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Stimulating Oral and Nasal Chemoreceptors for Preventing Aspiration Pneumonia in the Elderly

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Aspiration pneumonia remains a major cause of death in the elderly. However, fundamental and effective treatment has not been established yet. Onset of aspiration pneumonia is based on the presence of dysphagia, such as delayed triggering of the swallowing reflex. The swallowing reflex in the elderly is temperature sensitive, even if it is impaired. Swallowing reflex was delayed when the temperature of the food was close to body temperature. The actual swallowing time shortened when the temperature difference increases. The improvement of swallowing reflex by temperature stimuli could be mediated by the temperature-sensitive TRP channel. Administration of the TRPV1 agonists improves the delay of the swallowing reflex. Red wine polyphenols have been suggested to improve the swallowing reflex by increasing TRPV1 response. Food with menthol, an agonist of TRPM8 which is a cold temperature receptor, also decreased the delay in swallowing reflex. Olfactory stimuli, such as black pepper, can be a useful tool to improve swallowing reflex in people with lower ADL and consciousness levels. By combining these various sensory stimuli, we developed a protocol to start oral intake in patients with aspiration pneumonia This protocol shall continue to contribute to the ingestion of many older people.

Key words――dysphagia; swallowing reflex; aspiration pneumonia

INTRODUCTION

Morbidity and mortality from aspiration pneumonia continues to be a major health problem in the elderly. A swallowing disorder, such as a delayed triggering of the swallowing reflex, exists in patients with aspiration pneumonia. Swallowing is a complex phenomenon that involves tightly coupled interdependence among ongoing sensory and motor events before food enters the oral cavity until the swallow is complete. Dysphagia (swallowing difficulty) often leads to aspiration (ingested material entering the trachea), and may result from impairment of one or more of the many sensory-motor events that comprise normal swallowing. The oral cavity, pharynx, and larynx contain some of the richest and most diverse sensory receptors of the body, represented by dense intricate nerve supply to these regions.[1)]

Exact timing for movement of structures important for swallowing (i.e., tongue, larynx, pharynx) is imperative and highly sensory-reliant, such that even a one-second delay in movement can result in airway invasion of ingested material.[2)] Therefore, maintaining sensory input and its neural process to trigger swallowing is crucial to prevent aspiration pneumonia in elderly people. Swallowing can be divided into three phases: (1) the oral phase, when the tongue propels food posteriorly until the swallowing reflex is triggered; (2) the pharyngeal phase, when the reflexive swallow carries the bolus through the pharynx; and (3) the esophageal phase, when esophageal peristalsis carries the bolus through the cervical and thoracic esophagus into the stomach. Each phase has differential sensory input.

SENSORY INPUT TO INITIATE SWALLOWING

The oropharyngeal region has sensory fibers innervating the mucosa, submucosal, and muscle regions that provide mechanical receptors sensitive to touch and pressure, chemical receptors that respond to taste and water, stretch or length receptor as well as sensory fibers and receptors responding to pain and temperature.[3)] In initiating the oral phase of swallowing, stroking the soft plate, innervated by trigeminal

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nerve, will evoke a rhythmic movement of the tongue similar to the oral phase of swallowing. Sensory input from regions of the oropharynx and hypopharynx will evoke the pharyngeal phase of swallowing which is followed by the esophageal phase. The swallowing reflex, the main component of the pharyngeal phase, is elicited from specific areas of the pharynx and larynx, which are innervated by the glossopharyngeal nerve, the pharyngeal blanch of the vagal nerve, and the superior laryngeal nerve.

ENHANCEMENT OF SENSORY INPUTS ELICITING THE SWALLOWING REFLEX

Effective stimuli eliciting swallowing are mechanical stimuli, chemical and thermal stimulations. In the laryngeal regions, water stimulation is effective in eliciting swallowing reflex in healthy people.[4] However, in patients with aspiration pneumonia or dysphagia due to stroke, water cannot evoke swallowing reflex effectively.[5]

We found that the swallowing reflex was delayed the most around body temperature (30–40°C) and the delay shortened as the difference in temperature apart from body temperature even in elderly patients with aspiration pneumonia.[6] Based on the finding concerning the temperature sensitivity of swallowing reflex in the dysphagic elderly, we also found the agonists for temperature-sensitive transient receptor potential (TRP) channels improve swallowing reflexes in dysphagic patients. The administration of a pastille with capsaicin as an agonist stimulus of TRPV1, a warm temperature receptor, decreased the delay in the swallowing reflex.[7] Water containing menthol, an agonist of TRPM8 which is a cold temperature receptor also decreased the delay in swallowing reflex.[8] These results suggest that the food containing these spices may prevent the elderly from aspiration pneumonia by improving the swallowing reflex.

However, spices such as capsaicin and menthol often induce too strong chemesthesis to use on a regular basis. Therefore, we contrived the means to stimulate TRPV1 without inducing a pungent sensation. One is to use a capsaicin homologue, named capsiate, an extract from non-pungent cultiver of red peppers named CH-19 Sweet.[9] The other mean is to use red wine polyphenol compounds as a flavor in mixture with a small amount of capsaicin.[10]

BRAIN STEM CONTROL OF SWALLOWING

Swallowing movements are produced by a central pattern generator located in the medulla oblongata. Three separates sets of brain stem nuclei mediate the oral, pharyngeal, and esophageal phases of swallowing.[11] The trigeminal nucleus and reticular formation probably contain the oral phase pattern generating neural circuitry. The nucleus tractus solitaries is nuclei for a primary sensory relay and contain the pattern generating circuitry of both the pharyngeal and esophageal phases of swallowing.[12] Like any other central pattern generator, the swallowing central pattern generator and its rhythmic and sequential activity is based on the endogeneous pacemaker properties.[13] On the other hand, the sensory input from the oropharynx is also necessary to initiate and to feedback during discrete and/or sequential swallowing.[14]

CORTICAL CONTROL OF SWALLOWING

For many years, medical literature has asserted that swallowing is controlled primarily by the brainstem. However, advances in human brain imaging has provided evidence that cortical and subcortical structures play a critical role in swallowing control, showing consistent activity in the primary motor cortex, the primary sensory cortex, insular cortex and the anterior cingulated gyrus.[15] Because of its nature, reflexive swallowing activates both sensory and motor areas in the cortex (Fig. 1). The most consistent areas in neuroimaging studies include the primary sensorimotor cortex, sensory motor integration areas, the insula and frontal operculum, the anterior cingulated cortex, and supplementary motor areas.[16] Malandraki and colleagues found that, in cortical areas involved in swallowing, the sensory processing areas were deteriorated by aging rather than motor processing areas.[17]

Swallowing impairment is more common with bilateral hemispheric strokes, but can also occur with unilateral infarction of either hemisphere.[18] The


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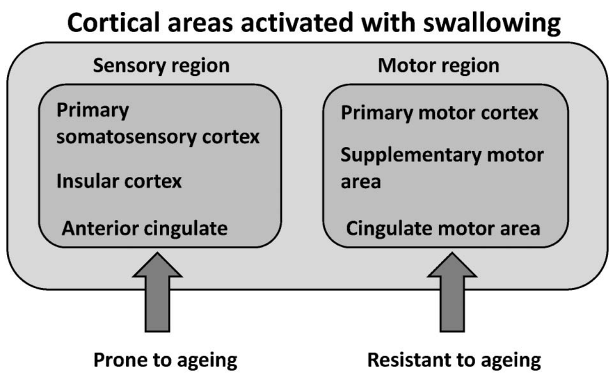

Fig. 1. Cortical Areas Activated with Swallowing

results suggest that one side of the cortex may play a dominant role, and that role would include more control over the initiation and intensity of the swallow. Damage to subcortical regions including the basal ganglia can also induce dysphagia.[19)]

ENHANCEMENT OF CORTICAL AREAS INVOLVED IN THE SWALLOWING REFLEX

We found that the swallowing reflex is continuously improved by chronic stimulation of TRPV1 using a troche containing capsaicin, which is a TRPV1 agonist. The mechanism of why chronic stimulation of thermoreceptors improve swallowing and cough reflexes is speculative. Afferent neuronal pathways provide for discriminative sensation and for homeostatic control of body temperature. In discriminative sensation, the lamina-I neurons carry temperature signals to the final insular cortex with one or two relays.[20)] Since the insular cortex is the crucial cortical area involved in swallowing, we speculate that repeated thermoreceptor stimulation may restore the function of the insular cortex, resulting in restoration of the functions of the swallowing reflex and cough reflex.

Oral care has long been recognized as helping to keep the bacteria in the mouth, leading to preventing pneumonia. We investigated the effects of oral care on airway protective reflexes and found that one-month daily oral care significantly improved both swallowing and cough reflexes in the elderly nursing home patients.[21,22)] Our data suggest that oral care may improve the swallowing reflex and the ability to perform ADLs among elderly patients. Toothbrushing, pain stimuli to gingiva, is known to activate the insular cortex in a functional MRI study.[23)] The insular cortex function is crucial in swallowing and is impaired in patients with aspiration pneumonia and severe dysphagia.[24)] We speculate that repeated oral nociceptive sensory stimulation may restore the function of the insular cortex, resulting in restoration of the functions of swallowing reflex and cough reflex.

When we investigated the effect of black pepper essential oil inhalation on nursing residents, we found that black pepper oil improved the swallowing reflex and serum substance P concentration, suggesting that olfactory stimulation using black pepper is an effective method to treat feeding and swallowing disorders and to prevent aspiration pneumonia.[25)] In a single photon emission tomography study, we found that olfactory stimulation with black pepper oil increased cerebral blood flow in the anterior cingulate cortex and the insular cortex.[25)]

AFFERENT AND CORTICAL PATHWAYS OF OLFACTION

The primary olfactory neuron is a bipolar cell with cell bodies in the olfactory epithelium of the nasal mucosa. The axons, originating in the basal pole of the primary olfactory neurons, are gathered in bundles of some hundred fibers in an envelope of glial cells known as ''sheath cells.'' These guide the neurons, the constant renewal of which innervates the olfactory bulb in a targeted manner. The olfactory bulb is the first relay in the olfactory system; it comprises about 8000 glomeruli, which receive the primary olfactory neuron axons. All messages from sensory neurons expressing a given receptor protein converge on a single glomerulus. The efferent (mitral) glomeruli cells transmit this information to the piriform cortex. There is thus an authentic map of neuronal activation, known as the glomerular odotopic map.[26)] The axons of the olfactory bulb mitral cells successively cross the olfactory peduncle and olfactory tract before projecting onto the primary olfactory cortex; the information processed in the piriform cortex then projects to various brain areas: the orbitofrontal cortex, amygdala, hypothalamus, insula, entorhinal cortex and hippocampus.[27)] The secondary olfactory cortex receives fibers from the primary olfactory areas, and is situated mainly in the insula and entorhinal cortex, the input area of the hippocampus attached to the parahippocampal cortex (Fig. 2).[28,29)] Since the insular cortex is a common pathway of olfactory sysem, other odors as well as black pepper have the possibility to improve the swallowing reflex.

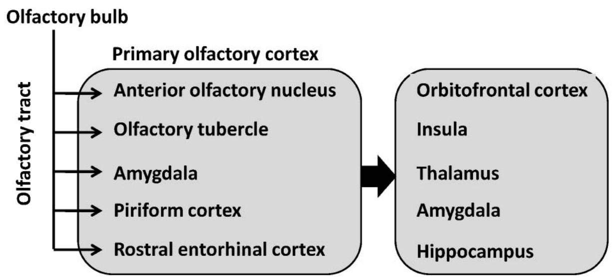

Fig. 2. Afferent Path Way of the Olfactory System from Olfactory Bulb to Cortical Areas

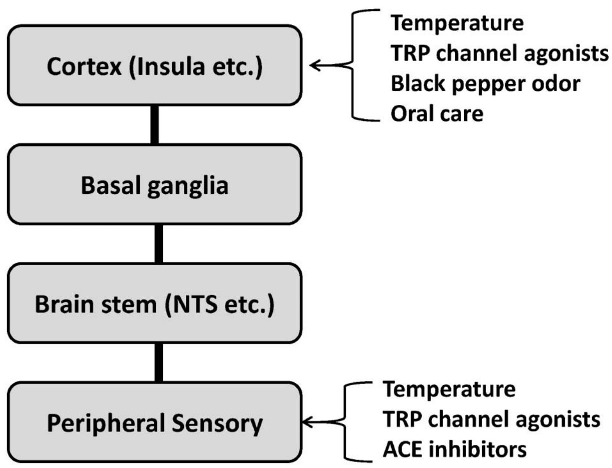

Fig. 3. A Hierarchy of Neuronal Control of Swallowing and Sites of Means to Improve Swallowing Reflex

CONCLUSIONS

In this manuscript, we showed the hierarchical structure of neuronal control of swallowing. Figure 3 shows the site of action in the remedies to improve the swallowing reflex. Using these remedies, we developed a protocol to start eating more efficiently and safely as an intensive stepwise method to start oral intake. Using this protocol, the incidence of pneumonia and the number of febrile days for 1 month from the start of oral intake were significantly reduced.[30] Implementation of this protocol would help avoid re-aspiration in many elderly people with aspiration pneumonia. In addition, this protocol is also applicable to feeding training and rehabilitation of all feeding and swallowing disorders.

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