CASE REPORT

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Trigeminal nerve: MRI anatomy and case presentation of trigeminal neuralgia due to arterial compression

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Abstract

Trigeminal neuralgia (TN), also known as *tic douloureux* is a chronic neuropathic pain disorder characterized by sporadic episodes of extreme, sudden burning or shock-like face pain that last from a few seconds to 2 minutes. Trigeminal neuralgia has a reported incidence of 5.9/100 000 women and 3.4/100 000 men in USA. The exact pathophysiology is still unclear, but demyelization leading to abnormal discharge in fibers of the trigeminal nerve is a probable cause. In the majority of cases, no structural lesion is detected but in almost 15% of patients medical imaging methods like MRI, CT or angiography can identify a vein or artery that compresses the nerve which results in focal demyelization. The authors present a case of trigeminal neuralgia investigated by MRI, which identified a vascular compression of the nerve 9 mm after emerging the pons by the superior cerebellar artery (SCA) and one of its branches. The authors also realize a review of the MRI anatomy of the trigeminal nerve.

Keywords: trigeminal neuralgia, MRI imaging, vascular compression, trigeminal nerve anatomy.

Introduction

Trigeminal neuralgia (TN), also known as *tic douloureux* is a chronic neuropathic pain disorder characterized by sporadic episodes of extreme, sudden burning or shock-like face pain that last from a few seconds to 2 minutes. The pain occurs unilaterally following the sensory distribution of trigeminal nerve and can be physically and mentally incapacitating [1].

In the majority of cases, no structural lesion is detected but in almost 15% of patients medical imaging methods like MRI, CT or angiography can identify a vein or artery that compresses the nerve which results in focal demyelination. In some cases, trigeminal neuralgia can be secondary to a tumor that invades, severely compresses or distorts the nerve or to multiple sclerosis within the brainstem [2–4].

We present a case of trigeminal neuralgia investigated by MRI, which identified a vascular compression of the nerve 9 mm after emerging the pons by the superior cerebellar artery (SCA) and one of its branches. We also realize a review of the MRI anatomy of the trigeminal nerve.

Patient, Methods and Results

A 50-year-old female patient is addressed to the neurology service for a right-side facial neuralgia. Biological, stomatological and neurological tests revealed negative results. A MRI exam is indicated in order to complete medical investigations.

Axial sequences revealed that at 9 mm after exiting the pons an artery and one of its branches cross the left trigeminal nerve. Coronal sequences illustrate better the narrow relation between the trigeminal nerve and two arteries (Figures 1 and 2).

TOF angiography sequences allowed us to precisely identify the arteries as the superior cerebellar artery and one of its branches (Figure 2). A more curved aspect of the left SCA as compared to the opposite side is demonstrated by the angiographic reconstruction (Figure 3).

After demonstrating the vascular cross-compression of the trigeminal nerve, a microvascular decompression through a small occipital craniotomy was attempted as the patient stated no amelioration of her condition after treatment with anticonvulsants for two years. An inert implant was placed in order to maintain the decompression.

Six months after the surgery the patient was hospitalized for severe chest pain associated to severe idiopathic arterial hypotension and hypovolemia. An emergency thoracic injected CT scan was performed that revealed the rupture of a type A arterial dissection. Unfortunately, the patient died in the following 30 minutes by hemorrhagic shock. The autopsy and histopathological examination were performed sustaining

the death diagnosis of hemorrhagic shock secondary to the rupture of a type A arterial dissection. Meanwhile, due to the particular medical condition of the case, trigeminal ganglion was sampled and embedded in paraffin. The sample was cross-sectioned in 3 μm slices, HE stained, in order to microscopically visualize the trigeminal ganglion (Figure 4, a and b).

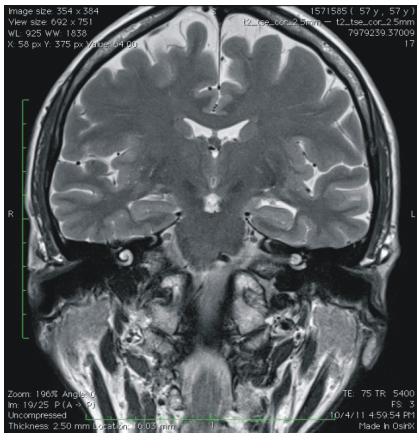


Figure 1 – ***T2TSE sequence showing intersection of the trigeminal nerve with the SCA and one of her branches.***

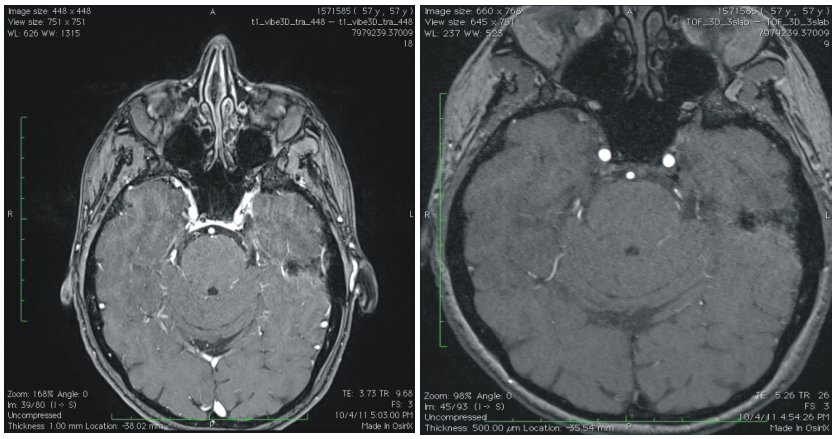


Figure 2 – ***Volumetric interpolated brain examination (VIBE) and Time of Flight (TOF) sequences displaying how the trigeminal nerve passes beneath the SCA.***

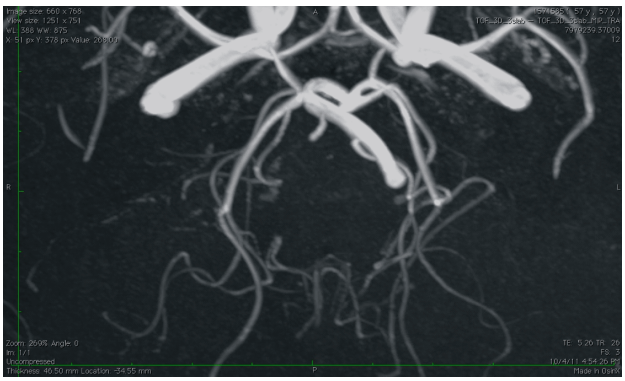
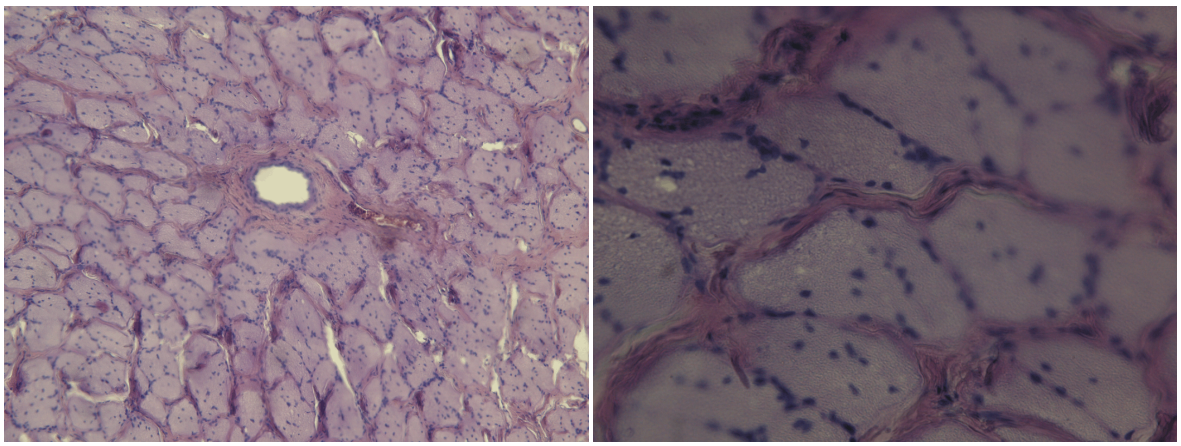


Figure 3 – ***TOF angiography of the posterior fossa.***



(a) **(b)**

Figure 4 – ***Trigeminal ganglion without pathological changes: (a) HE staining, ×100; (b) HE staining, ×400.***

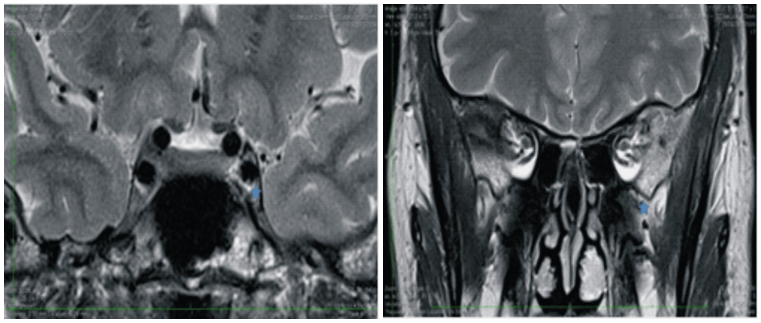


Figure 5 – ***Maxillary branch of the trigeminal nerve in the cavernous sinus (T2 TSE sequence).***

Figure 6 – ***Mandibular branch in the infratemporal fossa (T2 TSE sequence).***

Discussion

The trigeminal nerve, the largest of the cranial nerves with exclusive cephalic distribution, is mixed, with branchiometric organization, and supplies the sensitive and motor innervations of the first pharyngeal arch derived structures. Unlike other branchiometric nerves (VII, IX and X), at the level of the superficial origin, the trigeminal nerve trunk does not contain preganglionic fibers for the parasympathetic ganglia attached to its terminal branches (cilliary, otic, pterygopalatine, submandibulary and the ganglia of the cavernous sinus) [5]. These fibers arrive to the different trigeminal branches on their extracranial course following various anastomoses. The same course present the postganglionic sympathetic fibers with origin in the cervical sympathetic ganglia that enter the skull as carotic and vertebral plexus and reach their peripheral targets through anastomoses with the terminal branches of the trigeminal nerve [6, 7].

The sensory component of the trigeminal nerve supplies the exteroceptive and proprioceptive somatic innervations of the scalp, surface tegument, skull osteo-periosteum, meninges of the anterior and middle cerebral fossae, the soft parts of the orbit, nasal cavity and para-nasal sinuses, oral cavity, teeth and temporomandibular joint. *The motor component* innervates the muscles that develop from the first pharyngeal arch mesenchyme and act on the osteofibrous structures derived from the same arch as the mandible (temporal, masseter, medial and lateral pterygoid muscles, milohyoid and the anterior belly of the digastric muscles), the malleus (m. tensor tympani) and palate (m. tensor velipalatini) [8, 9].

Functional organization of the trigeminal system

The real origin of the motor fibers is located in the masticatory pontine nucleus, vertical neuronal column shaped, enclaved in the lateral tegmental area, medially from the principal pontine sensory nucleus.

The masticatory nucleus consists of α and γ motoneurons, grouped into a lateral subnucleus that innervates the levator muscles of the mandible, and a medial subnucleus that innervates the depressor muscles of the mandible, and interneurons, located in the supratrigeminal and intertrigeminal nuclei that receive the supranuclear afferences. The masticatory nucleus receives direct afferences from the trigeminal mesencephalic nucleus where closes bineuronal reflex arches that control the activity of the masticator muscles, secondary trigeminal, homo and heterolateral fibers from the subnuclei of the sensitive trigeminal column carrying information from the lingual and nasal mucous membranes and closing the mastication multisynaptic reflex arches, direct and crossed fibers from the corticonuclear tract that establish multiple prenuclear synapses with the inter and supratrigeminal interneurons and with the nuclei of the reticular formation (*parabranchialis*, *Köllicker–Füse area* and *area tegmentalis lateralis*, *pars caudalis*). Only few fibers synapse directly with the masticatory moto-neurons [7, 10, 11].

The real origin of the sensory fibers is different, depending upon the peripheral input quality. The general somatic afferent fibers (GSA) that carry the exteroceptive protopathic (pressure, pain and thermal) and epicritic sensibility (fine, discriminatory, tactile and pressure sensibility) from the head and surface skin and mucosae, originate in the pseudo-unipolar neurons of the Gasser ganglion. The afferent central axons of these neurons constitute the main sensitive root (*portio major*) and form the peripheral input of the principal and spinal trigeminal nuclei. These axons enter the brainstem through the lateral part of the pontine ventral surface and follow the thick Aβ and γ fibers (that bifurcate into *short ascendant branches* that synapse in the main pontine nucleus and *long descendant branches* that synapse in different subdivisions of the spinal nucleus). The descendant fibers are disposed around the ventro-medial surface of the spinal nucleus and form the spinal trigeminal tract that descends caudally until the dorso-lateral Lissauer tract of the first two cervical spinal segments. It has a somatotopic organization, the fibers of the ophthalmic division being located most ventrally) and the thin C and δ fibers (that do not bifurcate, bend caudally, enter the spinal trigeminal tract and end in *pars caudalis* of the *spinal nucleus* where participate to the formation of the trigeminal analgesic system) [7, 10, 12].

The sensitive trigeminal nuclear column consists of principal pontine, spinal and mesencephalic nuclei.

The principal pontine nucleus, located laterally to the entrance of the main root, is relatively spherical shaped, with the caudal pole fused without limit of demarcation with *pars oralis* of the spinal nucleus. It represents the first relay of trigeminal information processing system, consisting of ovoid small and middle size neurons. It is somatotopically organized with ophthalmic neurons disposed ventrally, maxillo-mandibular neurons, dorsally, and the ones from the oral cavity dorsocaudally, expanding in the *pars oralis* of the spinal nucleus. The functional organization of the principal nucleus is similar with that of the gracilis and cuneatus nuclei. Its efferences form the ventral trigeminothalamic tract that decussate on the midline and forms the trigeminal lemniscus, situated on the posterior surface of the medial lemniscus and ending in the thalamic ventral posteromedial nucleus (VPM). The axons of the thalamic neurons project in the inferior part of the primary sensitive area (S1). The axons from the dorsocaudal part of the principal nucleus remain homo-laterally, bend ascendantly, form the dorsal trigemino-thalamic tract and end in the ventral posteromedial nucleus (VPM) so that the oral cavity has bilateral thalamocortical representation [7, 10, 12].

The spinal trigeminal nucleus, the largest of the trigeminal system, is located in the medulla oblongata and consists rostrocaudally of three subdivisions sub-nucleus oralis (*pars oralis*) (that fuses cranially with the main pontine nucleus and expands caudally to the superior third of the inferior olivar nucleus), subnucleus interpolaris (*pars interpolaris*) (that fuses cranially with the oral subnucleus and expands caudally until the level of the pyramidal decussation. The oralis and interpolaris subnuclei are functionally associated to the principal

pontine nucleus and their axons enter the ventral trigemino-thalamic tract, synapse with the VPM thalamic nucleus and project on the primary sensitive area S1), and subnucleus caudalis (*pars caudalis*) (that expands caudally, from the pyramidal decussation level to the C2 spinal segment, where it continues with the substantia gelatinosa of the dorsal horn. Like the spinal cord dorsal horn it is laminary organized and receives the Aδ and C trigeminal afferences that synapse with the interneurons of the trigeminal analgesic system (lamine I–IV) [13].

The efferences of these systems form the *dorsal trigeminothalamic tract* that crosses the midline, joins the anterolateral spinothalamic pathway and synapse in the VMpo, ventroposterior complex and intralaminary thalamic nuclei. The thalamic nuclei project on the cortex of posterior insula and on the anterior part of gyrus cinguli. The caudal trigeminal subnucleus receives afferences that belong to the central pain control system: the corticobulbar glutamatergic fibers (it is known that 60% of the cortico-spinal pathway establishes excitatory synapses with the interneurons of sensitive structures from the brainstem and the spinal cord), the opiodergic direct fibers from *substantia grisea centralis* (that synapse on the lamina I neurons, and indirect fibers from the other supramesencephalic centers as hypothalamus, amygdala, limbic and insular cortex that via the descendant reticular formation of the brainstem participate to the edification of the central pain control system), the serotoninergic rapheospinal fibers from other raphe nuclei and from the rostral ventromedial medulla and the adrenergic fibers from the mesencephalic cells group A5, A6 and A7, *locus coeruleus* and *locus subcoeruleus* [7, 10, 11].

Many neurons of the caudal subnucleus respond to cutaneous or tactile stimuli and are excited by electrical, chemical or mechanical nociceptive stimuli from the cervicofacial and tongue muscles indicating a convergence of the superficial and profound afferences in the caudal subnucleus.

The mesencephalic trigeminal nucleus consists of primary pseudo unipolar neurons (like that of the spinal ganglia) that forms a thin column located in the depth of the mesencephalic tegmentum along the ventrolateral margin of the central periapeductal gray matter. The pseudounipolar axons of these neurons divide into peripheral branches that leave the pons via the motor root of the trigeminal nerve and establish neuroreceptor synapses with the proprioreceptors, central branches that inflect rostrally, form the mesencephalic trigeminal tract and synapses with the α-neurons of the masticatory nucleus, closing bineuronal masticatory reflexes. The mesencephalic trigeminal nucleus contains bipolar and multipolar neurons that connect it with the cerebellum and the reticular formation of the brainstem [13, 14].

The superficial origin of the trigeminal nerve is located on the lateral part of the pons ventral surface and represents the landmark of the conventional limit between pons and the middle cerebral peduncle. It consists of two roots, one larger, principal (*portio major*) located ventrocaudally that is sensitive (*radix sensoria*), and another one secondary (*portio minor*), motor (*radix motoria*) dorsorostrally located. At the exit from the pons the principal trigeminal root has a pluri-fascicular appearance, which preserves until the trigeminal pore [7].

The peripheral course and relations

The trigeminal nerve is the shortest cranial nerve of approximately 12 mm, because its transdural segment is incomplete, limited to the *cavum Meckeli*. The nerve lasts from the superficial origin until the concave margin of the Gasser ganglion and presents a trans-cisternal segment, *pars compacta*, located infratenorially in the posterior cerebral fossa and a transdural segment, *pars triangularis*, contained in *cavum Meckeli* [15].

Pars compacta, sagittally disposed, is a fascicular cord shaped ellipsoid on cross section. It presents an anteromedial, pontine surface, a posterolateral, cerebellar surface, a superior margin, crossed by the superior cerebellar artery that separates it from the trochlear nerve, and an inferior margin related with the loop of the anteroinferior cerebellar artery. From its origin, *pars compacta* directs ascendant, mediolaterally, perforates the Liliequist membrane, crosses the pontocerebellar cistern, inflects laterally, enters the trigeminal pore and continues with *pars triangularis* until the concave border of the Gasser ganglion [7, 11].

Pars triangularis, horizontally disposed in the plane of petrosal part superior surface, is trapezoidal shaped and presents a superior surface related with the hypocampal uncus through the superficial lamina of the cavum, inferior surface related through the deep lamina of the *cavum Meckeli* with the abducens, greater and lesser petrosal nerves and with the intrapetrosal segment of the internal carotid artery, medial margin related with the abducens nerve, lateral margin participating in the formation of the posteromedial triangle (Kawase), greater base corresponding to the concave margin of the semilunar ganglion, lesser base corresponding to the trigeminal pore. *Pars triangularis* has a particular, false plexial aspect because the thin fasciculi of the *pars compacta* dissociate, fan and intersect in various directions before entering the *hilus ganglii* [15, 16].

The *cavum Meckeli*, the largest perineural cistern of the skull base, is a complex trapezoid shaped meningeal structure of the middle cerebral fossa, consisting of an osteopahimeningeal container and neuroliquidian content. The *cavum Meckeli* presents the lesser base, oriented posteromedially, that corresponds to the trigeminal pore, the greater base, oriented antero-laterally, that corresponds to the sphenoidal margin of the foramen lacerum and sends toward the superior orbital fissure, toward the foramen rotundum and foramen ovale, three dural tunnels that contain the terminal branches of the trigeminal nerve and their adjacent cisterns, the medial margin, that fuses with the lateral wall of the cavernous sinus, the lateral margin along which the superficial and profound cavum laminae reunite and attach on the contour of the trigeminal fossa [10, 11].

The trigeminal ganglion (semilunar, of Gasser) contains the primary afferent neurons whose central axons will form the sensory root of the trigeminal nerve. It is contained in the *cavum Meckeli*, is flattened crescent

shaped, elongated and thinner at extremities, with a narrowing, *isthmus ganglia*, between the origins of the maxillary and mandibular nerves.

Morphologically, the ganglion presents anterolateral surface, convex mediolaterally and craniocaudally, from which detach the terminal branches of the trigeminal nerve, posteromedial surface, concave mediolaterally and craniocaudally. The craniocaudal concavity is very deep and forms the sinus of the trigeminal ganglion (*sinus ganglii*), through which exit the central axons of the sensitive root and form *pars triangularis*, deep surface, crossed mediolaterally by the motor root that takes the way of the mandibular nerve, superficial surface, narrowed between the origins of the maxillary and mandibular nerves forming *isthmus ganglia*, and corresponds to the inferior surface of the temporal lobe, medial, anterosuperior extremity, adherent to the cavernous sinus by the ophthalmic nerve dural tunnel, lateral, posteroinferior extremity that extends medially until the foramen ovale [17, 18].

Structurally, the trigeminal ganglion consists of pseudounipolar neurons grouped in columns separated by axons bundles and of satellite cells that encapsulate each neuronal soma. The size of the neuronal somata varies proportionally with the thickness of their axons, the largest ones being the Aβ neurons. Each neuron of the Gasser ganglion emits a short axon which bifurcates in a peripheral branch that takes the way of a terminal trigeminal branch and another one central that forms the sensitive root (*radix sensoria*) of the trigeminal nerve and synapses with the pontobulbar relays [13].

The main trigeminal branches are: the ophthalmic nerve, the maxillary nerve and the mandibular nerve. (Figures 5 and 6).

The most frequent disorder of the trigeminal system is the trigeminal neuralgia or the "painful tic of the surface" (suicide disease, Fothergill disease, *tic douloureux*) with a reported incidence of 5.9/100 000 women and 3.4/100 000 men in USA. The disease is characterized by episodes of intense facial pain in the territory of one of the trigeminal branches. The pain is triggered suddenly at simple touch of a skin area and varies with remission times and intensifications. Among the trigeminal branches, the most affected is the maxillary nerve, the mandibular nerve, and rarely the ophthalmic nerve [9].

The trigeminal lesions localization could be [1, 2, 8]:

▪ Supranuclear, unilateral, of central motor neuron type that produces the unilateral paralysis of the masticator muscles with deviation of the mandible to the lesion side or bilateral, that determines pseudobulbar palsy (spastic masticator paralysis). The lesions of the trigeminothalamic tract result in an anesthesia of the controlateral surface;

▪ In the brainstem, the impairment of the motor nucleus of the trigeminal nerve determine fasciculation, paresis or atrophy of the masticator muscles. Could be associated with contralateral hemianesthesia of the members and the trunk by the involvement of the spinothalamic tract and internuclear ophthalmoplegia by the involvement of the medial longitudinal fascicle;

▪ In the cerebellopontine angle, the impairment of the trigeminal roots determine paresis of the masticator muscles, ipsilateral facial hemianesthesia and the loss of the corneal reflex;

▪ In the *cavum Meckeli* and the apex of the petrosal part of the temporal bone, the trigeminal nerve could be impaired in the apical petrositis, Gradenigo syndrome or the paratrigeminal syndrome Raeder when the trigeminal lesion is accompanied by Horner syndrome.

The exact pathophysiology is still unclear; but demyelination leading to abnormal discharge in fibers of the trigeminal nerve is a probable cause. The most frequent causes include vascular compression of its root, posterior fossa or gasserian tumor, or brainstem multiple sclerosis. The artery most commonly responsible for the compression is the superior cerebellar artery followed by an abnormal course of the basilar artery [3].

Anticonvulsants like Carbamazepine are the first choice in medical treatment of TN and if prove inefficient second line medications like (Oxcarbazepine, Phenytoin, Gabapentin) are used [3].

Patients with pain refractory to medication are tobe referred for surgical decompression of the nerve if MRI examination demonstrates a vascular compression.

MRI investigation is to always be performed in case of trigeminal nerve pathology as it can be involved in generalized neurological conditions or be the origin/ affected by brain tumors like schwannomas or neurofibromas [17].

MRI scan protocol

A standard protocol for evaluation of trigeminal symptoms includes axial T2-weighted images of the whole brain and axial thin-sliced (<1 mm) T2-weighted images of the cisternal trigeminal nerve course for evaluation of the normal cisternal segment and fluid filled Meckel's cave. Axial thin-sliced (3 mm) T1-weighted image of the trigeminal nerve course are used to identify a fat-filled superior orbital fissure and pterygopalatine fossa. The normal fat planes of skull base and the symmetrical appearance of masticator muscles should also be checked. After administration of Gd, axial and coronal thin-sliced (3 mm) T1-weighed images are made to look for contrast enhancing lesions on the cysternal and peripheral trigeminal course and to evaluate the cavernous sinus. Pending on clinical and imaging findings, additions and modifications can be made to this scan protocol. A TOF angiography can be added in case of vascular anomaly, FLAIR in case of demyelinating disease and DWI in case of ischemia and epidermoid cyst. GE T2-weighted images (T2*) images are helpful to look for hemosiderin deposits and cavernoma. Sagittal T1-weighted images can be used for better evaluation of the extension of a mass in the posterior fossa.

Conclusions

The trigeminal nerve is the largest cranial nerve with both a sensory and motor function. MRI is an excellent technique to evaluate the trigeminal nerve. In every examination for trigeminal symptoms, imaging of Meckel's cave, the cavernous sinus, the skull base foramina, the pterygopalatine fossa and the peripheral

trigeminal nerve course should be included. On MRI, we always look for a normal gray and white matter and brainstem, a normal cisternal segment, a fluid filled Meckel's cave, a homogeneously enhancing cavernous sinus, a fat-filled superior orbital fissure and pterygo-palatine fossa, a normal foramen rotondum and ovale, and asymmetrical appearance of the masticator muscles with normal fat planes of the skull base. In order to narrow the differential diagnosis it is indicated to use a segmental approach and to keep in mind that the most frequent anomalies are ischemia and multiple sclerosis, meningioma involving the cisternal segment, Meckel's cave and the cavernous sinus, and metastasis and peri-neural tumor spread along the trigeminal nerve course.

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