International Neuropsychiatric Disease Journal
4(2): 92-101, 2015; Article no.INDJ.2015.030
ISSN: 2321-7235

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Pictorial Essay of Cranial Nerves Lesions on MRI Our Experience

Imran Nazir Salroo[1], Aamir Yousuf[2*], Kousar Sideeq[3], Waseem Ahmad Shah[4] and Rafiq Ahmad[5]

[1]Department of Radiaodiagnosis and Imaging, SMHS Hospital GMC Srinagar, University of Kashmir, J and K, India.
[2]Department of Otorhinolaryngology, SMHS Hospital GMC Srinagar, University of Kashmir, J and K, India.
[3]Department of Community Medicine, SMHS Hospital GMC Srinagar, University of Kashmir, J and K, India.
[4]Department of Otorhinolaryngology, SKIMS Medical Institute, Kashmir, J and K, India.
[5]Deaprtment of Otorhinolaryngology, SMHS Hospital GMC Srinagar, University of Kashmir, J and K, India.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/INDJ/2015/17894
Editor(s):
(1) Pasquale Striano, Pediatric Neurology and Muscular Diseases Unit, University of Genoa, G. Gaslini Institute, Genova, Italy.
Reviewers:
(1) Sushil Sharma, Saint James School of Medicine, The Netherlands.
(2) Arturo Solís Herrera, Research and Development, Human Photosynthesis Study Center, Mexico.
(3) Anonymous, University of Virginia Health Care, Israel.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=1005&id=29&aid=9716

Short Research Article

Received 29th March 2015
Accepted 14th May 2015
Published 11th June 2015

ABSTRACT

The twelve pairs of cranial nerves originate from various regions of brain from anterior to posterior, and are designated as per their attachments to the brain. The various bony channels and foramina in the skull base holds and transmits the cranial nerves along with vasculature. It is essential for all the skull base neurosurgeons and the radiologist to be wise enough with the complex anatomy of skull base for early suspicion and localization of skull base lesion, and for early the uraupectic decision making. In present era for diagnostic purposes, CT and MRI are complementary to each other and are frequently used for localization of lesion. The aim of this Pictorial essay is to

**Corresponding author: E-mail: miraamir_83@yahoo.com;*

demonstrate the cranial nerve lesions through MR imaging, their signal intensity and their extension to soft tissues.

Keywords: Cranial nerves; magnetic resonance imaging.

1. INTRODUCTION

The brief description of the anatomy of the cranial nerves from origin to terminal branches is vital for making this pictorial assay of cranial nerve lesions more comprehensive. An overview of the cranial nerves is given in Table 1. Magnetic resonance imaging is the method of choice to evaluate the cranial nerves, although the skull base is more clear on CT, the nerves themselves can only be visualized in detail on MRI. To see right sequence of nerves I to XII the right sequence must be used [1,2]. Cranial nerves with thicker main trunk are visible simply on MR-images: The Ophthalmic, Optic, trigeminal, Oculomotor as well as the facial and Vestibulocochlear nerves can be easily identified on 4 mm T2w images. The smaller cranial nerves are more difficult to delineate and thin section images are required. MRI is indispensible in defining the lesions of the cranial nerves. The intention of this article is to present to readers the pictorial description of various cranial nerve pathologies on magnetic resonance imaging (MRI). There are various reports about imaging of the cranial nerves that show the capabilities of sub millimeter heavily T2-weighted images, like the CISS or balanced FFE-sequences for the description of the anatomy of the cranial nerves. [4,5]. However, these patterns will only define the course of the cranial nerves within the basal cisterns, and this is helpful in clinically-suspected cases of neurovascular compression symptoms in most other cases more reliable information is needed to find the cause of cranial nerve palsy.

2. DESCRIPTION OF CASES

An interdepartmental descriptive cross sectional study was done for evaluation of various cranial nerve tumors over a period of one and half year in SMHS hospital, a tertiary care centre in valley of Kashmir, J & K. The cases were referred from departments of Neurosurgery, Ophthalmology and Otolaryngology & Head and Neck Surgery for imaging purposes. The MRI images of various patients having cranial nerve tumour lesions were collected and are being presented here.

Relatively well defined large mass in the right nasal cavity extending superiorly through the cribriform plate of ethmoid along the olfactory nerve into the right anterior cranial fossa with large intracranial component. Esthesioneuro-blastoma.

Table 1. Cranial nerve overview [3]

I : Olfactory nerves
The olfactory nerve transmits olfactory impulses from the olfactory epithelium of the nose to the brain. The olfactory nerve actually the olfactory tract and bulb, and is an outgrowth of the forebrain. Primary sensory neurons are bipolar and are confined to the olfactory epithelium. Their central processes make up the numerous nerves which pass through the cribriform plate of the ethmoid bone. They synapse with secondary sensory neurons forming the olfactory bulb and tract. On inferior surface of frontal lobe, above orbital plate of frontal bone Axons pass posteriorly in olfactory tract, through olfactory striae to limbic system of brain, particularly the uncus and amygdala of the temporal lobe, thus providing connections with memory circuitry and much else.
II: Optic nerves
The optic pathway transmits visual impulses from the retina to the brain. The optic nerve is the neural connection between the eyeball and the optic chiasma. Like the olfactory nerve the optic nerve is not actually a nerve but an outgrowth of the diencephalon (the thalamic structures). Optic nerve passes posteriorly from eyeball, surrounded by meninges, subarachnoid space, cerebrospinal fluid (CSF). As in the olfactory system, the primary sensory neurons are bipolar and are confined to the sensitive epithelium (retina), the axons of secondary sensory neurons forming

the optic nerve, chiasma and tract. Optic nerve passes within common tendinous ring (giving origin to extrinsic ocular muscles) and exits orbit through optic canal with ophthalmic artery below. Nerve surrounded by tube-like extension of three meningeal layers and subarachnoid space containing CSF. Optic nerves communicate at chiasma, anterior to hypophysis. At chiasma, fibres from nasal portion of each retina (impulses from temporal visual fields) cross to optic tract of opposite side. From chiasma, optic tracts extend back to lateral geniculate bodies (LGBs). Some axons bifurcate sending branches to midbrain for visual reflexes. In LGB, axons of retinal ganglion cells synapse with cell bodies of neurons forming optic radiation. Axons pass backwards, skirting posterior limb of internal capsule and lentiform nucleus (thus retrolenticular). Axons pass around inferior horn of lateral ventricle and end in visual cortex (occipital lobe). Some axons in the optic tracts bifurcate to give twigs which pass into the midbrain. These mediate visual reflexes and are connected to the pretectal nuclei (for the pupillary light reflex) and the superior colliculus and medial longitudinal fasciculus (for lens accommodation, eye movements, etc.).

III, IV, VII : (Occulomotor, Trocler, Abducen)

The oculomotor (III), trochlear (IV) and abducens (VI) nerves innervate the extrinsic ocular muscles which move the eyeball. It is difficult to consider these nerves separately since both eyes move simultaneously to fix on a single point: eye movements are thus said to be conjugate. These nerves innervate the extrinsic ocular muscles. ***Oculomotor (III)*:** Superior division: levator palpebrae superioris (LPS), superior rectus.- Inferior division: medial rectus, inferior rectus, inferior oblique. Also contains parasympathetic fibres from Edinger– Westphal nucleus to ciliary ganglion. Through its parasympathetic components, the oculomotor nerve also causes constriction of the pupil (miosis) and has a role in accommodation. From interpeduncular fossa of midbrain, passes through lateral wall of cavernous sinus. Superior and inferior divisions enter orbit through superior orbital fissure within common tendinous ring. **Trochlear nerve** (IV). superior oblique Smallest cranial nerve. From dorsal aspect of midbrain (uniquely), just below inferior colliculus. Passes around side of midbrain, through lateral wall of cavernous sinus, superior orbital fissure lateral to common tendinous ring. Passes above LPS to reach superior oblique. **Abducens nerve** (VI). (lateral rectus) Arises from **pontomedullary junction** near midline, above rootlets of XII. Ascends to pass through cavernous sinus, on internal carotid artery, superior orbital fissure (within common tendinous ring). Supplies lateral rectus muscle.fissure.

V: Trigeminal nerves:

The trigeminal nerve is for sensation from the skin of the anterior part of the head, the oral and nasal cavities, the teeth and the meninges. It has three divisions (ophthalmic, maxillary and mandibular) subsequently treated as separate nerves. Its mandibular division also carries motor fibres to muscles used in chewing.

Attachment, course, divisions

- Attached to lateral aspect of pons, near middle cerebellar peduncle.
- Passes below tentorium cerebelli, to middle cranial fossa.
- Trigeminal (sensory) ganglion in depression on temporal bone.
- Splits into ophthalmic (Va), maxillary (Vb) and mandibular (Vc).

Trigeminal ganglion: It contains cell bodies of primary sensory neurons in all three divisions of trigeminal nerve, except those of proprioceptive neurons .It is partially surrounded by cerebrospinal fluid in recess of subarachnoid space: trigeminal, or Meckel's, cave.

VII: Facial nerves

The facial nerve supplies the muscles of facial expression. Its other functions are:

- taste sensation from the anterior portion of the tongue and oral cavity;
- parasympathetic secretomotor function of the salivary, lacrimal, nasal and palatine glands.

Origin: It originates from **cerebellopontine angle** – lateral part of pontomedullary junction. Two adjacent roots: **motor root** (larger, more medial); nervus intermedius (smaller, more lateral) – so called because it is found between two larger nerves (main root of VII and VIII). Nervus intermedius conveys parasympathetic and sensory fibres and may be part of VIII initially **Intracranial course and branches:** From cerebellopontine angle, crosses posterior cranial fossa, enters internal acoustic meatus (IAM; with VIII). Nervus intermedius joins main root of facial nerve in IAM. Geniculate ganglion is deep in IAM: this houses cell bodies of sensory fibres (no synapses) in VII. Nerve turns posteriorly into: Facial canal running posteriorly along medial wall of tympanic (middle ear) cavity, and gives branch to stapedius (attached to stapes); Chorda tympani given off just before VII emerges at stylomastoid foramen; this passes anteriorly across tympanic membrane into infratemporal fossa where it joins lingual nerve; Emerges at stylomastoid foramen. **Extracranial course and branche:** Outside stylomastoid foramen, small branches of VII supply occipital belly of occipitofrontalis, stylohyoid and posterior belly of digastric, and a variable amount of cutaneous sensation from skin of external auditory meatus. Nerve enters parotid gland where it forms intricate plexus. Branches of VII are superficial in the gland. Five groups of branches emerge superficially from anterior border of parotid gland: temporal, zygomatic, buccal, mandibular and cervical. These supply muscles of facial expression including orbicularis oculi, orbicularis oris, buccinator and platysma

VII: Vestibulocochlear nerves:

The vestibulocochlear nerve is the sensory nerve for hearing (cochlear) and equilibration (vestibular). Arises laterally in cerebellopontine angle. Passes with VII into internal acoustic meatus (temporal bone). Cochlear portion (anteriorly) and vestibular portion (posteriorly).

Cochlear nerve and ganglion

- Bipolar primary sensory neurons (like olfactory and visual systems) originate from organ of Corti in basilar membrane in floor of cochlear duct (scala media).
- Cell bodies in cochlear ganglion situated in modiolus, or axis around which cochlea twists. Ganglion thus also known as spiral ganglion.
- Central processes pass in cochlear nerve to cochlear nuclei. Cochlear nuclei – medial geniculate body – auditory cortex
- Cochlear nuclei laterally in floor of fourth ventricle.
- Subsequent sensory neurons pass bilaterally to inferior colliculi (tectum of midbrain) and medial geniculate bodies (diencephalon).
- Inferior colliculi concerned with auditory reflexes.
- Some neurons pass to other centres (e.g. medial longitudinal fasciculus, reticular formation, spinal cord) for integration with other systems.
- Ascending pathways are multisynaptic, other components being superior olive, trapezoid body, lateral lemniscus. Commissural fibres also occur between inferior colliculi, medial geniculate bodies. Axons from medial geniculate bodies project through internal capsule to auditory cortex in upper part of temporal lobe on inferior operculum, just below lateral fissure (territory of middle cerebral artery). The vestibular pathways are intimately connected with the cerebellum. These are some of the oldest neural pathways in the animal kingdom.

Vestibular nerve and ganglion: cerebellum

- Bipolar primary sensory neurons originate from hair cells in vestibular apparatus: saccule, utricle, semicircular ducts. Cell bodies in vestibular ganglion in temporal bone Centra processes pass in vestibular nerve either directly to cerebellum, or to vestibular nuclei in medulla.
- Vestibular impulses pass to floccule, nodule, uvula, fastigial nucleus -. Vestibular nuclei in floor of fourth ventricle. Fibres descend in vestibulospinal tracts to spinal cord, others pass to medial longitudinal fasciculus for integration with eye muscle nuclei.
- Other fibres from nuclei pass to cerebellum (in addition to those passing directly from vestibulocochlear nerve to cerebellum).
- Vestibular system projects to ventral posterior nucleus of thalamus and since we have a

conscious awareness of stability in space, impulses may pass to parts of cerebral cortex

IX,X,XI : Glossopharyngeal nerves, Vagus nerves, Accessory nerves:

The glossopharyngeal, vagus and accessory nerves leave the skull through the jugular foramen. the glossopharyngeal nerve is unimportant except for its role in the gag reflex. The main function of the glossopharyngeal nerve is the sensory supply of the oropharynx and posterior part of the tongue. Its other functions are the motor supply to stylopharyngeus; conveying parasympathetic fibres part of the way to parotid gland and sensory supply from the carotid sinus, carotid body,

Origin, course and branches

- From medulla by a vertical series of rootlets lateral to olive, above and in series with those of X and XI.
- Passes through jugular foramen (middle portion). Two sensory ganglia: superior and petrosal (inferior).
- Parasympathetic axons from inferior salivatory nucleus to otic ganglion (for parotid gland) enter tympanic branch .May also convey sensory fibres from ear.
- Nerve descends in neck, supplying stylopharyngeus and carotid body.
- Passes between internal and external carotid arteries to enter pharynx. Sensory fibres to pharyngeal plexus supplying mucosa kin of the external acoustic meatus and tympanic membrane. The main functions of the vagus are phonation and swallowing. It also transmits cutaneous sensory fibres from the posterior part of the external auditory meatus and the tympanic membrane. It supplies the gut tube as far as the splenic flexure of the transverse colon (roughly), and the heart, tracheobronchial tree and abdominal viscera. The vagus is the most extensively distributed of all cranial nerves. Its name reflects both its wide distribution and the type of sensation it conveys (Latin: vagus – vague, indefinite, wandering).
- Arises from medulla by rootlets lateral to olive.
- Leaves posterior cranial fossa through jugular foramen (middle portion). In and below foramen are two sensory ganglia: jugular and nodose, containing cell bodies of sensory fibres. Auricular branch passes through canal in temporal bone and conveys sensory. Descends in carotid sheath posteriorly behind internal jugular vein and internal/common carotid arteries. Gives pharyngeal branches, and superior laryngeal nerve which has internal (sensory above vocal cords) and external (cricothyroid) branches.
- Cardiac (slowing heart rate) and tracheal (sensory) branches arise in the root of neck and upper thorax.
- Recurrent laryngeal nerves arise in superior mediastinum: left related to ligamentum arteriosum, right to subclavian artery. Both ascend between trachea and oesophagus laryngeal muscles (not cricothyroid) and sensation of larynx below vocal cords, trachea, oesophagus.
- Forms oesophageal plexus. Enters abdomen through oesophageal hiatus in diaphragm as anterior and posterior trunks and fibres from external acoustic meatus and tympanic membrane contributes fibres to abdominal viscera and to coeliac, superior mesenteric and myenteric plexuses. Branches pass in lesser omentum alongside lesser curvature of stomach to innervate pyloric antrum (nerves of Latarjet), and to give hepatic branches. Parts and functions

The accessory nerve has two parts: cranial and spinal.

Cranial accessory: This arises from a caudal extension of the nucleus ambiguus by rootlets below and in series with those of IX and X. It joins the vagus, from which it is functionally indistinguishable (its name: accessory vagus). Some people hold that the muscles of the larynx and pharynx are innervated by the cranial accessory, leaving the vagus 'proper' with parasympathetic fibre only, but this is not certain. Clinically, such distinctions are unnecessary in any case, since when something goes wrong, it tends to affect a large area of the brain stem such that X and XI are likely to be affected along with other nerves.

Spinal accessory: This is motor to the muscles bounding the posterior triangle of the neck: sternocleidomastoid and trapezius

Origin and course of spinal accessory • Rootlets from **upper four or five segments of spinal cord** continue series of rootlets of IX, X and cranial XI.• Emerge between ventral and dorsal spinal nerve roots, just behind denticulate ligament. **Ascends through foramen magnum** to enter posterior cranial fossa. Briefly runs with cranial XI before emerging through jugular foramen (middle compartment). Passes deep to sternocleidomastoid which it supplies. Enters roof of posterior triangle of neck. Surface marking in posterior triangle: one third o way *down* posterior border of sternocleidomastoid to one third of way *up* anterior border of trapezius.

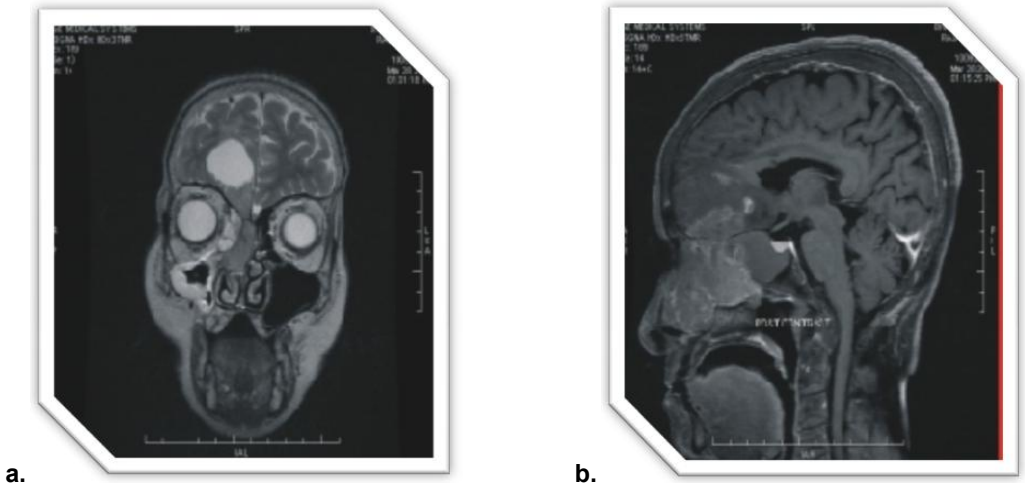
XII -Hypoglossal nerve:

The hypoglossal nerve supplies the muscles of the tongue. Movements of the tongue are important in chewing, in the initial stages of swallowing and in speech. It also conveys fibres from C1 which innervate the strap muscles.

Origin, course and branches The hypoglossal nerve (XII):

- Originates from medulla by vertical series of rootlets between pyramid and olive.Hypoglossal (condylar) canal in occipital bone
- Receives motor fibres from C1 and descends to submandibular region.
- Turns forwards, lateral to external carotid artery, hooking beneath origin of occipital artery. Passes lateral to hyoglossus and enters tongue from below.
- Gives descendens hypoglossi to ansa cervicalis carrying fibres from C1 to strap muscles; other C1 fibres remain with XII to supply geniohyoid.
- Supplies intrinsic muscles of tongue, hyoglossus, genioglossus and styloglossus.

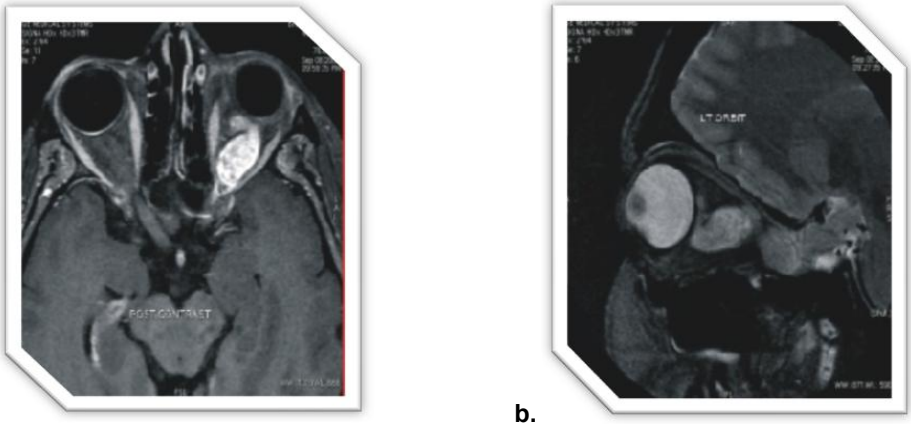
Case 1. Olfactory Nerve



a. **b.**

Fig. 1. (a). T2 Coronal section of brain and paranasal sinus at level of maxillary sinus. (b). T1 post gadolinium sagittal section of brain

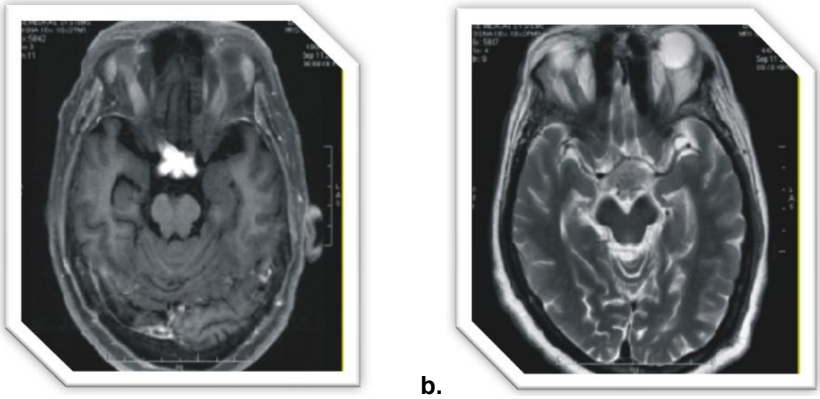
Case 2. Optic Nerve



a. b.

Fig. 2. (a).T1w post gadolinium axial sections of orbits (b).T2w sagittal section of brain Left optic nerve is thickened, tortuous from the posterior end of the globe too the optic foramen with diffuse intense enhancement. Optic nerve Glioma

Case 3. Optic Nerve



a. b.

Fig. 3. (a). T1w post contrast axial section of brain at level of optic chiasma (b). T2 w axail section of brain

Well enhancing lobulate lesion in the optic chiasma,extending to retro orbital intracranial right optic nerve from the optic canal to chiasma. Optic Chiasmatic Glioma.

Elongated homogeneously enhancing soft tissue involving the left trigeminal nerve in its pontine cisternal ganglionic and cavernous sinus segements. Lymphomatous Involvement Of The Left Trigeminal Nerve.

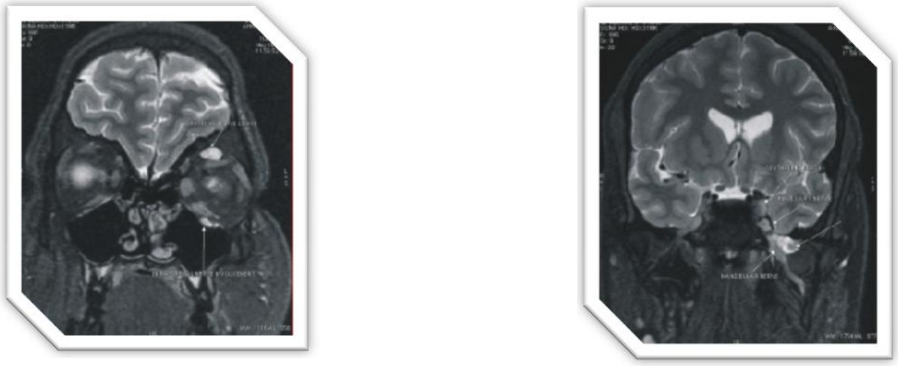
Right paratid gland adenoid cystic carcinoma with retrogade perinuural extension into the mastoid segemnt of right 7^{th} neve.

Case 4. Trigeminal Nerve

a b

Fig. 4. (a) T1w post gadolinium axial section (b) T2w axial section

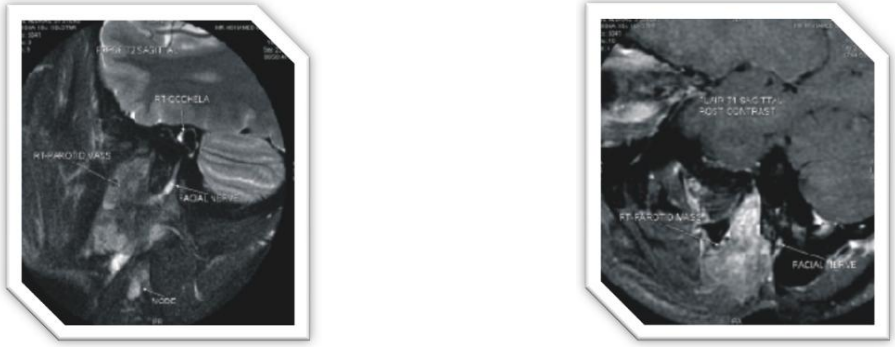
Case 5. Trigeminal Nerve



a. b.

Fig. 5. (a) (b) T2 w coronal sections Showing Neurofibroma involving opthalmic maxillary and mandibular divisions of trigeminal nerve

Case 6. Facial Nerve



a b

Fig. 6. (a) T2 w sagittal section (b). T1 post contrast sagittal section

Case 7. Vestibular Nerve

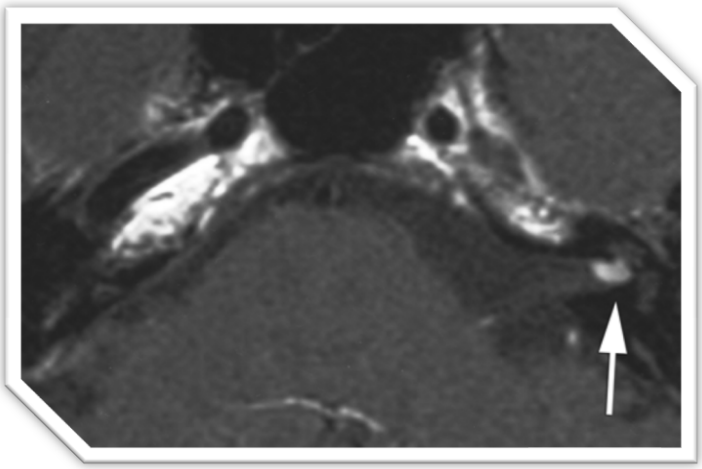
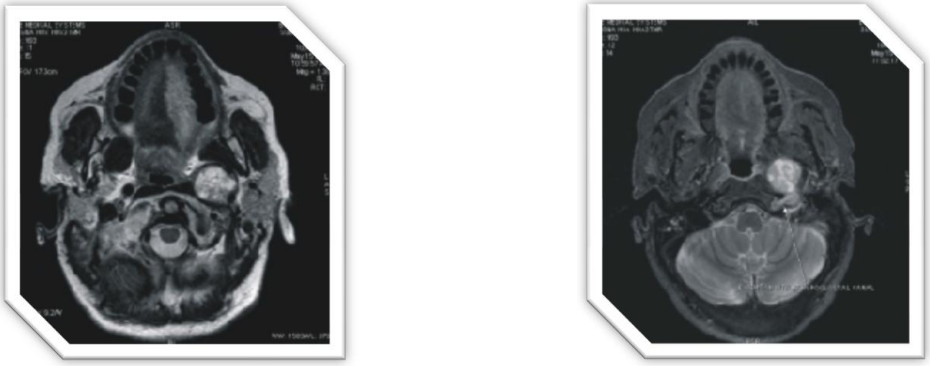


Fig. 7. T1w contrast enchased axial section showing small enhancing lesion arising from left inferior vestibular nerve. Acoustic Nerve Schwanoma

Case 8. Hypoglossal Nerve



a. **b.**

Fig. 8. (a) T2w axial (b) T1w axial section

Hypoglossal schwanoma: with fatty atrophy of left side of tongue.

3. CONCLUSION

Many imaging methods can be used to evaluate the various skull base and intracranial neural lesions and, among them, the CT scan is considered the best examination available to characterize bone abnormalities. However, MRI identifies earlier involvement of the bone marrow, even before the development of cortical destruction, which is only shown later on CT. MRI is the modality of choice for evauluation of cranial nerve pathlogies. FIESTA/CISS sequence is very useful to pick up cisternal segmentt lesion, post contrast study should be done in suspected cranial nerve pathologies.[4] Abnormal cranial nerve enhancement on MRI may at times be the first and only suspicion of an underlying sinister lesion evolving in process.

CONSENT

All authors declare that 'written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=1005&id=29&aid=9716