Clinical significance of sarcopenic dysphagia for patients with esophageal cancer undergoing esophagectomy: A review

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Abstract
The relationships among esophagectomy for esophageal cancer, dysphagia, and sarcopenia are still unclear. We considered appropriate interventions for patients with resectable esophageal cancer for the purpose of reducing postoperative dysphagia and aspiration pneumonia. Dysphagia in patients with esophageal cancer is caused by patient characteristics, such as pathophysiology and age, or complications after esophagectomy. Recently, sarcopenic dysphagia, defined as dysphagia associated with whole-body sarcopenia, has attracted attention in various fields, and a large proportion of patients with esophageal cancer are expected to have sarcopenic dysphagia. Our systematic review and meta-analysis suggested that preoperative sarcopenia in patients with esophageal cancer is related to pulmonary complications after esophagectomy, and some reports also suggested that sarcopenia in swallowing-related muscles, such as the geniohyoid muscle and tongue, might be associated with postoperative pneumonia or dysphagia after esophagectomy. However, clinical studies on sarcopenic dysphagia in patients with esophageal cancer have been limited. To prevent sarcopenic dysphagia after esophagectomy, perioperative interventions involving not only swallowing rehabilitation, but also physical exercise and nutritional support are important. Moreover, several reports have suggested that the chin-down maneuver might be effective for preventing aspiration after an esophagectomy. To inhibit the progression of sarcopenic dysphagia after esophagectomy, evaluations and interventions by multidisciplinary staff are likely to be necessary.

Keywords
esophageal cancer, rehabilitation, sarcopenic dysphagia, swallowing function

INTRODUCTION

Recently, minimally invasive esophagectomy and perioperative management have been adopted with the aim of reducing surgical complications after esophagectomy.1 However, pulmonary complications after esophagectomy sometimes lead to fatalities2; therefore, prevention is an important consideration in perioperative management. One of the most important reasons for postoperative pneumonia is dysphagia. Old age, malnutrition, sarcopenia, multiple primary cancers, vocal code paralysis, and so on have been implicated in postoperative dysphagia, and these characteristics are often features of esophageal cancer patients and the required surgical procedures. Several previous reports have suggested a relationship between sarcopenia and surgical outcomes after esophagectomy.3
and dysphagia caused by sarcopenia has recently become a topic in various fields. However, only a few reports have suggested a relationship between dysphagia arising from sarcopenia and surgical outcomes after esophagectomy, and interventional approaches for preventing dysphagia remain unclear.

The aim of this review was to summarize previous reports suggesting a relationship among esophagectomy for esophageal cancer, dysphagia, and sarcopenia. Appropriate interventions to reduce postoperative dysphagia and aspiration pneumonia in patients with resectable esophageal cancer will also be considered.

2 | MATERIALS AND METHODS

To evaluate the relationship between preoperative sarcopenia and pulmonary complications after esophagectomy in patients with esophageal cancer, a structured search was conducted using PubMed, the Cochrane Library, and Web of Science. The English search terms were “esophagectomy” AND “sarcopenia” AND “pulmonary complication.” The reference lists of all the included studies were also searched to identify additional studies of possible relevance. The inclusion criteria were a retrospective or prospective cohort study, patients with esophageal or esophagogastric junctional cancer, an evaluation of preoperative sarcopenia, and an evaluation of pulmonary complications, including pneumonia, after esophagectomy. The exclusion criteria were review articles, conference abstracts, non-English articles, and duplicated publications. The details of the included studies are shown in Table 1. The meta-analysis was performed using Review Manager 5.3 software.

3 | DYSPHAGIA

3.1 | Mechanism of dysphagia

Swallowing involves a series of processes: the intake of food into the oral cavity, the formation of a food bolus through chewing, and the passage of the food bolus through the pharynx and esophagus. Dysphagia arises from a disorder in one of these processes. The major symptoms of dysphagia are aspiration and residue. Aspiration means that sputa, food, and drink enter the larynx and trachea. Residue means that the food bolus remains in the oral cavity or pharynx because of a reduction in transfer.

3.2 | Evaluation of dysphagia

Initially, the repetitive saliva swallowing test (RSST) was used as a screening examination for patients with dysphagia. Later, a videofluoroscopic swallowing test (VFSS) or an endoscopic evaluation of swallowing also began to be performed, as required. The movement of the vocal cords, the response of the larynx, the pharyngeal residue of saliva, and its penetration into the larynx are typically evaluated using an endoscopic examination, and the Hyodo–Komagome score is usually used as an endoscopic scoring system in Japan. On the other hand, the degree of penetration into the larynx and trachea and their response can be measured using VFSS according to a penetration-aspiration scale (PAS). Transportation of the bolus during swallowing can be observed, and dysphagia and pharyngeal residue can be evaluated using both examinations. Additionally, the range, speed, and timing of various organ movements associated with swallowing can also be analyzed, and the mechanisms of swallowing and pharyngeal residue can be investigated. If these mechanisms are intact, rehabilitation to solve the swallowing problems is possible.

3.3 | Relationship between dysphagia and esophageal cancer

There are various reasons for dysphagia after esophagectomy for patients with esophageal cancer. These reasons are shown below.

3.3.1 | Pathophysiology

Many patients with advanced esophageal cancer have dysphagia before treatment because of severe stenosis caused by a large primary tumor or swelling of the metastatic lymph nodes along the esophagus. Patients with malnutrition can also have poor swallowing. Reportedly, 15%–30% of esophageal cancer patients have multiple primary cancers, and the rate of head and neck cancer was particularly high. Esophageal cancer patients with a history of surgery or radiotherapy in the head and neck region often have poor swallowing before treatment for esophageal cancer.

3.3.2 | Aging

Most esophageal cancer patients are elderly; for example, most patients with esophageal cancer in Japan are in their 60s or 70s. Therefore, a reduction in swallowing because of aging is often considered to be an underlying cause. Presbyphagia is not a disease; however, a slight change in swallowing function, such as delayed transportation in the oral cavity, a reduction in pharyngeal muscle strength, or an increase in pharyngeal residue, was found in elderly patients, and penetration into the larynx and aspiration can occur in such patients.

3.3.3 | Dysphagia after esophagectomy

The following things are considered to be causes of dysphagia: an abnormal larynx elevation caused by scarring around the trachea and larynx, a reduced cough reflex caused by a decrease in blood flow in the trachea, the bending of reconstructed organs, and a decrease in
| Authors       | Year | Region | Study design | Cohort size | Sarcopenia Evaluation | PC in patients with sarcopenia | Characteristics of cohort |
|--------------|------|--------|--------------|-------------|-----------------------|-------------------------------|---------------------------|
| Ida et al    | 2015 | Japan  | Retrospective | 138 patients | 61 (44%) BIA          | 21 patients (34%)             |                           |
| Makra D et al| 2016 | Japan  | Retrospective | 104 patients | 29 (28%) BIA          | 11 patients (38%)             |                           |
| Nishigori T et al | 2016 | Japan  | Retrospective | 199 patients | 149 (75%) CT (L3 SMI) | 47 patients (32%)             |                           |
| Elliott JA et al | 2017 | Ireland | Retrospective | 207 patients | 49 (24%) CT (L3 SMI)  | 27 patients (55%) Neoadjuvant therapy |                           |
| Paireder M et al | 2017 | Austria | Retrospective | 130 patients | 80 (62%) CT (L3 SMI)  | 11 patients (14%) Neoadjuvant therapy |                           |
| Jarvinen T et al | 2018 | Finland | Retrospective | 115 patients | 92 (80%) CT (L3 SMI)  | 26 patients (28%) Neoadjuvant therapy |                           |
| Saeki H et al | 2018 | Japan  | Retrospective | 157 patients | 85 (54%) CT (L3 SMI)  | 8 patients (9%) NACRT         |                           |
| Siegal SR et al | 2018 | USA    | Retrospective | 173 patients | 127 (73%) CT (L3 SMI) | 18 patients (14%)             |                           |
| Xu J et al   | 2019 | China  | Retrospective | 141 patients | 73 (52%) CT (L3 SMI)  | 52 patients (71%) MIE         |                           |
| Matsunaga T et al | 2019 | Japan  | Retrospective | 163 patients | 82 (50%) BIA          | 11 patients (13%)             |                           |
| Oguma J et al | 2019 | Japan  | Retrospective | 194 patients | 28 (14%) CT (L3 SMI)  | 7 patients (25%) Superficial ESCC |                           |
| Soma D et al | 2019 | Japan  | Retrospective | 102 patients | 45 (44%) CT (L3 SMI)  | 20 patients (44%)             |                           |
| Kurita D et al | 2020 | Japan  | Retrospective | 161 patients | 19 (12%) HGS          | 9 patients (47%) MIE, Male    |                           |
| Srpicic M et al | 2020 | Slovenia | Retrospective | 139 patients | 23 (17%) CT (L3 SMI)  | 13 patients (57%)             |                           |

Abbreviations: BIA, bioelectrical impedance analysis; CT, computed tomography; ESCC, esophageal squamous cell carcinoma; HGS, handgrip strength; MIE, minimally invasive esophagectomy; NACRT, neoadjuvant chemoradiotherapy; PC, pulmonary complication; SMI, skeletal muscle index.
the swallowing pressure caused by laryngeal nerve paralysis. An elevated larynx can cause obstruction because the isolation of the infrahyoid muscle during cervical lymph node dissection can prevent it from relaxing during subsequent swallowing. This can induce an obstruction in the upper esophagus and a closing insufficiency of the larynx, leading to a decrease in pharynx clearance and penetration into the larynx. Laryngeal nerve paralysis can be reduced with a surgeon’s effort, because this is a postoperative complication caused by the surgical procedure. On the other hand, scarring around the trachea and a decrease in tracheal blood flow are unavoidable, as they are normal conditions after surgery.

In terms of the relationship between surgical procedure and postoperative dysphagia, a three-field lymphadenectomy, compared with a two-field lymphadenectomy, and retrosternal reconstruction were reportedly related to dysphagia.

4 | SARCOPENIC DYSPHAGIA

4.1 | Relationship between sarcopenia and outcomes after esophagectomy

The concept of sarcopenia was first introduced in 1989 as an age-dependent decline in muscle mass, strength, and physical function. The diagnostic criteria for sarcopenia were revised in 2019, and sarcopenia was defined as a gradual and generalized loss of skeletal muscle strength and mass. Moreover, severe sarcopenia was diagnosed as the additional loss of physical condition. Sarcopenia can derive from not only aging, but also systemic disease such as malnutrition, advanced organ failure, inflammatory disease, and malignancy. Several patients with esophageal cancer are likely to be diagnosed as having sarcopenia, since many are elderly and have malnutrition or dysphagia. Several reports have shown that preoperative sarcopenia is associated with postoperative pulmonary complications (PC) among patients undergoing surgery for esophageal cancer. On the other hand, some reports have suggested that sarcopenia is not associated with PC after esophagectomy. To assess the relationship between preoperative sarcopenia and PC after esophagectomy in previously reported patients with esophageal cancer, a structured review was conducted, as mentioned previously. Finally, a total of 14 references were included in this review (Table 1). Among the included studies, the prevalence of preoperative sarcopenia ranged from 12%–80%, while the prevalence of PC after esophagectomy ranged from 9%–71%. A meta-analysis of the included studies revealed that preoperative sarcopenia significantly increased the risk of pulmonary complications after esophagectomy in patients with esophageal cancer (risk ratio = 1.92, 95% confidence interval [CI] = 1.64, 2.25, P <.00001) (Figure 1). However, a relationship between swallowing function and PC was not reported in any of the included studies. In the future, the possible association of sarcopenic dysphagia with PC after esophagectomy in patients with esophageal cancer should be evaluated.

Additionally, some reports suggested that sarcopenia is also associated with a poor prognosis after surgery. Moreover, several reports have suggested that sarcopenia in patients with locally advanced esophageal cancer is associated with the morbidity of dose-limiting toxicities after neoadjuvant chemotherapy or chemo-radiotherapy. A loss of skeletal muscle mass during neoadjuvant therapy has also been reported to be associated with postoperative complications and long-term survival.

4.2 | Definition of sarcopenic dysphagia

In 2012, Kuroda et al first reported a correlation between arm muscle mass and swallowing function, and sarcopenia was subsequently
suggested to be an independent risk factor of dysphagia.\textsuperscript{48,49} A diagnostic algorithm for dysphagia associated with sarcopenia was created by the Working Group on Sarcopenic Dysphagia in Japan in 2017. Dysphagia caused by whole-body sarcopenia was first categorized as “sarcopenic dysphagia” in 2019.\textsuperscript{50}

Swallowing-related muscles, such as the tongue, the geniohyoid muscle, and the pharyngeal wall were evaluated using an ultrasound study,\textsuperscript{51} a computed tomography study,\textsuperscript{52} and a magnetic resonance imaging study,\textsuperscript{53} and these muscle masses were found to be related to aging.\textsuperscript{49} The geniohyoid muscle mass was also related to tongue pressure and jaw-opening strength,\textsuperscript{54} and tongue pressure was related to dysphagia in older individuals.\textsuperscript{55,56} Because of the difficulty in measuring swallowing-related muscle volumes, the diagnostic algorithm for sarcopenic dysphagia, mentioned above, was developed to include only muscle strength.

\section*{4.3 Sarcopenic dysphagia and esophageal cancer}

Clinical studies on sarcopenic dysphagia in patients with esophageal cancer have been limited until now. Only three previous reports have evaluated swallowing function or dysphagia in patients undergoing esophagectomy. Mayanagi et al suggested that preoperative sarcopenia and laryngeal nerve palsy were independent risk factors of postoperative dysphagia in 187 patients with esophageal cancer in a retrospective study.\textsuperscript{25} Katsumata et al reported that a reduction in geniohyoid muscle mass caused dysphagia in patients after surgery for esophageal cancer\textsuperscript{57}; furthermore, Yokoi et al suggested that a decrease in tongue pressure before and after surgery was significantly associated with postoperative pneumonia among inpatients with esophageal cancer after esophagectomy\textsuperscript{58} (Table 2). These findings suggested that dysphagia after esophagectomy seemed to be related to factors associated with patient characteristics; therefore, perioperative interventions for patients with esophageal cancer might improve their swallowing function. Recently, neoadjuvant therapy has become the gold standard for patients with locally advanced esophageal cancer; however, the starting time and details of swallowing training after an esophagectomy are still controversial, and there is no evidence showing a clinical effect of postoperative dysphagia intervention. Considering the load of anastomosis and aspiration, indirect training for swallowing is usually undergone until the beginning of oral ingestion; thereafter, direct training is performed. As mentioned above, the swallowing function is decreased by an

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
References & Yokoi et al & Katsumata et al & Mayanagi et al \\
\hline
Reported date & 2019 & 2019 & 2021 \\
\hline
Study design & Longitudinal study & Retrospective study & Retrospective study \\
\hline
Sample size & 59 & 54 & 187 \\
\hline
Measurement & Tongue pressure measurement, RSST & Geniohyoid muscle mass (CT image), VF & PMI (CT image), VF, FEES \\
\hline
Evaluation & Change in tongue pressure & Change in geniohyoid muscle mass & Sarcopenia as decrease of PMI \\
\hline
Outcomes & Decrease in tongue pressure was associated with the length of ICU stay. & Decrease in geniohyoid muscle mass causes the dysphagia. & Sarcopenic patients with esophageal cancer developed postoperative dysphagia. \\
\hline
\end{tabular}
\caption{Relationship between sarcopenia and dysphagia in patients with esophageal cancer}
\end{table}

\begin{small}
Abbreviations: FEES, fiberoptic endoscopic evaluation of swallowing; ICU, intensive care unit; PMI, psoas muscle mass index; RSST, repetitive saliva swallowing test; VF, videofluoroscopic swallowing study.
\end{small}
esophagectomy; therefore, continuous swallowing training before and after surgery and improvement of the swallowing procedure are important. Okumura et al suggested that perioperative swallowing rehabilitation, including pursed lip breathing, a cervical range of motion exercise, shoulder stretches, jaw opening, tongue exercises, and submental muscle training did not change swallowing biomechanics but decreased the volume of laryngeal and pharyngeal residue in patients after an esophagectomy. The chin-tuck maneuver has been recommended as a swallowing method after an esophagectomy in many reports. This maneuver was suggested to improve airway protection and pyriform sinus residue and to increase the upper esophageal sphincter (UES) opening diameter and prolong the duration of UES opening, compared with the neural position (Table 3).

6 | CONCLUSION

The causes of dysphagia after esophagectomy are numerous, and previous reports have suggested that these factors are closely associated with sarcopenic dysphagia. There has been no evidence regarding interventions for esophageal cancer patients with sarcopenic dysphagia for the purpose of preventing postoperative dysphagia until now; therefore, further evaluations are expected in the future. Importantly, sarcopenia and dysphagia should be accurately evaluated before surgery, and interventions should be consistently performed both before and after esophagectomy. Not only swallowing interventions for dysphagia, but also physical therapy and nutritional support for sarcopenia should be performed simultaneously in cooperation with a multidisciplinary staff. Moreover, a guarantee of manpower resources to provide the intervention and the adherence of patients continuing the intervention are also extremely important. To solve these problems, interventional manuals for medical staff and brochures for patients should be created to allow them to understand fully the significance of interventions and to enhance the motivation of patients.

Because of the development of multimodal therapy for esophageal cancer, which is a refractory cancer, treatment outcomes have been improved. In the future, medical staff should emphasize not only the “cure,” but also the “care” of patients with esophageal cancer after an esophagectomy. To do this, evaluations and interventions by a multidisciplinary staff who are aware of sarcopenic dysphagia will be important.

DISCLOSURE

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ETHICAL APPROVAL

The protocol for this research project has been approved by a suitably constituted Ethics Committee of the institution and it conforms to the provisions of the Declaration of Helsinki. The Ethics Committee of the National Cancer Center Hospital, Approval No. 2020-287.

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REFERENCES

1. Takeuchi H, Miyata H, Ozawa S, Udagawa H, Osugi H, Matsubara H, et al. Comparison of short-term outcomes between open and minimally invasive esophagectomy for esophageal cancer using a nationwide database in Japan. Ann Surg Oncol. 2017;24:1821–7.

2. Mbouni IW, Reddy S, Lidor AO. Complications after esophagectomy. Surg Clin North Am. 2019;99:501–10.

3. Wang PY, Xu LD, Chen XK, Xu L, Yu YK, Zhang RX, et al. Sarcopenia and short-term outcomes after esophagectomy: a meta-analysis. Ann Surg Oncol. 2020;27:3041–51.

4. Pikus L, Levine MS, Yang YX, Rubesin SE, Katzka DA, Laufer I, et al. Videofluoroscopic studies of swallowing dysfunction and the relative risk of pneumonia. AJR Am J Roentgenol. 2003;180:1613–6.

5. Yoshikawa H, Furuta K, Ueno M, Egawa M, Yoshino A, Kondo S, et al. Oral symptoms including dental erosion in gastroesophageal reflux disease are associated with decreased salivary flow volume and swallowing function. J Gastroenterol. 2012;47:412–20.

6. Oba S, Tohara H, Nakane A, Tomita M, Minakuchi S, Uematsu H. Screening tests for predicting the predicting the prognosis of oral intake in elderly patients with acute pneumonia. J Gerontol. 2017;105:96–102.

7. Langmore SE, Schatz K, Olsen N. Fiberoptic endoscopic examination of swallowing safety: a new procedure. Dysphagia. 1988;2:216–9.

8. Sakamoto T, Horiuchi A, Makino T, Kajiyama M, Tanaka N, Hyodo M. Determination of the cut-off score of an endoscopic scoring method to predict whether elderly patients with dysphagia can eat pureed diets. World J Gastrointest Endosc. 2016;8:288–94.

9. Logemann JA. Swallowing physiology and pathophysiology. Otalaryngol Clin N Am. 1988;21:377–90.

10. Lee SY, Cheon HJ, Kim SJ, Shim YM, Zo JI, Hwang JH. Clinical predictor of aspiration after esophagectomy in esophageal cancer patients. Support Care Cancer. 2016;24:295–9.

11. Borders JC, Brates D. Use of the penetration-aspiration scale in dysphagia research: a systematic review. Dysphagia. 2020;35:583–97.

12. Baba Y, Yoshida N, Kinoshita K, Iwatsuki M, Yamashita YI, Chikamoto A, et al. Clinical and prognostic features with esophageal cancer and multiple primary cancers. A retrospective single-institution study. Ann Surg. 2018;267:478–83.

13. Lee GD, Kim YH, Kim JB, Choi SH, Kim HR, Kim DK, et al. Esophageal cancer associated with multiple primary cancers: surgical approaches and long-term survival. Ann Surg Oncol. 2013;20:4260–6.

14. Pezdić M, Strojan P, Boletzár IH. Swallowing disorder after treatment for head and neck cancer. Radiol Oncol. 2019;53:225–30.

15. Schindler A, Denaro N, Russi EG, Pizzorni N, Bossi E, Merlotti A, et al. Dysphagia in head and neck cancer patients treated radiotherapy and systemic therapies: literature review and consensus. Crit Rev Oncol Hematol. 2015;96:372–84.

16. Watanabe M, Toh Y, Ishihara R, Kono K, Matsubara H, Murakami K, et al. Comprehensive registry of esophageal cancer in Japan, 2014. Esophagus. 2022;19:1–26.

17. Namiasiavay-MacDonald AN, Riquelme LF. Presbyphagia to dysphagia: multiple perspectives and strategies for quality care of older adults. Semin Speech Lang. 2019;40:227–42.

18. Lee ML, Kim JU, Oh DH, Park JY, Lee KJ. Oropharyngeal swallowing function in patients with presbyphagia. J Phys Ther Sci. 2018;30:1357–8.

19. Kato H, Miyazaki T, Sakai M, Sano A, Tanaka N, Kimura H, et al. Videofluoroscopic evaluation in oropharyngeal swallowing after radical esophagectomy with lymphadenectomy for esophageal cancer. Anticancer Res. 2007;27:4249–54.

20. Yasuda T, Yano M, Miyata H, Yamasaki M, Takiguchi S, Fujiwara Y, et al. Evaluation of dysphagia and diminished airway protection after three-field esophagectomy and remedy. World J Surg. 2013;37:416–23.

21. Mafune T, Mikami S, Otsubo T, Saij O, Matsuhashita T, Enomoto T, et al. An investigation of factors related to food intake ability and swallowing difficulty after surgery for thoracic esophageal cancer. Dysphagia. 2019;34:592–9.

22. Rosenberg JH. Summary comments. Am J Clin Nutr. 1989;50:1231–3.

23. Cruz-Jentoft AJ, Bahat GBJ, Boirie Y, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing. 2019;48:601.

24. Chen LK, Woo J, Assantachai P, Auyeung TW, Chou MY, Iijima K, et al. Asian working Group for Sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc. 2020;21:300–7.

25. Mayanagi S, Ishikawa A, Matsu K, Matsuda S, Irino T, Nakamura R, et al. Association of preoperative sarcopenia with postoperative dysphagia in patients with thoracic esophageal cancer. Dis Esophagus. 2021;34;doaa121.

26. Papaconstantinou D, Vretakakou K, Paspala A, Misiakos EP, Charalampopoulos A, Nastos C, et al. The impact of preoperative sarcopenia on postoperative complications following esophagectomy for esophageal neoplasia: a systematic review and meta-analysis. Dis Esophagus. 2020;33;doaa002.

27. Nishigori T, Okabe H, Tanaka E, Tsunoda S, Hisamori S, Sakai Y. Sarcopenia as a predictor of pulmonary complications after esophagectomy for thoracic esophageal cancer. J Surg Oncol. 2016;113:678–84.

28. Kurita D, Oguma J, Ishiyama K, Hirano Y, Kanamori J, Daiko H. Handgrip strength predicts postoperative pneumonia after thoracoscopic-laparoscopic esophagectomy for patients with esophageal cancer. Ann Surg Oncol. 2020;37:3173–81.

29. Siegel SR, Dolan JP, Dewey EN, Guimaraes AR, Auyeung TW, Chou MY, Schipper PH, et al. Sarcopenia is not associated with morbidity, mortality, or recurrence after esophagectomy for cancer. Am J Surg. 2018;215:813–7.

30. Saeki H, Nakashima Y, Kudou K, Sasaki S, Jogo T, Hirose K, et al. Neoadjuvant chemoradiotherapy for patients with cT3/nearly T4 esophageal cancer: is sarcopenia correlated with postoperative complications and prognosis? World J Surg. 2018;42:2894–901.

31. Ida S, Watanabe M, Yoshida N, Baba Y, Umezaki N, Harada K, et al. Sarcopenia is a predictor of postoperative respiratory complications in patients with esophageal cancer. Ann Surg Oncol. 2015;22:4432–7.

32. Makura D, Ono R, Inoue J, Kashima M, Oshikiri T, Nakamura T, et al. Preoperative sarcopenia is a predictor of postoperative pulmonary complications in esophageal cancer following esophagectomy: a retrospective cohort study. J Geriatr Oncol. 2016;7:430–6.

33. Elliott JA, Doyle SL, Murphy CF, King S, Guinan EM, Beddy P, et al. Sarcopenia: prevalence, and impact on operative and oncologic...
outcomes in the multimodal management of locally advanced esophageal cancer. Ann Surg. 2017;266:822–30.

34. Paireder M, Asari R, Kristo I, Rieder E, Tamandi D, Ba-Salamah A, et al. Impact of sarcopenia on outcome in patients with esophageal resection following neoadjuvant chemotherapy for esophageal cancer. Eur J Surg Oncol. 2017;43:478–84.

35. Järvinen T, Ilonen I, Kauppi J, Salo J, Räsänen J. Loss of skeletal mass during neoadjuvant treatments correlates with worse prognosis in esophageal cancer: a retrospective cohort study. World J Surg Oncol. 2018;16:27. https://doi.org/10.1186/s12957-018-1327-4

36. Xu J, Zheng B, Zhang S, Zeng T, Chen H, Zheng W, et al. Effect of preoperative sarcopenia on postoperative complications of minimally invasive esophagectomy for esophageal squamous cell carcinoma. J Thorac Dis. 2019;11:2535–45.

37. Matsuanga T, Miyata H, Sugimura K, Motoori M, Asukai K, Yanagimoto Y, et al. Prognosis significance of sarcopenia and systemic inflammatory response in patients with esophageal cancer. Anticancer Res. 2019;39:449–58.

38. Soma D, Kawamura YI, Yamashita S, Wake H, Nohara K, Yamada K, et al. Sarcopenia, the depletion of muscle mass, an independent predictor of respiratory complications after oncological esophagectomy. Dis Esophagus. 2019;32:doy092. https://doi.org/10.1093/dote/doy092

39. Srpic M, Jordan T, Popuri K, Sok M. Sarcopenia and myosteatosis at presentation adversely affect survival after esophagectomy for esophageal cancer. Radiol Oncol. 2020;54:237–46.

40. Deng HY, Zha P, Peng L, Hou L, Huang KL, Li XY. Preoperative sarcopenia is a predictor of poor prognosis of esophageal cancer after esophagectomy: a comprehensive systematic review and meta-analysis. Dis Esophagus. 2019;32:doy115.

41. Nakashima Y, Saei K, Nakanishi R, Sugiyama M, Kurashige J, Oki E, et al. Assessment of sarcopenia as a predictor of poor outcomes after esophagectomy in elderly patients with esophageal cancer. Ann Surg. 2018;267:1100–4.

42. Oguma J, Ozawa S, Kazuno A, Yamamoto M, Ninomiya Y, Yatabe K. Prognostic significance of sarcopenia in patients undergoing esophagectomy for superficial esophageal squamous cell carcinoma. Dis Esophagus. 2019;32:doy104.

43. Tan BH, Brammer K, Randhawa N, Welch NT, Parsons SL, James EJ, et al. Sarcopenia is associated with toxicity in patients undergoing neo-adjuvant chemotherapy for oesophageal cancer. Eur J Surg Oncol. 2015;41:333–8.

44. Anandavadivelan P, Brismar TB, Nilsson M, Johar AM, Martin L. Sarcopenic obesity: a probable risk factor for dose limiting toxicity during neo-adjuvant chemotherapy in oesophageal cancer patients. Clin Nutr. 2016;35:724–30.

45. Reisinger KW, Bosmans JW, Uittenbogaart M, Alsomallai A, Poeze M, Sosef MN, et al. Loss of skeletal muscle mass during neoadjuvant chemoradiotherapy predicts postoperative mortality in esophageal cancer surgery. Ann Surg Oncol. 2015;22:4445–52.

46. Jarvinen T, Ilonen I, Kauppi J, Salo J, Rassinen J. Loss of skeletal muscle mass during neoadjuvant treatments correlates with worse prognosis in esophageal cancer: a retrospective cohort study. World J Surg Oncol. 2018;16:27.

47. Kuroda Y, Kuroda R. Relationship between thinness and swallowing function in aniseice older adults: implications for sarcopenic dysphagia. J Am Geriatr Soc. 2012;60:1785–6.

48. Maeda K, Akagi J. Sarcopenia is an independent risk factor of dysphagia in hospitalized older people. Geriatr Gerontol Int. 2016;16:515–21.

49. Murakami K, Hirano H, Watanabe Y, Edahiro A, Ohara Y, Yoshida H, et al. Relationship between swallowing function and the skeletal muscle mass of older adults requiring long-term care. Geriatr Gerontol Int. 2015;15:1185–92.

50. Fujishima I, Fuji-Kurachi M, Ara H, Hyodo M, Kagaya H, Maeda K, et al. Sarcopenia and dysphagia: position paper by four professional organizations. Geriatr Gerontol Int. 2019;19:91–7.

51. Tamura F, Kikutani T, Tohara T, Yoshida M, Yaegaki K. Tongue thickness relates to nutritional status in the elderly. Dysphagia. 2012;27:556–61.

52. Umekazi T, Nakazawa K, Miller AD. Behaviors of hypoglossal hyoid motoneurons in laryngeal and vestibular reflexes and in glutation and emesis. Am J Phys. 1999;274:950–5.

53. Molfenter SM, Amin MR, Branski RC, Brumm JD, Hagiwara M, Roof SA, et al. Age-related changes in pharyngeal lumen size: a retrospective MRI analysis. Dysphagia. 2015;30:321–7.

54. Baba T, Goto T, Fujimoto K, Honda T, Yagi K, Nagao K, et al. Age-related changes in genioglossal muscle morphology predict reduced swallowing function. J Oral Health Biosci. 2017;30:18–25.

55. Yoshida M, Kikutani T, Tsuga K, Utanohara Y, Hayashi R, Akagawa Y. Decreased tongue pressure reflects symptom of dysphagia. Dysphagia. 2006;21:61–5.

56. Maeda K, Akagi J. Decreased tongue pressure is associated with sarcopenia and sarcopenic dysphagia in the elderly. Dysphagia. 2015;30:80–7.

57. Katsumata K, Mikami S, Otsubo T, Mafune T. Relation between decrease in genioglossal muscle mass and dysphagia after surgery for thoracic esophageal cancer. J St Marianna Univ. 2019;10:63–70.

58. Yokoi A, Ekuni D, Yamanaka R, Hata H, Shirakawa Y, Morita M. Change in tongue pressure and related factors after esophagectomy: a short-term, longitudinal study. Esophagus. 2019;16:300–8.

59. Wakabayashi H, Matsushima M, Momosaki R, Yoshida S, Mutai R, Yodoshi T, et al. The effects of resistance training of swallowing muscles on dysphagia in older people: a cluster, randomized, controlled trial. Nutrition. 2018;48:111–6.

60. Maeda K, Akagi J. Treatment of sarcopenic dysphagia with rehabilitation and nutritional support: a comprehensive approach. J Acad Nutr Diet. 2016;116:573–7.

61. Okumura T, Shimada Y, Watanabe T, Nakamichi N, Nagata T, Tsukada K. Functional outcome assessment of swallowing (FOAMS) scoring and videofluoroscopic evaluation of perioperative swallowing rehabilitation in radical esophagectomy. Surg Today. 2016;46:543–51.

62. Kumai Y, Samejima Y, Watanabe M, Yamoto E. Videofluoroscopic evaluation of pharyngeal swallowing dysfunction after esophagectomy with three-field lymph node dissection. Eur Arch Otorhinolaryngol. 2017;274:321–6.

63. Kumai Y, Yoshida N, Kamenosono Y, Matsubara K, Samejima Y, Baba H, et al. Effects of chin-down maneuver on the parameters of swallowing function after esophagectomy with 3-field lymphadenectomy examined by videofluoroscopy. Arch Phys Med Rehabil. 2017;98:1174–9.

64. Lewin JS, Hebert TM, Putnam JB, DuBrow RA. Experience with the chin tuck maneuver in postesophagectomy aspirators. Dysphagia. 2001;16:216–9.