Uniportal versus Multiportal Thoracoscopic Complex Segmentectomy: Propensity Matching Analysis

Ying-Yuan Chen, MD, Wei-Li Huang, MD, Chao-Chun Chang, MD, Yi-Ting Yen, MD, PhD, and Yau-Lin Tseng, MD, PhD

Purpose: Uniportal video-assisted thoracoscopic surgery (VATS) complex segmentectomy has been challenging for thoracic surgeons. This study was designed to compare the perioperative outcomes between uniportal and multiportal VATS complex segmentectomy.
Methods: Data on a total of 122 uniportal and 57 multiportal VATS complex segmentectomies were assessed. Propensity score (PS) matching yielded 56 patients in each group. A crude comparison and PS matching analyses, incorporating preoperative variables, were conducted to elucidate the short-term outcomes between uniportal and multiportal VATS complex segmentectomies.
Results: The uniportal group had a significantly shorter operation time (173 min vs. 195 min, $p = 0.004$), pleural drainage duration (2.5 d vs. 3.5 d, $p <0.001$), and postoperative hospital stay (4.2 d vs. 5.3 d, $p <0.001$) before matching, and a significant difference was also observed after matching for pleural drainage duration (2.5 d vs. 3.6 d, $p <0.001$) and postoperative hospital stay (4.5 d vs. 5.2 d, $p = 0.001$). The numbers of dissected lymph nodes in N1 and N2 stations, the intraoperative and postoperative complication rates were not significantly different between these two groups.
Conclusions: The uniportal VATS complex segmentectomy was not inferior to multiportal VATS in terms of perioperative outcomes and therefore should be considered as a viable surgical approach for treatment.

Keywords: complex segmentectomy, multiportal, propensity score, uniportal, video-assisted thoracoscopic surgery

Introduction

Segmentectomy, a lung parenchyma-preserving surgery, may be performed in those with pulmonary infectious diseases, for certain patients needing metastasectomy and for treatment of early stage lung cancer.[1,2] Traditionally, segmentectomies can be subdivided into simple and complex. Complex segmentectomy is getting more and more importance because it can be used to tailor the range of pulmonary resection, especially for small lung lesions. However, the dissection of the bronchovascular structure and division of the parenchyma in complex segmentectomy can be quite difficult and challenging for surgeons.[3,4]

Uniportal video-assisted thoracoscopic surgery (UP-VATS) has developed rapidly worldwide in recent decades. Although UP-VATS has the advantages of better cosmetic incision and faster recovery, it is generally believed that the dexterity and fineness of instrument operation under UP-VATS are more limited than those under multiportal VATS (MP-VATS).[5] There are currently

uncertainties regarding whether complex segmentectomies using the UP-VATS technique can be done with similar outcomes as those achieved using MP-VATS. The literature is currently limited on comparisons between these two approaches. Therefore, in the present study, we aimed to compare the perioperative results of UP-VATS and MP-VATS complex segmentectomies.

Materials and Methods

We reviewed the institutional surgical database that was established prospectively from 2002. A total of 221 patients underwent VATS complex segmentectomies in the period from July 2010 to July 2017. We limited the inclusion criteria to unilateral and single anatomical resection in each operation. Patients who had synchronous double anatomical resection, concurrent bilateral surgery, and repeated surgery in the same hemithorax were excluded (**Fig. 1**). For propensity score (PS) matching, the patients without a preoperative pulmonary function test (within 3 months before surgery) were excluded as well. A complex segmentectomy is defined as a segmentectomy that is other than a simple segmentectomy. Demographics (age and gender), underlying diseases, pulmonary function, and perioperative data (operation time, blood loss, complications, duration of pleural drainage, and duration of postoperative hospital stay) were recorded. Charlson comorbidity index (CCI) was used to assess the comorbidity severity, and was categorized into four levels, based scores 0, 1–2, 3–4, and ≥5, for analysis. The use of an increased number of access ports, converting to open thoracotomy, and unplanned changes from segmentectomy to lobectomy were all viewed as conversion. The American Joint Committee on Cancer (AJCC) 8th edition classification was used for staging primary lung cancer. This study was approved by the Institutional Review Board of our hospital (B-ER-105-406).

Surgical technique

All patients were operated on under general anesthesia with selective one lung ventilation. The method used for UP-VATS was that used in previous work. For MP-VATS, one or two additional 1.5 cm ports were created for the thoracoscope (6th or 7th ICS, mid-axillary line) and for assistance (5th or 6th intercostal space (ICS), posterior axillary line).

Segmentectomy is defined as resection of the target segment after dividing the segmental pulmonary bronchus and artery, and selectively, the inter- and intra-segmental pulmonary veins. The bronchus was transected using a
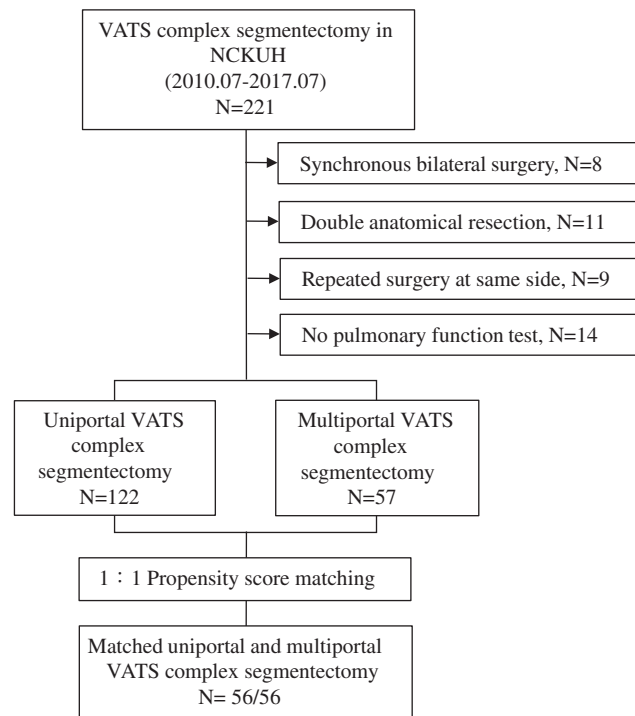

Fig. 1 The flow chart of patient selection.

stapler device (Endo-GIA, Covidien, Mansfield, MA, USA, or Endo-cutter, Ethicon Endo-Surgery, Guaynabo, Puerto Rico, USA). The intersegmental plane was demarcated using an inflation-deflation method. The stapling method was used to carry out the segmentectomy to minimize air leakage from the lung parenchyma. Sealant tissue glue or biosynthetic sheets were rarely used.

Statistical analysis

PS analysis was conducted using logistic regression to create a PS for each of the patients. We matched patients in two groups who had the closest PS in sum. The variables used to estimate the PS were age, gender, body mass index (BMI), the percentage of forced expiratory volume in 1 second (FEV1) to its predicted value (FEV1%), and the CCI.

For clinical data, the continuous variables were presented as means ± standard deviations and the categorical variables were presented as frequencies (%). Differences between the UP-VATS and MP-VATS groups were determined both before and after PS matching. The statistical methods used for comparison were the t-test and the Mann–Whitney U test for continuous variables and the chi-square test and the Fisher's exact test for categorical variables. A p value less than 0.05 indicated a significant difference. IBM SPSS Statistics for Windows, version 19.0 (IBM Corp., Armonk, NY, USA), was used for analysis.

Table 1 Demographic data of uniportal and multiportal VATS complex segmentectomy

Variables	All (N = 179)	Before matching			After matching		
		Uniportal (N = 122)	Multiportal (N = 57)	*p* Value	Uniportal (N = 56)	Multiportal (N = 56)	*p* Value
Age (years)[a]	59.3 ± 3.3	60.6 ± 12.7	56.7 ± 14.4	0.067	56.4 ± 14.1	56.5 ± 14.5	0.974
Male gender[a]	83 (46.4)	57 (46.7)	26 (45.6)	>0.999	24 (42.9)	25 (44.6)	>0.999
Surgical indication				0.081			0.249
Primary lung cancer	112 (62.5)	83 (74.1)	29 (50.9)		36 (64.3)	28 (50.0)	
Metastasis	13 (7.3)	7 (5.7)	6 (10.5)		6 (10.7)	6 (10.7)	
Benign disease	54 (30.2)	32 (26.2)	22 (38.6)		14 (25.0)	22 (39.3)	
Pulmonary function							
FEV1 (L)	2.30 ± 0.71	2.38 ± 0.74		0.309	2.37 ± 0.84	2.38 ± 0.75	0.947
FEV1%[a]	97.0 ± 16.3	96.8 ± 16.7		0.812	94.5 ± 17.7	97.6 ± 15.7	0.315
CCI[a]				0.962			0.763
0	82 (45.8)	56 (45.9)	26 (45.5)		25 (44.6)	26 (46.4)	
1–2	63 (35.2)	42 (34.4)	21 (36.8)		18 (32.1)	21 (37.5)	
3–4	22 (12.3)	16 (13.1)	6 (10.5)		6 (10.8)	5 (8.9)	
≥5	12 (6.7)	8 (6.6)	4 (7.0)		7 (12.5)	4 (7.2)	
BMI[a]	23.9 ± 3.5	23.7 ± 3.4	24.3 ± 3.5	0.237	24.0 ± 2.8	24.1 ± 3.0	0.893

[a]Variables used for estimating propensity score. BMI: body mass index; CCI: Charlson comorbidity index; FEV1: forced expiratory volume in 1 second; VATS: video-assisted thoracoscopic surgery

Results

A total of 179 patients who underwent VATS complex segmentectomies were included; the mean patient age was 59.3 years and females (53.6%) were slightly predominant (**Table 1**). There were 122 (68.2%) cases in the UP-VATS group and 57 (31.8%) cases in MP-VATS group. The PS matching yielded 56 patients in each group. Before matching, there was a tendency for older age (*p* = 0.067) in the UP-VATS group, higher rate of primary lung cancer and less benign disease (*p* = 0.081). After matching, the two groups were more comparable in terms of baseline characteristics (**Table 1**). The distribution of complex segmentectomies is detailed in **Table 2**.

Perioperative outcomes

The UP-VATS group had a shorter operation time (*p* = 0.004), shorter duration of pleural drainage (*p* <0.001), and shorter postoperative hospital stay (*p* <0.001) before matching (**Table 3**). The difference in operation time did not reach statistical significance after matching; however, the duration of pleural drainage (*p* <0.001) and postoperative hospital stay (*p* <0.001) still were significantly shorter in the UP-VATS groups. The blood loss, intraoperative, and postoperative complication rates were all comparable between the two groups before and after matching. There was no 30-day mortality in both groups.

There were six (3.4%) intraoperative complications; five vascular injuries and one adjacent segmental bronchial injury. All the five vascular injuries (four in UP-VATS and one in MP-VATS) were controlled and repaired thoracoscopically without any conversion. However, bronchial injury (in the UP-VATS group) resulted in only one case of conversion from segmentectomy to lobectomy. The postoperative complication rate was 6.1% (11/179). The most common complication was prolonged air leakage and massive subcutaneous emphysema (N = 9), followed by pulmonary infections (N = 4). The intraoperative and postoperative complication rates were not significantly different between the UP-VATS and MP-VATS groups both before and after matching.

Lung cancer subgroup

More than 90% of our cases had adenocarcinoma based on histology and the majority (90%) had stage 0 or IA; the distribution was similar in the UP-VATS and MP-VATS groups. The tumor sizes were smaller in the UP-VATS group without statistically significant differences after matching (*p* = 0.120). The number of N1 and N2 lymph nodes yielded intraoperatively was similar in both groups.

Discussion

This study compared the perioperative outcomes of patients who underwent UP-VATS and MP-VATS complex segmentectomies. By PS matching between these two groups, we showed that the UP-VATS groups had

Table 2 The location of resected complex segments

	Uniportal		Multiportal	
	Right	Left	Right	Left
RUL/LUL				
RS^1/LS^{1+2}a+b	23	9	11	1
RS^{1}a	2			
RS^2/LS^{1+2}c	18	3	21	2
S^3	2	1	3	1
RS^1+S^2/LS^{1+2}	6	11	2	3
S^1+S^{2}a	3			
LS^{1+2}a+b +S^3		1		
RS^{1}a+S^2			2	
RS^{1}a+S^{2}a	5			
RS^2+S^{3}a	1			
RS^{2}b	1			
RS^{2}b+S^{3}a	2			
LS^{1+2}c +S^4+S^5		1		
S^3+S^4+S^5			1	
LS^{1+2}+S^3+S^6		1		
RML				
S^4	2		1	
S^5	1		1	
RLL/LLL				
S^6+S^9+S^{10}			1	
S^{6}a+b	2			
S^{6}c		1		
RS^8	1			
S^9	2			
S^{10}	3			1
RS^7+S^8 or LS^{7+8}	5	2	1	1
RS8^b			1	
LS^{7+8}a				1
LS^{7+8}+S^9		1		
LS^{7+8}a+S^9+S^{10}		1		
RS^8+S^9	3			
S^9+S^{10}	5	3	1	1
Total	87	35	46	11

LLL: left lower lobe; LS: left lung segment; LUL: left upper lobe; RLL, right lower lobe; RML: right middle lobe; RS: right-lung segment; RUL: right upper lobe; S: segment

similar operation time, blood loss, intraoperative and postoperative complication rates, but shorter duration of pleural drainage and postoperative hospital stay. The UP-VATS group also yielded similar numbers of both N1 and N2 lymph nodes than the MP-VATS group according to primary lung cancer subgroup.

The first case of UP-VATS segmentectomy was published in 2012 and since then, some series have been reported.[6–9] A few studies have had compared UP-VATS and MP-VATS segmentectomies.[10,11] The results of a study by Shih et al., comprising 52 UP-VATS and 46 MP-VATS segmentectomies, showed that wound length was the only better outcome with UP-VATS segmentectomies while other perioperative outcomes were comparable between groups.[10] Han et al.[11] reported that patients with UP-VATS segmentectomies had fewer postoperative complications and shorter postoperative hospital stay in an analysis of 34 UP-VATS versus 11 MP-VATS segmentectomies. However, the number of complex segmentectomies in past studies has been limited. There were 179 complex segmentectomies assessed in our study and to our knowledge, largest number evaluated thus far. In addition, our complex segmentectomies covered a variety of spectrums, from single segmentectomies to combined subsegmentectomies, distributed in each lobe, especially in the UP-VATS group.

Compared with simple segmentectomies, complex segmentectomies have a high degree of anatomical bronchial

Table 3 Perioperative outcome of uniportal and multiportal VATS complicated segmentectomy

Variables	All (N = 179)	Uniportal (N = 122)	Multiportal (N = 57)	p Value	Uniportal (N = 56)	Multiportal (N = 56)	p Value
Operation time (min)	180 ± 68.2	173 ± 53	195 ± 50	0.004*	175 ± 52	192 ± 46	0.057
Estimated blood loss (mL)	66 ± 101	61 ± 98	79 ± 109	0.204	71 ± 122	77 ± 109	0.373
Histology[a]				0.998			
Adenocarcinoma	104 (92.8)	77 (92.8)	27 (93.1)				
SqCC	4 (3.6)	3 (3.6)	1 (3.4)				
Others	4 (3.6)	3 (3.6)	1 (3.4)				
Pathologic stage[a]				0.716			
0	22 (19.6)	18 (21.7)	4 (13.8)				
IA	77 (68.8)	55 (66.3)	22 (75.9)				
IB	10 (8.9)	7 (8.4)	3 (10.3)				
IIIA	2 (1.8)	2 (2.4)	0				
yIA	1 (0.9)	1 (1.2)	0				
Tumor size (cm)[a]		1.36 ± 0.8	1.8 ± 1.5	0.033*			
Numbers of dissected LN[a]							
N2		14.8 ± 9.7	13.6 ± 8.8	0.734			
N1		6.2 ± 5.1	7.0 ± 5.7	0.522			
Intraoperative complication	6 (3.4)	5 (4.1)	1 (1.8)	0.666	4 (7.1)	1 (1.8)	0.364
Conversion	1 (0.9)	1 (0.8)	0	>0.999	0	0	–
Postoperative complication	11 (9.8)	5 (4.1)	6 (10.5)	0.095	2 (3.6)	6 (10.7)	0.271
Pleural drainage (day)	2.9 ± 2.1	2.5 ± 2.0	3.5 ± 2.2	<0.001*	2.5 ± 1.9	3.6 ± 2.2	<0.001*
Postoperative stay (day)	4.5 ± 3.5	4.2 ± 3.8	5.3 ± 2.6	<0.001*	4.5 ± 5.2	5.2 ± 2.6	0.001*

[a]Only primary lung cancer cases were analyzed. *Significant difference. LN: lymph node; SqCC: squamous cell carcinoma; VATS:video-assisted thoracoscopic surgery.

and vascular complexities making structures difficult to identify intraoperatively. Moreover, the boundaries for simple segments are generally planar, whereas the boundaries of complex segments are often in multiple directions.[3] Therefore, it can be more difficult to divide complex segments when instruments are operated in a single direction or are limited by angle changes as seen in UP-VATS. However, the results of our study showed that the UP-VATS complex segmentectomy group was not inferior to the MP-VATS group in terms of operation time and intraoperative complications; the operation time even had a shorter trend. These findings may be because those in the MP-VATS group were treated relatively earlier in our practice. However, this also shows that with accumulated experience and familiarity with anatomy and operation techniques, the results of UP-VATS were not worse than those with MP-VATS. The results here suggest that the dexterity in dissecting and stapling in complex segmentectomy was not influenced greatly in implementing the uniportal VATS approach.

For one-way access in UP-VATS, it is important to dissect the surrounding lung tissue away from the root of target segmental bronchus and vessels as completely as possible so that the bronchovascular bundle can be rotated or twisted to compensate the limitation in access angle for linear stapler. It is better to ligate target segmental blood vessels and bronchi directly with tie, if a linear stapler is difficult to be applied to them. It is better to directly use energy devices to treat the intersegmental plane at the target segmental hilum. Once the distal stumps of transected bronchus and vessels are dragged distantly from the hilum, the remaining intersegmental plane usually can be stapled easily.

The intraoperative and postoperative complication rates were similar between the SP-VATS and MP-VATS groups. Although there were slightly more intravascular injuries in UP-VATS, but it did not reach significance. In fact, the surgical data of UP-VATS are collected prospectively from the first operation. Therefore, some small blood vessel injuries that may have been overlooked and not recorded in the surgical records in the past will also be truthfully presented. At the same time, as segmentectomy becomes more and more complicated, the blood vessels must be dissected more finely, so some small vascular injuries are prone to occur, some are avulsion injuries caused by pulling, and some are thermal injuries caused by energy devices. But these small injuries can almost be controlled by direct compression or suture, so there is no need to convert to MP-VATS. The UP-VATS

group had less chest tube drainage time and shorter hospital stay, though the criteria for chest tube removal changed with time. UP-VATS complex segmentectomies appeared to be performed safely and had comparable perioperative results if surgeons had enough experience. However, it should be remembered that never be hesitated to convert to MP-VATS or thoracotomy surgery if encounter a situation where the operation cannot be performed safely with SP-VATS.

Oncological adequacy is a major concern in cancer surgery. The prognosis of patients who undergo lobectomies versus segmentectomies for primary lung cancer less than 2 cm has been shown to be similar[12–14] and that of complex versus simple segmentectomies was also comparable.[3,15] For UP-VATS, we yielded similar stations and numbers of mediastinal LNs as for when we performed MP-VATS. Our results demonstrated that oncological adequacy was not compromised by UP-VATS, although long-term results are required to confirm this finding. From our perspective, the prognosis of patients with primary lung cancer will likely be comparable among those who undergo UP-VATS versus MP-VATS for complex segmentectomies if the extent of resection and radicality of lymph node dissection are similar.

This study was a monocentric retrospective study. We used a PS matching method to reduce baseline differences between the two groups; however, there were still some limitations. The MP-VATS group had an earlier operative period, less cases, relatively simple, and less variation in type of segmentectomy. It was difficult matching these two groups in terms of location and type of segmentectomy. The surgeries were done by different surgeons with different experiences, but more than of the surgeries were done by Y-L Tseng in both groups. The results may not be influenced a lot by this factor. Postoperative pain is also an important parameter of the quality of the operation. But because the earlier cases of MP-VATS lacked pain scale evaluation, we did not include it in this analysis. A prospective and randomized study design is required for a more comprehensive and accurate comparison.

Conclusion

Our results demonstrated that the UP-VATS complex segmentectomy could be performed safely by experienced thoracic surgeons, and results were not inferior to MP-VATS. Oncological principles were not compromised significantly; however, long-term results still require investigation.

Acknowledgments

Disclosure Statement

The authors declared no conflict of interest.

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