RESEARCH ARTICLE

Suitable Food Textures for Videofluoroscopic Studies of Swallowing in Esophageal Cancer Cases to Prevent Aspiration Pneumonia

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Abstract

Aims: To determine suitable food textures for videofluoroscopic study of swallowing (VFSS), in order to predict and prevent subsequent aspiration pneumonia in esophageal cancer patients with dysphagia after surgery. **Materials and Methods:** We evaluated 45 hospitalized esophageal cancer patients who underwent surgery between January 2012 and December 2013. The control group consisted of 43 patients treatmed from January 2010 until December 2011 and were not examined by VFSS. Test foods, which were presented in order of increasing thickness, included thin barium sulfate (Ba) liquid (3 or 10 ml), slightly thickened Ba liquid (3 or 10 ml), a spoonful of Ba jelly, and a spoonful of Ba puree. **Results:** Patients could most safely swallow puree, followed by jelly. The 3-mL samples of both the thin and thick liquids put patients at risk for aspiration pneumonia, with incidence rates of 13% and 11%, respectively. While 64.4% of patients could swallow all test foods and liquids safely, 35.6% were at risk for aspiration pneumonia when swallowing liquids. Even though >30% of patients were at risk, only 1 (2.2%) in the VFSS group developed aspiration pneumonia, which occurred at the time of admission. Following VFSS, no incidence of aspiration pneumonia was observed. However, aspiration pneumonia occurred in 4 (9.3%) control patients during hospitalization. **Conclusions:** Postoperative esophageal cancer patients were more likely to aspirate any kind of liquid than solid foods, such as jellies. VFSS is very useful in determining suitable food textures for postoperative esophageal cancer patients.

Keywords: Dysphagia - esophageal cancer - food texture - swallowing - videofluoroscopic

Introduction

Cancer patients frequently experience malnutrition (Sharma et al., 2015). Particularly in patients with esophageal cancer, dysphagia is the most common symptom among postoperative complications, such as esophageal stenosis and recurrent nerve paralysis. Such complications can negatively affect the quality of life of patients, leading to increased dysphagia, eating difficulties, and coughing (Chang et al., 2014). Evidence-based perioperative management protocols, such as the enhanced recovery after surgery (ERAS) protocol, can promote quick recovery from major surgery and also reduce healthcare costs by decreasing the duration of postoperative hospitalization (Yatabe et al., 2014). Postoperative early oral intake is a key factor in the ERAS protocol. Initiating early oral intake can promote early identification of dysphagia, thereby enabling the prediction and prevention of aspiration.

Techniques to identify dysphagia include videoendoscopic examination of dysphagia (Bastian, 1991), flexible fiberoptic examination of swallowing (Rosevear and Hamlet, 1991), videoendoscopy (Logemann, 1988), video nasal endoscopic evaluation of the swallow (Donzelli et al., 2001), endoscopic swallowing examination (Crary et al., 2004), and videofluoroscopic swallowing study (VFSS). Even though each of these approaches has advantages and disadvantages, VFSS is one of the most objective and is considered the gold standard for diagnosis of dysphagia in Japan (Tohara et al., 2003). Modification of food texture is an important approach to increase oral intake among dysphagia patients (Sura et al., 2012). However, for postoperative esophageal cancer patients, there is no clear methodology to determine the most suitable food texture to identify dysphagia, risk of dysphagia, or foods that are safe for intake. VFSS is a

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useful test to identify and assess the level of swallowing ability among patients with dysphagia. However, it is unclear whether VFSS is suitable to predict and prevent subsequent aspiration pneumonia in esophageal cancer patients after surgery or to identify food textures that are not appropriate for patients with dysphagia. Therefore, we conducted this study to address these two clinical questions.

Materials and Methods

Subjects

The protocol of this cross-sectional study was approved by the ethics committee of Shigei Medical Research Hospital. The study cohort included 45 postoperative esophageal cancer inpatients who underwent initial surgery between January 2012 and December 2013 (the VF group) and underwent VFSS a few days after admission. The control group consisted of 43 patients admitted between January 2010 and December 2011 who were not examined by VFSS. Background differences between the two groups were analyzed. Patients who underwent complete laryngectomy, who experienced symptoms for more than 6 months since surgery, and who were unable to understand the testing protocol were excluded. The purpose of the study was explained to all patients, and written informed consent was obtained from each.

Evaluation method

The VF group patients were examined by VFSS, in which each was instructed to swallow samples of food while sitting upright. The testing protocol is shown in Figure 1. The test foods included the following, in order of increasing thickness: a thin liquid (volumes of 3 and 10 mL), slightly thickened liquid (volumes of 3 and 10 mL), spoonful of jelly (4.5 g), and spoonful of puree (4.5 g). If patients had difficulty swallowing 3 mL of liquid, thin or thick, they were not presented with the 10-mL sample. In such cases, after testing the 3-mL sample, the jelly and puree were tested. All data were analyzed using a penetration- aspiration scale (Rosenbek et al., 1996). We defined the patient to be at risk if they had a penetration or aspiration. A few days after the swallowing tests, all patients underwent biochemical, body composition, and respiratory function tests.

Standardization of test foods

Swallowing capacity was tested using four types of test foods: a liquid suspension of barium sulfate (liquid), a thickened suspension of barium sulfate (thickened liquid), a barium-containing jelly (jelly), and a barium-containing puree (puree). These foods conformed to the guidelines of The Japanese Society of Dysphagia Rehabilitation (Cichero et al., 2013).

Liquid: Barium sulfate (Baricon Meal; Horii Pharmaceutical Industries, Ltd., Osaka, Japan) was diluted with water to a concentration of 66.7% (w/v).

Thickened liquid: Barium sulfate (Baricon Meal) was diluted with water to a concentration of 66.7% (w/v).

Subsequently, a thickening agent (Toromi Up Perfect; Nisshin OilliO Group, Ltd., Tokyo, Japan) was added to a concentration of 1.0%.

Jelly: Barium sulfate (Barytgen Sol; FUSHIMI Pharmaceutical Co., Ltd., Kagawa, Japan) concentration was controlled to 50% (w/v) by adding water and then mixing with a gelling agent (SoftiaG; NUTRI Co., Ltd., Mie, Japan) by heating and stirring. The concentration of barium sulfate was then controlled to 35.8% (w/w).

Puree: Barium sulfate (Barutgen Sol) concentration was controlled to 50% (w/v) by adding water and then mixing with a thickening agent (Neohaitoromi-ru; Food Care Co., Ltd., Kanagawa, Japan). The concentration of barium sulfate was then controlled to 35.7% (w/w).

Viscosity measurement in liquid and thickened liquid

Viscosity was measured using a HAAKE™ RheoStress 6000 rheometer (Thermo Fisher Scientific GmbH, Dreieich, Germany). The cone-and-plate viscometer mode was used with a cone diameter of 35 mm, cone angle of 1°, and truncation gap of 52 μm. Viscosity was evaluated at a specific shear rate of 50 s-1. The samples were equilibrated at $20 \pm 0.1°C$ in the rheometer.

Measurement of the physical properties of the jelly and puree

Measurement of the physical properties was performed using a creep meter (RE2-3305; Yamaden Co., Ltd., Tokyo, Japan). The measured temperature was $20 \pm 0.1°C$. A dish was filled with the test food and compressed twice with a plunger (diameter of 20 mm) at a clearance of 5 mm and compression speed of 1 mm/s. A texture curve was produced through calculation of hardness, cohesion, and adhesion of the substances.

Statistical analysis

Data were analyzed using the SPSS Statistics 19.0 package for Windows (IBM Japan, Tokyo, Japan). Values are expressed as the mean ± standard deviation. Epidemiologic analysis was performed using the chi-squared test and one-way analysis of variance. Tukey's honest significant difference test was used to evaluate significant differences among three or more groups. A probability (p) value < 0.05 was considered statistically significant. Pearson's correlation analysis was used to identify correlations between parameters.

Results

Participant demographics

The demographic data of the study participants are shown in Table 1. There were no significant differences in sex, age, or body mass index (VF group,20.5kg/m²;control group,20.7kg/m²) between the VF and control groups.

Reliability testing

The swallowing tests were evaluated by a speech–language pathologist, a surgeon, and a dietitian, who arrived at a consensus of which test food was most suitable for each subject. Results were analyzed blindly by the same surgeon and dietitian, who reviewed the swallowing

tests digitally 3–4 months after the initial evaluation.

Viscosity measurements

Viscosity measurements for the test foods in this study were examined. The viscosity of the liquid was 45.0 ± 11.5 mPas·s and that of the thickened liquid was 374.8 ± 5.1 mPas·s. The physical properties of the jelly were as follows: hardness, 2897 N/m²; cohesion, 0.29; and adhesion, 20 J/m³. The physical properties of the puree were as follows: hardness, 361 N/m²; cohesion, 0.89; and adhesion, 75 J/m³. The physical properties of the jelly were similar to those of pudding (i.e., relatively stiff), and the physical properties of the puree were similar to those of
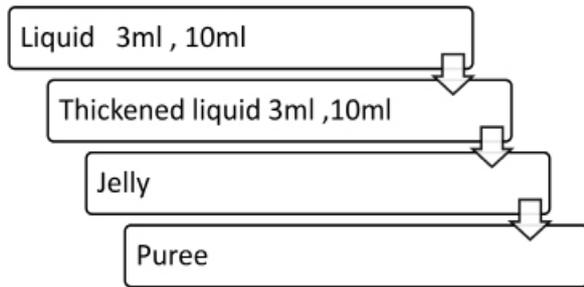

mixed yogurt.

VFSS results

As shown by the VFSS results in Table 2, the study participants could most safely swallow the puree, followed by the jelly. All patients were able to swallow the puree, and laryngeal penetration occurred in only one when swallowing the jelly. Four patients (8.9%) aspirated the 3 mL of liquid, making it the most difficult food to swallow. The thickened liquid was safer to swallow than the thin liquid, although all were still at risk for aspiration and laryngeal penetration. The 3 mL of liquid and 3 mL of thickened liquid posed the greatest risk, at incidences of 6 (13%) and 5 (11%) patients, respectively. There was a significant difference in the risk of laryngeal penetration between the liquid (10 mL) and thickened liquid (10 mL), as compared to the jelly and puree. There was less laryngeal penetration of the jelly and puree than the liquid (10 mL) and thickened liquid (10 mL).

The incidence of penetration or aspiration in response to each of the tested liquids and foods is shown in Table 3. While 64.4% of patients could safely swallow all of the tested foods, 35.6% were at risk when swallowing liquids.

Incidence of aspiration pneumonia

Within the at-risk subset of the subject group, only one (2.2%) case of aspiration pneumonia was reported at the time of admission. In the control group, however, aspiration pneumonia occurred in four (9.3%) patients during hospitalization (p = 0.15).

Discussion

The aim of this study was to determine whether VFSS is suitable to identify food textures that are inappropriate for patients with dysphagia in order to predict and prevent subsequent aspiration pneumonia in esophageal cancer patients after surgery. There were two important clinical

Figure 1. Measurement Protocol

Table 1. Participant Demographics

	The VF Group	The Control Group
Sex (males: females)	40:5	42:1
Ages (years)	67.6 ± 9.3	68.8 ± 9.4
Height (cm)	163.8 ± 5.8	165.2 ± 7.0
Weight (kg)	55.0 ± 10.9	56.7 ± 10.0
Muscle mass (kg)	38.8 ± 16.6	-
REE (kcal)	1254.6 ± 497.5	1160.2 ± 272.1
Serum albumin (g/dl)	3.6 ± 0.3	3.4 ± 0.4
Number of hospitalization days (days)	39.4 ± 31.6	41.6 ± 25.5

None of the comparisons were significant

Table 2. Patient Results by VFSS

	Liquid (3 ml)	Liquid (10 ml)	Thickened liquid (3 ml)	Thickened liquid (10 ml)	Jelly	Puree
Normal (n)	39	34	40	32	44	45
Laryngeal penetration(n)	2	4*§	3	5*§	1	0
Aspiration (n)	4	2	2	1	0	0
Total (n)	45	40	45	38	45	45

* p < 0.05 compared with jelly; § p < 0.01 compared with puree

Table 3. Swallowing Profile Patterns

	Liquid (3 ml)	Liquid (10 ml)	Thickened liquid (3 ml)	Thickened liquid (10 ml)	Jelly	Puree
29 cases	o	o	o	o	o	o
4 cases	o	o	o	×	o	o
4 cases	×	no try	×	no try	o	o
2 cases	o	×	o	o	o	o
1 case	o	o	o	o	×	o
1 case	o	×	o	×	o	o
1 case	×	×	o	no try	o	o
1 case	o	×	×	×	o	o
1 case	o	×	o	no try	o	o
1 case	×	no try	o	no try	o	o

o: normal swallow; ×: penetration or aspiration

observations.

First, postoperative esophageal cancer patients were more likely to aspirate thin liquid than thickened liquid, and more likely to aspirate any kind of liquid than solid foods, such as jelly or puree. Second, VFSS is the optimal method to assess the postoperative swallowing capacity of esophageal cancer patients. All patients were accurately assessed by VFSS, which is a useful procedure for the prevention of postoperative aspiration pneumonia.

VFSS can be used to determine the safety of continuing oral food intake and to better understand the pathophysiological mechanisms underlying dysphagia and aspiration (Argolo et al., 2015). The results of this study showed that purees or jellies were associated with a lower prevalence of penetration and aspiration than any of the tested liquids among the cohort of postoperative esophageal cancer patients. Some studies have claimed that fluids are safer than solid foods when aspirated, although fluid presents a higher risk of aspiration than solid food (Jung et al., 2014). It is widely believed that swallowing safety is linked to viscosity, with more viscous foods associated with a lower risk of aspiration (Kuhlemeier et al., 2001). The same results were confirmed in the postoperative esophageal cancer patients included in the present study. Liquids are typically thickened to slow the speed of transit through the oral and pharyngeal phases of swallowing in order to avoid aspiration into the airway and to improve transit to the esophagus (Popa Nita et al., 2013; Steele et al., 2015). However, although liquid has traditionally been thought to be easier to tolerate than thickened liquid or food in the early stage of recovery after esophageal surgery, the results of this study suggest that modified food, especially puree, is the better choice when swallowing ability is unknown. We propose two reasons why modified foods, such as puree or jelly, are more suitable for delivery of postoperative nutrition to esophageal cancer patients: 1) easy flow from the pharynx to the esophagus; 2) lower likelihood of flow into the trachea before swallowing, and easy recording of the timing of swallowing.

Second, the assessment of swallowing ability using VFSS presents a useful modality to identify proper compensatory modification of food or liquid in order to prevent aspiration pneumonia in patients who require post-esophageal cancer surgery.

VFSS is useful to diagnose aspiration and, thus, is helpful to prevent aspiration pneumonia. McCullough et al. (2012) reported that intra-rater reliability on measures of penetration-aspiration appears acceptable in VFSS, and Holas et al. (1994) indicated that the relative risk of developing pneumonia was greater for those patients who aspirated than for those who did not. In the present study, VFSS was used to evaluate penetration aspiration, a common complication of dysphagia (Rosenbek et al., 1996; Clav*e* et al., 2004). Even though over 30% of the patients in this study were at risk of dysphagia, only one patient in the VFSS group had experienced aspiration pneumonitis at the time of admission. After VFSS, there were no cases of aspiration pneumonitis. VFSS was not useful to predict the risk of dysphagia; therefore, patients were offered appropriately modified food or

liquid. Although no significant difference was observed, it was possible to prevent aspiration pneumonia among patients in the VFSS group, who presented with fewer complications than those in the control group.

There are two issues that affect the safety of VFSS. First, VFSS should be performed in combination with esophagography, which employs Gastrografin® (diatrizoate meglumine/diatrizoate sodium solution). However, Gastrografin® is reportedly harmful to dysphagia patients when aspirated. The viscosity of Gastrografin® is 18.5 mPa·s (Popa Nita et al., 2013), which is similar to that of the liquid used in the present study. Therefore, since over 30% of patients in this study were "at risk" of aspirating liquid, it is advisable to evaluate patients using barium at the time of esophagography and VFSS. Second, it is important to determine the safest food for postoperative nutritional support using VFSS. Some studies reported that using a liquid at first is best, while others recommended against the initial use of liquid. Moreover, Jung et al. (2014) reported that the accuracy and safety of VFSS are not affected by the order in which test foods are presented. In this study, 3 mL of liquid test food was used initially, assuming that a smaller volume was safer. Thus, we demonstrated that the safest order of presentation was puree or jelly first, followed by 3 mL of thickened liquid, 3 mL of thin liquid, 10 mL of thickened liquid, and finally, 10 mL of thin liquid when combining esophagography with VFSS.

There were some limitations to this study. First, swallowing function was not fully evaluated in patients who showed severe oral phase dysphagia or severe esophageal stenosis during the swallowing studies. The patients with severe oral phase dysphagia were not fully evaluated because the total swallowing volume capacity was less than the volume of the test foods used in the study. Also, many test foods remained in the pharynx of patients with severe esophageal stenosis, so we stopped the test and performed esophagoscopic bougienage. Second, the first test food was liquid for all patients. Therefore, some patients might have easily aspirated because it was their first swallow after surgery.

In conclusion, this study clearly showed that postoperative esophageal cancer patients were more likely to aspirate liquid than thickened liquid, and more likely to aspirate any kind of liquid than solid foods, such as jellies. In addition, VFSS is the best method to assess swallowing ability in postoperative esophageal cancer patients.

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