A Study of the Changes in Laryngeal Elevation Distance and Dysphagia after Thoracic Esophageal Cancer Surgery

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Abstract

Objective: Dysphagia occurring after surgery to treat thoracic esophageal cancer is commonly believed to be caused by recurrent laryngeal nerve (RLN) paralysis and injury to the muscles involved in swallowing due to manipulation during cervical lymph node dissection. However, we previously performed studies in our department and reported that RLN paralysis and dysphagia are not necessarily related. We also found that geniohyoid muscle atrophy, which occurs due to perioperative fasting, may also cause dysphagia. Meanwhile, some reports have documented a relationship between dysphagia and decreased laryngeal elevation distance (LED) during videofluorography (VF) in elderly patients and after esophageal cancer surgery. There are few published reports of a relationship between dysphagia and changes in the LED that have compared pre- and postoperative VF findings. We therefore performed a study of the relationship between the incidence of dysphagia and changes in pre- and postoperative LED.

Method and Results: The subjects of the present study were 72 patients who underwent surgery to treat thoracic esophageal cancer in our department from April 2014 to March 2020. All patients underwent pre- and postoperative VF, during which we measured the LED. We divided them into an aspiration (A) group of 17 patients and a non-aspiration (NA) group of 55 patients. The difference between the pre- and postoperative LED values was 14.12 ± 5.67 mm in the A group, which was significantly larger than the NA group value (8.63 ± 4.83 mm, P = 0.0002). The rate of change in the LED was significantly greater in the A group at 45.72 ± 15.69%, compared with 31.69 ± 14.67% in the NA group (P = 0.0011).

Conclusion: There was a significant decrease in LED among patients presenting with postoperative dysphagia after esophageal cancer surgery, suggesting that LED measurement may be a useful quantitative indicator assessable during VF.

Key words
Esophageal cancer, postoperative dysphagia, laryngeal elevation distance, videofluorography swallowing examination

Introduction

Dysphagia that occurs after surgery to treat thoracic esophageal cancer is usually believed to be caused by recurrent laryngeal nerve (RLN) paralysis and manipulation during cervical lymph node dissection (LND).1–3) However, we have performed studies in our department and have already documented that RLN paralysis and dysphagia are not necessarily related.4) Our previous reports have also shown that geniohyoid muscle atrophy, which occurs due to perioperative fasting, may also cause dysphagia.5) In our hospital, we assess patients with thoracic esophageal cancer by means of swallowing videofluorography (VF) before and after surgery and use these assessment outcomes as an indicator to determine when to restart oral intake and the appropriate type of food for the patient to prevent aspiration pneumonia. Mean-
while, some reports have documented a relationship between dysphagia and decreased laryngeal elevation distance (LED) during VF in elderly patients and between shortening of the LED detected during VF after esophageal cancer surgery and dysphagia. However, few published reports have shown a relationship between dysphagia and changes in the LED by comparing pre- and postoperative VF findings. We therefore performed a retrospective study of the relationship between the incidence of dysphagia and changes in LED by measuring pre- and postoperative laryngeal elevation using VF.

Patients and Methods

The patients of the present study were selected from those who had undergone subtotal esophagectomy, narrow gastric tube reconstruction, and cervical esophagogastrointestinal anastomosis in addition to LND in two or three regions to treat thoracic esophageal cancer in our department from April 2014 to March 2020. Ultimately, we selected 72 patients who had undergone computed tomography (CT) scans and VF both preoperatively and again within postoperative day (POD) 7. All thoracic procedures, including esophageal transection and mediastinal LND were performed via thoracoscopy, whereas all abdominal procedures, including abdominal LND and creation of the gastric tube, were performed via laparoscopic surgery. Reconstruction was performed via a retrosternal route in 71 patients and a retromediastinal route in one patient. Postoperative nutritional management consists of fasting from immediately after surgery to POD 7. During that time, in addition to intravenous replacement fluid, administration of an intestinal nutritional supplement through the intestinal fistula of 240 kcal/day is begun from POD 2 and is gradually increased every day to reach 1200 kcal/day on POD 6. On POD 7, VF is performed to confirm the presence or absence of swallowing dysfunction, and oral intake is started.

Patients

The endpoints of this study were as follows: sex, age, T and N factors based on the clinical findings, disease staging, presence of neoadjuvant chemotherapy, duration of surgery, volume of blood loss during surgery, presence of postoperative complications, presence of RLN paralysis, presence of postoperative dysphagia, midline sagittal cross-sectional area of the geniohyoid muscle (CSA-GH) pre- and postoperatively, and the differences in and rate of change in the LED. The T and N factors and pathological staging were determined using the 11th edition of the Japanese Classification of Esophageal Cancer. The Clavien-Dindo classification (CDC) was used to assess complications.

Assessment of RLN paralysis

An otorhinolaryngologist assessed RLN paralysis by examining the vocal cords using a laryngeal fiberscope immediately after surgery and on POD 7. We define RLN paralysis when disorders of vocal cord movement are present regardless of clinical symptoms such as hoarseness, when the vocal cords are in a fixed position (median, recurrent laryngeal, intermediate, or dilated), or when paresis is present.

Videofluorography

VF was performed preoperatively and on POD 7. In addition, the diagnosis of dysphagia was made based on the VF results on POD 7. VF findings in patients diagnosed as having dysphagia were ① frank aspiration, ② laryngeal invasion with the inability to achieve rapid clearance, and ③ residues in the vallecula and pyriform sinus that are not cleared despite multiple swallowing attempts, based on the method described by Logemann. The contrast agent was created by mixing 35 mL of iopamidol and 40 mL of water, then adding 1 g of thickener. Patients were assessed while swallowing 5 mL boluses of this solution at a time. The entire examination was recorded on a digital versatile disc (DVD) and then assessed by a neurologist and two speech-language-hearing therapists who regularly assess feeding and swallowing functions.

Laryngeal elevation distance measurement (Fig. 1a, b)

The LED was measured using the VF videos in DIPP-MotionV (Ditect Co., Ltd.), a video analysis software program. The measurement method was based on the method of Fujiwara et al. The horizontal axis passing through the center of the fifth cervical vertebra (C5) in the lateral VF image views was defined as the X axis. The line perpendicular to the X axis that passed through C5 was defined as the Y axis. The position of the vocal cords at rest was defined as the initial position, and the maximum distance of laryngeal elevation measured on the Y axis due to swallowing was defined as the LED. In addition to the measured values, we also calculated the rate of change to correct for inter-individual differen-
ces due to age, sex, and stature.

**Measurement of the suprahyoid muscle mass**

The geniohyoid muscle mass was measured as a proxy for the suprahyoid muscle mass. We used a measurement method described by Feng et al., the easiest of which entailed measuring the midline sagittal CSA-GH to derive its muscle mass (Fig. 2). The area value was calculated automatically by the software after manually determining the region of interest (ROI). We used a 64- or 80-row Toshiba Aquilion CT scanner, set the slice thickness to 1.00 mm, and performed contrast-enhanced imaging in all patients except those with renal dysfunction or contrast agent allergy who were unable to tolerate the procedure. The image analysis software Ziostation2 (Ziosoft Co., Ltd.) was used to perform the measurements.

**Statistical analysis**

Continuous variables are displayed as median

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**Fig. 1.** Method for measuring the laryngeal elevation distance (LED). a. The horizontal axis passing through the center of C5 in the lateral videofluorography image view was defined as the X axis. A line perpendicular to the X axis that passed through C5 was defined as the Y axis. The position of the vocal cords at rest was defined as the initial position, and the maximum distance of laryngeal elevation measured on the Y axis due to swallowing was defined as the LED. b. Method for measuring the LED. The arrow indicates the LED.

**Fig. 2.** Method for measuring the midline sagittal cross-sectional area of the geniohyoid muscle. The cross-sectional area of the midline geniohyoid muscle as outlined by the orange dashes was measured in a CT sagittal section and used as the muscle mass of the geniohyoid muscle.
values. Analysis was performed using the Student t-test, and a p value of <0.05 was considered to be statistically significant. We used JMP software (version 14, SAS Institute, Cary, NC, USA) for statistical analysis.

This study was approved by the St. Marianna University School of Medicine bioethics committee (approval no.: 4449).

Results

Patient characteristics (Table 1)
The patients comprised 56 men and 16 women with a mean age of 69 years (range: 40–82 years). The mural depths of tumor invasion based on the clinical diagnosis were T1a in 0 patients, T1b in 21 patients, T2 in 15 patients, T3 in 34 patients, and T4 in 2 patients. The N factors were N0 in 24 patients, N1 in 13 patients, N2 in 15 patients, and N3 in 2 patients, and clinical disease staging was stage I in 32 patients, II in 15 patients, III in 21 patients, and IV in 1 patient. There were no cases of swallowing dysfunction before surgery.

Postoperative outcomes (Table 2)
The mean duration of surgery was 450.87 ± 79.79 min, and the mean volume of blood loss was 228.97 ± 28.33 g. Seventeen patients were diagnosed as having dysphagia during VF, and 55 were not. The mean rate of change in the CSA-GH after surgery was 14.01 ± 15.27%. Among the postoperative complications, anastomotic leaks occurred in 7 patients (CDC Grade II in 3 patients and IIIa in 4 patients), respiratory complications occurred in 9 patients (CDC Grade II in 7, Grade IIIa in 1, and Grade IV in 1 patient), chylous fistulas occurred in 2 patients (CDC Grade II in both), pulmonary thromboembolism occurred in 1 patient (CDC Grade IIIa), postoperative cervical hematoma occurred in 1 patient (CDC Grade IIIb), and surgical site infection occurred in 19 patients (CDC Grade I in 3, Grade II in 8, and Grade IIIa in 8 patients). Multiple complications may have occurred in the same patient. RLN paralysis was observed in 32 patients (44.44%) The median length of the postoperative hospital stay was 20.5 days (range: 10–106 days), and there were no surgical deaths.

Laryngeal elevation distance measurement (Table 3)
The mean preoperative LED was 27.21 ± 5.97 mm, whereas the mean postoperative LED was 17.29 ± 4.48 mm. The mean difference in pre- and postoperative LED values was 9.92 ± 5.52 mm, and the rate of change in the LED was 35.00 ± 15.98%.

Comparison of the presence of postoperative dysphagia (Table 4)
Based on VF on POD 7, the patients were div-
Table 4. Clinical Variables in Patients with or without Aspiration

<table>
<thead>
<tr>
<th>Variable</th>
<th>NA (n=55)</th>
<th>A (n=17)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex ratio (M/F)</td>
<td>42:13</td>
<td>14:3</td>
<td>0.6037</td>
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<tr>
<td>Age (years)</td>
<td>69 (40-82)</td>
<td>69 (46-81)</td>
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<td>Operation time (min)</td>
<td>452.80±81.36</td>
<td>444.64±76.55</td>
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<td>Blood loss volume (g)</td>
<td>216.49±231.88</td>
<td>269.35±269.81</td>
<td>0.4321</td>
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<td>Neoadjuvant chemotherapy (No/Yes)</td>
<td>22/33</td>
<td>4/13</td>
<td>0.2166</td>
</tr>
<tr>
<td>Dissection (3 field:2 field)</td>
<td>9:46</td>
<td>5:12</td>
<td>0.2348</td>
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<tr>
<td>Complication (No/Yes)</td>
<td>33/22</td>
<td>8/9</td>
<td>0.3463</td>
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<tr>
<td>Postoperative RLN paralysis (No/Yes)</td>
<td>34/21</td>
<td>6/11</td>
<td>0.0544</td>
</tr>
<tr>
<td>Hospital stay (days)</td>
<td>20 (12-82)</td>
<td>25 (10-106)</td>
<td>0.3739</td>
</tr>
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<td>CSA-GH change rate (%)</td>
<td>11.69±15.77</td>
<td>21.51±10.80</td>
<td>0.0194*</td>
</tr>
<tr>
<td>LED difference (mm)</td>
<td>8.63±4.83</td>
<td>14.12±5.67</td>
<td>0.0002*</td>
</tr>
<tr>
<td>LED change rate (%)</td>
<td>31.69±14.67</td>
<td>45.72±15.69</td>
<td>0.0011*</td>
</tr>
</tbody>
</table>

NA: no aspiration group, A: aspiration group, RLN: recurrent laryngeal nerve, CSA-GH: cross-sectional area of the geniohyoid muscle, LED: laryngeal elevation distance. * P< 0.05

We divided the 55 patients not diagnosed as having aspiration during VF on POD 7 into three groups to perform a comparative investigation: an non-dysphagia (ND) group of 38 patients who showed absolutely no decrease in swallowing function, a poor swallowing function (PSF) group of 17 patients who showed mild laryngeal invasion or findings such as residues in the vallecula or pyriform sinus but were able to initiate oral intake despite PSF, and an aspiration (A) group of 17 patients who had difficulty initiating oral intake. There were no statistically significant differences between the ND and PSF groups in terms of the differences in LED and CSA-GH and the rates of change in the LED and CSA-GH. However, statistically significant differences were observed between the PSF and A groups in the difference in LED (P = 0.0096) and the rates of change in the LED (P = 0.0320) and CSA-GH (P = 0.0215) (Fig. 4a-c). No statistical correlation was observed between the rate of change in the CSA-GH and that in the LED.

**Discussion**

One of the issues preventing the initiation of oral intake after esophageal cancer surgery is the presence of dysphagia. Despite a favorable postoperative clinical course, long-term oral intake may be difficult due to dysphagia, or the patient may develop respiratory complications such as aspiration pneumonia, which may necessitate long-term admission. For this reason, we believe that it is important to appropriately assess preoperative swallowing ability and prevent these issues.

RLN paralysis and injury of the muscles involved in swallowing as a result of manipulation during cervical LND are commonly believed to cause postoperative dysphagia after esophageal cancer surgery. According to the National Clinical Database in Japan, the incidence of RLN paralysis after esoph-
ageal cancer surgery is 9.7–13.9%. Many institutions evaluate the presence or absence of RLN paralysis only by the presence or absence of clinical symptoms such as hoarseness; however, we assess all cases of vocal cord paralysis in our department by means of postoperative laryngeal fiberscopy. This is why the incidence of 44.44% reported in our department is higher than that in previous reports, although most of our cases were CDC Grade I, and we observed no cases of frank aspiration. A report similar to ours that entailed assessment of RLN paralysis by means of laryngeal fiberscopy after esophageal cancer surgery documented an incidence of 64%. We believe that the differences in the incidence rate were due differences in the methods used to assess RLN paralysis. At our hospital, Mafune et al. assessed postoperative dysphagia by means of VF and reported that RLN paralysis is not necessarily related to dysphagia. The present study also showed that when we focused on the patients in whom postoperative dysphagia was observed, RLN paralysis was present in 64.71% of the patients and not present in 35.29%. RLN paralysis tended to be more commonly observed in patients with dysphagia during VF, although the difference was not statistically significant.

The muscles involved in swallowing are the anterior neck muscles, which are divided into the suprahyoid muscles (geniohyoid, mylohyoid, and stylohyoid muscles and the anterior belly of the digastric muscle) and the infrahyoid muscles (sternothyroid, thyrohyoid, sternohyoid, and omohyoid muscles). The suprahyoid muscles are involved in the elevation

Fig. 3. a. Box plot of laryngeal elevation distance (LED) in patients with or without aspiration. b. Box plot of LED change rate in patients with or without aspiration. c. Box plot of cross-sectional area of the geniohyoid muscle (CSA-GH) change rate in patients with or without aspiration.
and anterior motion of the hyoid bone, whereas the infrahyoid muscles elevate the thyroid cartilage and depress the hyoid bone.\textsuperscript{10} Postoperative dysphagia is caused by changes in these anterior neck muscles.\textsuperscript{21} A report by Katsumata et al.\textsuperscript{5} from our department showed that the CSA-GH, measured using CT, decreased due to disuse atrophy secondary to postoperative fasting and stated that this is one of the causes of postoperative dysphagia. The present study also showed similar results, with a significantly higher rate of decrease in CSA-GH in the A group than in the NA group.

Normally, it is possible to assess the anatomy, swallowing motion, and presence and degree of dysphagia during VF. The penetration-aspiration scale\textsuperscript{15} is a quantitative assessment scale that is widely used to determine the presence and degree of laryngeal invasion and aspiration, but the outcomes vary based on the person performing the assessment. VF has also been reported to be useful for semiquantitative assessment during each phase of swallowing (oral transit time, pharyngeal transit time, and pharyngeal delay time).\textsuperscript{10,16} We perform VF pre- and postoperatively to prevent aspiration caused by postoperative dysphagia in all patients who undergo thoracic esophageal cancer surgery. The items assessed during VF are mastication, formation of a food bolus, influx of the food bolus into the pharynx before the reflex is initiated, swallowing reflex, laryngeal invasion, vallecular residues, pyriform sinus residues, aspiration,
cough reflex, delayed choking, expectoration after aspiration, and regurgitation from the esophagus. These items are considered to ensure that oral intake is initiated at the appropriate time after esophageal cancer surgery and that the type of food is appropriate. However, VF has also been reported to be useful for assessing dysphagia by measuring the LED in the elderly. Yasuda et al. measured the LED using VF after esophageal cancer surgery and reported dysphagia and shorter LED measurements due to surgical manipulation in the neck. We believe that the transection of the sternohyoid and sternothyroid muscles that occurs during cervical LND may cause dysphagia, whereas postoperative muscle scarring may affect swallowing function and contribute to the onset of dysphagia. Furthermore, compared to patients in whom conventional cervical LND is performed, those who undergo complete dissection of the infrahyoid muscles experience a lesser degree of reduction in laryngeal elevation, which is useful for improving the prognosis of swallowing function. Dysphagia was reported to occur in 33% to 47% of patients after esophageal cancer surgery in previous reports, but the incidence of 23.61% that we observed during this investigation was lower. We perform complete dissection of the infrahyoid muscles at our hospital, which results in reduced infrahyoid muscle scarring. This is probably why there was no significant difference between the two-region dissection and the three-region dissection regarding the occurrence of dysphagia. However, a few reports have performed analysis of hyoid bone motion during swallowing by means of quantitative VF assessment, although there are very few reports of the quantitative assessment of decreased laryngeal elevation using VF. In addition, few reports have documented a relationship between dysphagia and postoperative changes in the LED, and few have compared pre- and postoperative VF findings.

When we measured the LED as a quantitative assessment item during the present study, we found that the difference between the pre- and postoperative LED values was significantly greater in the A group than in the NA group. We believe that the LED decreases in patients with dysphagia after esophageal cancer surgery. In addition, we found that the rate of change in the LED was also significantly greater in the A group when we calculated these values taking inter-individual differences into account. We also observed a statistically significant difference between the PSF group and A group in terms of the differences in and rate of change in the LED. Therefore, we believe that there is a major difference in swallowing function between patients who show mild laryngeal invasion or findings such as residues in the vallecula or pyriform sinus, but who are able to initiate oral intake despite PSF, and patients with dysphagia who have difficulty initiating oral intake. We further believe that these results support the diagnostic accuracy of the assessment of swallowing function using VF and suggest that LED may be a useful indicator for assessing swallowing function using VF. We did not observe any correlation between the rate of change in the LED and in CSA-GH, which we believe was due to the mutual involvement of the superhyoid and infrahyoid muscles in laryngeal elevation. This suggests that multiple factors, such as RLN paralysis, superhyoid muscle atrophy, and infrahyoid muscle scarring, contribute to the development of postoperative dysphagia. Thus, to reduce postoperative dysphagia after esophageal cancer surgery, measures must be taken to adopt appropriate protective techniques that prevent RLN paralysis, early rehabilitation to prevent perioperative geniohyoid muscle atrophy, and appropriate techniques to decrease cervical manipulation involving the infrahyoid muscles.

Conclusion

There was a significant decrease in LED among patients who presented with postoperative dysphagia after esophageal cancer surgery, suggesting that LED measurement may be a useful quantitative indicator assessable during VF.

Acknowledgments

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Conflicts of interest

The authors have nothing to disclose.

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