

The spinal trigeminal nucleus — considerations on the structure of the nucleus caudalis

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The caudal part (nucleus caudalis) of the spinal trigeminal nucleus is considered to be the site of the second order neurons of the nociceptive pathways of the face. Recent studies have supported the co-participation in these circuits of the oral part of the same nucleus (nucleus oralis). The aims of the present study are: 1) to determine the morphology of the nucleus caudalis in human preparates; 2) to consider whether there is any structural basis for the pathways of signal transmission observed in animal experiments; 3) to provide evidence-based support for further consideration on the orofacial pathways.

The studies were made using the Bielschowsky silver staining technique (on blocks) applied to drawn pieces of brainstems from human cadavers. On the sections the outer laminae of the nucleus are distinguishable, while the inner part hardly exposes any laminar configuration on transverse cuts. A marginal plexus with small polygonal or rounded small cells appears configured in 3 parts, namely dorsal, intermediate and ventral. Outer to the marginal plexus a clear band marks it off from the interstitial plexus, which appears more delicate. Within the marginal plexus is substantia gelatinosa with rare randomly distributed small or medium-sized cells. The inner magnocellular layers consist of clusters of small cells specifically allocated to fibre bundles, isolated small cells and large cells, pear-shaped or fusiform, appearing either bipolar or multipolar. The marginal and interstitial plexuses can represent the framework for modulation and vertical signal transmission within the spinal trigeminal nucleus, while the magnocellular layers seem to be mainly responsible for contralateral projection.

It seems that the outer laminae of the spinal trigeminal nucleus may represent the receiver and the inner laminae the transmitter of the signal on the trigeminal pathway at brainstem level.

Key words: brain stem, spinal trigeminal nucleus, human morphology

INTRODUCTION

Primary trigeminal fibres from the trigeminal ganglion project to trigeminal nuclei located within the substance of the brainstem, the main sensory nucleus in the pons and the spinal trigeminal nucleus located in the medulla and rostral segments of the spi-

nal cord. The spinal trigeminal nucleus continues caudally with the substantia gelatinosa of the dorsal column of the spinal cord and is divided into three subnuclei, the oral, the interpolar and the caudal. The last is conventionally associated with thermal and noxious stimuli, carried mainly by the 5th cranial nerve.

The trigeminal sensory nuclear complex has a strategic role as the major brainstem relay of many types of somatosensory information from the face and mouth. Within this complex modulatory mechanisms are considered [13] and experimental studies have involved both the subnucleus oralis and the subnucleus caudalis in the orofacial nociceptive pathways [4, 6, 10].

Even though classical studies on the structure of these nuclei consider the laminar organisation of the spinal trigeminal nucleus similar to that of the spinal dorsal horn [8], there are recent comments suggesting a different organisation of the nucleus caudalis to the spinal systems [1].

Interstitial islands of neurons embedded in the spinal trigeminal tract are well described in rodents in the ventral transition region from the nucleus caudalis to the nucleus interpolaris [11] and are related to integrative functions [12].

The aim of the present study is to describe the structure of the nucleus caudalis in humans and to correlate the results with experimental and neurophysiological data.

MATERIAL AND METHODS

Drawn pieces of brainstems were obtained by autopsy of human adults, with the approval of the ethics committee of the Carol Davila University of Medicine and Pharmacy. Silver staining of the drawn pieces using the Bielschowsky technique (on blocks) enabled results to be obtained which were suitable for representing the complex cytoarchitectonics of the nucleus caudalis.

RESULTS

The spinal trigeminal tract appears to be, on transverse cuts, layered. The outer layer consists of fibre bundles intermingled with small neurons (average $6\ \mu$) — the interstitial cells (Cajal), which show various shapes: triangular, rounded, polygonal or star-shaped. Some of these cells are medium-sized (average $8\ \mu$). The interstitial cells send thin dendrites interconnecting the cells within the clusters at this level and achieving an interstitial plexus. Some of the corresponding axons and long dendrites leave this layer, continuing deeply towards the substantia gelatinosa.

Deep in the middle layer of the spinal trigeminal tract is the layer of marginal cells consisting of medium-sized (average $10\ \mu$) neurons interconnected within a marginal dendritic plexus with 3 distinctive parts: dorsal, intermediate and ventral, thus corre-

sponding to the mandibular, maxillary and ophthalmic nerve projections [3]. The marginal cells appear pear-shaped, rounded or polygonal and send axons grouped in fascicles towards the substantia gelatinosa.

The substantia gelatinosa at the level of the caudal nucleus consists of rare cells, on average $8\ \mu$, appearing as fusiform. This lamina of the caudal nucleus is largely traversed by nervous fibres, both dendrites and axons.

The inner magnocellular layers appear as the core of the caudal nucleus. Small rounded cells of $8\text{--}10\ \mu$ are disposed grouped in small clusters or dispersed at this level. Interconnected between and intermingled with abundant glial cells, these neurons send out contralateral projections grouped in bundles. Large neurons (average $22\ \mu$) are also found at this level and are pear-shaped, fusiform, multipolar or bipolar in appearance. The large multipolar neurons send out dendrites externally connected to neighbouring small neurons of the magnocellular core and project the axon internally to be incorporated within the efferent bundles (Fig. 1–6).

DISCUSSION

The presence of the interstitial cells in the description of Ramon and Cajal [2] and their lack in recent papers and textbooks generates several problems. Are these cells similar to the ICC belonging to the gastrointestinal tract? What role do these cells play within the spinal trigeminal nucleus? If intermingled with the descending primary trigeminal fibres, which lamina of the spinal trigeminal nucleus can they be considered to belong to?

The presence of two distinctive cellular plexuses, interstitial and marginal, at the nucleus caudalis level, with a ventro-dorsal somatotopy that can be associated with the somatotopic projections of the trigeminal peripheral branches, allows them to be considered as local structures involved in signal modulation and longitudinal correlation between the spinal trigeminal subnuclei, thus correlating with experimental studies [5].

The longitudinal correlation between the trigeminal subnuclei at brainstem level is morphologically sustained by modulatory projections from the rostral trigeminal subnuclei [7, 9].

The core of the nucleus caudalis, separated by the substantia gelatinosa from the marginal plexus, consists of medium-sized neurons, either grouped or disseminated, intermingling with magnocellular solitary neurons with a polarised dispo-

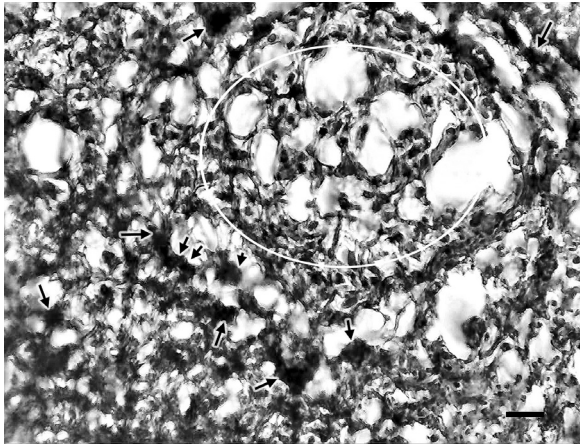


Figure 1. The interstitial cells (arrows) and plexus intermingle with descending trigeminal fibres (selection) outer to the marginal layer.

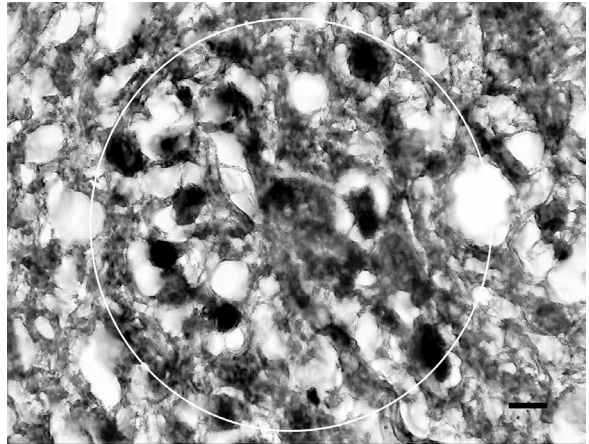


Figure 2. A cluster of argyrophilic marginal cells (selection) interconnected within a dendritic plexus sending their axons grouped towards the substantia gelatinosa.

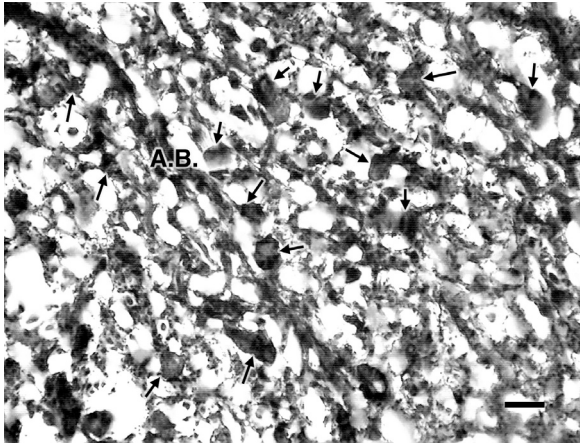


Figure 3. The deep magnocellular part of nucleus caudalis exhibits clusters of small cells (arrows) sending axons grouped in bundles (A.B.) towards the midline.

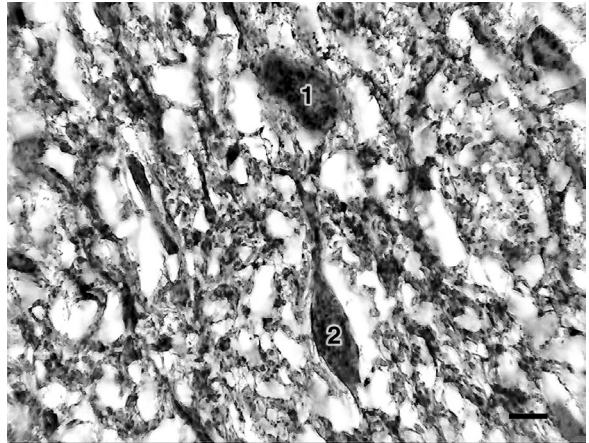


Figure 4. Large neurons (1, 2) within the magnocellular core of the nucleus caudalis; the externally placed neuron (2) is configured as a bipolar cell.

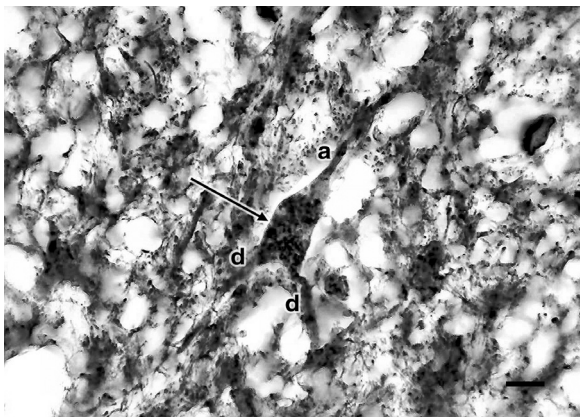


Figure 5. Large neuron (arrow) within the magnocellular core, with thick outer dendrites (d) and an inner axon (a) leaving the axonal cone.

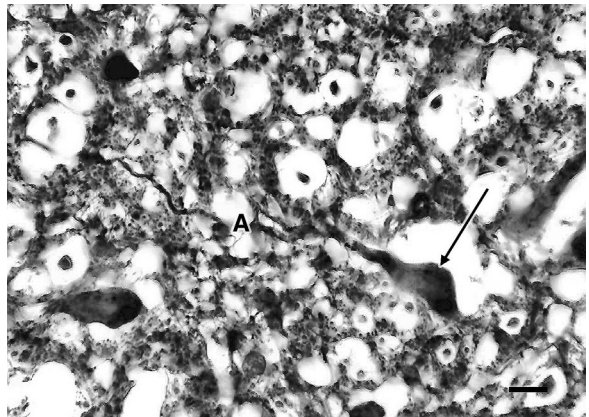


Figure 6. Magnocellular neuron (arrow) with a long-distance travelling axon (A) towards the midline.

sition, their axonal cone and axon being directed towards the midline.

The outer layers of the nucleus caudalis seem to represent the receiver structures that integrate, modulate and disperse the received signal within that segment and between segments, while the nuclear core is mainly responsible for the contralateral transmission of the signal.

REFERENCES

1. Bereiter DA, Hirata H, Hu JD (2000) Trigeminal subnucleus caudalis: beyond homologies with the spinal dorsal horn. *Pain*, 88: 221–224.
2. Cajal RS (1911) *Histologie du Systeme nerveux de l'homme et des vertebres*. Tome II, A.Maloine Editeur, Paris 864–868
3. Carpenter MB (1985) *Core text of neuroanatomy*. 3rd Ed. Williams & Wilkins, Baltimore USA 108–109.
4. Chen Yu C, Hu B, Hu JW, Dostrovsky JO, Sessle BJ (2002) Central sensitization of nociceptive neurons in trigeminal subnucleus oralis depends on integrity of subnucleus caudalis. *J Neurophysiol*, 88: 256–264.
5. Dallel R, Duale C, Molat J-L (1998) Morphine administered in the substantia gelatinosa of the spinal trigeminal nucleus caudalis inhibits nociceptive activities in the spinal trigeminal nucleus oralis. *J Neurosci*, 18: 3529–3536.
6. Dallel R, Villanueva L, Woda A, Voisin D (2003) Neurobiologie de la douleur trigeminale. *Medecine/Sciences*, 19: 67–74.
7. Falls WM (1984) The morphology of neurons in trigeminal nucleus oralis projecting to the medullary dorsal horn (trigeminal nucleus caudalis): a retrograde horseradish peroxidase and Golgi study. *Neuroscience*, 13: 1279–1298.
8. Gobel S, Falls WM, Hockfield S (1977) The division of the dorsal and ventral horns of the mammalian caudal medulla into eight layers using anatomical criteria. In: *Pain in the trigeminal region: proceedings of a symposium held in the Department of Physiology, University of Bristol, England, on 25–27 July*, Elsevier/North-Holland Biomedical Press, Amsterdam, New York 443–453.
9. Hockfield S, Gobel S (1982) An anatomical demonstration of projections to the medullary dorsal horn (trigeminal nucleus caudalis) from rostral trigeminal nuclei and the contralateral caudal medulla. *Brain Res*, 252: 203–211.
10. Luccarini P, Cadet R, Duale C, Woda A (1998) Effects of lesions in the trigeminal oralis and caudalis subnuclei on different orofacial nociceptive responses in the rat. *Brain Res*, 803: 79–85.
11. Phelan KD, Falls WM (1989) The interstitial system of the spinal trigeminal tract in the rat: anatomical evidence for morphological and functional heterogeneity. *Somatosens Mot Res*, 6: 367–399.
12. Phelan KD, Falls WM (1991) The spinotrigeminal pathway and its spatial relationship to the origin of trigemino-spinal projections in the rat. *Neuroscience*, 40: 477–496.
13. Sessle BJ (2000) Acute and chronic craniofacial pain: brainstem mechanisms of nociceptive transmission and neuroplasticity, and their clinical correlates. *Crit Rev Oral Biol Med*, 11: 57–91.