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ORIGINAL ARTICLE

Early chest tube removal after thoracoscopic lobectomy with the aid of an additional thin tube: a prospective multi-institutional study

Ryoichi Nakanishi[1,2] · Yoshihisa Fujino[3] · Masato Kato[4] · Takashi Miura[5] · Manabu Yasuda[2] · Risa Oda[1] · Keisuke Yokota[1] · Katsuhiro Okuda[1] · Hiroshi Haneda[1]

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Abstract

Objectives There is no evidence concerning the appropriate drainage volume for indicating chest tube removal after pulmonary lobectomy. A prospective multi-institutional cohort study was designed to elucidate the safety of early chest tube removal after thoracoscopic lobectomy.

Methods Between April 2009 and November 2011, 310 patients with suspected or histologically documented lung cancer were screened. Patients without air leakage or bloody, chylous, or purulent pleural effusion underwent chest tube removal on the day after thoracoscopic lobectomy, independent of the drainage volume. The subjects were classified into three groups as tertiles according to the drainage volume that was observed for approximately 24 h after surgery. The associations between the drainage volume and the development of complications were investigated, with several clinical factors taken into account.

Results The 162 patients who were enrolled underwent early chest tube removal via this protocol and were classified into three groups according to their drainage volume (0–219 mL, $n = 52$; 220–349 mL, $n = 56$; and ≥ 350 mL, $n = 54$). A 7F backup tube placed within the dead space to prevent troubles was removed by postoperative day 4 in all patients because nothing happened. Univariate and multivariate analyses showed that the drainage volume was not associated with the risk of complications.

Conclusions Early removal of the chest tube on the day after thoracoscopic lobectomy appears to be a safe treatment protocol in patients without air leakage or bloody, chylous, or purulent pleural effusion; however, careful surveillance is needed for patients who have a drainage volume of ≥ 350 mL/day.

Clinical registration number University Hospital Medical Information Network Clinical Trials Registry, 000028971 (Japan).

Keywords Drainage · Lung cancer · Pleural effusion · Postoperative complications · Video-assisted thoracoscopic surgery (VATS)

Introduction

The full expansion of the remaining lung tissue without any major fluid collection is the desired surgical goal after pulmonary lobectomy for non-small cell lung cancer (NSCLC). In patients without air leakage or bloody, chylous,

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✉ Ryoichi Nakanishi
ryoichi@med.nagoya-cu.ac.jp

[1] Department of Oncology, Immunology and Surgery, Nagoya City University Graduate School of Medical Sciences, 1 Kawasumi, Mizuho-cho, Mizuho-ku, Nagoya 467-8601, Japan

[2] Department of Thoracic Surgery, Shin-Kokura Hospital, Kitakyushu, Japan

[3] Department of Preventive Medicine and Community Health, University of Occupational and Environmental Health, Kitakyushu, Japan

[4] Department of Thoracic Surgery, Hamanomachi Hospital, Fukuoka, Japan

[5] Department of Thoracic Surgery, Shin-Bepp Hospital, Oita, Japan

or purulent pleural effusion, chest tube removal has traditionally been performed when the drainage volume has been 100–250 mL for 24 h due to variations among institutions in the criteria for tube removal concerning drainage volume [1–3]. No clear evidence to support the proper drainage volume has been reported in the literature. Chest tube removal reduces pain and improves the forced expiratory volume in 1 s [3]. Therefore, early tube removal leads to the fast-track recovery of the patient [4].

Our single-institutional study previously showed that early chest tube removal on the day after video-assisted thoracoscopic surgery (VATS) lobectomy, independently of the drainage volume, appears to be safe in well-selected patients [5]. In this background, this prospective multi-institutional cohort study was designed to further elucidate the safety of early chest tube removal after VATS lobectomy.

Materials and methods

Patient selection

Between April 2009 and November 2011, 310 consecutive patients with suspected or histologically diagnosed lung cancer were recruited from the three participating centers, underwent elective VATS lobectomy with mediastinal node dissection, and were screened for this prospective study. The indications for this procedure were based on the standard criteria for open thoracotomy. The patients who were included had an Eastern Cooperative Oncology Group performance status (PS) of 0–2. All patients with limited single-station N2 disease or preoperative stage IV disease with treatable brain metastasis were eligible for inclusion [6], while the patients who received induction therapy were excluded. Patients undergoing pneumonectomy were excluded. The seventh edition of the TNM lung cancer staging system was used in this study [7]. The present study received ethical approval from the Institutional Review Board of Clinical Research of each hospital, and informed consent for this study was obtained from all patients.

Surgery

Under single-lung anesthesia, lobectomy was performed with the preoperative intention to accomplish VATS procedures with three or four incisions without rib spreading, by referencing a previous study [8]. Different surgeons performed this surgery at each institution. The surgical technique has been described in more detail elsewhere [5]. After pneumostasis and hemostasis were confirmed, a 24F or 28F chest tube was placed in the apical and posterior pleural space through the trocar wound on the mid-axillary line. Moreover, in all patients, a small 7F backup tube was placed within the dead space under thoracoscopic guidance to prevent pneumothorax and excessive fluid accumulation, which can be caused by the early removal of the thick chest tube. The wounds were then closed. To decrease the size of the dead space, in all cases, the tube was connected to a water-sealed drainage bottle and kept on suction (negative pressure 10 cm H_2O) until chest tube removal. This study did not employ a digital active drainage device.

Study design and data acquisition

Early chest tube removal was indicated when the following clinical criteria were satisfied [5]: (1) the absence of air leakage; (2) the absence of densely bloody, chylous, or purulent pleural effusion; (3) the absence of atelectasis on a chest roentgenogram on postoperative day 1; and (4) the removal of the orotracheal tube after recovery from anesthesia. In the patients who met these criteria, the thick chest tube was removed on the day after VATS lobectomy, independent of the drainage volume.

Operative mortality was defined as death within the first 30 days after surgery or during hospitalization. Postoperative morbidity was defined by the development of complications during hospitalization or after discharge from the hospital. The follow-up data were obtained from the records of the post-discharge visits and from regular follow-up examinations in which radiography was performed.

Statistical analysis

The subjects were classified into three groups as tertiles according to the drainage volume for approximately 24 h after surgery. Continuous variables were expressed as the mean and standard deviation (SD), and categorical variables were presented as a number (percentage). A univariate logistic regression analysis was performed to evaluate the age–sex-adjusted odds ratios of the clinical variables, including the drainage volume associated with the development of complications. Since the number of the subjects was small, it was inappropriate to include all of the confounding factors in a multivariate logistic regression analysis. Thus, the confounding factors were selected based on the results of the univariate analysis. A multivariate logistic regression analysis was performed to investigate the relationship between the drainage volume and the development of complications including tobacco use, pleural adhesion, fused fissure, operative procedure and bleeding volume. These results were expressed as odds ratios and 95% confidence intervals. P value of <0.05 was considered to indicate statistical significance. All statistical analyses were carried out using the STATA software program (version 12, StatCorp LP, College Station, TX).

Results

Demographic data

Of the 310 patients, the 10 for whom open thoracotomy was originally planned due to extensive disease and 4 from whom insufficient data were acquired were excluded from the analysis. Although the remaining 296 patients showed the absence of atelectasis on a chest roentgenogram on postoperative day 1, 134 patients who presented with air leak ($n = 129$), densely bloody effusion ($n = 3$), or chylous effusion ($n = 2$) were excluded from the study. The remaining 162 patients who were enrolled underwent early chest tube removal on the day after surgery (Fig. 1), independent of the drainage volume (median 280 mL; range 25–890 mL).

As noted in the methods, the patients were classified into three groups based on their drainage volume. Table 1 shows the demographic variables of these three groups (0–219 mL, $n = 52$; 220–349 mL, $n = 56$; and ≥ 350 mL, $n = 54$). The median age was 71 years (range 21–87 years); 55 patients (34.0%) were ≥ 75 years of age. The study population included 84 women and 78 men. A poor functional status (defined by a PS of 2) was seen in two patients. 83 patients had a smoking history (mean pack-years 47). The preoperative stages were as follows: I ($n = 129$), II ($n = 10$), III ($n = 20$) and IV ($n = 3$). There were no significant differences in the demographic variables of these three groups.

Perioperative data

Table 2 shows the perioperative variables of the three groups. The thoracoscopic exploration showed pleural adhesion in 50 patients (30.9%) and a fused fissure in 95 patients (58.6%). Lobectomy was performed using three operative procedures: VATS through monitor vision alone, without rib spreading (complete VATS; $n = 118$; 72.8%), VATS using both monitor and direct vision without rib spreading (hybrid VATS [9]; $n = 23$; 14.2%) and conversion to thoracotomy ($n = 21$; 13.0%). The mean length of the largest wound (called the access wound) in each of the three procedures was as follows: complete VATS (52.9 [SD 8.2] mm), hybrid VATS (86.5 [SD 19.0] mm) and conversion to thoracotomy [136.7 (SD 54.3) mm]. A significant difference was observed in the length of the access wound among the three procedures ($p < 0.001$). The treatment modality included lobectomy in 159 patients (including one patient who underwent combined lingulectomy and three patients who underwent combined wedge resection of the adjacent lobe) and bilobectomy in 3 patients. The distribution of the lobectomies was as follows: right upper lobe ($n = 38$), middle

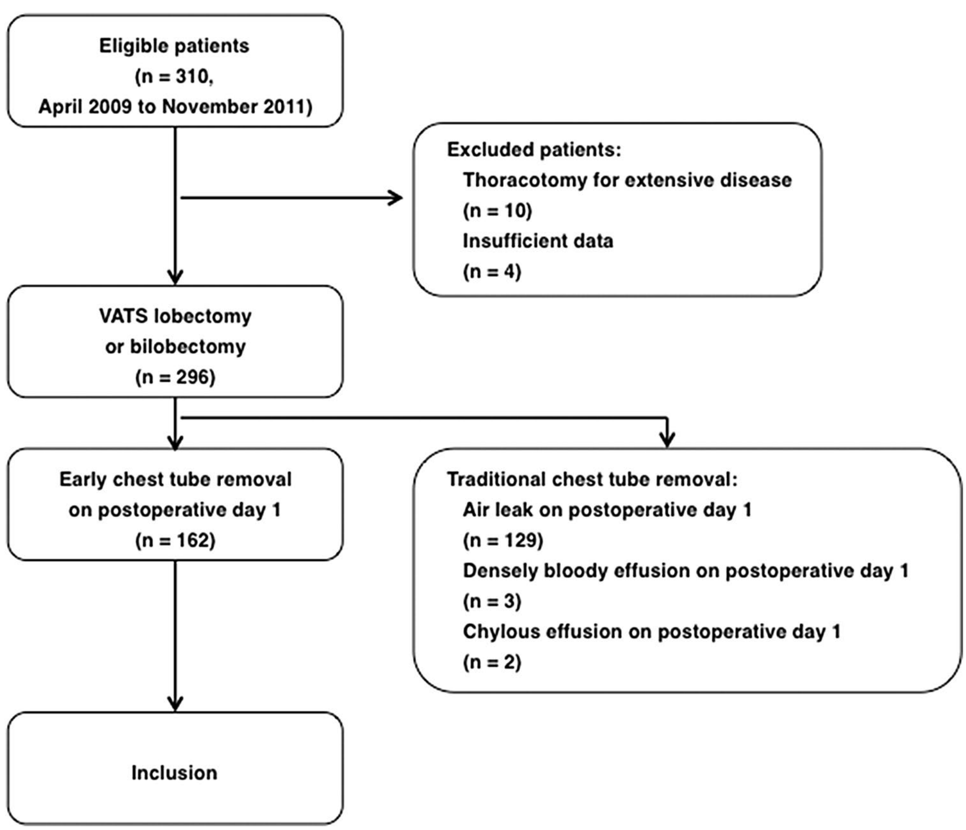

Fig. 1 Flowchart of patient selection

Table 1 Demographic data

	Drainage volume (mL)			p value
	0–219 $n=52$	220–349 $n=56$	≥350 $n=54$	
Mean drainage volume (SD) (mL)	126.5 (51.8)	281.9 (36.3)	469.6 (110.7)	
Mean age at enrolment (SD)	66.7 (12.0)	69.6 (10.5)	70.9 (8.4)	0.101[a]
Sex, male (%)	24 (46%)	27 (48%)	27 (50%)	0.924[b]
Performance status, 0 (%)	47 (90%)	45 (80%)	48 (89%)	0.523[b]
Mean pack-years of tobacco use (SD)	22.5 (33.3)	25.3 (31.6)	24.8 (28.5)	0.887[a]
COPD (%)	6 (12%)	13 (23%)	8 (15%)	0.241[b]
Affected side, right (%)	29 (56%)	31 (55%)	28 (52%)	0.904[b]
Preoperative stage, I (%)	44 (84%)	44 (79%)	41 (76%)	0.510[b]
II	3 (6%)	5 (9%)	2 (4%)	
III	4 (8%)	7 (12%)	9 (16%)	
IV	1 (2%)	0	2 (4%)	

SD standard deviation, *COPD* chronic obstructive pulmonary disease

[a]p values are derived from the analysis of variance

[b]p values are derived from Chi-square test

Table 2 Perioperative data

	Drainage volume (mL)			p value
	0–219 $n=52$	220–349 $n=56$	≥350 $n=54$	
Pleural adhesion (%)	15 (29%)	11 (20%)	24 (44%)	0.018[b]
Fused fissure (%)	36 (69%)	31 (55%)	28 (52%)	0.159[b]
Operative procedure, complete VATS (%)	42 (81%)	46 (82%)	30 (56%)	0.010[b]
Hybrid VATS	6 (11%)	6 (11%)	11 (20%)	
Conversion	4 (8%)	4 (7%)	13 (24%)	
Mean number of segment resected (SD)	3.8 (1.3)	3.7 (1.1)	4.3 (1.1)	0.025[a]
Mean operative time (SD) (min)	233 (58.3)	224 (50.9)	232 (58.2)	0.609[a]
Mean bleeding volume (SD) (mL)	92 (82.8)	88 (81.9)	148 (131)	0.003[a]
Primary lung cancer (%)	50 (96%)	55 (98%)	52 (96%)	0.398[b]
Postoperative stage, I (%)	37 (74%)	40 (73%)	34 (65%)	0.778[b]
II	6 (12%)	5 (9%)	6 (12%)	
III	4 (8%)	7 (13%)	10 (19%)	
IV	3 (6%)	3 (5%)	2 (4%)	
Complication, total (%)	13 (25%)	8 (14%)	17 (31%)	
Atrial fibrillation	3 (6%)	3 (5%)	1 (2%)	0.547[b]
Pleural effusion requiring thoracentesis	0	1 (2%)	3 (6%)	0.169[b]
Pneumonia	2 (4%)	0	3 (6%)	0.225[b]
Pneumothorax	2 (4%)	2 (4%)	4 (7%)	0.590[b]
Sputum retention requiring bronchoscopy	2 (4%)	0	1 (2%)	0.334[b]
Mean postoperative hospital stay (SD) (days)	10.5 (4.5)	11.6 (5.6)	15.9 (13.8)	0.005[a]

VATS video-assisted thoracoscopic surgery; *SD* standard deviation

[a]p values are derived from the analysis of variance

[b]p values are derived from Chi-square test

lobe ($n=25$), right lower lobe ($n=22$), right middle and lower lobes ($n=3$), left upper lobe ($n=39$), and left lower lobe ($n=35$). The mean number of anatomical pulmonary segments resected was 3.9 (SD 1.2). The mean operative time and bleeding volume were 230 (SD 56) minutes and 110 (SD 104) mL, respectively. The final pathologic analysis included primary lung cancer in 157 patients (96.9%), secondary lung cancer in 2 patients (1.2%), and benign tumor in

3 patients (1.9%). Among the 157 patients with primary lung cancer, the postoperative stages were as follows: I ($n = 111$), II ($n = 17$), III ($n = 21$), and IV [$n = 8$; patients who had brain metastasis preoperatively ($n = 3$) and a low-grade pleural dissemination during surgery ($n = 5$)].

Both the operative and perioperative (30 days) mortality rates were 0%. The hospital mortality was 0.6% (one patient). This case of in-hospital death involved an 83-year-old male patient who died of pneumonia after contralateral pneumothorax on postoperative day 36. 38 patients (23.4%) had postoperative complications, including brain infarction, ileus, and respiratory disease, during a mean postoperative follow-up period of 11 months. The distribution of the respiratory complications is shown in Table 2. The 7F backup tube was removed on postoperative day 3–4 in all patients and no patients underwent rescue drainage through the 7F tube. Four patients (2.5%) in whom the drainage volume on the day after surgery was 345, 430, 460, and 580 mL/day suffered from late pleural effusion and required thoracentesis. There were no common characteristics in these four patients, who underwent complete VATS ($n = 1$), hybrid VATS ($n = 1$), and conversion ($n = 2$). The three patients with stage I disease recovered easily, while the patient with stage IIIA N2 disease whose drainage was 580 mL/day required thoracentesis three times as well as antibiotic treatment. Although five patients suffered from pneumonia, there were no findings to suggest an association between pneumonia and early chest tube removal. There were no differences in the prevalence of postoperative complications among the three groups, whereas a greater drainage volume was associated with a higher frequency of pleural adhesion, a more invasive operative procedure, a larger number of resected segments, a larger bleeding volume and a longer hospital stay (Table 2).

Association between the drainage volume and complications

The univariate analysis identified the presence of pleural adhesion, the operative procedure and the bleeding volume as risk factors for the development of complications; the drainage volume was not associated with the development of complications (Fig. 2). The patients with pleural adhesion showed a higher odds ratio of 2.46 for complications in comparison to the patients without pleural adhesion. The hybrid VATS and conversion groups were both more likely to develop complications than the complete VATS group, with odds ratios of 3.40 and 5.80, respectively. A bleeding volume of ≥ 200 mL was also associated with a higher odds ratio of 3.82 for the development of complications in comparison to a bleeding volume of < 200 mL.

The multivariate logistic regression analysis showed that the drainage volume was not associated with the development of complications (Fig. 3). The odds ratios of the variables that we considered to be confounding factors with regard to the association between the drainage volume and the development of complications were as follows. The odds ratio for the development of complications in the hybrid VATS group (using the complete VATS group as a referent) was 2.39 (95% confidence interval 1.62–3.52; $p < 0.001$). The odds ratio of the conversion group was 3.61 (95% confidence interval 1.69–7.72; $p = 0.001$).

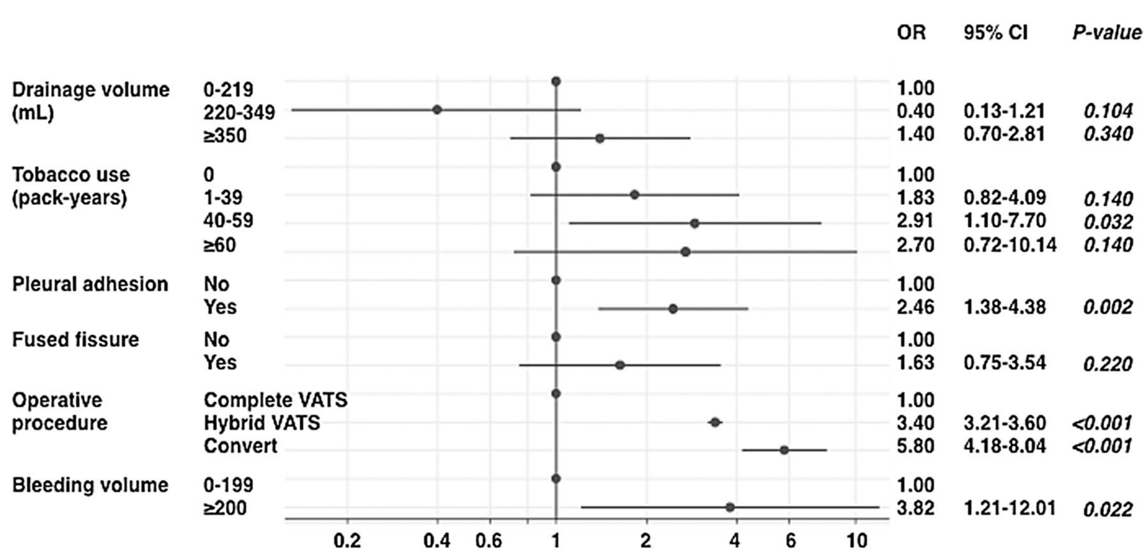

Fig. 2 Univariate analysis

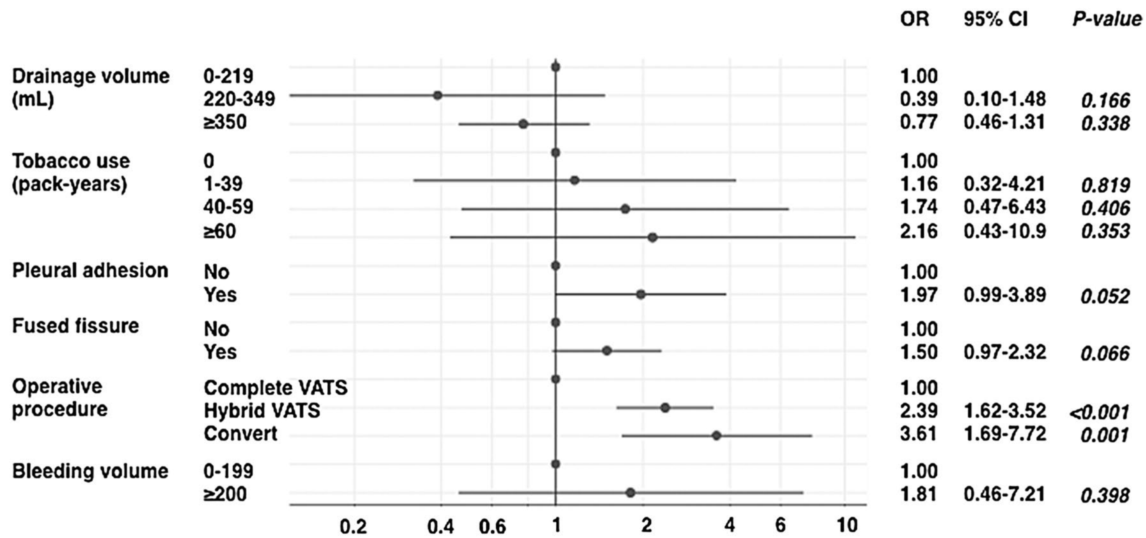

Fig. 3 Multivariate logistic regression analysis

Discussion

The safe drainage volume threshold for chest tube removal after pulmonary lobectomy remains controversial. Regarding open lobectomy, several authors have reported successful removal of the chest tube at up to 200 mL/day [1], 300 mL/day [10], 400 mL/day [11], and 450 mL/day [12]. The proportion of patients requiring intervention, such as thoracentesis or reinsertion of the chest tube after chest tube removal, in the above-described reports was 2.7% at 200 mL/day [1], 4.9% at 300 mL/day [10], and 9.2% at a drainage threshold of 400 mL/day [11]. Regarding VATS lobectomy, several authors reported the successful removal of the chest tube at up to 300 mL/day [13], 400 mL/day [14], 500 mL/day [15], and no limit [5]. The proportion of patients requiring intervention after chest tube removal in these reports was 0% at 400 mL/day [14], 2.8% at 500 mL/day [15], and 4.0% at the unlimited drainage threshold [5]. Early tube removal at a greater drainage volume appears associated with a higher rate of needing intervention, as also shown by a randomized controlled trial [16]. For equivalent drainage volumes, the rate of needing intervention in VATS patients tended to be lower than in thoracotomy patients. This multi-institutional study showed an acceptable proportion of intervention of 2.5% at the unlimited drainage threshold despite including conversion to thoracotomy.

Recently, lymphatic drainage has been considered to play a major role in pleural fluid turnover based on studies of lymphatic stomata in the parietal pleura of animals [17] and humans [18]. The resorption of pleural fluid is probably performed through lymphatic stomata in the parietal pleura rather than through the visceral pleura [19]. Zocchi reported that a combination of factors might be responsible for pleural effusion, including factors that change the transpleural pressure balance, factors that impair lymphatic drainage, and factors that increase mesothelial and capillary endothelial permeability [20]. After a pulmonary lobectomy, the change in the transpleural pressure balance due to the dead space, the impairment of lymphatic drainage by surgical trauma and the increased mesothelial and capillary endothelial permeability induced by surgical stress disturb the resorption of fluid, leading to pleural effusion. The disturbance of the resorption of pleural fluid may recover more quickly in patients undergoing complete VATS lobectomy than in patients who undergo open lobectomy including conversion to thoracotomy because the lymphatic drainage in the parietal pleura is less impaired by the lower degree of trauma and because the increases in mesothelial and capillary endothelial permeability are mild due to the decreased surgical stress [21–23]. In practice, a randomized control study has shown that drainage volumes on the day after VATS lobectomy were significantly smaller than those after open lobectomy [24]. VATS may lead to a reduced risk of intervention after chest tube removal compared with thoracotomy.

The mechanism underlying the increase in pleural effusion may also include the following factors: the presence of pleural adhesion may impair lymphatic drainage because of the larger degree of trauma to the parietal pleura caused by pleural abrasion; the removal of a larger number of pulmonary segments may increase the amount of pleural effusion, mainly because of the change in the transpleural pressure balance due to a larger dead space; and intrathoracic bleeding may also impair the drainage because of its action as a barrier to the parietal pleura [5]. In the present study, although three thoracentesis procedures were required by one of the subjects with stage IIIA

N2 disease, careful postoperative surveillance reduced the risk of empyema. Caution should be exercised concerning the drainage volume in patients with stage IIIA N2 disease, which requires the mediastinal node dissection, as node dissection is associated with slightly greater chest tube drainage than node sampling [25].

This study proved that there was no correlation between the drainage volume and the prevalence of postoperative complications, but showed that a greater drainage volume was significantly associated with a longer postoperative hospital stay. This is due to the fact that several patients who had a drainage volume of ≥ 350 mL/day required prolonged hospitalization because of serious complications, including brain infarction, ileus and interstitial pneumonia. Although there seem to be no close causal associations between such serious complications and greater drainage volumes, a drainage volume of ≥ 350 mL/day may suggest the need for close attention during postoperative care. This figure may be reasonable, as the daily physiological pleural fluid filtration is estimated to be 350 mL/day [2, 19, 26].

Other criteria for early chest tube removal included the protein content of drainage fluid based on the method for differentiating exudates and transudates [27]. Olgac et al. reported that early chest tube removal was feasible if the pleural fluid-to-blood protein ratio was ≤ 0.5, regardless of the daily drainage volume, and none of the patients required intervention after tube removal [28]. The volume criterion alone is not necessarily a good predictor for early chest tube removal, as there were several patients who met the volume criteria but required intervention after tube removal in several studies [1, 10–16]. Large-scale studies are needed to confirm that the pleural fluid-to-blood protein ratio is a good predictor.

Several limitations associated with the present study warrant mention. The main limitations are the small size of the cohort and lack of a randomized trial comparing early chest tube removal with traditional criteria. We intended to expand this protocol performed in a pioneering institution to other institutions using the traditional criteria to obtain the basic data necessary for a randomized trial, as other institutions had a negative attitude toward this protocol. We included all complications in the analyses due to the small number of complications, and due to ambiguity to define the complications related to pleural effusion. Further investigation of the complications limited to those related to the accumulation of pleural effusion is thus warranted. The dissected node was not assessed in this study because of the lack of any associations between the extent of mediastinal node dissection and chest tube duration [25].

Conclusion

Early removal of the chest tube on the day after VATS lobectomy appears to be a safe treatment protocol in patients without air leak or bloody, chylous, or purulent pleural effusions; however, careful surveillance is needed for patients who have a drainage volume of ≥ 350 mL/day.

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