Original Article

Comparison of different approaches in complete thoracoscopic segmentectomy of lung lower lobe

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Background: Safe and oncologically acceptable segmentectomy outcomes were reported for early-stage lung cancer. The high-resolution computed tomography allowed us to find detailed structures inside the lungs, such as the pulmonary ligaments (PLs). Hence, we have presented the relatively anatomically challenging thoracoscopic segmentectomy, for the resection of the lateral basal segment, the posterior basal segment, and both segments through the PL as a PL approach. This study aimed to retrospectively examine the lung lower lobe segmentectomy, excluding the superior and basal segments (from S7 to S10), using the PL approach as an option to treat the lower lobe tumors of the lung. We then compared the efficacy of the PL approach in terms of safety with the interlobar fissure (IF) approach. The characteristics of the patients, intra- and postoperative complications, and surgical outcomes were analyzed.

Methods: Of the 510 patients who underwent segmentectomy for malignant lung tumors from February 2009 to December 2020, 85 were included in this study. Among them, 41 underwent a complete lung lower lobe thoracoscopic segmentectomy, excluding S6 and basal segments (from S7 to S10), using the PL approach, and the remaining 44 used the IF approach.

Results: The median age in 41 patients in the PL group was 64.0 years (range, 22–82), and that in 44 patients in the IF group was 66.5 years (range, 44–88), with significant differences in gender between these groups. Video-assisted thoracoscopic surgery and robot-assisted thoracoscopic surgery were performed on 37 and 4 patients in the PL group and 43 and 1 patient in the IF group, respectively. Postoperative complication frequency was not significantly different between these groups. The most common complications were the air leaks that persisted for over 7 days in 1 and 5 patients in the PL and IF groups, respectively.

Conclusions: Complete thoracoscopic segmentectomy of the lower lobe, excluding S6 and basal segments, using the PL approach is a reasonable option for lung lower lobe tumors compared with the IF approach.

Keywords: Segmentectomy; pulmonary ligament; thoracoscopic surgery; lung cancer; lung lower lobe

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Introduction

Computed tomography (CT) technology advances made small and peripheral lung nodule detection possible. Many studies have reported safe and oncologically acceptable segmentectomy results of small and peripheral lung nodules, including early-stage lung cancer, over the last 20 years (1,2).

The high-resolution CT (HRCT) allowed us to find detailed structures inside the lungs. In particular, HRCT can clearly visualize the pulmonary ligament (PL). The PL consists of a double serous layer of visceral pleura, forms the intersegmental septum, and enters the lung parenchyma (3). We have presented the relatively difficult thoracoscopic segmentectomy (TS), such as resection of the lateral basal segment (S9), the posterior basal segment (S10), and both segments through PL, because it helped establish a new surgical approach (4).

In the present study, retrospective examinations were performed to determine whether performing lung lower lobe segmentectomy, excluding superior segment (S6) and basal segments (from S7 to S10), using the PL approach could be an option to treat the lower lobe tumors of the lung and its efficacy was compared in terms of safety with the interlobar fissure (IF) approach. The 30- and 90-day mortality and complications were evaluated in terms of safety. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-1535/rc).

Highlight box

Key findings

- The thoracoscopic segmentectomy using the pulmonary ligament approach was performed safety.

What is known and what is new?

- Safe and oncologically acceptable segmentectomy outcomes were reported for early-stage lung cancer.
- In the present study, retrospective examinations were performed to determine whether performing lung lower lobe segmentectomy, using the pulmonary ligament approach could be an option to treat the lower lobe tumors of the lung and its efficacy was compared in terms of safety with the interlobar fissure approach.

What is the implication, and what should change now?

- Complete thoracoscopic segmentectomy of the lower lobe using the pulmonary ligament approach is a reasonable option for lung lower lobe tumors.
- A larger case series and comparative study should be performed to determine the real significance of complete lower lobe thoracoscopic segmentectomy through the pulmonary ligament approach.

Methods

Patient selection

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). After the approval by the Research Ethics Committee of Tokyo Women's Medical University (Nos. 4988 and 5363), the study retrospectively reviewed the institution's medical records. Informed consent was obtained from all patients, and patient anonymity was preserved.

From February 2009 to December 2020, 510 patients underwent segmentectomy for lung tumors at Tokyo Women's Medical University Hospital (Tokyo, Japan). This study excluded 68 patients due to benign tumors, inflammatory disease, and pulmonary arteriovenous fistula, in addition to 357 patients who underwent upper and middle lobe, superior, and basal segmentectomy. Therefore, this study included 85 patients. Of these, 41 patients were scheduled to receive a complete lower lobe TS using the PL approach (PL group), and 44 patients were scheduled to receive a complete lower lobe TS using the IF approach (IF group) (*Figure 1*). Regarding the choice of the technique, a complete lower lobe TS using the PL approach was performed in cases where PLs were detected using preoperative CT.

Preoperative evaluation data included the comprehensive patient history, the physical examination results, the imaging data of CT scans and positron emission tomography, and the pulmonary function test results.

Resected specimens were histopathologically examined, and histologic typing was performed following the World Health Organization/International Association for the Study of Lung Cancer Histological Classification of Lung Tumors (5,6). Each case was reclassified according to the eighth edition of the tumor, node, and metastasis classification for lung cancer.

Patient characteristics, intra- and postoperative complications, and surgical outcomes were analyzed. Recurrent diseases were diagnosed by radiographic and pathologic confirmations. Local recurrence was defined as tumor progression within the ipsilateral hilum or mediastinum. After the operation, measurement of tumor markers and chest X-ray were performed every month, and chest CT scans were performed at least once every 6 months.

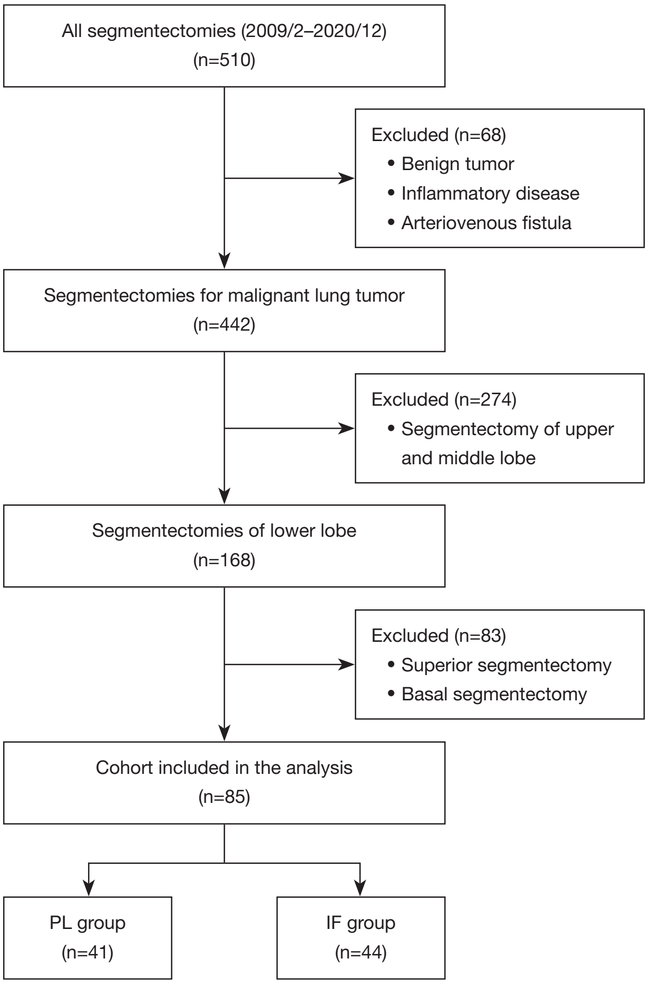


Figure 1 Study flowchart. PL, pulmonary ligament; IF, interlobar fissure.

Thoracoscopic procedures

As previously mentioned, all patients were examined with contrast-free HRCT to create a virtual three-dimensional (3D) lung model. This allows software made in-house (CTTRY, Tokyo Women's Medical University, Tokyo, Japan) to create a patient-specific virtual 3D lung model on a personal computer before the thoracoscopic surgery, and the 3D lung model was used as navigation during segmentectomy (*Figure 2*) (7-10).

Video 1 presents a concept video of thoracoscopic S9 and/or S10 segmentectomy via a PL approach. Below are the surgical procedures for video-assisted thoracoscopic surgery (VATS) and robot-assisted thoracoscopic surgery (RATS), separately.

VATS procedure was previously reported, where the patient was under general anesthesia with split ventilation using a double-lumen endotracheal tube in the lateral decubitus position. A small skin incision of approximately 2.5–4 cm in length was made along the anterior axillary line of the fifth intercostal space (ICS). One assistant port was placed at the posterior axillary line of the eighth or ninth ICS, as well as a camera port at the midaxillary line (*Figure 3A*). The inferior pulmonary veins and their branches and the superior (V6) and basal veins were exposed by dividing the intersegmental septum formed by the PL (*Figure 3B*). The branch of the basal pulmonary vein and the branch of the segmental pulmonary vein were excised from the identified patient-specific 3D image preoperatively. The dissection proceeded along the intersegmental septum, exposing the pulmonary arteries running along the bronchi, transecting the target bronchus, and then transecting the target pulmonary artery (*Figure 3C,3D*). The local lymph nodes were dissected, as the bronchi were exposed, to submit for intraoperative frozen section diagnosis. Lower lobectomy was converted if the local lymph nodes were positive for metastasis on intraoperative frozen section diagnosis. After transection of the bronchi and pulmonary arteries, anterior basal vein (V8) was exposed and lung parenchyma was dissected along V8 for dividing the segments (*Figure 3E*). The intersegmental veins were used to identify the intersegmental plane. Especially, V6b + c was exposed to dissection along the outer sidewall of the lateral and posterior basal segmental bronchus.

RATS follows VATS, but the RATS segmentectomy was performed with 5-port incisions, including an assistant port as a carbon dioxide (CO_2) insufflation port. A 12-mm trocar (AirSeal® access ports, ConMed, Largo, FL, USA) was inserted as an assistant port in the fifth ICS anteriorly in the anterior axillary line with the pleural space as the entry point. Then, two 8-mm robotic trocars were inserted, one as a port for the robotic camera in the ninth ICS at the middle-axillary line and the other as port 4 in the left side RATS or port 1 in the right-side RATS in the posterior side of the tip of the scapula. Two 12-mm robotic trocars were inserted in ports 1 and 3 in the eighth ICS anteriorly along the anterior axillary line and in the ninth ICS along the posterior axillary line at the left side or inserted in ports 4 and 2 in the eighth ICS anteriorly along the anterior axillary line and in the ninth ICS along the posterior axillary line at the right side, respectively. After which, the daVinci Xi® surgical system (Intuitive Surgery, Sunnyvale, CA, USA) was docked (*Figure 3F*). All four robotic arms were used. A CO_2 insufflation system (AirSeal® system, ConMed, FL,

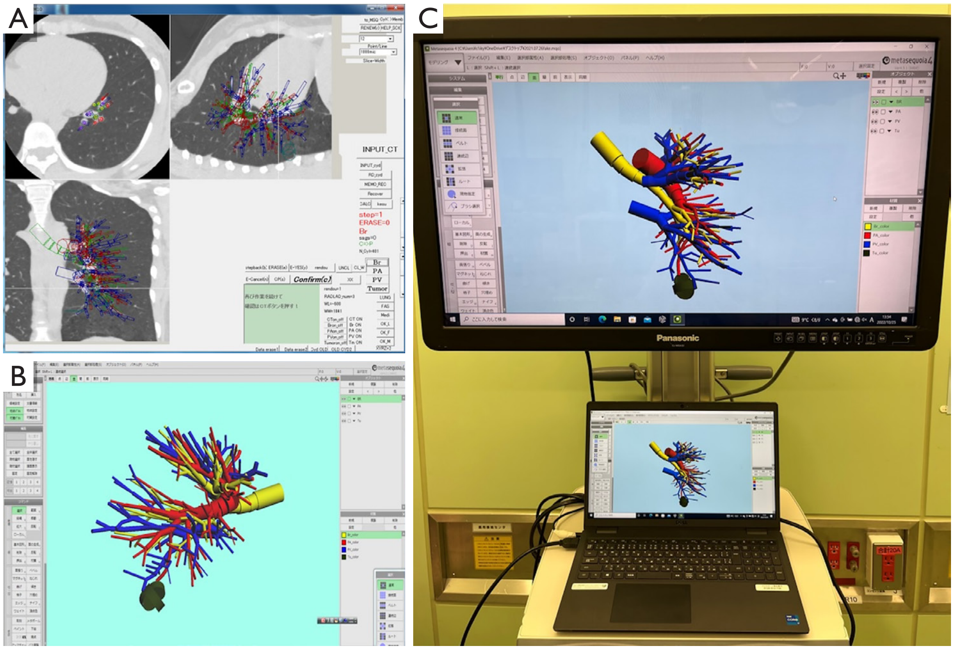
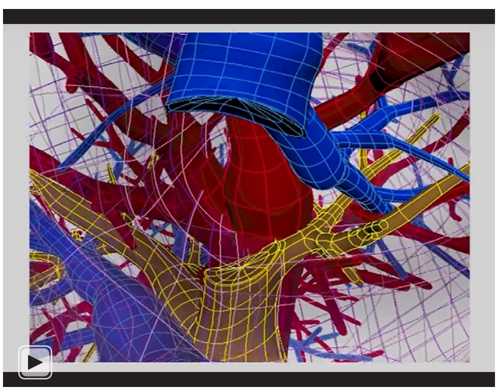
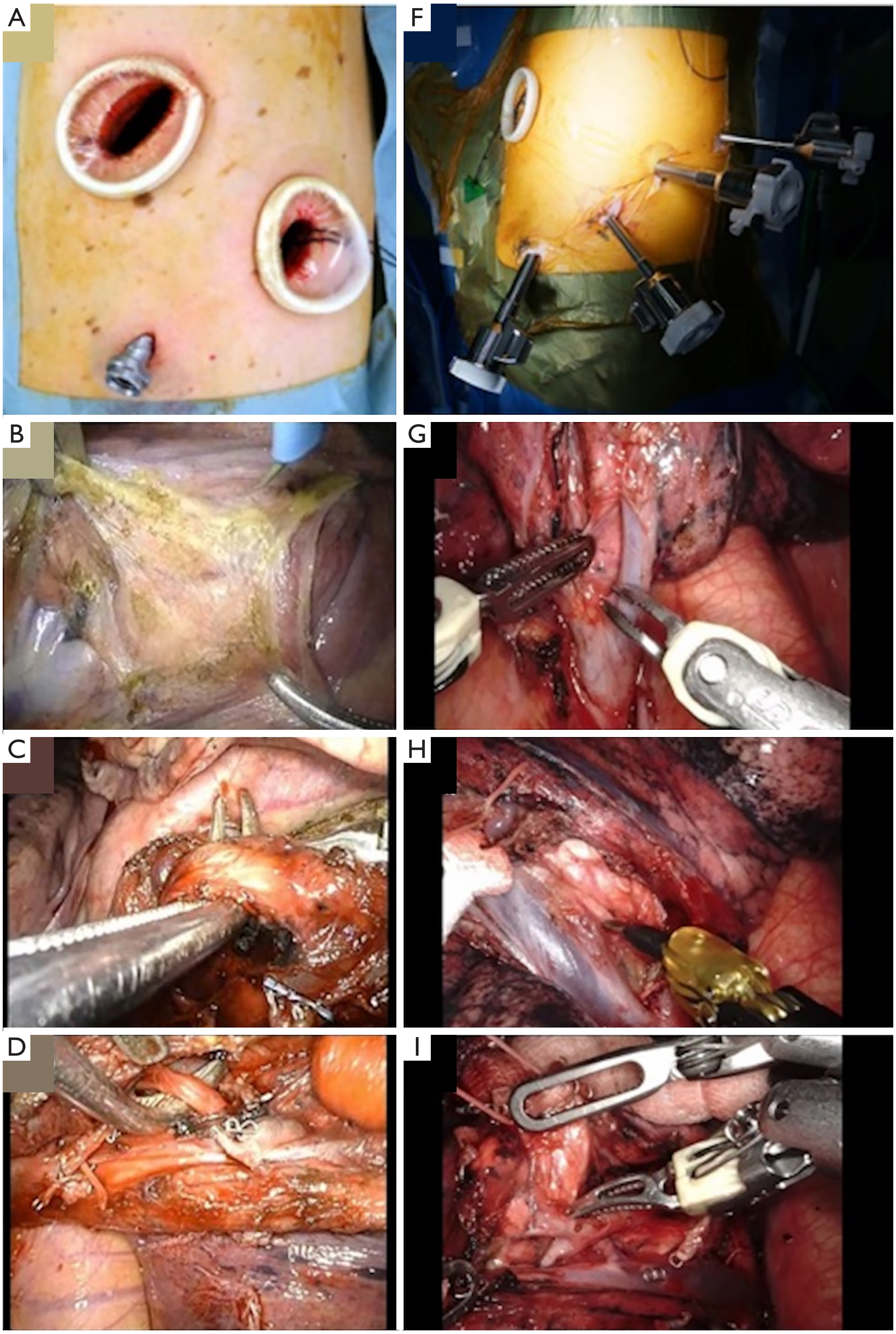


Figure 2 Creation of patient-specific virtual 3D lung model on a PC and intraoperative navigation using a 3D lung model. After the communications-in-medicine (DICOM) format images were uploaded to a PC, the surgeon used the homemade software "CTTRY" (Tokyo Women's Medical University, Tokyo, Japan) to manually mark the pulmonary arteries, veins, bronchi, and tumor on high-resolution computed tomography images (A). The location and thickness of the pulmonary vessels and bronchi were rendered as cylinders of various sizes. The 3D image was reconstructed using the software Metasequoia 4 (http://metaseq.net/jp/) based on the obtained numerical data (B). The scene in the operating room. The patient-specific virtual 3D lung model image on the PC was shown in the monitor and used as intraoperative navigation (C). 3D, three-dimensional; DICOM, digital imaging and communications in medicine; PC, personal computer.



Video 1 A concept video of thoracoscopic segmentectomy of the lateral basal segment, the posterior basal segment, or both segments performed using a pulmonary ligament approach. Division of the intersegmental septum formed by the PL exposed the inferior pulmonary vein, and both the lateral (V9) and posterior basal (V10) veins were then transected. Next, the intersegmental septum was dissected to expose the bronchi and pulmonary arteries. The target bronchi were exposed and transected, followed by the target pulmonary arteries. PL, pulmonary ligament.

USA) was used at a set pressure of 5 mmHg. Fenestrated bipolar forceps, Maryland bipolar forceps or a permanent cautery spatula, and Cadiere forceps were inserted through ports 1, 3, and 4 (Intuitive Surgery), respectively. The PL was incised up to the inferior pulmonary vein after lifting the left lower lobe using the Cadiere forceps (*Figure 3G*). After the basal pulmonary vein was exposed, both the lateral (V9) and posterior basal (V10) veins were transected using robot staplers, and V8 was exposed and lung parenchyma was dissected along V8. Then, the intersegmental septum is dissected and the targeted bronchi and pulmonary artery were exposed and excised similar to VATS (*Figure 3H,3I*). An intravenous injection of indocyanine green was administered, and observation under fluorescence navigation revealed intersegmental planes since 2018. Then, the target segment was resected using the robot staplers (*Figure 3J*). After removing the resected lung segments from the thoracic cavity, the remaining lower lobe of the lung was pulled toward the sternum. Lymph nodes at levels 7, 11, and 12 were dissected after making a mediastinal pleural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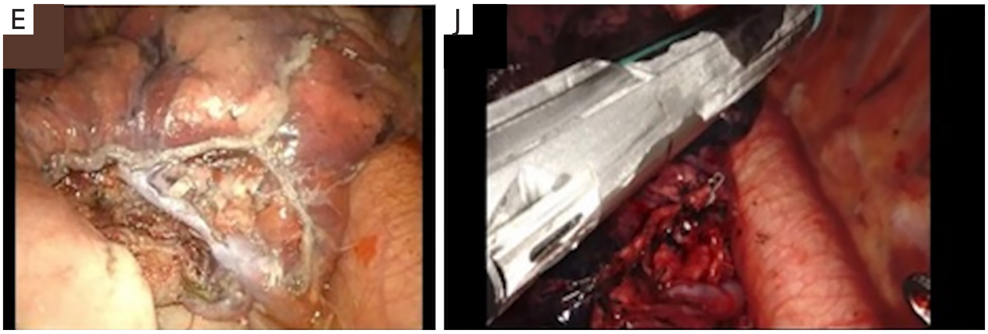

Figure 3 Intraoperative view of VATS and RATS. The left and right columns of photographs represent VATS and RATS. Port placement of VATS (A) and RATS (F) in the left chest. A small skin incision was made along the anterior axillary line at the fifth ICS. A camera port was placed at the middle-axillary line of the eighth ICS, and an assistant port was placed at the posterior axillary line of the ninth ICS (A). A 12-mm trocar (AirSeal® access ports, ConMed, Utica, NY) was inserted into the fifth ICS anteriorly in the anterior axillary line as an assistant port. A robotic camera port was placed at the middle-axillary line of the ninth ICS. An 8-mm robotic trocar was inserted in the ninth ICS at the posterior side of the tip of the scapula. Two 12-mm robotic trocars were inserted in the eighth ICS anteriorly in the anterior axillary line and the ninth ICS at the posterior axillary line (F). After lifting up the left lower lobe, the PL is incised up to the inferior pulmonary vein in VATS (B) and RATS (G). Forceps are manipulated from above the monitor screen in VATS (B,C), while the robotic forceps are operated from the bottom of the monitor screen in RATS (G,H). The dissection proceeded along the intersegmental septum, thereby exposing the pulmonary arteries running along the bronchi, transecting the target bronchus, and then transecting the target pulmonary artery, in VATS (C,D) and RATS (H,I). After the transection of the bronchus and pulmonary artery, the segments were divided into VATS (E) and RATS (J). ICS, intercostal space; RATS, robot-assisted thoracoscopic surgery; VATS, video-assisted thoracoscopic surgery.

incision cranially along the bronchi from the bronchial stump.

Statistical analysis

JMP Pro software (version 14.0.0, SAS institute, Cary, NC, USA) was used for the statistical analysis. P values were calculated by Fisher's exact test or the chi-square test for categorical data, or Mann-Whitney's U-test for continuous data. Continuous variables are expressed as the median with minimum and maximum values, and categorical variables are expressed as numbers and percentages (%). A P value of <0.05 was considered significant.

Results

Table 1 shows the characteristics of the 85 patients, including 41 in the PL group with a median age of 64.0 years (range, 22–82) and 44 in the IF group with a median age of 66.5 years (range, 44–88), and significant differences were found in the gender between the PL and IF groups. The preoperative pulmonary function test revealed a median functional vital capacity (FVC) of 3.04 L (range, 2.03–5.75) and 3.29 L (range, 1.96–5.88), a median forced expiratory volume in 1 second ($FEV_{1.0}$) of 2.39 L (range, 1.30–4.34) and 2.32 L (range, 1.40–3.97), and median percentage of diffusing capacity corrected for alveolar volume ($\%DL_{CO}$) of 79.8% (range, 35.3–114.9%) and 72.7% (range, 39.3–114.9%) in the PL and IF groups, respectively. A significant difference was found in the $\%DL_{CO}$ between the two groups.

Resected segments are summarized in *Table 2*. *Table 3* showed the surgical outcomes. VATS and RATS were performed in 37 and 4 patients in the PL group and 43 and 1 patient in the IF group, respectively. The two groups have no conversion to open thoracotomy. The median operation times were 215 minutes (range, 118–404) and 173.5 minutes (range, 110–276) in the PL and IF groups, respectively, and the median estimated blood losses were 15 mL (range, 2–332) and 10.5 mL (range, 2–105), respectively. A significant difference was noted in terms of the operation duration between the two groups. The median chest tube duration was 4 days (range, 2–11) and 3 days (range, 1–14) and the median postoperative hospital stay was 8 days (range, 5–14) and 8 days (range, 4–19) in the PL and IF group, respectively. The two groups experienced no intraoperative complications. Four postoperative complications were observed in 2 (4.9%) and

Table 1 Patient characteristics

Variables	PL group	IF group	P value
Age, median [range] (years)	64.0 [22–82]	66.5 [44–88]	0.275
Gender, n (%)			0.005
Male	14 (34.1)	29 (65.9)	
Female	27 (65.9)	15 (34.1)	
Comorbidity, n (%)			
Hypertension	14 (34.1)	15 (34.1)	0.831
Diabetes mellitus	4 (9.8)	8 (18.2)	0.355
CAD	2 (4.9)	3 (6.8)	1.000
COPD	5 (12.2)	5 (11.4)	1.000
CVD	2 (4.9)	5 (11.4)	0.435
Collagen disease	2 (4.9)	3 (6.8)	1.000
FVC, median [range] (L)	3.04 [2.03–5.75]	3.29 [1.96–5.88]	0.293
$FEV_{1.0}$, median [range] (L)	2.39 [1.30–4.34]	2.32 [1.40–3.97]	0.972
$\%DL_{CO}$, median [range] (%)	79.8 [35.3–114.9]	72.7 [39.3–114.9]	0.047

P values were calculated by Fisher's exact test or the chi-square test for categorical data, or Mann-Whitney's U-test for continuous data. PL, pulmonary ligament; IF, interlobar fissure; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; CVD, cerebrovascular disease; FVC, functional vital capacity; $FEV_{1.0}$, forced expiratory volume in 1 second; $\%DL_{CO}$, percentage of diffusing capacity corrected for alveolar volume.

Table 2 Resected segments

Location	PL group, n (%)	IF group, n (%)
Right		
S7	0	2 (4.5)
S8	0	10 (22.7)
S9	3 (7.3)	0
S10	3 (7.3)	1 (2.3)
S8 + 9	1(2.4)	4 (9.1)
S9 + 10	5 (12.2)	1 (2.3)
Left		
S8	0	14 (31.8)
S9	5 (12.2)	2 (4.5)
S10	9 (22.0)	3 (6.8)
S8 + 9	0	5 (11.4)
S9 + 10	15 (36.6)	2 (4.5)

PL, pulmonary ligament; IF, interlobar fissure; S7, medial basal segment; S8, anterior basal segment; S9, lateral basal segment; S10, posterior basal segment.

7 (15.9%) patients in the PL and IF groups, respectively. The most common complication was persistent air leaks for over 7 days in 1 and 5 patients in the PL and IF groups, respectively. Other patients with paroxysmal atrial fibrillation and pneumonia were classified as grade II by the Clavien-Dindo classification (11). All other complications were minor. The 30- and 90-day mortality rate was 0%. There was no re-admitted case within 30 days. The median maximal tumor diameter was 14 (range, 3–25) and 15 (range, 5–68) mm in the PL and IF groups, respectively. The tumor histology was lung cancer in 20 (adenocarcinoma in 18, squamous cell carcinoma in 2 patients) and metastatic lung tumor in 21 patients in the PL group, and lung cancer in 19 (adenocarcinoma in 17, squamous cell carcinoma in 1, and large cell neuroendocrine carcinoma in 1 patient) and metastatic lung tumor in 25 patients in the IF group. Lymph node dissection in primary lung cancer was 1a in 6, 1b in 7, and 2a-1 in 7 patients in the PL group, and 1a in 7, 1b in 10, and 2a-1 in 2 patients in the IF group. Local recurrence was observed 1 (2.4%) and 4 (9.1%) patients in the PL and IF groups, respectively.

Table 3 Surgical outcomes

Variables	PL group	IF group	P value
Surgical procedure, n (%)			0.192
VATS	37 (90.2)	43 (97.7)	
RATS	4 (9.8)	1 (2.3)	
Conversion to open thoracotomy, n	0	0	–
Operation time, median (min)	215	173.5	0.002
Blood loss, median (mL)	15	10.5	0.503
Chest tube duration, median [range] (days)	4 [2–11]	3 [1–14]	0.861
Postoperative hospital stay, median [range] (days)	8 [5–14]	8 [4–19]	0.796
Intraoperative complications, n	0	0	–
Postoperative complications, n (%)	2 (4.9)	7 (15.9)	0.158
Persistent air leaks	1 (2.4)	5 (11.4)	0.204
Atrial fibrillation	1 (2.4)	0	0.482
Pneumonia	0	2 (4.5)	0.495
30-day mortality, n	0	0	–
90-day mortality, n	0	0	–
Maximal tumor diameter, median [range] (mm)	14 [3–25]	15 [5–68]	0.195
Pathology, n (%)			0.658
Lung cancer			
Ad	18 (43.9)	17 (38.6)	
Sq	2 (4.9)	1 (2.3)	
LCNEC	0	1 (2.3)	
Metastases	21 (51.2)	25 (56.8)	
Lymph node dissection, n (%)			0.186
1a	6 (30.0)	7 (36.9)	
1b	7 (35.0)	10 (52.6)	
2a-1	7 (35.0)	2 (10.5)	
Complete resection of target tumor, n (%)	41 (100.0)	44 (100.0)	–
Local recurrence, n (%)	1 (2.4)	4 (9.1)	0.362

P values were calculated by Fisher's exact test or the chi-square test for categorical data, or Mann-Whitney's U-test for continuous data. PL, pulmonary ligament; IF, interlobar fissure; VATS, video-assisted thoracoscopic surgery; RATS, robot-assisted thoracoscopic surgery; Ad, adenocarcinoma; Sq, squamous cell carcinoma; LCNEC, large cell neuroendocrine carcinoma.

RATS was performed on 4 patients (1 male and 3 females) in the PL group (*Table 4*). The median age was 57.5 years (range, 20–67). In RATS, the median FVC, $FEV_{1.0}$, $\%DL_{CO}$, chest tube duration, and postoperative hospital stay were 2.80 L (range, 2.03–3.94), 2.36 L (range, 1.55–3.01), 58.5% (range, 56.1–80.8%), 4 days (range, 3–7), and 8.5 days (range, 8–11), respectively. A patient developed paroxysmal atrial fibrillation, which was considered a postoperative complication. The median maximal tumor diameter was 16 mm (range, 3–20). The tumor histology was lung cancer in 1 and metastatic lung tumor in 3 patients. No 30- and 90-day mortalities and complete resection of target tumor

Table 4 Characteristics of the patients who underwent robot-assisted thoracoscopic surgery in the pulmonary ligament group

Characteristics	Values
Number of patients	4
Age, median [range] (years)	57.5 [20–67]
Gender, n (%)	
Male	1 (25.0)
Female	3 (75.0)
Comorbidity	
CAD, n (%)	1 (25.0)
FVC, median [range] (L)	2.80 [2.03–3.94]
$FEV_{1.0}$, median [range] (L)	2.36 [1.55–3.01]
$\%DL_{CO}$, median [range] (L)	58.5 [56.1–80.8]
Chest tube duration, median [range] (days)	4 [3–7]
Postoperative hospital stay, median [range] (days)	8.5 [8–11]
Intraoperative complications, n	0
Postoperative complications, n (%)	1 (25.0)
Atrial fibrillation, n (%)	1 (25.0)
30-day mortality, n	0
90-day mortality, n	0
Maximal tumor diameter, median [range] (mm)	16 [3–20]
Pathology, n (%)	
Lung cancer	
Ad	1 (25.0)
Metastases	3 (75.0)

CAD indicates coronary artery disease; FVC, functional vital capacity; $FEV_{1.0}$, forced expiratory volume in 1 second; $\%DL_{CO}$, percentage of diffusing capacity corrected for alveolar volume; Ad, adenocarcinoma.

were reported.

Table 5 showed the comparison of two groups excluding the patient who underwent medial basal (S7) and/or anterior basal (S8) segmentectomy. No significant intergroup differences were noted in terms of the surgical outcomes between two groups.

Discussion

Sublobar lung resection, which was a complex procedure, was applied as a compromise for patients with poor lung function and other comorbidities when formal anatomical lobectomy is contraindicated; however, sublobar lung resection has a low complication incidence and is considered an alternative for stage IA non-small cell lung cancers of ≤2 cm. Additionally, sublobar resection is technically more difficult than lobectomy and requires an intimate 3D knowledge of the relationship between the relevant bronchi and pulmonary vessels (12,13).

Remarkable progress was made in imaging technology, thereby allowing 3D processing of CT images. CT data 3D images are useful for identifying the 3D branching pattern of the pulmonary vessels and bronchi. Previously, our department reported a patient-specific virtual 3D pulmonary model for thoracoscopic lung resections (7-10) and used virtual 3D pulmonary reconstruction models by homemade software, named "CTTRY" (Tokyo Women's Medical University), for preoperative simulation. Sublobar lung resection, such as segmentectomy and subsegmentectomy, is intended to extirpate irreversible diseases with a minimal loss of functional lung tissue. Several reports demonstrated lung function preservation in sublobar lung resection compared with lobectomy (14).

Conventional segmentectomy of S9, S10, or both has an IF that cuts into the lung parenchyma between the S6 and the S8. We reported VATS segmentectomy of S9, S10, and both segments with a new approach that does not require interlobar separation, utilizing the reconstruction of patient-specific virtual 3D pulmonary models (4). The PL, which has become clearer with advanced CT technology, consists of a double serous layer of visceral pleura, which forms the intersegmental septum (4). The intersegmental septum is divided into the medial basal segment and S10 of the right lung, and S8 and S10 of the left lung, although there are exceptions (3). The PL is thus considered useful for intersegmental division of the lung parenchyma during S9, S10, and both segmentectomies (4). Several studies were published after reporting our TS of the S9, S10, and both through a PL approach (15,16). Conventional segmentectomy of S9, S10, and both are performed from the IF; thus, segmentectomy is possible without preoperative simulation. As the TS using the PL approach is not performed for the interloper separation, the surgical manipulation is considered easy during the ipsilateral second and more surgeries after the surgery.

A significant difference was noted in terms of the %DLco between the two groups. No significant difference between the two groups in terms of comorbidities was

Table 5 Comparison of excluding the patient who underwent medial basal segment and/or anterior basal segmentectomy

Variables	PL group	IF group	P value
Age, median [range] (years)	64.0 [22–82]	63.5 [44–80]	0.941
Gender, n (%)			0.026
Male	14 (34.1)	12 (66.7)	
Female	27 (65.9)	6 (33.3)	
Surgical procedure, n (%)			0.303
VATS	37 (90.2)	18 (100.0)	
RATS	4 (9.8)	0 (0)	
Conversion to open thoracotomy, n	0	0	–
Operation time, median (min)	215	187	0.141
Blood loss, median (mL)	15	15	0.908
Chest tube duration, median [range] (days)	4 [2–11]	3.5	0.688
Postoperative hospital stay, median [range] (days)	8 [5–14]	8	0.443
Intraoperative complications, n	0	0	1.000
Postoperative complications, n (%)	2 (4.9)	3 (16.7)	0.160
Persistent air leaks	1 (2.4)	3 (16.7)	0.080
Atrial fibrillation	1 (2.4)	0	0.504
30-day mortality, n	0	0	–
90-day mortality, n	0	0	–
Maximal tumor diameter, median [range] (mm)	14 [3–25]	15 [10–40]	0.153
Pathology, n (%)			0.555
Lung cancer			
Ad	18 (43.9)	7 (38.9)	
Sq	2 (4.9)	0	
Metastases	21 (51.2)	11 (61.1)	
Lymph node dissection, n (%)			0.579
1a	6 (30.0)	3 (42.9)	
1b	7 (35.0)	3 (42.9)	
2a-1	7 (35.0)	1 (14.2)	
Local recurrence, n (%)	1 (2.4)	2 (11.1)	0.218

P values were calculated by Fisher's exact test or the chi-square test for categorical data, or Mann-Whitney's U-test for continuous data. PL, pulmonary ligament; IF, interlobar fissure; VATS, video-assisted thoracoscopic surgery; RATS, robot-assisted thoracoscopic surgery; Ad, adenocarcinoma; Sq, squamous cell carcinoma.

observed, but patients in the IF group had comorbidities such as anemia and pulmonary disease. The operation time was significantly longer in the PL group than in the IF group, because the IF group included approximately 50% bilateral S8 segmentectomy. There was a difference in the difficulty of the segmentectomy performed in the two groups. No significant differences were found in the operation time between two groups excluding the patient who underwent S7 and/or S8 segmentectomy. Additionally, the IF group was operated by the qualified surgeons, whereas the PL group were operated by surgeons, including trainees, who were performing segmental resection for the first time. During the introduction phase of the TS of the PL approach, the operation time was longer because it was a surgical procedure that had not been performed before; however, the operation time has gradually decreased with experience. Indeed, the median operation time for the first and last 10 cases of the PL group in VATS were 237.5 and 188 minutes, respectively. The frequency of postoperative persistent air leaks was not significantly different in the PL group than in the IF group because the PL is incised up to the inferior pulmonary vein, thereby allowing easy basal pulmonary vein exposure. As the frequency of 30- and 90-day mortality and complications showed no significant intergroup differences, the TS using the PL approach was performed to ensure safety.

One of the key issues in performing sublobar lung resection of malignant lung tumors is the oncological outcome. No significant differences were found in the local recurrence between the two groups. Segmentectomy through a PL approach is considered one of the good surgical techniques for lung tumors of S9 or S10.

In Japan, the national health insurance began covering RATS pulmonary segmentectomy for malignant lung tumors in 2020, considering the increasing number of performed domestic RATS procedures. In this study, 5 patients (4 in the PL group and 1 in the IF group) underwent RATS in 2020. Recently, RATS segmentectomy was performed safely with excellent perioperative outcomes and safety (17-19). RATS segmentectomy is feasible compared with the conventional two-dimensional (2D) VATS segmentectomy of S9, S10, and both through a PL approach. The use of robotic surgical systems yields accurate 3D high-definition images with improved ergonomics that allow surgeons to conduct accurate and improved intuitive maneuvers, which reduces the burden on the assistant surgeon. Multijointed robotic forceps allow easy mobilization on the diaphragmatic surface of the inferior lobe to the cranial side and easy dissection of the intersegmental septum to expose the pulmonary vessels and bronchi in the RATS procedure compared with the conventional 2D VATS TS through a PL approach. Our previously reported VATS technology may confer a higher risk of incomplete lymph node dissection than the traditional procedures, while the RATS technique articulates lymphadenectomy, which is difficult to execute with thoracoscopy and can be easily performed with robotic instruments (20). In this study, lymph nodes at levels 7, 11, and 12 were dissected in the PL group. RATS removes the known physiological tremor in VATS. This results in an excellent precision level necessary for such a challenging case (20). Additionally, the RATS learning curve was reported to be shorter than the VATS learning curve (21,22). The RATS technique may be quick to master although segmentectomy of S9, S10, and both with the PL approach is extremely technically challenging (23).

As important limitations, this study was a non-randomized and retrospective single institutional study with small sample size. Hence, a larger case series and comparative study should be performed to determine the real significance of complete lower lobe TS, excluding S6 and basal segments [from the medial basal segment (S7) to S10], through the PL approach. Furthermore, as no patient underwent S7 and/or S8 segmentectomy in the PL group, there was a bias between the two groups. Local recurrences were biased because of approximately 50% of cases in the field of primary lung cancer and insufficient follow-up period in some cases.

Conclusions

In conclusion, complete TS of the lower lobe, excluding S6 and basal segments (from S7 to S10), through the PL approach is a reasonable option for tumors located in the lower lobe compared with the IF approach.

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Footnote

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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. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Research Ethics Committee of the Tokyo Women's Medical University (Nos. 4988 and 5363) and written informed consent was obtained from all patients.

References

1. Okada M, Koike T, Higashiyama M, et al. Radical sublobar resection for small-sized non-small cell lung cancer: a multicenter study. J Thorac Cardiovasc Surg 2006;132:769-75.
2. Tsutani Y, Miyata Y, Nakayama H, et al. Appropriate sublobar resection choice for ground glass opacity-dominant clinical stage IA lung adenocarcinoma: wedge resection or segmentectomy. Chest 2014;145:66-71.
3. Berkmen YM, Drossman SR, Marboe CC. Intersegmental (intersublobar) septum of the lower lobe in relation to the pulmonary ligament: anatomic, histologic, and CT correlations. Radiology 1992;185:389-93.
4. Kikkawa T, Kanzaki M, Isaka T, et al. Complete thoracoscopic S9 or S10 segmentectomy through a pulmonary ligament approach. J Thorac Cardiovasc Surg 2015;149:937-9.
5. Travis WD, Brambilla E, Nicholson AG, et al. The 2015 World Health Organization Classification of Lung Tumors: Impact of Genetic, Clinical and Radiologic Advances Since the 2004 Classification. J Thorac Oncol 2015;10:1243-60.
6. Rami-Porta R, Asamura H, Travis WD, et al. Lung cancer - major changes in the American Joint Committee on Cancer eighth edition cancer staging manual. CA Cancer J Clin 2017;67:138-55.
7. Kanzaki M, Wachi N, Onuki T. Simulating video-assisted thoracoscopic lung resection using a virtual 3-dimensional pulmonary model on a personal computer. J Thorac Cardiovasc Surg 2011;142:243-4.
8. Kanzaki M, Maeda H, Wachi N, et al. Complete video-assisted thoracoscopic multi-subsegmentectomy based on patients' specific virtual 3-D pulmonary models. Asian J Endosc Surg 2013;6:110-5.
9. Kanzaki M, Kikkawa T, Shimizu T, et al. Presurgical planning using a three-dimensional pulmonary model of the actual anatomy of patient with primary lung cancer. Thorac Cardiovasc Surg 2013;61:144-50.
10. Kanzaki M. Advanced thoracoscopic surgery to modern pulmonary disease: The Japanese approach. In: Latifi R, Rhee P, Gruessner RWG, editors. Technological Advances in Surgery, Trauma and Critical Care. New York, NY: Springer, 2015:249-60.
11. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004;240:205-13.
12. Handa Y, Tsutani Y, Mimae T, et al. Complex segmentectomy in the treatment of stage IA non-small-cell lung cancer. Eur J Cardiothorac Surg 2020;57:114-21.
13. Suzuki K, Saji H, Aokage K, et al. Comparison of pulmonary segmentectomy and lobectomy: Safety results of a randomized trial. J Thorac Cardiovasc Surg 2019;158:895-907.
14. Matsumoto T, Kanzaki M, Amiki M, et al. Comparison of three software programs for three-dimensional graphic imaging as contrasted with operative findings. Eur J Cardiothorac Surg 2012;41:1098-103.
15. Oizumi H, Kanauchi N, Kato H, et al. Anatomic thoracoscopic pulmonary segmentectomy under 3-dimensional multidetector computed tomography simulation: a report of 52 consecutive cases. J Thorac Cardiovasc Surg 2011;141:678-82.
16. Liu C, Liao H, Guo C, et al. Single-direction thoracoscopic basal segmentectomy. J Thorac Cardiovasc Surg 2020;160:1586-94.
17. Liang H, Liang W, Zhao L, et al. Robotic Versus Video-

assisted Lobectomy/Segmentectomy for Lung Cancer: A Meta-analysis. Ann Surg 2018;268:254-9.
18. Nguyen D, Gharagozloo F, Tempesta B, et al. Long-term results of robotic anatomical segmentectomy for early-stage non-small-cell lung cancer. Eur J Cardiothorac Surg 2019;55:427-33.
19. Pardolesi A, Park B, Petrella F, et al. Robotic anatomic segmentectomy of the lung: technical aspects and initial results. Ann Thorac Surg 2012;94:929-34.
20. Kanzaki M. Current status of robot-assisted thoracoscopic surgery for lung cancer. Surg Today 2019;49:795-802.
21. Kanzaki M, Mitsuboshi S, Koen A, et al. Effects of robot- and video-assisted thoracoscopic lobectomy experiences on the learning curve of lobectomy. Turk Gogus Kalp Damar Cerrahisi Derg 2021;29:527-35.
22. Bouabdallah I. Robotic left S9-10 lung segmentectomy: how I do it? J Vis Surg 2020;6:44.
23. Mitsuboshi S, Shidei H, Koen A, et al. A pulmonary ligament approach for portal robotic segmentectomy of the lateral and posterior basal segments: a case report. J Med Case Rep 2021;15:196.

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