Surg Today (2016) 46:543–551
DOI 10.1007/s00595-015-1203-6

ORIGINAL ARTICLE

Functional outcome assessment of swallowing (FOAMS) scoring and videofluoroscopic evaluation of perioperative swallowing rehabilitation in radical esophagectomy

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Received: 23 February 2015 / Accepted: 11 May 2015 / Published online: 16 June 2015

Abstract
Purpose Oropharyngeal swallowing dysfunction following esophagectomy has been associated with the surgical disruption of muscle strength and flexibility of the oropharyngeal structures. We assessed the value of perioperative swallowing rehabilitation (SR) in patients who underwent radical esophagectomy.
Methods We instituted routine perioperative SR for patients with esophageal cancer and retrospectively compared postoperative swallowing function between the patients who received ($n = 12$) vs. those who did not receive ($n = 14$) SR.
Results The average duration of pre- and postoperative SR was 23.0 and 26.0 days, respectively. Preoperatively, the functional outcome assessment of the swallowing (FOAMS) score was 7 (full marks) in all 26 patients, whereas the average score at hospital discharge was 6.3 vs. 5.5 in the patients who received vs. those who did not receive SR, respectively ($p = 0.049$). Videofluoroscopic examination ($n = 12$) demonstrated that the maximum superior excursion of hyoid bone increased significantly with preoperative SR ($p = 0.030$), as well as postoperative SR ($p = 0.046$). However, perioperative SR did not reduce the incidence of postoperative aspiration pneumonia or the duration of hospital stay.
Conclusions Swallowing function after radical esophagectomy was improved by perioperative SR; however, further investigations are needed to assess the clinical significance of SR in reducing surgical complications.

Keywords Perioperative swallowing rehabilitation · Videofluoroscopic evaluation · Esophagectomy · Esophageal cancer

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Introduction

Improved survival after surgery for esophageal cancer has been achieved through better surgical procedures, such as minimally invasive esophagectomy, and advances in perioperative management [1]. The preoperative care program, which includes smoking cessation [2], respiratory rehabilitation [3, 4], and oral care [5] have also been demonstrated to decrease pulmonary complications following esophagectomy.

On the other hand, many patients still suffer from oropharyngeal dysphagia following esophagectomy even without anastomotic obstruction [6]. The pharyngeal stage of swallowing consists of biological features, such as propelling the food bolus through the pharynx and the upper esophageal sphincter (UES) to the esophagus, and airway protection during food passage to prevent aspiration. During these processes, the hyoid bone is pulled upward and forward by contraction of the suprahyoid and thyrohyoid muscles to seal the laryngeal vestibule with the epiglottis. At the same time, the muscles contract to pull the hyolaryngeal complex forward to open the UES [7, 8].

Videofluoroscopic examinations reveal that reduced hyoid bone excursion and the UES opening after radical esophagectomy are associated with altered swallowing and

Table 1 Instructions for swallowing exercises

(1) Pursed-lip breathing
Sit up straight, relax your neck and shoulder muscles
Breathe in (inhale) slowly through your nose for two counts, keeping your mouth closed
Pucker or "purse" your lips as if you were going to whistle or gently flicker the flame of a candle
Breathe out (exhale) slowly and gently through your pursed lips while counting to four
(2) Cervical range of motion exercise
Head tilts, forward and back
Gently bow your head and try to touch your chin to your chest
Hold for 10 s
Raise your chin back to the starting position
Tilt your head back as far as possible so you are looking up at the ceiling
Hold for 10 s
Return your head to the starting position
Head tilts, side to side
Tilt your head to the side, bringing your ear toward your shoulder
Hold for 10 s
Return your head to the starting position
Head turns
Turn your head to look over your shoulder
Tilt your chin down and try to touch it to your shoulder
Hold for 10 s
Return your head to the starting position
(3) Shoulder stretch
Reach up over your head with both arms
Squat putting the arms around your knees with breathing out and put your head down to look at your tiptoes
Hold for 10 s
Return to the starting position
(4) Jaw opening
Open your jaw as wide as you can until you feel a stretching, but no pain
Hold this maximum open position for 10–30 s
Relax and close your mouth
Repeat this open position 5 times
(5) Tongue exercises
Tongue extension
Poke your tongue out between your lips
Stick out your tongue as far as you can
Hold the tongue steady and straight for 10–30 s
Relax and then repeat 5 times.
Tongue retraction
Retract your tongue, touching the back of your tongue to the roof of your mouth
Hold for 1–3 s
Relax and then repeat 5 times
Tongue tip up
Put the tip of your tongue behind your top teeth
Open your mouth as wide as possible maintaining tongue contact
Hold for 3–5 s
Relax and then repeat 5 times
Tongue tip down
Put the tip of your tongue behind your bottom teeth
Open your mouth as wide as possible maintaining tongue contact
Hold for 3–5 s
Relax and then repeat 5 times
(6) Shaker exercises
Sustained hold
Lift your head to look at your toes
Keep your shoulders flat on the floor/bed
Hold this position for 30 s
Release
Repeat 3 times and rest for 1 min between repetitions
Lift and lower (same starting position as for sustained hold)
Lift your head and look at your toes
Let your head go back down with control
Repeat 30 times
Rest in between as needed

a risk of aspiration in the early postoperative period [7, 8]. These abnormalities in oropharyngeal swallowing function after transthoracic esophagectomy are generally associated with reduced laryngeal movement, caused by the surgical reconstruction procedure in the neck, with resulting adhesion formation, scarring, and inflammation, rather than by inadvertent neurological damage, suggesting a possible positive effect of swallowing rehabilitation (SR) [7–10].

SR, in the form of muscle strengthening programs, has been shown to improve swallowing function in healthy subjects, as well as in neurologically impaired subjects [11, 12]. The preventative and therapeutic effects of swallowing exercises for patients with head and neck cancer undergoing chemoradiation therapy have been well demonstrated [13, 14]. However, there have been no reports on SR in the perioperative management of patients undergoing esophagectomy.

The purpose of this study was to assess the preventative and therapeutic effects of perioperative SR in patients undergoing radical esophagectomy. First, we instituted routine perioperative SR and then we compared, retrospectively, the postoperative swallowing function of the patients who participated vs. those who did not participate in the rehabilitation program, by using functional outcome assessment of swallowing (FOAMS) scoring. We then evaluated the effect of the swallowing exercises, videofluoroscopically.

Patients and methods

Patients and perioperative management

The subjects of this study were 26 patients who underwent radical esophagectomy for thoracic esophageal cancer in Toyama University Hospital, between January, 2012 and

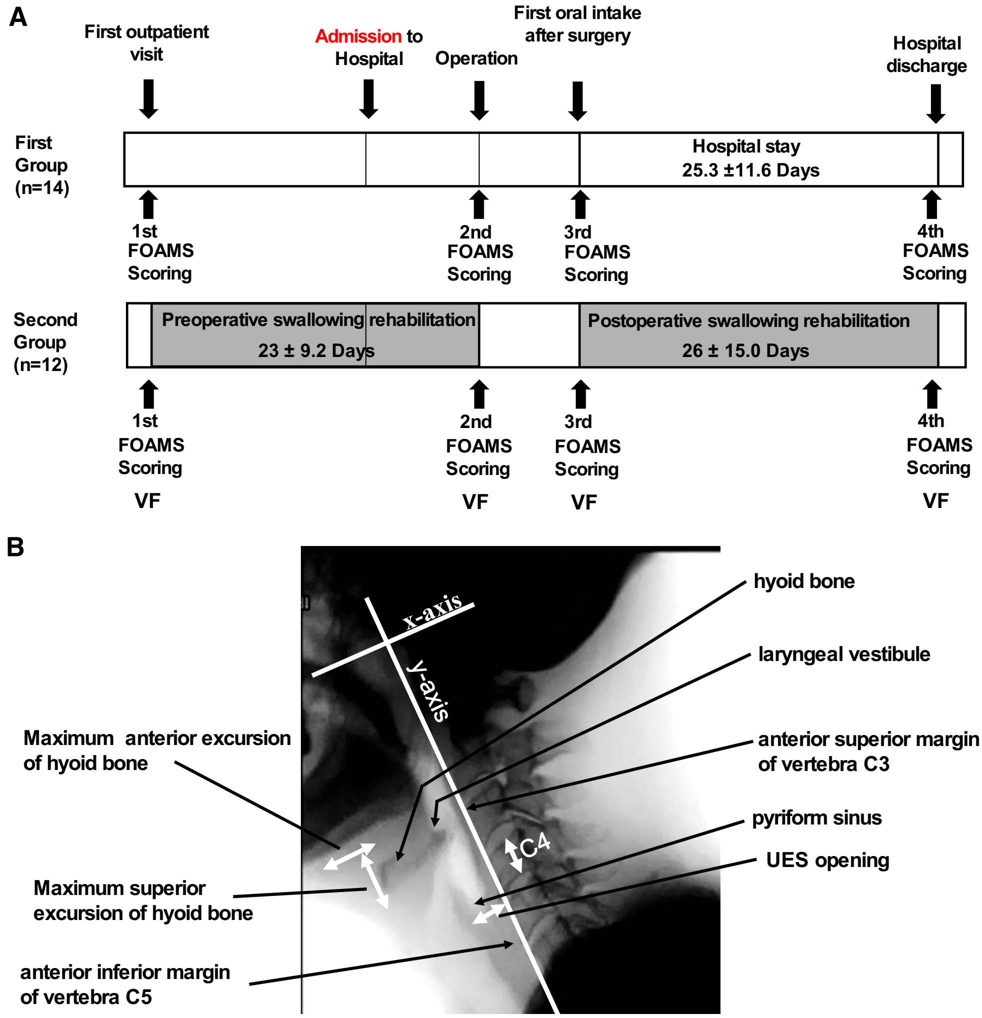

Fig. 1 The perioperative swallowing rehabilitation program and evaluation of swallowing function. **a** Schedule of the evaluation of swallowing function by using the FOAMS scoring scale in the first group and by using the FOAMS scoring scale and VF in the second group. **b** Anatomy and *marked points* in the lateral view of the VF study. The *y-axis* was set based on the line from the anterior superior margin of vertebra C3 to the anterior inferior margin of vertebra C5. The *x-axis* was set based on the line perpendicular to the *y-axis*. The height of the vertebra C4 body was measured for the standard in each patient

September, 2014. Immediately after radical esophagectomy was scheduled, approximately 2–4 weeks prior to their operation, each patient was given verbal and written instructions about the preoperative program for esophagectomy, which consisted of smoking cessation, respiratory rehabilitation, and oral care with dental brushing. In April, 2013, a swallowing exercises program was designed and added to the perioperative care program. Thus, 14 patients who did not have SR included in their program (January, 2012–March, 2013) and 12 patients who did have the SR as part of their program (April, 2013–September, 2014) were compared historically. We named the groups "the first group" and "the second group", respectively. Written informed consent was obtained from all the patients prior to the preoperative care program and surgery. All cases were classified according to the International Union Against Cancer TNM Classification 7th edition [15] and the classification of the Japan Esophageal Society [16, 17]. Postoperative complications were counted when they were categorized as Grade II or more by the Clavien–Dindo classification [18].

Swallowing exercises program

Table 1 shows the instructions for the swallowing exercises program. The program included pursed lip breathing, a cervical range of motion exercise, shoulder stretches, jaw opening, tongue exercises, and Shaker exercises, all designed for muscle strengthening and to maintain flexibility of the oral and pharyngeal structures for improved swallowing function [19–22].

The patients were instructed by the speech pathologist (N.N.) and nurses in the surgical ward to perform the swallowing exercises five times a day at home and continue after admission to the hospital, up until the day before surgery. Postoperative SR was initiated from the time oral intake was resumed after confirming the absence of anastomotic leakage, and continued at least until discharge from the hospital (Fig. 1a). The functional outcome assessment of swallowing (FOAMS), established by the Wisconsin Speech Language Pathology and Audiology Association [23], was used to evaluate the perioperative swallowing function at four time points in the first and second groups, respectively: at the first outpatient visit or before preoperative SR; the day before surgery or after preoperative SR; at the time of first oral intake after surgery or before postoperative SR; and on the day before hospital discharge or after postoperative SR (Fig. 1a). In this scoring system, a numerical score of 1–7 is assigned to each participant's level of swallowing competency, with a score of 1 being the worst and 7 being the best, corresponding to functional swallowing (Table 2) [22, 23].

Videofluoroscopic swallowing examination (VF)

Patients in the second group underwent a modified videofluoroscopic barium examination [24] using Iopamidol (equivalent to 300 mg of organic iodine per ml), being a nonionic water soluble iodine-containing contrast medium, to prevent pneumonia at aspiration [25–27]. To prepare the Iopamidol Jelly, 30 g of gelatin was dissolved in 100 ml of Iopamidol solution and cooled at 4 °C for 6 h. After placing a 1.5 cm cube of Iopamidol jelly in the mouth of the patients, using a teaspoon, they were instructed to masticate and swallow naturally. Imaging during the fluorography was recorded at 30 frames/s in a lateral view. The video images were analyzed frame-by-frame in slow motion to measure the observation point. The y-axis was set based on the line from the anterior superior margin of vertebra C3 to the anterior inferior margin of vertebra C5. The x-axis was set based on the line perpendicular to the y-axis. The height of the vertebra C4 body was measured for the standard in each patient (Fig. 1b).

To assess the incomplete pharyngeal clearance, we measured the volume (height × width) of the laryngeal vestibule residue and the volume of the pyriform sinus residue after the initial swallow. To assess the biomechanical abnormalities, we measured the maximum superior excursion of hyoid bone, the maximum anterior excursion of hyoid bone, and the anteroposterior diameters of the UES opening during each swallow. The UES opening was taken from the narrowest area within the pharyngoesophageal junction when this area became maximally opened during bolus transit across the sphincter. The VF was performed at the four time points for each group, as shown in Fig. 1a.

Table 2 The FOAMS Scoring Scale (established by the Wisconsin Speech Language Pathology and Audiology Association)

(1) Profound
Not allowed oral intake
Requires enteral or parenteral feeding to maintain adequate nutrition and hydration
Profoundly impaired airway protection
(2) Severe
Primary mode of nutrition and hydration is non-oral
Oral intake is limited to therapeutic feeding/directed swallowing therapy supervised by a speech pathologist because of severely impaired airway protection
(3) Moderately/severe
Partially dependent on non-oral enteral/parenteral feeding for nutrition and hydration
Fairly safe swallowing only when diet consistency and/or liquid consistency is modified
Inconsistently utilizes compensatory swallowing strategies even with close supervision or constant cuing
(4) Moderate
Primary mode of nutrition and hydration is oral
Safe swallowing function only when diet consistency and/or liquid consistency is modified
Inconsistently utilizes compensatory swallowing strategies even with close supervision or constant cuing
(5) Mild/moderate
Primary mode of nutrition and hydration is oral
Safe swallowing function only when diet consistency and/or liquid consistency is modified
Requires compensatory swallowing strategies with constant supervision
Additional time is usually necessary for meals because of the swallowing strategies
(6) Mild
Safe and efficient swallowing only when diet consistency and/or liquid consistency is modified
May require compensatory swallowing strategies with occasional cueing
Additional time is usually necessary for meals because of the swallowing strategies
(7) Functional
Safe and efficient swallowing of thin liquids and diet that may be modified for dentition or digestive needs
Adequate airway protection
Requires no cueing to utilize compensatory swallowing strategies
Additional time may be required during meals to ensure safe intake

Surgical procedure

All patients from the two groups underwent thoracoscopic esophagectomy in the prone position. Lymph nodes were dissected preserving the recurrent laryngeal nerve on both sides. Reconstruction was performed with a gastric tube via a retrosternal route in 20 patients, whereas colonic interposition via a subcutaneous route was performed in the other 6 patients who had previously undergone distal gastrectomy. A left collar incision was made and the left half of the sternohyoid and sternothyroid muscles was divided, exposing the cervical esophagus, avoiding the recurrent laryngeal nerves. None of the 26 patients underwent dissection of the supraclavicular or lateral cervical lymph nodes.

Table 3 Patients' characteristics

	First group ($n = 14$)		Second group ($n = 12$)		p
	n	%	n	%	
Age					
Average ± SD	65.9 ± 9.7		68.0 ± 5.1		0.25
Sex					
Male/female	13/1	92.9/7.1	12/0	100.0/0	0.35
BMI					
Average ± SD	22.2 ± 2.4		22.3 ± 5.4		0.46
PS					
1, 2	11	78.6	10	83.3	0.48
3	3	21.4	2	16.7	
TNM (Japan Esophageal Society)					
I/II	11	78.6	5	41.7	0.08
III/IV	3	21.4	7	58.3	
TNM (UICC)					
I/II	12	85.7	8	66.7	0.07
III/IV	2	14.3	4	33.3	
Neoadjuvant chemotherapy	5	35.7	6	50.0	0.11
Reconstruction					
Stomach	11	78.6	9	75.0	0.83
Colon	3	21.4	3	25.0	
Postoperative complications (Clavien-Dindo Classification grade II or III)					
Aspiration pneumonia	3	21.4	3	25.0	0.83
Recurrent laryngeal nerve palsy	4	28.6	2	16.7	0.48
Anastomotic leakage	2	14.3	2	16.7	0.87
Duration between operation and first postoperative oral intake					
Days (average ± SD)	9.6 ± 5.3		11.0 ± 5.5		0.32
Duration of hospital stay after first postoperative oral intake					
Days (average ± SD)	25.3 ± 11.6		26.0 ± 15.0		0.42
Duration of hospital stay after surgery					
Days (average ± SD)	32.4 ± 12.2		36.1 ± 10.7		0.22
Rehospitalization for pneumonia within 3 months after surgery	3	21.4 %	0	0 %	
Body weight change 3 months after surgery					
Postoperative/preoperative (%, average ± SD)	90.6 ± 5.5		91.4 ± 5.8		0.36

Statistical analysis

All analyses were carried out with JMP 9.0 software (SAS Institute Inc., Cary, NC, USA). Differences in the volume of the laryngeal vestibule or pyriform sinus residue, the maximum excursion of hyoid bone, and the anteroposterior diameters of the UES opening between the different points in the VF study were analyzed by the paired t test.

The relationship between the VF findings and clinicopathological characteristics of the patients were assessed using the Chi squared test. $p < 0.05$ was used for significance.

Results

Patient's characteristics

Table 3 summarizes the clinical characteristics of the patients. None had a tumor causing obstruction or recurrent laryngeal nerve paralysis before surgery and all had a good nutritional status. There were no significant differences between the first and second groups in clinicopathological characteristics such as age, gender, Body Mass Index, the American Society of Anesthesiologists (ASA) physical status, TNM classification, reconstruction procedure, or interval between the operation and resuming oral intake. No

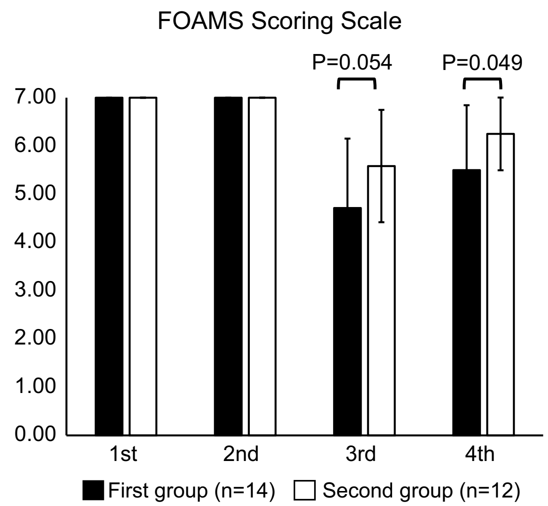

Fig. 2 The perioperative FOAMS scoring scale in the first and second groups. The FOAMS scoring scale was used to evaluate the perioperative swallowing function at four time points in each patient, as shown in Fig. 1a

significant difference was observed between the first and second groups in the incidence of postoperative aspiration pneumonia, body weight loss, or duration of hospital stay after surgery. None of the patients suffered postoperative complications categorized as GradeIIIb or more according to the Clavien–Dindo classification.

Effect of the perioperative swallowing exercises program

At the first time point, the FOAMS Scoring Scale was 7 (full marks) for all the patients, indicating efficient swallowing ability (Fig. 2). At the second time point, after preoperative SR with the period (average ± SD) of 23.0 ± 9.2 days, the FOAMS Scoring Scale was also 7 for all the patients (Fig. 2). The FOAMS Scoring Scale (average ± SD) at the third time point was significantly lower than that at the first time point in both groups, being 4.7 ± 1.4 ($p \leq 0.01$) and 5.6 ± 1.2 ($p \leq 0.01$) in the first and second groups, respectively, although it was higher in the second group ($p = 0.054$). After postoperative SR and after a period (average ± SD) of 26 ± 15.0 days, the FOAMS Scoring Scale (average ± SD) at the fourth time point recovered significantly from that at the third time point, to 5.5 ± 1.3 ($p \leq 0.01$) and 6.3 ± 0.8 ($p \leq 0.01$) in the first and second groups, respectively. Compared with the first time point, the FOAMS Scoring Scale at the fourth time point was significantly decreased in the first ($p \leq 0.01$) and second ($p \leq 0.01$) groups, although the scores in the second group were significantly higher than those in the first group ($p = 0.049$, Fig. 2).

Videofluoroscopic examination of swallowing ability

To assess the effect of the SR on perioperative swallowing function in detail, VF was performed for the second group of patients at all four time points (Fig. 1a). The volume of laryngeal vestibule residue after initial swallowing did not differ significantly between the first and second time points. However, when we focused on the six patients with laryngeal vestibule residue at the first time point, the volume tended to decrease, with a p value of 0.079 (Fig. 3a). The volume of pyriform sinus residue after initial swallowing did not differ significantly between the first and second time point, but again, whe0n we focused on the four patients with pyriform sinus residue at the first time point, the volume was found to decrease significantly, with a p value of 0.047 (Fig. 3b). On the other hand, the maximum superior excursion of hyoid bone during swallowing increased significantly, with a p value of 0.030 (Fig. 3c). Between the second and third time points, the volume of laryngeal vestibule residue, as well as the volume of pyriform sinus residue, increased significantly, with p values of 0.003 and 0.031, respectively (Fig. 3a, b). On the other hand, the maximum superior excursion of hyoid bone decreased significantly, with a p value of 0.007 (Fig. 3c). Between the third and fourth time points, the volume of laryngeal vestibule residue, as well as the volume of pyriform sinus residue, decreased significantly, with p values of 0.031 and 0.027, respectively (Fig. 3a, b). On the other hand, the maximum superior excursion of hyoid bone increased significantly, with a p value of 0.046 (Fig. 3c).

The maximum anterior excursion of hyoid bone during swallows did not differ significantly among the four time points. The anteroposterior diameters of the UES opening during swallowing did not differ significantly among the four time points.

In the second group, two patients (patients 2 and 12) suffered laryngeal nerve palsy, and two (patients 6 and 7) suffered anastomotic leakage. On the other hand, the variant plot in Fig. 3b indicated patient 9, and the variant plot in Fig. 3c indicated patients 2, 5, 8 and 9, suggesting no significant association among these postoperative complications and the VF findings.

Discussion

This study demonstrated that the FOAMS Scoring Scale was significantly lower at the time of hospital discharge than preoperatively, which is consistent with previous reports [6, 8]. However, after the introduction of perioperative SR, the FOAMS Scoring Scale at the fourth time point was significantly higher than that of the first group ($p = 0.049$), suggesting a positive effect of SR for the protection and/or restoration of swallowing ability.

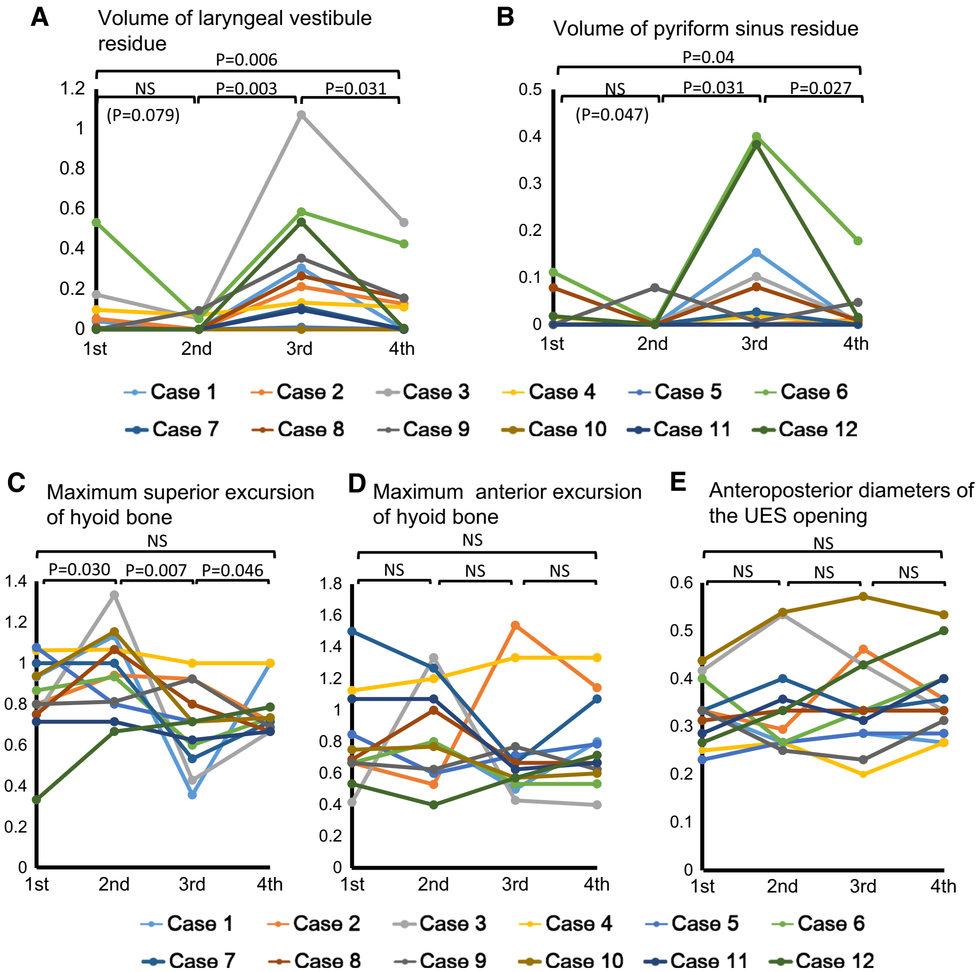

Fig. 3 Perioperative swallowing function evaluated by videofluoroscopy (VF). VF was performed in the second group ($n = 12$) at the four time points in each patient, as shown in Fig. 1a. **a** The volume of laryngeal vestibule residue after initial swallowing. **b** The volume of pyriform sinus residue after initial swallowing. **c** The maximum superior excursion of hyoid bone during swallows. **d** The maximum anterior excursion of hyoid bone during swallows. **e** Antero-posterior diameters of the UES opening during swallowing

The perioperative SR in this study included pre- and postoperative rehabilitation. The effect of preoperative SR was unclear when it was assessed by the FOAMS Scoring Scale because all the patients demonstrated a full score at their first hospital visit. However, the Scoring Scale at the third time point in the second group tended to be higher than that of the first group ($p = 0.054$). Moreover, the extent of recovery between the third and fourth time points was almost the same in the two groups, suggesting that the preoperative SR had a preventative effect to minimize impairment of postoperative swallowing function. The recovery of the FOAMS Scoring Scale between the third and fourth points was attributed to the positive effect of oral food intake, through direct swallowing exercises and restored activities in daily living with the postoperative ambulation program.

In this study, postoperative SR was started as soon as oral intake was resumed postoperatively, after confirming the absence of anastomotic leakage by videofluoroscopy. However, introducing postoperative SR even earlier could be more effective because our SR consists of indirect swallowing exercises. More importantly, our findings could not show the clinical significance of perioperative SR to reduce the incidence of postoperative aspiration pneumonia, body weight loss, or duration of hospital stay after surgery. Evaluation of a large scale, prospective, and comparative study with earlier introduction of postoperative SR is needed to further assess the clinical significance of perioperative SR.

Our investigation using videofluoroscopic examination demonstrated significantly lower maximum superior excursion of the hyoid bone at the fourth time point than preoperatively, which supports the finding of a previous study [7]. Conversely, to our knowledge, this is the first study to show a significantly increased volume of the laryngeal vestibule and pyriform sinus residue after esophagectomy. Furthermore, a significant increase in the maximum superior excursion of hyoid bone and a decrease in the volume of the laryngeal vestibule and pyriform sinus residue, were observed in parallel with restoration of the FOAMS Scoring Scale. Taken together with a previous report that the volume of pyriform sinus residue, as well as laryngeal movement, was a good indicator to assess the effect of SR exercise in tube-fed patients [22], it is possible that these indicators are also useful to assess swallowing function after esophagectomy.

The maximum superior excursion of hyoid bone was significantly increased after preoperative SR. Moreover, when we focused on the patients with residue in the laryngeal vestibule or pyriform sinus at the first time point, significant improvement of the residue was observed after preoperative SR, compatible with previous reports that an SR program improved swallowing function even in healthy individuals [11, 12]. Based on the reports on prophylactic swallowing exercises for patients with head and neck cancer treated with chemoradiation therapy [13, 14], our videofluoroscopic findings further suggested a possible preventive effect of preoperative SR in patients undergoing radical esophagectomy.

In summary, our assessment using the FOAMS Scoring Scale demonstrated that improved swallowing function after radical esophagectomy was achieved through a perioperative SR program. The videofluoroscopic findings also demonstrated improved hypopharyngeal movement along with the SR. However, as the clinical significance of the reduction in the incidence of postoperative aspiration pneumonia or duration of hospital stay could not be confirmed, further investigations are warranted.

Acknowledgments We thank the Surgical Nursing Team at Toyama University Hospital for instructing and supporting the patients: Ms. M. Nagaki, Ms. J Matsushima, Ms. K Jozuka, and Ms. M Matsuda. We also thank Ms. Keiko Yago of the Dietary and Nutrition Service at Toyama University Hospital for preparing the Iopamidol Jelly. This work was supported in part by a Grant-in-Aid for Scientific Research (C) MEXT KAKENHI Grant Number 23591920.

Conflict of interest We declare no conflicts of interest relating to this research.

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