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Original

Efficiency of Incentive Spirometry for Video-Assisted Thoracoscopic Surgery for Esophagectomy

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Abstract: Transthoracic subtotal esophagectomy for esophageal cancer is a highly invasive procedure, associated with high mortality and morbidity rates. We examined the use of video-assisted thoracoscopic and laparoscopic surgery for esophagectomy (VATS-E). Further, incentive spirometry (IS) is commonly used in perioperative rehabilitation for esophagectomy. We investigated whether pulmonary complications after VATS-E are related to changes in the perioperative IS volumes and whether such changes could be predictive of these complications. This study included 63 patients who underwent VATS-E from June 2008 to December 2009. IS volumes before and after surgery were recorded for all patients. The perioperative IS volumes and clinicopathological factors were correlated with the incidence of postoperative pneumonia and atelectasis. Nine patients (14.5%) had postoperative pneumonia, and thirteen (22.2%) had atelectasis. Univariate analysis showed an increased risk of atelectasis in patients with diabetes and an increased risk of pneumonia in patients with a long operating time and for whom the lung was adhered to the thoracic wall. The vital capacity (VC) correlation coefficient was 0.674. Further, the risk of pneumonia was high in patients with 13% less than the minimum IS volume/preoperative VC ratio and 22% with less than the average IS volume/preoperative VC ratio. Multivariate regression models for pneumonia showed the same results regarding the IS volume/VC ratio. The results indicated that IS volumes could be used to predict the incidence of complications after VATS-E, and thereby facilitate early application of interventions to prevent pulmonary complications.

Key words: esophageal cancer, postoperative pulmonary complications, incentive spirometry, VATS-E

Introduction

Transthoracic subtotal esophagectomy used for the treatment of esophageal cancer is a highly invasive procedure that is associated with high mortality and morbidity rates[1,2].

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Complications from this procedure can drastically reduce patient survival[3]. In addition, open esophagectomy has a higher risk of pulmonary complications than abdominal surgeries. Several new surgical devices, perioperative management techniques, and minimally invasive procedures have been developed for esophagectomy[3]. In particular, the newly developed minimally invasive surgeries may reduce postoperative complications and have other benefits such as lower blood loss, a shorter hospital stay, and preservation of respiratory muscles; however, these techniques require additional application and validation[4, 5].

Since 1996, we have trialed minimally invasive video-assisted thoracoscopic and laparoscopic surgery for esophagectomy (VATS-E). VATS-E includes lymphadenectomy for esophageal cancer. This method has produced fewer complications, but postoperative pulmonary complications remain unavoidable. Postoperatively, patients undergo physiotherapy to reverse atelectasis and secretion retention and this may include deep breathing exercises, positioning, airway clearance techniques, and mobilization[6].

Incentive spirometry (IS) is one of the most popular methods for lung expansion in the postoperative period. IS involves deep breathing through a device that provides visual feedback with the aim of promoting sustained maximal inspiratory efforts toward enhancing the total lung capacity[7]. IS is thought to maximize both the accuracy of breathing techniques and patient motivation[7]. It was found to be effective in reducing postoperative complications after upper abdominal surgery[8, 9]. However, the benefits of IS during the postoperative recovery period may not be realized in patients undergoing esophagectomy because of poor compliance, residual pain, and the general feeling of debility.

Many different incentive spirometers are available, categorized as either flow type or volume type. Both are important for physiological lung re-expansion and therefore ideal for postoperative use[10]. Volume-oriented IS devices, such as Coach 2™ (Fig. 1), appear to improve diaphragmatic activity and decrease the effort of breathing to a greater extent than flow-orientated devices[6]. Volume-oriented devices may thus be more suitable for the postoperative period due to the associated lower levels of breathing effort, pain, fatigue, and increased patient incentive to achieve their best potential spirometry volume with these devices[11].

In our department, the pre- and postoperative IS volumes of all patients undergoing VATS-E are recorded, specifically the volume inspired on the third attempt in each cycle of IS. In this study, we investigated the relationship between postoperative pulmonary complications for VATS-E and the perioperative change in IS volumes, with the hypothesis that complications can be predicted on the basis of such volume changes.

Patients and Methods

Patients

This study included 63 patients who underwent VATS-E for thoracic esophageal cancer at the Department of Gastroenterological and General Surgery, Showa University, from

Fig. 1. Incentive Spirometry Device Coach 2™

June 2008 to December 2009. The median patient age was 64.14 years (range, 41～81 years), and there were 48 men and 15 women. The pre- and postoperative IS volumes were recorded for all patients. Those who did not have both the pre- and postoperative IS volumes recorded were excluded. The World Health Organization (WHO) performance status in all cases was either 0 or 1. Histologically, the main lesion was diagnosed as squamous cell carcinoma in 61 cases, and small cell carcinoma in 2 cases. All patients received thoracic epidural analgesia, and all but 7 were extubated at the end of the surgery (1～3 days). While 25 patients (39.7%) directly underwent surgery, 29 (46.0%) received preoperative chemoradiotherapy, and 9 (14.3%) underwent preoperative chemotherapy alone. Surgery was performed 4～8 weeks after neoadjuvant treatment. Preoperative chemoradiotherapy and staging of the tumor did not influence the choice of technique.

All patients underwent detailed preoperative cardiopulmonary risk assessment based on their medical history, chest X-ray and electrocardiogram (ECG), the left ventricular ejection fraction (EF) of echocardiography, and pulmonary function assessed by spirometry, including vital capacity (VC) and forced expiratory volume at 1 second (FEV1.0%). Forty-nine patients underwent spirometry postoperatively.

Recording of IS volumes

The IS volumes of all patients were recorded at our department before and after the operation. During the preoperative visit, patients were educated on the proper technique of using the IS device and were instructed to use it for breathing at least 3 times every day. They were requested to record the volume inspired on the third attempt in each cycle of using the spirometer. The average and minimum IS volumes for each day were also

recorded.

The perioperative IS volumes were computed using the pre- and postoperative data. The preoperative volume was the average of IS volumes recorded from admission until the operation. The postoperative scores were computed from day 1 to day 7 after the operation, and then the average volume, minimum volume, and decrease in IS volume compared with the preoperative value were determined. The average and minimum volumes were correlated with the VC determined during preoperative spirometry.

Comparison

Postoperative pulmonary complications were categorized as pneumonia and atelectasis. Pneumonia was diagnosed clinically and radiologically. Clinical findings included dyspnea, cough, infective sputum, abnormal lung sound, fever (> 38℃), and an increase in the number of circulating leucocytes (10,000/mm^3). The radiological findings included consolidation on X-ray scans. Pneumonia was diagnosed for cases in which sputum was aspirated by bronchoscopy and/or mini-tracheotomy. Atelectasis was diagnosed in cases showing positive radiological findings only.

We examined whether postoperative pulmonary complications are correlated with perioperative IS volumes and clinicopathological factors, with the latter divided into pre- and intraoperative factors. Preoperative factors considered were age, sex, body mass index, history of smoking, alcohol consumption, diabetes mellitus (DM), chemoradiation therapy, albumin level, clinical stage, spirometric data, and echocardiographic data. The spirometry data collected were VC, %VC, and FEV1.0%. Postoperative factors considered were operating time, intrathoracic operating time, bleeding, intrathoracic bleeding, and adhesion of the lung and thoracic wall. The preoperative comorbidities and clinicopathological data in this cohort of patients are summarized in Table 1.

Treatment Procedures

The standard therapies in our department for thoracic esophageal cancer employ the video-assisted thoracoscopic approach, hand-assisted laparoscopic approach, and cervical anastomosis. In all patients in the current study, the esophageal cancers were located in the left lateral decubitus. Five ports were introduced into the right pleural cavity, and a radical esophagectomy and mediastinal lymphadenectomy were carried out under thoracoscopic guidance. An esophageal substitute was reconstructed from a gastric tube made using hand-assisted laparoscopy and inserted via the retrosternal route[12, 13]. Three patients underwent reconstruction using a pulled-up ileocecal valve. Further, 29 patients with locally advanced cancer underwent preoperative chemoradiotherapy, involving 35 ～ 42 Gy of radiation with chemotherapy comprising cisplatin/nedaplatin and 5-fluorouracil. Three patients underwent definitive chemoradiotherapy, involving > 50 Gy of radiation and cisplatin plus 5-fluorouracil.

Table 1. Clinicopathological findings

Preoperative factors	Intraoperative factors
Age	Operating time (min)
Sex	Intrathoracic operating time (min)
BMI	Bleeding (g)
Smoking history	Intrathoracic bleeding (g)
Alcohol history	Adhesion
Diabetes	
Albumin (g/dl)	
Preoperative chemoradiation therapy	
[a]Clinical stage	
Inspiratory function	
VC	
%VC	
FEV1.0%	
Cardiography : EF ratio (%)	

C-stage : clinical stage of Japanese Classification of Esophageal Cancer 10th edition
VC : Vital capacity
FEV1.0% : Forced expiratory volume at 1 second
EF ratio : Left ventricular ejection fraction

Statistical analysis

The perioperative IS volumes and clinicopathological factors were correlated with postoperative pneumonia and atelectasis.

The chi-square test was used to compare the IS volumes and the clinicopathological factors between the groups, while the Mann-Whitney *U*-test was used to compare surgical outcomes. Multivariate analysis was performed using a logistic regression. $P < 0.05$ was considered statistically significant. Data were analyzed using the StatView software package (Abacus Concepts, Berkeley, CA, USA). Significant differences in the distribution frequencies of the data in Tables 1～3, except for age, were determined using Fisher's exact test. The Mann-Whitney *U*-test was applied to identify differences in age, operative time, and blood loss and to compare the values of these parameters between the groups.

Results

Of the total of 63 patients, postoperatively 22 (37.5%) had some form of pulmonary complication : 9 (14.5%) had pneumonia, while 13 (22.2%) had atelectasis. Of the postoperative pneumonia cases, 7 were bronchial pneumonia, and 2 were a change for the worse in radiation pneumonitis. The mean time of diagnosis for all complications was 5.67 days after operation (range, 2～12 days).

Univariate analysis showed an increased risk of atelectasis in patients who had DM, but no risk of pneumonia in patients with any of the considered preoperative factors (Table 2).

Table 2. Preoperative clinicopathological factors associated with postoperative pulmonary complications

Clinical factors	Postoperative pneumonia			Postoperative atelectasis		
	Yes (n = 9)	No (n = 54)	*P* value	Yes (n = 14)	No (n = 39)	*P* value
Age (y)	65.2	64.1	N.S.	66.0	63.8	N.S.
Body mass index	21.4	21.0	N.S.	20.6	21.2	N.S.
Serum albumin (g/dl)	3.9	4.0	N.S.	3.9	4.0	N.S.
Sex (male/female)	8/1	40/14	N.S.	9/5	39/10	N.S.
Smoking (yes/no)	9/0	51/3	N.S.	13/1	47/2	N.S.
Diabetes (yes/no)	0/9	4/5	N.S.	4/10	0/39	< 0.01
Pre-CRT (yes/no)	6/3	23/31	N.S.	8/6	21/28	N.S.
C-stage (0-I/II-IVa)	6/3	33/21	N.S.	9/5	30/19	N.S.
%VC (%)	109.6	112.1	N.S.	112.3	111.6	N.S.
FEV1.0%	71.8	76.3	N.S.	74.8	76.0	N.S.
EF (%)	65.0	65.3	N.S.	66.6	64.9	N.S.

C-stage : clinical stage of Japanese Classification of Esophageal Cancer 10th edition
Pre-CRT : Preoperative chemoradiation therapy
%VC : Percentage of vital capacity
FEV1.0% : Forced expiratory volume at 1 second
EF: Left ventricular ejection fraction

Table 3. Postoperative clinicopathological factors associated with postoperative pulmonary complications

Clinical factors	Postoperative pneumonia			Postoperative atelectasis		
	Yes (n = 9)	No (n = 54)	*P* value	Yes (n = 14)	No (n = 39)	*P* value
Operating time (min)	461.7	370.3	< 0.01	366.4	388.2	N.S.
400 ≦ /400 >	8/1	19/35	< 0.01	4/10	23/26	
Intrathoracic operating time (min)	260.7	220.2	N.S.	222.9	226.9	N.S.
210 ≦ /210 >	8/1	25/29	< 0.05	7/7	26/23	
Bleeding (g)	716.1	257.9	N.S.	292.1	332.3	N.S.
300 ≦ /300 >	5/4	19/35		5/9	19/30	
Intrathoracic bleeding (g)	563.9	151.2	N.S.	157.1	225.3	N.S.
200 ≦ /200 >	4/5	19/35		6/8	17/32	
Adhesion (yes/no)	5/4	8/46	< 0.05	2/12	11/38	N.S.

In contrast, univariate analysis showed an increased risk of pneumonia in patients who had a longer operating time and intrathoracic operating time and adhesion of the lung to the thoracic wall. However, the risk of atelectasis was not associated with intraoperative factors in any patient (Table 3).

The correlation coefficient of VC was significant at 0.674, but that of %VC and FEV1.0% were not ($r = 0.117$ [$p > 0.05$] and 0.07 [$p > 0.05$], respectively). In a proportion of IS volume, the correlation coefficients of VC and %VC were significant at 0.525 and 0.432 (p

Table 4. Correlation coefficients of VC, %VC, and FEV1.0% for IS volumes

Relationship (r)	VC	% VC	FEV1.0%
Average preoperative IS volume (n = 63)	0.674**	0.117	0.07
Rate of decrease in IS volume (n = 49)	0.525**	0.432*	0.249

VC : Vital capacity
FEV1.0% : Forced expiratory volume at 1 second
* $p < 0.05$
** $p < 0.01$

Table 5. Correlation between IS volumes and postoperative pulmonary

IS volume	Postoperative pneumonia			Postoperative atelectasis		
	Yes (n = 9)	No (n = 54)	*P*-value	Yes (n = 14)	No (n = 39)	*P* value
Average	848.41 ± 431.35	1009.15 ± 427.35	N.S.	768.01 ± 282.61	1050.20 ± 444.86	< 0.05
Reduction rate	0.44 ± 0.13	0.55 ± 0.26	N.S.	0.44 ± 0.130	0.56 ± 0.26	< 0.05
Minimum	527.78 ± 363.24	657.78 ± 349.74	N.S.	491.07 ± 179.91	681.53 ± 377.86	N.S.

complications
IS : Incentive spirometry

Table 6. Ratio of IS volume/preoperative VC for postoperative pneumonia

	Yes (n = 9)	No (n = 54)
Minimum IS volume/preoperative VC ≤ 13%	6 (66.7%)	15 (27.8%)
Average IS volume/preoperative VC ≤ 22%	6 (66.7%)	13 (24.1%)

VC : Vital capacity
IS : Incentive spirometry

< 0.01), respectively, but the FEV1.0% was not (r = 0.249 [p > 0.05]) (Table 4).

Next, we examined the correlation between postoperative complications and the IS volumes. The average, minimum, and decrease in IS volume were not correlated with postoperative pneumonia, but the average and decrease were correlated with atelectasis (Table 5).

Neither the average nor minimum IS volume/preoperative VC ratio was found to be a risk factor for atelectasis. However, patients with 13% less than the minimum ratio and 22% less than the average ratio were found to be at a higher risk for pneumonia ($p < 0.05$). The results of the correlation of spirometric data and IS volumes are shown in Table 6, and those of the multivariate regression models for pneumonia are shown in Tables 7 and 8.

Table 7. Logistic regression analysis for postoperative pneumonia and minimum IS volume

	SD	*P* value	OR	95% CI
Minimum IS volume/VC ≤ 13%	0.950	0.0265	8.23	1.28–52.98
Adhesion	0.987	0.0832	5.58	0.80–38.25
Operating time	1.181	0.0364	11.84	1.17–119.90

SD : standard deviation
OR : Odds ratio
CI : Confidence interval
VC : Vital capacity
IS : Incentive spirometry

Table 8. Logistic regression analysis for postoperative pneumonia and average IS volume

	SD	*P* value	OR	95% CI
Average IS volume/VC ≤ 22%	1.041	0.0104	14.40	1.87–110.76
Adhesion	1.044	0.1614	4.36	0.58–33.41
Operating time	1.290	0.0218	19.30	1.54–242.16

SD : standard deviation
OR : Odds ratio
CI : Confidence interval
VC : Vital capacity
IS : Incentive spirometry

Discussion

Despite improvements in the surgical techniques and perioperative management of esophageal surgery, the morbidity and mortality rates remain high in comparison to other procedures[14, 15]. Reported perioperative morbidity and mortality rates of up to 60% and 14%, respectively, have been associated with esophagectomy for esophageal cancer[16]. In recent years, several techniques have been recommended to prevent pulmonary complications after esophagectomy, such as thoracic epidural analgesia, patient-controlled epidural analgesia, smoking cessation, preoperative respiratory rehabilitation, postoperative early rehabilitation, oral care, steroid administration, neutrophil elastase inhibitor administration, and minimally invasive surgical procedures[3, 17]. However, the only factor found to be an independent predictor of reduced postoperative respiratory failure is minimally invasive surgery[18–20]. Patients undergoing minimally invasive esophagectomy showed less surgical access-related trauma and possibly less impairment of respiratory function in the postoperative period, and such procedural changes are associated with lower pulmonary complication rates. Less restrictive pulmonary damage was also reported following thoracoscopic surgery compared to open surgery, because thoracoscopic surgery can reduce pulmonary damage caused by chest wall

injury[21]. Murai *et al*[22] reported that VATS-E is less invasive and safer than esophagectomy via open thoracotomy with respect to postoperative quality of life and perioperative care.

As perioperative management in the present study, we used minimally invasive surgery, epidural analgesia, steroids, smoking cessation at least 1 month before the surgery, and respiratory rehabilitation using IS before and after the operation. Extubation was performed on the day of surgery, and from 1 postoperative day onward, the patients underwent rehabilitation including walking, IS, and oral intake of water. In general, if patients experience difficulty in expectoration, suction by bronchoscopy is conducted[23]. However, patients who underwent VATS-E at our department first underwent rehabilitation including walking and IS, and at our department, suction is not conducted using bronchial fiber, thin tracheal intubation. Patients who required suction in such a manner were diagnosed with pneumonia in this study.

Recent studies have identified several factors that contribute to the decreased incidence of pulmonary complications after esophagectomy. Risk factors for perioperative pulmonary complications include obstructive pulmonary injury, clinical stage, age, neoadjuvant chemoradiation therapy, and bleeding during the surgery[24]. In particular, some studies have reported preoperative respiratory functions as risk factors. Fan *et al*[25] reported a good correlation between the incidence of complications and the preoperative peak expiratory flow rate when it was less than 65% of the predicted normal value. Further, Nagawa *et al*[26] reported accurate assessments of the risk of postoperative pulmonary complications by calculating a risk score based on VC, liver cirrhosis, and tumor stage, while Avendano *et al*[27] found that patients with FEV1.0% $<$ 65% of the predicted value are at risk for pulmonary complications after esophagectomy.

The purpose of the present study was to identify factors that predict pulmonary complications after VATS-E, with the aim of instituting preventive interventions at an early stage. All patients who underwent VATS-E in this study also underwent rehabilitation using IS. We therefore investigated whether pulmonary complications after VATS-E are correlated with perioperative changes in the IS volumes and whether complications can predicted on the basis of changes in the IS volumes.

In this study, 13 of the 63 patients had atelectasis, and the factors correlated to this postoperative complication were found to be the average IS volume and a decrease in the IS volume. The atelectasis improved with rehabilitation that included walking and IS. Therefore, we do not believe that atelectasis has an important clinical influence. However, we were unable to predict pulmonary complications from IS volumes alone. A reason for this could be that the maximum volume of IS using the Coach 2™ in adult patients is usually a maximum volume of 2500 ml and 4000 ml. In the present study, it was 2500 ml, and in 15 patients, the preoperative average IS volume was 2500 ml. Thus, it is likely that in some of these patients, the volume exceeded 2500 ml. Each score of the average IS volume,

decrease in IS volume, and minimum IS volume was not correlated with postoperative pneumonia, while the correlation coefficient of VC was 0.674 ($P < 0.01$). We thus proposed that the ratio of the IS volume to VC could be used as a predictive factor, because this ratio indicates intraoperative respiratory function and considers differences among patients. Using this ratio, we then showed that the risk of postoperative pneumonia was high in patients with 13% less than the minimum ratio and 22% less than the average ratio. Future investigation will now focus on the change in IS volume using the 4000 ml device because of the consideration of patient differences.

This study precluded patients who had pulmonary dysfunction, since those with severe respiratory dysfunction and pneumonia up to 1 month before the operation and those who had smoked for at least 1 month before the surgery were not eligible to undergo VATS-E. Since the risk of postoperative respiratory complications was high for these patients, we treated them using the mediastinoscopic approach or salvage surgery by VATS-E. This could be another reason why we were not able to predict pulmonary complications from the IS volumes alone.

In conclusion, using IS we identified factors predictive of pneumonia after VATS-E. We believe that future studies could enable prediction of pulmonary complications by early using the IS volume.

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