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Review Article

Treatment and evaluation of dysphagia rehabilitation especially on suprahyoid muscles as jaw-opening muscles☆

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Summary In our aging society, the number of patients with dysphagia, which is associated with disease and aging, is rapidly increasing. The swallowing reflex is a complex process that involves coordinated contractions of swallowing muscles. Many researchers have reported that age-related changes, such as frailty and sarcopenia, affect swallowing muscles and contribute to the decline in the swallowing function. Thus, simple, non-invasive evaluation methods and exercises for swallowing muscles in elderly patients with dysphagia are important.

Anterior—superior hyolaryngeal elevation during swallowing results from contractions of the suprahyoid muscle, which plays a primary role in opening the upper esophageal sphincter, along with relaxation of the cricopharyngeal muscle and laryngeal closure. Thus, many researchers have studied methods for evaluating and augmenting suprahyoid muscles. On the other hand, some researchers have reported on dysphagia rehabilitation focused on jaw-opening actions, because hyolaryngeal elevation muscles correspond with jaw-opening muscles. In this study, we describe a new dysphagia evaluation method and an exercise that focuses on suprahyoid muscles with application of jaw-opening actions.

Abbreviations: SH, suprahyoid; sEMG, surface electromyography; 320-ADCT, 320-row area detector computed tomography; JOF, jaw-opening force; JOE, jaw-opening exercise; JOFT, jaw-opening force test; JOR, jaw-opening against resistance.

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1. Introduction

Dysphagia or swallowing difficulty is a common problem in elderly. In Japan, the prevalence of dysphagia has been reported at 13.8% in community-dwelling elderly individuals [1], and 63.8% in nursing home residents [2]. Symptoms of dysphagia occur not only due to cerebrovascular and neuromuscular disease, but also due to frailty [3,4] and sarcopenia [5,6]. Frailty has been defined by Fried et al. [7] as ''a clinical state of increased vulnerability and decreased ability to maintain homeostasis that is age-related and centrally characterized by declines in functional reserves across multiple physiologic systems.'' Sarcopenia is a geriatric syndrome characterized by progressive and generalized loss of skeletal mass, strength, and function [8]. The swallowing reflex is a complex process that involves coordinated contraction of swallowing muscles. The swallowing muscles, including the tongue [9,10], suprahyoid (SH) [11,12], and pharyngeal muscles [13], are affected by frailty and sarcopenia, which contribute to the decline of the swallowing function. The relationships between dysphagia and frailty or sarcopenia are interdependent. The presence of dysphagia, including malnutrition and aspiration pneumonia, contributes to the development of frailty and sarcopenia, while frailty and sarcopenia contribute to dysphagia. Thus, dysphagia rehabilitation should include a swallowing evaluation, and exercises should be recommended to patients with age-related dysphagia to prevent aspiration pneumonia and improve swallowing function.

Jaw-movement, a common phrase in gerodontology, is comprised of closing movement, lateral movement, and opening movement. Jaw-opening is achieved by contraction of the SH muscles and the lateral pterygoid. Some SH muscles are involved not only in hyoid elevation but also in jaw opening, by virtue of pulling the lower jaw down via contraction of the muscles. These muscles include the mylohyoid muscle, the anterior belly of the digastric muscles, and the geniohyoid muscle. SH muscles also play a primary role in elevating hyolaryngeal structures during swallowing. In other words, the jaw-opening muscles correspond with certain hyoid elevation muscles. In this review article, we describe a newly-developed dysphagia evaluation method and an exercise that focuses on SH muscles with application of a jaw-opening actions.

2. Suprahyoid muscle contraction during swallowing: significance and traditional evaluation

Bolus transport from oral cavity into pharynx is archived by dynamical lingual deformation and movement. As the bolus is propelled into the upper esophagus, the pharynx is typically completely obliterated by the tongue pushing against the contracting posterior pharyngeal wall [14]. In addition, the upper esophageal sphincter (UES) is opened via anterior—superior traction of the hyoid and larynx, due to SH muscle contraction on the relaxed cricopharyngeal muscle [15—17]. Decreased elevation of the hyoid and larynx causes insufficient opening of the UES, resulting in an increased amount of pharyngeal residue and risk of aspiration [18,19]. Superior hyolaryngeal excursion during swallowing is thought to contribute to airway protection prevented aspiration. Anterior hyolaryngeal excursion is thought to be more related to upper esophageal sphincter opening [16,17,19,20]. The mylohyoid and geniohyoid muscles attach to the body of the hyoid [21]. The digastric and stylohyoid muscles, which have no direct attachments to the hyoid bone, are connected with SH muscles and tendinous or fibrous connective tissue [21]. SH muscles play a primary role in controlling hyoid bone movement during swallowing due to their attachment to the hyoid bone [22,23]. Various techniques have been used to study the physiological and biomechanical aspects of SH muscles. A well-known videofluorographic study can evaluate SH muscle strength indirectly by verifying and quantifying the upward and subsequent forward movement of the hyoid bone during swallowing [24,25]. Logemann reported that older men exhibited significantly reduced maximal superior and anterior hyoid movement, as compared to younger men. These data support the hypothesis of reduced muscular reserve [26]. Electromyography (EMG) recordings have been used to assess SH muscle activity patterns [27—29]. Submental surface electromyography (sEMG) recordings are commonly used in the investigation of swallowing disorders and are recorded simultaneously from the submental muscles which consist of mylohyoid, anterior belly of the digastric, geniohyoid, genioglossus, and platysma [30]. However, the primary contributions to submental surface recordings were made by the mylohyoid, anterior belly of the digastric, and geniohyoid muscles [30]. Contributions from the genioglossus and platysma muscles were minimal [30]. Electromyography studies have been used to analyze the temporal characteristics and amplitude aspects of SH muscle contraction, as well as activity patterns of the SH muscle. The duration of submental sEMG activities are affected by sensory inputs such as volume and viscosity of the bolus swallowed [27—29]. Furthermore, Pearson et al. reported that, based on physiological cross-sectional areas of muscles taken from cadavers, the geniohyoid has the most potential to move the hyoid anteriorly, and the mylohyoid has the most potential to move the hyoid superiorly [32]. The use of 320-row area detector computed tomography (320-ADCT) facilitates quantitative kinematic analysis of dynamic changes in SH muscle con-