EMBJ.ORG FOR YOUNG DOCTORS

EUROMEDITERRANEAN BIOMEDICAL JOURNAL
2017,12 (37) 170–177
(*FORMERLY: CAPSULA EBURNEA*)

Review

SOMATOTOPY OF THE TRIGEMINAL COMPLEX: NERVE, GANGLION, NUCLEUS.

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ARTICLE INFO

Article history:
Received 30 August 2017
Revised 18 October 2017
Accepted 22 November2017

Keywords:
Trigeminal complex, nucleus, nerve, ganglion.

ABSTRACT

This paper summarizes, in a modern fashion and with a number of molecular, functional and magnetic resonance imaging details, the main morphological data about the trigeminal complex (i.e., trigeminal nerve, ganglion and nucleus). Indeed, this information is the basis to understand pathophysiology and semiotics of diseases involving these anatomical structures.

1. Introduction

Previous our study are regarding the somatotopy of the spinal nerve [1] and oculomotor complex [2], thus we study the somatotopy of trigeminal complex. The trigeminal nerve, V cranial nerve, has three branches: ophthalmic nerve, maxillary nerve and mandibular nerve; it is a mixed nerve containing both sensory and motor fibers. All the general somatic afferent fibers conveying both exteroceptive and proprioceptive impulses have their cell bodies in the trigeminal ganglion or Gasser' ganglion and only the proprioceptive afferent fibers from the neuromuscular spindles of the masticatory muscles have their cell bodies in the trigeminal mesencephalic nucleus. The trigeminal motor fibers innervating the masticatory muscles, tensor tympani and tensor veli palatini muscles have their cell bodies in the trigeminal motor nucleus in the rostral part of the pontine tegmentum. We studied the somatotopic organization of the trigeminal complex because of its importance in the diagnose and treat patients suffering for orofacial pain and tempomandibular joint disorders [3].

2. Trigeminal nerves

Ophthalmic nerve leaves the trigeminal ganglion (TG), enters the sinus cavernous, passes its wall of the dura mater upon the trochlear and oculomotor nerves, hence exits the cranium through the superior orbital fissure, entering the orbit innervates the forehead, upper eyelid, cornea, conjunctiva, dorsum of the nose, mucous membranes of the nasal vestibule and frontal sinus. The ophtalmic nerve is purely sensory or afferent in function. It supplies sensory branches to: the ciliary body, the cornea and the iris; the lacrimal gland and conjunctiva; portions of the mucous membrane of the nasal cavity, sphenoidal sinus and frontal sinus; the skin of the eyebrow, eyelids, forehead, and nose; the tentorium cerebelli, dura mater and the posterior area of the falx cerebri [4].

Maxillary nerve exits the cranium through the foramen rotondum supplies the upper lip, lateral and posterior portions of the nose, upper cheek, anterior portion of the temple, and the mucous membranes of the nose, upper jaw, upper teeth, and roof of the mouth to the palatopharingeal arch, midfacial region including the skin of the midfacial regions, the lower eyelid, side of nose, and upper lip; the mucous membrane of the nasopharynx, maxillary sinus, soft palate, palatine tonsil, roof of the mouth, the maxillary gingivae, and maxillary teeth. This vast and complex division of the trigeminal nerve is intimately associated with many sources of orofacial pain, often mimicking maxillary sinus and/or temporomandibular joint involvement [5].

Mandibular nerve is the largest of the three divisions, exits the cranium through the foramen ovale, with sensory fibers innervates the lower lip, the posterior portion of the cheek and the temple, external ear, the mucous membranes of lower jaw, lower teeth, cheek, anterior two-third of the tongue and floor of the mouth. The mandibular nerve is a mixed nerve which, like the ophthalmic and maxillary divisions, conveys afferent fibers, but unlike the former two divisions, also contains motor or efferent fibers to the masticatory muscles, the mylohyoid and anterior digastric

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DOI: 10.3269/1970-5492.2017.12.37
 ISSN: 2279-7165 - Available on-line at www.embj.org

muscles, and the tensor veli palatini and tensor tympani muscles. So intimately associated with dentistry, the mandibular nerve has also been termed the dental nerve by anatomists in the past [6].

The motor division of the nerve supplies the masticatory muscles: masseter, temporal, pterygoid, mylohyoid, and digastric muscles which also produce elevation, depression, protrusion, retraction, and the side-to-side movements of the mandible. The motor division also supplies the tensor tympani and tensor palati muscles. The mandible upon opening deviates toward the paralyzed side when there is unilateral paralysis of the masticatory muscles; this direction of the mandible is due to the action of normal pterygoids on the opposite side [7].

3. Trigeminal fetal ganglion

Phylogenesis.

The Trigeminal complex develops from two separate ganglia, the ophthalmic and maxillomandibular[8].In anamniotes, the ophthalmic and maxillomandibular lobes of the trigeminal complex are referred as the profundal and trigeminal placodes, respectively in most organisms the two ganglia fuse during embryogenesis into a single unit, while in Xenopus, the profundal and the trigeminal ganglia are separated distally but fused at their proximal end as they condense around stage 24 [9].In fish [10], frogs [9], birds [11,12] and mice the profundal/trigeminal or ophthalmic/maxillomandibular placodes contribute cutaneous sensory neurons to their respective ganglia in a similar manner [13].Theses neurons extended peripheral axons underneath the skin of the head to detect mechanical, chemical, and thermal stimuli, and central axons into the hindbrain, to communicate these inputs to the central nervous system. *In mammals*, the ophthalmic division of the trigeminal ganglion complex innervates the skin of the head region, the eyeball and eye muscles, and the nose; the maxillary division innervates the upper jaw, while the mandibular division innervates the lower jaw and tongue[8].

The TG somatotopy and nerve organization is only partially conserved through amniote evolution, possibly in relation to the modification of facial somatosensory structures and morphologies[14].

Ontogeny.

The TG has a mixed origin and contains neurons from both the neural crest and from placodes. The profundal/trigeminal placodes or ophthalmic/maxillomandibular are positioned halfway between the prospective eye and ear, adjacent to the future midbrain-hindbrain boundary and factors secreted by the dorsal neural tube are implicated in trigeminal placode induction [15,16].

The cranial neural crest originates the glial cells and all supporting cells entirely as the transplantation experiments in chick embryos have shown [11,17]. The neurogenic placodes, in contrast, generate exclusively sensory neurons for the trigeminal ganglion and other cranial ganglia. Studies using more recently available molecular markers for placodes, such as the transcription factors Sox3 [18,19] and Ngn1 [13]and Ngn2 [20] have confirmed these early findings: these markers are expressed in presumptive placodal domains well before neural crest migration has begun [21].

It was shown that Wise, a Wnt modulator expressed in the surface ectoderm overlying the TG plays a role in promoting the assembly of placodal and neural crest cells [22].

ANP (atrial natriuretic peptide) was found in the rat spiral ganglion in both neurons and glial satellite cells [23] and ANF-like immunoreactivity was found to be present in nerve fibers in laminae I/II of the spinal cord and in neurons of spinal and trigeminal ganglia [24].

The ANP immunoreactivity in rat fetal TG evidence a diffuse ANP-immunopositivity in rat developing at 16^{th} days of the fetal life; while in rat trigeminal ganglion at 18^{th} days of fetal life the ANP immunopositivity is closed to peripheral layer (Figure 1).

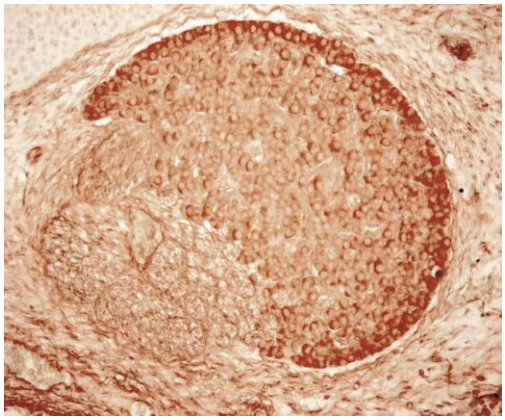

Figure 1 - Foetal rat trigeminal ganglion. ANP immunopositive neurons are peripherally.

Since in the spinal ganglia a diffuse ANP immunopositivity is evidenced, thus it is possible think that ANP immunopositivity is in neurons originated from the neural crests only and thus the location of ANP immunopositive neurons indicates that these neurons are originated from neural crest and migrate to the periphery of TG.

During the development the fetal somatotopy of the trigeminal gangliar cells seems of special interest, because during fetal life it has an impact upon somatotopic pattern formation in the brainstem. In the developing rat trigeminal somatosensory system, injury to afferent inputs prevents somatotopic pattern formation; however, afferent impulse blockade does not [25].The E-16 rat fetal somatotopy is adult-like, so in foetuses the neurons which innervated mandibular fields were located posterolaterally while neurons with ophthalmic or maxillary projections were restricted to the anteromedial and central parts of the ganglion, respectively [26,27].

4. Trigeminal adult ganglion

The TG is located in the apex of the anterior cerebral surface of the petrous bone in the middle cranial fossa. The TG consists of pseudounipolar neurons whose the peripheral processes or the afferent fibers are associated with touch and nociceptive stimuli; the TG is crossed by both the afferent fibers originating from the trigeminal mesencephalic nucleus and are associated with proprioception an stretch receptor and the efferent fibers originated in the trigeminal motor nucleus.

The sensitive neurons have a peripheral process forming the three divisions of the trigeminal nerve: the ophthalmic nerve, maxillary nerve

and mandibular nerve. The ophthalmic and the maxillary divisions are wholly sensory; the mandibular division is the entire motor root supplying the masticatory muscles, but also sensory fibers.

Recently, neurons in the TG, containing substance P, calcitonin gene-related peptide, and pituitary adenylate cyclase-activating peptide, have been shown to project to the mammalian pineal gland. Finally, nerve fibers originating from perikarya located in the brain containing, for example, GABA, orexin, serotonin, histamine, oxytocin, and vasopressin innervate the pineal gland directly via the pineal stalk. [28].

Somatotopy of trigeminal ganglion.

TG is somatotopically organized; its somatotopic representation, in mediolateral direction, is distinguished:

1. *opthalmic division* is located anteromedially,
2. *mandibular division* is located posterolaterally,
3. *maxillary division* in between.

The ophthalmic and maxillary regions of the trigeminal ganglion are well separated, whereas the maxillary and the mandibular regions overlap in mammals [29,30]. In cat [31]and monkey [32] the trigeminal gangliar cells are organized somatotopically along the mediolateral axis and the dorsoventral axis. Following application of HRP to the inferior alveolar nerve, infraorbital nerve, and periodontal ligament, labelled cells were found in the ipsilateral TG and periodontal receptor afferents were found in the Mes V [33].

The gangliar ophthalmic division.

In the *monkey* [34] the labeled cell bodies of protoneurons of the primary afferent fibers innervating the cornea were observed in the medial region of the ipsilateral TG. Most of the neurons were concentrated in the ganglion area that lies caudally directly on the fibers of the ophthalmic nerve entering but a smaller number of cells lying more laterally near the region where the ophthalmic and maxillary nerves come together. A very small number of neurons in one animal innervated the cornea by sending their fibers into the maxillary nerve.

In the *guinea pig* [35] a musculosomatically representation was found. In the ipsilateral ophthalmic part of the TG at a wide range along the dorsoventral axis expressing an overlap of the representation areas.

The TG has a organization with a representation along dorsoventral axis:

1. *Dorsal part*: superior rectus muscle-superior oblique muscle
2. *Intermediate part*: lateral rectus muscle -medial rectus muscle
3. *Ventral part*: inferior rectus muscle-inferior oblique muscle

This somatotopy can be reported to spatial organization along cranialcaudal direction of the muscles in the eye; on contrary, no organization along the mediolateral axis was observed.

The gangliar maxillary and mandibular divisions.

In *monkey and baboon* [33] it was found that the incisor and canine representations had a large and predominant Hrp-labelled neurons in the ipsilateral TG; the molar representation in the TG was sparse and all labelled neurons supplied ipsilateral teeth.

The maxillaris teeth had *middle compartment* of the TG,

The mandibular teeth had *posterolateral* compartment of the TG.

It is suggested that the *anterior teeth* with greater connections to the Mes V and the ganglion may impart greater sensory perception and be involved in jaw reflexes to ensure a good occlusal relation during mastication, while the afferent connections of the *molars* may initiate complex jaw reflexes during the occlusal phase of mastication.

The TG presents also a functional somatotopy.

The TG contains large cell bodies (Aβ) of mechanoreceptive afferents and the small cell bodies of nociceptive fibers (Aδ and C); each of the three divisions of the trigeminal nerve consists of "processes"of neurons with cell bodies in the TG.

The neuronal bodies for both large (Aβ) and small (C and Aδ) fibers are arranged segmentally within the TG.[36].

Cell bodies of the *mechanoreceptive and nociceptive* afferents of:

1. *ophthalmic* division (V1) are found *medially and anteriorly,*
2. *mandibular* division (V3) are *caudal and lateral*,
3. *maxillary* (V2) division are present in between the ophthalmic division and the mandibular division.

Thus, the somatotopic activation patterns observed for both "brush and thermal pain" correspond to the anatomical organization of the feline TG. The cell bodies which send axons to the ophthalmic, maxillary and mandibular nerves were located in the anteromedial, middle and posterolateral portions of the ipsilateral TG, respectively. Overlap was found, especially in the maxillary and mandibular areas [30].

5. Trigeminal nucleus

The trigeminal nucleus is constituted of masticatory nucleus and sensory nucleus.

The trigeminal masticatory nucleus (TMN).

It innervates the masticatory muscles and it is involved in the trigeminal circuits responsible for chewing [37]. The masticatory behavior is a circuit with a rithmic jaw movements produced during mastication is generated by a "Central Pattern Generator" (CPG) located in the pons and medulla. Neurons within the CPG have intrinsic properties that produce a rhythmic activity, but the output of these neurons is modified by inputs that descend from the higher centers of the brain, and by feedback from sensory receptors, in order to constantly adapt the movement to the food properties.

The TMN of the trigeminal nerve is an ovoid column of the typical multipolar motor cells that lies medial to the motor root and the principal sensory nucleus.

Representation of the masticatory muscles was studied, by the horseradish peroxidase method within the rat TMN which could be divided cytoarchitecturally in: dorsolateral and a ventromedial division. [38].

Within the ***dorsolateral division***, the temporal muscle was represented dorsomedially, the masseter muscle dorsolaterally and laterally, and the lateral and medial pterygoid muscles ventrolaterally. Within the ventromedial division, the anterior digastric muscle was represented dorsomedially and the mylohyoid muscle ventrolaterally. Distribution of antidromic field potentials evoked by stimulation of the mylohyoid and masseteric nerves coincided with the results from the HRP investigation (Table 1).

Dorsolateral division	Muscles	*Ventromedial division*	Muscles
Dorsomedially	Temporal	Dorsomedially	Anterior digastric
Dorsolaterally	Masseter	Dorsolaterally	
Laterally	Masseter	Laterally	
Ventrolaterally	Lateral /medial pterigoid	Ventrolaterally	Myloid

Table 1 - Motor trigeminal nucleus: dorsolateral and ventromedial divisions.

Successively [39], contrary to the classically accepted scheme, the topographical representation of the masticatory muscles of the rat by studying retrograde transport of horseradish peroxidase from individual muscles was showed that the temporalis and masseter muscles are separately represented dorsolaterally, the pterygoids dorsomedially and the jaw-opening mylohyoid and anterior belly of digastric ventrally within the motor nucleus, corresponding to the arrangement of the muscles on the head (Table 2).

Part of motor trigeminal nucleus	Neurons for muscles
Dorsolaterally	Temporalis
Dorsolaterally	Masseter
Dorsomedially	Pterygoids
Ventrally	Anterior belly of digastric
Ventrally	Mylohyoid

Table 2 - Motor trigeminal nucleus: dorsolateral and ventromedial divisions.

In young adult albino Wistar rats [40] it was found that in the TMN the neurons innervating each masticatory muscle show following somatotopic arrangement:

1. Neurons innervating the temporalis muscle are located in the medial and dorsomedial parts;
2. Neurons innervating the masseter muscle are located in the intermediate and lateral;
3. Neurons innervating the medial and lateral pterygoid muscles are located in the lateral, ventrolateral and ventromedial parts, respectively;
4. Neurons innervating the mylohyoid and the anterior belly of the digastric muscles are located in the most ventromedial part of the caudal one-third of the nucleus (Table 3).

Part of motor trigeminal nucleus	Neurons for muscles
Medial	Temporalis
Dorsomedial	Temporalis
Intermediate	Masseter
Lateral	Masseter
Ventrolateral	Pterygoid
Ventromedial	Anterior digastrics

Table 3 - Motor trigeminal nucleus.

Most masticatory motor neurons send axons running ventrolaterally in between the motor and the chief sensory nuclei of the trigeminal nerve; however, those of the mylohyoid and anterior belly of the digastric muscles ascend dorsally to the dorsal aspect of the caudal nucleus and then turn ventrolaterally to join the motor root of the trigeminal nerve. Furthermore, the dendrites of the motor neurons of jaw closing muscles (JCM) converge dorsocaudally to the supratrigeminal region. The diameters of neurons of each JCM display a bimodal distribution. However, an unimodal distribution is present in the motor neurons from each JCM. It is suggested that the motor nucleus innervating the JCM is comprised of alpha- and gamma-motor neurons; thus, itis a neural basis for the regulation of the muscle tone and biting force.

In the young and adult cat [41] TMN was found a clear dorsoventral somatotopic distribution; the superior muscles have their motoneurons located dorsally in the nucleus and the inferior muscle ventrally; that the two main jaw closers, temporalis and masseter, are represented in the dorsal and central parts of the nucleus; located more ventrally are the motoneurons for the pterygoideus medialis and lateralis, the jaw closers and abductor muscles; finally motoneurons for the jaw openers, and the anterior belly of the digastricus and mylohyoideus, occupy the ventromedial part of the nucleus. All muscles have been found to be represented along the entire length of the nucleus, with the same dorsoventral layering (Table 4).

Part of motor trigeminal nucleus	Neurons for muscles
Dorsal central	Temporalis masseter
Dorsal central	Temporalis masseter
Ventrally	Pterygoidei l/m
Ventromedial	Anterior belly digastric
Ventromedial	Mylohyoideus

Table 4 - Somatotopy of the masticatory muscle motoneurons in the young and adult cat.

In rabbit TMN [42] by labeled retrogradely with horseradish peroxidase was show the localisation within the TMN of the motoneurons supplying different regions of the rabbit masseter muscle. The motoneurons for the masseter muscle are confined to the dorsal and lateral sections of the motornucleus, along its full rostrocaudal extent. Within this subnucleus, the motoneurons for the superficial masseter occupy the dorsolateral portion, the motoneurons for the deep masseter the dorsomedial portion; furthermore the anatomical and functional subdivision of the deep masseter into an anterior and posterior portion appeared to be matched by a separation of the motoneurons for these portions in the rostrocaudal direction along the nucleus. The separation of the motoneurons for the anterior and posterior deep masseter is not complete, indeed the territories in the motornucleus overlap each other for about 50%.

The well-established differentiation in motor tasks between the masseter portions during feeding is thus clearly reflected in a separation of motoneurons, making possible differentiation of descending or afferent input to the separate regions in the nucleus (Table 5).

Portions of subnucleus	Masseter nucleus
Dorsolateral	Superficial masseter
Dorsomedial	Deep masseter

Table 5 - Somatotopy in the rabbit TMN of the motoneurons supplying different regions of the rabbit masseter muscle.

However [43] the differential identification of αMNs and γMNs was studied in the in dorsolateral TMN (dlTMN)based on the size of cell bodies that were retrogradely stained with HRP. And it was found that the dl-TMN is composed of 65% αMNs and 35% γMNs; the size distribution of αMNs was bimodal, while that of γMNs was almost the same as that of the population of small αMNs, suggesting the presence of αMNs as small as γMNs. Consistent with the size concept of motor units, the presence of smaller jaw-closing αMNs was coherent with the inclusion of jaw-closing muscle fibers with smaller diameters compared to limb muscle fibers.

Sensory trigeminal nucleus

The trigeminal sensory nucleus lies lateral to the entering trigeminal root fibers in the upper pons.

1. fibers of the *ophthalmic division* terminate ventrally,
2. fibers of the *maxillary division* are intermediate,
3. fibers of the *mandibular division* are most dorsal.

Thus, it is dorsoventral axis: mandibular, maxillary, ophthalmic fibers. The cell have large receptive fields and respond to a wide range of pressure stimuli with little adaptation.

The trigeminal nucleus extends through the whole of the midbrain, pons and medulla. The nucleus is divided in three parts, from rostral to caudal: mesencepfalic nucleus, pontine nucleus (or “primary nucleus” or “main sensory nucleus" or "principal nucleus"), spinal trigeminal nucleus.

Spinal trigeminal nucleus.

The spinal trigeminal nucleus is divided cytoarchitecturaly in three parts [44].

1.*Pars oralis*, extending caudally to the rostral third of the inferior olivary nucleus, caudally to the level of the rostral pole of the hypoglossal nucleus.

2.*Pars interpolaris* extending from the pars oralis to decussation of the pyramidis, caudally to the level of the obex.

3.*Pars caudalis* which begins at level of the obex extending caudally as far as second cervical spinal segment.

Physiological studies [45] in the cat reveal that a somatotopic map of the face exists at all level within the spinal trigeminal nucleus. Throughout the nucleus the face is represented in upside down fashion with the jaw dorsal and the forehead ventral.

The *pars oralis* receives impulses from the head, mouth, nose and eyes, cells have small receptive fields and the dominant representation is of internal structures.

The *pars interpolaris* has small receptive fields and is related mainly to cutaneous facial regions. The *pars caudalis* has large receptive fields and responds to light pressure over proximal parts of the face (forehead, cheeks and region of the jaw angle). Although neuronal receptive field size generally is related to peripheral innervation density, an extensive study of the trigeminal nuclear complex in the monkey failed to demonstrate any consistent variation of the receptive field size throughout its rostrocaudal extent [4].

The regions [46] in the *caudal pars (nucleus)*are disposed in rostrocaudal direction: the perioral region, (nose, mouth) intermediate (eye, mentum, cheeks) and region posterior (submentum, preauricular area and cranial vault), each part of them receive fibers from three trigeminal branches which are disposed in mediolateral: mandibular, maxillary and ophthalmic (Figure 2; A and B).

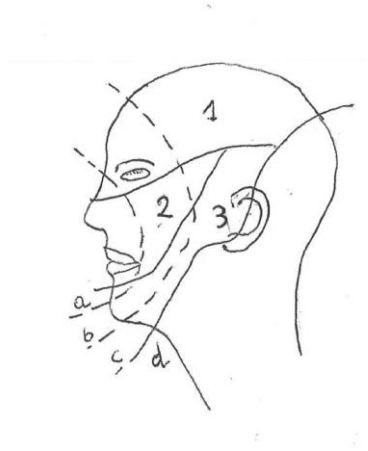

Figure 2 A - 1. Ophtalmic area; 2. Maxillary area; 3. Mandibular area; a) Border of the perioral zone; b) Intermediate maxillary zone, c) Mandibular zone; d) Zones innervated from the glossopharingeal and vagal nerves.

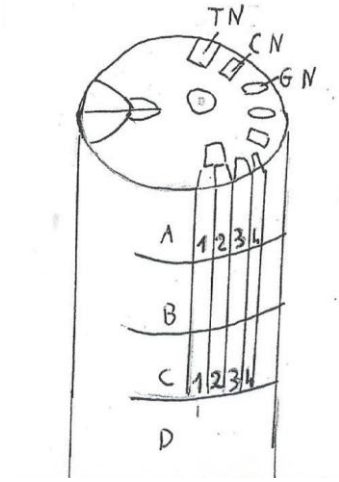

Figure 2 B - Map distribution in craniocaudal and mediolateral direction of the corrisponding superficial zones in the caudal trigeminal nucleus: 1. Ophthalmic branch. 2. Br. Maxillary branch. 3.Mandibular branch. 4. Intermediate, glossopharyngeus, vagus nerves. A, B, C zones correspond to: a, b, c, concentric zones of Fig 2A. TN: Tract solitary nucleus, CN: Cuneate nucleus, GN: Gracile nucleus.

In *Macaca fascicularis* [34] the corneal afferent neurons terminate to the transitional zone between caudal pars interpolaris and rostral pars caudalis(i.e., the "periobex" region of the TBNC) and moderately to the trigeminal main sensory nucleus, pars oralis, and caudal pars caudalis at the level of the pyramidal decussation.

Principal sensory nucleus.

This nucleus lies lateral to the entering trigeminal root fibers in the upper pons.

1. fibers of the *ophthalmic division* terminate ventrally,
2. fibers of the *maxillary division* are intermediate,
3. fibers of the *mandibular division* are most dorsal.

Thus is axis dorso-ventral, dorso-ventral sense: mandibular, maxillary, ophthalmic fibers. The cell have large receptive fields and respond to a wide range of pressure stimuli with little adaptation.[19].

The trigeminal pontine nucleus

Trigeminal nerve divisions containing primary afferent fibers to the dorsal division of the principal sensory trigeminal nucleus(Vp) and the results of cat studies by the transganglionic horseradish peroxidase method indicate that pterygopalatine, superior alveolar, infraorbital, buccal, lingual, inferior alveolar and mental nerves contain primary afferent fibers terminating in the dorsal division of the Vp probably conveying sensory information chiefly from the intraoral structures [47].

The trigeminal mesencephalic nucleus.

This nucleus forms a slender cell column near the lateral margin of the central gray of the upper part of the IV ventricle and cerebral aqueduct. The mesencephalic nucleus constitutes of large primary neurons inside the brainstem; their processes are slender and form the mesencephalic tract of the trigeminal nerve that descends to the level of the trigeminal motor nucleus provides collaterals to motor cells and appears to emerge as part of the motor root. The mesencephalic nucleus receives the afferents fibers conveying proprioceptive impulses (pressure, kinestesis) from theet, periodontium, hard palate muscles of mastication and jont capsule.

The mesencephalic nucleus contains the cell bodies of primary afferent neurons that innervate *muscle spindles in masticatory muscles* and mechanoreceptors in the periodontal ligaments [48].Numerous labeled neurons were found in ipsilateral MesV following masticatory muscle injections. The scattered distribution of labeled cells, and their presence among clusters of unlabeled cells, suggests the muscle representations overlap. Just a few MesV neurons were labeled after *extraocular muscle* injections; this correlates with the small number of muscle spindles present in macaque extraocular muscles, suggesting MesV cells supplying extraocular muscle spindles may contribute a minor component to oculomotor proprioception.

In monkey and baboon [33] the periodontal afferent neurons of all incisor, canine, molar teeth were well represented in the Mes V, although the incisors had a significantly higher number of labelled neurons than the canines or molars. The primary cell bodies of the periodontal afferents were located mainly in the caudal part of the ipsilateral Mes V from the level of the inferior colliculus to the floor of the fourth ventricle in the pons. The caudal periodontal Mes V neurons may be favourably located to make collateral connections with the trigeminal motor nucleus for jaw reflexes.

Central connections between the Mes V and spinal V [48] were studied by injection of biotinylated dextran amine (BDA) into the spinal trigeminal nucleus (Vs). The presence of retrogradely labeled MesV cells indicated a projection to Vs from MesV. These injections also anterogradely labeled terminals that lay in close association with MesV cells, suggesting an ascending projection from Vs to MesV. Finally, a small number of MesV neurons were labeled following WGA-HRP injections into the upper cervical spinal cord.

This pattern of central connections indicates a combined MesV and Vs information to guide the mastication.

6. Functional magnetic resonance imaging data

The recent data by functional magnetic resonance imaging (fMRI) reveal that orofacial cutaneous and muscle nociceptive information and innocuous cutaneous stimulation are differentially represented within the trigeminal nuclear complex [49]. So, during *cutaneous pain* the signal intensity increased within the entire rostrocaudal extent of the spinal trigeminal nucleus (SpV), encompassing the ipsilateral oralis (SpVo), interpolaris (SpVi) and caudalis (SpVc) subdivisions. in contrast, in contrast, *muscle pain* did not activate SpVi, but instead activated a discrete region of the ipsilateral SpVo and SpVc.

The muscle noxious stimulation activated a region of the ipsilateral lateral pons in the region of the trigeminal principal sensory nucleus (Vp). Innocuous orofacial stimulation (lip brushing) also evoked a significant increase in signal intensity in the ipsilateral Vp; however, *non-noxious muscle* stimulation showed *no increase* in signal in this area.

The first proprioceptive information [50] relays in the trigeminal mesencephalic nucleus which contain neuron subpopulations: under normal circumstances subpopulation contains only Glu that is a strong candidate for a major neurotransmitter; certain small MTN neurons, most likely interneurons are GABAergic.

Furthermore, NOS immunoreactivity can be detected in the caudal as well as the mesencephalic-pontine junction parts of the MTN and this suggests a mediatory role for NO in some aspects of synaptic transmission in the MTN.

Remarkably, no immunoreactivity to any of the neuropeptides examined is observed in the cell bodies of MTN neurons and only fibers and their terminals show peptide-immunolabeling. Most of the labeled peptidergic fibers have immunopositive varicosities that form pericellular basket-like arborizations around unlabeled MTN perikarya. It is predicted that under normal conditions the pericellular arborizations can function as an intranuclear key communication medium between immunopositive projections and immunonegative MTN neurons in the proprioceptive information processing. A.A. conclude that the divergent neurochemical content of the cells in the nucleus, should it exist, is likely to be linked with different neuronal functions.

7. Final remarks

The somatotopy in the fetal and adult life is similar. In the TG the afferent fibres of ophthalmic maxillary and mandibular division are located in the anteromedially, the mandibular are posterolaterally and maxillary in between, thus gangliar neurons are organized along obliquous the mediolateral axis (ophthalmic, maxillary mandibular neurons) and dorsoventral axis (mandibular, maxyllary, ophthalmic neurons).

Furthermore the ophthalmic subnucleus has a representation along dorsoventral axis: dorsal neurons to rectus and superior oblique muscles, intermediate part to medial and lateral rectus muscle, ventral part to inferior rectum andinferior oblique muscles. The MTN in rat with any exception,the data are according that the temporal muscle is dorsally, the masseter muscle is dorsolaterally, the pterygoids and mylohyoid muscles are ventrally. The STN is divided in three parts: spinal, pontine, mesencephalic nucleus. The spinal nucleus is subdivided in parts: oralis, interpolaris, and caudal, receive fibers of three divisions with a somatotopic map with the face is represented in upside down fashion with jaw dorsal and forehead ventral. The caudal part receives fibers from the divisons disposed in rostrocaudal direction with perioral region, intermediate, posterior region and each pars receives fibers from the division with a mediolaterally architecture; mandibular, maxilllary, ophthalmic region. The pontine nucleus presents a dorsoventral axis: mandibular, maxillary, opthalmic division. The mesencephalic nucleus contains cell bodies of primary afferent neurons suppling the muscle spindles in the masticatory muscles and extraocular muscles. The mesencephalic nucleus and spinal nucleus are thus connected between.

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