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Quantitative evaluation of age-related alteration of swallowing function: Videofluoroscopic and manometric studies

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ABSTRACT

Objective: Swallowing function progressively deteriorates with advancing age, leading to high morbidity and mortality in the elderly population. To establish strategies for treatment of age-related swallowing disorders, the mechanisms of such disorders must be quantitatively clarified. The purpose of this paper was to elucidate the swallowing function of healthy elderly individuals by comparison with that of young adults by videofluorographic and manometric examinations.

Methods: The subjects were 70 healthy volunteers with no history of diseases affecting swallowing function. They were classified into three groups according to age: the young adult group (21–32 years of age, $n = 8$), early elderly group (60–69 years of age, $n = 39$), and late elderly group (70–83 years of age, $n = 23$). Their swallowing functions were quantitatively evaluated by videofluorographic and manometric studies.

Results: Videofluorographic examination showed no significant differences in the moving distances of the hyoid bone and larynx in the pharyngeal swallowing phase between the young and elderly groups. The pharyngeal transit time (PTT) of the bolus in the elderly group was longer and the percentage of laryngeal elevation (%LE) was lower than those in the young group. Manometric examination revealed higher hypopharyngeal swallowing pressure in the elderly groups. The traveling velocity of the swallowing pressure in the upper esophageal sphincter (UES) region and the UES relaxation time decreased with aging. Reduction of the UES pressure during the pharyngeal swallowing phase was insufficient in 15.4% of the early elderly group and 30.4% of the late elderly group. Additionally, the UES zone was broadened in 20.5% of the early elderly group and 26.1% of the late elderly group.

Conclusion: Videofluorographic and manometric examinations quantitatively demonstrated that the swallowing reflex was delayed and UES opening was impaired by aging. UES dysfunction may develop secondary by increased tonicity and decreased elasticity of the cricopharyngeal muscle. Stimulation of oropharyngeal sensory function and exercising the laryngeal levator muscles may be effective for age-related swallowing disorders.

1. Introduction

Swallowing is accomplished by precise and coordinated movements of the oral cavity, pharyngolarynx, and esophagus. The pharyngeal phase of swallowing is essential in this series of movements. It is triggered by reflexes arising from a series of voluntary movements of the oral cavity and pharyngeal sensory stimulation. Elevation of the tongue and larynx thrusts the food bolus against the posterior wall, raises the pressure in the pharynx, and seals off the laryngeal aditus. A fall in the pressure of the upper esophageal sphincter (UES) occurs immediately afterward, and a gradient of pressure is established that favors propulsion of the bolus. The wave of high pressure generated in the pharynx then sweeps progressively downward to the stomach [1]. Dysphagia may result from a defect or disorder in any part of the above-described mechanism or from mechanical obstruction to the bolus propelled by this mechanism. In some patients, dysphagia is related entirely to difficulty in initiating voluntary swallowing or to defects in the reflex coordination of oropharyngeal movement.

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The progressive deterioration of swallowing function with advancing age is termed presbyphagia and amplifies the potential risk of aspiration pneumonia. The average life expectancy reaches 83 years in Japan, which is the longest in the world according to the 2013 World Health Statistics [2]. In this aging society, aspiration pneumonia has increasingly become a critical issue and is now the third most common cause of death. During the aging process, the larynx shifts downward, the swallowing reflex becomes delayed, and the strength and velocity of the muscles involved in swallowing decrease. Furthermore, various protective mechanisms such as the glottal closure reflex, airway clearance mechanism, and immune activity decrease with aging. These factors together or alone might cause aspiration or suffocation in the elderly. Ekberg and Feinberg [3] reported that when videofluoroscopic examination was performed in healthy elderly people aged 72–93 years, 25% of them demonstrated pharyngeal ingestion or decreased constriction of the pharyngeal muscle, and 39% of them demonstrated disturbed function of the cricopharyngeal muscle. Only 16% of them showed normal swallowing function. However, the mechanism of deterioration of swallowing function in the elderly remains unclear.

Swallowing function can be assessed by various methods, such as flexible endoscopy [5,6], videofluorography [5,7], manometry [8,9], and echography [10]. In this study, videofluorographic and manometric examinations were used to quantitatively investigate the effect of aging on swallowing function. Videofluorography has been the standard tool for examining dysphagia. It has a great advantage in studying dysphagia of neurological origin, not only in terms of achieving a detailed dynamic evaluation of all phases of deglutition, but also in terms of revealing the presence of aspiration with high sensitivity and specificity [11]. Manometric examination also provides quantitative information on swallowing physiology: the timing and strength of oropharyngeal movement, the manner of upper UES relaxation and contraction, and esophageal function. It is particularly advantageous for evaluating UES function over other swallowing examinations. Based on the results of these two examinations, the morphological and physiological effects of aging on swallowing function were discussed.

2. Materials and methods

2.1. Subjects

The subjects were 70 healthy volunteers with no history of diseases that may affect swallowing function. None of them subjectively complained of an apparent swallowing disorder. They were divided into three groups based on age: a young group (21–32 years of age), early elderly group (60–69 years of age), and late elderly group (70–83 years of age). The young group comprised 8 subjects (2 male and 6 female subjects with a mean age of 24.3 years), the early elderly group comprised 39 subjects (6 male and 33 female subjects, mean age of 65.0 years), and the late elderly group comprised 23 subjects (7 male and 16 female subjects, mean age of 72.7 years). The Ethics Committee of Kochi Medical School Hospital approved the design of this study. Before starting the study, all subjects were asked to sign an informed consent form. In this examination, the volunteer who gathered had more women than men accidentally.

2.2. Examination procedures

All subjects were examined by flexible laryngoscopy and confirmed to have no pharyngolaryngeal lesions prior to the videofluorographic and manometric studies. A series of examinations was performed on the same day.

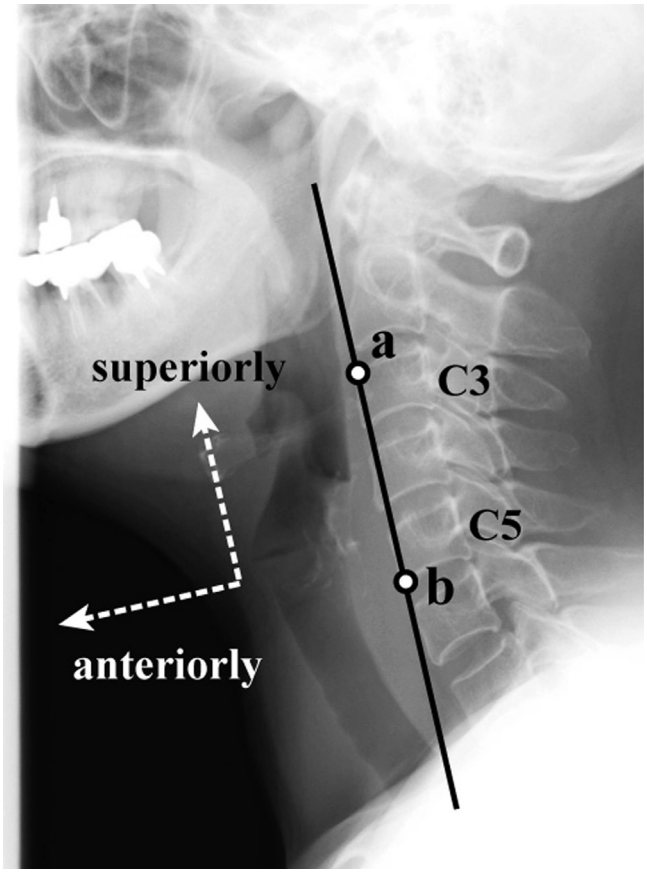

Fig. 1. Quantitative evaluation of videofluorographic examination. Maximum anterior and superior moving distances of the hyoid bone and thyroid cartilage were measured using image analysis software. "Anterior" and "superior" were defined as perpendicular and parallel, respectively, to the line connecting the anterosuperior edge of C3 (a) and the anteroinferior edge of C5 (b).

2.2.1. Videofluorographic examination

The subjects were instructed to stand on an X-ray platform in an upright position. They were asked to drink 10 ml of 140% (w/v) barium sulfate as contrast medium for each swallow. Lateral and anteroposterior images were monitored and simultaneously recorded by a DVD recorder at 30 frames/s. The recorded images were imported into a personal computer and later quantitatively analyzed using dedicated motion analysis software (DIPP-Motion Pro2D; DITECT Corp., Japan). In this study, four parameters were employed: (1) Maximum anterior and superior moving distances of the hyoid bone and thyroid cartilage. "Anterior" and "superior" were defined to be perpendicular and parallel, respectively, to the line connecting the anterosuperior edge of C3 and anteroinferior edge of C5 (Fig. 1). (2) Laryngeal elevation delay time (LEDT), which was calculated by subtracting the time at which the contrast medium reached the pyriform sinus from the time at which the larynx was maximally elevated. It is an indicator of the promptness of the swallowing reflex and laryngeal elevation (normal range, <0.35 s)[4]. (3) Pharyngeal transit time (PTT) of the bolus of contrast medium, defined as the time interval between when the bolus head enters the pharynx and the bolus tail passes through the pharyngeal entrance. (4) Percent laryngeal elevation (%LE), which indicated the ratio of laryngeal elevation to the maximum elevation distance when the bolus head reaches the pyriform sinus.

2.2.2. Manometric examination

Manometric examination was performed in a sitting position. A three-channel intraluminal pressure transducer (16S-307; Gaeltec

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