Three Subtypes of Trigeminal Schwannoma in Relation with Meninges Pattern for Surgical Consideration: Anatomy and Histological Study

Agung Budi Sutiono¹,²*, Azela Glady², Muhammad Zafrullah Arifin¹, Ahmad Faried¹, Kazunari Yoshida² and Takeshi Kawase²

¹Department of Neurosurgery, Padjadjaran University, Hasan Sadikin Hospital, Indonesia
²Department of Neurosurgery, Keio University School of Medicine, Japan

Abstract

Background: Trigeminal schwannomas may originate from the root, the ganglion, or the peripheral branches of the trigeminal nerve. Trigeminal schwannomas are rare tumors that comprise of 0.2% of all intracranial tumors.

Objective: To clarify the pattern of trigeminal schwannomas in relation with meninges for surgical considerations.

Methods: We used 3 adults head cadaver specimens were used for surgical simulation and taken for immunohistochemical staining to observe the meninges pattern and applied in surgical technique.

Results: This was confirmed qualitatively with Masson’s Trichrome staining for collagen and elastin for the cranial dura. In our study we found that the dura wrapped the trigeminal nerve from the beginning of gasserian gangglion which change into interdural space. It becomes periosteal dura after passing through the foramen, we call it extracranial part. The Myelin basic protein staining shows the nerve filament which covered by piamater at the root entry zone. The arachnoid clearly covers the nerve bundle from entering Meckel cave and becoming perineurium in the interdural space. At the extracranial part the nerve filamen or bundle is only covered by periosteal dura or similar to epineurium structures.

Conclusion: From our discussion get conclusion for surgical method, that is 1. We did surgery sub arachnoidal dissection in posterior fossa, 2. submeningoperisoteal dura dissection in middle fossa 3. subperiosteal dissection in infra temporal fossa.

INTRODUCTION

The trigeminal nerve is the largest and most complex of the 12 cranial nerves (CNs). It supplies sensations to the face, mucous membranes, and other structures of the head. It is the motor nerve for the muscles of mastication and contains proprioceptive fibers. It emerges from the ventrolateral surface of the pons and runs anteriorly for 1–2 cm [1,2] through the cerebellopontine cistern to reach the petrous apex. Vascular structures such as the petrosal vein and the superior cerebellar artery lie close to the trigeminal nerve. Over the petrous apex, 7 mm from the medial lip of the internal acoustic meatus, [3] the Gasserian ganglion is enveloped by a dural deflection forming the Meckel cave, which is present lateral to the cavernous sinus and the carotid artery. The Meckel cave was observed as the space between the meningeal layer and the peristeal layer of dura, which appeared to be tightly attached to the petrous apex. The trigeminal ganglion, postganglionic trigeminal roots, and subarachnoid cistern were identified within the Meckel cave. The width of the oval-shaped Meckel cave corresponded to the mediolateral diameter of the trigeminal ganglion and its length corresponded to the distance from the anterior edge of the trigeminal ganglion to the trigeminal porus. At its superior limit, the Meckel cave was in close proximity to the cavernous sinus. It almost reached the floor of the middle
cranial fossa inferiorly. The mean mediolateral length, thickness, and width of the trigeminal ganglion was 16.1 mm, 2.52 mm, and 3.78 mm, respectively [4]. As it leaves the Meckel cave, the trigeminal nerve is divided into three branches: the ophthalmic (V1), maxillary (V2), and mandibular (V3) branches. These three nerves run under the middle fossa dura mater and leave the temporal bone through the lateral wall of the cavernous sinus (for V1), foramen rotundum (for V2), and foramen ovale (for V3) [3,5], and sometimes schwannomas growth is present that may or may not be covered by meninges.

Functionally, the trigeminal nerve has two portions: the “pars compacta,” which constitutes the triangular portion and comprises the primary afferent fibers that are responsible for the special sensibility of the face; and the motor root, which carries the branchiomotor fibers to the muscles of mastication. The motor root runs practically separated from the “pars compacta” but together with the cranial portion of the nerve. At the level of the Meckel cave, it is oriented medially and leaves the skull together with the maxillary nerve [4,5].

The intracranial-extradural portions of V2 and V3 are surgically identified using the foramen spinosum as an anatomical landmark, which is located at the sphenoid bone and contains the middle meningeal artery. The foramina ovale and rotundum are located 2–5 mm superoanteriorly and 10–12 mm superomedially to the foramen spinosum [4,5].

Trigeminal schwannomas may originate from the root, the ganglion, or the peripheral branches of the trigeminal nerve. Trigeminal schwannomas are rare tumors that comprise approximately 0.2% of all intracranial tumors [6]. The trigeminal nerve can be surgically classified into three segments: a) cisternal, from the brainstem to the petrous apex; b) interdural, from the Meckel cave to the foramina; and c) extradural (V1, V2, and V3) [4,5]. However, there is little information available on the type of trigeminal schwannomas in relation with the meninges structure for surgical consideration. Therefore, the objective of this article is to describe this information through histological staining and cadaver dissection.

METHODS

Anatomic Study

Ethical approval for this study was obtained from the Ethics Committee of Keio University Hospital. 3 adults head cadaver specimens were used for surgical simulation using a Zeiss microscope (Carl Zeiss Co., Oberkochen, Germany) at magnifications ranging from X3 to X40. The heads were embalmed with 10% formalin before dissection. The internal carotid artery and internal jugular vein were injected with colored latex (red for arteries, blue for veins).

Histological study

En block cadaver specimens were taken from pons to the foraminas whereas the branch of trigeminal nerves are entering to the foraminas. The dura mater was preserved for histological Masson’s trichrome staining (Figure 1). After 3 months, ethylenediamine tetracetic acid solution was used for the decalcification process. After washing in methanol (70%-100%) and xylene, the sample was embedded in paraffin and cut into 6-mm-thick slices in sagittal and axial sections. Masson trichrome staining provides a clear understanding of structures, with collagen staining blue smooth muscle, nerve, cytoplasm, and erythrocytes staining red; and nuclei staining black. Special attention was given on the REZ, Meckel’s cave and foramina to observed the characteristic trigeminal nerve and its meninges structures [7,8].

Clinical study

Case 1: A 36 years old female with chief complaint numbness on the right face. The MRI images revealed, there was hyperintense mass on the right cavernous sinus that enhanced homogeneously with contrast on T1 weighted imaging. The bone window CT scan shows bone erosion on the ovale foramen in which the mandibular nerve coursing (Figure 2).

Case 2: A 37 years old male presented with 6 month graduating worst of double vision preceded with intermittent headache since 1 year ago. General physical and neurological examinations showed no abnormalities except paralysis on left eye movement N VI and III, and paresis on left N V1. MRI imaging revealed on T1 weighted shows hyperintense mass at left cavernous sinus, enhanced homogeneously with contrast, on T2 weighted shows an hypo hyperintense mass at left cavernous sinus (Figure 3).

RESULTS

Anatomy

The trigeminal nerve consist of sensory and motor roots and leave the brain stem through the substance of the lateral part of the pons. It cross the posterior cranial fossa and climb the ridge of the petrous temporal bone toward the middle cranial fossa. In here, they encounter the dura mater as it turns back off the ridge onto the undersurface of the tentorium cerebelli. The nerve does not pierce the dura, nor does the dura blend immediately with the epineurium. Instead, the dura is prolonged around the nerve, over the petrous ridge and into the middle cranial fossa, more specifically into the cavernous dural venous sinus. Based on this finding, the trigeminal nerve is passing from subdural space which is start from lateral pons to the entrance of Meckel cave, and before entering cavernous sinus, it wraps by periosteal and meningeal dura, therefore we call it interdural space. At the last course, trigeminal nerve will go to the extradural space (Figure 4).

Histology

The dura mater is the outermost and most substantial
meningeal layer of the central nervous system (CNS) tissue that acts as a protective membrane for the brain. This was confirmed qualitatively with Masson’s trichrome staining for collagen and elastin of the cranial dura. In our study, we found that the dura wrapped the trigeminal nerve from the beginning of the gasserian ganglion, which passes into the interdural space. Thus, it becomes periosteal dura after passing through the foramen; we call it the extracranial part. The myelin basic protein staining shows the nerve filament, which is covered by pia mater at the root entry zone. The arachnoid clearly covers the nerve bundle from entering the Meckel cave and becoming perineurium in the interdural space. At the extracranial part, the nerve filament or bundle are only covered by periosteal dura or similar epineurium structures (Figures 5A–F).

Clinical application

With respect to case number 1 and 2 (Figure 2 and 3), the patients have a lesion in the intracavernous sinus that slightly expands to the posterior fossa. It was confirmed as schwannomas. We operated using the subtemporal extradural–intradural approach for case number 1 and 2. We did not expose the temporal lobe (Figure 6).

DISCUSSION

The trigeminal nerve is the largest cranial nerve and is responsible for tactile, proprioceptive, and nociceptive sensory supply of the face along with motor supply to the muscles of mastication. The principal sensory nucleus and the motor nucleus of the nerve lie in the lateral aspect of pons, where as the mesencephalic nucleus extends from the upper pons to the midbrain. The nerve exits the brainstem at the ventral aspect of mid pons and proceeds across the prepontine cistern anteriorly towards the Meckel cave where the sensory gasserian ganglion of the trigeminal nerve is located. The three divisions, namely the ophthalmic (CNV1), maxillary (CNV2), and mandibular (CNV3) nerves, branch out from the ganglion. The Meckel cave is a dural invagination along the medial aspect of the middle cranial fossa, continuous with the prepontine cistern. Based on this, we classified the trigeminal nerve into three compartment part: subdural, interdural, and extradural (Figure 7).

Trigeminal neurinomas are relatively rare tumors and represent 0.2% of all intracranial tumors [11,12]. It generally arises from the Schwann cells of the sensory root and can originate in any section of the fifth cranial nerve and correspondingly a variety of symptoms and signs may develop [13]. Most trigeminal neurinomas, irrespective of the site they spread to, have an association with this region of the nerve [14]. The tumor grows and spreads in the available spaces [15]. The Meckel cave can accommodate a large amount of the tumor, which bloats up the cave.
The relationship of the trigeminal ganglion with the dura
was complex. Meningeal investment of the anterior surface
of the trigeminal ganglion was strictly adherent to the surface
of the trigeminal ganglion, whereas it was only adherent on
the anterior third on the posterior surface of trigeminal ganglion.
This space was related to the infratentorial basal cisterns
through the trigeminal nerve. Elevation of the middle fossa
dura was limited medially because of the adherence to the V3
branch of the trigeminal nerve and the cavernous sinus. During
extradural subtemporal retraction, the middle meningeal artery
and the V3 were identified before exiting the skull base through
their respective foramina. The skeletonization of the foramen
spinosum and foramen ovale allowed visualization of the lateral
wall of the Meckel cave after releasing the dura and retracting
the V3 medially. The foramen ovale was always found to be just
anterior to the Meckel cave. The greater superior petrosal nerve

Therefore, some of the signs found in our patient are as
follows: trigeminal schwannomas present with dysesthesia;
mild facial pain; frontotemporal headaches; symptoms caused
by mass effect; compression of adjacent structures, namely
conductive hearing loss from Eustachian tube blockage; diplopia
or hemianopsia from cavernous sinus involvement; or facial soft
tissue asymmetry.

Three compartments of trigeminal schwannoma, which are
located in the posterior fossa, middle fossa, and infratemporal
fossa, can be explained in more detail based on the meningeal
surrounding structures, as shown in Figure 8. Jefferson [9]
grouped trigeminal schwannomas into three types based on their
location within the cranium. Type A denotes tumor growth in the
middle fossa, whereas type B constitutes tumor in the posterior
fossa anterior to the brainstem. Type C includes both middle and
posterior fossa and is referred to as a "dumbbell" type. Type D,
which was added later, is used if the tumor has an extracranial
extension. Similarly, Yoshida et al. [10] classified trigeminal
schwannomas in hopes of unifying a surgical approach based on
presentation and a tumor found in the middle fossa, posterior
fossa, and extracranial extension. Extracranial tumors were
further divided into orbital, infratemporal, and pterygopalatine
fossae extensions.

Figure 4 Subtemporal approach in the cadaver specimen shows the
exposure of trigeminal nerve. A) Interdural space and Meckel cave are
opened and we expose the subdural and interdural trigeminal nerve
(*) as well as the posterior fossa dura (**) after drilling Kawase’s
triangle. B) The lateral part of foramen ovale and rotundum have been
drilled to expose extradural part of trigeminal nerve (*).

Figure 5 A-C Specimens was stained by Masson Trichrome and
D-F by using Myelin Basic Protein. A) Brain stem, Root entry zone
trigeminal nerve at the brain stem. The sensoric root makes a bulging
and covered by piamater (**), motor root is separately observed (*)
and AICA loop is passing between them. The transformation from
central nervous part to the peripheral part of trigeminal nerve is
located on the piamater line. B) The arachnoid cover and wrap the
nerves at porus of meckel’s cave (*), making isolation between the
nerves bundle and meckel’s dural fold. C) Foramina site, Section in
foramen ovale (*). Arachnoid disappear and the nerve wrap with
meningeal dura tightly before passing the foramen. After penetrating
foramen, the nerves are wrapped with periosteum as continuation
from periosteal dura. D) The arachnoid covered from the surface of
brain stem (*) toward trigeminal nerves (**). Nerve filament courses
from brain stem to trigeminal root entry zone in well direction. E)
Arachnoid wrap the nerves, continue to become perineurium making
septation (arrow) between the nerve bundles. F) The nerve filament
is covered by endoneurium (arrow), and bundling with perineurium
(double arrow).
(GSPN) was found to be posterolateral to the Meckel cave [4].

In our study, the case of trigeminal schwannoma arising from three compartments would be covered by three different meninges. Figure 8 shows a subdural type (posterior fossa) covered by arachnoid (red line), interdural type (middle fossa) covered by meningeal-periosteal dura (blue line), and interperiosteal type (infratemporal fossa) covered by periosteum (purple). Histological analysis revealed that when the tumor is located in the anterior segment, we do not need to resect in posterior segment. When the tumor is located in the red line, which is in the arachnoid, it is essential to open the durameter surgically; however, when the tumor is located in the blue line, which is in meningeal periosteal dura, we only need to open the...
superficial duramater.

CONCLUSION

We define that there are three surgical technique, 1) We did surgery sub arachnoidal dissection in posterior fossa, 2) submeningoperisoteal dura dissection in middle fossa 3) subperiosteal dissection in infra temporal fossa. If the tumor located near by the foramen, whereas the nerves bundle are wrapped tightly with meningeal dura, so care must be taken when removing the tumor in this area. On the basis of our limited experience, we believe that the best treatment for trigeminal schwannoma is complete microsurgical removal of the lesion and that this treatment should be considered the gold standard therapeutic modality for the majority of cases.

REFERENCES