Study of intracranial part of facial nerve along with its clinical implications

Abstract:

Facial nerve, also known as seventh cranial nerve, is comprised of motor and sensory roots. Both these roots of facial nerve are attached to ponto-medullary junction.The motor root innervates muscles of facial expression and sensory part provides secretomotor fibers to lacrimal, submandibular and lacrimal glands and tase fibers to anterior two third of tongue. The facial nerve passes through posterior cranial fossa and then trough temporal bone. It emerges out of cranium through stylomastoid foramen and passes through parotid gland and ultimately innervating facial muscles. The facial nerve may be injured anywhere in its course in the cranium and in extracranial course. If facial nerve is injured, anywhere in its course, it leads to paralysis of facial muscles along with diminished secretion from the glands innervated by this nerve. In addition, there is lose taste sensation in anterior two third of tongue leading to helm of complications. Aim of this chapter is to highlight the intracranial course and related complications of facial nerve. For this, various databases like google scholar, scielo, pubmed etc articles and anatomical books were explored, information is consolidated and presented in this chapter.

Key wors: facial nerve, submandibular gland, facial muscles

Introduction:

The facial nerve also known as cranial nerve VII mainly innervates muscles of facial expression. So, this nerve is also known as the nerve of facial expression. Besides, it also carriestaste sensations from the anterior two-thirds of the tongue and supplies preganglionic parasympathetic fibers to several head and neck structures [1, 2, 3]. The nerve is mixed nerve consisting of both motor and sensory roots. The sensory root is also known as nervous intermedius [4, 5, 6]. Both the roots are attached to the lower border of the Pons between olive and inferior cerebellar peduncle [4, 5, 6, 7, 8] at the ponto-medullary junction (Figure 1).

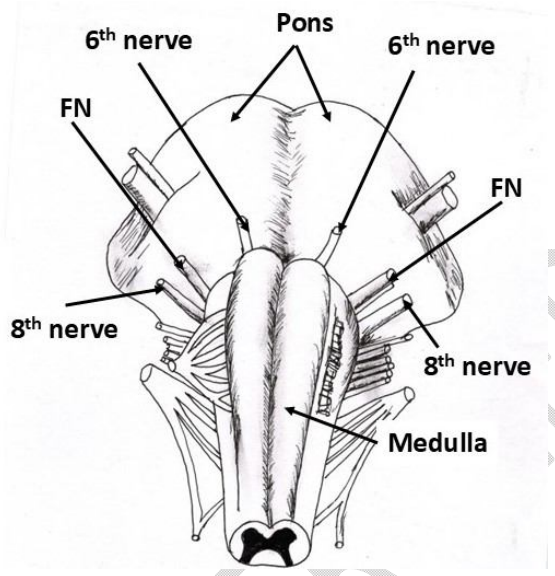

Figure 1: The facial nerve attached to ponto-medullary junction.

FN: Facial nerve

The nerve from the pons passes through the facial canal in the temporal bone and exits the skull at the stylomastoid foramen (4. 5).The part of the facial nerve in posterior cranial fossa and through temporal bone also known as cranial part of facial nerve.The course of facial nerve is quite variable and comprehension of intratemporal and extratemporal path is important for precise diagnosis and successful surgery in the head and neck region. Hence the study was carried out. The aim of the study is to consolidate the information regarding intracranial or temporal path of facial nerve and to elucidate related clinical implications. The literature was searched using various data bases like researchgate, google scholar, medline,

pubmed and scielo. After exploring data related to work, data was consolidated and presented in this chapter.

Developmentally, this nerve is the nerve of the second brachial arch innervating all muscles derived from mesoderm of the second arch (4, 5).

Nucleus related to facial nerve (4, 5):

Four nuclei are related to facial nerve which are described below:

1. Motor nucleus: It lies in the lower part of pons medial to the spinal nucleus of trigeminal nerve. This nucleus of facial nerve has cortico-nuclear connections. The neurons of the dorsal part of this nucleus innervate muscles of scalp and upper face. The upper face has bilateral cortical representation while ventral part of this nucleus innervates musculature of lower part of face and connected to contralateral cortex (4, 5).
2. Superior salivatory nucleus is divided into salivatory and lacrimatory nuclei. The nerve fibers of the salivatory nucleus contains pre-ganglionic parasympathetic fibers of submandibular and sublingual salivary glands while lacrimatory nucleus houses pre- ganglionic parasympathetic fibers for lacrimal gland (4).
3. Nucleus of tractus solitarius is located in the medulla oblongata and it is sensory in nature carrying taste fibers from anterior two-third of the tongue (4).
4. Nucleus of the spinal tract of trigeminal nerve contain fibers providing sensory fibers to the external ear (4, 5).

Functional Components:

The facial nerve is composed of following four functional components (4, 5):

1. Branchial efferent fibers arising from facial nucleus innervating musculature developing from mesoderm of second brachial arch
2. General visceral efferent fibers sprouting from superior salivatory nucleus providing secretomotor fibers to lacrimal, submandibular and sublingual glands (4, 5).
3. Special visceral afferent fibers arising from nucleus of tractus solitarius and providing taste fibers to the anterior two third of tongue
4. General somatic afferent fibers budding from spinal nucleus of trigeminal nerve and providing general sensations to the anterior two third of tongue (4, 5).

Course of facial nerve:

The fibers of the facial nerve after originating from the motor nucleus turn around the abducent nucleus (Figure 2) creating internal genu.

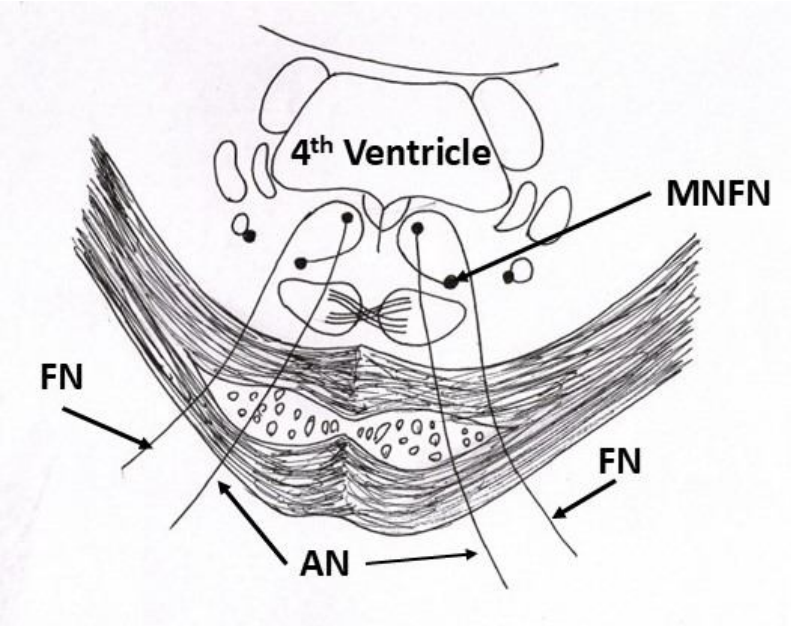

Figure 2: Section of pons displaying fibers of facial nerve after originating from motor nucleus of facial nerve turns round the abducent nucleus forming internal genu.

MNFN: motor nucleus of facial nerve, FN: facial nerve, AN: abducent nerve

This internal genus of the facial nerve forms prominence called facial colliculus in the floor of the fourth of ventricle. The fibers of the facial nerve emerge out of the pons and gain attachment to the ponto-medullary junction (4, 5).

The two roots of facial nerve namely motor root and nervous intermedius also known as nerve of Wrisberg from the ponto-medullary junction traverses the cerebello-pontine angle and passes towards the internal acoustic meatus. The nervus intermedius so called because of its position as it travels through the cerebellopontine angle between the facial nerve and the vestibulocochlear nerves (9).

In its course towards the internal acoustic meatus housed in temporal bone, the facial nerve is accompanied by vestibulocochlear and labyrinthine artery (4, 5, 7).The mean distance between the point where the nerves exit the pons and the place where they enter into the internal acoustic meatus is approximately 15.8 mm. The facial nerve and the nervus intermedius lie above and slightly anterior to vestibulocochlear nerves (9). The

vestibulocochlear nerve enters the internal acoustic meatus lying below and the facial nerve lying superiorly along the roof of the internal acoustic meatus (9).
The facial nerves travels through the temporal bone and leaves the temporal bone through stylomastoid foramen.

Thus, the course of facial nerve is divisible into two parts namely temporal also called cranial part and extratemporal course also called extracranial part which are vividly elaborated into the succeeding paragraphs.

Temporal or intracranial course of facial nerve (Figure 3):

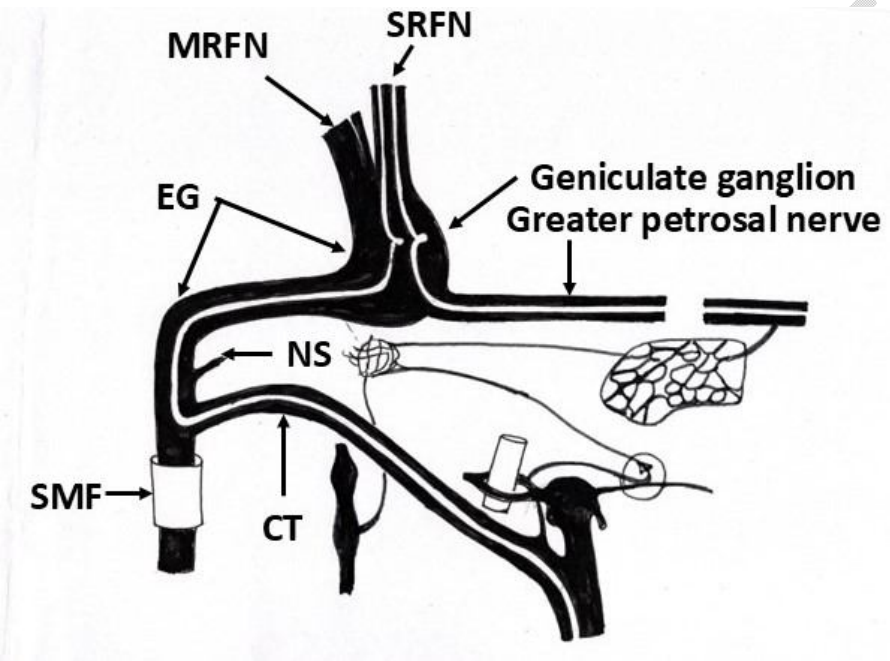

Figure 3: Temporal course of facial nerve with branches in the temporal bone

MRFN: motor root of facial nerve, SRFN: sensory root of facial nerve, EG: external genu, NS: nerve to stapedius, CT: chorda tympani nerve, SMF: stylomastoid foramen

The temporal course of facial nerve is divided into meatal and facial canal. The meatal part is through internal acoustic canal.

Course of facial nerve through internal acoustic canal:
The facial nerve along with vestibulocochlear and labyrinthine artery courses through internal acoustic canal and reaches lateral end of this canal namely fundus where the sensory and motor roots of facial nerve fuse together to form the trunk of facial nerve. Now, the fundus of the internal acoustic canal which forms the medial wall of the internal ear is divided into

upper and lower compartments by the falciform crest (crista falciformis). There is large opening in the upper compartment of fundus leading into the facial canal contained into the petrous temporal bone. The facial nerve enters the facial canal through this openingwhich is separated from the superior vestibular nerve by a vertical bony ridge namely the Bill bar and travels through the facial canal or fallopian canal named after Gabriel Fallopiusand exits the temporal bone or cranium through stylomastoid foramen (4, 5, 9).

The facial nerve, the nervus intermedius, and the vestibulocochlear nerve at the level of the CerebelloPontineangle and in the internal acoustic meatus are closely related to each other and may culminate into disturbances in tearing, taste, salivary gland flow, hearing, balance, and facial function due to lesions at this level.

Course of facial nerve through facial canal:

The course of facial nerve in the facial canal is divided into three parts namely labyrinthine part, tympanic part and mastoid part which are described below:

1. Labyrinthine part: The labyrinthine part of the facial nerve lies deep to the middle cranial fossa and is the smallest part in the facial canal measuring about 3.5-4mm in length. The term labyrinthine part is used as this part of the facial nerve lies immediately posterior to the cochlea. The nerve passes forward, perpendicular to the axis of the temporal bone above the vestibule of the inner ear to reach the anterior end of the medial wall of the middle ear (5). The facial nerve lies posterolateral to the ampullae of the horizontal and superior semicircular canals and on the anterior part of the vestibule (9). The labyrinthine part of the facial nerve is the thinnest part of the facial nerve and is likely to be compressed if there is edema of facial nerve. This is the only part of the facial nerve which does not have anastomosing arterial cascades, making the area vulnerable to embolic phenomena, low-flow states, and vascular compression. Immediately after coursing through the labyrinthine part, the facial nerve bends backwards making a bend known as first external genu which bears geniculate ganglion (5). In the internal acoustic meatus, the facial nerve gives off a communicating branch to the vestibulo-cochlear nerve.

Geniculate ganglion: It is sensory ganglion of facial nerve situated at the external genu of the facial nerve in the facial canal. Geniculate ganglion contains pseudounipolar neurons. The peripheral process of this ganglion carries taste sensations via chorda tympani of facial nerve and general sensations from the auricle through communicating branch from facial nerve to auricular branch of vagus nerve while the central processes of ganglion containing taste sensations end on the nucleus tractus solitarius and those containing cutaneous sensations end

on spinal nucleus. Apart from this, preganglionic parasympathetic fibers reach the geniculate ganglion via nervous intermedius. The post ganglionic fibers from geniculate ganglion courses out in the greater petrosal nerve which unite with the deep petrosal nerve to form nerve of pterygoid canal. The nerve of pterygoid canal carries the preganglionic parasympathetic fibers to the sphenopalatine ganglion. The external petrosal nerve also joins the geniculate ganglion (5).

Petrosal nerves:The greater petrosal nerve after originating from the geniculate ganglion courses through the temporal bone and passes out of it through the hiatus for the greater petrosal nerve and reaches the middle cranial fossa (10). The nerve passes deep to the trigeminal (Gasserian) ganglion crosses the foramen lacerum and on entering the pterygoid canal the greater petrosal nerve unites with the deep petrosal nerve to become the nerve of the pterygoid canal. The nerve of pterygoid canal carrying the preganglionic parasympathetic fibers relay in the sphenopalatine ganglion also known as pterygopalatine ganglion. The postganglionic parasympathetic fibers from pterygopalatine ganglion are carried via branches of the maxillary divisions of the trigeminal nerve innervating the lacrimal gland and mucus glands of the nasal and oral cavities. The external petrosal nerve branch from the geniculate ganglion carries sympathetic fibers to plexus around the middle meningeal artery (10). Another small branch from geniculate ganglion joins the tympanic plexus to form the lesser petrosal nerve.

2. **Tympanic part**: The tympanic segment is located between the geniculate ganglion and the horizontal semicircular canal and measures 8-11mm in length. The nerve passes deep to the cochleariform process and the tensor tympani and come to lie opposite to the medial wall of the tympanic cavity postero-superior to the oval window (9). The cochleariform process serves an important landmark for locating the facial nerve.The medial wall of the tympanic cavity is often very thin and the middle ear mucosa may lay in direct contact with the facial nerve (9). Occasionally, the facial canal is found to be deficient near the oval window in 25-55% of cases. So, clinician must be aware that the facial nerve may be dehiscent or prolapsed along the tympanic part especially in patients with congenital ear deformities (9). The facial nerve then exits from the middle ear between the posterior wall of the external auditory canal and the horizontal semicircular canal near the vicinity of the pyramidal eminence. Here the facial nerve takes second turn forming second external genu. In this location, the facial nerve can be identified by the horizontal semicircular canal, the fossa incudis, and the digastric ridge as the facial nerve almost always lies inferolateral to the lateral semicircular canal. Sometimes, due to

cholesteatoma or tumor, it is difficult to locate lateral semicircular canal. In such situation, other landmarks should be used to locate the facial nerve. The distal part of the tympanic segment of the facial nerve may be approached through facial recess approach. While carrying out facial recess approach, the chorda tympani nerve and the fossa incudis can be used to locate the facial nerve to avoid injury to the nerve (9).

3. **Mastoid part**: The mastoid segment begins at the external second genu which lies postero-lateral to the pyramidal process. The nerve continues vertically down the anterior wall of the mastoid process to the stylomastoid foramen. The digastric ridge marks the infero-lateral part of the vertical course of the facial nerve in the temporal bone. In poorly pneumatized temporal bones, the digastric ridge may be difficult to identify.The mastoid segment is the longest part of the intratemporal course of the facial nerve, measuring about 10-14mm in length. During middle ear surgery, the facial nerve is vulnerable to be damaged at the pyramidal turn (9).

Three branches sprout from the mastoid segment of the facial nerve namely the nerve to the stapedius muscle, the chorda tympani nerve, and the nerve from the auricular branch of the vagus nerve. The auricular branch of the vagus nerve arises near the jugular foramen and joins the facial nerve just distal to the point at which the nerve to the stapedius muscle arises. The auricular branch of the vagus carries pain fibers from the external acoustic meatus. The chorda tympani nerve arises about 5 mm above stylomastoid foramen. The chorda passes upward in the middle ear between the incus and the handle of the malleus, and forward across the inner aspect of the upper portion of the tympanic membrane. Then, the nerve exits the base of the skull through the petrotympanic fissure also known as the canal of Huguier to join the lingual nerve. The chorda tympani nerve carries preganglionic parasympathetic secretomotor fibers to the submandibular and sublingual glands. The nerve also carries taste fibers from the anterior two-thirds of the tongue and fibers from the posterior wall of the external acoustic meatus responsible for pain, temperature, and touch sensations (4, 9). The nerve to stapedius originates opposite pyramidal eminence and innervates the stapedius muscle (4).

During temporal course, the facial nerve is enclosed withinthe bony facial canal. So, if there is inflammation of the facial nerve, the facial may be compressed in the bony canal or if there is traumatic injuries to the temporal bone; these conditions will cause various complications.

Central connections of the facial nerve nuclei:

Central connections of the facial nerve nuclei have been vividly elaborated by Crosby and DeJonge along with Nelson (11, 12). The motor face area which is located on the precentral

and postcentral gyri regulate activities of voluntary facial muscles.The facial motor nerves are represented with the forehead uppermost and the eyelids, midface, nose, and lips sequentially located more inferiorly in the motor face area.

Impulses from the facial motor area are carried through the corticobulbar tract to the internal capsule then through the midbrain to the lower pons, where they synapse in the pontine facialnerve nucleus (13). The facial nerve nucleus is divided into an upper and a lower half, bilaterally.The corticobulbar fibers from the upper face cross and recross en route to the pons while these fibersto the lower face cross only once. So, facial motor nucleus supplying lower facial muscles are regulated by cortico-nuclear fibers from the facial motor area of contralateral cerebral hemisphere as is evident from the experiments on monkeys and part of the motor nucleus supplying upper facial muscles is regulated by cortico-nuclear fibers from the facial motor areas of both cerebral hemisphere (4, 13). These observations explain the fact that focal lesion in the face area on one side of motor cortex spares eyelid closure and forehead movement but lower face is paralysed (13).
The fibers conveying taste sensations from solitary nucleus crosses to opposite side and ascends as solitary-thalamic tract into ventral postero-medial nucleus of thalamus and fibers from the thalamus are projected to area number 3, 1, 2 of cerebral cortex.

Clinical implications resulting from facial nerve lesion:

Facial nerve lesion may be supra-nuclear, nuclear or infra-nuclear

Supra-nuclear lesion of the facial nerve: When the cortico-nuclear fibers anywhere between their origin from the motor facial area up to facial nerve nucleus in the pons are injured, it is known as supra-nuclear lesion of the facial nerve. In such type of paralysis, there will be loss of movements of lower facial muscles of the opposite side with the sparing of the upper facial muscles. Upper facial muscles escape paralysis as these have bilateral representation in the motor cortex (4, 12, 13, 14).

The voluntary movements of the lower face are significantly affected as compared to emotional movements of the face.

Injury to lower midbrain above the facial motor nucleus:

Injury occuring in inferior part of midbrain superior to facial nucleus leads to paralysis of face of opposite side along with paralysis of musculature of upper and lower limbs and also affecting sixth cranial nerve resulting in internal strabismus.

Nuclear Paralysis: As it is well known that facial motor nucleus is located in lower part of pons with intimate relation with abducent or sixth cranial nerve and its nucleus. So, if any injury occurs in the ventro-medial part of pons including vascular injury, the facial nerve nucleus, sixth cranial nerve in concurrent with cortico-spinal fibers of pyramidal tract are also injured. This injury culminates into lower motor neuron type paresis causing paralysis of all facial muscles on the side of injury. This is associated with internal squint as lateral rectus muscle of affected side is injured (4, 9). Many syndromes are associated with injury to pons involving facial muscles (9). Some important syndromes are described below:

1. Foville syndrome: In this syndrome, there is injury to lateral part of pons causing facial paralysis and analgesia along with horner syndrome and deafness on the side of lesion (9).
2. Millard-Gubler syndrome: when lesion occurs in the nucleus it leads to facial paralysis due to injury to facial nerve, internal squint due to lesion in sixth cranial nerve on the affected side and hemiplegia on the opposite side of lesion due to involvement of cortico-spinal fibers (4, 14).
3. Möbius syndrome: In this syndrome, the facial nerve lesion occurs near the vicinity of fundus of internal acoustic meatus. It manifests as facial nerve and sixth cranial nerve paralysis on the side of lesion (9).

Infra-nuclear paralysis: Infranuclear paralysis occurs when facial nerve is paralysed travelling through temporal bone or after exiting through the stylomastoid foramen. In this chapter, the paralysis of facial nerve is limited to its course in the temporal bone. The facial nerve, while traversing temporal bone, is most vulnerable to injury in the internal acoustic meatus and in facial canal.

1. **Lesion in the internal acoustic meatus**: When the facial nerve is injured while traversing the internal acoustic meatus, it produces Bell's palsy and deafness as here both facial nerve and eight cranial nerves are intimately related to each other (16, 17
2. **Lesion of facial nerve** at the first external genu in the facial canal: Injury in this situation causes decreased lacrimation, submandibular salivary secretion, diminished

taste sensation on the anterior two-third of tongue, hyperacusis due to injury to nerve to stapedius together with signs and symptoms of Bell's palsy (16, 17).

3. When the facial nerve is recovering from its injury proximal to geniculate ganglion, few salivary fibers sometimes passe in the greater petrosal nerve and the reach the pterygopalatine ganglion. In such condition lacrimation is produced during eating which is known as crocodile tears syndrome (9).

Development of facial nerve: The facial nerve is the nerve of second pharyngeal arch. During the third week of intrauterine life, the facio-acoustic primordium develops and this primordium is the source of facial and vestibulo-cocclear nerves. At the beginning of fourth week of development, the chorda tympani is observed to branch from the facial nerve (8). The geniculate ganglion, nervus intermedius, and greater petrosal nerve develop during the fifth week of gestation. In the meantime, the musculature of face develops. With the development of muscles of face, the facial nerve traverses the face innervating muscles of the face. In the new born, anatomy of facial nerve is developed almost fully akin to adult (8).

Vascular Supply of the Facial Nerve: The motor facial area in irrigated by Rolandic artery branch of the middle cerebral artery. The motor nucleus of facial nerve located in the pons is irrigated by the anterior inferior cerebellar artery. The labyrinthine and cochlear arteries branches of anterior inferior cerebellar artery irrigate facial nerve in the internal acoustic meatus. In addition, superficial petrosal branch of the middle meningeal artery irrigates the temporal part of facial nerve (7, 15).

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