Anatomy of Trigeminal Nerve

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Key Points

- Trigeminal nerve is the largest cranial nerve, and is a mixed nerve
- It is the principal sensory nerve for face and part of scalp, and gives motor supply to muscles of mastication
- Trigeminal ganglion is the largest sensory ganglion that lies within the Meckel's cave, and is the only sensory ganglion which is intracranial
- Various physiological reflexes (trigeminocardiac reflex, blink reflex, oculocardiac reflex, maxillomandibular reflex, diving reflex, and masseter reflex) are described in relation to trigeminal nerve
- Trigeminal neuralgia is a severe disabling condition where pain occurs in the distribution of one or more divisions of trigeminal nerve

Introduction

Trigeminal nerve is the fifth (V) cranial nerve and is also known as ***Trifacial nerve***. It is the largest of the twelve cranial nerves and has a broad territory of distribution. It is a mixed nerve with both motor and sensory fibers. The nerve originates from the brainstem (pons) and supplies various structures of the head and face. It is a paired nerve, and each nerve supply ipsilateral half of the head and face. Each trigeminal nerve has three main branches and so the name trigeminal (from Latin word "trigeminus" meaning three twins). The sensory modalities of the facial region are more complex and specialized than any other part of the body. There are zones of dense innervation in the

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territory of trigeminal nerve, and therefore have more number of neurons which explains the larger size of the trigeminal nerve compared to other nerves.

Functional Components

Trigeminal nerve has two functional components i.e. *special visceral or branchial efferent* (motor fibers) supplying the muscles derived from Ist branchial or pharyngeal arch and *general somatic afferent* (sensory fibers) carrying general sensations from head and face. The motor fibers originate from the motor nucleus of trigeminal whereas the sensory fibers terminate into the sensory nuclei of trigeminal in the brainstem. The components, function, central connections, location of cell bodies, and peripheral distribution of trigeminal nerve fibers are summarized in Table 1.

Trigeminal Nerve Nuclei

The sensory and motor nuclei of trigeminal nerve are located in the brainstem (Fig. 1). The sensory nucleus of trigeminal is a collection of three nuclei located in the midbrain, pons, medulla and upper two segments of cervical cord. These are

Table 1 Summary of the components, function, central connections, location of cell bodies, and peripheral distribution of trigeminal nerve fibers

Components	Function	Central connections	Location of cell bodies	Peripheral distribution
General Somatic Afferent (GSA)	General sensations (touch, pain, temperature)	Main Sensory Nucleus and Spinal Nucleus of V	Gasserian Ganglion	Sensory nerve endings to skin & mucous membrane of the head & face through ophthalmic, maxillary & mandibular nerves
	(Proprioception)	Mesencephalic Nucleus of V	Mesencephalic Nucleus of V	Sensory nerve endings in the muscles of mastication through mandibular nerve & in the extraocular muscles through ophthalmic nerve
Special Visceral Efferent (SVE)	Mastication	Motor Nucleus of V	Motor Nucleus of V	Motor nerve endings to temporalis, masseter, pterygoids, mylohyoid, tensor tympani, and tensor veli palatini through motor root of mandibular nerve

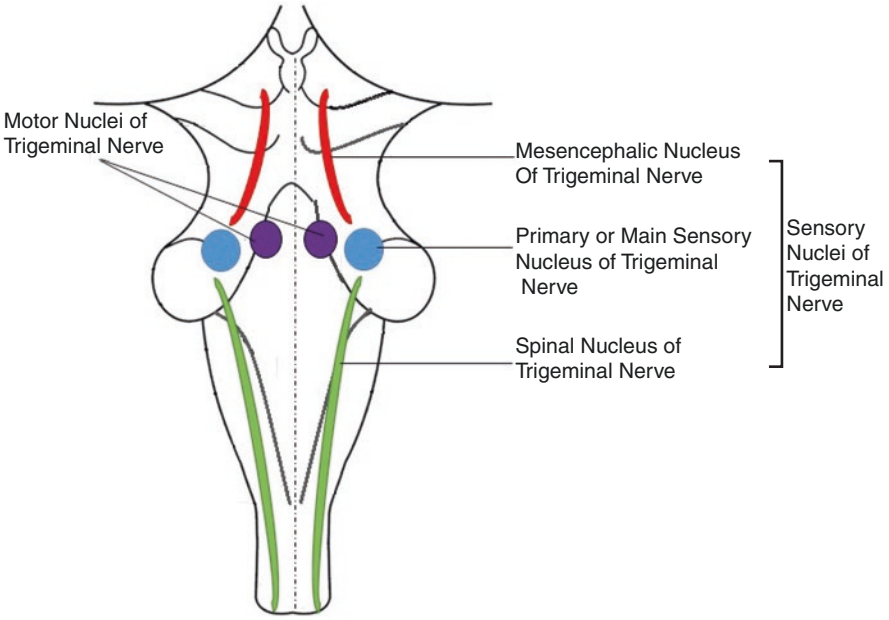

Fig. 1 Location of trigeminal nerve nuclei in the brainstem

the *mesencephalic nucleus* (in the midbrain), *principal or main sensory nucleus* (in the upper part of pons) and *spinal nucleus* (extending into the lower part of pons, medulla and upper two cervical segments of the spinal cord). The spinal nucleus is subdivided into three parts or sub-nuclei (i.e. the pars oralis, pars interpolaris and pars caudalis). The *motor nucleus* of the trigeminal nerve is located in the upper and dorsal part of pons, medial to the main sensory nucleus of trigeminal nerve.

The mesencephalic nucleus receives proprioceptive impulses from muscles of mastication, temporomandibular joint and probably from extraocular muscles. The main sensory nucleus receives touch sensation, and spinal nucleus receives pain and temperature sensation from the skin of head and face, mucous membrane of oral cavity, nasal cavity and paranasal sinuses, and meninges via the sensory root fibers. The motor nucleus supplies the derivatives of the first pharyngeal (mandibular) arch which includes muscles of mastication, mylohyoid, anterior belly of digastric, tensor veli palatini and tensor tympani via motor root fibers [1].

Trigeminal Roots and Nerve

The trigeminal nerve emerges from the ventrolateral surface of the pons at its junction with the middle cerebellar peduncle. It arises by a large lateral *sensory root* and a small medial *motor root* (Fig. 2). The point where the roots emerge from the brain

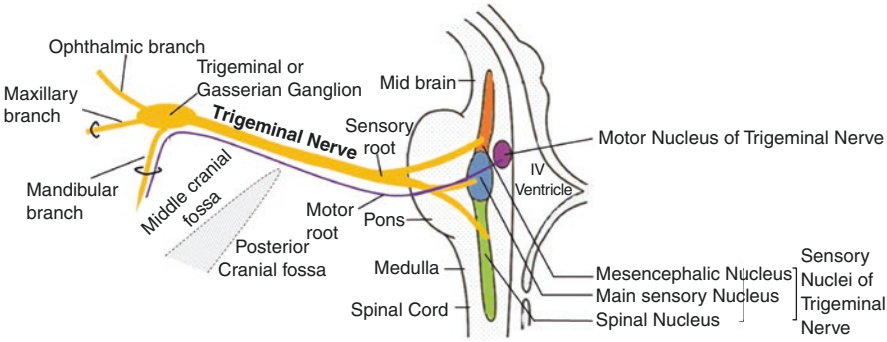

Fig. 2 Origin and course of trigeminal nerve

stem is known as ***root entry zone*** **(REZ)**. The fibers of the sensory root of the trigeminal nerve enter the pons and terminate into the sensory nuclei. The fibers of the motor nuclei form the motor root that emerge from the pons. The sensory and motor roots of trigeminal nerve are analogous to the dorsal (sensory) and ventral (motor) roots of the spinal nerves. The motor and sensory roots exist as separate bundles and together form the trigeminal nerve.

The trigeminal nerve passes forward, upwards and laterally from the posterior cranial fossa to reach the apex of the petrous part of the temporal bone in the middle cranial fossa. The nerve travels through the subarachnoid space from the pons into the Meckel's cave (described later) where the sensory root of the trigeminal nerve enlarges to form a crescentic structure known as the trigeminal ganglion (Fig. 2). The motor fibers lie below the sensory ganglion and do not entre the trigeminal ganglion. From the anterior aspect of the trigeminal ganglion arise the three peripheral branches of the trigeminal nerve viz: the ophthalmic, maxillary and mandibular branches (Fig. 2).

Trigeminal Ganglion

It is a sensory ganglion of the trigeminal nerve. It is the largest sensory ganglion of the body and the only sensory ganglion that lies inside the cranial cavity. It corresponds to the dorsal root ganglion (sensory) of a spinal nerve. Antonius Hirsh in 1965, first described this ganglion with the terminology **Gasserian ganglion** in honor of his teacher Johann Lorenz Gasser, an Austrian anatomist. The ganglion is an expansion of sensory root from the pons [2]. It is a crescent shaped structure with convex anterior margin, and so also known as **Semilunar Ganglion**. It lies in the floor of the middle cranial fossa in a small impression near the apex of petrous part of temporal bone [3, 4]. It invaginates a dural fold known as **Trigeminal or Meckel's Cave (Cavum Trigeminale)** that is formed by folding of meningeal layer of duramater around the ganglion [3–5] (Fig. 3).

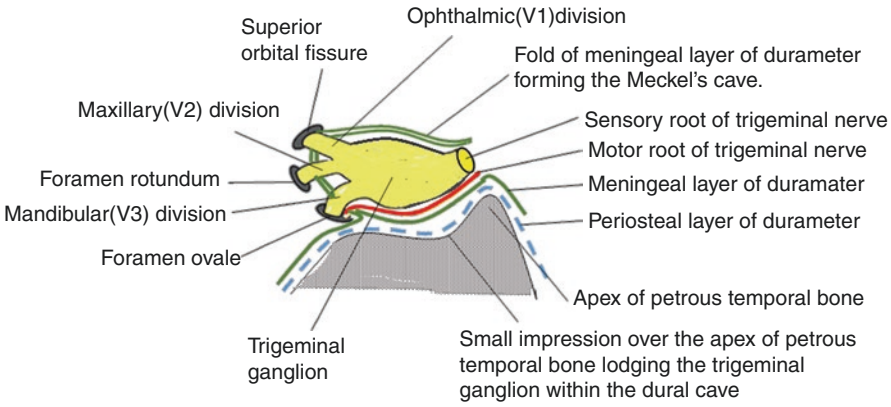

Fig. 3 Trigeminal ganglion in Meckel's cave

Branches of Trigeminal Nerve

There are three peripheral branches of the trigeminal nerve which arise from the anterior aspect (convex margin) of the trigeminal ganglion. These are the ophthalmic (V1), maxillary (V2) and mandibular (V3) nerves. These branches pierce the Meckel's cave and passes forward to exit the middle cranial fossa through small openings or foramen. Each of these three divisions further divides into multiple branches to supply various structures. The ophthalmic and maxillary divisions carry only sensory fibers whereas the mandibular division carries both sensory and motor fibers. Some of the peripheral branches also contain pre- or post-ganglionic parasympathetic and post ganglionic sympathetic fibers that supply the various glands of face, mouth, nose and eyes [6].

- **Ophthalmic Nerve** is a pure sensory nerve which originates from the anterolateral aspect of trigeminal ganglion. It is the smallest of the three divisions of trigeminal nerve. It lies in the lateral wall of the cavernous sinus and branches into the frontal, lacrimal and nasociliary nerves. All the three branches pass through the superior orbital fissure into the orbit. Within the cavernous sinus it also gives a meningeal branch and fine twigs to oculomotor, trochlear and abducens nerves that carry sensory fibers (proprioception) to extraocular muscles supplied by these nerves.
- **Maxillary Nerve** is a sensory branch which lies in the lateral wall of the cavernous sinus. It leaves the middle cranial fossa by passing through the foramen rotundum and enters the pterygopalatine fossa.
- **Mandibular Nerve** is the largest branch from the trigeminal ganglion. It immediately leaves the middle cranial fossa by passing through the foramen ovale and enters the temporal fossa. It is accompanied by the motor root of trigeminal nerve as it passes through the foramen oval and the two joins together in the

temporal fossa. Thus, the mandibular branch of the trigeminal nerve is a mixed nerve having both sensory and motor fibers.

Connections of Trigeminal Nerve Fibers

The afferent sensory neurons of the trigeminal nerve transmit sensory impulses. These are *pseudo-unipolar neurons* i.e. single process emerges from the cell body which divides into peripheral and central processes (Fig. 4). The cell bodies of these pseudo-unipolar neurons lie in the trigeminal ganglion and their processes pass into the trigeminal nerve and its branches. The peripheral processes of these neurons lie in the three peripheral branches of trigeminal nerve whereas the central processes pass in the sensory root of trigeminal nerve (Fig. 5). These are the *first order neurons* and they terminate in the main sensory nucleus and spinal nucleus of the trigeminal nerve. These neurons carry the touch, pain and temperature sensations. However, the pseudo-unipolar neurons which carry proprioceptive impulses from the muscles of mastication and extraocular muscles (*first order neuron*) have their cell body located in the mesencephalic nucleus of trigeminal nerve in the midbrain

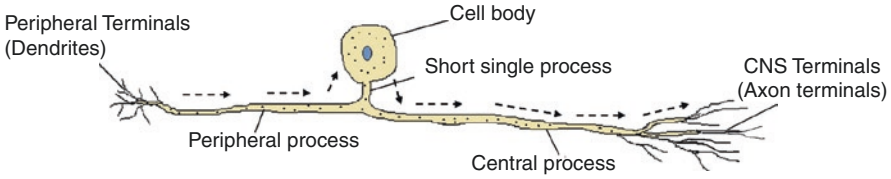

Fig. 4 Pseudo-unipolar neuron

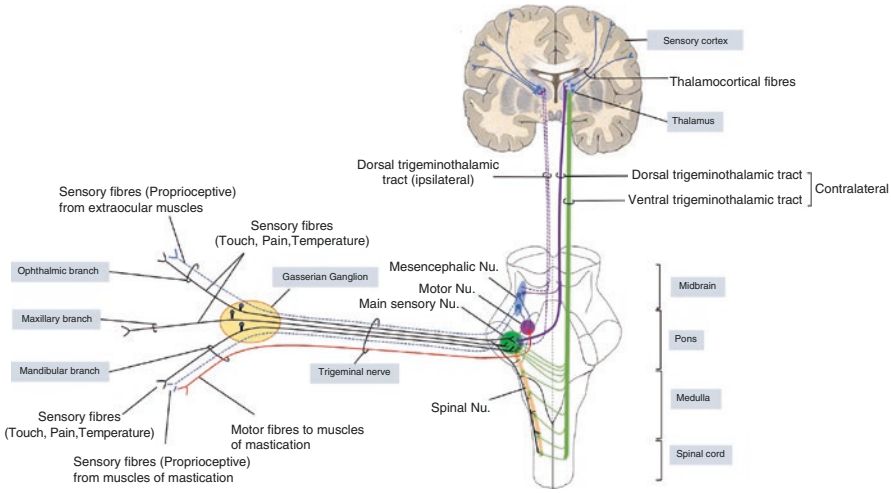

Fig. 5 Connections of trigeminal nerve fibers

(and not in the trigeminal ganglion) [6]. The peripheral process of these neurons travel from the muscles of mastication (muscle spindles) through the motor root of mandibular division, trigeminal ganglion and the trigeminal nerve to reach the cell bodies in mesencephalic nucleus (Fig. 5).

The first order neurons synapse with the *second order neurons* located in the sensory nucleus of trigeminal (mesencephalic, main sensory and spinal nucleus) in the brain stem. The axons of second order neurons cross to the opposite side and ascends in the *ventral and dorsal trigeminothalamic tracts* to relay in the *ventral postero-medial (VPM) nucleus* of the thalamus [6, 7]. The ventral (anterior) trigeminothalamic tract receives crossed fibers from contralateral main sensory and spinal nucleus of trigeminal and carry crude touch, pain and temperature sensations. The dorsal (posterior) trigeminothalamic tract mostly receives crossed fibers from the contralateral main sensory nucleus and few uncrossed fibers from ipsilateral main sensory nucleus and they carry fine touch and proprioceptive sensations. Both the anterior and posterior trigeminothalamic tracts projects to the VPM nucleus of thalamus. These fibers (second order neurons) synapse with neurons in the thalamus i.e. *third order neurons*. The axons of the third order neurons (thalamocortical fibers) project on to the sensory cerebral cortex posterior to the central sulcus [6, 7] (Fig. 5).

The first order neurons in the mesencephalic nucleus (proprioceptive fibers) have a short central process. These neurons synapse with the neurons in the motor nucleus of trigeminal nerve (forming reflex arch for jaw jerk or masseteric reflex) and with the second order neurons in the mesencephalic nucleus that carry proprioceptive impulse to the VPM nucleus of thalamus (via dorsal trigeminothalamic tracts) and then to the primary sensory cortex via thalamocortical fibers.

There are numerous intra- and inter-nuclear connections within the nuclei of trigeminal [8] and between the trigeminal nuclei and other brainstem nuclei [6]. The short internuncial neurons connect the sensory nucleus of trigeminal with other motor nuclei including oculomotor, trigeminal, facial, vestibular, glossopharyngeal, vagal, and hypoglossal. It also has connections with superior colliculus, and cerebellar cortex [9, 10]. In addition, there are neurons projecting from the cerebral cortex to the sensory and motor nucleus of trigeminal nerve in the brain stem (corticobulbar tracts) on each side. Most of these fibers are crossed (from contralateral cortex) and they have inhibitory function (inhibit sensory and motor nuclei of trigeminal nerve).

Areas Supplied by Trigeminal Nerve

The trigeminal nerve innervates various structures of head and face through its branches (Table 2). The areas supplied by the three primary divisions of trigeminal nerve is shown in Fig. 6. The Ophthalmic (V1) branch gives sensory supply to upper third of face including forehead, upper eyelid, conjunctiva, cornea, nose, nasal mucosa, frontal sinus, lacrimal gland and scalp up to vertex. It also forms the afferent limb of corneal reflex. The Maxillary (V2) branch supplies sensory fibers to middle

third of the face including skin over temple, lower eyelid and conjunctiva, cheek, upper lip, nares, nasal mucosa, upper teeth and gums, maxillary sinus, mucous membrane of palate and pharynx, and dura mater of middle cranial fossa. Maxillary nerve also conveys secretomotor fibers to the lacrimal gland and the glands of palate, nose, maxillary sinus and oral cavity [11, 12]. The sensory fibers of Mandibular (V3) branch supplies the lower third of face including lower lip, chin, lower jaw except the small area over the angle of mandible, lower teeth and gums, part of auricle, temple, and part of meninges [11]. The motor fibers of V3 supply muscles of mastication (masseter, temporalis, medial and lateral pterygoid), mylohyoid, anterior belly of digastric, tensor veli palatini, and tensor tympani. Mandibular nerve forms both afferent and efferent limbs of jaw-jerk (masseter or masticatory) reflex.

Table 2 Areas innervated by the branches of trigeminal nerve

	Branches	Innervation
Trigeminal Ganglion	Meningeal branches	Duramater (middle cranial fossa, tentorium cerebelli)
Ophthalmic (V1) Nerve	Meningeal branches	Durameter (anterior cranial fossa tentorium cerebelli, falx cerebrii), superior sagittal sinus.
	Twigs to III, IV, VI CNs	Extraocular muscles (proprioceptive sensory fibers)
– Frontal nerve	Supraorbital neve	Upper eyelid, conjunctiva, forehead, Scalp
	Supratrochlear nerve	Upper eyelid, conjunctiva, forehead
– Nasociliary nerve	Anterior ethmoidal nerve	Mucous membranes of frontal, ethmoid and sphenoid sinuses, nasal cavity
	Posterior ethmoid nerve	Mucous membranes of sphenoid sinus
	Infratrochlear nerve	Bridge of nose, upper eyelid and conjunctiva
	Long ciliary nerves	Sensory innervation to eye (cornea, ciliary bodies, iris)
		Contains sympathetic fibers to dilator pupillae muscle
– Lacrimal nerve		Lacrimal gland, upper eyelid, conjunctiva
		Contains parasympathetic fibers to lacrimal gland
Maxillary (V2) Nerve	Middle meningeal branch	Duramater(middle cranial fossa) middle meningeal vessel
– Two branches to Pterygopalatine Ganglion (Pterygopalatine nerves)	Nasopalatine nerve	Nasal cavity, palate Superior& middle turbinate, septum
	Pharyngeal nerve	Soft and hard palate, nasopharynx
	Greater Palatine nerve	Hard palate, palatal gingiva
	Lesser Palatine nerve	Nasopharynx, uvula, tonsil, soft palate

(continued)

Table 2 (continued)

	Branches	Innervation
– Zygomatic nerve	Zygomaticotemporal nerve	Skin over the temporal region, lacrimal gland (carry parasympathetic fibers from VII nerve to lacrimal gland)
	Zygomaticofacial nerve	Skin over the zygomatic bone, cheek
– Posterior superior alveolar nerve		Gingiva, maxilla, alveolar periosteum, maxillary teeth (molar, premolar), maxillary sinus, nasal floor
– Infraorbital nerve	Middle Superior Alveolar	Maxillary teeth (premolar), alveolar periosteum
	Anterior Superior Alveolar	Maxillary teeth (canine, incisors), alveolar periosteum
	Inferior Palpebral nerve	Lower eyelid, cheek
	External Nasal nerve	Nares
	Superior Labial nerve	Upper lip
Mandibular (V3) Nerve	Recurrent meningeal nerve	Duramater (middle cranial fossa)
	Medial pterygoid nerve	Medial pterygoid, tensor veli palatini, tensor tympani muscles
– Anterior division	Masseteric nerve	Masseter muscle, temporomandibular joint
	2 Deep temporal branches	Temporalis muscle
	Lateral pterygoid nerve	Lateral pterygoid muscle
	Buccinator nerve	Buccinator muscle
	Buccal nerve	Skin and mucous membrane of cheek and gingiva
– Posterior division	Auriculotemporal nerve	Skin of the auricle, meatus, and temporal region, tympanic membrane. Parasympathetic and sympathetic supply to the parotid gland after relay in the Otic ganglion
	Lingual nerve	Sensory to anterior tongue and gingiva. Taste sensations to the anterior 2/3 of tongue and parasympathetic fibers to facial nerve (communicates with VII CN)
	Inferior alveolar nerve	
	– Mylohyoid branch	Mylohyoid, anterior belly of digastric muscle
	– Dental branches	Lower molars, premolars, canine, gingiva
	– Incisive branch	Lower incisors, gingiva
	– Mental branch	Skin of chin, lower lip, gingiva

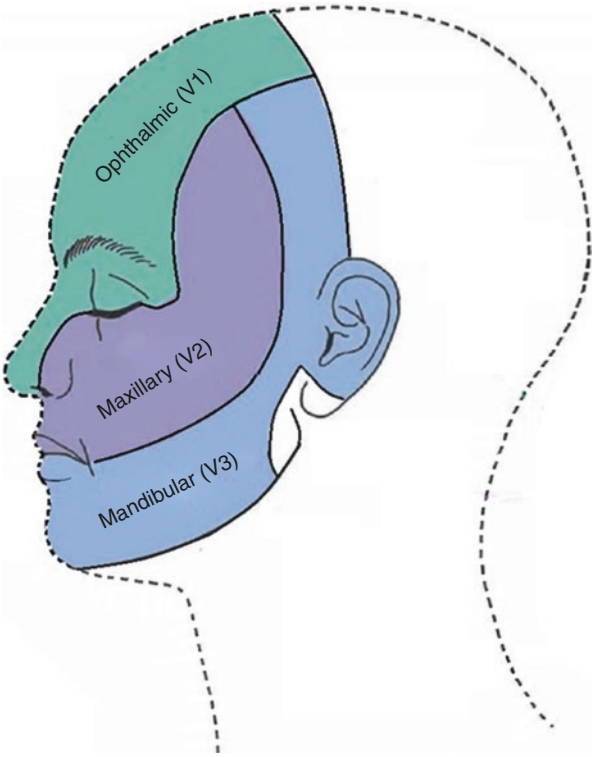

Fig. 6 Sensory distribution of three primary divisions of the trigeminal nerve

Clinical Significance

The trigeminal nerve is associated with various clinical conditions of head and face regions. ***Trigeminal Neuralgia (TGN)*** **or** ***Tic Douloureux*** presents with severe pain in the area of distribution of one or more divisions of the trigeminal nerve. It more frequently involves maxillary and mandibular divisions of the trigeminal nerve then the ophthalmic division. Compression of the nerve by vascular loops may lead to TGN [13–15]. There is a higher prevalence of pain on the right side which may probably be explained by the fact that the foramen rotundum and ovale are significantly narrower on right side as compared to left which may lead to easy compression on the nerves on right side [16]. Other painful condition in the distribution of trigeminal nerve may be trigeminal *postherpetic neuralgia* presenting with cutaneous allodynia and hyperalgesia.

Sensory deficit (hypoesthesia) in the territory of supratrochlear and supraorbital nerve may occur due to injury to these nerves or following surgery in prone position due to pressure on forehead and compression of these nerves by improperly positioned head rest. Injury to infraorbital branch of maxillary nerve may cause ***Numb Cheek Syndrome*** [17] and to mental nerve may cause ***Numb Chin***

Syndrome [18, 19]. Lesion of the motor root of trigeminal nerve may lead to ***Hemimasticatory Spasm*** characterized by recurrent spasm of masseters and temporalis muscle on one side [20].

In ***Lateral medullary syndrome*** (*Wallenberg Syndrome* or *Posterior Inferior Cerebellar Artery (PICA) Syndrome),* there occurs loss of pain and temperature sensation on ipsilateral side of the face and on contralateral side of the body. The ascending spinothalamic tract which carries pain and temperature sensation from contralateral side of body lies adjacent to descending spinal tract of trigeminal nerve carrying pain and temperature sensation from ipsilateral face, and hence, the effect. The PICA supplies the lower cerebellum, lateral medulla, and choroid plexus of the fourth ventricle. Infarction due to interrupted blood supply to lateral medulla after occlusion of PICA or vertebral artery may cause this syndrome [21, 22].

Trigeminal nerve is associated with several neurophysiological reflexes such as ***Trigeminal blink reflex, Trigeminocardiac reflex, Occulocardiac reflex, Maxillomandibular reflex, Diving reflex, Sucking reflex, Masseter reflex (Jaw jerk)*** each of which has its clinical significance. ***Marcus Gunn phenomenon*** (**Marcus-Gunn jaw-winking** or **trigemino-oculomotor synkineses**) and ***Inverse Marcus Gunn phenomenon*** (or **Marin-Amat syndrome**) are some of the other conditions associated with this nerve.

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