura opening of the MC can be covered by a piece of subgaleal periosteum and stabilized with fibrin glue. A fat patch will cover the air cells that have been opened during the approach, particularly if an anterior petrosectomy has been done. Hitching sutures are done at the periphery of the dura exposure to prevent an epidural haematoma in the early post-op. The bone flap is repositioned and fixed with low profile titanium plates. Careful attention is given to reinsert the temporal muscle on the muscular cuff that has been left before the craniotomy. The skin is closed in two layers without any drainage system.

Modulation of the approach

- A zygomatic osteotomy can be added to visualize the upper MC while avoiding any excessive temporal retraction [3, 6] but is not systematically performed.
- An additional anterior petrosectomy [4] is discussed in case of posterior fossa extension of the tumour and when the porus trigeminus is not enlarged enough to remove the tumour trough it.
- An intracavernous resection is discussed for oncological purpose in case of selected diseases: The additional steps are an epidural anterior clinoid process resection and selection of the appropriate triangle to be opened [1].

Specific perioperative considerations and information to give to the patient

- Before surgery, an informed consent is obtained from the patient about his/her understanding of the principles, the goals and the risk of surgery. Special consideration is given to the risk of potential facial numbness, anaesthesia and pain that may be the consequences of the surgical manipulation of the nerve during tumour removal.
- After surgery, the patient is kept bed ridden during 24 h in the neurointensive care unit. A brain CT scan is performed in the 48 h after surgery to rule out any haematoma in the operative field and to look for any temporal lobe swelling. This latter event may happen in up to 10 % of cases, including asymptomatic cases.

Case illustration (video & Figs. 3 and 4)

This 35-year-old man presented with trigeminal dysesthesia in V2 & V3 territories on the right side. Cranial MR showed a

tumour mass inside the MC on the right side that was diagnosed as a schwannoma. This patient was considered to be eligible for a radiosurgical treatment that was delivered in 2006 with an excellent postradiosurgical course. Five years after radiosurgery, tumour progression was noted while the patient experienced trigeminal numbness. A multidisciplinary discussion of the case led us to propose a microsurgical resection of the tumour mass via an epidural intracranial approach. Operatively, dissection of the tumour inside the MC could be achieved safely due to the evidence of a clear plane of dissection from the trigeminal fibers and thanks to the softness of the tumour texture. However, a small fragment of tumour located in the prepontine area could not be dissected safely from the ventral surface of the sensory root of the nerve. This fragment had to be left, and the patient was informed. The early postoperative course was uneventful except for a transient increasing of the facial hypesthesia. The patient was discharged at 10 days after surgery. Tumour specimen was diagnosed as a benign schwannoma. The postoperative MR images showed a 5-mm tumour remnant close to the pons and no residual disease into the MC. At 12 months after surgery, a small amount of hypesthesia was still present and the residue remained stable.

The key points

1. Understand the relevant anatomy and the behaviour of the disease
2. Consider the goals of surgery. Radical resection can be a reasonable goal for schwannomas and epidermoid cysts that originates primarily within the MC. Most meningiomas that grow-up from a wider area are usually eligible for subtotal resection.
3. Perform an extensive drilling of the floor of the middle fossa to expose the key landmarks: superior orbital fissure, rotundum and ovale foramen
4. Find the appropriate line to start the peeling of the outer layer of the dura to stay in the interdural space.
5. Do not perforate the medial wall of the MC to avoid intracavernous opening
6. Do not perforate the floor of the MC (petrolingual ligament) to avoid carotid artery damage
7. Preserve the dura that covers the temporal lobe
8. Identify under microscope the position of the nerve's fibers usually stretched by the disease.
9. Consider the need for an additional anterior petrosectomy and division of the tentorium if the tumour spreads into the prepontine area
10. Inform the patient about the risks of surgery at large and more specifically about potential trigeminal disturbances.

Comments

- Endoscopic endonasal approaches [2] share the same goal in the way they are extradural and without brain retraction. Whether these approaches offer the same level of exposure and the opportunity to control what spreads into the posterior fossa remains to be demonstrated by comparative anatomical studies and accumulation of clinical experience.
- The retrosigmoid suprameatal route [5] is a way to enter inside the MC through the porus trigeminus. There is a rational to use this approach for dumbbell-shaped tumors whose main part is inside the posterior fossa with limited extension into the MC.

Conclusion

Conducted in a stepwise manner, the intracranial epidural anterolateral approach, which is actually an interdural opening, is a safe, reliable and optimal procedure to control the diseases that develop within the MC. The tumour texture and its degree of adhesion to the trigeminal nerve's fibers may influence the extent of resection as long as the preservation of the nerve's fibers remains a priority. The major interests of this approach are the absence of brain exposure and its ability to be combined with an anterior petrosectomy if needed.

Conflict of interest None.

Presentation at conference None.

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