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THE MASS OF GENIOHYOID MUSCLE IS ASSOCIATED WITH MAXIMUM TONGUE PRESSURE AND TONGUE AREA IN PATIENTS WITH SARCOPENIC DYSPHAGIA

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Abstract: *Objectives:* We investigated the associations about the mass of geniohyoid and tongue muscle and the maximum tongue pressure in patients with sarcopenic dysphagia using ultrasonography. *Design:* Cross sectional study. *Setting:* 5 hospitals including 3 acute and 2 rehabilitation hospitals and 1 older facility. *Participants:* 36 inpatients with sarcopenic dysphagia. *Measurements:* Ultrasonography was performed for geniohyoid muscle and tongue. The area for geniohyoid and tongue muscles in sagittal plane and the mean brightness level (0-255) in the muscle area were calculated. Maximum tongue pressure as strength of swallowing muscle were investigated. Partial correlation coefficient and multiple regression analysis adjusting for age and sex were performed. *Results:* The mean age was 81.1 ± 7.9. Men were 23. The mean BMI was 19.0 ± 4.1. The mean maximum tongue pressure was 21.3 ± 9.3 kPa. The mean cross sectional area for geniohyoid muscles was 140 ± 47 mm^2. The mean brightness for geniohyoid muscle was 18.6 ± 9.0. The mean cross sectional area for tongue muscles was 1664.1 ± 386.0 mm^2. The mean brightness for tongue muscles was 34.1 ± 10.6. There was a significant positive correlation between area of geniohyoid muscle and maximum tongue pressure (r = 0.38, p = 0.04). Geniohyoid muscle area was an explanatory factor for maximum tongue pressure (p = 0.012) and tongue muscle area (p = 0.031) in multivariate analysis. *Conclusions:* Geniohyoid muscle mass was an independent explanatory factor for maximum tongue pressure and tongue muscle mass.

Key words: Dysphagia, sarcopenia, muscle, strength, ultrasonography.

Introduction

Sarcopenia is one of the causes of dysphagia (1-8). Sarcopenic dysphagia is defined as swallowing disorder due to sarcopenia in whole-body and swallowing muscles (3), and diagnostic algorithm for sarcopenic dysphagia was developed and verified recently (9). Evaluation and treatment for sarcopenic dysphagia is important because sarcopenia and dysphagia are common in older people (1, 3, 8). According to diagnostic algorithm for whole-body sarcopenia (1, 2) to evaluate mass, strength and function of swallowing muscles in the patient with sarcopenic dysphagia is important. The mass for swallowing muscles is able to measure using CT or MRI (10, 11). The mass of geniohyoid muscle and pharyngeal muscles in older people were reported smaller than that of young (11, 12). The ultrasonography measurement for swallowing muscle is non-invasive and convenient and can evaluate swallowing muscle mass and quality (12-19). The strength of swallowing muscle as tongue pressure was reported weaker than that of young (20). To investigate relationship between swallowing muscle mass and strength is important to reveal pathological condition in patients with sarcopenic dysphagia.

Swallowing muscle mass and strength are associated with whole-body muscle mass and strength. Tongue strength is associated with whole-body sarcopenia (5, 21, 22). Tongue pressure is associated with occlusal force (23), and the masseter muscle thickness is associated with hand grip strength in men (24). The quality of tongue muscle is associated with the presence of sarcopenic dysphagia (19).

Swallowing muscle mass, strength and quality can be detected by several modalities, although the relationship between swallowing muscle mass and quality is unknown in patients with sarcopenic dysphagia. Utanohara et al. (20) reported age-related change of maximum tongue pressure using tongue pressure measurement instrument. Feng et al. (10) reported CT could detect age-related change of geniohyoid muscle mass, however CT has problems as radiation exposure and expansive facility. Molfenter et al. (11) reported age-related change of swallowing muscle, but MRI is an expensive facility and need several limitations (e.g. metal implantation). Ultrasonography has no problem for radiation, it is portable and low-cost device than CT and MRI. Ultrasonography image provide us not only morphology but also intensity as muscle

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quality. We reported geniohyoid muscle area in older people was smaller than younger people and brightness in older people was higher echo intensity than young (25). However, there is no reports for relationship among swallowing muscle strength, geniohyoid muscle mass and tongue muscle in older inpatients with sarcopenic dysphagia.

The study purpose is to clarify the association between swallowing muscle mass and swallowing muscle strength, and the association of geniohyoid muscle and tongue muscle in sarcopenic dysphagia using ultrasonography.

Methods

Patients and parameters

A cross sectional study was performed in 5 hospitals including 3 acute and 2 rehabilitation hospitals and 1 older facility. Target population is patients aged 65 or older with dysphagia. Patients were included from acute, rehabilitation and chronic stage. Patients were conveniently recruited by their doctors, rehabilitation staffs and care staffs in each facility. Patients 65 years and older were able to answer questionnaires and perform motor task recommended to undergo a dysphagia rehabilitation by doctors included in the study. Exclusion criteria were having inappropriate general and cognitive conditions assessed by their doctors and no sarcopenic dysphagia. Study period was from Oct. 2016 – to Mar. 2017. Ethical committee of Hamamatsu city Rehabilitation Hospital approved this study. All patients were informed by oral explanation and documents and provided written informed consent prior to enrollment.

Examinations except ultrasonography were performed by rehabilitation staff and care staff in each facility. We detected sarcopenic dysphagia using "Diagnostic algorithm for sarcopenic dysphagia" (9). In the algorithm examiner divides participants into three categories as follows: probable sarcopenic dysphagia, possible sarcopenic dysphagia, and no sarcopenic dysphagia. In this algorithm, firstly researcher investigates whole-body sarcopenia in these steps. Muscle mass was evaluated using cut off value of calf circumference as 34 / 33 cm (men / women) (26) or skeletal muscle index by bioelectrical impedance method (7.0 / 5.7 kg/m^2) (27) or dual-energy X-ray absorptiometry energy (7.0 / 5.4 kg/m^2) (27). Muscle strength was evaluated using cut off value of hand grip strength (26 / 18 kg) (27). Gait speed was evaluated using cut off value as 0.8 m/s (1, 2, 27). Next, investigate swallowing function. And if subjects have obvious causative disease of dysphagia, they will be categorized to no sarcopenic dysphagia. In the last step, subjects are investigated maximum tongue pressure as swallowing muscle strength. In this study, we categorized probable and possible patients as sarcopenic dysphagia. Patients of "possible" and probable" group have common status. The status is having sarcopenia, having dysphagia and not having obvious causative disease.

Age, sex, diagnosis for admission, BMI, swallowing function (Food Intake LEVEL Scale: FILS (22)), maximum tongue pressure was investigated. And ultrasonography was performed. FILS was applied to know swallowing function. FILS is a verified examination for reliability and validity (22). In the FILS measurement, patients are divided to 10 levels as their swallowing function, 1-3 are severe level as no oral intake, 4-6 are moderate level as partially oral intake, 7-9 are mild level as totally oral intake, and 10 is normal level. Maximum tongue pressure applied to know strength of swallowing muscles using tongue pressure measurement instrument. In the ultrasonography we measured cross sectional area (CSA) of swallowing muscles to know mass of swallowing muscles. Simultaneously we computed brightness of target area using results of ultrasonography to know quality of swallowing muscle, because high brightness of muscle would indicate presence of fat.

Tongue pressure measurement and Ultrasonography

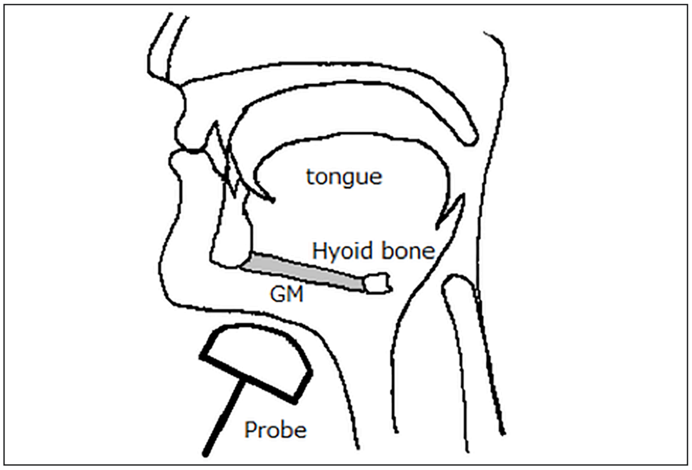
We used a tongue pressure measurement instrument (JMS Hiroshima, Japan) to measure the maximum tongue pressure (5). Tongue pressure was measured using a pressure raised balloon set between the front of the palate and the tongue. The patients were instructed to press the balloon by tongue to their palate folds. Maximum tongue pressure measurements were performed 3 times for each patient, the maximum scores were treated as results. We use an ultrasound material as M-Turbo (Fujifilm Sono Site, Tokyo, Japan) with a 5 to 15 MHz and convex-array transducer. The patients lay on a reclining bed at 30° to maintain head and neck posture. A transducer was set under the jaw in the central of sagittal plane. Patients were instructed to relax to keep their tongue in the rest position without jaw opening and speech. Ultrasonography measurement were performed 3 times for each muscle, the mean scores were treated as results. The ultrasonography was performed by only one well-trained dentist to decrease a bias caused on different testers. The area for tongue and geniohyoid muscles in sagittal plane were calculated using image J (Fig 1). Interesting area was identified manually. The mean brightness level (0-255) in the muscle area was calculated automatically by image J.

Statistical analysis

The means of age, maximum tongue pressure, CSA for tongue muscle, brightness for tongue muscle, CSA for geniohyoid muscle, brightness for geniohyoid muscle were calculated. The median of FILS were calculated, because FILS is ordinal variable. We computed the correlations among swallowing function, maximum tongue pressure and results of ultrasonography using partial correlation coefficient. The first multiple regression analysis was performed to know effects for maximum tongue pressure because maximum tongue pressure is associated with swallowing function (5). In the multiple regression analysis age, sex and CSA for geniohyoid muscle were treated as explanatory variables. First analysis is to know CSA for geniohyoid muscle is associated with maximum tongue pressure even after adjustment for age and sex. The second multiple regression analysis was performed. Second analysis is to know CSA for geniohyoid muscle is associated with tongue muscle mass even after adjustment for age and sex.

All analyses were performed using EZR (28) software, p - values < 0.05 were considered statistically significant in all the analyses.

Figure 1
The method of ultrasonography



The transducer was set under the central of jaw in sagittal plane. GM, Geniohyoid Muscle.

Results

A total of 55 patients initially participated in this study. Number, age, sex (men / women) in each facility as follows: acute hospitals (24, 79.2 ± 8.1 14 / 10), rehabilitation hospitals (25, 81.6 ± 6.1, 14 / 11), older facility (6, 88.8 ± 10.7, 2 / 4). Proportion of patients were acute 43.6%, rehabilitation 43.6% and order facility 10.9%. P-value of Kruskal – Wallis test for age in each facility group were 0.19. There was no significant difference for age. P-value of Fisher's exact test for sex proportion in each facility were 0.58. There was no significant difference for sex proportion. The number of 14 patients were possible sarcopenic dysphagia, and 22 was probable sarcopenic dysphagia. Nineteen patients were excluded because they had no sarcopenic dysphagia. A number of 36 patients including possible and probable sarcopenic dysphagia were finally analyzed for this study.

Diagnoses for admission were as follows: 7 hip fracture, 5 pneumonia, 3 heart failure, 3 cervical spine injury, 2 lumber injury, 2 hypovolemia, 14 others. The mean age was 81.1 ± 7.9. Men were 23. The mean BMI was 19.0 ± 4.1. The median FILS was 8 (7-9). The mean maximum tongue pressure was 21.3 ± 9.3 kPa. The mean CSA for tongue muscles was 1664.1 ± 386.0 mm^2. The mean brightness for tongue muscles was 34.1 ± 10.6. The mean CSA for geniohyoid muscles was 140 ± 47 mm^2. The mean brightness for geniohyoid muscle was 18.6 ± 9.0 (Table 1).

Table 1
Characteristics

Total n=36	
Age	81.4 ± 7.9
Sex (males)	23 (64%)
BMI	19.0 ± 4.1
Food Intake Scale LEVEL	8 (7- 8.25)
Maximum tongue pressure	21.3 ± 9.3 kPa
CSA for tongue muscle	1679.4 ± 312.3 mm^2
Brightness for tongue muscle	35.0 ± 10.5
CSA for geniohyoid muscle	136.3 ± 37.7 mm^2
Brightness for geniohyoid muscle	23.3 ± 5.9

CSA: cross sectional area.

There was a significant positive correlation between maximum tongue pressure and CSA for geniohyoid muscle (r = 0.38, p = 0.04). There was no significant correlation between swallowing function and CSA and brightness for swallowing muscles (Table 2). There was a significant positive correlation between BMI and tongue brightness (r = -0.40, p = 0.03).

Table 3 shows the results of the multivariate regression models for the maximum tongue pressure and CSA for geniohyoid muscle area, age, sex. The CSA for geniohyoid muscle was associated independently with maximum tongue pressure (p = 0.012). Table 4 shows the results of the multivariate regression analysis for cross sectional area for tongue muscle. The geniohyoid muscle was associated independently with cross sectional area for tongue muscle (p = 0.031).

Discussions

In this study, we detected two novel points. First, the CSA for geniohyoid muscle as mass of swallowing muscle was associated with maximum tongue pressure as strength of swallowing muscle in the patients with sarcopenic dysphagia. Second, the area of geniohyoid muscle was associated with the area of tongue muscle.

The CSA for geniohyoid muscle was associated with maximum tongue pressure in sarcopenic dysphagia. Geniohyoid muscle may play an important role for generation of maximum tongue pressure. We speculate the measurement for geniohyoid muscle mass is one of the properly method to diagnose sarcopenia in swallowing muscles. In contrast, tongue area was not associated with maximum tongue pressure. Geniohyoid muscle may play more important role for generating tongue pressure than tongue in sarcopenic dysphagia. CSA for geniohyoid muscle can be used for definite diagnostic criteria for sarcopenic dysphagia.

CSA for geniohyoid muscle was an independent risk factor to tongue muscle area even after adjustment for age and sex.

Table 2
Univariate correlations of each parameter

	BMI	FILS	MTP	GHM area	GHM brightness	Tongue area	Tongue brightness
Age	0.34	0.23	-0.34	0.28	-0.16	0.00	0.00
BMI		0.23	0.28	0.07	0.03	0.21	-0.40[*b]
FILS[*1]			0.19	-0.04	0.28	-0.31	0.22
MTP[*2]				0.38[*a]	-0.28	0.03	0.18
GHM[*3] area					0.10	0.29	0.03
GHM brightness						0.34	0.02
Tongue area							0.32
Tongue brightness							

*1) FILS: Food Intake LEVEL Scale as swallowing function, *2) MTP: Maximum Tongue Pressure, *3) GHM: Geniohyoid Muscle; *a and b) $p < 0.05$ in pairwise two-sided p-values, *a) $p = 0.04$ *b) $p = 0.03$

Table 3
Multivariate regression analysis for maximum tongue pressure

	β	95% CI	SE β	p-value
(Intercept)	28.980	-5.358 to 63.317	16.858	0.095
Geniohyoid muscle area	0.115	0.272 to 0.201	0.043	0.012
Sex	-0.693	-7.868 to 6.483	3.523	0.845
Age	-0.280	-0.710 to 0.149	0.211	0.193

Adjusted $R^2 = 0.14$; CI: Confidence interval, SE: Standard error

Table 4
Multivariate regression analysis for cross sectional area for tongue muscle

	β	95% CI	SE β	p-value
(Intercept)	1189.145	-1.961 to 2380.252	584.755	0.050
Geniohyoid muscle area	3.365	0.3358 to 6.3935	1.487	0.031
Sex	59.318	-189.583 to 308.218	0.485	0.631
Age	-0.078	-14.977 to 14.821	7.314	0.992

Adjusted $R^2 = 0.12$; CI: Confidence interval, SE: Standard error

We speculate the mass of tongue and geniohyoid muscle could be affected similarly by the factors promoting sarcopenia, because each muscle was reported to decline with aging (10, 11, 25). CSA for geniohyoid muscle could be an indicator for degeneration of swallowing muscle mass especially tongue. Loss of swallowing muscle mass causes oral frailty (29-32) and oral sarcopenia (32, 33). Oral frailty should be diagnosed and treated, because oral frailty affects physical frailty, dysphagia, malnutrition, need for long-term care, and mortality (29, 32).

Consideration to apply ultrasonography for swallowing muscle mass to stroke patients with sarcopenia could be useful to investigate the cause of dysphagia, although patients in this study were only sarcopenic dysphagia. Because stroke patient could have a risk for sarcopenia (34) and Sporns et al reported severity for dysphagia in patient having stroke with low muscle mass of geniohyoid muscle were worse than without low muscle mass of geniohyoid muscle (35). Moreover, chair-stand exercise is associated with dysphagia improvement in stroke patients with dysphagia (36). If a stroke patient with sarcopenia of swallowing muscle is detected using ultrasonography, the information can be contributed to consideration for sarcopenia treatment such as chair-stand exercise and as rehabilitation nutrition (4).

There are some limitations in this study. First, there were less severe dysphagia patients. Previous researches using ultrasonography (19) and CT (10) indicated the correlation between swallowing function and swallowing muscles. On the other hand, in this study there was no significant correlation between swallowing function and swallowing muscles. Second, sample size was relatively small. Third, we did not use the Asian Working Group for Sarcopenia (AWGS) 2019 criteria (37) for sarcopenia diagnosis. However, all patients included in this study were diagnosed as sarcopenic dysphagia whether the diagnostic criteria for AWGS2014 or AWGS2019.

In conclusion, geniohyoid muscle mass was an independent explanatory factor for maximum tongue pressure and tongue muscle mass. These results indicate the association between swallowing muscle mass and strength. The CSA of geniohyoid muscle measured by ultrasonography could be one of indicator for definite diagnosis of sarcopenic dysphagia.

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Ethical standards: Ethical committee of Hamamatsu city Rehabilitation Hospital was approved this study. All patients were informed by documents and provided written informed consent prior to enrollment.

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