Learning of thoracoscopic radical esophagectomy: How can the learning curve be made short and flat?

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Original article

Title

Learning of thoracoscopic radical esophagectomy: How can the learning curve be made short and flat?

Running title

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ABSTRACT

Attainment of proficiency in video-assisted thoracoscopic radical esophagectomy (VATS) for thoracic esophageal cancer requires much experience. We have mastered this procedure safely under the direction of an experienced surgeon. After adoption of the procedure, the educated surgeon directed induction of this surgical procedure at another institution. We evaluated the efficacy of instruction during the induction period by comparing the results at the two institutions in which VATS had been newly induced. We defined the induction period as the time from the beginning of VATS to the time when the last instruction was carried out. From January 2003 to December 2007, 53 patients were candidates for VATS at Kanazawa University (Institution 1). Of these, 46 patients underwent curative VATS by a single operator. We divided this period into 3 parts: the induction period of VATS, post-induction period, and proficient period when the educated surgeon of Institution 1 directed the procedure at Maebashi Red Cross Hospital (Institution 2). At Institution 1, 12 VATS were scheduled and 9 procedures (75%) (Group A) including 8 instructions were completed during the induction period (from January 2003 to August 2004). Thereafter, VATS was performed without instruction. In the post-induction period, 9 VATS were scheduled and 8 procedures (88.8%) (Group B) were completed from September 2004 to August 2005. Subsequently, 32 VATS were scheduled and 29 procedures (90.6%) (Group C) were completed during the proficient period (from September 2005 to December 2007). The surgeon at Maebashi Red Cross Hospital (Institution 2) started to perform VATS under the direction of

the surgeon who had been educated at Institution 1 from September 2005. VATS was completed in 13 (76.4%) (Group D) of 17 cases by a single surgeon including 7 instructions during the induction period at Institution 2 from September 2005 to December 2007. No lethal complication occurred during the induction period at both institutions. We compared the results of VATS among 4 groups from 2 institutions. There were no differences in the background and clinicopathological features among the 4 groups. The number of dissected lymph nodes and amount of thoracic blood loss were similar in the four groups [35(22-52) vs. 41(26-53) vs. 32(17-69) vs. 29(17-42) nodes, p=0.139; and 170(90-380) vs. 275(130-550) vs. 220(10-660) vs. 210(75-543) g, p=0.373, respectively]. There was no difference in the duration of the thoracic procedure during the induction period at the two institutions. However, the duration of the procedure was significantly shorter in the proficient period of Institution 1 [Group C: 266(195-555) min] than in the induction period of both institutions [Group A: 350(280-448) min (p=0.005) and Group D: 345 (270-420) ml (p=0.002)]. There were no surgery-related deaths in any of the groups. The incidence of postoperative complications did not differ among the 4 groups. Thoracoscopic radical esophagectomy can be mastered quickly and safely with a flat learning curve under the direction of an experienced surgeon. The educated surgeon can instruct surgeons at another institution on how to perform thoracoscopic esophagectomy. The operation time of thoracoscopic surgery is shortened by experience.

KEY WORDS: Esophageal Neoplasms, Esophagectomy, Thoracoscopy, Instruction, Education

INTRODUCTION

Esophageal cancer is one of the most common internal malignancies worldwide. It is also a challenging disease with a poor prognosis. The efficacy of esophagectomy with extended lymphadenectomy remains controversial because of the lack of a prospective randomized study, although some reports have shown that better survival can be obtained after extended rather than conventional lymphadenectomy [1, 2]. However, extended lymphadenectomy increases operative morbidity, especially pulmonary complications [2]. Thoracoscopic esophagectomy was developed to reduce the surgical insult in esophageal cancer treatment [3]. The benefits of thoracoscopic esophagectomy include minimizing the reduction in vital capacity secondary to chest wall injury and less surgical trauma with less production of cytokines and polymorphonuclear leukocyte elastase [4, 5], and it also provides survival results comparable to those obtained with open radical esophagectomy [6]. However, the benefit of thoracoscopic esophagectomy was not documented in studies conducted at institutions with limited experience [7-13]. The beneficial effects of thoracoscopic esophagectomy were reported in studies conducted at institutions in which the author/surgeon was someone who had experienced a substantial number of cases [14-17]. Because the attainment of proficiency in thoracoscopic radical esophagectomy requires much experience, satisfactory outcomes will only be obtained after development of a training course at a center that performs a sufficient number of esophageal surgeries to provide surgeons with the opportunity to refine necessary skills. Therefore, studies on thoracoscopic esophagectomy conducted at institutions that perform a

relatively small number of esophageal surgeries may show unfavorable results. From January 2003 until the present, we have been performing video-assisted thoracoscopic esophagectomy with extensive mediastinal lymphadenectomy (VATS) for thoracic esophageal cancer. During the initial induction period, we tried to master VATS safely under the direction of an experienced surgeon and with the regular surgical team at our institution. As a result, we could master VATS relatively quickly and safely with less thoracic blood loss in comparison with that in the initial cases that had been experienced at the director's institution [18]. After attaining proficiency in the procedure, the surgeon at our institution tried to introduce VATS at another institution by direct instruction.

In this report, we evaluated the efficacy of instruction during the VATS induction period by comparing the results of cases between two institutions in which VATS had been recently introduced.

MATERIALS AND METHODS

Patients

At Kanazawa University (Institution 1), we initially limited the VATS procedure to patients with esophageal cancer with T1 and T2 tumors without lymph node metastasis. After attaining surgical skills from our experience with the initial 6 cases, we enlarged the criteria to include T3 tumors with regional lymph node metastasis. T4 and bulky tumors that are not resectable by the VATS procedure, were not candidates for VATS. Other inclusion criteria were as follows: no previous upper gastrointestinal tract

operation, no previous radiation therapy, no extensive pleural adhesions, pulmonary function capable of sustaining single-lung ventilation, no concomitant serious medical condition such as liver cirrhosis, and patient preference for VATS. From January 2003 to December 2007, 70 patients with squamous cell carcinoma of the thoracic esophagus were assessed as being candidates for radical esophagectomy at Kanazawa University. Of these, 53 patients met our criteria for VATS. The first patient at Kanazawa University underwent the operation by specialist surgeons (Osugi et al.) [19] from Osaka City University, as a demonstration. Then, starting with the second patient, the specialist surgeon directed the surgeon (Ninomiya) at Kanazawa University in performing VATS. During the induction period of VATS, all members of the surgical team including the operator, assistant and scopist remained the same to ensure consistency and to obtain early and maximal cooperation in performing VATS that was directed by an experienced surgeon (Osugi). Osugi attended the first 10 operations at Kanazawa University including the first VATS that was performed by Osugi and one VATS that was converted to thoracotomy due to pleural adhesion, and directed and instructed the surgeon (Ninomiya), assistant and scopist during the VATS procedure about how to complete the procedure safely and how to maintain the curative dissection quality. After attaining proficiency in performing the procedure, the surgeon at Institution 1 (Ninomiya) operated on 1 patient and directed 7 VATS procedures at Maebashi Red Cross Hospital (Institution 2) starting in September 2005, as Osugi had done at Institution 1.

From September 2005 to December 2007, 17 patients with squamous

cell carcinoma of the thoracic esophagus were candidates for radical esophagectomy at Institution 2. Inclusion and exclusion criteria of VATS were the same as those at Institution 1. All patients were scheduled for VATS. VATS was performed in the first patient by Ninomiya, and in the 16 subsequent cases, VATS was performed by the surgeon (Tomizawa) at Institution 2 from September 2005 to December 2007 (the induction period at Institution 2).

We defined the induction period of VATS as the time from the beginning of VATS to the time when the last instruction was carried out. We divided the period when VATS had been performed in Institution 1 into 3 parts: the induction period, the post-induction period, and the proficient period when the surgeon who had been educated at Institution 1 directed the procedure at Maebashi Red Cross Hospital (Institution 2). The proficient period in Institution 1 corresponded with the induction period in Institution 2. The completion rate of curative VATS during the induction period of the two institutions and that during the subsequent periods in Institution 1 were compared.

The tumor was staged according to the TNM classification of the American Joint Committee on Cancer and the Union Internationale Control le Cancer. The clinicopathological factors and surgical outcomes of the curative procedure that had been performed thoracoscopically, including the duration of the thoracic procedure, amount of thoracic blood loss, number of dissected nodes and incidence of complications during the VATS procedure were compared among the four groups in 2 institutions. Values are expressed

as medians (range). The chi-square test was used to compare the clinicopathological factors. The Mann-Whitney U test and Kruskal-Wallis test were used to compare surgical outcomes. A p-value <0.05 was considered to be statistically significant.

Procedure

All patients at Institutions 1 and 2 underwent three-stage esophagectomy and reconstruction. The surgical procedure was the same at both institutions. During the thoracic procedure, the patient was placed in the left lateral position. A 5-cm minithoracotomy was created in the fourth or fifth intercostal space (ICS) in the mid-axillary line (AL) to insert a retractor with a width of 3cm designed by Osugi [19] and a camera. Four 11.5-mm trocars were inserted around the minithoracotomy as described previously [19]. The operator and assistants stood at the dorsal and ventral side of the patient, respectively, in the same way as open esophagectomy. Video monitors were placed oppositely on bilateral sides of the patient. The scopist operated a 30-degree telescope to show the axial plane of the mediastinum horizontally. The image on the monitor for the assistants was horizontally and vertically reversed from that of the operator to make correct eye-hand coordination as described previously [19]. All of the procedures were done thoracoscopically. The right lung was deflated and compressed with the retractor. Esophageal mobilization and en-bloc mediastinal lymph node dissection were performed in the same way as they are in open surgery with counter-traction by an assistant using a retractor. In particular, the lymph nodes around the

bilateral recurrent laryngeal nerves were completely removed with the identification and preservation of those nerves [18]. We used Thoracoscopic Jacobson Debaky Forceps (No. 9009-422R, SCANLAN, St. Paul, MN) for mediastinal dissection.

In the second stage, the patient was placed in the supine position. The second stage was done by laparotomy or hand-assisted laparoscopic surgery (HALS). The indication of HALS was as follows: no previous upper gastrointestinal tract operation, no previous radiation therapy, no previous upper abdominal surgery, no apparent abdominal lymph node metastasis, no concomitant abdominal malignant neoplasm, no concomitant serious medical condition such as liver cirrhosis, and patient preference for HALS. Following dissection of pericardiac and celiac axis nodes, the mobilized esophagus was pulled down through the enlarged hiatus. The stomach was prepared for reconstruction by division at the cardia with a stapler.

In the third stage, the cervical nodes were dissected through a collar incision, and the stomach was pulled up through the posterior mediastinum. The procedure was completed with cervical esophagogastric anastomosis.

The experience of the operators

The specialist surgeon (Osugi) [19] from Osaka City University who directed the operator (Ninomiya) at Kanazawa University had performed more than 200 conventional esophagectomies and 75 VATS when he started to teach the VATS procedure at Kanazawa University. He had received technical certification for thoracoscopic esophagectomy from the Japan

Society for Endoscopic Surgery in January 2005.

Before beginning VATS at Institution 1 (Kanazawa University), the operator (Ninomiya) had experienced 32 conventional esophagectomies and extended lymphadenectomies as an assistant and performed 1 procedure as the primary operator. Ninomiya had visited Osaka City University once to learn VATS from a specialist surgeon (Osugi) and was given didactic videos. He attempted VATS twice on pigs at the training center.

At Institution 2 (Maebashi Red Cross Hospital), the operator (Tomizawa) had performed 16 conventional esophagectomies and extended lymphadenectomies as the primary operator and experienced 20 operations as an assistant. The two operators at Institution 1 and 2 had little prior experience in scopic surgery. The annual number of esophagectomies at Institutions 1 and 2 was 15-20 and 4-6, respectively.

RESULTS

Among the 53 VATS that were scheduled at Kanazawa University (Institution 1), the VATS procedure was switched to conventional thoracotomy in 5 patients because of severe pleural adhesion in 1 patient, uncontrollable intraoperative bleeding in 1 patient, and contiguous tumor spread in 3 patients. One patient underwent palliative thoracoscopic esophagectomy, because it was found that the tumor invaded the right main bronchus. Thus, curative thoracoscopic esophagectomy and extensive lymphadenectomy were completed in 46 of 53 patients by a single surgeon (Ninomiya) at Institution 1. At Institution 1, the surgeon (Ninomiya) was

able to perform a complete thoracoscopic radical esophagectomy with his regular surgical team members without any direction after undergoing instruction for 8 cases under adequate direction by an experienced surgeon. The operator at Institution 1 received technical certification in thoracoscopic esophagectomy from the Japan Society for Endoscopic Surgery after the induction period. Among the 53 VATS procedures that were scheduled at Institution 1, 12 VATS were scheduled and 9 procedures (Group A) including 8 instructions were completed during the induction period (from January 2003 to August 2004). During the post-induction period, 9 VATS were scheduled and 8 procedures (88.8%) (Group B) were completed from September 2004 to August 2005. Subsequently, 32 VATS were scheduled and 29 procedures (90.6%) (Group C) were completed during the proficient period (from September 2005 to December 2007).

In Institution 2, the VATS procedure was converted to thoracotomy in 3 of the 17 patients. The reasons for operative conversion were as follows: pleural adhesion in 1, contiguous tumor spread in 1, and difficulty in performing the VATS procedure due to thoracic aortic aneurysm in 1 patient. VATS was completed in 13 (Group D) of 17 cases by a single surgeon (Tomizawa) at Institution 2 during the induction period from September 2005 to December 2007. No lethal complication occurred during the induction period at both institutions. After conversion to thoracotomy, all patients at both institutions underwent radical esophagectomy. The surgeon at Institution 2 mastered the VATS procedure after undergoing instruction for 7 cases under the direction of the surgeon (Ninomiya) who had been instructed

at Kanazawa University. The number of scheduled VATS procedures, number of VATS procedures converted to thoracotomy, and number of cases of non-curative resection in each period at the two institutions are shown in Table 1.

The clinicopathological factors and surgical outcome of the curative thoracoscopic procedure were compared among the 4 groups in 2 institutions. There were no differences in the background and clinicopathological characteristics among the 4 groups of patients (Table 2). The number of dissected mediastinal lymph nodes was similar among the 4 groups (Table 3). There was no difference in the duration of the thoracic procedure during the induction period of both institutions (Group A and Group D). The duration of the thoracic procedure in Group C was significantly shorter than that in Group A and Group D (p=0.005 and p=0.002, respectively) (Table 3, Fig. 1A). The amount of thoracic blood loss did not significantly differ among the 4 groups (Table 3, Fig. 1B). There were no surgery-related deaths in any of the groups. The rates of postoperative complications in each group are shown in Table 4. There were no statistically significant differences in the rates of postoperative complications among the 4 groups. The number (percentage) of cases who underwent HALS in the abdominal procedure in Groups A, B, C, and D was 4 (44.4%), 7 (87.5%), 21 (72.4%), and 11 (84.6%), respectively.

DISCUSSION

The present report indicates that the basic skills of the VATS procedure could be mastered safely in a relatively short period of time under

adequate direction. The learning curve of the VATS procedure may become flat by supervision by an experienced surgeon. The operation time of thoracoscopic surgery is shortened by experience. In addition, our results showed that the surgeon, who was taught the VATS procedure, could in turn teach this procedure to a surgeon at another institution.

Esophagectomy with extended lymphadenectomy is a complex surgery; therefore, a surgeon should pass through a learning curve before performing this procedure without supervision by an experienced surgeon [20]. It had been reported that it is necessary to perform six or more esophagectomies annually to improve the surgical outcome of conventional open surgery [21]. Furthermore, scopic surgery requires mastery of several basic technical skills using indirect two-dimensional optical systems. The performance of scopic surgery continues to improve as the number of cases has become considerable [22]. Similarly, the overall benefit of thoracoscopic esophagectomy tends to correlate with the number of cases experienced. However, continuing supervision of the fully trained surgeon would allow for shorter training periods [20]. Although thoracoscopic esophagectomy has been noted to reduce the surgical insult in esophageal cancer therapy, the difficulty in attaining proficiency in performing VATS has inhibited widespread adoption of this procedure. The induction of a complex surgery like VATS without sufficient knowledge and instrumentation may result in unsatisfactory outcomes and reduced prevalence of VATS. Furthermore, an educational system for training surgeons to perform VATS has yet to be established in Japan. However, sharing the knowledge of instrumentation

and instructing surgeons as to the techniques may help spread and induce new surgical methods such as VATS.

We recently reported the results of VATS induction at our institution and compared them with the results of VATS induction at the instructor's institution [18]. We could master the VATS procedure safely with less thoracic blood loss than that at the instructor's institution. The main reason for our favorable result may have been adequate instruction by an experienced surgeon. Adequate direction by the supervisor might have reduced the unexpected blood loss during manipulation. Osugi originally began to perform this procedure without receiving any direction in 1995. As a result, he required 17 cases to acquire the basic skills, and the learning curve flattened out after experiencing 35 cases [19]. Another reason might be the difference in time period during which the procedures were performed. Although the operation at our institution was performed under the same concept as that at the director's institution, knowledge about mediastinal anatomy, instrumentation, and the operative procedure may have progressed over this time period. As a result, a flat learning curve in mastering the VATS procedure could be obtained.

In the present study, both operators in the two institutions had experienced a substantial number of conventional open esophagectomies, but had little experience in scopic surgery. The mediastinal image provided by the oppositely situated monitors is similar to the image obtained by open thoracotomy for the operator as well as assistants by using a 2-monitor system. Therefore, the mediastinal anatomy could be easily understood by

each surgeon who was accustomed to open esophagectomy, although the monitor image is two-dimensional and the thoracoscopic procedure has less sensation. The usage of Debaky forceps and palm-gripped scissors also helps the operator be comfortable in manipulating similar instruments as those used in open surgery. We created a 5-cm mini-thoracotomy to insert a retractor with a width of 3cm, which was useful to retract the trachea in dissecting lymph nodes around the trachea. In addition, the mini-thoracotomy was useful in exfoliating pleural adhesion. We experienced 6 cases of severe entire pleural adhesion, which was an exclusion criterion for VATS, at Institution 1. However, we could complete VATS by exfoliating the pleural adhesion in five of the six cases using mini-thoracotomy. The monitor system and instrumentation was ingenuity made so that performing VATS had the same feeling as performing open esophagectomy. For these reasons, having previous experience in scopic surgery seems to not always be essential for mastering VATS surgery. In contrast, experience of having performed a substantial number of open esophagectomies might be necessary when beginning to learn VATS.

The Japan Society for Endoscopic Surgery began to provide certification for endoscopic surgery in January 2005, which is issued to operators who not only have a high-quality technique in scopic surgery but also have the potential to instruct another surgeon. A surgeon is considered for certification based on his/her accomplishments, number of cases operated, and the actual operation video without compilation. The specialist surgeon, Osugi, received this certification in January 2005. The operator in Institution

1 could receive this certification after the induction period (Period A). Primary education could be completed during 10 cases of VATS instruction at Institution 1. The results of the initial VATS procedure were not worse than those of the subsequent VATS procedures at both institutions. The learning curves at both institutions became flat by adequate instruction. Therefore, it is difficult to define the induction period accurately. In the present study, we defined the induction period as the time from the beginning of VATS to the time when the last instruction was carried out. The operator in Institution 1 began to teach the VATS procedure at Institution 2 after performing an additional 8 cases of VATS independently. Therefore, the surgeon at Institution 1 who had been taught the VATS procedure, could in turn successfully teach the VATS procedure to a surgeon at another institution after performing only 17 VATS procedures. The surgical team at Institution 2 could perform the entire operation by themselves after 6 cases of instruction. It was verified that the surgical team in Institution 2 mastered the operation procedure by overseeing another case with minimal instruction. Mastery of the procedure was judged by the certified surgeon at both institutions. In addition, the operator at Institution 2 received technical certification for endoscopic surgery from the Japan Society for Endoscopic Surgery after the induction period.

In the present study, we compared the operative results at 2 institutions at which VATS had been newly introduced recently. Conversion of VATS to thoracotomy was done in 5 of 53 cases in Institution 1 and 3 of 17 cases in Institution 2. The conversion rates to open surgery during the

induction period of both institutions were similar. The conversion mainly resulted from the patient's condition, e.g., pleural adhesion and tumor spread which were often difficult to assess accurately preoperatively. The operative results including number of dissected thoracic lymph nodes, thoracic blood loss, and duration of the thoracic procedure did not significantly differ during the induction period at the 2 institutions (Group A and Group D). Especially, the operative results except for the duration of the procedure were the same between Groups C and D. The VATS procedures in Groups C and D were performed during the same period of time (September 2005-January 2008).

Lethal complications occurred in thoracoscopic esophagectomies performed by surgeons with limited experience [8, 9]. These previous reports demonstrated the difficulty and danger in introducing the VATS procedure at centers that perform small numbers of esophageal surgeries. However, our data showed that successful VATS induction could be achieved with little blood loss and without lethal complications at two institutions by direct supervision, although the annual number of operated cases was relatively small at each institution. In particular, the annual number of esophagectomies performed at Institution 2 was only 4-6. It would be possible to enhance the experience of performing VATS by watching the recorded video repeatedly, even at centers performing a limited number of esophageal surgeries.

The rates of postoperative complications did not significantly differ among the 4 groups. However, the rate of postoperative recurrent nerve palsy was relatively high in all 4 groups. The highest rate of recurrent nerve palsy

of 65.5% was found among the latest 29 cases at Institution 1 (Group C), although the surgeon at Institution 1 had acquired the necessary surgical skills. Recurrent nerve palsy may have been due to manipulation related to dissecting the lymph nodes around the recurrent laryngeal nerves, which is also a difficult procedure to perform in conventional open surgery. These nodes show frequent metastasis of esophageal cancer [1, 23]. Preoperative diagnosis of lymph node metastasis is quite difficult, because small nodes of less than 5mm may also have metastasis [24, 25]. Dissection of recurrent nerve nodes has a survival benefit [1, 24]. We examined the recurrent nerve palsy precisely by postoperative bronchoscopy in all cases. Mild insufficient vocal cord movement was defined as recurrent nerve palsy. In addition, many cases showed delayed hoarseness a few days after the surgery, even though the bilateral vocal cords moved well the day after the surgery. In almost all cases, the recurrent nerve palsy was transient and recovered during the following 3 months. Permanent recurrent nerve palsy was observed in 2 cases (4.3%) at Institution 1 in which the nerve had been transected because of tumor involvement. The incidence of pulmonary infection associated with open esophagectomy combined with extended lymphadenectomy has been reported to be 27% [2]. The rates of pulmonary infection during the induction period at Institutions 1 and 2 were 33.3 and 30.7%, respectively, and were comparable to that in open esophagectomy. The risk of pulmonary complications in VATS was reported to decrease by experience [16]. Osugi et al. [16] estimated that the risk might be less than 20% after the first 20 cases. The incidence of pulmonary complications at Institution 1 decreased to 17.2%

after experiencing 17 cases of VATS; however, the difference did not reach statistical significance. A lower pulmonary complication rate would be expected as the surgeon gains further experience in performing the operation.

As shown in Table 2, we treated a relatively high percentage of stage I and stage II cancers at both institutions in comparison with Western countries. The prevalence of endoscopic screening in Japan might contribute to early detection of esophageal cancer. In Institution 1, we experienced 13 recurrences (28.2%) among the 46 cases within a median follow-up period of 1.98 years. The main initial recurrent site was a lymph node; lymph node metastasis developed in 6 patients (13.0%). However, recurrence was not found in the dissected area including recurrent laryngeal nodes in any of the cases. Local recurrence in the tumor bed was found in only 1 patient. Distant organ metastasis was seen in 5 patients (10.8%). No port-site recurrence was found. The overall 1-, 3-, and 5-year survival rates among the cases without lymph node metastasis (n=28) were 95.8%, 91.4%, and 81.3%, respectively. The overall 1-, 3-, and 5-year survival rates among the cases with lymph node metastasis (n=18) were 94.7%, 55.8%, and 47.8%, respectively. The 1,3 and 5-year survival rates among cases with lymph node metastasis are comparable to the survival rates after extensive lymphadenectomy via conventional thoracotomy or VATS [1, 2, 6, 14, 19].

One of the major problems in performing VATS is that it is a time-consuming procedure. This problem is also the main concern in all scopic surgeries. As shown in the present study, the operative time decreased

after the induction period. The procedure can be performed more smoothly after obtaining surgical knowhow and anatomic knowledge by direct instruction.

In conclusion, it is possible to attain the requisite basic skills to perform thoracoscopic radical esophagectomy for thoracic esophageal cancer in a relatively short period of time under the direction of an experienced or educated surgeon. Primary education of the regular surgical team by postaccreditation supervision is essential for the safe and rapid induction of complex scopic surgery. By flattening the learning curve, it may be possible to obtain satisfactory outcomes with thoracoscopic radical esophagectomies even in institutions performing small numbers of esophageal surgeries. The increase in the number of institutions performing VATS safely due to the dissemination of knowledge has contributed to this procedure's widespread adoption as a standard treatment for esophageal cancer. Of course, each surgeon can individually learn the techniques of thoracoscopic esophagectomy in certain centers with a sufficient volume of surgeries. However, our reported education system can result in inter-center dissemination of skills. As a result, minimally invasive radical esophagectomy will become widely and effectively performed.

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Figure legends

Fig. 1. Duration of thoracoscopic esophagectomy (A) and thoracic blood loss (B) at two institutions. Black columns indicate cases who underwent the operation under the direction of an experienced or educated surgeon, and white columns indicate cases who underwent the operation without direction. Black star: case with advanced stage with bulky tumor or large-size bulky lymph node with metastasis; white star: case with severe pleural adhesion; white circle: case with chronic active hepatitis.

Table 1. Number of the cases that underwent VATS in each period at two institutions

	Institution 1			Institution 2
	The induction period Jan. 2003 – Aug. 2004	The post-induction period Sept. 2004 – Aug. 2005	The proficient period Sept. 2005 - Dec. 2007	The induction period Sept. 2005 - Dec. 2007
Number of cases	12	9	32	17
Operated by director	1	0	0	1
Directed operation	9*	0	0	7
Conversion to thoracotomy	1	1	3	3
Pleural adhesion	1	0	0	1
Bulky tumor	0	1	2	1
Massive bleeding	0	0	1	0
Aortic aneurysm	0	0	0	1
Noncurative operation	1	0	0	0
Curative VATS by single operator	9 (75%) (Group A)	8 (88.8%) (Group B)	29 (90.6%) (Group C)	13 (76.4%) (Group D)

*Including 1 conversion to thoracotomy

Table 2. Comparison of clinicopathological characteristics among the 4 groups of patients with esophageal cancer

		Group A	Group B	Group C	Group D	*p*-value
Number of cases		9	8	29	13	
Gender	Man	8	7	24	12	0.856
	Woman	1	1	5	1	
Median age (range)		66 (52-70)	66 (61-77)	64 (53-80)	71 (59-79)	0.096
Location of tumor	Upper thoracic esophagus	3	2	5	1	0.308
	Middle thoracic esophagus	4	5	13	4	
	Lower thoracic esophagus	2	1	11	8	
Pathologic stage (pStage)	0	0	0	0	0	0.587
	I	3	4	11	2	
	IIa	3	0	7	3	
	IIb	1	1	4	4	
	III	1	3	5	4	
	IV	1	0	2	0	

Table 3. Comparison of the number of dissected mediastinal nodes, duration of the thoracic procedure and thoracic blood loss among the 4 groups

	Institution 1			Institution 2	
	Group A (n=9)	Group B (n=8)	Group C (n=29)	Group D (n=13)	*p*-value
Number of dissected nodes	35 (22-52)	41 (26-53)	32 (17-69)	29 (17-42)	0.139
Duration of procedure (min)	350 (280-448)	300 (230-455)	266 * (195-555)	345 (270-420)	0.003
Amount of blood loss (g)	170 (90-380)	275 (130-550)	220 (10-660)	210 (75-543)	0.373

Values are median (range). * p=0.005 vs. Group A, p=0.002 vs. Group D

Table 4. Comparison of postoperative complications among the 4 groups

Postoperative complications	Institution 1			Institution 2	*p*-value
	Group A (n=9)	Group B (n=8)	Group C (n=29)	Group D (n=13)	
Pneumonia and atelectasis	3 (33.3 %)	1 (12.5 %)	5 (17.2 %)	4 (30.7 %)	0.688
Recurrent nerve palsy	4 (44.4 %)	1 (12.5 %)	16 (65.5 %)	5 (38.4 %)	0.183
Unilateral	0 (0 %)	0 (0 %)	11 (37.9 %)	4 (30.7 %)	
Bilateral	4 (44.4 %)	1 (12.5 %)	5 (17.2 %)	1 (7.7 %)	
Chylothorax	1 (11.1 %)	0 (0 %)	0 (0 %)	0 (0%)	0.130
Anastomotic leakage	0 (0 %)	1 (12.5 %)	2 (6.8 %)	0 (0%)	0.515

Fig. 1A

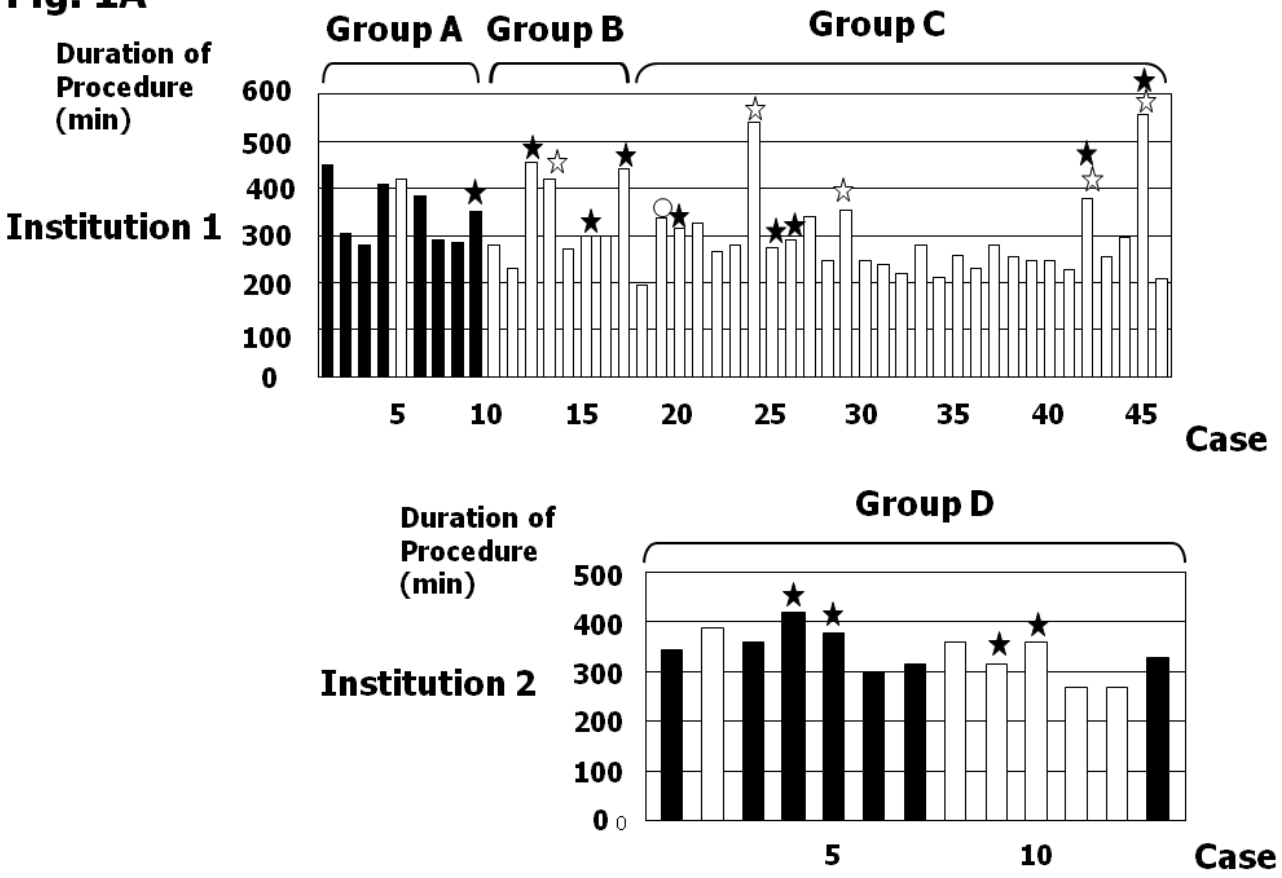
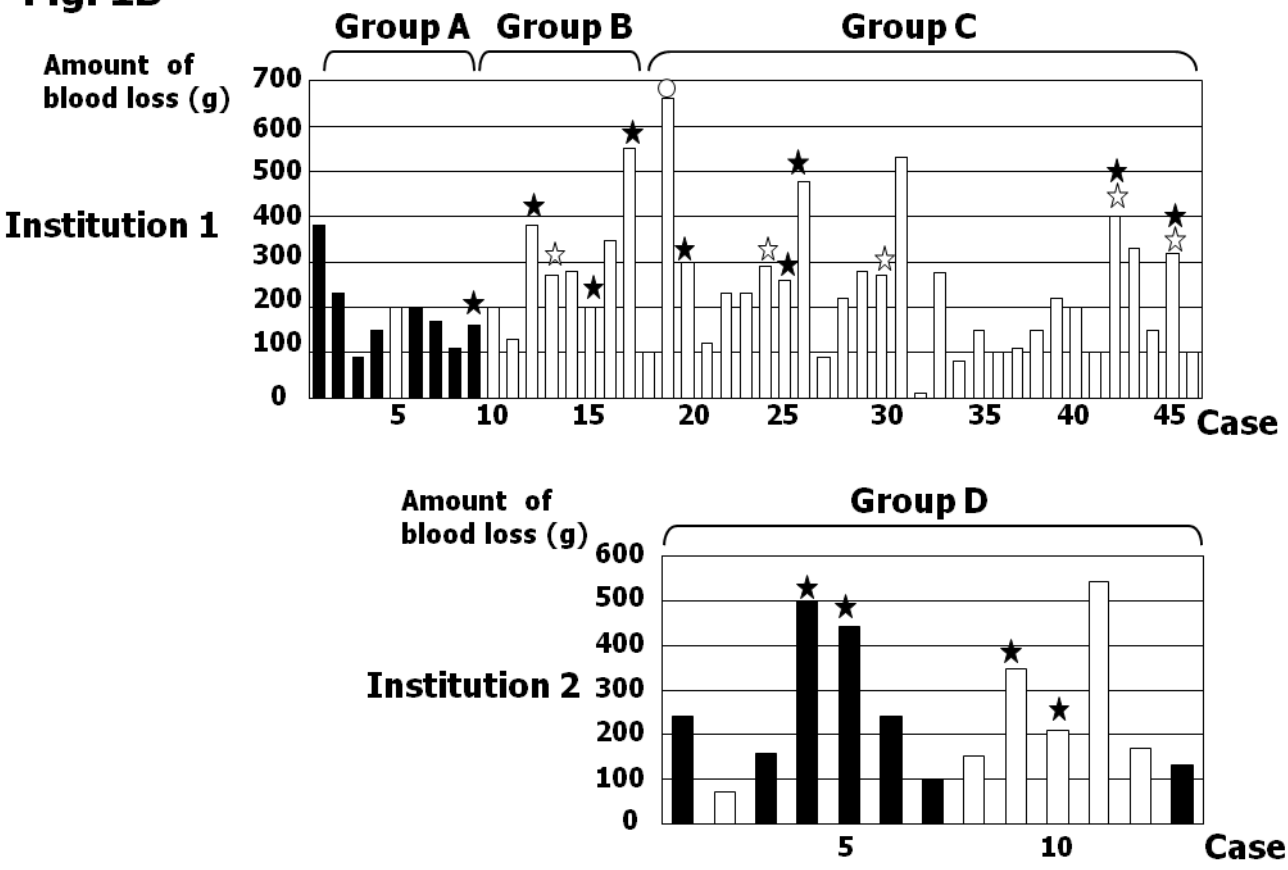

Group A
Group B
Group C
Duration of Procedure (min)
600
500
400
300
200
100
0
Institution 1
5
10
15
20
25
30
35
40
45
Case
Group D
Duration of Procedure (min)
500
400
300
200
100
0
0
Institution 2
5
10
Case

Fig. 1B


Group A
Group B
Group C
Amount of blood loss (g)
700
600
500
400
300
200
100
0
Institution 1
5
10
15
20
25
30
35
40
45
Case
Amount of blood loss (g)
Group D
600
500
400
300
200
100
0
Institution 2
5
10
Case