Radiologic Anatomy of the cranial nerves

Poster No.: C-1663
Congress: ECR 2013
Type: Educational Exhibit
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Keywords: Neuroradiology peripheral nerve, MR, CT, Education
DOI: 10.1594/ecr2013/C-1663

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Learning objectives

The main objective of this poster is to be familiar with the Radiological Anatomy of the cranial nerves with MR and CT images. The requests for many radiological tests are to rule out cranial nerve pathology and the exhaustive knowledge of the Anatomy, can be very helpful.

Background

There are twelve cranial nerves numbered in order as they emerge from cranial to caudal in the brain. These are: olfactory (I), optic (II), oculomotor (III), trochlear (IV), trigeminal (V), abducens (VI), facial (VII), vestibulocochlear(VIII), glosopharyngeal (IX), vagus (X), accessory (XI) and hypoglossal(XII) nerves.

Imaging findings OR Procedure details

I CRANIAL NERVE = OLFACTORY NERVE

Olfactory nerve is not a true nerve but an extension of the brain and provides the sense of smell. It is formed by neurosensory cells (neurons) placed in the epithelium of the nasal vault, whose axons, fila olfactoria, traverse the cribiform plate ,the so called transethmoidal segment. This segment is followed by an intracranial one in the olfactory sulcus, between the gyrus rectus and the orbital gyrus; also it can be subdivided into olfactory bulb, tract and cortex (fig 1).

The olfactory bulb, an enlargement of the olfactory tract, is closely apposed to the cribriform plate and is followed by the olfactory tract that, subsequently, splits into medial, intermediate and lateral stria(fig 2).

II CRANIAL NERVE = OPTIC NERVE

As well as the first cranial nerve, the optic nerve consists on the retinal ganglion cell axons, being so an extension of the brain and therefore not a true nerve. Both are myelinated by oligodendrocytes and not by Schwann cells as the rest of the cranial
nerves, and are covered by meninges. Optic nerve comprises four segments: intraocular, intraorbital, intracanalicular and intracranial.

INTRAOCULAR SEGMENT

In this segment, the retinal ganglion cell axons pierce the region of the sclera named lamina cribosa. Its length is about 1 mm.

INTRAORBITAL SEGMENT

This segment goes from the back of the globe to the orbital apex in a posteromedial direction and is surrounded by fat in the central region of the intraconal space. It is about 20-30 mm in length, which is longer than the distance from the globe to the optic chiasm to let movements of the eye. As surrounded by meninges, the pression changes affecting the intracranial vault, are transmitted via the cerebrospinal fluid in the subarachnoid space.

INTRACANALICULAR SEGMENT

It measures 4-9 mm in length and is located within the bony optic canal.

INTRACRANIAL SEGMENT

The intracranial segment is formed by 10 mm between the optic canal and the chiasm. It is covered by pia and surrounded by CSF within the suprasellar cistern. (figs. 3,4)

In the optic chiasm, the fibers from the temporal field of vision (which are the nasal retinal fibers) cross to the contralateral side, and so join the temporal fibers (which carry the nasal field of vision). (fig.5)

The retrochiasmatic structures are the optic tract, the lateral geniculate body, the optic radiation and visual cortex.

III CRANIAL NERVE = OCULOMOTOR NERVE

The oculomotor nerve is a mixed one: motor and parasympathetic. It consist of four parts: intraaxial, cisternal, cavernous and extracranial segments.

INTRAAXIAL SEGMENT

CISTERNAL SEGMENT
The third cranial nerve emerges from the mesencephalon and courses anterolaterally through the interpeduncular and prepontine cisterns.\(\text{fig. 6}\) It passes between the posterior cerebral (cranial) and superior cerebellar (caudal) arteries (\text{fig. 7}). Later on, it pierces the dura and enters the roof of the cavernous sinus.

CAVERNOUS SEGMENT

It courses anteriorly through lateral dural wall of the cavernous sinus being the most cranial nerve within the cavernous sinus and superolateral to cavernous internal carotid artery.

EXTRACRANIAL SEGMENT

The oculomotor nerve enters the orbit through the superior orbital fissure. It forks in superior and inferior branches.

IV CRANIAL NERVE = TROCHLEAR NERVE

It is a motor nerve which inervates the superior oblique muscle. Being the smallest of all cranial nerves, it is difficult to identify with MRI. Its named for the trochlea, a fibrous pulley structure in the eye; the tendon of the superior oblique muscle passes through it. This muscle leads the gaze towards the point of the nose. It is divided into four segments: intraaxial, cisternal, cavernous and extracranial.

INTRAAXIAL SEGMENT

The fibers exits inferior to inferior colliculus and so it is the only cranial nerve which emerges in the dorsal aspect of the brainstem.

CISTERNAL SEGMENT

the same as the III cranial nerve, but in a lower level, it goes between the posterior cerebral artery above and the superior cerebellar artery below. It pierces the dura to enter the lateral wall of the cavernous sinus, where it goes inferior to oculomotor nerve.

CAVERNOUS SEGMENT

EXTRACRANIAL SEGMENT

The trochlear nerve enters the orbit through the superior orbital fissure together with the III and VI cranial nerves.
V CRANIAL NERVE = TRIGEMINAL NERVE

It is the biggest cranial nerve and is divided into a small root lateral to the big sensory one.

INTRAAXIAL SEGMENT

The trigeminal nerve is formed by four nuclei, three sensory and one motor, which are located in the brainstem and the upper cervical cord.

PREGANGLIONIC OR CISTERNAL SEGMENT

The nerves emerge from both sides of the pons and courses anterosuperiorly through the prepontine cistern. Afterwards, it enter the Meckel cave through the porus trigeminus. (figs. 8,9)

INTERDURAL SEGMENT

The Meckel cave is formed by the meningeal layer of the dura lined with the arachnoid; it is filled with cerebrospinal fluid and continuous with the prepontine subarachnoid space. The sensory root makes synapses with the trigeminal ganglion, also known as Gasserian or semilunar ganglion, which is located in the inferior aspect of the Meckel cave.

(POSTGANGLIONIC) DIVISIONS (figs. 10,11)

Ophthalmic nerve (V1)

It courses in the lateral cavernous sinus wall, below the oculomotor and trochlear nerves. It exits the skull through superior orbital fissure (fig. 12) and it divides into lacrimal, frontal and nasociliary nerves.

Maxillary nerve (V2)

Also it courses in the lateral cavernous sinus wall, below the ophthalmic nerve. Later on, it goes through the foramen rotundum (fig. 13) and leads its way to the pterygopalatine fossa.

Mandibular nerve (V3)

It is formed by motor and sensory roots; the first one bypass the trigeminal ganglion. Both together exit directly from Meckel cave through foramen ovale (fig. 14) into the masticator space, without passing through the cavernous sinus.
VI CRANIAL NERVE = ABDUCENS NERVE

It is a motor nerve for the lateral rectus muscle, hence its name, that abduce the gaze. Five segments are noted as followed:

INTRAAXIAL SEGMENT

Paired abducens nuclei are located anterior to the fourth ventricle.

CISTERNAL SEGMENT

It emerges from the bulbopontine sulcus and travels anterosuperiorly within the prepontine cistern. (Fig. 15)

INTERDURAL SEGMENT

The abducens nerve penetrates the dura of the basisphenoid to enter the Dorello canal, and ascends to enter the cavernous sinus surrounded by arachnoid mater. Furthermore, it travels with the basilar venous plexus, also known as the petroclival venous confluence.

CAVERNOUS SEGMENT

The abducens nerve is the only nerve inside the cavernous sinus while the rest are located in the wall of the sinus.

EXTRACRANIAL SEGMENT

It enters the orbit through the superior orbital fissure together with the oculomotor and abducens nerves.

VII CRANIAL NERVE = FACIAL NERVE

It is a mixed nerve: motor, parasympathetic and sensory (taste).

INTRAAXIAL SEGMENT

This nerve has three nuclei: one motor and two sensory.

CISTERNAL SEGMENT

It emerges form the lateral brainstem in the pontomedullary junction to enter cerebellopontine angle cistern.
INTRATEMPORAL SEGMENT

The facial nerve in the temporal bone can be divided into four segments: (fig. 16, 17)

IAC segment: it extents from the porus acusticus to the IAC fundus. The IAC is divided into quadrants by the falciform transverse crest and the Bill bar vertically. The facial nerve occupies the anterosuperior quadrant.

Labyrinthine segment: connects fundal facial nerve to geniculate ganglion (anterior genu).

Tympanic segment: between the anterior and posterior genu, passing under lateral semicircular canal.

Mastoid segment: it exits this segment through the stylomastoid foramen.

EXTRACRANIAL SEGMENT

Exiting the stylomastoid foramen, the nerves leads to the parotid, where passes lateral to the retromandibular vein. This nerve branches within the parotid.

VIII CRANIAL NERVE = VESTIBULOCOCHLEAR NERVE

It is a sensory nerve of the balance (vestibular) and hearing (cochlear).

COCHLEAR NERVE

It arises from neurons located in the spiral ganglion within the modiolus of the cochlea. The peripheral fibers travel to the organ of Corti, in the cochlear duct within the cochlea, while the central fibers join to form the auditory component of the VIII cranial nerve.

VESTIBULAR NERVE

It arises from neurons located in the vestibular (Scarpa) ganglion located within the vestibular nerve in the fundal portion of the IAC, not visible on imaging. Peripheral fibers pass to sensory epithelium of utricle, saccule and semicircular canals. Central fibres join to form superior and inferior vestibular nerves.

The IAC is divided into four quadrants by the falciform crest (transverse crest) and the Bill bar (vertical bony structure), not visible on imaging. The facial nerve is located in the antero-superior quadrant, the cochlear nerve in the anteroinferior quadrant while the...
VIII vestibular branches pass through the posterosuperior and posteroinferior quadrants respectively. (fig.18)

The cochlear and the superior and inferior vestibular nerves join altogether near the porus acusticus to form the vestibulocochlear nerve which travels within the cerebelopontine angle to enter the lateral brainstem at the junction of the pons and the medulla(fig. 19).

The vestibular nuclear complex is formed by four nuclei located in the lower pons, at the level of the fourth ventricle.

IX CRANIAL NERVE=GLOSSOPHARYNGEAL NERVE

This cranial nerve is a mixed one, which carries the information of the taste to the posterior 1/3 of the tongue, sensation to middle ear and pharynx, parasympathetic fibers to the parotid gland, viscerosensory information to carotid body and sinus and motor fibers to stylopharyngeus muscle. It can be divided into four segments:

INTRAAXIAL SEGMENT

Glossopharyngeal nuclei are in upper and middle medulla.

CISTERNAL SEGMENT

Exits lateral medulla in the postolivary sulcus, just above the vagus nerve. Later on, the glossopharyngeal nerve together with the vagus nerve and the bulbar portion of the accesory nerve course anterolaterally within the basal cistern. (Fig.20)

SKULL BASE SEGMENT

Passes through the pars nervosa portion of the jugular foramen. The vagus and accesory nerves are posterior within the pars vascularis portion of the jugular foramen.(Fig.21)

EXTRACRANIAL SEGMENT

Exits skull base through jugular foramen into anterior nasopharyngeal carotid space, where it is lateral to internal carotid artery. Finally it ends in the posterior sublingual space in the floor of the mouth as it carries the taste to posterior 1/3 of the tongue.

X CRANIAL NERVE= VAGUS NERVE
The vagus nerve has four components: parasympathetic, motor, visceral and sensory ones. Four segments are noted:

**INTRAAXIAL SEGMENT**
Vagal nuclei are in the upper and middle medulla.

**CISTERNAL SEGMENT**
It exits the lateral medulla through the postolivary sulcus, underneath the glossopharyngeal nerve and above the bulbar portion of the spinal nerve; altogether travel anterolaterally through the basal cistern (Fig. 22).

**SKULL BASE SEGMENT**
The vagus nerve travels in the pars vascularis portion of jugular foramen.

**EXTRACRANIAL SEGMENT**
It exits the jugular foramen into nasopharyngeal carotid space and descends along posterolateral aspect of the internal carotid artery into the thorax. It passes anterior to the aortic arch on the left and the subclavian artery on the right.

The recurrent laryngeal nerve, an important branch of the vagus nerve, turns around at the level of the cervicothoracic junction on the right, while on the left, it does at the level of the aortopulmonary window. This is the reason why, when distal vagal neuropathy is present, such as in vocal cord paralysis, the CT scan should extend to the cervicothoracic junction on the right and to aortopulmonary window on the left.

**XI CRANIAL NERVE= ACCESSORY NERVE**
It is a motor cranial nerve supplying sternocleidomastoid and trapezius muscles. Four segments are defined: intraaxial, cisternal, skull base and extracranial.

**INTRAAXIAL SEGMENT**
Two different nuclei, the ambiguus and spinal nuclei arise the bulbar and spinal fibers respectively. The bulbar fibers exit the medulla inferiorly to vagus nerve while spinal fibers emerge from lateral aspect of cervical spinal cord, and then pass cranially through the foramen magnum.
CISTERNAL SEGMENT

Bulbar portion courses anterolaterally through the basal cistern together with the ninth and tenth cranial nerves. Finally, bulbar and spinal portions join together within the lateral basal cistern. (Figs. 23, 24)

SKULL BASE SEGMENT

The XI nerve are in the posterior aspect of the pars vascularis portion of the jugular foramen. Also the jugular bulb, the vagus and the glossopharyngeal nerves travel in this foramen.

EXTRACRANIAL SEGMENT

The accessory nerve exits the jugular foramen into nasopharyngeal carotid space. The bulbar portion fibers transfer to vagus nerve and innervate the muscles of pharynx and larynx. The spinal portion fibers supply the sternomastoid and trapezius muscles.

XII CRANIAL NERVE= HYPOGLOSSAL NERVE

It is a motor nerve to intrinsic and extrinsic muscles of the tongue, but for the palatoglossus muscle that is innervated by the vagus nerve.

Multiple rootlets emerge from the ventrolateral sulcus, also known as pre-olivary sulcus; they are sometimes intermixed with the vagus rootlets. Hypoglossal rootlets within the medullary cistern lead their way into the hypoglossal canal (Figs. 25, 26), where they fuse into a single nerve root. After leaving the skull base segment via the hypoglossal canal, the nerve in its extracranial segment travels in the posterior aspect of the carotid space (Figs. 27); later on, it turns around at the inferior margin of the posterior belly of the digastric muscle.

Images for this section:
Fig. 1: Coronal STIR-weighted images show the intracranial segment of the first cranial nerve. This segment is formed by the olfactory bulb, and the olfactory tract, and it is located in the olfactory sulcus, between the gyrus rectus and the orbital gyrus.
Fig. 2: Schematic view superimposed to a T2-weighted image. The olfactory bulb is located above the cribriform plate, very close to the frontal lobe and it is a thickening of the olfactory tract, which in its distal portion divides into the lateral, medial and intermediate olfactory striae, in the so-called olfactory trigone. Finally, the striae end in the entorhinal cortex, uncus and the inferomedial temporal lobe.
Fig. 3: Axial STIR images of the orbit (left) and of the brain (right) depict the optic nerve segments previous to the chiasm (intraocular, intraorbital, intracanalaricular and intracranial segments). After the optic chiasm, the fibers are called optic tracts.
Fig. 4: Several consecutive coronal STIR weighted-images of the orbit. From left to right, in the first row, the globes are noted, followed by the intraorbital segment of the optic nerves, which are surrounded by cerebrospinal fluid. In the second row the segments depicted are the intracanicular (first image) and the intracranial (second and third images). In the last row, the optic chiasm is noted, followed by the optic tracts.
Fig. 5: Schematic view of the visual path superimposed to a T2-weighted image. The optic chiasm is in the suprasellar cistern. In the optic chiasm, the fibers from the temporal field of vision (which are the nasal retinal fibers) crosses to the contralateral side, and so join the temporal fibers (which carry the nasal field of vision) of the contralateral eye.
Anterior to the optic chiasm the fibers are named as optic nerves, and posterior to the optic chiasm, as some fibers have crossed to the contralateral side, the fibers are named optic tracts.

Fig. 6: Axial FIESTA images: the third cranial nerve exits the midbrain into the interpeduncular cistern and travels anterolaterally through the prepontine cistern. Subsequently, it enters the cavernous sinus roof.
Fig. 7: The third cranial nerve in the prepontine cistern passes between the posterior cerebral (cranial) and superior cerebellar (caudal) arteries.
Fig. 8: Axial FIESTA image depicts the fifth nerve as it emerges from the lateral pons. Later on, it courses through the prepontine cistern and follows to the Meckel cave.
Fig. 9: Coronal FIESTA image shows the cisternal (or preganglionic) segment of the trigeminal nerve.
**Fig. 10:** Schematic view of the cavernous sinus superimposed to a T1-weighted image. Red circles represent the internal carotid artery. The third cranial nerve is located within the lateral wall of the cavernous sinus and it is the most cephalad of all the cranial nerves in the cavernous sinus. The fourth cranial nerve, V1 and V2 branches are inferior. The sixth cranial nerve is the only one nerve inside the cavernous sinus.
Fig. 11: Schematic views of a coronal T2 and sagittal T1 weighted images. The image on the left shows the mandibular nerve (V3) exiting the skull base through the foramen ovale without entering the cavernous sinus. The image on the right depicts the cisternal segment of the fifth nerve, from the brainstem to the Meckel cave. The sensory fibers make synapses with the trigeminal ganglion, and some of them, together with the motor fibers, exit the skull base through the foramen ovale as the mandibular nerve (V3). The remaining fibers in the cavernous sinus form the maxillary nerve (V2), which exits through the foramen rotundum and the ophtalmic nerve (V1), that exits through the superior orbital fissure.
Fig. 12: Axial CT image shows the superior orbital fissure. The ophthalmic (V1), III, IV and VI nerves exit the cavernous sinus through this foramen.
Fig. 13: Axial CT image depicts the foramen rotundum. The maxillary nerve (V2), goes through this foramen and so exits the cavernous sinus.
Fig. 14: Axial CT image shows the foramen ovale. The mandibular nerve (V3) exits the Meckel cave through the foramen ovale without entering the cavernous sinus. This nerve is formed by sensory fibers, which make synapses with the trigeminal ganglion, and motor fibers which bypass it.
**Fig. 15:** Four consecutive axial FIESTA images depict the origin of the sixth cranial nerve in the pons, its cisternal segment and its entering in the Dorello canal.
Fig. 16: Four ct reformated images show three different segments of the facial nerve in the temporal bone: the labyrinthine segment (from the fundus of the IAC to the geniculate ganglion (anterior genu), the tympanic segment (between the anterior and posterior genu) and the mastoid segment (from posterior genu to the stylomastoid foramen).
Fig. 17: Ct reformated images show different segments of the facial nerve.
**Fig. 18:** Saggital FIESTA image and a graphic below show the facial and the vestibulocochlear nerves (the latter formed by the cochlear and the superior and inferior vestibular branches) in the IAC. The IAC is divided into four quadrants by the falciform crest (transverse crest) and the Bill bar (vertical bony structure), not visible on imaging. The facial nerve is located in the antero-superior quadrant, the cochlear nerve in the anteroinferior quadrant while the VIII vestibular branches pass through the posterosuperior and posterioinferior quadrants respectively.
**Fig. 19:** Axial FIESTA images show the superior vestibular nerve (top) and the facial, cochlear and inferior vestibular nerves (bottom) within the inner auditory canal. In the surroundings of the porus acusticus, the three branches of the eighth cranial nerve (cochlear, superior and inferior vestibular nerves) join altogether to form a single nerve. The eighth cranial nerve travels in the cerebellopontine angle cistern to enter the pons at the junction of the pons with the medulla.
Fig. 20: Axial FIESTA image depicts the cisternal segment of the ninth cranial nerve. The glossopharyngeal nerve exits the lateral medulla in the postoliary sulcus, above the vagus nerve, and travels anterolaterally through the basal cistern to reach the pars nervosa portion of the jugular foramen.
Fig. 21: Axial CT image at the level of the clivus depicts the jugular foramen. The jugular spine divides the foramen in two: the pars nervosa portion occupied by the ninth cranial nerve and the pars vascularis portion occupied by the tenth and eleventh cranial nerves, altogether with the jugular vein.
Fig. 22: Axial FIESTA image depicts the cisternal segment of the vagus nerve. This nerve exits the lateral medulla in the postolivary sulcus, below the glossopharyngeal nerve and above the bulbar fibers of the accessory nerve. It travels in the basal cistern towards the pars vascularis portion of the jugular foramen, which shares with the eleventh cranial nerve and the jugular bulb.
Fig. 23: Coronal FIESTA image shows multiple rootlets of the accessory nerve emerging from both sides of the lateral medulla (arrows).
Fig. 24: Coronal FIESTA images. Bulbar portion of the eleventh cranial nerve courses anterolaterally through basal cistern together with ninth and tenth cranial nerves. Finally, bulbar and spinal portions join together within the lateral basal cistern.
Fig. 25: Axial CT image depicts the hypoglossal canal. The hypoglossal nerve crosses this canal, abandoning so the skull base.
**Fig. 26:** Coronal CT reformation shows the hypoglossal canal and its relationships with the surroundings structures.
Fig. 27: Axial T2-weighted MR image obtained at the level of nasopharynx depicts a schematic view of the IX, X and XII nerves in the carotid space.
Conclusion

The cranial nerves Anatomy is complex and its knowledge can help to identify the pathology.

References


Personal Information