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ORIGINAL ARTICLE

The impact of same-day chest drain removal on pulmonary function after thoracoscopic lobectomy

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Abstract

Objectives This study aims to assess the feasibility and impact on long-term pulmonary function of chest drain removal on the operation day following thoracoscopic right upper lobectomy for clinical stage I non-small cell lung cancer.

Methods We retrospectively evaluated the data of 116 patients between May 2013 and March 2019. We evaluated the correlations of clinical parameters of chest drain removal and medium- and long-term pulmonary function by comparing removal on operation day (R group) and retainment (D group).

Results The R group comprised 64 patients, and the D group had 52 patients. Fifty patients (96.2%) in the D group had chest drain removed within 3 postoperative days. Since February 2016, chest drain removal on operation day was performed in 64 of 74 patients (86.5%) according to our chest drain removal protocol. Removal of chest drains on operation day was associated with shorter postoperative hospitalization ($p < 0.01$) and lower postoperative complications ≧ grade II of the Clavien–Dindo classification ($p = 0.026$). Only one patient in the R group needed reinsertion. The R group had greater spirometry results at 3- and 12-postoperative months (POM). R group patients had statistically improved pulmonary functions from 3 to 12POM, while those in the D Group were stagnated at 6POM.

Conclusions Removal of chest drains on operation day using our protocol is safe and feasible for thoracoscopic right upper lobectomy. This protocol was statistically associated with slightly better long-term pulmonary function, which could not bring clinically meaningful medium- and long-term benefit.

Keywords Thoracoscopic lobectomy · Drain removal · Respiratory function

Introduction

Recently, video-assisted thoracoscopic surgery (VATS) was recommended as a safe and effective minimally invasive surgical approach for early-stage non-small cell lung cancer (NSCLC) [1]. In a recent randomized controlled trial, VATS reduced early and late fatal pulmonary complications and resulted in less impairment to quality of life (QOL) [2]. Early removal of chest drain is frequently associated with shorter postoperative hospital stay and reduction of postoperative pain that can improve patient QOL and early postoperative pulmonary function recovery [3–5]. Generally, chest drain removal is done when the 24 h drain output is less than 300–400 mL and when there is no air leakage [3–7]. We have adopted an enhanced recovery pathway for thoracoscopic pulmonary resection from June 2013. To optimize minimally invasive surgery, we have introduced chest drain removal on the same day after the operation since February 2016 [8]. However, a few institutions introduce tubeless management such as chest tube, urinary catheter, and continuous infusion line on the operative day. The effects on the physical function of chest drain removal on the operative day remain unknown. Right upper lobectomy for lung cancer is associated with postoperative complications such as prolonged air leak and chylothorax [9, 10]. Hence, we retrospectively analyzed the feasibility and impact on the postoperative medium- and long-term pulmonary function

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of chest drain removal on the day of surgery following thoracoscopic right upper lobectomy for lung cancer.

Patients and methods

Methods

We retrospectively assessed the data of 188 consecutive patients who underwent thoracoscopic right upper lobectomy for clinical stage I non-small cell lung cancer (NSCLC) at our institution between May 2013 and March 2019. Our screening examination included tumor markers, chest and abdominal computed tomography (CT), cerebellar magnetic resonance imaging, bone scintigraphy, and positron emission tomography (PET)-CT on demand. The following exclusion criteria were applied: history of other thoracic surgery, stage II or higher heart failure according to New York Heart Association functional classification; chronic kidney disease on dialysis, Child B or higher liver cirrhosis, and incomplete data including spirometry tests in postoperative months (POM) 3, 6, and 12. Patient data had been collected prospectively in a database registered and approved by the Review Board of Aichi Cancer Center (approval number: 2020-1-055). Patient informed consent was waived owing to the study's retrospective nature.

Surgical management

We performed thoracoscopic right upper lobectomy and mediastinal lymph node dissection using a four-port approach without rib spreading or direct vision. We prevented chylothorax from mediastinal lymph node dissection to use Hem-o-lock clips at the thoracic duct branch of the cranial side of 2R (the lower border of the right brachial artery), and intermediate site between 4R-4L lymph node (the left border of the trachea). If we detected air leak points by inflating the lung to a pressure of 20–25 cm of water, we sutured them using 4-0 PDS (Ethicon, Somerville, NJ). We basally used polyglycolic acid (PGA) sheet (Neoveil; Gunze, Osaka, Japan) and fibrin glue (Beriplast; CSL Behring, King of Prussia, PA) to cover staple lines or sutured points for additional reinforcement. Then, we inserted a 20 F chest tube into the pleural cavity through the port. The chest tube was set under continuous suction at 5 cm H_2O until the first mobilization without digital draining system. After confirming the swallowing condition, patients were fed fat-rich ice cream to detect the presence of chylothorax [8]. Within 4 h postoperatively, patients walked along with our staff and a nurse without oxygen support regardless of AM or PM surgery. Following the first mobilization, if there was no air leak, postoperative bleeding, drainage $\geqq$ 100 ml, abnormal roentgen image, or chylothorax, we immediately removed the chest drain. Urinary catheter was basally removed at the same time.

Patients' data

We collected the following patient data: age, sex, body mass index (BMI), and spirometry test results. Goddard score > 2 in any lobe was defined as emphysema in this report [11]. We also evaluated the prognostic nutritional index [12]. Operative outcomes were pleural adhesion (more than 1/3 of whole pleura), operative time, surgical blood loss, postoperative complication, C-reactive protein (mg/dl) at 2 weeks after discharge as prolonged postoperative inflammation, chest tube duration, and length of postoperative hospitalization. The histological findings were assessed according to the World Health Organization guidelines [13, 14]. Postoperative pain (yes or no form of questionnaire) in 3, 6, and 12POM.

Statistical analysis

The statistical analysis was performed using SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Statistical significance was set at p value < 0.05. We evaluated the correlations of clinical and perioperative parameters of the chest drain removal between the operative day group (R group) and the retained group (D group). Additionally, we evaluated the postoperative percentage of vital capacity (%VC), and forced expiratory volume in 1 s as a percentage of forced vital capacity (FEV1.0%) at 3, 6, and 12POM to compare between both groups. Postoperative recovery rate (PRR) (%) was calculated as (postoperative spirometry results at 3, 6, or 12POM / preoperative spirometry results) × 100. We assessed the PRRs in each group (3 vs 6POM, and 6 vs 12POM). The values are expressed as the average or median ± standard deviation with interquartile range. The Chi-square test and Fisher's exact test were used to compare categorical variables. The quantitative continuous variables were compared using the Student's t test or Mann–Whitney U test. The paired t test or Wilcoxon rank sum test was used to compare two related spirometry results in each group.

Results

Patient characteristics

We evaluated 116 patients (57 men and 59 women) who underwent thoracoscopic right upper lobectomy for clinical stage I NSCLC in our institution. Seventy-two patients were excluded, 67 of which had incomplete spirometry data, and 5 had previously received chest surgery (Fig. 1). Patient characteristics are shown in Table 1. The average age was

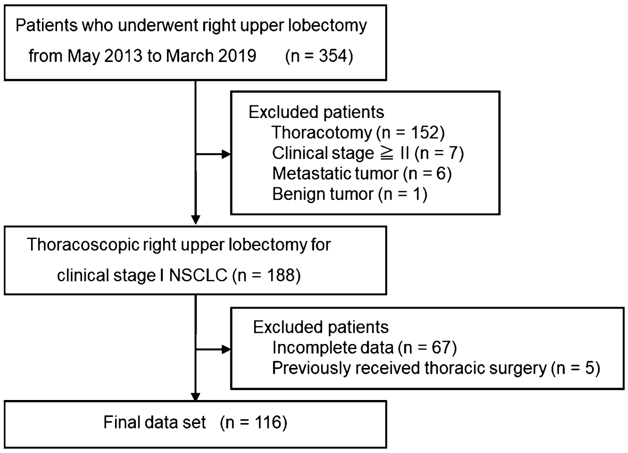

Fig. 1 Patients' flowchart

66.6 years. The number of patients before/after February 2016 were 42/74 (36.2/63.8%). We operated with both PGA sheet and fibrin glue in 113 patients (97.4%). The average operation time was 206 min, and the average intraoperative blood loss was 24.3 ml. The average chest tube duration was 0.7 days (range 0–9 days), and the average postoperative hospital stay was 3.7 days (range 2–11 days). Pathological diagnosis included 106 of adenocarcinoma (91.4%), and 8 of lymph node metastasis (6.7%). The R group comprised 64 patients (55.2%), and the D group had 52 patients (45.8%). Sixty-four of the 74 patients (86.5%) who were operated after February 2016 underwent chest drain removal on the operative day. In total, 121 patients were operated after February 2016, and 100 patients (82.6%) underwent chest drain removal on the operative day. Of them, only one patient was reinserted a chest drain. Because we had introduced this chest drain removal protocol since February 2016, no patient underwent chest drain removal on the operative day before then.

Clinicopathological parameters assessed between R and D groups

Table 2 shows the univariate analysis of clinicopathological parameters between the R and D groups. The median chest tube duration in the D group was 1 ± 1.3 days (range 1–9 days). In the D group, chest drain removal was performed in 40 patients on the first postoperative day (POD), 6 patients on the second POD, 4 patients on the third POD, 1 patient on the fourth POD, and 1 patient on the ninth POD. The R group had lower PNI ($p = 0.017$). Chest drain removal on the surgical day was associated with shorter postoperative

Table 1 Patient characteristics

Variables	Overall ($n = 116$) n (%), average ± SD, (range)
Age (year old)	66.6 ± 9.7 (29–87)
Sex (male/female)	57/59 (49.1/50.9%)
Smoking index ≧600 (yes/no)	34/82 (29.3/70.7%)
Emphysema (yes/no)	25/91 (21.6/78.4%)
Body mass index	22.3 ± 3.2 (14.9–31.9)
%VC	103.2 ± 13.5 (72–137)
FE1.0%	101.9 ± 16.1 (67.5–140.9)
PNI	50 ± 5.8 (38.1–90.6)
Operation	
Before/after February 2016	42/74 (36.2/63.8%)
Operative time (minute)	206 ± 42.2 (99–322)
Blood loss (ml)	24.3 ± 39.9 (0–320)
Polyglycolic acid sheet and fibrin glue (yes/no)	113/3 (97.4/2.6%)
Pleural adhesion (≧moderate) (yes/no)	17/99 (14.7/85.3%)
Chest drain removal on the operative day (yes/no)	64/52 (55.2/44.8%)
Postoperative complication (yes/no)	13/103 (11.2/88.8%)
Chest tube drainage period (day)	0.7 ± 1.1 (0–9)
Postoperative hospitalization (day)	3.7 ± 1.5 (2–11)
Pathological finding	
Adenocarcinoma/others	106/10 (91.4/8.6%)
Lymph node metastasis (negative/positive)	108/8 (93.3/6.7%)

SD standard deviation, *%VC* percent of vital capacity, *FEV1.0%* forced expiratory volume in 1 s as a percentage of forced vital capacity, *PNI* prognostic nutritional index

Table 2 The statistical evaluation of clinicopathological parameters between the R and D groups

Variables	R group ($n = 64$)	D group ($n = 52$)	p value
Age (year old) (average ± SD)	66.1 ± 8.7	67.3 ± 10.8	0.488[a]
Sex (male/female) (n, %)	27/37 (42.2/57.8%)	30/22 (57.7/42.3%)	0.097[b]
Smoking index ≧ 600 (yes/no) (n, %)	16/48 (25/ 75%)	13/39 (25/75%)	0.278[b]
Emphysema (yes/no) (n, %)	12/52 (18.8/81.2%)	13/39 (25/75%)	0.278[b]
Body mass index (median ± SD)	22.6 ± 3.1	21.9 ± 3.2	0.764[c]
%VC (%) (median ± SD)	100.5 ± 15	103 ± 11.3	0.270[c]
FEV1.0% (%) (median ± SD)	99.8 ± 17	104.4 ± 14.6	0.086[c]
PNI (median ± SD)	49.2 ± 6.9	51.1 ± 4	0.017[c]
Operation			
Before/after February 2016 (n, %)	0/64 (0/100%)	42/10 (80.8/19.2%)	< 0.01[b]
Operative time (minute) (median ± SD)	198 ± 36.6	203 ± 48.1	0.316[c]
Blood loss (ml) (average ± SD)	19.7 ± 42.4	29.9 ± 36.3	0.174[c]
Pleural adhesion (≧ moderate) (yes/no) (n, %)	11/53 (17.2/82.8%)	6/46 (11.5/88.5%)	0.279[a]
Postoperative hospitalization (day) (average ± SD)	3.3 ± 1.3	4.3 ± 1.5	< 0.01[c]
CRP at 2 weeks after discharge (mg/dl) (average ± SD)	0.4 ± 0.4	0.8 ± 1.7	0.109[a]
Adenocarcinoma/others (n, %)	59/5 (92.2/7.8%)	48/4 (92.3/7.7%)	0.63[d]
Lymph node metastasis (n, %)	6/58 (9.4/90.6%)	2/50 (3.8/96.2%)	0.214[d]
Postoperative pain			
3POM (yes/no) [n (R/D) = 40/44, %]	17/23 (42.5/57.5%)	17/27 (38.6/61.4%)	0.516[b]
6POM (yes/no) [n (R/D) = 48/50, %]	13/35 (27.1/72.9%)	11/39 (22/78%)	0.539[b]
12POM (yes/no) [n (R/D) = 51/50, %]	4/47 (7.8/92.2%)	4/46 (8/92%)	0.439[b]

R group chest drain removal on the operative day group, *D group* with chest drain on the operative day group, *%VC* percentage of vital capacity, *FEV1.0%* forced expiratory volume in 1 s as a percentage of forced vital capacity, *PNI* prognostic nutritional index, *CRP* C-reactive protein, *POM* postoperative month

[a]Student's *t* test

[b]Chi-square test

[c]Mann–Whitney test

[d]Fisher exact test

hospitalization ($p < 0.01$). Table 3 reveals the postoperative complications developed in 13 (11.2%) patients, who were assessed using Clavie–Dindo classification [15]. Postoperative complications ≧ grade II of the Clavien–Dindo classification were lower in the R group ($p = 0.026$). Prolonged air leak (≧ 5 days) occurred in one patient in each group. There was no chylothorax. Postoperative pulmonary and pleural complications developed only in one (1.6%) in the R group and three (5.8%) in the D group. There was no conversion to thoracotomy or 90-day postoperative death. (Fig. 1).

Postoperative spirometry results

Table 4 shows PRRs (%) at 3, 6, 12POM between both groups. The R group had superior %VC and FEV1.0 in 3POM ($p = 0.046$, 0.037). However, there was no significant difference in %VC and FEV1.0 in 6POM between both groups ($p = 0.496$, 0.696). Moreover, the R group had superior %VC in 12POM ($p = 0.026$). Figure 2 shows the PRR differences approximately 3 vs 6POM and 6 vs 12POM between both groups. Both groups had more PRRs of %VC and FEV.0% in 6POM than in 3POM (all $p < 0.01$). In the R group, the PRRs of % VC and FEv1.0% at 12POM were significantly improved than at 6POM (both p < 0.01). However, in the D group, there was no statistical difference in PRRs of %VC between 6 and 12POM ($p = 0.27$), and the PRRs of FEV1.0 in 12POM were inferior to 6POM ($p < 0.01$).

Discussion

Chest tubes cause increased pain, infection, immobilization, and prolonged hospital stays as well as incur medical costs [3–5, 16–18]. Surgeons should remove chest tubes as soon as the role of the chest tubes are unnecessary. Few studies reported chest drain removal within the operative day, and evidence including median- and long-term pulmonary functions on its success was insufficient. Right upper lobectomy for lung cancer requires more precise intraoperative procedures and postoperative management

Table 3 Postoperative complication

Variables	Overall ($n=116$)	R group ($n=64$)	D group ($n=52$)	p value
Clavien–Dindo classification				
I (n, %)	1 (0.9%)	1 (0.9%)	0 (0%)	
Liver failure	1	1	0	
II (n, %)	7 (6%)	1 (0.9%)	6 (11.5%)	
Congestive heart failure	3	1	2	
Pneumonia	1	0	1	
Arrhythmia	2	0	2	
Laryngeal edema	1	0	1	
IIIa (n, %)	2 (1.7%)	0 (0%)	2 (3.8%)	
Pleural effusion	1	0	1	
Bradyarrhythmia	1	0	1	
IIIb (n, %)	3 (%)	2 (3.1%)	1 (1.9%)	
Prolonged air leak (≧5 days)	2	1	1	
Subglottic stenosis	1	1	0	
Whole number	13 (11.2%)	4 (6.3%)	9 (17.3%)	0.06[a]
Total number ≧ class II	12 (10.3%)	3 (4.7%)	9 (17.3%)	0.026[a]

R group chest drain removal on the operative day group, *D group* with chest drain on the operative day group

[a]Chi-square test

Table 4 Postoperative recovery rate (%) at 3, 6, and 12POM between R and D groups

Variables	R group ($n=64$)	D group ($n=52$)	p value
3POM			
%VC (median ± SD)	89.3 ± 10.9	87.3 ± 8.5	0.046[a]
FEV1.0% (median ± SD)	88.2 ± 11.5	84.5 ± 10.4	0.037[a]
6POM			
%VC (average ± SD)	93.6 ± 9.5	92.4 ± 9.5	0.496[b]
FEV1.0% (median ± SD)	91.4 ± 10.6	91.6 ± 9.8	0.696[a]
12POM			
%VC (average ± SD)	96 ± 10.5	91.8 ± 9.7	0.026[b]
FEV1.0% (median ± SD)	93.6 ± 10.3	89.5 ± 10	0.406[a]

R group chest drain removal on the operative day group, *D group* with chest drain on the operative day group, *%VC* percentage of vital capacity, *FEV1.0%* forced expiratory volume in 1 s as a percentage of forced vital capacity, *POM* postoperative month

[a]Mann–Whitney test

[b]Student's t test

for early chest drain removal because it has higher rates of postoperative complications [9, 10]. Here, we evaluated the feasibility of chest drain removal on the day of surgery following thoracoscopic right upper lobectomy for lung cancer and its impact on medium- and long-term pulmonary function.

Ueda reported chest drain removal in the operating room in 53 (45.7%) of 116 patients who underwent thoracoscopic radical segmentectomy or lobectomy [19]. They concluded that reduced postoperative pain owing to the chest drain removal contributed to preserving early postoperative vital capacity and improving mobilization distance. Further, no case needed chest drain reinsertion in their no drain group. In our institution, chest drain removal on the operative day was adopted since February 2016 and was performed in 64 of 74 patients (86.5%); only one patient needed chest drain reinsertion for delayed air leak. Except for lower PNI in the R group, other variables, including chronic pain, were not significantly different between the two groups. Chest drain removal on operation day was associated with shorter postoperative hospitalization ($p<0.01$), and lower postoperative complications ≧ grade II of the Clavien–Dindo classification ($p=0.026$). We consider this chest drain removal protocol to have a good predictive value for reducing postoperative complications and hospital stay. These outcomes could corroborate the feasibility of earlier chest drain removal after thoracoscopic right upper lobectomy.

Intraoperative procedures to prevent air leak, chylothorax, and hemothorax are necessary for successful early chest drain removal. First, to manage intraoperative air leakage, Ueda reported that using polyglycolic acid mesh and fibrin glue with suturing air leak points resolved pneumatosis [20]. Our intraoperative procedure could also allow for sufficient air leakage control. Second, preventing postoperative chylothorax is another important step in surgical management.

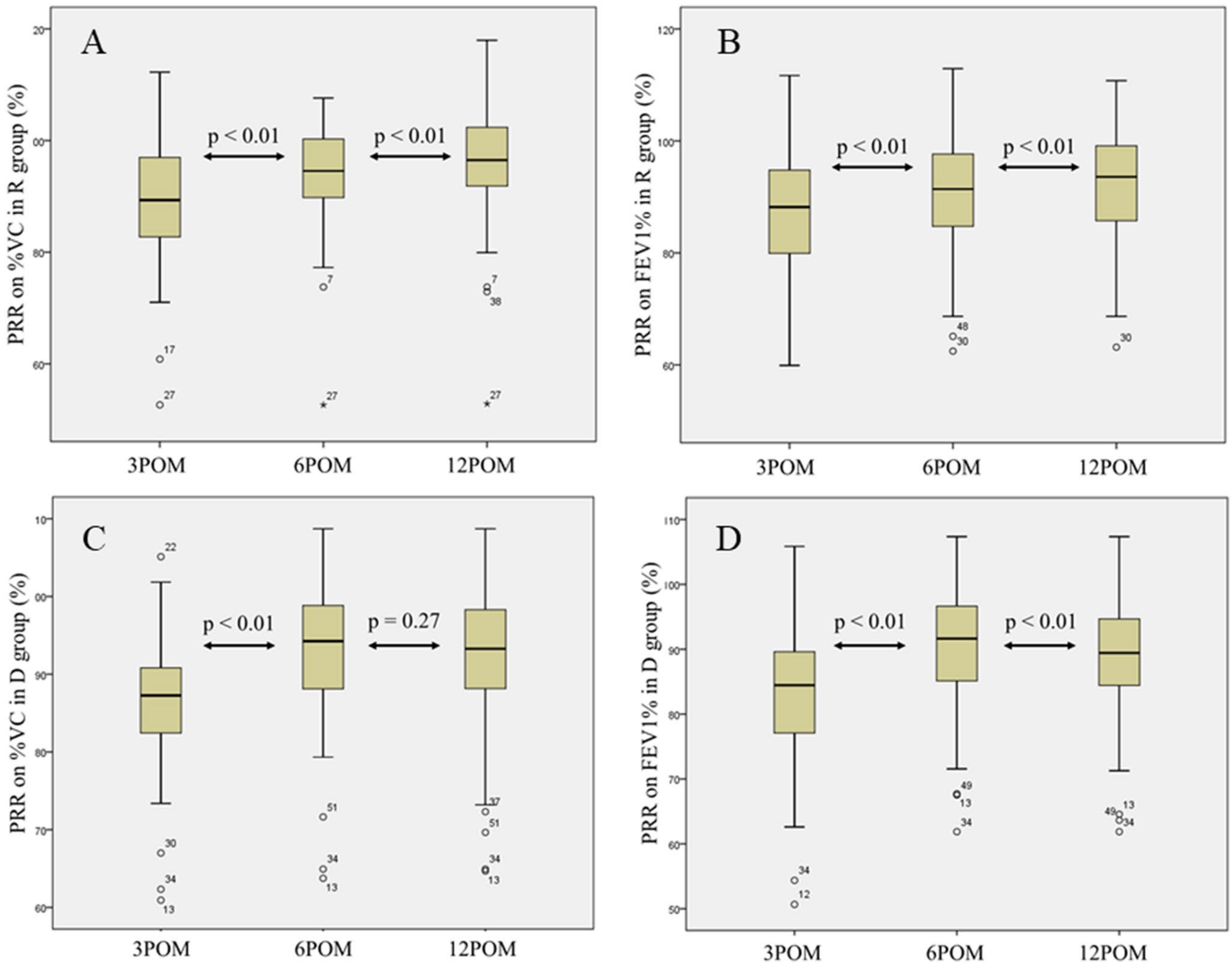

Fig. 2 The difference in postoperative recovery rate (%) approximately 3 vs 6POM and 6 vs 12POM in each group. **a** PRRs on %VC in the R group, **b** PRRs on FEV1.0 in the R group, **c** PRRs on %VC in the D group, and **d** PRRs on FEV1.0% in the D group. *a* Wilcoxon rank sum test, *b* Student's *t* test, *R group* chest drain removal on the operative day group, *D group* with chest drain on the operative day group, *%VC* percentage of vital capacity, *FEV1.0%* forced expiratory volume in 1 s as a percentage of forced vital capacity, *POM* postoperative month, *PRR* postoperative recovery rate

Liu reported that prophylactic ligation of the thoracic duct branch after 4R lymph-node dissection had significantly contributed to decreasing the incidence of postoperative chylothorax than did non-prophylactic ligation [10]. We used Hem-o-lock clips at the thoracic duct branch, specifically at the margin of the lymph node dissection area, and we had no recorded postoperative chylothorax. Surgeons should take adequate measures to prevent postoperative complications such as air leakage, chylothorax, or hemothorax, and perform early removal of chest drains on the operation day.

The benefits of early respiratory outcomes have already reported [4]. Here, we further evaluated the impact on the medium- and long-term pulmonary functions of chest drain removal on the operative day. Regarding both groups' spirometry results, the R group had greater values at 3 and 12POM. In comparisons of 3 vs 6POM and 6 vs 12POM in each group, the R group had statistically improved pulmonary functions from 3 to 12POM. Some authors reported that never smoker, the increasing numbers of resected subsegments affected greater compensatory response of long-term pulmonary function [21, 22]. In our study, removal of chest drain on operation day yielded slightly greater pulmonary functions. There were no significant differences in patient background, including preoperative smoking status and respiratory function between the two groups. We considered, unlike in the early postoperative period, there was no significant difference in chronic postoperative pain, which could not deliver a meaningful difference in medium- and long-term pulmonary function. We did not evaluate how activities in daily life after surgery affected the postoperative respiratory function. However, the differences of postoperative pulmonary functions could not bring clinically meaningful long-term benefit.

There are study limitations that need consideration. Our study was a retrospective observational study in a single facility. The reason for most excluded patients was incomplete spirometry tests, which may have affected the difference in long-term pulmonary functions. Second, postoperative pulmonary and pleural complications developed only in one in the R group and three in the D group, and we could not fully evaluate the influence between postoperative pulmonary function and postoperative complications. Future investigations are required to evaluate what other clinically meaningful long-term courses would be impacted by the early removal of the chest drain.

Conclusion

Our procedures and postoperative protocol could deliver a successful removal of chest drain on the operation day. Chest drain removal on operation day is safe and feasible in thoracoscopic right upper lobectomy for lung cancer, but could not bring clinically significant median- and long-term benefit in pulmonary function.

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Compliance with ethical standards

Conflicts of interest The authors have no conflicts of interest or any financial ties to disclose.

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