



# Comparison of stapler and electrocautery for division of the intersegmental plane in lung segmentectomy

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**Background:** We retrospectively compared the use of a stapler and electrocautery for division of the intersegmental plane during pulmonary segmentectomy.

**Methods:** We enrolled 156 patients who underwent pulmonary segmentectomy in our department between March 2006 and August 2020. The patients were divided into electrocautery (n=62) and stapler (n=94) groups based on the device used to divide the intersegmental plane. Patient characteristics, perioperative outcomes, and ratios of actual (calculated using software) to predicted (calculated by counting the resected segments) lung volumes were compared between the two groups. Additionally, we used multivariate analysis to identify the factors that contributed to the incidence of postoperative air leakage after cut-off value was set by receiver operating characteristic (ROC) curve analysis. Moreover, a subset analysis was performed based on the type of segmentectomy (common or uncommon). Common segmentectomies included resection of the basilar or superior segment of the lower lobe, or lingular or upper division of the left upper lobe; all other segmentectomies were classified as uncommon.

**Results:** Compared to the electrocautery group, the stapler group had shorter operative times (P=0.0027), duration of postoperative drainage (P=0.00037), and duration of postoperative hospitalization (P=0.0021). Moreover, incidence of postoperative  $\geq 3$  days drainage was significantly reduced in the stapler group (P=0.003). There were no significant differences between the stapler and electrocautery groups in the actual:predicted lung volumes at 6 months (1.01 and 1.04, respectively; P=0.28) or 12 months (1.06 and 1.07, respectively; P=0.68) after surgery. Preoperative lung volume was significantly correlated with preoperative vital capacity (VC) ( $\gamma=0.69$ ; P<0.001) and forced expiratory volume in 1 second (FEV<sub>1</sub>) ( $\gamma=0.48$ ; P<0.001). The multivariate analysis indicated that the use of stapler for division of intersegmental plane was the only factor that contributed to reducing the incidence of postoperative  $\geq 3$  days drainage (P=0.0027, odds ratio: 0.23, 95% CI: 0.086–0.597). In a subset analysis of uncommon segmentectomy, there were no significant differences among the groups in most perioperative results.

**Conclusions:** Compared to electrocautery, the use of a stapler for division of the intersegmental plane was associated with better perioperative outcomes, especially reduction of postoperative drainage time, and similar postoperative remnant lung volumes and function.

**Keywords:** Segmentectomy; intersegmental plane; stapler; electrocautery

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## Introduction

Lobectomy is the standard surgical procedure for primary lung cancer. However, several studies have demonstrated superior perioperative results and cancer outcomes after pulmonary segmentectomy compared to lobectomy (1-3). Therefore, pulmonary segmentectomy is increasingly being performed worldwide.

Pulmonary segmentectomy offers the advantage of sparing the lung parenchyma, leading to better lung function. However, the most appropriate method to identify the intersegmental plane during pulmonary segmentectomy is yet to be established. Researchers have studied inflation-deflation techniques, selective inflation of the target segment by jet ventilation, intravenous and endobronchial indocyanine green injection, and virtual-assisted lung mapping for identification of the intersegmental planes (4-8). The best method to divide the intersegmental plane is also controversial; the most commonly used methods are stapling and electrocautery (9-12).

Although the advantages of both techniques are well-documented, few studies have compared them (13-16). To determine the optimal method for division of the intersegmental plane during pulmonary segmentectomy, we retrospectively compared the use of a stapler and electrocautery in terms of the perioperative outcomes and residual lung volumes.

We present the following article in accordance with the STROBE reporting checklist (available at <https://dx.doi.org/10.21037/jtd-21-1397>).

## Methods

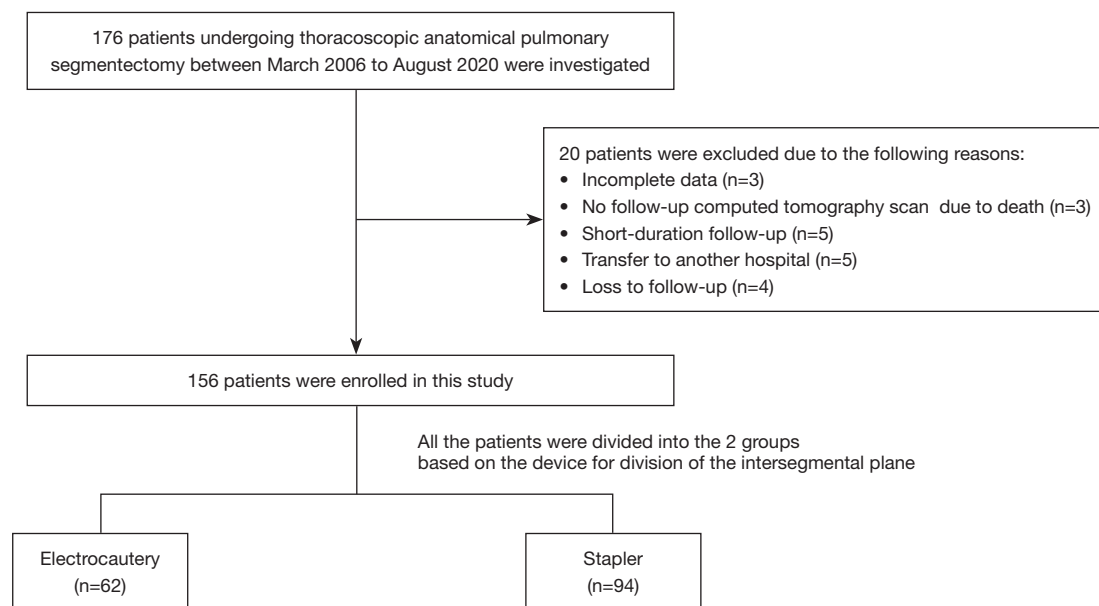
This study was conducted in accordance with the Declaration of Helsinki (2013 revision), and approved by the institutional ethics board of Japanese Red Cross Maebashi Hospital (No.: 2020-53, date: March 1, 2021). Informed consent was waived for this retrospective analysis.

We reviewed the records of 176 patients who underwent thoracoscopic anatomical pulmonary segmentectomy between March 2006 and August 2020 in our department. Patients who underwent pulmonary resection, radiotherapy or chemotherapy before or after segmentectomy were excluded from this study. Twenty patients were excluded due to incomplete data (n=3), no follow-up computed tomography (CT) scan due to death (n=3), short-duration follow-up (n=5), transfer to another hospital (n=5), or loss to follow-up (n=4). Thus, we included 156 patients in this

study (Figure 1), and divided them into electrocautery (n=62) and stapler (n=94) groups based on the device used to divide the intersegmental plane. All surgeries were performed by the same team of thoracic surgeons. Patient data obtained from the medical records included age, sex, smoking history, preoperative vital capacity (VC), forced expiratory volume in 1 second (FEV<sub>1</sub>), type of segmentectomy (intentional or unintentional, and common or uncommon), type of tumor (primary, metastatic, or benign), surgical approach (minithoracotomy, multiport thoracoscopic, or uniport thoracoscopic), resected segments, operative time, blood loss, incidence of massive intraoperative bleeding, conversion to thoracotomy, duration of postoperative drainage, duration of postoperative hospitalization, postoperative morbidity (Clavien-Dindo Classification grade  $\geq$  III), and readmission within 30 days postoperatively. In addition, we conducted receiver operating characteristic (ROC) curve analysis with the device used to divide the intersegmental plane as the dependent variable and the duration of postoperative drainage as the independent variable to set cut-off values. We compared the patient characteristics and perioperative outcomes between the two groups. In addition, we used multivariate analysis to identify the factors that contributed to the incidence of postoperative air leakage (the cut-off value would be set on the ROC curve analysis) among the parameters in patient's characteristics and the device for division of intersegmental plane. Moreover, a subset analysis was performed based on the type of segmentectomy. Common segmentectomies included resection of the basilar or superior segment of the lower lobe, or lingular or upper division of the left upper lobe; all other segmentectomies were classified as uncommon (17).

## Surgical indications

In our department, intentional pulmonary segmentectomy was performed for the patient with Stage 0 or IA1 non-small cell lung cancer when the patient accepted it. Unintentional pulmonary segmentectomy was for the patient without intrathoracic lymph node or distant metastasis who was contraindication for lobectomy due to limited pulmonary function or compromised status. We performed pulmonary segmentectomy for pulmonary metastases when they were completely resectable and too deeply located to perform wedge resection. Finally, all of the benign diseases in this study were initially suspected as malignancy.



**Figure 1** Patient enrollment in this retrospective study.

### *Surgical procedures*

The surgeries were performed using one-lung ventilation under general anesthesia with the patient in the lateral decubitus position. Different surgical approaches were used: minithoracotomy (from March 2006 to April 2012), a multiportal thoracoscopic approach (from May 2012 to January 2019) and a uniportal or multiportal thoracoscopic approach (from February 2019 to October 2019) and a uniportal thoracoscopic approach (since November 2019). Four surgeons (including HI, MK, NM, or other surgeon) performed any surgeries during the study period. Apart from the differences in approaches, all other surgical steps were similar. The dominant vessels (i.e., pulmonary artery or vein) were divided, and an intersegmental plane was identified using either the conventional inflation-deflation technique or near-infrared imaging after intravenous indocyanine green (ICG) administration (4-6). Intersegmental pulmonary veins in the hilum were used as landmarks to identify the intersegmental plane when an intersegmental plane was not clearly identified using those techniques. Following division of the target segmental bronchus during minithoracotomy or multiportal thoracoscopic approach, the intersegmental plane was divided using electrocautery (monopolar cautery) or stapling. In the minithoracotomy approach, electrocautery was frequently used based on the institutional policy

during the period. The choice of the device including electrocautery or staples depended on the surgeons' preference in multiportal approach. Finally, in the uniportal thoracoscopic approach, staples were generally used except for only a few patients because of difficulty in achieving the countertraction necessary for electrocautery. In the stapler group, the intersegmental plane was divided completely using staples. However, at least, two-thirds of outer area in an intersegmental plane was divided by electrocautery for any patients in the electrocautery group. Rest of the deep parenchyma was divided by staples. When we found major air leak, we sutured the leak point with an absorbable string, which was performed in both groups. Subsequently, the leak point was covered with fibrin glue (Bolheal; KM Biologics, Kumamoto, Japan; or Beriplast P; CSL Behring, King of Prussia, PA, USA), and an absorbable polyglycolic acid felt (Neoveil; Gunze Ltd., Kyoto, Japan). In the electrocautery group, the coverage was performed for the divided intersegmental plane in any patients to prevent delayed air leak even if we did not detect air leak in a seal test. Finally, a 24-Fr double-lumen chest tube was placed in the pleural cavity. At the morning round, our team checked the postoperative air leakage and pleural drainage volume. The chest tube was removed after the air leakage had stopped, and the volume of pleural effusion was reduced to  $\leq 300$  mL within 24 hours and the lung had expanded, as seen on chest X-ray. When postoperative air leak continued

for 2 days or longer, we took performing pleurodesis into consideration. In pleurodesis, materials involving OK-432 (Picibanil, Chugai: Pharmaceutical Co. Ltd., Tokyo, Japan), minocycline, or auto-blood was administered into thoracic cavity via the chest tube.

### Calculation of the lung volume

In our department, a 64-row multidetector CT scan was performed for all patients undergoing anatomical pulmonary resection within 2 weeks before surgery, and 6 and 12 months after surgery. The data were imported into Ziostation2 software (Ziosoft, Tokyo, Japan), and reconstructed to three-dimensional CT to calculate the pre- and post-operative lung volumes. Unfortunately, ipsilateral lung volumes during surgery cannot be calculated using this software. Therefore, we evaluated the changes in lung volume based on the pre- and post-operative values. Subsequently, we counted the resected lobes and calculated the postoperative predicted lung volume using the following formula: postoperative predicted lung volume = preoperative lung volume  $\times$   $(19 - n)/19$ , where  $n$  is the number of removed segments (18). The ratios of postoperative actual (calculated by Ziostation 2) and predicted (calculated by the formula above) lung volumes in the stapler and electrocautery groups were compared. Subset analysis was performed based on the type of segmentectomy (i.e., common or uncommon).

In addition, we evaluated the correlations between preoperative lung volume and pulmonary functions (VC and FEV<sub>1</sub>). Unfortunately, no postoperative lung function was measured in our department.

### Statistical analysis

Fisher's exact test was used to analyze the associations between categorical variables. Moreover, we used ROC curve analysis to set cut-off values for continuous variables. Student's *t*-test was used to analyze continuous variables, including the actual:predicted lung volume ratio. The correlations between variables were analyzed using Pearson's correlation. Multivariate analyses for categorical variables were performed using a logistic regression model. Results were considered significant at  $P < 0.05$ . Calculations and statistical tests were performed using the EZR graphical user interface (Saitama Medical Centre, Jichi Medical University, Saitama, Japan).

## Results

*Table 1* summarizes the preoperative patient characteristics. There were no significant differences between the groups in age, sex, or preoperative pulmonary functions (VC and FEV<sub>1</sub>). The stapler group included more patients with smoking history than the electrocautery group ( $P = 0.0015$ ). Intentional or uncommon types of segmentectomy, or uniportal approach were performed more frequently in the stapler than electrocautery group ( $P = 0.00022$ ,  $0.0045$ ,  $< 0.0001$ ). The stapler group included more patients with primary lung cancer than the electrocautery group ( $P = 0.00031$ ).

The details of surgical procedures performed in the electrocautery and stapler groups are presented in *Table 2*.

ROC curve analysis using the device used to divide the intersegmental plane as the dependent variable and the duration of postoperative drainage as the independent variable revealed an area under the curve (AUC) of 0.68 [95% confidence interval (CI): 0.6–0.76] (*Figure 2*). Based on the result (cut-off value: 2, specificity: 0.473, sensitivity: 0.825), the cut-off threshold of the duration of postoperative drainage was set on  $\leq 2$  and  $\geq 3$  days.

*Table 3* shows the perioperative outcomes of the two groups. There were no significant differences in blood loss, massive bleeding, conversion to thoracotomy, postoperative morbidity, or readmission within 30 days postoperatively between the groups. However, the stapler group had shorter operative times ( $P = 0.0027$ ), duration of postoperative drainage ( $P = 0.00037$ ), incidence of postoperative  $\geq 3$  days drainage ( $P = 0.003$ ) and duration of postoperative hospitalization ( $P = 0.0021$ ) compared to the electrocautery group. In addition, we did not find any significant differences between the stapler and electrocautery groups in terms of the postoperative actual:predicted lung volumes at 6 months (1.02 and 1.04, respectively;  $P = 0.35$ ) and 12 months (1.06 and 1.07, respectively;  $P = 0.78$ ). *Figure 3* demonstrates that the preoperative lung volumes calculated by Ziostation2 were significantly correlated with the preoperative VC ( $\gamma = 0.69$ ;  $P < 0.001$ ) and FEV<sub>1</sub> ( $\gamma = 0.48$ ;  $P < 0.001$ ).

In *Table 4*, the multivariate analysis indicated that the use of stapler for division of intersegmental plane was the only factor that contributed to reducing the incidence of postoperative  $\geq 3$  days drainage ( $P = 0.0027$ , odds ratio: 0.23, 95% CI: 0.086–0.597).

*Table 5* summarizes the results of a subset analysis based on preoperative patient characteristics and perioperative outcomes in the group with common type of segmentectomy. The stapler group had significantly shorter

**Table 1** Preoperative characteristics of the two groups

Variables	Electrocautery, n=62 (%)	Stapler, n=94 (%)	P value
Age (years)	69.3±9.9	70.4±12	0.55
Sex			0.25
Female	32 (51.6)	39 (41.5)	
Male	30 (48.4)	55 (58.5)	
Smoking history			0.0015
Yes	30 (48.4)	63 (67.0)	
No	26 (41.9)	31 (33.0)	
Unknown	6 (9.7)	0 (0.0)	
Preoperative VC (L)	2.68±0.78	2.89±0.79	0.1
Preoperative FEV <sub>1</sub> (L)	2±0.61	2.09±0.66	0.39
Types of segmentectomy-1			0.00022
Intentional	10 (16.1)	36 (38.3)	
Unintentional	15 (24.2)	32 (34.0)	
Others	37 (59.7)	26 (27.7)	
Types of segmentectomy-2			0.0045
Common	46 (74.2)	48 (51.1)	
Uncommon	16 (25.8)	46 (48.9)	
Tumor type			0.00031
Primary	25 (40.3)	67 (71.3)	
Metastatic	23 (37.1)	13 (13.8)	
Benign	14 (22.6)	14 (14.9)	
Approach			<0.0001
Minithoracotomy	23 (37.1)	3 (3.2)	
Multiport	36 (58.1)	57 (60.6)	
Uniport	3 (4.8)	34 (36.2)	
Method to identify an intersegmental plane			0.15
i-d technique	62 (100)	90 (95.7)	
ICG administration	0 (0)	4 (4.3)	

VC, vital capacity; FEV<sub>1</sub>, forced expiratory volume in 1 second; i-d technique, inflation-deflation technique; ICG, indocyanine green.

or less operative times (P=0.0025), postoperative drainage (P=0.0031), incidence of postoperative ≥3 days drainage (P=0.012) and postoperative hospitalization (P=0.019). Other parameters, including the actual:predicted lung volumes at 6 and 12 months postoperatively, were not significantly different. A subset analysis of the perioperative results of the uncommon segmentectomy group revealed

that the stapler group had significantly shorter postoperative hospitalization (P=0.022) although there were no significant differences about other parameters (*Table 6*).

## Discussion

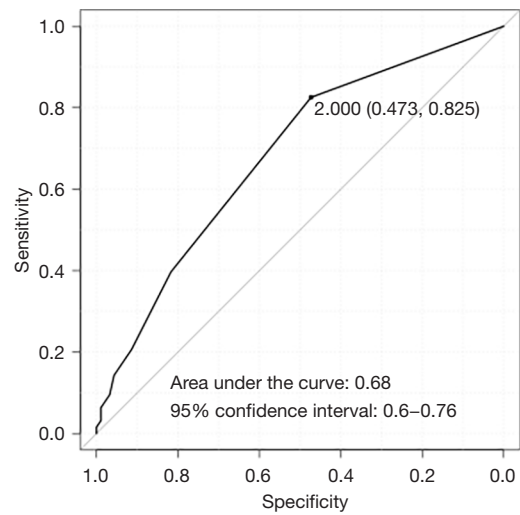
In this study, we compared perioperative parameters

**Table 2** Details of surgical procedures performed in the electrocautery and stapler groups

Surgical procedure	Electrocautery, Stapler,	
	n=62	n=94
<b>LUL</b>		
Superior segment: S <sup>1-3</sup>	14	13
Lingual segment: S <sup>4-5</sup>	5	3
Posterior segment: S <sup>1+2</sup>	3	8
Anterior segment: S <sup>3</sup>	2	4
Anterior + lingual segment: S <sup>3+4+5</sup>	0	2
Others	0	2
<b>LLL</b>		
Superior segment: S <sup>6</sup>	7	9
Basal segment: S <sup>8-10</sup>	5	2
Basilar anterior/lateral segment: S <sup>8+9</sup>	0	1
Basilar lateral/posterior segment: S <sup>9+10</sup>	1	0
<b>RUL</b>		
Apical segment: S <sup>1</sup>	2	2
Posterior segment: S <sup>2</sup>	1	7
Anterior segment: S <sup>3</sup>	3	3
Others	1	5
<b>RLL</b>		
Superior segment: S <sup>6</sup>	13	14
Basal segment: S <sup>7-10</sup>	2	7
Basilar medial/anterior segment: S <sup>7+8</sup>	0	2
Basilar anterior/lateral segment: S <sup>8+9</sup>	0	1
Basilar lateral/posterior segment: S <sup>9+10</sup>	3	9

LUL, left upper lobe; LLL, left lower lobe; RUL, right upper lobe; RLL, right lower lobe.

and postoperative lung volumes between stapler and electrocautery groups of patients undergoing pulmonary segmentectomy. Compared to electrocautery, stapler use was associated with superior perioperative outcomes, including operative, postoperative drainage, and postoperative hospitalization times. There was also a significant lower incidence of postoperative  $\geq 3$  days drainage in the stapler group compared to the electrocautery group. Moreover, the use of stapler for division of intersegmental plane was the only factor that contributed to reducing the incidence of postoperative  $\geq 3$  days drainage in the multivariate analysis.

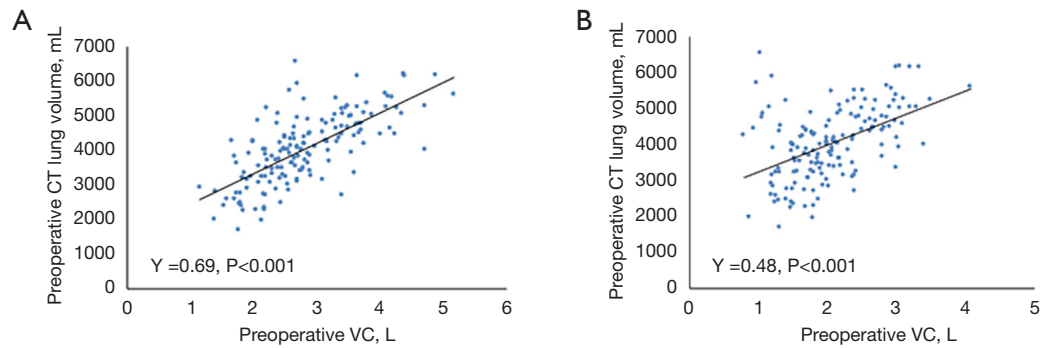
**Figure 2** Receiver operating characteristic curve analysis using the device used to divide the intersegmental plane as the dependent variable and the duration of postoperative drainage as the independent variable to set cut-off values.

These results were similar to those described in previous reports (13,14). Matsumoto *et al.* demonstrated that stapler use was associated with significantly shorter operative times and reduced rates of delayed air leakage compared to electrocautery (14). A prospective study comparing the use of a stapler and electrocautery, conducted by Chen *et al.*, demonstrated higher postoperative complication rates in the electrocautery than stapler group (13). Based on these results, the use of a stapler can be considered superior in terms of the rates of postoperative complications, especially pulmonary fistula. Pulmonary segmentectomy is a minimally invasive procedure suitable for patients with compromised lung function, such as elderly patients. Minimizing complications is important in these patients to ensure rapid postoperative recovery. Prolonged air leak (PAL) occurs more frequently with the use of electrocautery than staples, and is associated with significant morbidity and an increased risk of pulmonary complications (19).

Several studies have reported that the remnant lung shrinks after the use of staplers, which leads to worse postoperative pulmonary function compared to electrocautery (20,21). Asakura *et al.* reported that the use of staplers for division of the intersegmental plane of pig lungs reduced the volume of preserved lobes compared to the use of electrocautery (22). Conversely, Tao *et al.* found that the use of staplers did not negatively affect the volume of remnant lungs after segmentectomy compared to the use of electrocautery, based

**Table 3** Perioperative outcomes of the two groups

Variables	Electrocautery, n=62 (%)	Stapler, n=94 (%)	P value
Operative time (min)	188±57	162±50	0.0027
Blood loss (mL)	38±68	40±72	0.85
Massive bleeding	3 (4.8)	10 (10.6)	0.25
Conversion to thoracotomy	0 (0)	4 (4.3)	0.15
Duration of postoperative drainage (days)	2.9±2.2	1.9±1.3	0.00037
≤2	37 (59.7)	77 (81.9)	0.003
≥3	25 (40.3)	17 (18.1)	
Duration of postoperative hospitalization (days)	8.4±13	4.1±2.2	0.0021
Morbidity (Clavien-Dindo Classification grade ≥ III)	9 (14.5)	8 (8.5)	0.3
Readmission within 30 days postoperatively	3 (4.8)	2 (2.1)	0.39
Actual:predicted lung volume at 6 months postoperatively	1.02±0.17	1.04±0.16	0.35
Actual:predicted lung volume at 12 months postoperatively	1.06±0.14	1.07±0.17	0.78

**Figure 3** Preoperative lung volumes calculated by Ziostation2. VC, vital capacity.**Table 4** Multivariate analysis to identify the factors that contributed to the incidence of postoperative ≥3 days drainage

Factors	Odds ratio	95% confidence interval	P value
Age (years, continuous variables)	1.01	0.96–1.06	0.72
Sex male (vs. female)	0.55	0.2–1.49	0.24
Smoking status + (vs. –)	1.3	0.39–4.27	0.67
Preoperative VC (L, continuous variables)	3.4	0.74–15.5	0.11
Preoperative FEV <sub>1</sub> (L, continuous variables)	0.29	0.079–1.05	0.059
Types of segmentectomy-1 unintentional + others (vs. intentional)	0.77	0.26–2.28	0.64
Types of segmentectomy-2 common (vs. uncommon)	0.91	0.39–2.13	0.84
Tumor type metastatic + benign (vs. primary)	1.35	0.47–3.86	0.58
Approach uniport (vs. minithoracotomy + multiport)	2.1	0.74–5.84	0.17
Device for division of intersegmental plane stapler (vs. electrocautery)	0.23	0.086–0.597	0.0027

VC, vital capacity; FEV<sub>1</sub>, forced expiratory volume in 1 second.

**Table 5** Preoperative characteristics and perioperative outcomes of the electrocautery and stapler groups (common segmentectomy patients)

Variables	Electrocautery, n=46 (%)	Stapler, n=48 (%)	P value
Age (years)	70±11	69.7±11	0.74
Sex			0.41
Female	25 (54.3)	21 (43.8)	
Male	21 (45.7)	27 (56.2)	
Smoking history			0.011
Yes	19 (41.3)	31 (64.6)	
No	22 (47.8)	17 (35.4)	
Unknown	5 (10.9)	0 (0)	
Preoperative VC (L)	2.74±0.82	2.86±0.79	0.44
Preoperative FEV <sub>1</sub> (L)	2.09±0.61	2.09±0.67	0.97
Types of segmentectomy			0.031
Intentional	7 (15.2)	16 (33.3)	
Unintentional	12 (26.1)	16 (33.3)	
Others	27 (58.7)	16 (33.3)	
Tumor type			0.025
Primary	19 (41.3)	32 (77)	
Metastatic	17 (37)	7 (14.6)	
Benign	10 (21.7)	9 (18.8)	
Approach			<0.0001
Minithoracotomy	17 (37)	3 (6.2)	
Multiport	26 (56.5)	25 (52.1)	
Uniport	3 (6.5)	20 (41.7)	
Method to identify an intersegmental plane			1
i-d technique	46 (100)	47 (97.7)	
ICG administration	0 (0)	1 (2.1)	
Operative time (min)	187±62	151±50	0.0025
Blood loss (mL)	38±73	47±88	0.6
Massive bleeding	3 (6.5)	7 (14.6)	0.32
Conversion to thoracotomy	0 (0)	2 (4.2)	0.5
Duration of postoperative drainage (days)	3±2.3	1.8±1.3	0.0031
≤2	27 (58.7)	40 (83.3)	0.012
≥3	19 (41.3)	8 (16.7)	
Duration of postoperative hospitalization (days)	9.3±15	4.0±2.1	0.019
Morbidity (Clavien-Dindo Classification grade ≥ III)	7 (15.2)	4 (8.3)	0.35
Readmission within 30 days postoperatively	1 (2.2)	0 (0)	0.49
Actual:predicted lung volume at 6 months postoperatively	1±0.19	1.05±0.15	0.2
Actual:predicted lung volume at 12 months postoperatively	1.06±0.16	1.09±0.15	0.39

VC, vital capacity; FEV<sub>1</sub>, forced expiratory volume in 1 second; i-d technique, inflation-deflation technique; ICG, indocyanine green.



**Table 6** Preoperative characteristics and perioperative outcomes of the electrocautery and stapler groups (uncommon segmentectomy patients)

Variables	Electrocautery, n=16 (%)	Stapler, n=46 (%)	P value
Age (years)	70.3±7.8	71.1±13	0.81
Sex			0.77
Female	7 (43.8)	18 (39.1)	
Male	9 (56.2)	28 (60.9)	
Smoking history			0.34
Yes	11 (68.8)	32 (69.6)	
No	5 (31.3)	14 (30.4)	
Unknown	0 (0)	0 (0)	
Preoperative VC (L)	2.5±0.64	2.91±0.8	0.068
Preoperative FEV <sub>1</sub> (L)	1.77±0.56	2.09±0.66	0.081
Types of segmentectomy			0.015
Intentional	3 (18.8)	20 (43.5)	
Unintentional	3 (17.6)	16 (34.8)	
Others	10 (18.8)	10 (21.7)	
Tumor type			0.014
Primary	6 (37.5)	35 (76.1)	
Metastatic	6 (37.5)	6 (13)	
Benign	4 (25)	5 (10.9)	
Approach			<0.0001
Minithoracotomy	6 (37.5)	0 (0)	
Multiport	10 (62.5)	32 (69.6)	
Uniport	0 (0)	14 (30.4)	
Method to identify an intersegmental plane			0.56
i-d technique	16 (100)	43 (93.5)	
ICG administration	0 (0)	3 (6.5)	
Operative time (min)	191±40	173±48	0.18
Blood loss (mL)	36±54	32±48	0.8
Massive bleeding	0 (0)	3 (6.5)	0.6
Conversion to thoracotomy	0 (0)	2 (4.3)	1
Duration of postoperative drainage (days)	2.8±1.8	2±1.3	0.085
≤2	10 (62.5)	37 (80.4)	0.18
≥3	6 (37.5)	9 (19.6)	
Duration of postoperative hospitalization (days)	5.8±2.8	4.1±2.3	0.022
Morbidity (Clavien-Dindo Classification grade ≥ III)	2 (12.5)	4 (8.7)	0.64
Readmission within 30 days postoperatively	2 (12.5)	2 (4.3)	0.27
Actual:predicted lung volume at 6 months postoperatively	1.06±0.09	1.04±0.16	0.6
Actual:predicted lung volume at 12 months postoperatively	1.07±0.09	1.05±0.18	0.68

VC, vital capacity; FEV<sub>1</sub>, forced expiratory volume in 1 second; i-d technique, inflation-deflation technique; ICG, indocyanine green.

on a small number of participants (15). Therefore, the remnant lung can expand, and lung volumes can be preserved, even with use of a stapler. Prospective, comparative studies are required to confirm these results. However, such studies may be difficult to conduct because of the high frequency of postoperative complications in these patients (13).

Although the goal of lung volume preservation was to maintain lung function, data on postoperative pulmonary function were not collected in the present study. This is a retrospective study using clinical data that did not include postoperative pulmonary function that our team does not routinely examine postoperatively. Therefore, although the lung volumes were preserved, it is unclear if pulmonary functions were also preserved. However, our study revealed that preoperative lung volume was significantly correlated with preoperative pulmonary function. In addition, several authors previously reported that lung volumes calculated via quantitative CT analysis correlated well with the actual postoperative values, and were easier to calculate compared to other procedures such as ventilation/perfusion scintigraphy (23-26). In addition to preserved lung function, preserved lung volume is associated with improved outcomes in cases of repeat surgery (27).

In this study, an intersegmental plane was identified using either the conventional inflation-deflation technique or near-infrared imaging after ICG administration although the latter technique was applied only for 4 cases. Additionally, intersegmental pulmonary veins in the hilum were used as landmarks to identify the intersegmental plane when an intersegmental plane was not clearly identified using those techniques. These technical differences to identify an intersegmental plane might affect the postoperative lung volume because the demarcation line was a little different in each technique.

We performed subset analyses of perioperative outcomes and postoperative lung volumes in common and uncommon segmentectomies. An uncommon segmentectomy is technically more challenging because it requires division of multiple intersegmental surfaces, and exposure of the peripheral pulmonary vessels and bronchus. To overcome these technical difficulties, Suzuki *et al.* recommended that electrocautery should be used for division of the intersegmental plane in uncommon segmentectomy rather than staplers (3). However, in that study, electrocautery was associated with a higher incidence of PAL. Our study demonstrated that staplers and electrocautery had similar perioperative outcomes and postoperative lung volumes

in uncommon segmentectomy. Although the number of patients who underwent uncommon segmentectomy in our study was small, the use of staplers resulted in satisfactory perioperative outcomes and postoperative lung expansion in these cases, without the need for electrocautery.

### Limitations

This study had several limitations. First, it was a retrospective study with a small sample size and single-institution design. Second, the study period was relatively long. Third, the choice of device including electrocautery or staplers for division of an intersegmental plane was significantly correlated with the surgical approach including minithoracotomy, multiport and uniport. Fourth, staplers were more frequently used in the latter of study period because staplers were usually chosen in the uniportal approach, which might affect better perioperative outcomes in the stapler group. Additionally, postoperative lung volume was predicted based on the number of resected segments, because ZioStation2 software could only examine the existing lung volume. Therefore, bias may have been introduced in patients with target segments larger or smaller than predicted. Moreover, no postoperative pulmonary function, which was the most important for postoperative patients' quality of life, was measured. Finally, we did not evaluate the cancer outcomes.

### Conclusions

The use of staplers for division of the intersegmental plane during pulmonary segmentectomy led to better perioperative outcomes and similar postoperative remnant lung volumes compared to electrocautery. Moreover, even for the technically difficult uncommon type of segmentectomy, use of a stapler was not inferior to use of electrocautery about those evaluations. Therefore, we conclude that a stapler should be used for division of the intersegmental plane. Future studies should compare cancer outcomes between the use of staplers and electrocautery.

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*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (2013 revision), and approved by the institutional ethics board of Japanese Red Cross Maebashi Hospital (No.: 2020-53, date: March 1, 2021). Informed consent was waived for this retrospective analysis.

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