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ORIGINAL ARTICLE

Preoperative geniohyoid muscle mass in esophageal cancer patients is associated with swallowing function after esophagectomy

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Abstract

Aim: Dysphagia often develops after esophagectomy. The geniohyoid muscle is involved in swallowing movements, but its significance in esophagectomy patients remains unclear. We investigated the relationship of preoperative geniohyoid muscle mass with post-esophagectomy swallowing function.

Methods: We retrospectively analyzed 114 patients who underwent esophagectomy and gastric conduit reconstruction for esophageal malignancy. We evaluated preoperative geniohyoid muscle sagittal cross-sectional areas (cm^2) using computed tomography. Median values for each sex were considered as cutoff values. Dysphagia severity was assessed using the Penetration–Aspiration Scale (PAS) during videofluoroscopic swallowing studies performed 7–10 days postoperatively.

Results: The cross-sectional area was significantly larger in males than in females (3.2 ± 0.7 vs. 2.4 ± 0.5, $p < 0.01$: median in males: 3.2 cm^2, and in females: 2.3 cm^2). These values were used to define high and low cross-sectional area groups. The cross-sectional area correlated positively with grip strength (correlation coefficient (CC) = 0.530) and skeletal muscle index (CC = 0.541). Transthyretin levels (22.4 ± 6.8 vs. 25.4 ± 5.5, $p = 0.03$) and cross-sectional area (2.6 ± 0.7 vs. 3.2 ± 0.8, $p < 0.01$) were significantly lower in patients with (PAS score ≥6; 20%) than in those without aspiration during fluoroscopic swallowing studies. Recurrent laryngeal nerve palsy was significantly more frequent in those with than in those without aspiration during fluoroscopic studies (22% vs. 5%, $p = 0.03$). In the multivariate analysis, low cross-sectional area and recurrent laryngeal nerve palsy were both independent risk factors for aspiration during swallowing studies (odds ratio = 3.6, $p = 0.03$ and odds ratio = 6.6, $p = 0.02$, respectively).

Conclusion: Preoperative geniohyoid muscle mass, evaluated using neck computed tomography, can predict dysphagia after esophagectomy.

KEYWORDS
dysphagia, esophagectomy, geniohyoid muscle, recurrent laryngeal nerve palsy, swallowing function

1 | INTRODUCTION

Esophagectomy is a highly invasive treatment for esophageal cancer, and reducing complications is important. Pulmonary complications and other serious postoperative complications frequently occur.[1] One of the most common causes of pneumonia occurring after esophagectomy is dysphagia.[2] Dysphagia may occur after esophagectomy due to several reasons: an abnormal elevation of the larynx caused by scarring around the trachea and larynx, decreased cough reflux due to decreased blood flow in the trachea, bending of reconstructed organs, and decreased swallowing pressure due to laryngeal nerve paralysis.[2,3] Recently, sarcopenic dysphagia has been recognized as a swallowing disorder associated with systemic sarcopenia.[4] Aging and malnutrition are risk factors for systemic sarcopenia, and patients with esophageal cancer who often have these characteristics are considered to frequently have sarcopenic dysphagia.

The geniohyoid muscle is related to swallowing and has attracted attention as a measurement target for evaluating swallowing function.[5] The geniohyoid muscle volume has been associated with dysphagia in stroke patients[6] and in older individuals.[7] However, the relationship of this muscle with dysphagia in patients with esophageal cancer is unknown. We hypothesized that geniohyoid muscle mass, measured using computed tomography (CT) before esophagectomy, would be associated with postoperative swallowing function.

2 | METHODS

2.1 | Patients

We conducted this retrospective cohort study of patients who underwent esophagectomy at Hamamatsu University School of Medicine. Overall, 270 patients underwent esophagectomy and gastric tube reconstruction for esophageal malignancies between April 2017 and February 2023. Among 270 cases, we selected and assessed 114 cases after excluding 57 patients who did not undergo a video-fluoroscopic swallowing study (VFSS) postoperatively, 84 who underwent VFSS after postoperative day 11, seven who were unable to undergo VFSS in a sitting position, and eight who did not have a preoperative CT image of the geniohyoid muscle (Figure 1). All included patients underwent esophagogastroduodenoscopy and CT from the neck to the pelvis to determine the clinical stage. The clinical stages were determined based on the Union for International Cancer Control TNM classification of malignant tumors, 8th edition.[8]

2.2 | Assessment

2.2.1 | Sagittal cross-sectional area of the geniohyoid muscle

CT images taken immediately before surgery were analyzed. The SYNAPSE Vincent volume analyzer version 6.8 (Fujifilm Medical, Tokyo, Japan) was used, and two-dimensional images were reformatted and constructed in the sagittal and coronal planes. Relative to the coronal plane, the boundary of the geniohyoid muscle in the midsagittal plane section was identified, and the geniohyoid muscle area (GHMA, cm^2) was measured (Figure 2A,B). The median value for each sex was used as the cutoff value for the GHMA.

2.2.2 | Severity of postoperative dysphagia

At our institution, VFSS was routinely performed 7–10 days after esophagectomy. VFSS was canceled or postponed if anastomotic leakage or complications making it difficult to perform VFSS were suspected; such cases were excluded from this study. VFSS was performed by physicians specializing in rehabilitation and speech–language–hearing therapy. Dysphagia severity was assessed using the Penetration–Aspiration Scale (PAS),[9] which is an 8-point scale for evaluating airway invasion. This scale was developed to characterize the severity of airway invasion events viewed during VFSS, capturing

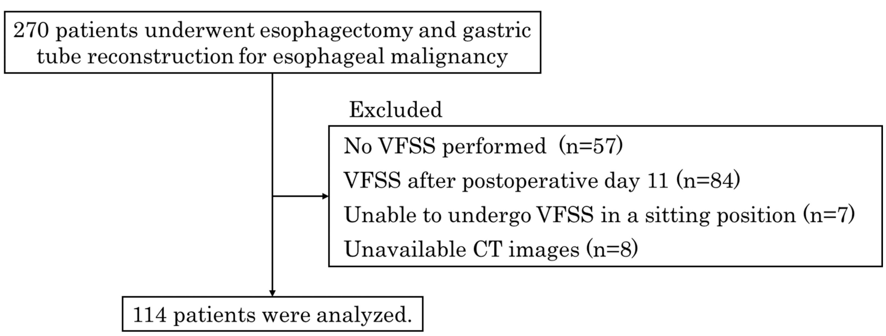

FIGURE 1 Flow diagram of this study.

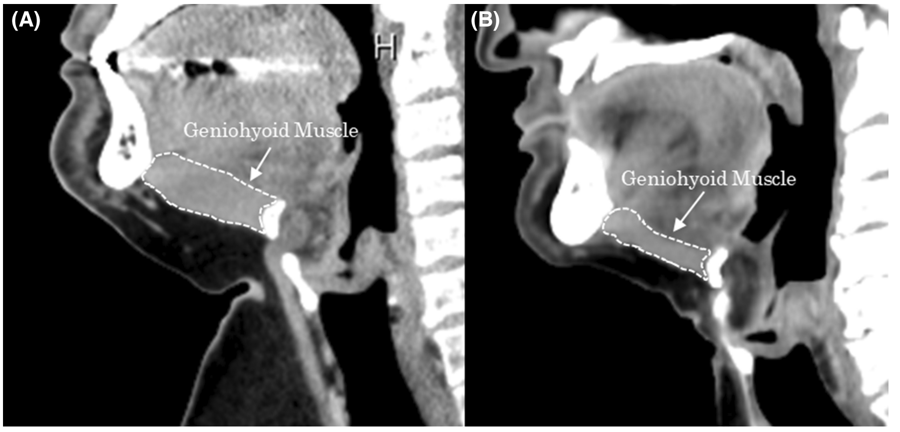

FIGURE 2 Representative computed tomography image used for the measurement of the geniohyoid muscle. (A) Non-sarcopenic case (GHMA 4.61 cm^2). (B) Sarcopenic case (GHMA 2.50 cm^2). GHMA: geniohyoid muscle sagittal cross-sectional area.

the location up to which material is observed to travel, and then qualifying that information based on whether the material remains at the end of the swallow or has been ejected to safer (anatomically higher) locations. A PAS score of one indicates no entry of material into the airway; PAS scores of 2–5 indicate penetration of material; and PAS scores of ≥6 indicate tracheal aspiration of material. This scale is widely used as an industry standard for the interpretation of VFSS.[10]

2.2.3 | Collection of other data

Blood test values obtained closest to surgery were examined, and the cutoff value was the lower limit of the reference range. Handgrip strength and quadriceps muscle strength were measured once each on the right and left sides, and the higher of the two values was used for each strength assessment. Arm circumference (AC), triceps skinfold thickness (TSF), and calf circumference (CaC) were measured preoperatively to estimate body fat and skeletal muscle mass. Bioelectrical impedance analysis (BIA) was performed using an InBody S-10 (InBody Japan Inc., Tokyo, Japan) to measure body composition. BIA measures the impedance of the human body and can estimate muscle mass and body water content by substituting the participant's height into the regression equation for each study population.[11] Skeletal muscle index (SMI) was calculated by dividing the skeletal muscle mass measured with BIA by the square of the height. Water content was evaluated using the ratio of extracellular water to total body water (ECW/TBW) measured with BIA. A high ECW/TBW is thought to indicate a state of edema or sarcopenia.[11,12] Additionally, the phase angle measured by BIA is calculated using the arctangent of the reactance-to-resistance ratio and is independent of traditional regression equations for estimating body composition.[11] A low phase angle is thought to indicate poor cell health condition.[11,13] Regarding CaC, grip strength, and SMI, the cutoff values were set at 34 cm, 28 kg, and 7.0 kg/m^2, respectively, for males and 33 cm, 18 kg, and 5.7 kg/m^2, respectively, for females, based on the Asian Working Group for Sarcopenia 2019 (AWGS 2019).[14] Postoperative complications that occurred within the initial 3 months after esophagectomy were evaluated according to the Clavien–Dindo classification by the attending physicians.[15] Postoperative pulmonary complications were evaluated using the definitions by the American Thoracic Society, the Centers for Disease Control and Prevention, and the Utrecht Pneumonia Scoring System.[16] Laryngoscopy was performed immediately before VFSS, and if vocal cord paralysis was observed, recurrent laryngeal nerve palsy (RLNP) was diagnosed.

2.2.4 | Perioperative care and surgical approach

All participants received standardized perioperative care according to HOPE, a multidisciplinary perioperative care team implemented at our institution in 2017.[17] At our institution, we routinely perform VFSS before initiating postoperative oral intake. Meals were started with a dysphagia diet and was later changed to a liquid diet in accordance with improvements in swallowing function.[17]

At our institution, right transthoracic subtotal esophagectomy with 2- or 3-field LN dissection was performed as a standard surgical procedure. Except for patients with low surgical tolerance or high surgical risk, bilateral cervical LNs dissection was generally performed for cancer in the middle or upper thoracic esophagus. Gastric tube reconstruction was performed with hand-sewn anastomosis in the neck.[18] Postoperative follow-up involved CT every 6 months and esophagogastroduodenoscopy annually for 5 years post-surgery. Overall survival (OS) was calculated from the day of surgery to the day of death. Patients were followed up until death or until completion of the study (January 31, 2024). Patients whose follow-up was interrupted or ongoing were considered as censored, with OS calculated based on the duration (days) until censoring.

2.3 | Statistical analysis

Parametric data are presented as means±standard deviation, nonparametric data as medians and interquartile ranges, and categorical data as percentages. Differences in categorical variables between groups were tested using the chi-square or Fisher's exact test. For continuous data, Student's *t*-test or Mann–Whitney *U* test was performed. Correlations between GHMA and other parameters were assessed using Pearson's product–moment correlation coefficient (CC) for parametric data and Spearman's rank CC for non-parametric data. Multivariate logistic regression analysis was performed to assess risk factors associated with postoperative dysphagia. Variables in the multivariate analysis were those that showed significant differences in the univariate analysis. Survival curves were generated using the Kaplan–Meier survival method and log-rank test. The threshold for significance was set up at *p* values <0.05.

All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria).[19]

3 | RESULTS

The clinical characteristics of the 114 patients included in the study are presented in Table 1. The average patient age was 67.8 years. The majority of patients were male. The predominant esophageal cancer was squamous cell carcinoma, followed by adenocarcinoma, whereas neuroendocrine carcinoma, malignant melanoma, and gastrointestinal stromal tumors accounted for a few cases. More than half of patients received preoperative chemotherapy or chemoradiotherapy, and more than half of the patients also underwent cervical lymph node dissection. The mean GHMA in this cohort was $3.1 \pm 0.8\,cm^2$. GHMA was significantly larger in males than in females ($3.2 \pm 0.7\,cm^2$ vs. $2.4 \pm 0.5\,cm^2$, $p < 0.01$). The median GHMA was $3.2\,cm^2$ in males and $2.3\,cm^2$ in females; these values were used as cutoff values to define high and low GHMA. The low GHMA group was significantly older (70.0 ± 9.8 vs. 65.6 ± 9.6 years, $p < 0.01$) and had a lower body mass index (20.8 ± 2.6 vs. $22.5 \pm 3.0\,kg/m^2$, $p < 0.01$) than the high GHMA group. There were no significant differences in performance status, histology, tumor location, clinical stage, preoperative treatment, surgical approach, cervical lymph node dissection, and reconstruction route between the two groups.

The correlations between the GHMA score and preoperative factors considered to be related to systemic sarcopenia are shown in Table 2. GHMA had moderately significant positive correlations with body mass index (CC = 0.507, $p < 0.01$), handgrip strength (CC = 0.530, $p < 0.01$), and SMI (CC = 0.541, $p < 0.01$), and weak positive correlations with AC (CC = 0.487, $p < 0.01$), CaC (CC = 0.439, $p < 0.01$), and quadriceps strength (CC = 0.417, $p < 0.01$). Meanwhile, GHMA had no correlation with age, albumin level, transthyretin level, TSF, ECW/TBW, or phase angle.

The postoperative PAS scores are presented in Table 3. Material entered the airway in 41% of patients. Twenty-three patients (20%) were categorized as having aspiration beyond the vocal folds (i.e., aspiration; PAS score ≥6). Patients were then classified according to the presence or absence of aspiration during VFSS, and their relationship with clinical factors was examined (Table 4). Age and surgical technique were not associated with postoperative aspiration during VFSS. The group with postoperative aspiration during VFSS had a significantly lower transthyretin level (22.4 ± 6.8 vs. 25.4 ± 5.5, $p = 0.03$) and significantly lower GHMA ($2.6 \pm 0.7\,cm^2$ vs. $3.2 \pm 0.8\,cm^2$, $p < 0.01$) than the group without aspiration. The frequency of RLNP was significantly higher in the group with than in the group without aspiration during VFSS (22% vs. 5%, $p = 0.03$).

The variables were converted to binary data to identify risk factors for tracheal aspiration. In the multivariate analysis, low GHMA and RLNP were both independent risk factors for tracheal aspiration (odds ratio (OR) = 3.6, $p = 0.03$ and OR = 6.6, $p = 0.02$, respectively).

We also examined whether dysphagia and related factors affected the occurrence of grade ≥ II pneumonia. Postoperative pneumonia occurred in nine patients (8%); however, PAS, GHMA, and RLNP were not associated with postoperative pneumonia (Table 5). Furthermore, upon examining the effect of GHMA on survival prognosis, no significant difference was observed in OS between high and low GHMA ($p = 0.31$, Figure 3).

4 | DISCUSSION

This retrospective study of 114 patients who underwent esophagectomy for esophageal malignancy showed that the severity of postoperative dysphagia was associated with geniohyoid muscle mass, as measured using preoperative neck CT.

Recently, the effects of sarcopenia have been recognized in various fields. Several reports have suggested an association between sarcopenia and surgical outcomes after esophagectomy.[20] Sarcopenia is a term used to describe a decrease in muscle mass, strength, and function throughout the body. Research focused specifically on the muscle mass involved in swallowing is also attracting attention.[5] However, research on this topic related to esophageal cancer is limited.[2] In this study, the correlation between GHMA and factors related to systemic sarcopenia was investigated. AC reflects body fat mass and skeletal muscle mass, whereas TSF reflects body fat mass.[21] CaC has been reported to be correlated with limb skeletal muscle mass.[22] CaC and grip strength are considered useful for estimating limb skeletal muscle mass in cases where body composition analyzers cannot be used and are also used in sarcopenia screening according to AWGS 2019 guidelines.[14] The ECW/TBW ratio is the ratio of extracellular water to total body water, which has been reported to be related to edema and nutritional status.[12] The phase angle serves as an indicator of cell membrane integrity and water distribution inside and outside the cell membrane, and it tends to decrease with age due to muscle mass loss and declining body fluid proportions.[11,13] GHMA showed a significant positive correlation with AC, CaC, grip strength, and SMI, although the correlations were not strong. Furthermore, age, albumin levels, and transthyretin levels did not show clear correlations with GHMA. These results suggest that measuring geniohyoid muscle mass is useful for specifically estimating swallowing function rather than systemic sarcopenia. The reason for the absence of a relationship between GHMA and TSF in

TABLE 1 Patient characteristics.

	All ($n = 114$)	Low GHMA ($n = 57$)	High GHMA ($n = 57$)	p-value
Age (years)	67.8 ± 9.8	70.0 ± 9.8	65.6 ± 9.6	<0.01
Sex, male/female (%)	95 (83)/19 (17)	48 (83)/9 (18)	47 (84)/10 (16)	>0.99
BMI, kg/m^2	21.6 ± 2.9	20.8 ± 2.6	22.5 ± 3.0	<0.01
Performance status (%)				0.37
0	88 (77)	41 (72)	47 (83)	
1	24 (21)	15 (26)	9 (16)	
2	2 (2)	1 (2)	1 (2)	
Histologic subtype (%)				0.87
Squamous cell carcinoma	83 (73)	43 (75)	40 (70)	
Adenocarcinoma	27 (24)	12 (21)	15 (26)	
Others	4 (3)	2 (4)	2 (4)	
Location of tumor (%)				0.39
Ce, Ut	16 (14)	9 (16)	7 (12)	
Mt	40 (35)	23 (40)	17 (30)	
Lt	36 (32)	14 (25)	22 (39)	
Ae, EGJ	22 (19)	11 (19)	11 (19)	
cStage (%)				0.86
0, I	40 (35)	19 (33)	21 (37)	
II	22 (19)	12 (21)	10 (18)	
III	44 (39)	21 (37)	23 (40)	
IV	8 (7)	5 (9)	3 (5)	
Preoperative treatment (%)				0.58
None	58 (51)	30 (53)	28 (49)	
Chemotherapy	50 (44)	23 (40)	27 (47)	
Chemoradiotherapy	6 (5)	4 (7)	2 (4)	
Thoracic approach (%)				0.37
Thoracotomy	25 (22)	15 (26)	10 (18)	
Thoracoscopy	89 (78)	42 (74)	47 (83)	
Abdominal approach (%)				0.43
Laparotomy	39 (34)	17 (30)	22 (39)	
Laparoscopy	75 (66)	40 (70)	35 (61)	
Cervical lymph node dissection performed (%)	61 (54)	32 (56)	29 (51)	0.71
Reconstruction route (%)				0.58
Posterior mediastinal	99 (87)	48 (84)	51 (90)	
Retrosternal	15 (13)	9 (16)	6 (11)	
GHMA (cm^2)	3.1 ± 0.8	2.5 ± 0.5	3.7 ± 0.7	<0.01

Note: Values are presented as mean ± standard deviation.

Abbreviations: Ae, abdominal esophagus; BMI, body mass index; Ce, cervical esophagus; EGJ, esophagogastric junction; GHMA, geniohyoid muscle midsagittal area; Lt, lower thoracic esophagus; Mt, mid-thoracic esophagus; Ut, upper thoracic esophagus.

this study was thought to be because TSF indicates fat rather than muscle mass. Additionally, approximately half of the patients in this study received chemotherapy or chemoradiotherapy before surgery, and the ECW/TBW ratio may not be related to muscle mass. In this study, geniohyoid muscle mass, but not other sarcopenia indicators, was most strongly associated with postoperative dysphagia. As the geniohyoid muscle is involved in swallowing movements, it may have a direct and significant impact on dysphagia.

Appropriate activity of swallowing-related muscles, such as the suprahyoid muscle, and tongue contraction are important during swallowing.[23–25] The suprahyoid muscles include the digastric, stylohyoid, mylohyoid, and geniohyoid muscles, each with slightly different functions.[23] The digastric muscle works to retract the chin and open the mouth, pulls the hyoid bone and the floor of the oral cavity upward, and is involved in deglutition.[23] The mylohyoid muscle also raises the floor of the mouth and tongue and aids in deglutition and speech.[23] The stylohyoid pulls the hyoid bone upward and backward, assisting in lifting the tongue and lengthening the floor of the mouth.[23] The geniohyoid muscle helps bring the hyoid bone upward and forward, widening the airway passage,[23] and plays a central role in swallowing.[24] The geniohyoid muscle is a short, slender, ribbon-shaped muscle that originates from the inferior genial tubercle and is inserted into the body of the hyoid bone.[23] In recent years, ultrasound examinations of swallowing-related muscles, especially the geniohyoid muscle, have been gaining attention.[5] Visualizing the geniohyoid muscle and evaluating its morphology and movement using ultrasonography may be useful in assessing swallowing function and determining the effectiveness of therapeutic interventions.[5] Neck ultrasound is not routinely performed in patients with esophageal cancer. In contrast, CT-based assessment of geniohyoid muscle mass is simple and effective for most patients with esophageal cancer, as cervical CT is often performed for esophageal cancer. Feng et al. reported that the cross-sectional area of the geniohyoid muscle measured using CT in older patients was associated with aging and aspiration.[25] Hasida et al. reported that the cross-sectional area of the geniohyoid muscle measured using CT is a potential predictor of postoperative dysphagia after salvage surgery in patients with head and neck cancer.[26] Their results suggested that the geniohyoid muscle mass is associated with swallowing function, which is consistent with the findings of our study.

TABLE 2 Correlation between GHMA and preoperative parameters.

Values	Correlation coefficient
Age	−0.269**
Albumin	0.046
Transthyretin	0.278**
BMI	0.507**
Arm circumference	0.487**
Calf circumference	0.439**
Triceps skinfold thickness	0.138
Quadriceps strength	0.417**
Handgrip strength	0.530**
SMI	0.541**
ECW/TBW	−0.176
Phase angle	0.334**

Note: Correlation coefficients (CC) were analyzed using Spearman's CC for non-normally distributed data or using Pearson's CC for normally distributed data.

Abbreviations: BMI, body mass index; ECW/TBW, extracellular water/total body water; GHMA, geniohyoid muscle midsagittal area; SMI, skeletal muscle mass index.

The * marks represent p values and *$p < 0.05$. **$p < 0.01$.

In the present study, the preoperative geniohyoid muscle mass and RLNP were independent risk factors for postoperative dysphagia. It is thus important to evaluate geniohyoid muscle mass preoperatively as it may be useful in predicting risk and preventing aspiration pneumonia and may also be meaningful for preoperative intervention. After esophagectomy, swallowing function declines at a certain frequency, and it is important that pneumonia is prevented. We previously reported that the frequency of pneumonia in these patients was reduced by introducing a multidisciplinary medical care team, proactively providing rehabilitation before surgery, and adjusting individual meals based on swallowing assessment after surgery.[17] For patients with dysphagia, we started with a homogeneous, smooth meal that could be scooped with a spoon and assembled into an appropriate bolus with simple intraoral movements. The texture of

TABLE 3 Postoperative Penetration–Aspiration Scale (%).

Point	Description	All ($n = 114$)
1	Material does not enter the airway	67 (59)
2	Material enters the airway, remains above the vocal folds, and is ejected from the airway	9 (8)
3	Material enters the airway, remains above the vocal folds, and is not ejected from the airway	8 (7)
4	Material enters the airway, contacts the vocal folds, and is ejected from the airway	4 (4)
5	Material enters the airway, contacts the vocal folds, and is not ejected from the airway	3 (3)
6	Material enters the airway, passes below the vocal folds, and is ejected into the larynx or out of the airway	7 (6)
7	Material enters the airway, passes below the vocal folds, and is not ejected from the trachea despite effort	11 (10)
8	Material enters the airway, passes below the vocal folds, and no effort is made to eject	5 (4)

TABLE 4 Risk factors for aspiration during VFSS.

	PAS ≥6 aspiration (+) $n=23$	PAS <6 aspiration (−) $n=91$	Univariate p-value	Multivariate OR (95% CI)	Multivariate p-value
Age	67.5±7.4	67.8±10.4	0.83		
Sex					
Male	19 (83%)	76 (84%)	>0.99		
Female	4 (17%)	15 (16%)			
BMI	20.7±2.6	21.9±2.9	0.08		
Performance status					
0	17 (74%)	71 (78%)	0.78		
1 or 2	6 (26%)	20 (22%)			
Location of tumor			0.81		
Ce or Ut	4 (17%)	12 (13%)			
Mt	9 (39%)	31 (34%)			
Lt	7 (30%)	29 (32%)			
Ae, EGJ	3 (13%)	19 (20%)			
Preoperative treatment					
None	12 (52%)	46 (51%)	>0.99		
CT or CRT	11 (48%)	45 (49%)			
Albumin	4.0 (3.7–4.3)	4.1 (3.8–4.7)	0.65		
Transthyretin	22.4±6.8	25.4±5.5	0.03		
Low	11 (50%)	28 (32%)	0.14	1.7 (0.59–4.57)	0.34
High	11 (50%)	60 (68%)			
Arm circumference	26.0±2.3	26.6±3.1	0.43		
Calf circumference					
Low	12 (66%)	32 (41%)	0.07		
High	6 (33%)	47 (59%)			
Triceps skinfold thickness	10 (8–14)	11 (8–15)	0.50		
Quadriceps strength	33.0 (27.4–44.9)	33.8 (31.2–40.3)	0.55		
Handgrip strength					
Low	0 (0%)	5 (12%)	0.58		
High	12 (100%)	37 (88%)			
SMI					
Low	11 (48%)	31 (36%)	0.34		
High	12 (52%)	56 (64%)			
ECW/TBW	0.393±0.008	0.390±0.007	0.09		
Phase angle	4.7±0.8	5.0±0.7	0.11		
GHMA	2.6±0.7	3.2±0.8	<0.01		
Low	16 (70%)	39 (43%)	0.03	3.6 (1.16–11.1)	0.03
High	7 (30%)	52 (57%)			
Cervical lymph node dissection					
None	8 (35%)	45 (49%)	0.25		
Performed	15 (65%)	46 (51%)			
Reconstruction route					
Posterior mediastinal	20 (87%)	79 (87%)	>0.99		
Retrosternal	3 (13%)	12 (13%)			

TABLE 4 (Continued)

	PAS ≥6 aspiration (+) *n* = 23	PAS <6 aspiration (−) *n* = 91	Univariate *p*-value	Multivariate OR (95% CI)	Multivariate *p*-value
RLNP					
Grade ≥ I	5 (22%)	5 (5%)	0.03	6.6 (1.30–33.80)	0.02
None	18 (78%)	86 (95%)			

Note: Values are presented as mean ± standard deviation. The cutoff value for transthyretin was 22. The cutoff values for GHMA were 3.2 for males and 2.3 for females.

Abbreviations: Ae, abdominal esophagus; BMI, body mass index; Ce, cervical esophagus; CRT, chemoradiotherapy; CT, chemotherapy; ECW/TBW, extracellular water/total body water; EGJ, esophagogastric junction; GHMA, geniohyoid muscle midsagittal area; Lt, Lower thoracic esophagus; Mt, mid-thoracic esophagus; PAS, Penetration–Aspiration Scale; RLNP, recurrent laryngeal nerve paralysis; SMI, skeletal muscle index; Ut, upper thoracic esophagus.

TABLE 5 Association between postoperative pneumonia and dysphagia.

		Postoperative pneumonia (+) *n* = 9	Postoperative pneumonia (−) *n* = 105	*p*-value
PAS	1	6 (67%)	61 (58%)	0.90
	2–5	2 (22%)	22 (21%)	
	6–8	1 (11%)	22 (21%)	
GHMA		3.4 ± 1.1	3.1 ± 0.7	0.18
	Low	5 (56%)	52 (50%)	1.00
	High	4 (44%)	53 (51%)	
RLNP	Grade ≥ I	0 (0%)	10 (10%)	1.00
	None	9 (100%)	95 (90%)	

Note: The cutoff values for GHMA were 3.2 for males and 2.3 for females.

Abbreviations: GHMA, geniohyoid muscle midsagittal area; PAS, Penetration–Aspiration Scale; RLNP, recurrent laryngeal nerve paralysis.

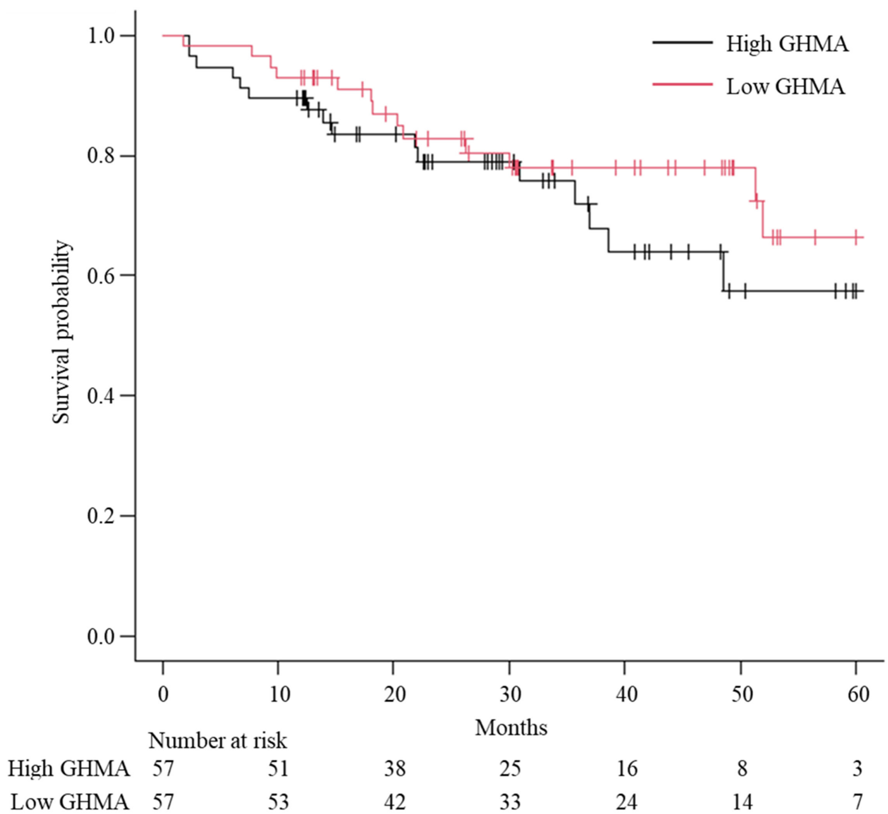

FIGURE 3 Kaplan–Meier curve for low and high GHMA.

the meal was adjusted based on the patient's condition. One week later, swallowing function was evaluated again using VFSS. In the present study, we found no relationship between dysphagia and the occurrence of pneumonia, which may have been due to these appropriate interventions for patients with poor swallowing function. Postoperative OS can be influenced by pulmonary complications after esophageal cancer surgery[27]; however, GHMA did not show significant impact on OS in the present study. Importantly, long-term survival was not adversely affected in patients with low GHMA if they received appropriate dietary intake, nutritional management, and rehabilitation to prevent aspiration pneumonia, despite their elevated risk of postoperative swallowing dysfunction.

Preoperative intervention is expected to be effective in treating sarcopenic dysphagia. Previous studies have indicated that expiratory muscle strength training (EMST) results in improved movement of the neurologically innervated submental muscle complex.[28] Pauloski et al. reported that 5 weeks of EMST in healthy adults significantly increased the GHMA as measured by ultrasound.[29] Various other types of possible rehabilitation procedures have been reported, which have suggested the importance of resistance exercises in addition to nutritional support; however, whether rehabilitation procedures are useful and which procedures are effective remain unclear.[30]

The current study had certain limitations. First, this retrospective analysis was performed at a single institution and included only a small number of patients. Second, the cutoff value of GHMA remains controversial. Few clinical studies have evaluated the geniohyoid muscle using CT. Further large-scale studies in other ethnicities and races are warranted.

5 | CONCLUSIONS

Preoperative geniohyoid muscle mass, evaluated using neck CT, is a potential predictor of dysphagia after esophagectomy. Patients with low geniohyoid muscle mass should be treated with caution to avoid postoperative aspiration pneumonia.

AUTHOR CONTRIBUTIONS

S. Kawata and Y. Hiramatsu designed the study and drafted the manuscript. J. Honke, T. Murakami, E. Booka, and T. Matsumoto were responsible for acquisition of clinicopathological data. K. Yamauchi was involved in evaluation of swallowing function. E. Booka, Y. Morita, H. Kikuchi, and H. Takeuchi contributed to editing and critical revision for important intellectual content. All authors revised the paper and approved the final version.

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CONFLICT OF INTEREST STATEMENT

Author H. Takeuchi is associate editor of *Annals of Gastroenterological Surgery*. The other authors declare no conflict of interests for this article.

ETHICS STATEMENTS

Approval of the research protocol: The study protocol was approved by the Ethics Committee of Hamamatsu University School of Medicine (19-026), and it conforms to the provisions of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent: Written informed consent was obtained from all study participants.

Registry and the registration no. of the study/trial: N/A.

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