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GUSTATORY PATHWAY: A REVELATION BASED ON CLINICAL STUDIES

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ABSTRACT

Loss of taste sensation is often noted in majority of CNS lesions, but this has not been given much importance by the medical community. The taste pathway as described in standard physiology textbooks do not support the available evidence on the loss of taste sensation in central lesions. Taste disorders related to central lesions can either be ipsilateral, contralateral or bilateral according to area of injury of the taste pathways. However, some questions remain, particularly regarding the exact crossing site of human gustatory afferents. In the present review an attempt is made to unveil the taste pathway based on clinical data available. Loss of taste sensations in relation to lesions in medulla, pons, midbrain and thalamus have been highlighted.

Keywords: Ipsilateral, Contralateral, Gustatory Pathway

INTRODUCTION

Taste and Olfaction are chemical senses that contribute significantly to the quality of life and are important stimulant for digestion, but these sensations are the least understood. Olfactory disorders have been noted in majority of neurodegenerative diseases but they have been underrated in clinical settings. Similarly, the role of taste sensation is also underrated in clinical setting. During the acute phase of stroke absence of taste sensation is not given much importance as it is overshadowed by the patient's other serious and life threatening problems. Most patients undergo numerous consultations for taste disorders, but this defect is mostly brushed off by the medical community and this can result in an adverse effect on the patient's quality of life. The knowledge that taste disorders is an early sign of significant life threatening diseases like neurodegenerative disorders, myasthenia gravis, lung cancer etc. is still not probed into.

A review of the sparse literature on taste disorder has brought to light the importance of knowledge

regarding the gustatory pathways. Lesions related to the taste pathway can result in either qualitative or quantitative deficits in taste sensation. Central lesions involving taste pathways seem to generate perceptions of quantitative taste disorders, in contrast to peripheral gustatory lesions that are hardly recognised as quantitative but sometimes as qualitative taste disorders by patients. Taste disorders mostly arise due to lesions of the peripheral pathways and the mechanism underlying this disorder is already known. But recently it has been noted that taste disorders can arise because of central lesions also. The mechanism for taste disorders due to central lesions is still unclear. Taste disorders related to central lesions can be assessed using gustometers, to know the exact region of loss of taste sensation, this combined with diagnostic imaging techniques like CT or MRI would help to accurately determine the site of lesion in the taste pathways. Taste disorders related to central lesions can either be ipsilateral, contralateral or

bilateral according to area of injury of the taste pathways. However, some questions remain, particularly regarding the exact crossing site of human gustatory afferents.

In spite of many recent advances in the field of gustatory neurobiology our knowledge of gustatory pathways and the processing of gustatory information are far from complete. Our knowledge of gustatory pathways is mainly based on anatomical studies via dissection and animal data via electrophysiological studies. But the recent clinical studies related to taste have questioned the knowledge regarding the gustatory pathways attained so far.¹ Many studies on lesions of gustatory pathways have noted ipsilateral, contralateral and bilateral loss of taste sensations. But the taste pathways as accepted by standard physiology textbooks are not able to explain this pattern of loss of taste sensation.

The ascend of taste pathways, levels of crossing and the termination of the gustatory pathways appears to be controversial when animal studies are compared with clinical observation. Human gustatory system is yet to be completely elucidated. To clarify the same, in this review an attempt is made to summarize the recent evidences regarding the lateralization of gustatory pathways based on clinical studies.

Taste pathway in animal

It was found that the neural pathways for taste vary in different species of animals. In monkeys there was only three orders of neurons in contrast to cats and rats who had four orders of neurons. The three orders of neurons in monkeys were from the tongue to nucleus of tractus solitarius, second order ascends ipsilaterally from tractus solitarius to thalamus and third order from thalamus to gustatory cortex on the ipsilateral sides. In cats, second order neurons end in pons and third order is from pons to thalamus and fourth from thalamus to cortex. No crossing over was noted in the taste pathways. In contrast to this, in the rats it was observed that from the

pons, ascend of the pathways were bilaterally to the thalamus and from thalamus also bilaterally ascend to the gustatory cortex. As the human gustatory pathways were designed based on the animal studies, these differences have created confusions regarding the exact nature of gustatory pathways.^{2,3}

Human gustatory pathway

Gustatory pathways in humans have three orders of neurons. The first order neurons i.e. the relatively slowly conducting taste fibres from each side unite in the nucleus of tractus solitarius in the medulla oblongata. There they synapse on second order neurons, the axons of which will cross to opposite side and join the medial lemniscus, ending with the fibres for touch, pain and temperature sensibility in the specific sensory relay nucleus of thalamus. Third order neurons arise from there and relay in the taste projection area in the cerebral cortex at the foot of the post central gyrus. Hence it was concluded that taste does not have a separate projection area but is represented in the portion of the post central gyrus that sub serves cutaneous sensation from face.⁴ This information about the taste pathway was further modified as follows "...there is no crossing in the taste pathway it ascends on the ipsilateral side".⁵ Anatomic knowledge of the gustatory pathway in the peripheral nervous system (including the solitary tract) in man has been provided by many researchers. That of the secondary pathway in the brainstem, however, remains at a rudimentary stage. Spontaneous destructions of various nervous pathways by diseases occasionally provide an opportunity to verify or even to deny anatomic data collected in animals by the experimental methods.

Recent reports from clinical studies have given further insights into the understanding of taste pathways challenging the concepts of standard physiology textbooks regarding the levels of crossing, the joining with medial lemniscus and also about the cortical representation of taste.

This review is designed to reach a consensus regarding these three aspects of the taste pathway. Loss of taste sensation in relation to lesions at different levels are highlighted in the present review.

Nucleus of tractus solitarius (NTS)

Regarding the NTS, which forms the first order neuron, it is proved that NTS has a caudal portion and rostral portion. All chemosensory information from the tongue carried by the three cranial nerves converges on the rostral part of NTS (rNTS)⁶. Visceral afferent inputs that convey information regarding the physiological status of the gastrointestinal system project to the caudal NTS⁷. Sensory information from the trigeminal nerves, relay in the rNTS. Hence Trigeminal stimulants with irritating effects can modulate taste responses in the rNTS.^{8,9} The rNTS is also a target of descending forebrain projections from the gustatory cortex (GC), prefrontal cortex, central nucleus of the amygdala (AMYce) & lateral hypothalamus (LH)¹⁰. The NTS thus offers the first opportunity for neural signals derived from the somatosensory and GI systems and other CNS nuclei to modulate incoming taste information¹¹.

Second order neurons

For almost a century, it was accepted that the second order neurons cross to the opposite side, it is now believed that leaving the NTS the taste pathways ascend ipsilaterally and cross at midbrain level to reach thalamus. Several recent case reports support this evidence. Extensive studies on lesions in the brain stem, incorporating both the clinical and MRI findings are supporting evidence to the ipsilateral ascend of central taste pathways upto the upper pontine or lower midbrain level. Associated partial sensory disturbance of the face or limb with lack of evidence of medial lemniscus decussation at the upper brainstem suggests that the medial

lemniscus may not directly convey taste sensation.¹² Another case report on a 34 yr old man, with cavernous hemangioma in the brain stem also resulted in ipsilateral taste loss with no other neurological abnormalities, suggesting that taste ascends ipsilaterally and has no connections with the medial lemniscus¹³. A case study conducted in the year 2000, suggested that the central gustatory pathway project from the NTS to the parabrachial nucleus, presumed to be pontine taste area, ascends ipsilaterally and is located laterally from the medial lemniscus.¹⁴

In a recent study conducted by Onada K. and Ikeda M. (2012), 38 patients with taste disorders due to central lesions were examined. The laterality of the taste disorders were extensively studied. It was observed that for lesions located from medulla to Pons, ipsilateral loss of taste was more. For lesions located above the midbrain ipsilateral, contralateral and bilateral cases were noted, but bilateral cases were more frequently detected. From the laterality of the taste disorders relative to the central lesions, it was suggested that the central gustatory pathway ascends ipsilaterally from the medulla to the pons, branches at the upper pons, and then ascends bilaterally from the midbrain to the cerebral cortex¹⁵. In autopsy study conducted in patients who died of pontine hemorrhage it was noted that there was reduction in the number of nerve fibres in the solitary tract compared to the other side and neuronal changes in the solitary tract nucleus on the same side as that of the pontine lesions¹⁶.

Third order neurons

Third order neurons extend from thalamus to gustatory cortex. It was noted in one case that acute right midbrain and thalamic infarcts resulted in bilateral ageusia indicating that some secondary projection fibres may cross in humans and consequently unilateral right sided ischemic lesions cause bilateral gustatory deficits¹⁷. 11 patients with thalamic infarcts and 13 patients with corona radiata infarcts were tested for

dysgeusia .It was noted that majority of the patients with both thalamic and corona radiate infarcts reported dysgeusia on the contralateral side suggesting that the gustatory pathways ascend contralaterally in the cerebral hemispheres and the pathway from the thalamus to the cortex is via the posterior part of the corona radiate¹⁸. Infarcts in the left thalamus resulted in bilateral loss of the ability to differentiate different taste sensations. This finding has led to further investigation into the central projections of taste fibres . In spite of the awareness of the role of thalamus and insular cortex in gustatory sensations the central pathway from the VPM thalamic nuclei in humans has not been elucidated. This is due to the paucity of functional imaging studies on taste disorders in patients with cortical or thalamic stroke. A PET investigation of taste sensation in healthy humans showed that the thalamus, insular cortex, anterior cingulate gyrus, parahippocampal gyrus, lingual gyrus, caudate nucleus, and temporal gyri participated in the discrimination of a salty taste¹⁹. However, these studies have not elucidated the termination laterality of fibers from the thalamic gustatory relay. From the data derived from studies on thalamic and cortical infarcts it was noted that the laterality of taste dominance is in the left hemisphere, with the right hemisphere only involved in the taste sensation of the right hemitongue²⁰. Left post insular lesions resulted in decrease taste perception on the contralateral side according to a case study done in the year 2005²¹. Cortex in humans is located in the rostradorsal insula according to studies conducted in nonhuman primates. Assessment of taste perception both quantitative and qualitative was done in patients with insular cortex lesions .It was observed that in patients with right insular cortex lesion there was loss of both quantitative and qualitative taste perception on the ipsilateral side of the lesion while in patients with left insular cortex lesion there was bilateral loss of taste recognition and ipsilateral loss of taste intensity²².

The unexpected deficit in the left-hemispheric stroke patients for taste recognition on the right side of the tongue suggests that taste information from both sides of the tongue passes through the left insula.

In two patients with supratentorial lesion, hypogeusia was contralateral to the lesion, and in 3 patients with supratentorial lesion hypogeusia was ipsilateral to the stroke. These findings highlight the importance of laterality of taste sensation.^{23,24} Current literature review on gustatory processing indicates that the gustatory function has bilateral representation .Apart from this ,interhemispherical transfer of information is also to be considered. Evidence suggests right insula lesions induce ipsilateral perception and recognition deficits, whereas left insula damage results in an ipsilateral deficit in taste perception but a bilateral deficit in taste recognition.²⁵ This suggests the left insula receives input from both sides of the tongue and relays this information to secondary taste areas. Damage to the left insula is also associated with difficulties in assigning taste adjectives to smell (e.g. classifying an odour as “sweet”) in the absence of impairment in olfactory processing.^{26, 27}

CONCLUSION

The current concepts regarding the central pathways of taste followed in standard physiology and neuroanatomy textbooks need to be reviewed. Based on clinical studies it is proved that the central pathways of taste crosses at higher levels i.e the second order neurons ascend on the ipsilateral side and then cross at the level of midbrain and end in thalamus of the opposite side .The course of the third order neuron is still not clear .From the available clinical data it suggests that the third order neuron ascends bilaterally from thalamus to cortex with the left insular cortex having dominance over the right in taste perception .

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