Change in tongue pressure and the related factors after esophagectomy: A short-term, longitudinal study

Aya Yokoi[1], Daisuke Ekuni[1,2], Reiko Yamanaka[3], Hironobu Hata[4], Yasuhiro Shirakawa[5], Manabu Morita[1]

1 Department of Preventive Dentistry, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, 2-5-1 shikata-cho, kita-ku, Okayama, Japan.

2 Advanced Research Center for Oral and Craniofacial Sciences, Okayama University Dental School, 2-5-1 shikata-cho, kita-ku, Okayama, Japan.

3 Division of Hospital Dentistry, Central Clinical Department, Okayama University Hospital, 2-5-1 shikata-cho, kita-ku, Okayama, Japan.

4 Department of Dentistry and Oral surgery, National Hospital Organization Hokkaido Cancer Center, 5-7-1-1 yamanote, nishi-ku, Sapporo, Japan.

5 Department of Gastroenterological Surgery, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, 2-5-1 shikata-cho, kita-ku, Okayama, Japan.

Corresponding author: Daisuke Ekuni, Department of Preventive Dentistry, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, 2-5-1 shikata-cho, kita-ku, Okayama, 700-8558, Japan. Phone:+81-86-235-6712, Fax:+81-86-235-6714, E-mail:dekuni7@md.okayama-u.ac.jp

Abstract

Background

Dysphagia is a prominent symptom after esophagectomy and may cause aspiration pneumonia. Swallowing evaluation after esophagectomy can predict and help control the incidence of postoperative pneumonia. The aim of this study was to clarify whether the change in tongue pressure was associated with any related factor and postoperative dysphagia/pneumonia in patients with esophageal cancer after esophagectomy.

Methods

Fifty-nine inpatients (41 males and 18 females; 33 - 77 years old) who underwent esophagectomy participated in this study. Measurement of tongue pressure and the repetitive saliva swallowing test (RSST) was performed before esophagectomy (baseline) and at 2 weeks postoperatively. The general data were collected from patients' medical records, including sex, age, type of cancer, cancer stage, location of cancer, operative approach, history of previous chemotherapy, surgical duration, amount of bleeding during surgery, incidences of postoperative complications, intubation period, period between surgery and initiation of oral alimentation, and intensive care unit (ICU) stay, blood chemical analysis, and lifestyle.

Results

Tongue pressure decreased significantly after esophagectomy ($p = 0.011$). The decrease of tongue pressure was significantly associated with length of ICU stay and preoperative tongue pressure on multiple regression analysis ($p < 0.05$). The decrease of tongue pressure in the RSST<3 or postoperative pneumonia (+) group was significantly greater than in the RSST≥3 ($p = 0.003$) or pneumonia (-) group ($p = 0.021$).

Conclusions

The decrease in tongue pressure was significantly associated with the length of ICU stay, preoperative tongue pressure, and the incidence of dysphagia and pneumonia among inpatient after esophagectomy.

Key words: deglutition; deglutition disorders; esophageal neoplasms; esophagectomy; intensive care units

Introduction

Esophagectomy for esophageal cancer is highly invasive and has a high risk of postoperative complications including damage to the recurrent laryngeal nerve, dysphagia and pneumonia [1]. Dysphagia is a prominent symptom through swallowing impairments after esophagectomy and may cause aspiration pneumonia [2, 3]. Aspiration pneumonia affects mortality during the early postoperative period [4-6]. Furthermore, patients after esophagectomy had lower quality of life scores across many domains including swallowing impairments [7]. Thus, improvement of swallowing function and prevention of aspiration pneumonia are necessary for patients after esophagectomy [8, 9].

Swallowing function can predict postoperative pneumonia after esophagectomy, and recovery of swallowing function reduces the incidence of postoperative pneumonia [10]. Thus, safe and easy evaluation of swallowing is desired to predict pneumonia. Measurement of tongue pressure has been developing using a non-invasive, easy, and portable device. A previous study showed that, using the device, tongue pressure was reduced 1-2 weeks after surgery for head and neck cancer including oral cavity as operative field and then, tongue pressure was associated with cancer stage and operative reconstruction [11]. Thus, exact monitoring of tongue pressure is important for evaluation of swallowing and oropharyngeal movements [12, 13].

The previous study showed that tongue pressure after esophagectomy was reduced among only 5 patients [11]. However, the factors related to changes in tongue pressure after esophagectomy remain unclear, unlike those after surgery for head and neck cancer including oral cavity as operative field. We hypothesized that tongue pressure after esophagectomy is decreased by some factors, and that the change in tongue pressure is associated with postoperative dysphagia/pneumonia in esophageal cancer patients as a review reports abnormal swallowing and increased pneumonia risks after esophagectomy [3]. The aim of this study was to clarify whether the change in tongue pressure was associated with any related factor and postoperative dysphagia/pneumonia in patients with esophageal cancer after esophagectomy.

Material and Methods

Ethics Statement

This was a longitudinal study. The study protocols were approved by the ethics committee of Okayama University Hospital (No. 1506-074, July 17, 2012). All procedures followed were in accordance with the ethical standards of the responsible committees on human experimentation (institutional and national) and with the Helsinki Declaration of 1964 and later versions. Written, informed consent was obtained from all patients for inclusion in the study.

Study population

The inclusion criteria were as follows: esophagectomy for primary esophageal cancer planned at the Department of Gastroenterological Surgery at Okayama University Hospital from January 2016 to December 2017; received oral hygiene care at the dental clinic; and had the ability to provide written, informed consent. Exclusion criteria were: inability to continue the study due to re-operation or other reasons; and undergoing postoperative swallowing rehabilitation (cervical range of motion exercise and tongue exercise) [13] that can change tongue pressure by a speech-language-hearing therapist because the therapist found patients with high risk of dysphagia using videofluorography.

Measurement of tongue pressure

Tongue pressure measurements were performed using the JMS tongue pressure measurement system (JMS Co. Ltd., Hiroshima, Japan) on the day before esophagectomy and 2 weeks postoperatively [14]. The patient was placed in a relaxed sitting position and asked to place the balloon on the anterior part of the palate. The patient was then asked to raise the tongue and compress the balloon onto the palate as much as possible for 5 s. Measurements were repeated three times, and the mean value was used as the individual tongue pressure. The change in tongue pressure was calculated by subtracting 2-weeks value from baseline.

Dysphagia screening test

The Repetitive Saliva Swallowing Test (RSST) as a dysphagia screening test was performed at the same time as measurement of tongue pressure [15] because RSST does not include intake per mouth which might make it a safer screening method unlike water swallowing test. The patient was instructed to repeatedly swallow saliva for 30 s and to count the number of swallows achieved. The number of swallows was counted by a dentist. The cutoff value was set at three swallows or less/30 s, because the sensitivity and specificity for dysphagia were 0.98 and 0.66 in the previous study [15].

General status assessment

Medical charts were reviewed to obtain information about age, sex, and several perioperative factors. Perioperative information included: body weight, height, cancer type, cancer stage (International Union Against Cancer ver. 7), tumor location, with or without previous chemotherapy, operative approach (thoracotomy or thoracoscopy), field of lymphadenectomy (<3-field or 3-feild), operative time, operative bleeding, extubation day, fever (≥38°C) days, incidence of pneumonia and aspiration, frequency of recurrent laryngeal nerve palsy and anastomotic leakage, reconstruction, laryngectomy, period between surgery and initiation of oral alimentation, length of ICU stay, preoperative number of white blood cells (WBC), serum C-reactive protein (CRP), and albumin (Alb). Pneumonia was postoperatively diagnosed by the below criteria. The necessary criterion for pneumonia diagnosis was a radiographic infiltrate by surgeons. Furthermore, a pneumonia diagnosis required at least 2 of the following 3 criteria: white blood count of 9800 (/µl) or higher; temperature of 38°C or higher; and purulent sputum [16]. The definition of movement from ICU to general ward was based on patients' condition with no-fever, no-respiratory and no-circulatory problem, and the improvement of physical activity (the ability of walking). Aspiration, recurrent laryngeal nerve palsy and anastomotic leakage were diagnosed using a laryngoscope at 1 week postoperatively. Then, patients who observed no complications were allowed to start oral alimentation. The information about lifestyle (drinking and smoking habits) was extracted from the patients' medical charts. Drinking status was categorized into [never; less than 5 days a week (light); 5 or more days a week, less than 360 mL a day (moderate); 5 or more days a week, 360 mL or more day (heavy)]. Smoking status was categorized into 'never', 'past', and 'current' [17].

Statistical analysis

The normality of data was investigated by the histogram, the Shapiro-Wilk test, the normal Q-Q plots, the skewness and the kurtosis [18]. We confirmed the normal distribution of the tongue pressure by the Shapiro-Wilk test (preoperative, $p = 0.501$; postoperative, 0.984; and change in tongue pressure, 0.615) as well as other methods. Sample size was estimated from the previous study [11]. The expected values of tongue pressure were 29.7 ± 2.0 kPa at the preoperative and 17.7 ± 2.3 kPa at the postoperative. Based on the data, a sample size of at least 54 was needed to provide power of 95% with an alpha of 0.05 using the paired *t*-test. Power analysis and sample size determination were calculated using statistical software (G*Power ver. 3.1.9.2, Universität Kiel, Germany) [19]. Data analysis was done with the Statistical Package for Social Science (SPSS version 20, SPSS Japan, Tokyo, Japan). The correlations between the decrease of tongue pressure and the other parameters were analyzed using Spearman's correlation coefficient and multiple regression analysis.

Furthermore, the patients were divided into two groups: dysphagia (RSST score < 3) (+) and (-) groups, pneumonia (+) and (-) groups at 2 weeks postoperatively, cervical and not-cervical groups, < 3-field lymphadenectomy and 3-field lymphadenectomy groups, postoperative aspiration (+) and (-) groups, recurrent laryngeal nerve palsy (+) and (-) groups or anastomotic leakage (+) and (-) groups [15]. Differences in the changes in tongue pressure between these two groups were analyzed by the Mann-Whitney *U* test. For tongue pressure, the comparison between tongue pressure at baseline and at 2 weeks postoperatively was also investigated by the paired *t*-test. The level of significance was set at $p < 0.05$.

Finally, the characteristics of participants were compared between the followed-up and excluded groups. Differences between the two groups were analyzed by the Mann-Whitney *U* test, the Fisher's exact test and Chi-squared test. The level of significance was set at $p < 0.05$.

Results

As shown in Figure 1, of the 84 patients, 59 [41 males and 18 females; 33 - 77 years old, 64.2 (mean) and 64.0 [median] years old) completed the study. Thus, the follow-up rate was 70.2%. Ten patients discontinued this study because they had severe malaise. The characteristics of the patients are shown in Table 1. Overall, eight patients (13.6%) developed pneumonia. Tongue pressure [median (25%, 75%) and mean ± SD] at baseline was 35.6 (30.4, 40.9) and 35.6 ± 7.3 kPa. All patients received postoperative oral hygiene care by nurses, and perioperative respiratory rehabilitation by physical therapists. All patients started tube feeding postoperatively within a few days. Fifty-five patients underwent gastric tube reconstruction. There were no cases of the laryngectomy.

Tongue pressure decreased significantly from baseline (35.6 ± 7.3 kPa) to 2 weeks postoperatively (34.2 ± 7.3 kPa) ($p = 0.011$, the paired *t*-test) (Figure 2). Tongue pressure in 37 patients (62.7%) decreased.

Table 2 shows the associations between change in tongue pressure (baseline to 2 weeks) and related parameters. The change in tongue pressure was significantly associated with operative time, period between surgery and initiation of oral alimentation, length of ICU stay and preoperative tongue pressure (all $p < 0.05$). In the multiple regression model, the change in tongue pressure was significantly associated with length of ICU stay ($p = 0.031$) and preoperative tongue pressure ($p = 0.046$) (Table 3). Furthermore, the period between surgery and initiation of oral alimentation was positively associated with the length of ICU stay.

Table 4 shows that the change in tongue pressure was greater in the RSST low-score group than in the high-score group ($p = 0.003$). The pneumonia (+) group showed a significantly larger decrease in tongue pressure than the pneumonia (-) group ($p = 0.021$). There were no significant differences in the change in tongue pressure with respect to the other clinical factors.

There were no significant differences between the followed-up (N = 59) and excluded groups (N = 25), except for the incidence of recurrent laryngeal nerve palsy and aspiration (Table 5, 6).

Discussion

In this study, tongue pressure decreased significantly in perioperative patients after esophagectomy for esophageal cancer. The decrease in tongue pressure was significantly associated with the length of ICU stay on multiple regression analysis. In gastrointestinal surgery, the patients who had to fast longer had longer postoperative ICU stays [20]. In the present study, the period between surgery and initiation of oral alimentation was positively associated with the length of ICU stay. Patients who had a longer length of ICU stay had a longer the period between surgery and initiation of oral alimentation, which led to decreased tongue pressure by disuse muscular atrophy.

The decrease in tongue pressure was significantly associated with the preoperative tongue pressure on multiple regression analysis. As the preoperative tongue pressure was higher, the decrease in tongue pressure was greater. Tongue pressure is one of the important parameters for evaluating a swallowing disorder, which is a prominent symptom after esophagectomy and may cause aspiration pneumonia [2]. Complications, including pneumonia, affect patients' quality of life and survival [7, 21, 22]. Thus, these findings suggest that we should pay attention to tongue pressure, especially to high level of preoperative tongue pressure in patients with esophageal cancer after esophagectomy.

The decrease in tongue pressure was significantly associated with the RSST score at 2 weeks postoperatively. The RSST is used for screening dysphagia, and one of the methods for assessment of swallowing function, as well as the tongue pressure [15]. The RSST is a predictor of aspiration [23, 24]. The decrease in tongue pressure may also be a predictor of aspiration in patients after esophagectomy. Patients with pneumonia showed a larger decrease in tongue pressure than those without pneumonia. Our finding suggests that decreased tongue pressure is associated with dysphagia and indirectly with the incidence of pneumonia.

Patients with aspiration did not show a larger decrease in tongue pressure than those without aspiration. We excluded the sever cases of postoperative aspiration because the patients received the rehabilitation (n=7), and the number of aspiration was small in the analyzed data (n=6) that might be the reason for no significant association between decrease in tongue pressure and aspiration in this study.

A lingual resistance exercise can significantly increase tongue pressure [25]. Therefore, a lingual resistance exercise for patients during the postoperative weeks might be important for preventing dysphagia and pneumonia.

The change in tongue pressure was not related to the recurrent laryngeal nerve palsy in this study. Tongue muscles are not innervated by the recurrent laryngeal nerve but the hypoglossal nerve [26]. Thus, the recurrent laryngeal nerve palsy did not affect the change in tongue pressure. The recurrent laryngeal nerve palsy was not related to postoperative pneumonia and aspiration (data not shown). The previous studies reported that recurrent laryngeal nerve palsy is the risk of pneumonia and aspiration [27, 28]. In the present study, the prevalence of the recurrent laryngeal nerve palsy was low. Thus, the effects of the recurrent laryngeal nerve palsy on pneumonia and aspiration was not statistically significant.

The change in tongue pressure was not related to anastomotic leakage. The anastomotic leakage and the laryngectomy for cervical esophageal cancer are risk factors for swallowing function [29, 30]. In this study, the severe cases of anastomotic leakage were excluded because they received swallowing rehabilitation and re-operation. Moreover, there were no cases of the laryngectomy. Thus, the association of the anastomotic leakage and the laryngectomy with change in tongue pressure was not significant in this study.

The change in tongue pressure was not related to the lymphadenectomy. The swallowing disorder after esophagectomy was affected stronger by operative time than by the field of lymphadenectomy [28]. Thus, the influence of the field of lymphadenectomy may be small for the tongue pressure compared to operative time in this study.

Furthermore, tongue pressure or the change in tongue pressure was not associated with cancer stage and location of cancer. In patients who underwent surgery for head and neck cancer, those with cancer stage III and IV showed significantly decreased tongue pressure compared with stages I and II [11]. The head and neck cancer patients with advanced stages had more problems with oral function than the patients with early-stage disease [31]. Head and neck cancer surgery, which resects an oral organ and causes abnormal oral function, may more strongly affect tongue pressure than esophagectomy.

The patients in this study may not represent a specific population. First, eight patients (13.6%) developed pneumonia in this study. Several surveys have reported that pneumonia after esophagectomy has incidence rates of 8.7 - 17.7% [32, 33]. The incidence rate in this study was within the range. Second, the mean tongue pressure at baseline (35.6 kPa) was within the range in the previous studies (29.7 - 40.7 kPa) of Japanese elderly people using the same device [12, 34, 35].

The median length of ICU stay was 5 days. The length in this study was longer than that in other studies (1-2 days) [36, 37]. The reason may depend on our definition of movement from ICU to general ward. Because all patients received medical cares and physical rehabilitation in ICU until getting objective condition with no-fever, no-respiratory and no-circulatory problem, and the ability of walking, the ICU stay tended to be longer.

This study has some limitations. First, this was a short-term longitudinal study. The longer-term effects were not investigated. Second, this study was conducted in a single institution. A multi-center study will be needed to extrapolate these findings to general inpatients with esophageal cancer after esophagectomy. Third, since the follow-up rate was low, selection bias may have been present. Although only the prevalence of recurrent laryngeal nerve palsy and aspiration was significantly different between patients who were and were not followed-up, it is possible that the low follow-up rate led to an over- or under-estimation of the true relationship. Fourth, dysphagia was not diagnosed using videofluorography and fiberoptic endoscopic evaluation, but a screening method was used because of the safety, and the good sensitivity and specificity [15]. Fifth, we did not measure the tongue pressure in an acute phase within one week after esophagectomy although postoperative one week is the period with a highest risk for aspiration or pneumonia. Finally, we did not consider other important confounding factors including pathophysiological mechanisms [3].

In conclusion, a decrease in tongue pressure was significantly associated with length of ICU stay, preoperative tongue pressure, dysphagia, and pneumonia among inpatients with esophageal cancer after esophagectomy. To the best of our knowledge, this is the first report to clarify the impact of esophagectomy on tongue pressure.

Acknowledgments

This work was supported by Grants-in-Aid for Scientific Research (No. 15K11416) from the Ministry of Education, Culture, Sports, Science and Technology, Tokyo, Japan.

Conflict of interest

Aya Yokoi, Daisuke Ekuni, Reiko Yamanaka, Hironobu Hata, Yasuhiro Shirakawa, and Manabu Morita declare that they have no conflict of interest.

References

1. Tachimori Y, Ozawa S, Numasaki H, et al. Comprehensive registry of esophageal cancer in Japan, 2009. Esophagus. 2009;13:110-37.

2. Martin RE, Letsos P, Taves DH, et al. Oropharyngeal dysphagia in esophageal cancer before and after transhiatal esophagectomy. Dysphagia. 2001;16:23-31.

3. Kaneoka A, Yang S, Inokuchi H, et al. Presentation of oropharyngeal dysphagia and rehabilitative intervention following esophagectomy: a systematic review. Dis Esophagus. 2018;31.

4. Heitmiller RF, Jones B. Transient diminished airway protection after transhiatal esophagectomy. Am J Surg. 1991;162:442-6.

5. Atkins BZ, Shah AS, Hutcheson KA, et al. Reducing hospital morbidity and mortality following esophagectomy. Ann Thorac Surg. 2004;78:1170-6.

6. Wu N, Zhu Y, Kadel D, et al. The prognostic influence of body mass index, resting energy expenditure and fasting blood glucose on postoperative patients with esophageal cancer. BMC Gastroenterol. 2016;16:142.

7. Taioli E, Schwartz R M, Lieberman-Cribbin W, et al. Quality of life after open or minimally invasive esophagectomy in patients with esophageal cancer-a systematic review. Semin Thorac Cardiovasc Surg. 2017;29:377-90.

8. Yamamoto M, Yamasaki M, Sugimoto K, et al. Risk evaluation of postoperative delirium using comprehensive geriatric assessment in elderly patients with esophageal cancer. World J Surg. 2016;40:2705-12.

9. Ra J, Paulson EC, Kucharczuk J, et al. Postoperative mortality after esophagectomy for cancer: development of a preoperative risk prediction model. Ann Surg Oncol. 2008;15:1577-84.

10. Berry MF, Atkins BZ, Tong BC, et al. A comprehensive evaluation for aspiration after esophagectomy reduces the incidence of postoperative pneumonia. J Thorac Cardiovasc Surg. 2010;140:1266-71.

11. Hasegawa Y, Sugahara K, Fukuoka T, et al. Change in tongue pressure in patients with head and neck cancer after surgical resection. Odontology. 2017;105:494-503.

12. Ono T, Kumakura I, Arimoto M, et al. Influence of bite force and tongue pressure on oro-pharyngeal residue in the elderly. Gerodontology. 2007;24:143-50.

13. Okumura T, Shimada Y, Watanabe T, et al. Functional outcome assessment of swallowing (FOAMS) scoring and videofluoroscopic evaluation of perioperative swallowing rehabilitation in radical

esophagectomy. Surg Today. 2016;46:543-51.

14. Takahashi M, Koide K, Arakawa I, et al. Association between perioral muscle pressure and masticatory performance. J Oral Rehabil. 2013;40:909-15.

15. Oguchi K, Saitoh E, Baba M, et al. The Repetitive Saliva Swallowing Test (RSST) as a screening test of functional dysphagia (2) validity of RSST. Jpn J Rehabil Med. 2000;37:383-8 (In Japanese).

16. Tsubosa Y, Sato H, Tachimori Y, et al. Multi-institution retrospective study of the onset frequency of postoperative pneumonia in thoracic esophageal cancer patients. Esophagus. 2014;11:126-35.

17. Yokoi A, Maruyama T, Yamanaka R, et al. Relationship between acetaldehyde concentration in mouth air and tongue coating volume. J Appl Oral Sci. 2015;23:64-70.

18. Henderson AR. Testing experimental data for univariate normality. Clin Chim Acta. 2006;366:112-29.

19. Faul F, Erdfelder E, Lang AG, et al. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007;39:175-91.

20. Pereira NC, Turrini RNT, Poveda VB. Perioperative fasting time among cancer patients submitted to gastrointestinal surgeries. Rev Esc Enferm USP. 2017;51:e03228.

21. Chang YL, Tsai YF, Wu YC, et al. Factors relating to quality of life after esophagectomy for cancer patients in Taiwan. Cancer Nurs. 2014;37:4-13.

22. Luc G, Durand M, Chiche L, et al. Major post-operative complications predict long-term survival after esophagectomy in patients with adenocarcinoma of the esophagus. World J Surg. 2015;39:216-22.

23. Yoshikawa H, Furuta K, Ueno M, 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.

24. Oba S, Tohara H, Nakane A, et al. Screening tests for predicting the prognosis of oral intake in elderly patients with acute pneumonia. Odontology. 2017;105:96-102.

25. Robbins J, Gangnon RE, Theis SM, et al. The effects of lingual exercise on swallowing in older adults. J Am Geriatr Soc. 2005;53:1483-9.

26. Fregosi RF, Ludlow CL. Activation of upper airway muscles during breathing and swallowing. J Appl Physiol (1985). 2014;116:291-301.

27. Scholtemeijer MG, Seesing MFJ, Brenkman HJF, et al. Recurrent laryngeal nerve injury after esophagectomy for esophageal cancer: incidence, management, and impact on short- and long-term outcomes. J Thorac Dis. 2017;9:S868-78.

28. Lee SY, Cheon HJ, Kim SJ, et al. Clinical predictors of aspiration after esophagectomy in esophageal cancer patients. Support Care Cancer. 2016;24:295-9.

29. Huang Q, Zhong J, Yang T, et al. Impacts of anastomotic complications on the health-related quality of life after esophagectomy. J Surg Oncol. 2015;111:365-70.

30. Pillon J, Gonçalves MI, De Biase NG. Changes in eating habits following total and frontolateral laryngectomy. Sao Paulo Med J. 2004;122:195-9.

31. Veldhuis D, Probst G, Marek A, et al. Tumor site and disease stage as predictors of quality of life in head and neck cancer: a prospective study on patients treated with surgery or combined therapy with surgery and radiotherapy or radiochemotherapy. Eur Arch Otorhinolaryngol. 2016;273:215-24.

32. Yoshida N, Watanabe M, Baba Y, et al. Risk factors for pulmonary complications after esophagectomy for esophageal cancer. Surg Today. 2014;44:526-32.

33. Shiozaki A, Fujiwara H, Okamura H, et al. Risk factors for postoperative respiratory complications following esophageal cancer resection. Oncol Lett. 2012;3:907-12.

34. Yamanashi H, Shimizu Y, Higashi M, et al. Validity of maximum isometric tongue pressure as a screening test for physical frailty: Cross-sectional study of Japanese community-dwelling older adults. Geriatr Gerontol Int. 2018;18:240-9.

35. Utanohara Y, Hayashi R, Yoshikawa M, et al. Standard values of maximum tongue pressure taken using newly developed disposable tongue pressure measurement device. Dysphagia. 2008;23:286-90.

36. Yatabe T, Kitagawa H, Yamashita K, et al. Comparison of the perioperative outcome of esophagectomy by thoracoscopy in the prone position with that of thoracotomy in the lateral decubitus position. Surg Today. 2013;43:386-91.

37. Liu YW, Yan FW, Tsai DL, et al. Expedite recovery from esophagectomy and reconstruction for esophageal squamous cell carcinoma after perioperative management protocol reinvention. J Thorac Dis. 2017;9:2029-37.

Table 1. Characteristics of participants (N=59)

Variable		Median (25%, 75%) / Number (%)
Age (y)		64 (61, 69)
Sex	Male	41 (69.5)
	Female	18 (30.5)
Height (m)		1.64 (1.59, 1.71)
Weight (kg)		60.0 (51.3, 64.6)
Body mass index (kg/m^2)		21.2 (19.3, 22.1)
Cancer type	Squamous cell carcinoma	57 (96.6)
	Adenocarcinoma	2 (3.4)
Pathological Stage	0	4 (6.8)
	1	17 (28.8)
	2	17 (28.8)
	3	18 (30.5)
	4	3 (5.1)
Location of cancer	Cervical	4 (6.8)
	Thoracic	44 (74.6)
	Abdominal	11 (18.5)
Chemotherapy	(+)	39 (66.1)
Operative approach	Thoracotomy	8 (13.6)
	Thoracoscopy	51 (86.4)
Lymphadenectomy	<3-field	20 (33.9)
	3-field	39 (66.1)
Operative time (min)		540 (501, 579)
Operative bleeding (ml)		170 (100, 345)
Extubation after surgery (days)		1 (1, 1)
Period between surgery and initiation of oral alimentation		9 (8, 11)
Number of fever (≥38°C) days		2 (1, 4)
Preoperative WBC count (10^3/µl)		4.87 (4.14, 5.41)
Preoperative CRP concentration (mg/dl)		0.09 (0.04, 0.17)
Preoperative albumin concentration (g/dl)		3.9 (3.6, 4.1)
Postoperative pneumonia	(+)	8 (13.6)
Postoperative aspiration	(+)	6 (10.2)
Recurrent laryngeal nerve palsy	(+)	8 (13.6)
Anastomotic leakage	(+)	5 (8.5)
Length of ICU stay (days)		5 (5, 6)
Smoking status	Never	11 (18.6)
	Past	48 (81.4)
	Current	0 (0.0)
Drinking frequency (/week)	Never	10 (16.9)
	Light	1 (1.7)
	Moderate	48 (81.4)
	Heavy	0 (0.0)
Preoperative tongue pressure (kPa)		35.6 (30.4, 40.9)
Preoperative RSST score		4 (4, 5)

WBC, white blood cell; CRP, C-reactive protein; ICU, intensive care unit; RSST, repetitive saliva swallowing test.

Table 2. Associations between change in tongue pressure (baseline - 2 weeks) and related parameters (N=59)

Variable	Spearman correlation coefficient	p value
Age	0.117	0.376
Pathological stage	-0.033	0.802
Operative time (min)	0.302	0.020
Operative bleeding (ml)	0.032	0.809
Extubation after surgery (days)	0.088	0.507
Period between surgery and initiation of oral alimentation	0.273	0.036
Fever (≥38°C) days	0.071	0.593
Preoperative WBC count (10^3/μl)	-0.025	0.853
Preoperative CRP concentration (mg/dl)	0.233	0.075
Preoperative albumin concentration (g/dl)	-0.120	0.367
Preoperative BMI (kg/m^2)	0.099	0.455
Length of ICU stay (days)	0.293	0.024
Preoperative tongue pressure (kPa)	0.342	0.008

WBC, white blood cell; CRP, c-reactive protein; Alb, albumin; ICU, intensive care unit;

Table 3. Correlations between decrease in tongue pressure (baseline - 2 weeks) and perioperative parameters on multiple regression analysis (N=59)

Variable	Standardized coefficient	p value
Operative time (min)	0.219	0.071
Period between surgery and initiation of oral alimentation (days)	0.231	0.059
Length of ICU stay (days)	0.264	0.031
Preoperative tongue pressure (kPa)	0.243	0.046

ICU, intensive care unit.

Table 4. Associations between clinical factors and change in tongue pressure (baseline - 2 weeks) (N=59)

Variable		Change in tongue pressure (kPa)	p value[a]
RSST score at 2 weeks	≥3	0.70 (-1.43, 4.23)[b]	0.003
	<3	4.47 (-2.26, 6.83)	
Location of cancer	Cervical	1.98 (-2.33, 5.65)	0.695
	Not-cervical	0.73 (-1.43, 5.03)	
Lymphadenectomy	<3-field	-0.13 (-2.55, 2.51)	0.082
	3-field	1.87 (-0.20, 5.07)	
Postoperative pneumonia	(+)	5.43 (2.21, 6.61)	0.021
	(-)	0.63 (-2.00, 3.07)	
Postoperative aspiration	(+)	1.65 (-2.23, 4.88)	0.990
	(-)	0.73 (-1.43, 5.05)	
Recurrent laryngeal nerve palsy	(+)	1.18 (-3.11, 3.86)	0.618
	(-)	1.53 (-1.43, 5.07)	
Anastomotic leakage	(+)	0.70 (-1.00, 8.13)	0.499
	(-)	1.53 (-1.48, 4.56)	

RSST, repetitive saliva swallowing test; [a] Mann-Whitney *U* test, [b] Median (25%, 75%)

Table 5. Differences in general information between the analyzed (followed-up) group and the excluded group (N=84)

Variable		Followed-up group (n=59)	Excluded group (n=25)	p-value
Age (y)		64 (61, 69)[a]	66 (61, 71)	0.502[c]
Sex	Male	41 (69.5)	21 (84.0)	0.167[d]
	Female	18 (30.5)	4 (16.0)	
Height (m)		1.64 (1.59, 1.71)[b]	1.67 (1.62, 1.72)	0.457[c]
Weight (kg)		60.0 (51.3, 64.6)	59.8 (51.1, 68.4)	0.551[c]
Body mass index (kg/m^2)		21.2 (19.3, 22.1)	22.0 (18.6, 24.2)	0.674[c]
Cancer type	Squamous cell carcinoma	57 (96.6)	23 (92.0)	0.579[e]
	Adenocarcinoma	2 (3.4)	2 (8.0)	
Pathological Stage	0/1/2	38 (64.4)	13 (52.0)	0.287[d]
	3/4	21 (35.6)	12 (48.0)	
Location of cancer	Cervical	4 (6.8)	1 (4.0)	1.000[e]
	Thoracic/Abdominal	55 (93.2)	24 (96.0)	
Smoking status	Never	11 (18.6)	4 (16.0)	1.000[e]
	Past	48 (81.4)	21 (84.0)	
Drinking frequency (/week)	Never/Light	11 (18.6)	8 (32.0)	0.181[d]
	Moderate	48 (81.7)	17 (68.0)	
Preoperative tongue pressure (kPa)		35.6 (30.4, 40.9)	35.9 (29.3, 42.4)	0.891[c]
Preoperative RSST score		4 (4, 5)	4 (3, 4)	0.051[c]

WBC, white blood cell; CRP, c-reactive protein; ICU, intensive care unit; RSST, repetitive saliva swallowing test.

[a] Median (25%, 75%), [b] Number (%), [c] Mann-Whitney *U* test, [d] χ^2 test, [e] Fisher's exact test,

Table 6. Differences in perioperative factors between the analyzed (followed-up) group and the excluded group (N=84)

Variable		Followed-up group (n=59)	Excluded group (n=25)	p-value
Chemotherapy	(+)	39 (66.1)[a]	16 (64.0)	0.853[c]
Operative approach	Thoracotomy	8 (13.6)	3 (12.5)	1.000[d]
	Thoracoscopy	51 (86.4)	21 (87.5)	
Lymphadenectomy	3-field	39 (66.1)	12 (52.2)	0.243[c]
Operative time (min)		540 (501, 579)[b]	561 (484, 688)	0.313[e]
Operative bleeding (ml)		170 (100, 345)	190 (135, 495)	0.372[e]
Extubation after surgery (days)		1 (1, 1)	1 (1, 1)	0.102[e]
Period between surgery and initiation of oral alimentation (days)		9 (8, 11)	10 (8, 22)	0.175[e]
Number of fever (≥38°C) days		2 (1, 4)	3 (2, 4)	0.197[e]
Preoperative WBC count (10^3/µl)		4.87 (4.14, 5.41)	5.37 (4.06, 6.56)	0.223[e]
Preoperative CRP concentration (mg/dl)		0.09 (0.04, 0.17)	0.13 (0.07, 0.81)	0.065[e]
Preoperative albumin concentration (g/dl)		3.9 (3.6, 4.1)	3.6 (3.4, 4.1)	0.065[e]
Postoperative pneumonia	(+)	8 (13.6)	8 (34.8)	0.059[d]
Postoperative aspiration	(+)	6 (10.2)	7 (30.4)	0.040[d]
Recurrent laryngeal nerve palsy	(+)	8 (13.6)	10 (43.5)	0.003[c]
Anastomotic leakage	(+)	5 (8.5)	1 (4.3)	1.000[d]
Length of ICU stay (days)		5 (5, 6)	6 (5, 6)	0.622[e]

WBC, white blood cell; CRP, c-reactive protein; ICU, intensive care unit

[a] Median (25%, 75%), [b] Number (%), [c] χ^2 test, [d] Fisher's exact test, [e] Mann-Whitney *U* test

Figure Legends

Figure 1. Recruitment flow chart

Figure 2. The difference in the tongue pressure between the baseline and 2 weeks postoperatively.

Tongue pressure decreased significantly from baseline to 2 weeks postoperatively (p = 0.011, the paired *t*-test).