Original Article

Uniportal thoracoscopic pulmonary segmentectomy provides good perioperative results and early postoperative recovery

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Background: Although video-assisted thoracoscopic surgery (VATS) segmentectomy has become widespread, the advantage of uniportal VATS (U-VATS) segmentectomy over multiportal VATS (M-VATS) remains controversial. The purpose of this study was to verify the safety and usefulness of U-VATS segmentectomy compared with conventional hybrid/multiportal segmentectomy.

Methods: Here, we retrospectively reviewed the data from anatomical pulmonary segmentectomy cases in a single institution from March 2010 to March 2021. Patients were divided into the U-VATS and hybrid/multiportal VATS (H/M-VATS) groups. Perioperative results were compared between the groups after matching for patient background characteristics. In addition, cases of complex segmentectomy were selected from each group and compared in terms of perioperative results.

Results: A total of 180 patients underwent pulmonary segmentectomy during the study period at this institution, comprising 57 cases in the U-VATS group and 123 cases in the H/M-VATS group. After matching for age, sex, disease, tumor location, and type of segmentectomy, no significant differences between the groups were seen in blood loss, major intraoperative bleeding, rate of conversion to thoracotomy, postoperative complications, or re-hospitalization within 30 days after discharge. Operation time (141±46 *vs.* 174±45 min, P<0.001), postoperative drainage duration (1.5±1.2 *vs.* 2.3±1.8 days, P=0.007), and postoperative hospital stay (3.4±2.0 *vs.* 4.6±2.5 days, P=0.006) were significantly lower in the U-VATS group. Subgroup analysis of the complex segmentectomy cases also revealed that operation time (146±34 *vs.* 185±47 min, P<0.001), postoperative drainage duration (1.5±1.3 *vs.* 2.2±1.2 days, P=0.021), and postoperative hospital stay (3.0±1.4 *vs.* 4.9±2.1 days, P<0.001) were significantly reduced in the U-VATS group.

Conclusions: U-VATS segmentectomy appears as safe and feasible as H/M-VATS segmentectomy. An experienced surgeon can make a smooth transition to U-VATS.

Keywords: Uniportal video-assisted thoracoscopic surgery (U-VATS); segmentectomy; complex segmentectomy

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Introduction

Uniportal video-assisted thoracoscopic surgery (U-VATS) was first introduced and applied to anatomical lung resection 10 years ago (1,2); however, its potential advantages over other VATS techniques remains controversial (3-10). A reduction in the number of wounds may help reduce postoperative pain, as well as offer cosmetic benefits

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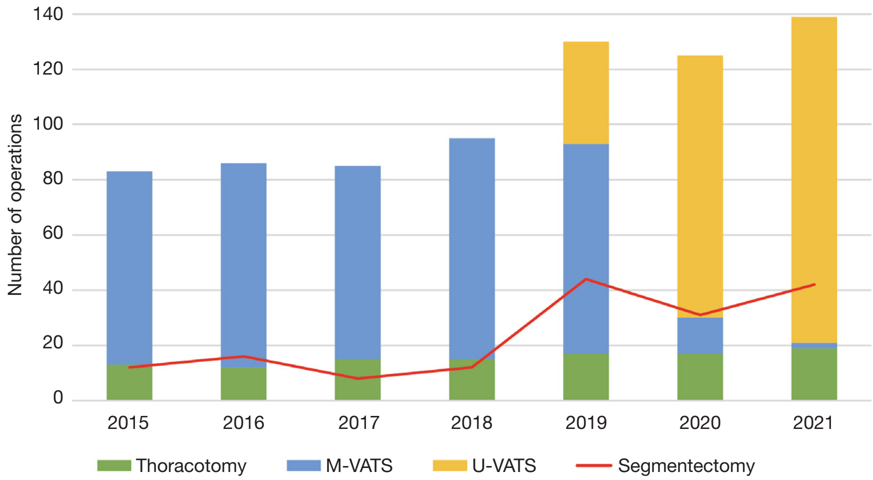

Figure 1 Number of VATS anatomical pulmonary resections per year at our institution. VATS, video-assisted thoracoscopic surgery; M-VATS, multiporal VATS; U-VATS, uniportal VATS.

(5,6,9,10), but achieving this requires specialist surgical techniques. Furthermore, recent years have seen an increase in opportunities to perform segmentectomy for early-stage primary lung cancer instead of lobectomy (11-14); therefore, more complicated surgical procedures are now required.

Segmentectomy is usually divided into single and complex segmentectomies, depending on the technical characteristics. Simple segmentectomies are relatively less challenging technically, involving the dissection of only one intersegmental plane containing the superior segment of the lower lobe (S6) and the basilar segment of each side (the left upper division and left lingual segment). Complex segmentectomies can be more challenging to perform as vessels and bronchi must be dissected to the periphery and include several intersegmental planes in three dimensions. Although several reports have described complex segmentectomy to be equally safe as simple segmentectomy (15,16), whether U-VATS complex segmentectomy can also be performed just as safely is unclear.

In our previous report in 2021 (17), we established a technique for VATS anatomical lung resection, and U-VATS anatomical lung resection has been performed since February 2019. Since, the number of cases has steadily increased (*Figure 1*). In this study, we compare the perioperative results from U-VATS segmentectomy performed at our institution with those using the conventional method [hybrid/multiportal VATS (H/M-VATS) segmentectomy], as well as evaluated the safety and usefulness of U-VATS segmentectomy. We present the following article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-555/rc).

Methods

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the institutional ethics board of Japanese Red Cross Maebashi Hospital (approval No. 2020-52). The need to obtain individual patient consent for participation in this research was waived due to the retrospective nature of the analysis.

Patient selection

Data from consecutive patients who underwent anatomical pulmonary segmentectomy for lung lesions at our institution between March 2010 and March 2021 were evaluated retrospectively. We divided the patients into the U-VATS and H/M-VATS groups. Perioperative results were compared between these groups after matching for patient background characteristics. Cases of segmentectomy were then selected from each group, and the perioperative results were compared using the same method (*Figure 2*).

The criteria for selecting patients for segmentectomy at our institution are (I) clinical stage 0–IA1 (Tis-1aN0M0) primary lung cancer confirmed by careful preoperative staging using computed tomography (CT) and/or positron emission tomography/CT (also known as intentional limited surgery); (II) clinical stage IA2–IB (T1b-2aN0M0) primary

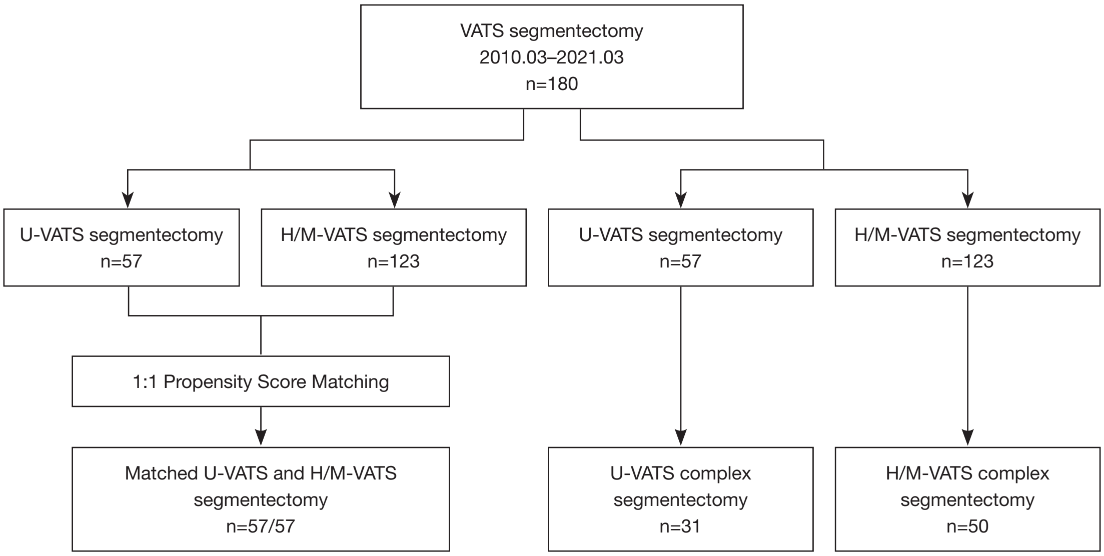

Figure 2 Flow diagram of patient selection. VATS, video-assisted thoracoscopic surgery; U-VATS, uniportal VATS; H/M-VATS, hybrid/multiportal-VATS.

lung cancer in patients who cannot tolerate radical surgery due to complications and/or poor pulmonary function (passive limited surgery); and (III) metastatic or benign lung tumors for which a sufficient margin was difficult to secure during wedge resection due to the tumor location and size.

Surgical procedures

All surgeries were performed under general anesthesia with the patient in the lateral decubitus position and under differential lung ventilation. Automatic staplers were usually used for vessel and bronchial transections, but suture ligation using 3-0 silk was performed depending on the vessel diameter or the angle of stapler insertion. For segment identification, an inflation-deflation technique or jet ventilation technique was used initially. However, after May 2020, this was replaced by intravenous administration of indocyanine green and a near infrared light thoracoscope. The intersegmental plane was divided using electrocautery or a stapler. Electrocautery was frequently used until 2015 (in almost all hybrid and a portion of multiportal cases), and the decision to use this technique was made by the surgeon. Two-thirds of the outer area in an intersegmental plane was divided by electrocautery, and the remaining deep parenchyma was further divided using staplers. The use of staplers has increased since 2016, including in the uniportal approach, in which staplers are solely used for almost all cases. Intentional limited surgery is often performed for only pure or part-solid ground-glass nodules with a size of the solid part ≤1 cm, and thus it would be uncommon to perform lymphadenectomy in these cases. In almost all cases, hilar lymph nodes were sampled.

H/M-VATS was performed mainly by three senior surgeons, two of whom also perform U-VATS. The overall surgical approach, particularly in terms of multiportal VATS (M-VATS) *vs.* U-VATS, was decided by each individual surgeon.

U-VATS procedure

U-VATS for anatomical lung resection was first used in February 2019. Details of the U-VATS procedure have been described previously (17). Briefly, the operator must stand on the ventral side of the patient with an assistant on the dorsal side. A 3.5–4.0 cm skin incision is created in the fourth or fifth intercostal space in the anterior axillary line, and an XS Alexis wound retractor (Applied Medical, Rancho Santa Margarita, CA, USA) is fitted. A 10 mm 30° thoracoscope is then fixed on the dorsal side of the wound margin, securing a space on the ventral side for the surgeon to operate using surgical instruments (*Figure 3A*). The chest drain is placed on the ventral side of the wound.

H/M-VATS procedure

At our institution, hybrid VATS was performed from 2010

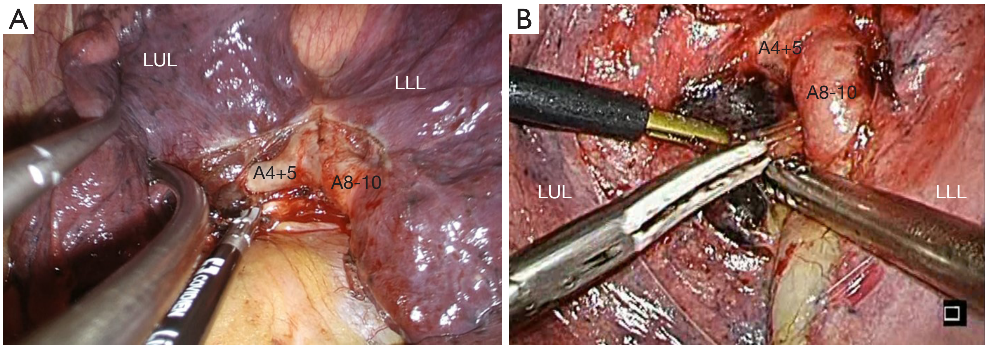

Figure 3 Surgical views of the left anterior and lingular (S3+4+5) segmentectomy. (A) U-VATS view. All instruments and thoracoscope are inserted from the same direction. (B) M-VATS view. Instruments and thoracoscope are inserted from four directions. LUL, left upper lobe; LLL, left lower lobe; VATS, video-assisted thoracoscopic surgery; U-VATS, uniportal VATS; M-VATS, multiportal-VATS.

to 2012. In this procedure, an 8.0 cm skin incision is created within the fourth or fifth intercostal space along the mid-axillary line, and the surgeon is positioned directly from the wound. A 10-mm-diameter flexible camera is inserted through a 1.5 cm skin incision in the anterior axillary line of the sixth intercostal space. A thoracic drain is placed through a port in the sixth intercostal space along the anterior axillary line.

At this institution, M-VATS for anatomical lung resection was first performed during 2012. A 2.0 cm skin incision is created in the fourth intercostal space along the anterior axillary line and a 1.5 cm skin incision in the sixth intercostal space along the anterior axillary line, and an XXS Alexis wound retractor is fixed for each wound. A 10 mm flexible camera is inserted via the 1.5 cm skin incision in the sixth intercostal space on the anterior axillary line. When four ports are used, an additional 15 mm skin incision is made in the seventh intercostal space below the scapula for use as the assistant's port (*Figure 3B*). The chest drain is placed via the port in the sixth intercostal space along the anterior axillary line.

Postoperative management

The chest drainage tube was removed after confirming both the absence of air leakage and a discharge volume of less than 300 mL. Postoperative complications were evaluated using the Common Terminology Criteria for Adverse Events (version 5.0). Major complications were defined as a requirement for additional treatment. After discharge, patients were followed up in the outpatient clinic on postoperative day 7, then again at 1 month, 3 months, and every 6 months thereafter.

Statistical analysis

Propensity score matching was performed between the U-VATS and H/M-VATS groups to minimize bias. We performed a one-to-one matching analysis between U-VATS and H/M VATS groups on the basis of estimated propensity scores of each patient. Application of propensity score matching involves estimation of the propensity score followed by matching of patients according to their estimated propensity score and comparison of outcomes in matched patients. Propensity scores were calculated using a logistic regression model that included the following variables: age, sex, disease, tumor location, and type of segmentectomy (simple or complicated).

Fisher's exact test was applied to compare categorical variables. Student's t-test and the Mann-Whitney U test were used to compare continuous variables. Values of $P<0.05$ were considered statistically significant.

All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). More precisely, EZR is a modified version of R Commander designed to add statistical functions frequently used in biostatistics.

Results

A total of 180 patients underwent pulmonary segmentectomy during the study period at this institution, comprising

Table 1 Patient characteristics of all patients and comparisons between U-VATS and H/M-VATS groups

Variables	All (n=180)	Before matching			After matching		
		U-VATS (n=57)	H/M-VATS (n=123)	P	U-VATS (n=57)	H/M-VATS (n=57)	P
Age	69.1±13	70.2±11	68.6±13	0.427	70.2±11	70.9±14	0.778
Sex, male	95 (52.8)	30 (52.6)	65 (52.8)	1.000	30 (52.6)	33 (57.9)	0.707
Disease				0.014			0.163
Primary lung cancer	110 (61.1)	42 (73.7)	68 (55.3)		42 (73.7)	49 (86.0)	
Metastatic tumor	33 (18.3)	4 (7.0)	29 (23.6)		4 (7.0)	4 (7.0)	
Others	37 (20.6)	11 (19.3)	26 (21.1)		11 (19.3)	4 (7.0)	
Tumor location				0.169			0.948
Right upper lobe	38 (21.1)	17 (29.8)	21 (17.1)		17 (29.8)	15 (26.3)	
Right lower lobe	53 (29.4)	18 (31.6)	35 (28.5)		18 (31.6)	17 (29.8)	
Left upper lobe	62 (34.4)	15 (26.3)	47 (38.2)		15 (26.3)	18 (31.6)	
Left lower lobe	27 (15.0)	7 (12.3)	20 (16.3)		7 (12.3)	7 (12.3)	
Kinds of segmentectomy				0.107			1.000
Simple	–	26 (45.6)	73 (59.3)		26 (45.6)	27 (47.4)	
Complex	–	31 (54.4)	50 (40.7)		31 (54.4)	30 (52.6)	

Data are shown as number (%) or mean ± standard deviation. VATS, video-assisted thoracoscopic surgery; U-VATS, uniportal VATS; H/M-VATS, hybrid/multiportal-VATS.

57 cases in the U-VATS group and 123 cases in the H/M-VATS group (*Figure 2*). The characteristics of all patients (95 males, 52.8%; 85 females, 47.2%; mean age, 69.1 years; range, 29–84 years) are shown in *Table 1*. There were 110 cases of primary lung cancer, consisting of 62 and 48 cases that received intentional and passive limited surgery, respectively. Before matching, there were slightly more patients with primary lung cancer in the U-VATS group than H/M-VATS group (P=0.014). After matching for age, sex, disease, tumor location and segmentectomy subtype, the two groups were compared (*Table 1*).

Comparison of perioperative outcomes between the U-VATS and H/M-VATS groups after matching

A comparison of the perioperative outcomes between the U-VATS and H/M VATS groups after matching are shown in *Table 2*. The operation time was significantly shorter in the U-VATS group than H/M VATS group (141±46 *vs.* 174±45 min, P<0.001). The postoperative drainage duration (1.5±1.2 *vs.* 2.3±1.8 days, P=0.007) and postoperative hospital stay (3.4±2.0 *vs.* 4.6±2.5 days, P=0.006) were also significantly shorter in the U-VATS group. There were no significant differences in the rates of blood loss, major intraoperative bleeding, conversion to thoracotomy, postoperative complications, or re-hospitalization within 30 days after discharge.

Postoperative complications occurred in five patients (8.8%) within the U-VATS group and three patients (5.3%) within the H/M-VATS group, including atrial fibrillation in one patient, prolonged air leakage in three patients, delayed pneumothorax in two patients, and hypoxemia in two patients.

Comparison of perioperative outcomes between U-VATS and H/M-VATS complex segmentectomies

The sites of the resected complex segmentectomies in each group are shown in *Table 3*. There was no significant difference in the resected segment site between the groups. The perioperative outcomes of U-VATS and H/M-VATS complex segmentectomies are compared in *Table 4*. The operation time was significantly shorter in the U-VATS group than H/M-VATS group (146±34 *vs.* 185±47 min, P<0.001). The duration of postoperative drainage (1.5±1.3 *vs.* 2.2±1.2 days, P=0.021) and postoperative hospital stay

Table 2 Comparison of perioperative results between U-VATS and H/M-VATS segmentectomy after propensity score matching

Variables	U-VATS (n=57)	H/M-VATS (n=57)	P
Operative time (min)	141±46	174±45	<0.001
Blood loss (mL)	41±83	28±45	0.288
Intraoperative significant bleeding	4 (7.0)	6 (10.5)	0.742
Conversation to thoracotomy	3 (5.3)	1 (1.8)	0.618
Postoperative drainage (days)	1.5±1.2	2.3±1.8	0.007
Postoperative hospital stay (days)	3.4±2.0	4.6±2.5	0.006
Postoperative complications	5 (8.8)	3 (5.3)	0.716
Re-hospitalization within 30 days of discharge	1 (1.8)	1 (1.8)	1.000

Data are shown as mean ± standard deviation or number (%). VATS, video-assisted thoracoscopic surgery; U-VATS, uniportal VATS; H/M-VATS, hybrid/multiportal-VATS.

Table 3 Locations of resected segments in complex segmentectomy

Variables	U-VATS (n=31)	H/M-VATS (n=50)	P
Locations			0.660
Left side, n (%)	7 (22.6)	18 (36.0)	
Upper lobe	7 (22.6)	16 (32.0)	
S1+2	3 (9.7)	9 (18.0)	
S3	3 (9.7)	5 (10.0)	
S3+4+5	1 (3.2)	2 (4.0)	
Lower lobe	0	2 (4.0)	
S8+9	0	1 (2.0)	
S9+10	0	1 (2.0)	
Right side, n (%)	24 (77.4)	32 (64.0)	
Upper lobe	16 (51.6)	21 (42.0)	
S1	3 (9.7)	2 (4.0)	
S1+3	3 (9.7)	0	
S2	6 (19.4)	8 (16.0)	
S3	4 (12.9)	7 (14.0)	
Others including subsegment	0	4 (8.0)	
Lower lobe	8 (25.8)	11 (22.0)	
S7+8	1 (3.2)	2 (4.0)	
S7+8+9	1 (3.2)	0	
S8	1 (3.2)	0	
S8+9	0	1 (2.0)	
S9+10	5 (16.1)	8 (16.0)	

VATS, video-assisted thoracoscopic surgery; U-VATS, uniportal VATS; H/M-VATS, hybrid/multiportal-VATS.

(3.0±1.4 *vs.* 4.9±2.1 days, P<0.001) were also significantly shorter in the U-VATS group. There were no significant differences in the rates of blood loss, major intraoperative bleeding, rate of conversion to thoracotomy, postoperative complications, or re-hospitalization within 30 days after discharge.

Postoperative complications occurred in three patients (9.7%) in the U-VATS group and four patients (8.0%) in the H/M-VATS group and comprised prolonged air leak in four patients, delayed pneumothorax in one patient and hypoxemia in two patients.

Oncological outcomes in primary lung cancer patients

During the observation period, seven patients developed lung cancer recurrence, comprising local recurrence in five patients (staple line recurrence in three patients and ipsilateral intrathoracic lymph nodes metastasis in two patients) and distant metastasis in two patients. All seven patients were in the H/M-VATS group, and only one underwent intentional limited surgery.

Discussion

The recent transition at our institution from hybrid to M-VATS and subsequently to U-VATS has been successful, and U-VATS segmentectomy has been performed without the problems often associated with other VATS procedures, even in cases requiring complex segmentectomy. The postoperative complication rates were quite low, thereby enabling an early recovery.

Table 4 Comparison of the perioperative results between U-VATS and H/M-VATS complex segmentectomy

Variables	U-VATS (n=31)	H/M-VATS (n=50)	P
Operation time (min)	146±34	185±47	<0.001
Blood loss (mL)	17±34	34±52	0.120
Intraoperative significant bleeding	0	4 (8.0)	0.292
Conversation to thoracotomy	0	2 (4.0)	0.522
Postoperative drainage (days)	1.5±1.3	2.2±1.2	0.021
Postoperative hospital stay (days)	3.0±1.4	4.9±2.1	<0.001
Postoperative complications	3 (9.7)	4 (8.0)	1.000
Re-hospitalization within 30 days of discharge	1 (3.2)	2 (4.0)	1.000

Data are shown as mean ± standard deviation or number (%). VATS, video-assisted thoracoscopic surgery; U-VATS, uniportal VATS; H/M-VATS, hybrid/multiportal-VATS.

Several previous reports have indicated reduced invasiveness of pulmonary segmentectomy compared with lobectomy, with equal oncological outcomes (11-14). Therefore, the use of pulmonary segmentectomy for small-sized non-small cell lung cancer is expected to increase. However, the results of a Japanese randomized control trial comparing lobectomy with segmentectomy (JCOG0802/WJOG4607L) (18) are awaiting publication. Since the advantages of pulmonary segmentectomy are now known, this surgical procedure should be performed via not only minithoracotomy or the conventional multiportal approach but also the uniportal approach, which is emerging worldwide. Our results indicate that U-VATS pulmonary segmentectomy is feasible. Moreover, complex segmentectomy, which is considered technically difficult, was also safely performed in this study. Thus, highly experienced surgeons can perform any type of segmentectomy appropriately via the uniportal approach.

The U-VATS group showed superior results to the H/M-VATS group, specifically with regards to operative time. Many previous reports comparing perioperative outcomes between U-VATS and M-VATS revealed that operative time is often faster with U-VATS. It was therefore concluded that U-VATS is a more useful approach than M-VATS, although U-VATS is still considered technically difficult due to interference among instruments and the limited insertion angles caused by inserting all instruments including the thoracoscope from a single small wound (19-22). However, in many of those studies, U-VATS was established after heavy use of thoracotomy or M-VATS. This may cause a bias in the U-VATS results due to a relatively recent learning curve. Our previous study demonstrated the learning curve of thoracoscopic lobectomy for in a single surgeon, and we conclude that implementation of U-VATS dose not negatively affect the learning curve of thoracoscopic lobectomy (23). Nevertheless, it is difficult to empirically determine if U-VATS is superior to M-VATS as a thoracoscopic approach considering that U-VATS was not performed until a later time period. Therefore, we focused on assessing whether U-VATS can be implemented successfully with not only lobectomy but also segmentectomy.

Postoperative drainage duration and postoperative hospital stay were both significantly shorter in the U-VATS group. This is likely because postoperative management has been more aggressive in recent years. For example, earlier removal of the drainage tube and shorter hospital stay are now recommended. Early removal of the chest drainage tube after lung resection has been reported to reduce postoperative pain and improve respiratory function, and is thought to help improve respiratory status and prevent complications (24,25). Therefore, regardless of the thoracotomy type (M-VATS *vs.* U-VATS), drainage tubes are now removed earlier. Changes in the method of intersegmental division might also have an effect. Electrocautery was often used in the H/M-VATS group, and as reported before (26), this may have affected the difference in drainage duration. Moreover, the enhanced recovery after surgery program (a multidisciplinary clinical care bundle that optimizes pre-, intra-, and postoperative care) was adopted by this institution in 2015, and it may have also contributed to early postoperative recovery and shorter hospitalization. Another important factor is the potential for reduced postoperative pain with U-VATS. As reported previously (27), U-VATS creates only a small wound in the anterior axillary line, which has a relatively wide intercostal space and may therefore produce less pressure on the intercostal nerves, leading to reduce postoperative pain compared with M-VATS, which creates a second wound in the posterior axillary line. Reduced postoperative pain may in turn lead to an earlier recovery and a shortened hospital stay.

There are a few important limitations to this study. First, this was a retrospective, single-center, observational cohort study. Second, since the research period was >10 years, perioperative results were affected by the proficiency of the surgeons and changes in perioperative management, as stated above. Third, after the introduction of U-VATS in 2019, the decision of whether to use U-VATS *vs.* M-VATS was made by each surgeon for each case, so selection bias may have been present. Finally, due to the short follow-up in the U-VATS group, long-term prognoses could not be examined. In the case of intentional limited surgery for malignant diseases, proving curability is important.

In conclusion, U-VATS segmentectomy appears as safe and feasible as H/M-VATS segmentectomy, even for complex segmentectomy cases. An experienced surgeon can make a smooth transition to U-VATS. A larger number of cases from multiple centers should be examined, with further investigation into long-term prognosis.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-555/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-555/dss

Peer Review File: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-555/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-555/coif). HI serves as an unpaid editorial board member of *Journal of Thoracic Disease* from August 2020 to July 2022. The other authors have no conflicts of interest to declare.

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 institutional ethics board of Japanese Red Cross Maebashi Hospital (No. 2020-52), The need to obtain individual patient consent for participation in this research was waived due to the retrospective nature of the analysis.

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