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ORIGINAL ARTICLE – THORACIC ONCOLOGY

Handgrip Strength Predicts Postoperative Pneumonia After Thoracoscopic–Laparoscopic Esophagectomy for Patients with Esophageal Cancer

Daisuke Kurita, MD, Junya Oguma, MD, PhD, Koshiro Ishiyama, MD, Yuki Hirano, MD, PhD, Jun Kanamori, MD, PhD, and Hiroyuki Daiko, MD, PhD, FACS

Division of Esophageal Surgery, National Cancer Center Hospital, Tokyo, Japan

ABSTRACT

Background. Despite advances in minimally invasive surgery, postoperative pneumonia after esophagectomy remains a frequent complication. Sarcopenia, defined as low muscle strength and quantity, has been associated with adverse surgical outcomes in numerous cancers. The recent definition and diagnostic criteria for sarcopenia have emphasized muscle strength rather than muscle quantity as the primary indicator of sarcopenia, although most studies have focused only on muscle quantity. This study aimed to determine the association of muscle strength and quantity with postoperative pneumonia after thoracoscopic–laparoscopic esophagectomy (TLE).

Methods. This retrospective, single-center, observational study investigated 161 men undergoing TLE for esophageal cancer between May 2017 and October 2019. Handgrip strength (HGS) and skeletal muscle mass index (SMI) were used respectively as proxy for muscle strength and quantity. The SMI was assessed using preoperative computed tomography at the L3 vertebral level. Predictors of postoperative pneumonia were determined using multivariate analysis.

Results. The study subjects had TLE performed for squamous cell carcinoma (n = 131), adenocarcinoma (n = 24), and other cancers (n = 6). Postoperative pneumonia developed in 28 patients (17.4%). In the multivariate analysis, HGS was significantly associated with postoperative pneumonia (odds ratio [OR], 1.21; 95% confidence interval [CI], 1.08–1.35; p = 0.001]. No association was found between SMI and postoperative pneumonia (p = 0.964). Comparison of the areas under the receiver operating characteristic curves for postoperative pneumonia prediction showed that the value for HGS was significantly higher than for SMI (0.79 vs 0.65, respectively; p = 0.012).

Conclusions. Low HGS was a significant predictor of postoperative pneumonia after TLE for esophageal cancer.

Keywords Esophageal cancer · Handgrip strength · Pneumonia · Skeletal muscle mass index

Surgical outcomes for esophageal cancer have improved because of recent advances in multimodal treatment.[1,2] However, even with improved surgical techniques and management, postoperative pneumonia remains a major problem.[3,4] Therefore, identifying patients at higher risk for the development of postoperative pneumonia is an important clinical target.

Sarcopenia, defined as a muscle disease ("muscle failure," number CM M62.84 in the International Statistical Classification of Disease and Related Health Problems, 10th revision), is associated with adverse surgical outcomes for various malignancies.[5–7]

For patients with esophageal cancer, sarcopenia is a significant predictor of postoperative short- and long-term outcomes.[8] Notably, in 2018, the European Working Group on Sarcopenia in Older People (EWGSOP) revised their definition and diagnostic criteria for sarcopenia (known as EWGSOP2), placing muscle strength at the forefront, instead of muscle quantity, as the primary indicator of a sarcopenia diagnosis.[9] However, most previous studies based their definition of sarcopenia on muscle quantity alone.[8,10–12]

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H. Daiko, MD, PhD, FACS
e-mail: hdaiko@ncc.go.jp

Handgrip strength (HGS), associated with a variety of aging outcomes,[13,14] is commonly used for sarcopenia diagnosis as a measure of muscle strength.[9] However, only one study has described an association between HGS and postoperative pneumonia after esophagectomy, and most patients in the study underwent open transthoracic esophagectomy.[15] Recently, minimally invasive approaches such as thoracoscopic–laparoscopic esophagectomy (TLE) have been increasingly performed and are associated with a lower incidence of postoperative pneumonia than the open approach.[16–18]

Regarding developments in surgical techniques, this study enrolled only patients undergoing TLE, which is our standard approach. In addition, despite the revised sarcopenia definition highlighting the validity of muscle strength,[9] data on comparisons of muscle strength and quantity as indicators of surgical outcomes in malignancies are lacking. Therefore, comparing the association of muscle strength and quantity with postoperative pneumonia after TLE also is an important issue.

The current study aimed to examine the association of muscle strength and quantity with postoperative pneumonia after TLE for esophageal cancer.

METHODS

Study Design and Patients

This retrospective, single-center, observational study was performed at the National Cancer Center Hospital in Japan between May 2017 and October 2019. For 206 (90.4%) of the 228 consecutive esophageal cancer patients undergoing transthoracic subtotal esophagectomy with gastric tube reconstruction (excluding salvage surgery after definitive chemoradiotherapy), HGS was measured within 30 days before surgery. This study enrolled 190 (161 men and 29 women; age range, 34–81 years) of these 206 patients undergoing TLE for analysis.

The current study was approved by the National Cancer Center Institutional Review Board (2017-061), and the requirement for informed consent was waived.

Treatment

Patients with locally advanced thoracic esophageal cancer, defined as cancer classified higher than cT2 or cN1, received neoadjuvant treatment according to national guidelines.[19] Neoadjuvant treatment included two cycles of cisplatin and 5-fluorouracil; three cycles of docetaxel, cisplatin, and 5-fluorouracil; or chemoradiotherapy with two cycles of cisplatin and 5-fluorouracil. Our standard surgical procedure for thoracic esophageal cancer is thoracoscopic subtotal esophagectomy with the patient in the prone position, followed by laparoscopic gastric tube reconstruction through the retrosternal route and cervical anastomosis.

HGS Measurement

Using a digital handgrip dynamometer (T.K.K.5401, Takei Scientific Instruments Co., Ltd., Niigata, Japan), HGS was measured twice for each hand within 30 days before surgery. After preoperative treatment, we measured the HGS of all the patients who underwent preoperative treatment. The patients performed the measurements while standing with their forearm, wrist, and elbow in a neutral position. During the measurements, the patients were instructed and verbally encouraged by a trained physical therapist to exhibit the best possible force. The highest of the four measurements was used in the statistical analyses. According to EWGSOP2, HGS was categorized as low HGS (< 27 kg for men and < 16 kg for women) or high HGS (≥ 27 kg for men and ≥ 16 kg for women).[9]

Skeletal Muscle Mass Index Measurement

All the patients underwent computed tomography (CT) within 30 days before surgery as part of routine preoperative assessment for clinical staging. The cross-sectional area of the skeletal muscle at the midpoint of the L3 vertebra on CT was retrospectively calculated using the NIH ImageJ software (National Institutes of Health, Bethesda, MD) with a threshold of -29 to $+150$ Hounsfield units and normalized to height (m^2) to yield the skeletal muscle mass index (SMI) (cm^2/m^2).[20]

Data Collection

The data collected by chart review were preoperative clinical data (age, sex, body mass index, HGS, SMI, smoking status, pulmonary function, albumin, C-reactive protein, comorbidities, tumor histology, location, clinical stage, and neoadjuvant treatment) and surgical data (operative time, blood loss volume, margin status, complications, postoperative hospital stay, mortality, and 30-day readmission).

Pulmonary function comprised the percentage of vital capacity and the percentage of forced expiratory volume in 1 s (FEV1.0%). Smoking status was defined as current smoker (quit smoking < 1 year before surgery) or non-current smoker (never or formerly smoked). Pack-years was defined as packs of cigarettes per day multiplied by years of smoking. Comorbidities were chronic pulmonary disease (chronic obstructive pulmonary disease, asthma, or interstitial lung disease), diabetes mellitus, cardiovascular

disease, liver cirrhosis, and chronic kidney disease. Clinical stage was based on the seventh tumor-node-metastasis (TNM) classification of the Union for International Cancer Control and categorized as stages 1A–2B or stages 3A–4. Neoadjuvant treatment involved chemotherapy and chemoradiotherapy. Margin status was classified as negative (macro- and microscopically clear) or positive (macro- or microscopically residual). Mortality was defined as death within 30 days after surgery or in-hospital death without discharge.

Outcomes Evaluation

The primary study outcome was postoperative pneumonia, defined as the presence of new or progressive infiltrates shown on chest radiographs or CT scans and at least two of the following three criteria: fever lower than 38 °C, leukopenia or leukocytosis (white blood cell count $< 4 \times 10^9$/L or $> 10 \times 10^9$/L), and purulent sputum. Postoperative complications occurring within 30 days after surgery were coded as Clavien–Dindo grade 2 or higher, but as an exception, recurrent laryngeal nerve palsy included Clavien–Dindo complications classified as grade 1 or higher.[21]

Statistical Analysis

Tests for normality and homogeneity were performed using Shapiro–Wilk's test and Levene's test, respectively. We used *t* tests and the Mann–Whitney *U* test to compare the averages of continuous variables, and Fisher's exact test and the Chi square test to compare the proportions of categorical variables. Univariate logistic regression analysis was performed to assess the association between the various predictors and postoperative pneumonia. Variables with p values lower than 0.05 in the univariate analysis were included in the multivariate model, and the absence of multicollinearity was confirmed with Spearman's rank correlation coefficient ($r < 0.5$) and variance inflation factors (< 5). A p value lower than 0.05 was considered statistically significant.

Regarding low and high HGS, we compared postoperative complications, postoperative hospital stay, and 30-day readmission between the two groups. A receiver operating characteristic (ROC) curve was used to assess the predictive value and optimal cutoff value for HGS and SMI for postoperative pneumonia. The area under the ROC curves (AUC) was compared for these variables using DeLong's test. All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphic user interface for R (The Foundation for Statistical Computing, Vienna, Austria).[22]

RESULTS

Patients

A comparison by sex showed that postoperative pneumonia was diagnosed for 28 (17.4%) of 161 males and 0 (0%) of 29 females ($p = 0.009$) (Table 1). The female patients had significantly better pulmonary function and smoked less than the male patients ($p < 0.05$). We subsequently excluded all female patients because of the small number, resulting in 161 male patients included for further analysis.

Predictive Factors for Postoperative Pulmonary Complications

We evaluated the associations between the clinical variables and postoperative pneumonia in uni- and multivariate logistic regression analyses (Table 2). Of the variables with a p value lower than 0.05 in the univariate analysis, body mass index (BMI) correlated markedly with SMI (Spearman's $r = 0.66$; $p < 0.001$) (Table 3). Therefore, to avoid multicollinearity, we excluded BMI from the multivariate analysis.

Multivariate logistic regression analysis showed that significant predictive factors for postoperative pneumonia were HGS (odds ratio [OR], 1.21; 95% confidence interval [CI], 1.08–1.35; $p = 0.001$), age (OR, 1.09; 95% CI, 1.00–1.19; $p = 0.040$), FEV1.0% (OR, 0.94; 95% CI, 0.89–1.00; $p = 0.046$), and postoperative recurrent laryngeal nerve palsy (OR, 3.84; 95% CI, 1.30–11.30; $p = 0.015$). No association was found between SMI and postoperative pneumonia ($p = 0.964$). The variance inflation factors were low (range 1.05–2.05), indicating no collinearity.

Low HGS Versus High HGS

Although the rate of postoperative pneumonia was significantly higher in the low-HGS group (47.4%) than in the high-HGS group (13.4%) ($p < 0.001$), no significant difference was observed for the other postoperative complication rates (Table 4). Postoperative hospital length of stay was significantly longer in the low-HGS group (16 days; interquartile range [IQR], 14.0–25.5 days) than in the high-HGS group (14 days; IQR, 12.0–16.8 days) ($p = 0.001$).

ROC Analysis

The ROC analysis showed optimal cutoff values of 32.7 kg (sensitivity, 0.79; specificity, 0.72) for HGS and 47.1 cm^2/m^2 (sensitivity, 0.79; specificity, 0.52) for SMI

TABLE 1 Patients' characteristics

	Male (n = 161)	Female (n = 29)	p value
Age (years), median [IQR]	68 [61–71]	65 [56–71]	0.133
BMI (kg/m^2), median [IQR]	22.7 [20.4–24.4]	20.5 [18.7–22.2]	< 0.001*
HGS (kg), median [IQR]	34.4 [30.7–38.1]	22.3 [19.4–23.8]	< 0.001*
Low-HGS, no. (%)	19 (11.8)	4 (13.8)	0.759
SMI (cm^2/m^2), median [IQR]	46.8 [42.1–51.4]	39.0 [35.7–42.4]	< 0.001*
Current smoker, no. (%)	59 (36.6)	5 (17.2)	0.042*
Pack-year, median [IQR]	32 [15–46]	0 [0–18]	< 0.001*
VC (%), median [IQR]	108.8 [101.2–120.3]	114.2 [108.0–124.3]	0.375
FEV1.0 (%), median [IQR]	75.1 [70.0–79.4]	77.4 [75.3–79.7]	0.045*
Albumin (g/dl), median [IQR]	4.1 [3.9–4.4]	4.1 [3.9–4.3]	0.377
CRP (mg/dl), median [IQR]	0.10 [0.04–0.29]	0.04 [0.02–0.07]	< 0.001*
Comorbidity, no. (%)			
Chronic pulmonary disease	15 (9.3)	0 (0)	0.133
Diabetes mellitus	27 (16.8)	2 (6.9)	0.262
Carduivascular disease	15 (9.3)	1 (3.4)	0.474
Liver cirrhosis	6 (3.7)	0 (0)	0.593
Chronic kidney disease	7 (4.3)	0 (0)	0.597
Histology, no. (%)			0.595
Squamous cell carcinoma	131 (81.4)	26 (89.7)	
Adenocarcinoma	24 (14.9)	3 (10.3)	
Others	6 (3.7)	0 (0)	
Location, no.(%)			0.411
Upper third	26 (16.2)	5 (17.2)	
Middle third	76 (47.2)	17 (58.6)	
Lower third	59 (36.6)	7 (24.2)	
Clinical stage, no.(%)			0.665
IA–IIB	68 (42.2)	11 (37.9)	
IIIA–IV	93 (57.8)	18 (62.1)	
Neoadjuvant treatment, no. (%)			1.000
None	37	(23.0) 7	(24.2)
Chemotherapy alone	119 (73.9)	21 (72.4)	
Chemoradiation	5 (3.1)	1 (3.4)	
Operative time (min), median [IQR]	339 [288–387]	296 [261–345]	0.003*
Blood loss (ml), median [IQR]	78 [47–147]	62 [39–101]	0.096
Margin status, no. (%)			0.080
Negative	144 (89.4)	29 (100.0)	
Positive	17 (10.6)	0 (0)	
Postoperative complications, no. (%)			
Pneumonia	28 (17.4)	0 (0)	0.009*
Initial ventilatory support > 48 h	0 (0)	0 (0)	1.000
Re-intubation for respiratory failure	2 (1.2)	0 (0)	1.000
Recurrent laryngeal nerve palsy	32 (19.9)	6 (20.7)	0.495
Anastomotic leakage	14 (8.7)	2 (6.9)	1.000
SSI	9 (5.6)	3 (10.3)	0.398
Arrhythmia	14 (10.5)	2 (6.9)	1.000
Chylothorax	9 (5.6)	3 (10.3)	0.398
Cervical lymphorrhea	5 (3.1)	3 (10.3)	0.105

TABLE 1 (continued)

	Male (n = 161)	Female (n = 29)	p value
Hospital stay after surgery, median [IQR]	14 [12–18]	13 [11–15]	0.340
Mortality, no. (%)	1 (0.6)	0 (0)	1.000
30-day readmission, no. (%)	5 (3.1)	1 (3.4)	1.000

*Statistically significant

IQR interquartile range, *BMI* body mass index, *HGS* handgrip strength, *SMI* skeletal muscle mass index, *VC* vital capacity, *FEV1.0* forced expiratory volume in 1 s, *CRP* C-reactive protein, *no*. number, *SSI* surgical site infection

TABLE 2 Predictive factors for postoperative pneumonia

	Pneumonia +	Pneumonia −	Univariate			Multivariate		
	(n = 28)	(n = 133)	OR	95% CI	p value	OR	95% CI	p value
Age (years), median [IQR]	70 [68–74]	66 [60–71]	1.11	1.04–1.19	0.002	1.09	1.00–1.19	0.040*
BMI (kg/m^2), median [IQR]	20.2 [19.3–23.0]	23.1 [21.3–25.0]	0.79	0.68–0.92	0.003			
Handgrip strength (kg), median [IQR]	28.7 [25.8–32.4]	35.1 [32.1–38.9]	1.21	1.11–1.32	< 0.001	1.21	1.08–1.35	0.001*
SMI (cm^2/m^2), median [IQR]	44.4 [40.3–46.9]	47.3 [42.8–51.7]	1.09	1.02–1.17	0.015	1.00	0.91–1.10	0.964
Current smoker, no. (%)	10 (35.7)	49 (42.7)	0.95	0.41–2.23	0.910			
Pack-year, median [IQR]	42 [13–49]	32 [15–45]	1.01	0.99–1.02	0.321			
VC (%), median [IQR]	107.5 [97.8–116.2]	109.1 [101.8–120.7]	0.98	0.95–1.00	0.094			
FEV1.0 (%), median [IQR]	70.1 [66.3–77.9]	75.5 [71.0–80.1]	0.93	0.89–0.98	0.008	0.94	0.89–1.00	0.046*
Albumin (g/dl), median [IQR]	4.1 [3.5–4.3]	4.1 [4.0–4.4]	0.30	0.11–0.83	0.021	1.96	0.40–9.71	0.409
CRP (mg/dl), median [IQR]	0.20 [0.04–0.76]	0.10 [0.04–0.24]	1.42	1.02–1.99	0.040	1.31	0.82–2.09	0.262
Comorbidity, no. (%)								
Chronic pulmonary disease	6 (21.4)	9 (6.8)	3.76	1.22–11.60	0.022	3.70	0.84–16.20	0.083
Diabetes mellitus	5 (17.9)	22 (16.5)	1.10	0.38–3.20	0.866			
Carduivascular disease	2 (7.1)	13 (9.8)	0.71	0.15–3.34	0.665			
Liver cirrhosis	0 (0.0)	6 (4.5)	0.00	0.00–Inf	0.988			
Chronic kidney disease	2 (7.1)	5 (3.8)	1.97	0.36–10.70	0.433			
Location (upper third), no. (%)	1 (3.6)	25 (18.8)	0.16	0.02–1.23	0.079			
Clinical stage (IIIA–IV), no. (%)	19 (67.9)	74 (55.6)	1.68	0.71–3.99	0.237			
Neoadjuvant treatment, no. (%)								
Chemotherapy alone	21 (75.0)	98 (73.7)	1.07	0.42–2.74	0.885			
Chemoradiation	0 (0.0)	5 (3.8)	0.00	0.00–Inf	0.989			
Operative time (× 10 min), median [IQR]	34.1 [28.7–38.0]	33.4 [29.1–38.9]	1.00	0.95–1.07	0.888			
Blood loss (× 10 ml), median [IQR]	8.8 [5.7–13.3]	7.6 [4.5–15.2]	1.00	0.96–1.03	0.867			
Margin status (positive), no. (%)	4 (14.3)	13 (9.8)	1.54	0.46–5.12	0.483			
Postoperative recurrent laryngeal nerve palsy, no. (%)	12 (42.9)	31 (23.3)	2.47	1.06–5.77	0.037	3.84	1.30–11.30	0.015*

*Statistically significant

OR odds ratio, *CI* confidence interval, *IQR* interquartile range, *BMI* body mass index, *SMI* skeletal muscle mass index; *VC* vital capacity, *FEV1.0* forced expiratory volume in 1 s, *CRP* C-reactive protein, *no*. number

TABLE 3 Spearman's rank correlation matrix between predictor variables

	Age	BMI	HGS	SMI	FEV1.0	Albumin	CRP	Chronic pulmonary disease
BMI	− 0.09							
HGS	− 0.38	0.38						
SMI	− 0.23	0.66	0.49					
FEV1.0	− 0.19	0.12	0.17	0.15				
Albumin	− 0.24	0.26	0.31	0.35	0.12			
CRP	0.04	− 0.06	− 0.20	− 0.17	− 0.09	− 0.39		
Chronic pulmonary disease	0.02	− 0.13	− 0.04	− 0.06	− 0.12	0.01	0.14	
Recurrent laryngeal nerve palsy	− 0.09	− 0.12	− 0.01	− 0.01	0.04	− 0.01	0.10	0.05

BMI body mass index, *HGS* handgrip strength, *SMI* skeletal muscle mass index, *FEV1.0* forced expiratory volume in 1 s, *CRP* C-reactive protein

TABLE 4 Comparison of outcomes between the low-HGS versus high-HGS groups

	Low-HGS (n = 19)	High-HGS (n = 142)	p value
Postoperative complications, no. (%)			
Pneumonia	9 (47.4)	19 (13.4)	< 0.001*
Recurrent laryngeal nerve palsy	7 (36.8)	36 (25.4)	0.431
Anastomotic leakage	1 (5.3)	13 (9.2)	1.000
SSI	2 (10.5)	7 (4.9)	1.000
Arrhythmia	3 (15.8)	11 (7.7)	0.218
Chylothorax	2 (10.5)	7 (4.9)	0.287
Cervical lymphorrhea	0 (0)	5 (3.5)	1.000
Hospital stay after surgery, median [IQR]	16.0 [14.0–25.5]	14.0 [12.0–16.8]	0.001*
Mortality, no. (%)	0 (0)	1 (0.7)	1.000
30-day readmission, no. (%)	1 (5.3)	4 (2.8)	0.271

*Statistically significant

no. number, *HGS* hand grip strength, *SSI* surgical site infection, *IQR* interquartile range

(Fig. 1a–d). The AUC value from the ROC analysis for HGS was significantly higher than for SMI (0.79 vs 0.65; p = 0.012).

DISCUSSION

To our knowledge, this retrospective study is the first to examine the association between muscle properties (strength and quantity) and postoperative pneumonia after TLE for esophageal cancer. Multivariate analysis showed that the significant predictive factors for postoperative pneumonia were HGS, age, FEV1.0%, and postoperative recurrent laryngeal nerve palsy. However, our findings showed no significant association between SMI and postoperative pneumonia. Furthermore, we used ROC curves and AUC analysis to compare the validity of HGS and SMI as predictors of pneumonia. The AUC value for HGS was significantly higher than for SMI.

As with previously reported data, we found that age, pulmonary function, and recurrent laryngeal nerve palsy were strongly associated with pneumonia.[23–25] Furthermore, our data suggested that low HGS could explain why postoperative pneumonia was more likely to develop in some patients than expected. However, the mechanism of the association between low HGS and pneumonia remains unclear. Several studies reported that low HGS was associated with systemic impaired muscle function, which contributes to decreased pulmonary and swallowing functions.[26,27] Also, impaired muscle function was closely related to immune senescence secondary to inflammatory cytokines and other peptides.[28] These conditions could affect the development of pneumonia. Although TLE was associated with less surgical stress and postoperative pain, which can improve pulmonary function, systemic muscle failure, chronic pulmonary disease, and recurrent laryngeal nerve palsy had a strong influence on the development of pneumonia as a result of the aforementioned mechanisms.

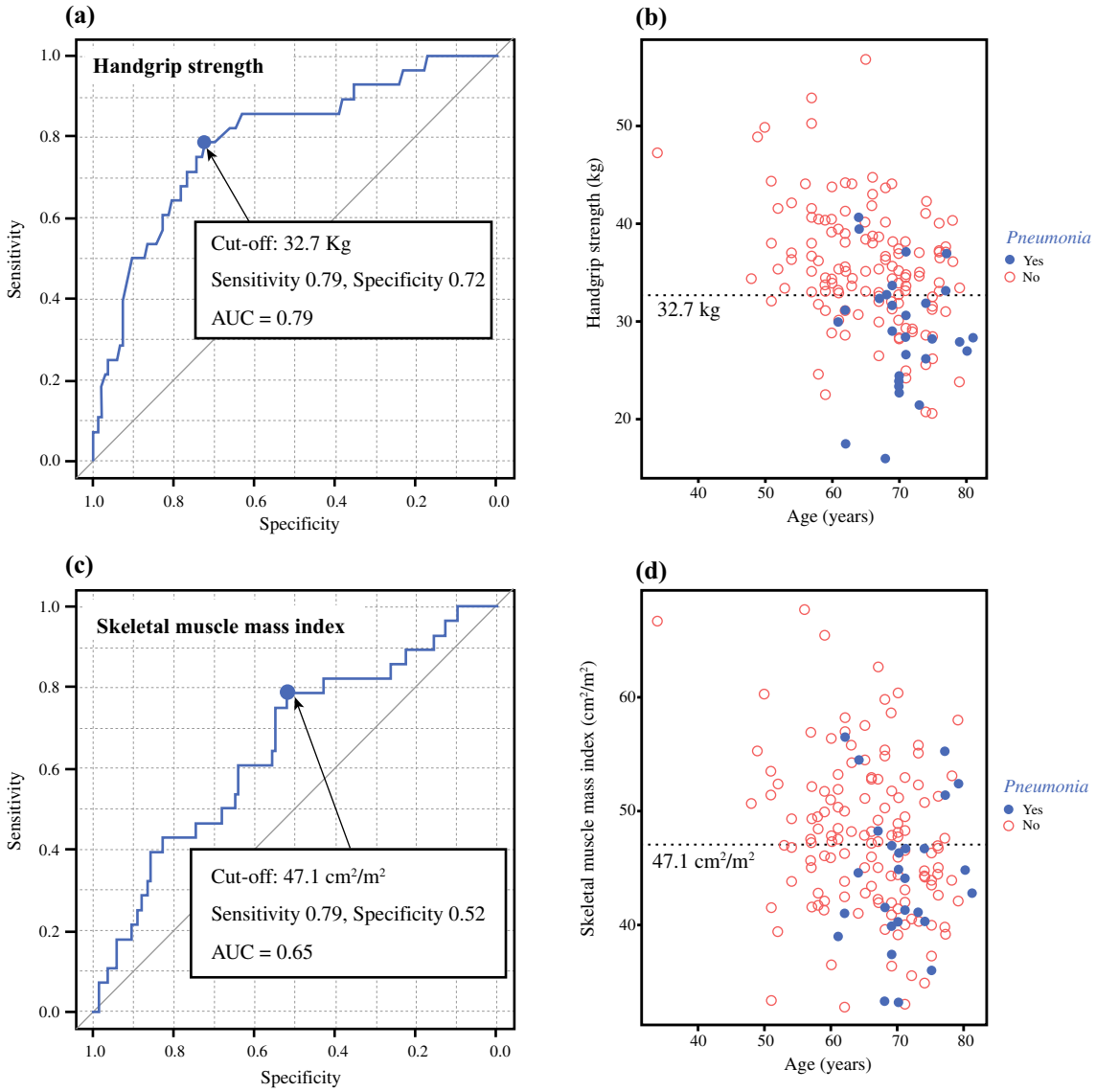

FIG. 1 **a** Receiver operating characteristic (ROC) analysis of handgrip strength. **b** Scatterplot of handgrip strength and age for pneumonia. **c** ROC analysis for skeletal muscle mass index. **d** Scatterplot of skeletal muscle mass index and age for pneumonia

To our knowledge, no previous reports have compared the effect of muscle strength and quantity on surgical outcomes for patients with esophageal cancer and other malignant tumors. A recent systematic review and meta-analysis showed that muscle strength had a stronger correlation with muscle functional decline than muscle quantity in older patients.[14] Furthermore, the revised sarcopenia definition highlighted that muscle strength was the primary parameter for a sarcopenia diagnosis.[9] Previous studies evaluating muscle quantity found links between sarcopenia and postoperative pneumonia. However, our findings showed that measurement of muscle strength was more useful because it is a more sensitive parameter.

Recently, multimodal prehabilitation, namely, preoperative physical exercise and nutritional support, resulted in less postoperative pneumonia after esophagectomy.[29,30] However, the focus of these programs was limited mainly to patients' perioperative management. Furthermore, neoadjuvant treatment for locally advanced esophageal cancer was a standard approach, although several studies reported that neoadjuvant treatment led to muscle wasting and physical deconditioning.[31,32] Therefore, to improve muscle function and reduce postoperative pneumonia, early detection of high-risk patients and extended prehabilitation during neoadjuvant treatment are considered essential. As a measurement easy to perform and inexpensive, HGS could

help detect preoperative high-risk patients requiring specific interventions to reduce postoperative pneumonia. Because we measured HGS just before surgery in the current study, further studies are needed to examine the impact of neoadjuvant treatment on HGS.

In the current study using EWGSOP2 criteria, the rate of male patients with low HGS ($\leq$ 27 kg) was only 11.8%, and this cutoff value showed high specificity (0.92) but very low sensitivity (0.32) to predict postoperative pneumonia. Several diagnostic criteria for sarcopenia have been proposed by some research groups such as EWGSOP, the International Working Group for Sarcopenia, and the Asian Working Group for Sarcopenia.[33–35] Although these criteria have different definitions and cutoff values, EWGSOP2 redefined its criteria and provided firm scientific evidence. However, with EWGSOP2, the cutoff value for low HGS was determined based on a *T* score of − 2.5 or lower in the healthy United Kingdom population.[36] Few studies have evaluated whether HGS is useful as a predictor of surgical outcomes for various cancer patients, and an optimal cutoff value must be determined in future studies.

The current study had several limitations. First, it was a retrospective observational study evaluating a small number of patients from a single institution, which might have caused patient selection bias. However, despite the retrospective design, we enrolled more than 90% of consecutive patients.

Second, our method of measuring HGS was inaccurate, leading to differences in recorded values. As recommended, HGS is measured with patients resting their forearm on the arm of the chair in the sitting position.[37]

Third, we measured the L3 CT-based SMI to estimate muscle quantity although multiple techniques are options, namely, dual-energy x-ray absorptiometry, bioelectrical impedance analysis, CT, or magnetic resonance imaging. However, it is not known which method is the most representative of muscle quantity.[9]

Fourth, because no female patients experienced pneumonia, even after we increased the total number of enrolled patients, we could not meet our aim of including female patients. We therefore excluded data for women from the analysis. Studies comparing both men and women who experience postoperative pneumonia after TLE are needed.

In conclusion, the results of this retrospective study demonstrated that HGS was a significant predictive factor of postoperative pneumonia after TLE for esophageal cancer and could have a stronger impact than SMI. Further studies are needed to examine the impact of neoadjuvant treatment on HGS and to establish methods to decrease the rate of postoperative pneumonia among patients with esophageal cancer and low HGS.

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CONFLICT OF INTEREST The authors declare that they have no conflict of interest.

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