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Operative Benefits of Artificial Pneumothorax in Thoracoscopic Esophagectomy in the Left Lateral Decubitus Position for Esophageal Cancer

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Abstract

Objectives: This study aimed to evaluate operative benefits of artificial pnuemothorax in thoracoscopic esophagectomy in the left lateral decubitus position. Methods: We retrospectively analyzed short-term surgical outcomes including learning curve of 60 consecutive patients who underwent thoracoscopic esophagectomy with artificial pnuemothorax in the left lateral decubitus position between April 2010 and November 2012 in our department. Results: The median operation time and intraoperative blood loss were 443 min and 220 ml, respectively, and these values were 174 min and 95 ml, respectively, in the thoracic phase of surgery. The median number of harvested lymph node was 37. Only 1 patient required conversion to open esophagectomy. The postoperative 30-day mortality rate was 1.7%. The thoracic operation time significantly decreased after an experience of 10 cases and intraoperative blood loss during thoracic phasesignificantly decreased after an experience of 20 cases ($p < 0.05$), and operation time remained constant for the following cases. The number of harvested lymph nodes did not exhibit significant changes with an increase in the number of case experienced. Conclusions: Artificial pneumothorax provided the shorting of learning curve at the thoracoscopic esophagectomy in the left lateral decubitus position.

Keywords

Thoracoscopic Esophagectomy, Artificial Pneumothorax, Left Lateral Position

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1. Introduction

Esophagectomy with extended lymphadenectomy remains the primary treatment option for resectable esophageal cancer [1] [2]. However, this procedure is highly invasive and is associated with high rate of morbidity and mortality rate [3]-[5]. Since the first report by Cushieri *et al*., minimally invasive surgery for esophageal cancer has been performed with increasing frequency, because it reduces the operative invasiveness and provides the rapid postoperative recovery [6]-[8]. On the other hand, the comparison of clinical outcomes between minimally invasive (MIE) and open esophagectomy (OE), the operation time is significantly longer. Moreover, the incidence of anastomotic leakage and reoperation is significantly higher in MIE [9]. Although thoracoscopic esophagectomy is potentially feasible and less invasive alternative, a large multi-center clinical trialis need for confirming the clinical benefits of this procedure.

Thoracoscopic esophagectomy in the prone position is performed under artificial pneumothorax [10] [11]. The advantages of this technique include enhanced visualization of operative fields and surgeons' ergonomics than left lateral position. However, thoracoscopic esophagectomy in prone position takes a significant longer operation time and is not established for emergent thoracotomy [12]. Therefore, the patients' position during thoracoscopic esophagectomy remains unclear and does not allow for significant conclusions.

We have developed a new technique in thoracoscopic esophagectomy combining left lateral position with artificial pneumothorax. The aim of this retrospective study is to evaluate the technical feasibility and effect of this technique on terms of operation time and intraoperative blood loss.

2. Materials and Methods

We retrospectively analyzed all the patients who underwent thoracoscopic esophagectomy with artificial pneumothorax in the left lateral decubitus position followed by laparoscopic gastric mobilization between April 2010 and November 2012 at our institution. The detailed of our operative techniques have been described in previous report [13]. During this period, thoracoscopic esopagectomy was indicated for 60 patients with thoracic esophageal cancer. All thoracoscopic esophagectomy were performed by a single surgeon. He has previously experienced esophagectomy under thoracotomy in 200 cases with esophageal cancer in other institutions.

All the patients underwent preoperative esophagogastroscopy with biopsy, computed tomography (CT) from the neck to abdomen, barium swallow, and positron emission tomography/CT. Preoperative and postoperative staging, and treatment criteria followed the Japanese Guidelines for Diagnosis and Treatment of Carcinoma of the Esophagus [14]. Patients with diagnosed as clinical stage II or III esophageal cancer by preoperative examination received 2 courses of neoadjuvant chemotherapy with 5-fluorouracil and cisplatin. These patients underwent surgery 4 weeks after the termination of neoadjuvant chemotherapy. Patients with stage I esophageal cancer underwent esophagectomy without neoadjuvant chemotherapy. Chemoradiation or chemotherapy was indicated for patients with clinical stage IV (including T4) cancer.

This study measures included the clinicopathological factors and short-term surgical outcomes of the patients and improvements in operation time and intraoperative blood loss with an increased number of operated cases. To define the learning curve of our procedure in terms of operation time and estimated blood loss, the 60 patients were divided into 6 sequential groups (n = 10 each). Other learning indicators such as requirement for blood transfusion, rate to conversion to conventional open surgery, rate of postoperative complications, and number of harvested lymph nodes, were evaluated for statistical significance.

3. Statistical Analysis

All data were analyzed using SPSS version 19 (SPSS, Inc., Chicago, II, USA). Statistical analyses were performed using Kruskal-Wallis test for continuous variables and chi-squared test for categorical variables. Data are expressed as median and range. Probability (P) values of <0.05 were considered statistically significant in all tests.

4. Results

The clinicopathological and operative findings of the patients are shown in **Table 1**. The tumor location was in the upper third of the thoracic esophagus in 9, middle third in 36, and lower third in15, respectively. For 38 out

Table 1. Patients' clinicopathological and operative findings.

Factors		N or median	(% or range)
Gender	Male:Female	45:15	
Age (year)		65.0	(46 - 80)
Tumor location	Upper:Middle:Lower	9:36:15	
ASA Score	ASA1:ASA2:ASA3	4:37:19	
Neoadjuvant chemotherapy	Present:Absent	38:22	
Operative procedure (Thoracic)	Thoracoscopy Convert to thoracotomy	59 1	98.3% 1.7%
Operative procedure (Abdominal)	Laparoscopy Laparotomy	56 4	93.3% 6.7%
Extent of lymph node dissection	3 field:2 field	15:45	
Operation time (min)	Total	443	(240 - 874)
	Thoracic	174	(97 - 352)
Blood loss (ml)	Total	220	(20 - 1575)
	Thoracic	95	(10 - 520)
Number of harvested lymph node		37	(11 - 101)
Type of tumor	SCC:AD	59:1	
Depth of tumor invasion	pT1a:pT1b:pT2:pT3:pT4	2:14:12:30:2	
Lymph node metastasis	pN0:pN+	28:32	
Pathological stage	I:II:III:IV	9:22:20:9	
Lymphatic invasion	Present:Absent	28:32	
Venous invasion	Present:Absent	35:25	
Postoperative complications	Anastomotic leakage Pneumonia	5 4	(8.3%) (6.7%)
	Conduit necrosis	2	(3.3%)
	Chylothorax	2	(3.3%)
	Bleeding	1	(1.7%)

Postoperative complications included Clavien-Dindo classification grade III and higher. SCC: Squamous cell carcinoma, AD: Adenocarcinoma.

of 60 patients, chemotherapy was performed preoperatively. One patient was converted to the conventional thoracotomy, because of difficulty with maintain of one lung ventilation. The abdominal procedure was performed laparoscopically in 56 patients. Three field lymphadenectomy was performed in 15 patients, other was performed 2-field lymphadenectomy. Median numbers of lymph node harvested was 37 (range 11 to 101). Median operation time was 443 minutes (range 240 to 874), and those in thoracic was 174 minutes. Median estimated blood loss was 220 ml, those in the thoracic was 95 ml (range 10 to 520). Hospital mortality rate was 1.7% (n = 1) because of tracheal necrosis followed by conduit failure. There was no other death during the hospital stay. Postoperative complications (grade 3 and higher as stated by modified Clavien-Dindo classification) were occurred in 14 patients [15]. The most frequent postoperative complication was anastomotic leakage (n = 5, 8.3%). The postoperative pneumonia developed in only 4 patients (6.7%).

Thechronological changes of operative outcomes were shown in **Table 2**. There were no significant differences in patients' background, frequency of perioperative blood transfusion and postoperative complications were not significantly different in each group. The operation time, estimated blood loss and number of harvested lymph nodes did not significantly different with an increase in the number of operated cases. **Figure 1** show the box plots of median operation time and blood loss in thoracic phase according to the operative experiences. Following an experience of 10 cases, the thoracic operation time was significantly decreased and reached plateau.

Table 2. Patients' characteristics of 6 sequential groups of 10 cases in each group.

Factors		Number of cases						*P* value
		1 - 10	11 - 20	21 - 30	31 - 40	41 - 50	51 - 60	
Gender	Male:Female	6:4	8:2	10:0	5:5	6:4	10:0	0.2824
Age	(median)	69.5	70.5	62.0	63.0	64.5	64.0	0.3057
BMI	(Kg/m^2)	22.4	18.9	22.2	19.8	19.4	21.1	0.9922
Location	Upper	1	1	1	2	2	2	
	Middle	6	8	5	6	4	7	0.7747
	Lower	3	1	4	2	4	1	
Convert to thoracotomy		0	1	0	0	0	0	0.4056
Operation time	(minutes)	469	440	292	371	492	449	0.3707
Blood loss	(ml)	372	293	203	210	220	300	0.1291
Dissected lymph nodes	(number)	53	36	33	27	51	38	0.2322
Blood transfusion		2	1	2	1	2	3	0.8638
Complications		3	3	0	2	4	2	0.3899
Mortality		0	1	0	0	0	0	0.4056

Postoperative complications included Clavien-Dindo classification grade III and higher.

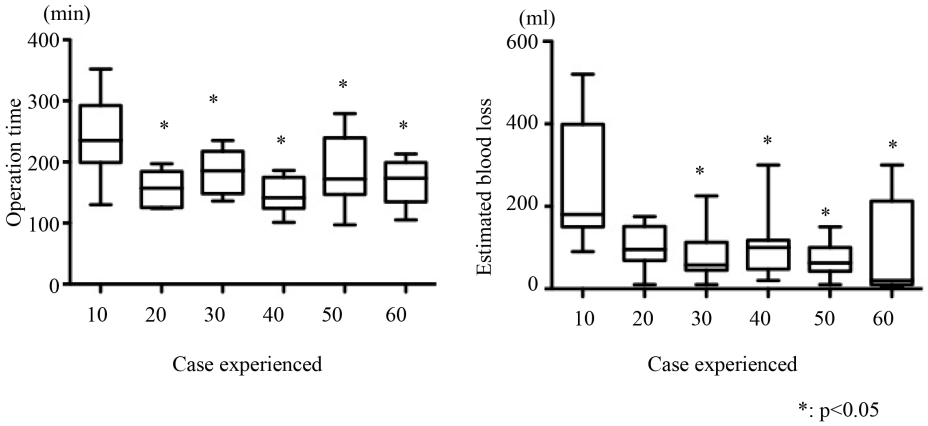

Figure 1. Box plots of operation time and blood loss of thoracic phase grouped according to the operative experience. After the experienced of 10 cases, the thoracic operation time was significantly decreased and reached plateau ($p < 0.05$). The blood loss of thoracic phase also significantly decreased after 20 cases experienced.

The blood loss during thoracoscopic procedure significantly decreased after 20 cases experienced.

5. Discussion

Since the first report by Cushieri *et al*, many case series have reported for clinical benefits of thoracoscopic esophagectomy compared with open esophagectomy [6]. Several reports concluded that benefits of thoracoscopic esophagectomy were lower intraoperative blood loss and fewer postoperative pulmonary complications [7] [8]. Otherwise, it is reported that the cases with reoperation and postoperative complication were possibly increased in minimally invasive technique by analyzing web based Japanese clinical database [9]. Despite its several clinical advantages and provide clear visualization of the surgical field by optical devices over open esophagectomy, thoracoscopic esophagectomy is technically complex and has longer surgical duration during the

learning phase. Therefore, the effective devices and techniques are required to make it possible to shorten the learning curve of the thoracoscopic esophaegctomy.

The artificial pneumothorax with CO_2 insufflation has been used in thoracoscopic esophagectomy in prone position [10] [16] [17]. The safety of artificial pneumothorax during thoracoscopic esophagectomy has been described in several articles. Zhang, Y. *et al*. reported that the artificial pneumothorax did not interfere with physiological functions of the patients performed in left semi-prone position [16]. Saikawa, D. *et al*. reported that no excessive increases in airway pressure or clear circulatory depression were found in the prone position with artificial pneumothorax [17]. However, none the reports described the safety and benefit of artificial pneumothoraxin left lateral decubitus positionso far. In left lateral decubitus position without artificial pneumothorax, the exclusion of right lung using wide retractor is needed for maintenance of the surgical field [7]. In our experiences of artificial pneumothorax during thoracoscopic esphagectomy under left lateral position, the right lung collapsed rapidly and mediastinum tissue containing lymph nodes are fully expanded. The dissection of mediastinum lymph nodes was able to perform with less blood loss with facility. In all cases, the thoracic procedures were completed with no complication. We think that the thoracic operation time have been able to be decreased rapidly by using artificial pneumothorax.

Several authors have already concluded that thoracoscopic esophagectomy produced fewer postoperative complications than open surgery and comparable oncological outcomes [18] [19]. Nevertheless, the comparison between prone and left lateral decubitus position in thoracoscopic esophagectomy is still debate. Teshima, J. *et al.* concluded that thoracoscopic esophagectomy in prone position is superior to left lateral decubitus position in terms of blood loss and postoperative pulmonary complication [20]. Noshiro *et al.* described that the thoracoscopic esophagectomy in prone position has ergonomic advents for surgeons, but significantly longer operation time [10]. Other report showed that left lateral position provides more excellent hemodynamic parameters than prone position [21]. We think that the advantages of left lateral than prone position were shorter thoracic operation time and suitable for emergent thoracotomy. Moreover, operative field of mediastinum is able to fully expose by artificial pneumothorax. In these reasons, thoracoscopic esophagectomy in left lateral position has become the standard approach for esophageal cancer in our institution. Anyway, both positions are safe and technically feasible. There are no conclusive results which position was superior in thoracoscopic esophagectomy. The selection of approach in thoracoscopic esophagectomy is committed to surgeons' preference. Further prospective randomized study is required to establish for choice of surgical approach.

Till date, few reports have described the learning curve of thoracoscopic esophagecotmy. Only 5 case series have reported so far (**Table 3**) [22]-[26]. Osugi *et al*. first described the benefits of surgeons' experience in thoracoscopic esophagectomy at left lateral position in 2003 [22]. They concluded that the incidence of postoperative pulmonary complications, duration of operation and amount of intraoperative blood loss were significantly decreased after an experience of 34 cases; however, the first 16 cases were associated with high risk of complications. Therefore, satisfactory outcomes with this procedure can be obtained only in centers with experience in performing a sufficient number of esophageal surgeries. On the other hand, Guo *et al*. reported that at an experience of least 30 cases of thoracoscopic esophagectomy was required for surgeons to achieve general competence [25]. After 30 cases, operative time, blood loss and postoperative hospital stay began to decline. In addition, a greater number of retrieved nodes were harvested and a lower incidence of postoperative major complications was observed after 30 cases experienced. Many reports on the learning curve of thoracoscopic esophagectomy have shown that an experience from 30 to 40 cases is required for surgeons to achieve a plateau. Our results suggested that the artificial pneumothorax in thoracoscopic esophagectomy was provided the clear operative view and able to shorten the learning for reach the plateau inthoracic operation time.

6. Conclusion

Thoracoscopic esophagectomy with artificial penumothorax in the left lateral decubitus position is a safe and feasible technique. Our technique is able to decrease the number of cases required to achieve competence and has considerable advantage in surgical technique. However, the oncologic outcomes of thoracoscopic esophagectomy compared the left lateral position with prone position remain to controversial and will require further randomized studies.

Institutional Review Board

The study protocol has been approved by the Institutional Ethics Committees of all participating institutions.

Table 3. Previous reports related to learning curve of thoracoscopicesophagectomy.

No	Author	Year	Total numbe of cases (N)	Required for learning (N)	Thoracic procedure	Abdominal prodedure
1	Osugi H	2002	80	34	Left lateral	Laparotomy
2	Song SY	2009	24	14	Left lateral	Laparoscopy
3	Kunisaki C	2011	92	40	Left lateral	Laparoscopy
4	Guo W	2012	89	30	Left lateral	Laparotomy
5	Lin J	2012	80	40	Left lateral	Laparoscopy
6	Our report	-	60	20	Left lateral	Laparoscopy

No	Results				
	Short operating time	Low blood loss	Low postoperative complications	Increased of retrieved nodes	Short ICU or hospital stay
1	+	+	+	+	ND
2	+	ND	+	ND	+
3	+	+	ND	+	+
4	+	+	+	ND	+
5	+	ND	ND	+	ND
6	-	-	-	-	-

ND: Not described.

Competing Interest

The authors have declared that no competing interest exists.

Limitations

1) This study holds the limitation of retrospective with small number sample size.
2) This study is single surgeon experience of surgical procedure; therefore personal bias cannot be avoided.

Prospective multicenter studies with more samples are needed to establish the feasibility of thoracoscopic esophagectomy with artificial pneumothorax.

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