

Anatomy of the Trigeminal Nerve.

Key Anatomical Facts for MRI Examination of Trigeminal Neuralgia.

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Introduction

Trigeminal Neuralgia (TN) is currently a frequent reason for carrying out a crano-encephalic Magnetic Resonance Imaging (MRI) examination in Neuroradiology Departments.

It is a precise clinical diagnostic entity, although its pathophysiology and treatment are under discussion and permanently revised.

Multiple disorders may produce TN, but in most patients it is not possible to identify a specific cause to account for the clinical condition.

Certain anatomical relationships have likewise been indicated as probably related with facial pain, giving rise to neurovascular conflict conditions.

Figure 1

Diagram of the Vth intra-axial nuclei on a median SE 1 sequence image in the sagittal plane.

Mn: mesencephalic nucleus

Pn: pontine nucleus

MSn: medullar-spinal nucleus



A detailed knowledge of the trigeminal nerve (V) anatomy, including its origin, course, relationships and distribution branches, is essential for a correct interpretation of the images, and correspondingly for an accurate diagnosis.

Objectives – Materials – Methods

To revise the anatomy of the V cranial nerve and its different segments, with a special interest in those of fundamental importance for the correct interpretation of high resolution MRI studies.

MRIs, carried out with a closed-system field 1.5T power resonator with conventional sequences and high resolution protocols (FIESTA), were used to analyze the trigeminal nerve anatomy in its different sectors.

Micro-dissections with multiple approaches and fine sections in the 3 planes of space in 5 adult cadaver heads (Department of Anatomy, School of Medicine, Neuroanatomy Laboratory), dissected with the aid of a neurosurgical microscope with x4 and x8 magnification, registered photographically the disposition and anatomical relationships of the structures in the 3 planes of space.

Next, anatomical sections of the previous frozen sections, in the axial, coronal and sagittal planes were carried out.

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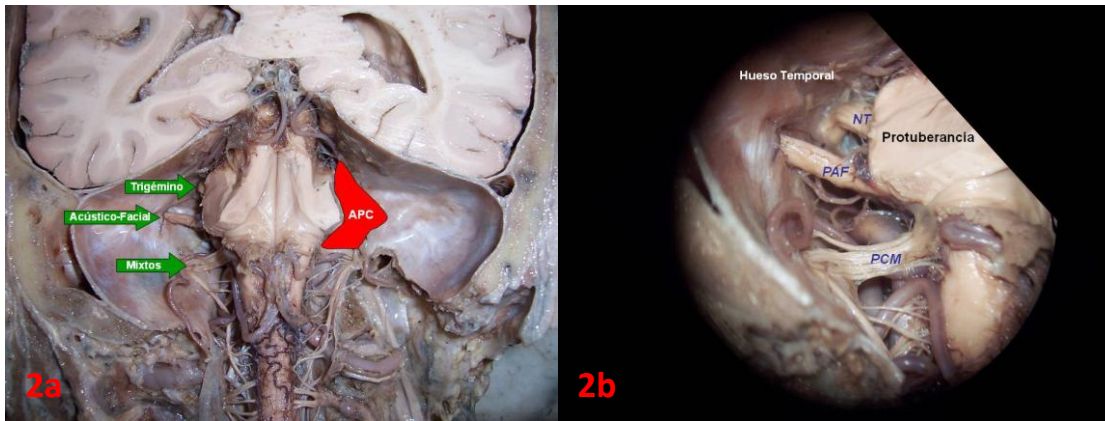


Figure 2

- a.- Cadaveric preparation in coronal section combined with micro-dissection of the posterior fossa where it is possible to observe the area corresponding to the cerebellopontine angle (CPA) and its three nervous levels: the lower floor with the cerebellar nerves (IX, X y XI), the middle floor with the acoustic-facial bundle (VII y VIII) and the upper floor with the trigeminal nerve (V).
 - b.- At higher magnification it is possible to observe the micro-dissection of the right CPA with greater detail of the V in situ in the upper floor of the region.
- TN: trigeminus nerve
 AFB: acoustic facial bundle
 MCN: mixed cranial nerves

Results

Descriptive Anatomy of the Trigeminal Nerve

The Vth is the most developed and extensive cranial nerve, with a broad distribution territory. It is a mixed nerve conducting sensitive and motor somatic fibers to the face, and is conceptually responsible for all its sensitive innervation (touch, pain, temperature and proprioception) together with the motor innervation of the mastication apparatus. Originating in the posterior fossa of the brain stem, it follows a long and complex course towards its distribution territory, crossing several regions with a complex anatomy and establishing important relationships with several structures. The nerve fibers originate in the brainstem and are part of several grey matter nuclei occupying all the brainstem and even the first spinal cervical segments. Each of these sensitive and motor nuclei represents different processing centers, and there is a true systematization of the information this nervous tract is responsible for conducting. Figure 1

The sensitive nucleus is the largest, comprising 3 true sub-nuclei, each responsible for each aspect of the general sensitivity. The highest is the mesencephalic nucleus, located in the tegmentum close to the midline and to the grey matter close to the Sylvian aqueduct. The neurons that form this nucleus are in charge of the proprioceptive integration in the Vth nerve territory, high level information for correct mastication. The main nucleus is in the pons, it is also situated in the depth of the tegmentum, and is responsible for the tactile integration of the territory of this nerve. Finally, the inferior nucleus occupies the tegmentum of the medulla, extending caudally to the first segments of the cervical spine, and is in charge of thermal and pain information. Its location explains the possible appearance of symptoms in the facial territory in patients with a degenerative/inflammatory disorder of the upper cervical spine. There is one single motor nucleus, located in the pons tegmentum, supplying the

mastication muscles, and is correspondingly called mastication nucleus.

The fibers related with all these nuclei gather in the pons and emerge through the lateral sector of its anterior aspect, forming a thick nervous tract with two roots: a thicker and lateral sensitive root and a thinner more medial motor root.

The only intra-axial segment of the Vth ends there and initiates its long course to its distribution territory; it is formed by different sub-segments before dividing itself into its terminal branches (the cisternal and Gasserian or transdural segments). Figure 2

The point where the roots emerge in the brainstem is called "REZ" (Root Entry Zone), an anatomical landmark of great functional hierarchy. Figure 3

the temporal bone, where it finds Meckel's space region. During this course, surrounded by cerebrospinal fluid, it presents distant relations with cranial nerves VI, VII and VIII, and vascular relations, with the superior petrous vein (Dandy), and more especially arterial relations. Figures 2 and 4

This is the point where the variants in the trajectories and the resulting arterial loops, may generate sites of close contact between the arterial, pulsating vessels and the nervous tract which may result in neurovascular conflict.

Two arteries may be related: the middle and the superior cerebellar arteries, according to the height of its origin in the basilar trunk and the direction of its initial portion. Figure 5

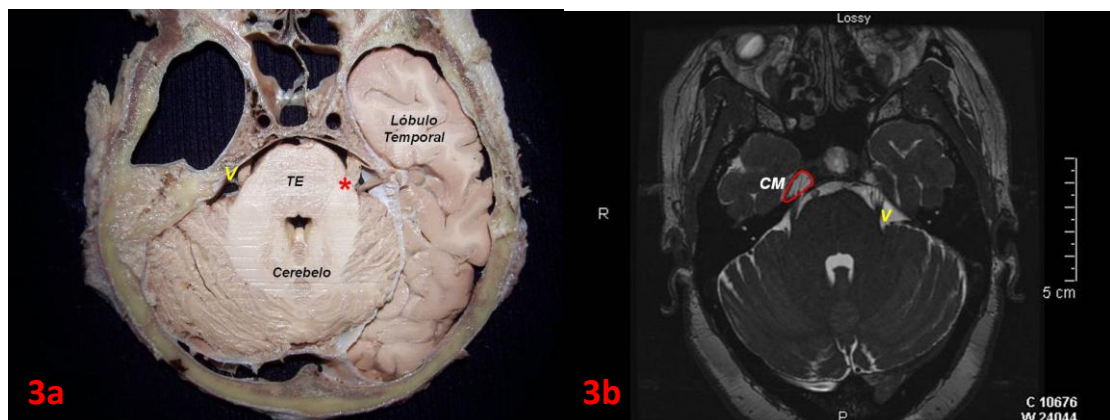


Figure 3

a.- Anatomical section in the axial plane at the level of the upper sector of the CPA and the normal course of the Vth from the pons to Meckel's space. The point at which the Vth arises (*) or REZ, of great topographic importance, is indicated. BS: brainstem

b.- Section selected from the FIESTA protocol in a patient with no disorder, at a similar level as the anatomical section. The red dotted line shows the area corresponding to Meckel's space (MS), the hyper-intense sector in this sequence due to the presence of cerebrospinal fluid forming a true cistern at that level. The clearly variable appearance of the nervous tract (V) may be clearly observed: as a single tract at right and multiple small filaments at left.

The cisternal (Vc) or pre-ganglionic segment occupies the upper floor sector of the cerebellopontine angle, above the acoustic-vestibulo-facial bundle, heading upwards and laterally, from the posterior fossa to the apex of the petrous portion of

It later enters Meckel's space, the region where the Gasserian ganglion is located, a ganglionic station relaying sensitive information, and following which its three terminal branches originate: the ophthalmic

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(V1), maxillary (V2) and mandibular (V3) nerves.

This region is a space carved in a dural fold, occupied in nearly all specimens by cerebrospinal fluid. Here the nervous trunk is formed by multiple small nerve roots and the ganglion is formed actually by a true network of minute nerve filaments and therefore should be called plexus rather than ganglion. Only the sensitive fibers form part of this structure, the small motor tract passes, in the majority of cases, below the ganglion –as may be clearly observed in the dissections carried out. Figure 6

After the Gasserian ganglion, the distribution branches, already separated in all cases, run forward seeking for the different orifices in the skull base though which they reach their distribution territory. Figure 7

Prior to this, the three sensitive branches establish a close relationship with the lateral wall of the cavernous sinus, passing through the width of the duramater, especially V1 and V2.

After going through this sector, V1 reaches the superior orbital fissure (sphenoidal cleft) and crosses it to reach the orbit where it is distributed.

Its distribution territory encompasses the sensitivity of the eye-globe and conjunctiva, eyelids, frontal region, the skin of the nose and naso-sinusal mucosa, and the vegetative innervation of the lacrimal glands.

The second branch, V2, goes towards the foramen rotundum in the middle fossa of the skull, reaching the pterygo-palatine region where it subdivides into multiple collateral branches.

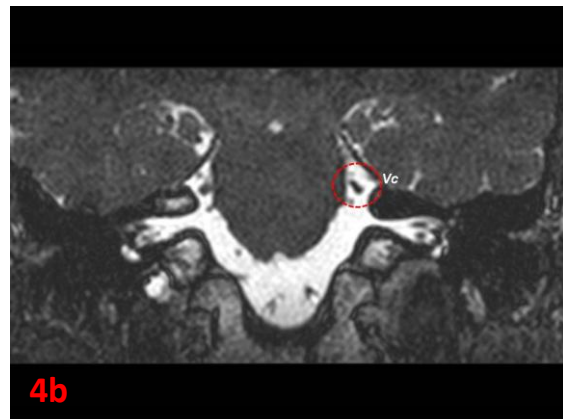
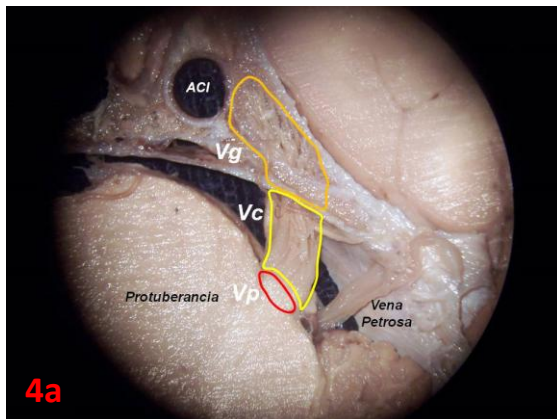


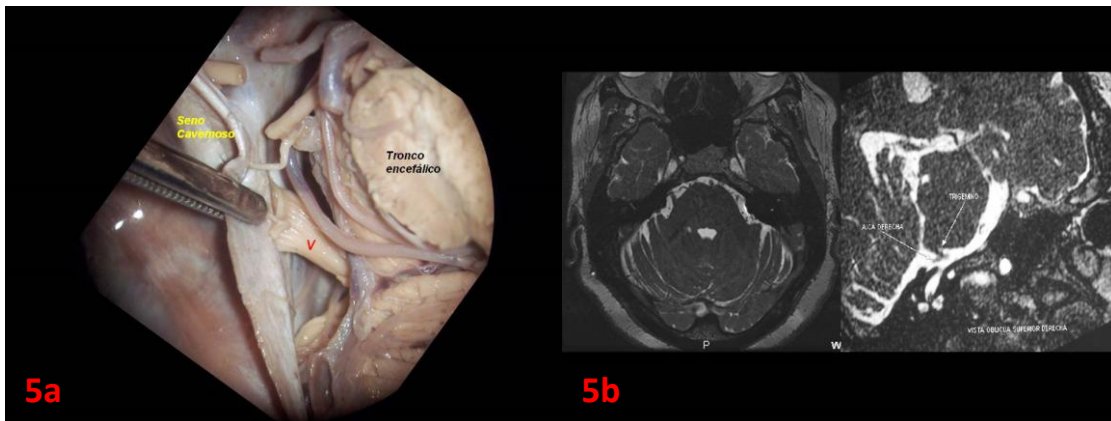
Figure 4

a.- Micro-dissection of the section referred to in figure 3a, at left, the three portions of the Vth tract are indicated: pontine (Vp), cisternal (Vc) and Gasserian or plexual (Vg) segments.

ICA: internal carotid artery

b.- Coronal reconstruction of FIESTA sequence to observe the cisternal trajectory of the Vth, highlighted at left in the CPA cistern.

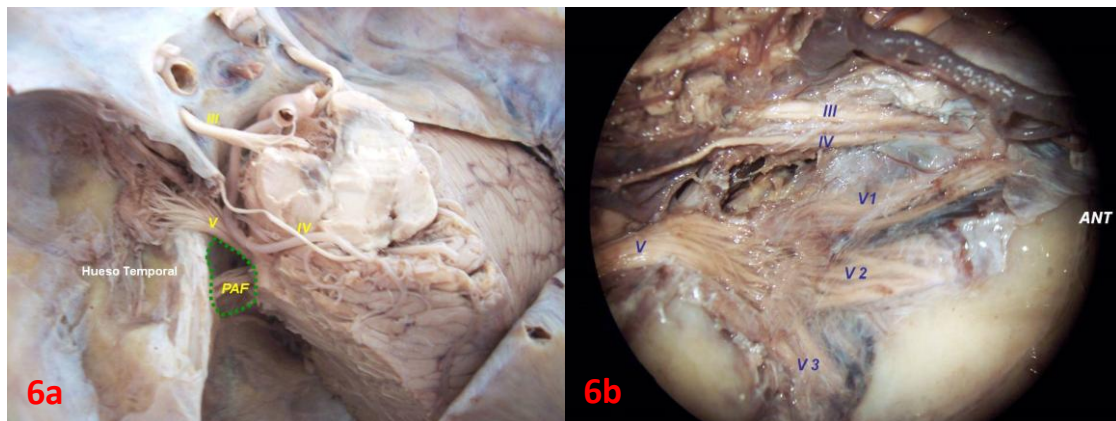
c.- Left parasagittal reconstruction of the FIESTA sequence showing the whole course from the REZ to the MS.

**Figure 5**

- a.- Anatomical section: micro-dissection of the right cranial nerve V showing its cisternal segment with its close vascular relationships. It is possible to observe the nervous tract (V) intimately related with the right middle cerebellar artery and a thick neighboring venous vessel (Dandy's petrous vein).
- b.- Selection of FIESTA sequence slices (axial and reconstruction) where it is possible to observe the nervous tract at right in relation with a small, tubular and sinuous vascular structure corresponding to a loop in the right middle cerebellar artery.

The main tract of this branch continues in the floor of the orbit to emerge in the face through the infraorbital orifice and is distributed in the skin of the middle facial territory and part of the oral cavity. Finally V3, which travels together with the motor root of the nerve, crosses the base of

skull through the foramen ovale, and reaches the deep masticator space. There it forms multiple sensitive branches destined for the lower third of the face and part of the oral cavity, additionally to the temporo-mandibular joint, while the motor branches supply the mastication muscles.

**Figure 6**

- a.- Cadaveric preparation with dissection of the Gasserian segment of the cranial nerve V. The dura mater of the CM was separated to show the continuity between Vc and Vg.
- b.- Different anatomical specimen showing a lateral view of the right Vth, the plexiform appearance of Vg, and its three terminal branches: V1 ophthalmic, V2 maxillary and V3 mandibular. The relation between the V and the cavernous sinus walls, particularly the lateral wall are likewise highlighted, together with the oculomotor (III) and trochlear (IV) cranial nerves that cross that region.

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Trigeminal Imaging Anatomy

In all cases analyzed, each of the components of the trigeminal system was clearly identified, with the exception of the previously described nuclei.

A thick nerve tract surrounded by cerebrospinal fluid (cisternal portion of the V) was observed in all cases from its site of origin in the brainstem until it enters into Meckel's space, and in all the specimens it was possible to identify two differentiated components: the sensory and motor branches.

In all cases it was possible to correctly locate the REZ, and also individualize the main vascular relations the nerve presents along this course.

In all cases its entry to Meckel's space was observed and correctly visualized in the 3 planes of space, with a higher resolution in the sagittal reconstructions and in the axial plane.

The Gasserian ganglion was observed within Meckel's space and the anatomical findings were corroborated in all cases. Thus, a plexiform structure where the branches of the nervous trunk converge and where the three terminal branches arise was observed in 100% of cases.

Discussion

The anatomy of the trigeminal is well known and has been described in detail by numerous classical and contemporary authors (1-3).

At present, the advent of new technologies has enabled a very precise study of the anatomy of this complex nervous tract and the regions it crosses, and this requires a deep knowledge of this anatomy and the imaging projections (4, 5).

The use of high spatial resolution imaging allows the study of each of the portions of the trigeminal nerve seeking anatomical variants and/or pathological elements that

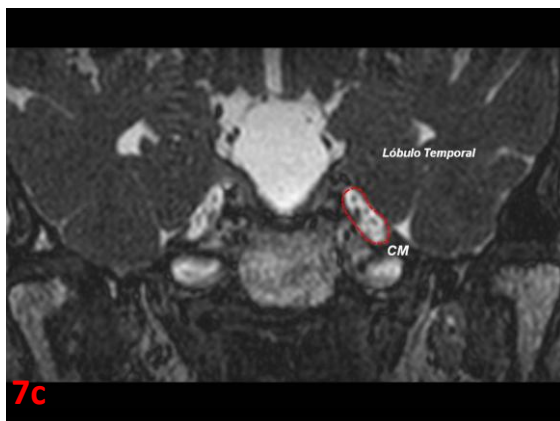
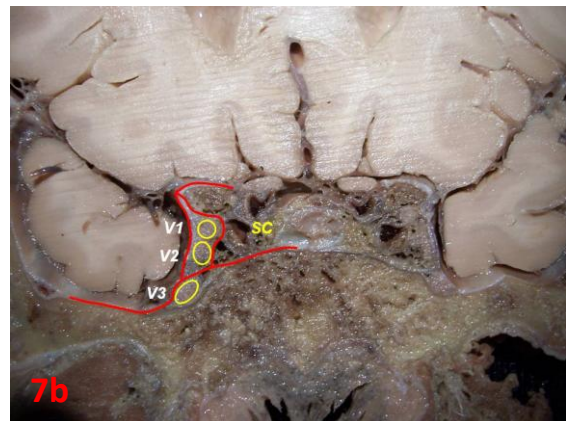
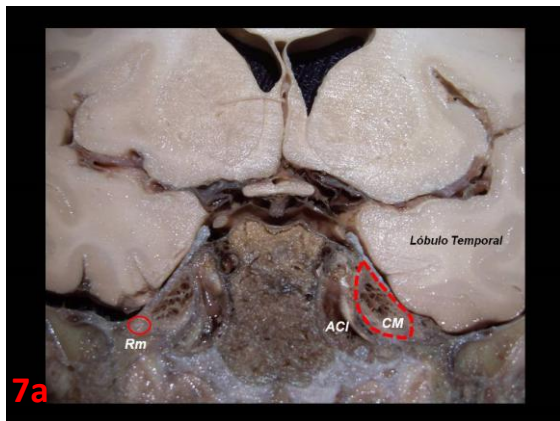


Figure 7

Coronal anatomical slices (a and b) in the region of CM and the cavernous sinus. In a the plexiform appearance of the Gasserian ganglion is highlighted together with its relation with the motor branch of the V th (Rm). In b a more anterior section where it is possible to identify the three terminal branches of the trigeminal and its course throughout this complex anatomical region is shown. In c an image of a coronal FIESTA sequence corresponding to the anatomical sections.

could explain the clinical presentation of a relatively frequent syndrome such as the TN (6, 7).

This may occur, not only with involvement of the nervous trunk or its distribution branches, but also of its intra-axial portions or those in the region of Meckel's space, thus, making it necessary to identify them correctly (5).

Several disorders of different sorts may give rise to this clinical condition, the majority of which, such as for example tumoral lesions, may be easily assessed with MRI using conventional sequences.

In some situations it is fundamental to consider the precise anatomical details and search for the relations between the nervous tract in its different portions, especially trying to establish its vascular links seeking for possible conflicts (contact points) among the structures.

Furthermore, these sequences (FIESTA, GE HealthCare) are based on volumetric 3D acquisitions, which enable the reconstruction using axial images in a simple and fast manner, and obtaining similar resolution coronal and sagittal images (6, 7).

In this manner we pass from an anatomy of slices to the multi-planar study of these small structures with more information when studying the Vth and the regions it crosses.

In our milieu, the study of the trigeminal nerve anatomy together with that of all the nervous system structures has undergone a revolution with the acquisition of new technologies, and this demands we revisit basic concepts applied to diagnostic imaging.

Conclusions

TN is a specific entity, with a characteristic clinical presentation and multiple causes, some simply arising from the close anatomical relations between the Vth and neighboring vascular structures.

In all the studies analyzed it is possible to clearly identify the Vth in its different

portions with great resolution. In the high resolution sequences the nervous tract and its portions may be observed in great detail together with the region of Meckel's space, with an excellent correlation with the cadaveric dissections.

It is essential to have an accurate knowledge of the anatomy of the Vth, together with that of the regions and spaces it crosses, in order to achieve an adequate anatomic imaging analysis in studies with excellent spatial resolution such as MRI.

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