Relation between Decrease in Geniohyoid Muscle Mass and Dysphagia after Surgery for Thoracic Esophageal Cancer

Kenta Katsumata, Shinya Mikami, Takehito Otsubo, and Taichi Mafune

(Received for Publication: August 20, 2019)

Abstract

Objective: Recurrent laryngeal nerve (RLN) paralysis was previously believed to be a major cause of dysphagia after esophageal cancer surgery. However, reports from recent years have indicated that dysphagia may be caused by decreased laryngeal elevation due to cervical lymph-node dissection (LND). For this reason, we studied whether a relation exists between postoperative decrease in geniohyoid muscle mass and postoperative dysphagia in patients treated for thoracic esophageal cancer.

Methods and Results: Our study was retrospective and included 54 patients who underwent surgery for esophageal cancer at our hospital between April 2014 and August 2018. Computed tomography (CT) had been performed on postoperative days (POD) 5–8 and laryngeal video fluoroscopy on POD 7. The patients were divided between those with and without dysphagia and those with and without preoperative sarcopenia, and clinical variables were compared between the patient groups. The dysphagia group (n=12) had significantly lower postoperative prealbumin (PA) values (18±7 vs. 22±6; P<0.05) than the non-dysphagia group (n=42). Three-region cervical LND was performed in a greater percentage of patients in the dysphagia group than in the non-dysphagia group (9/3 (75.0%) vs 15/27 (35.7%); P<0.05). In addition, decreases in the psoas major and geniohyoid muscle cross-sectional areas were significantly less in the dysphagia group 93.0±5.1% vs. 98.4±8.3%; P<0.05 and 77.5±11.3% vs. 88.2±16.5%; P<0.05, respectively). The cross-sectional area of the geniohyoid muscle was significantly smaller in patients with preoperative sarcopenia than in those without sarcopenia 82.8±11.1% vs. 90.6±21.1%; P<0.05).

Conclusion: Our findings suggest that a postoperative decrease in geniohyoid muscle mass causes the dysphagia seen in patients after esophageal cancer surgery. In addition, dysphagia may occur more readily in patients with pre-existing sarcopenia.

Key words

Esophageal cancer, geniohyoid muscle, dysphagia, perioperative period, sarcopenia

Introduction

Recurrent laryngeal nerve (RLN) paralysis has long been considered a major cause of dysphagia after esophageal cancer surgery. Recently, postoperative reduction in laryngeal elevation was shown to cause dysphagia in patients who have undergone this type of surgery. Decreased laryngeal elevation may occur as a consequence of restricted elevation of the larynx caused by scarring of the anterior neck muscles from cervical lymph node dissection (LND) performed during esophageal cancer surgery. In 2014, Mafune, et al. showed that the effects of cervical LND, rather than RLN paralysis, cause dysphagia after this type of surgery.

Dysphagia can be non-surgery-related. It has been associated with sarcopenia in elderly persons who do not have esophageal cancer. There are indications that survival time of patients with both cancer and sarcopenia is not as long as that of patients with...
cancer but without sarcopenia. The reported prevalence of sarcopenia among Japanese is 7.5% to 8.2%, and, in older adults, association has been found between low hand grip strength, loss of skeletal muscle mass, and dysphagia.

The geniohyoid muscle, mylohyoid muscle, and anterior belly of the digastric muscle are suprahyoid muscles that elevate the hyoid bone, and the action of these muscles result in laryngeal elevation. Feng et al. reported that advancing age and decreased geniohyoid muscle mass influenced swallowing of healthy individuals and of individuals who suffered from aspiration.

We hypothesized that changes in muscle mass that occur during postoperative fasting of patients treated for esophageal cancer are associated with poor swallowing function, and we conducted a retrospective study in to investigate whether a relation exists between dysphagia and the midline sagittal cross-sectional area of the geniohyoid muscle as measured on pre-and postoperative computed tomography (CT) images.

Patients and Methods

Patients

The study included 54 patients who had undergone subtotal esophagectomy, cervical esophagogastric anastomosis for narrow gastric tube reconstruction, plus LND for treatment of thoracic esophageal cancer in our department during the period April 2014–August 2018. CT images had been obtained for these patients before surgery and between postoperative day (POD) 5 and POD 8. Lymph nodes were dissected from three regions, the neck, chest and abdominal regions, or two regions, the chest and abdominal regions. All thoracic procedures, including esophageal transection and mediastinal LND were performed thoracoscopically, and all abdominal procedures, including abdominal LND and creation of the gastric tube, were performed laparoscopically. The superior margins for cervical LND were the cervical paraesophageal (no. 101) and supraclavicular (no. 104) lymph nodes. To reduce the incidence of perioperative respiratory complications, patients underwent preoperative physical therapy, and they began rehabilitation on the day after surgery.

Patients were fed enterally via enterostomy starting on POD 2, and until resumption of oral intake on POD 7, fluids were replaced intravenously. Calorie intake was 240 kcal/day on POD 2 and was increased gradually to 1200 kcal/day by POD 6. On POD 7, before the start of oral intake, video fluoroscopy (VF) was performed to determine whether the patient would experience dysphagia.

VF

VF tests were performed for all 54 patients preoperatively and on POD 7. Determination of the presence or absence of dysphagia was based on the POD 7 VF results. VF findings in patients determined to have dysphagia were frank aspiration and laryngeal penetration with an inability to achieve rapid clearance, as described by Logemann et al. The test was performed with a mixture of 35 mL iopamidol and 40 mL water, to which 1 g of thickener was added. Patients were asked to swallow 5-mL boluses of the fluid over the 10- to 15-min test period, and their swallowing function was evaluated.

Examination for RLN paralysis

Laryngeal fibroscopy was performed immediately after surgery and on POD 7 to identify cases of RLN paralysis. RLN paralysis was diagnosed when the vocal cord(s) remained in a fixed position (midline, midline-adjacent, intermediate, or open). Thus, partial paralysis was taken as RLN paralysis.

Muscle mass measurement

The psoas major muscle mass was used as a substitute for total body skeletal muscle mass. The cross-sectional area on both the preoperative and postoperative CT images of each psoas major muscle (CSA-PMM) was measured at the level of the third lumbar vertebra (L3), the two values were added and taken as the psoas major muscle mass (Fig. 1a), as described by Hamaguchi et al.
The geniohyoid muscle mass was used as a substitute for the suprahyoid muscle group mass. The geniohyoid muscle mass was measured according to the method described by Feng et al.\textsuperscript{7}, i.e., by measuring the midline sagittal cross-sectional area of the geniohyoid muscle (CSA-GH) (Fig. 1b), on both the preoperative and postoperative CT images. The images had been obtained with a 64- or 80-row Toshiba Aquilion CT scanner, set to a slice thickness of 1.00 mm. Contrast-enhanced imaging was performed for all patients except those with renal dysfunction or a history of iodine allergy. Measurement was performed by the first author, using Ziostation 2 (3D medical imaging processing workstation) (Ziosoft Inc., Tokyo, Japan). To avoid errors, all measurements were obtained twice.

Variables examined

For the purpose of the study, patients were divided between those with and those without dysphagia, and the following variables were examined and compared between the two groups: patient sex, age, pre- and postoperative (POD 7) body mass index (BMI), pre- and postoperative (POD 7) prealbumin (PA) concentration, Onodera prognostic nutritional index (PNI)\textsuperscript{9}, preoperative psoas muscle index (PMI), T stage, N stage, disease stage, use of neoadjuvant chemotherapy, duration of surgery, surgical blood loss volume, preoperative presence of sarcopenia, presence of RLN paralysis on POD 7, neoadjuvant chemotherapy, cervical LND, complications, length of the postoperative hospital stay, presence of postoperative dysphagia, change in CSA-PMM and change in CSA-GH were compared between these two groups. Change in CSA-PMM was calculated as postoperative CSA-PMM/preoperative CSA-PMM and reported as a percentage, and change in CSA-GH was calculated as postoperative CSA-GH/ preoperative CSA-GH and reported as a percentage.

T stage and N stage were determined in accordance with the Japanese Classification of Esophageal Cancer (11th edition)\textsuperscript{10}, and RLN paralysis was diagnosed laryngoscopically by an otolaryngologist. In addition, sarcopenia was diagnosed on the basis of criteria devised for Asians by Hamaguchi et al.\textsuperscript{11}, i.e., when the PMI fell below 6.36 cm\textsuperscript{2}/m\textsuperscript{2} in men and 3.92 cm\textsuperscript{2}/m\textsuperscript{2} in women.

Patients were also divided between those with and those without preoperative sarcopenia, and the following variables were compared between these two groups: sex, age, pre- and postoperative BMI and PA, CSA-PMM(%), and CSA-GH(%).

Statistical analysis

Variables are shown as mean (and range), mean ±SD, or median values. Differences in study variables between patients with and without dysphagia were analyzed by Fisher's exact test or logistic regression analysis, as appropriate, with P<0.05 considered statistically significant. JMP software (version 13, SAS Institute, Cary, NC, USA) was used for all statistical analyses.

The study procedures were approved by the ethics committee of St. Marianna University School of Medicine, Japan (approval number 4449).

Results

Of the 54 study patients, 42 were men and 12 were women. Mean age was 69 years (40–80 years), and mean BMI was 20.72±2.60 kg/m\textsuperscript{2}. PA was 25.56±6.34 mg/dL, and the Onodera PNI was 46.51±4.26. The mean preoperative PMI was 5.82±1.39 cm\textsuperscript{2}/m\textsuperscript{2} among men and 4.22±0.8 cm\textsuperscript{2}/m\textsuperscript{2} among women, and 33 of the 54 patients met the diagnostic criteria for sarcopenia preoperatively. Tumor stages were as follows: T1a (0 patients), T1b (17 patients), T2 (12 patients), T3 (25 patients), and T4 (0 patients). N stages were as follows: N0 (24 patients), N1 (13 patients), N2 (15 patients), and N3 (2 patients). Disease stages were as follows stage I (8 patients), stage II (27 patients), stage III (19 patients). There was no stage IV disease. Clinical characteristics of the total patients and per dysphagia vs. non-dysphagia group are shown in Table 1.
Table 1. Patient Characteristics

|                          | Value               |
|--------------------------|---------------------|
| Sex ratio (M/F)          | 12/42               |
| Age (years)              | 69 (40-80)          |
| Preoperative BMI         | 20.72 ± 2.60        |
| Postoperative BMI        | 20.43 ± 2.39        |
| Preoperative PA (mg/dL)  | 25.56 ± 6.34        |
| Postoperative PA (mg/dL) | 21 ± 6              |
| Onodera’s PNI            | 46.51 ± 4.26        |
| Preoperative PMI (cm²/m²)|                    |
| Men                      | 5.82 ± 1.39         |
| Women                    | 4.22 ± 0.89         |
| Preoperative sarcopenia  |                     |
| Yes                      | 33                  |
| No                       | 21                  |
| cT stage                 |                     |
| T1a                      | 0                   |
| T1b                      | 17                  |
| T2                       | 12                  |
| T3                       | 25                  |
| T4                       | 0                   |
| cN stage                 |                     |
| N0                       | 24                  |
| N1                       | 13                  |
| N2                       | 15                  |
| N3                       | 2                   |
| Disease stage            |                     |
| I                        | 8                   |
| II                       | 26                  |
| III                      | 19                  |
| IV                       | 0                   |
| NAC                      |                     |
| Yes                      | 19                  |
| No                       | 35                  |
| Operation time (min)     | 479.76 ± 76.82      |
| Blood loss volume (g)    | 264.04 ± 253.55     |
| Dissection (2 regions:3 regions) | 30:24:00 |
| Postoperative RLN paralysis |                     |
| Yes (left: right: bilateral) | 26 (18:4:4) |
| No                       | 28                  |
| Dysphagia                |                     |
| Yes                      | 12                  |
| No                       | 42                  |
| Complications            |                     |
| Yes                      | 17                  |
| No                       | 37                  |
| Hospital stay (days)     | 20 (10-82)          |
| Perioperative mortality  | 0                   |

Number of patients is shown unless otherwise indicated.

BMI: body mass index, PA: pre-albumin, PNI: prognostic nutrition index, PMI: psoas muscle index, RLN: Recurrent laryngeal nerve, NAC: neo-adjuvant chemotherapy.

Operative and postoperative variables of the total patients are shown in Table 1. Operation time was 479.76±76.82 minutes, and blood loss volume was 264.04±253.55 g. PA on POD 7 was 21±6 mg/dL, and mean postoperative BMI was 20.43±2.39 kg/m², with both values being lower than the preoperative values. RLN paralysis was confirmed in 26 of the 54 patients on POD 7. The RLN paralysis was left-sided in 18 patients (midline in 2 patients, midline-adjacent in 12 patients, intermediate in 1 patient, open in 1 patient, and complete in 2 patients), right-sided in 4 patients (midline in 2 patients, midline-adjacent in 1 patient, complete in 1 patient), and bilateral in 4 patients (left midline-adjacent-right complete in 3 patients and left complete-right midline-adjacent in 1 patient). Twenty-two of the 26 patients with RLN paralysis were followed up regularly for 6 months or more after the surgery. The remaining 4 patients did not return regularly for postoperative examinations. The paralysis improved within 6 months in 17 (77.3%) of the 22 patients.

Dysphagia was diagnosed by VF of POD 7 in 12 of the 54 patients. Oral intake was possible within 3 months in all 12 of these patients. In addition, complications occurred in 14 of the 54 patients (suture dehiscence in 4 patients, respiratory complications in 3 patients, chylous fistula in 1 patient, postoperative cervical hematoma in 1 patient, and surgical site infection in 5 patients). Median postoperative hospital stay was 20 days (10–82 days), and there was no perioperative mortality.

Clinical characteristics of patients with and without dysphagia are shown in Table 2. The postoperative PA concentration and inclusion of cervical LND differed significantly between the two groups (P=0.0384 and P=0.0157, respectively). Mean CSA-PMM differed significantly between the two groups (at 93.0% in the dysphagia group and 98.4% in the non-dysphagia group; P=0.021) (Fig. 2a). Mean CSA-GH also differed significantly between the two groups (at 77.5% and 88.2%, respectively; P=0.0318) (Fig. 2b). No other factor, including the presence of RLN paralysis, differed significantly between the two groups.

Data are shown for patients with and without preoperative sarcopenia in Table 3. No statistically significant between-group difference was found in sex, age, pre- or postoperative BMI or PA, the occurrence of complications, CSA-PMM, or CSA-GH (Fig. 3a, b).
Table 2. Clinical Variables in Patients with and without Dysphagia

|                                | Dysphagia (n=12) | No dysphagia (n=42) | P value |
|--------------------------------|------------------|---------------------|---------|
| Sex ratio (M/F)                | 10;2             | 10;32               | 0.714   |
| Age (years)                    | 70.5 (48-79)     | 69 (40-80)          | 0.2889  |
| BMI Preoperative               | 20.07 ± 2.31     | 20.9 ± 2.42         | 0.3208  |
| BMI Postoperative              | 19.63 ± 2.20     | 20.65 ± 2.42        | 0.1846  |
| PA (mg/dL) Preoperative        | 25.08 ± 6.07     | 25.69 ± 6.49        | 0.768   |
| PA (mg/dL) Postoperative       | 18 ± 7           | 22 ± 6              | 0.0384  |
| PNI                            | 47.89 ± 3.37     | 46.12 ± 4.44        | 0.1761  |
| PMI (cm²/m²)                   | 0.6729           | 0.6729              |         |
| Male                           | 5.80±1.49        | 4.81±1.04           | 0.8733  |
| Female                         | 4.21±0.77        | 4.32±1.85           | 0.8705  |
| Operation time (min)           | 462.83 ± 72.00   | 484.60 ± 78.28      | 0.3761  |
| Blood loss volume (g)          | 297.17 ± 305.81  | 254.57 ± 239.99     | 0.6131  |
| Preoperative sarcopenia (N/Y)  | 3;9              | 18;24               | 0.2631  |
| Postoperative RLN paralysis (N/Y)| 4;8             | 24;18               | 0.1961  |
| NAC (N/Y)                      | 3;9              | 16;26               | 0.5061  |
| Dissection (3 regions:2 regions)| 9;3             | 15;27               | 0.0157  |
| pT (T0/T1a/T1b/T2/T3/T4)       | 0/1/4/0/7/0      | 2/8/14/5/12/1       | 0.3829  |
| pN (N0/N1/N2/N3)               | 6/1/5/0          | 21/10/110/1         | 0.4836  |
| pStage (I/II/III/IV)           | 1/3/3/5/0        | 8/8/14/11/1         | 0.7263  |
| Complications (Y/N)            | 5;7              | 12;30               | 0.4855  |
| Postoperative hospital stay (days)| 28 (10-45)     | 19 (12-82)          | 0.3018  |
| CSA-PMM (%)                    | 93.0 ± 5.1       | 98.4 ± 8.3          | 0.021   |
| CSA-GH (%)                     | 77.5 ± 11.3      | 88.2 ± 16.5         | 0.0318  |

Number of patients is shown unless otherwise indicated.

BMI: body mass index, PA: pre-albumin, PNI: prognostic nutrition index, PMI: psoas muscle index, RLN: Recurrent laryngeal nerve, NAC: neo adjuvant chemotherapy, CSA-PMM: cross-sectional area of the psoas major muscle (preoperative CSA-PMM/postoperative CSA-PMM), CSA-GH: cross-sectional area of the geniohyoid muscle (preoperative CSA-GH/postoperative CSA-GH).

Discussion

The Japan Clinical Oncology Group (JCOG) used the Clavien-Dindo classification system\(^{12}\) to create the JCOG Postoperative Complications Criteria\(^{13}\) for detailed assessment of postoperative complications in Japan. However, there is some variation between hospitals in terms of the evaluation of RLN paralysis after esophageal cancer surgery. Yonekawa et al.\(^{1}\) reported occurrence of RLN paralysis in 25.9% of patients after esophageal cancer surgery and occurrence of aspiration in 78.5% of patients with such paralysis. Okamura et al.\(^{14}\) reported a similar RLN paralysis incidence of 25.1%. RLN paralysis is diagnosed by means of vocal cord examination performed with a laryngeal fiberscope when patients present with hoarseness or dysphagia. The incidence of RLN paralysis among our study patients was high at 48.1%, and although we diagnosed RLN paralysis by laryngeal fiberscopy, we included asymptomatic cases. We therefore believe that the method of evaluation used at our hospital is stricter than methods used for other reported studies and that our method better facilitated detection.

The incidence of dysphagia after esophageal cancer surgery among our study patients (22.2%, 12/54 patients) was lower than that reported elsewhere (33% to 47% of patients)\(^{3}\). All 12 of our pa-
patients who suffered postoperative dysphagia were able to start oral intake within 3 months. Therefore, we believe that we were able to prevent serious complications, such as aspiration, and to preserve patients’ swallowing function by performing an objective evaluation using VF and starting indirect swallowing rehabilitation immediately after patients were diagnosed with dysphagia.

RLN paralysis has been believed to be a major cause of dysphagia after esophageal cancer surgery and closely related to the condition\(^5\). However, in recent years, reports have indicated that RLN paralysis is not directly related to dysphagia and have instead stated that decreased postoperative laryngeal elevation and the inclusion of cervical LND are major risk factors for development of dysphagia\(^2\)–\(^4\). Yasuda et al.\(^3\) indicated that cervical LND may lead to restricted laryngeal elevation due to scarring of the

---

**Table 3.** Clinical Variables in Patients with and without Preoperative Sarcopenia

|                | Sarcopenia | No sarcopenia | P value |
|----------------|------------|---------------|---------|
| Sex ratio (M/F)| 5/28       | 7/14          | 0.1795  |
| Age            | 70 (40-79) | 67 (50-80)    | 0.9368  |
| BMI            |            |               |         |
| Preoperative   | 20.31 ± 2.65 | 21.36 ± 2.44 | 0.143   |
| Postoperative  | 20.16 ± 2.55 | 20.85 ± 2.11 | 0.2935  |
| PA (mg/dL)     |            |               |         |
| Preoperative   | 25.52 ± 6.08 | 25.62 ± 6.89 | 0.9528  |
| Postoperative  | 21 ± 7     | 22 ± 6        | 0.4626  |
| Complication (Y/N) | 13/20 | 4/17          | 0.1429  |
| CSA-PMM        | 98.0 ± 8.4 | 96.1 ± 7.2    | 0.3828  |
| CSA-GH         | 82.8 ± 11.1 | 90.6 ± 21.1  | 0.0734  |

BMI: body mass index, PA: pre-albumin, CSA-PMM: cross-sectional area of the psoas major muscle (preoperative CSA-PMM/postoperative CSA-PMM), CSA-GH: cross-sectional area of the geniohyoid muscle (preoperative CSA-GH/postoperative CSA-GH)
muscle tissue. Aspiration occurred in 30.8% (8/26) of our study patients in whom RLN paralysis developed, a percentage that is considerably lower than the 78.5% reported by Yonekawa et al. In addition, RLN paralysis was found in 4 (14.2%) of the 28 patients found to be capable of oral intake. This also suggests that RLN paralysis is not directly related to dysphagia.

To evaluate swallowing function, Shimizu et al. measured the midline sagittal cross-sectional area of the geniohyoid muscle ultrasonographically and reported that a decreased cross-sectional area negatively affected swallowing function. Feng et al. measured the cross-sectional area of the geniohyoid muscle on coronal CT images, dividing the muscle into thirds—the anterior, middle and posterior thirds—for measurement of the midline sagittal cross-sectional area of the geniohyoid muscle on easily obtained CT images.

We found the postoperative iliopsoas muscle cross-sectional area to be 98.4% that of the preoperative iliopsoas muscle cross-sectional area among patients without dysphagia but 93.0% that of the preoperative iliopsoas muscle cross-sectional area among those with dysphagia, a difference that was statistically significant. Regarding change in the muscle, a decrease to 95.2% on POD 7 was previously reported in patients who had undergone living-donor hepatic transplantation. A decrease to 93.0% in psoas major muscle mass of our patients with dysphagia is relatively high. Reasons for this may include postoperative body movements and patients’ rehabilitative progress, factors that require further research.

The postoperative midline sagittal cross-sectional area of the geniohyoid muscle was also significantly smaller in our dysphagia group than in our non-dysphagia group (11.8% vs. 22.5%). The decrease in geniohyoid muscle mass was greater than that in psoas muscle mass, but there is no obvious reason for this difference. The greater decrease might have been caused by decreased postoperative swallowing movements, which decreased to a greater extent than body movements. This factor, too, warrants further investigation.

Sarcopenia is broadly classified as either primary sarcopenia, which occurs with advancing age, or secondary sarcopenia, which occurs due to inactivity, disease, or poor nutrition. A certain number of patients with esophageal cancer who meet the indications for surgery will also have decreased dietary intake. We believe that such decreases increase the chance of secondary sarcopenia occurring during the outpatient follow-up period or even later. Nishigori et al. reported preoperative sarcopenia in 149 of 199 (74.9%) patients with esophageal cancer. As shown in Table 3, the CSA-GH of patients who had sarcopenia before surgery was smaller than that of patients who did not have sarcopenia before surgery. This suggests that the presence of sarcopenia before surgery is likely to dispose patients to geniohyoid muscle atrophy. The relation between sarcopenia and
postoperative swallowing movements also warrants further study.

Future studies that focus on the maintenance and enhancement of both total-body muscle mass and of muscles involved in swallowing, such as the geniohyoid muscle, during postoperative rehabilitation are also warranted.

**Conclusion**

Results of our study suggest that decrease in the cross-sectional area of the geniohyoid muscle causes the dysphagia seen in patients after surgery for esophageal cancer. In addition, the condition appears to occur more readily in patients with preoperative sarcopenia.

**Acknowledgments**

We offer our heartfelt gratitude to speech-language-hearing therapist Shinobu Tochimoto, Dr. Yoshihiro Akazawa, Dr. Shigeru Kasugai, and Dr. Masahiko Fukasawa of the Department of Otorhinolaryngology at St. Marianna University School of Medicine Hospital for their assistance during this study.

**Conflicts of Interest**

The authors have nothing to disclose.

**References**

1) Yonekawa H, Shima S, Gotoh M, et al. Bronchial aspiration after resection of intrathoracic esophageal cancer. Jpn J Gastroenterol Surg 1990; 23: 1790–1795.

2) Kumai Y, Samejima Y, Watanabe M, et al. Videofluoroscopic evaluation of pharyngeal swallowing dysfunction after esophagectomy with three-field lymph node dissection. Eur Arch Otorhinolaryngol 2017; 274: 321–326.

3) Yasuda T, Yano M, Miyata H, et al. Evaluation of dysphagia and diminished airway protection after three-field esophagectomy and a remedy. World J Surg 2013; 37: 416–423.

4) Mafune T, Mikami S, Otsubo T, et al. An investigation of factors related to food intake ability and swallowing difficulty after surgery for thoracic esophageal cancer. Dysphagia 2019; 34: 592–599.

5) Maeda K, Akagi J. Sarcopenia is an independent risk factor of dysphagia in hospitalized older people. Geriatr Gerontol Int 2016; 16: 515–521.

6) Japanese Association on Sarcopenia and Fraility. Guidelines for the Management of Sarcopenia 2017, Life Science, Tokyo, 2017.

7) Logemann JA. Evaluation and Treatment of Swallowing Disorders, 2nd ed, Ishiyaku, Tokyo, 2000.

8) Feng X, Todd T, Lintzenich CR, et al. Aging-related geniohyoid muscle atrophy is related to aspiration status in healthy older adults. J Gerontol A Biol Sci Med Sci 2013; 68: 853–860.

9) Onodera T, Goseki N, Kosaki G. Prognostic nutritional index in gastrointestinal surgery of malnourished cancer patients. Nihon Geka Gakkai Zasshi [in Japanese] 1984; 85: 1001–1005.

10) Japan Esophageal Society. Japanese Classification of Esophageal Cancer, 11th ed, Kanehara, Tokyo, 2015.

11) Hamaguchi Y, Kaido T, Okumura S, et al. Proposal for new diagnostic criteria for low skeletal muscle mass based on computed tomography imaging in Asian adults. Nutrition 2016; 32: 1200–1205.

12) Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004; 240: 205–213.

13) http://www.jcog.jp/doctor/tool/JCOG_Clavien-Dindo_ver2.0.pdf

14) Okamura A, Watanabe M, Imamura H, et al. Current status of recurrent nerve palsy after thoracoscopic esophagectomy and significance of perioperative management team in preventing postoperative pneumonia. J Jpn Bronchoesophageal Soc 2017; 68: 189–191.

15) Shimizu S, Hanayama K, Nakato R, et al. Ultrasonographic evaluation of genioid muscle mass in perioperative patients. Kawasaki Med J 2016; 42: 47–56.

16) Xue FS, Liu YY, Liu Q. Perioperative loss of psoas muscle is associated with patient survival in living donor liver transplantation. Liver Transpl 2018; 24: 623–633.

17) Nshigori T, Okabe H, Tanaka E, et al. Sarcopenia as a predictor of pulmonary complications after esophagectomy for thoracic esophageal cancer. J Surg Oncol 2016; 113: 678–684.