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Uniportal versus multiportal video-assisted thoracoscopic surgery does not compromise the outcome of segmentectomy

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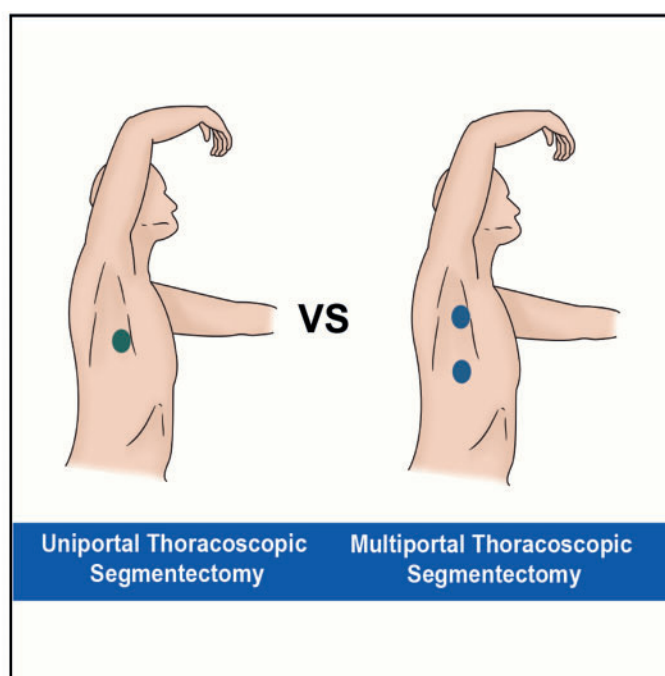
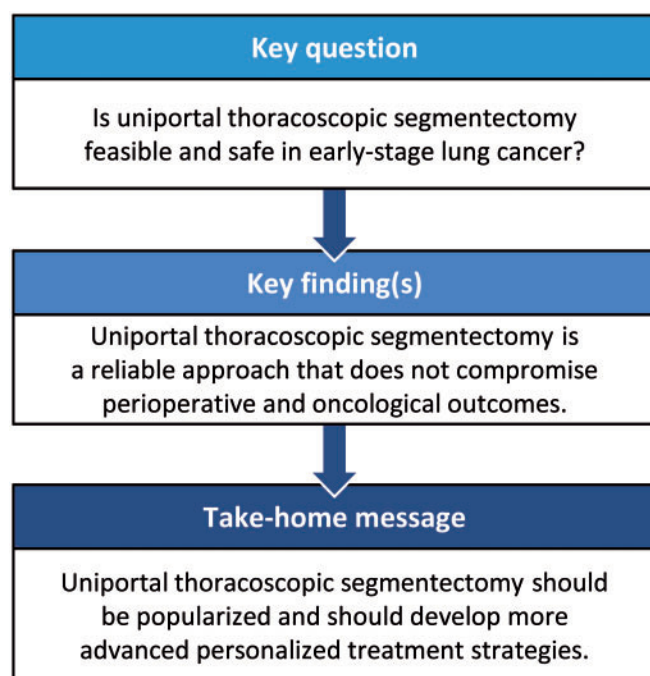
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Abstract



OBJECTIVES: The goal of this study was to compare the feasibility and safety of uniportal thoracoscopic segmentectomy (UTS) with that of multiportal thoracoscopic segmentectomy (MTS).

METHODS: From January 2014 to December 2015, a total of 1056 patients who underwent thoracoscopic segmentectomy were identified, including 375 and 681 who had simple and complex segmentectomies, respectively. A propensity matched analysis was applied to compare perioperative indicators. Survival outcomes, which included disease-free survival and overall survival, were assessed by Kaplan–Meier estimates and Cox hazards regression analysis.

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RESULTS: Propensity matching generated 454 paired patients for the UTS and MTS cohorts; the perioperative results were comparable. Survival analysis indicated that the surgical approach (UTS versus MTS) was not an independent risk factor in either disease-free survival ($P=0.247$) or overall survival ($P=0.870$) of patients with invasive adenocarcinoma. A shorter operative time was observed in patients who had a UTS ($P<0.001$) or an MTS ($P=0.011$) via a simple segmentectomy compared with those who had a complex segmentectomy. Moreover, 147 and 266 corresponding cases were selected to compare the UTS and MTS in the simple and complex segmentectomy groups, respectively. MTS showed slightly longer operative times (119 vs 108 min; $P=0.007$) and drainage duration ($P=0.010$) in the simple segmentectomy group. In contrast, UTS was associated with statistically longer operative times (141 vs 133 min; $P=0.016$) in the complex segmentectomy group.

CONCLUSIONS: Although minor differences could be found in the simple and complex segmentectomy groups, respectively, these results were clinically irrelevant. Our study supports UTS as a feasible and safe surgical technique.

Keywords: Segmentectomy U-VATS M-VATS

ABBREVIATIONS

BMI	Body mass index
CI	Confidence interval
CT	Computed tomography
DFS	Disease-free survival
HR	Hazard ratio
MTS	Multiportal thoracoscopic segmentectomy
OR	Odds ratio
OS	Overall survival
UTS	Uniportal thoracoscopic segmentectomy
VATS	Video-assisted thoracoscopic surgery

INTRODUCTION

An analysis of patients with stage IA non-small-cell lung cancer showed that both the incidence of small non-small-cell lung cancer (≤ 2 cm) and the use of segmentectomy are increasing with the widespread screening of low-dose helical computed tomography (CT), which was based on the Surveillance, Epidemiology, and End Results database (1998–2009) [1]. Meanwhile, several investigators supported the idea that segmentectomy possessed comparable efficacy with lobectomy in selected patients over the past dozen years [2, 3]. With the impressive advancement of surgical instruments and techniques, video-assisted thoracoscopic surgery (VATS) had been widely accepted as a safe and effective surgical approach instead of conventional thoracotomy [4]. Controversy existed with regard to the numbers of ports in thoracoscopic approaches, although VATS was associated with shorter hospital stays, fewer complications and decreased short-term postoperative pain [5, 6]. Previous studies implied that the uniportal thoracoscopic approach could reduce the operative time and intraoperative blood loss [5–7]. Nevertheless, these studies focused mainly on patients who had a lobectomy. A comparison of uniportal thoracoscopic segmentectomy (UTS) versus multiportal thoracoscopic segmentectomy (MTS) based on a large-scale data set has never been performed.

According to the surgical procedure and the number and form of intersegmental planes, segmentectomy could be further categorized into simple and complex segmentectomy [8–10]. The resection of segments right S6, left S6 and left upper division (S1–3) and the lingula segments (S4–5) was defined as simple segmentectomy. Complex segmentectomy included the resection of segments other than those covered by a simple segmentectomy. Two independent retrospective studies recently showed that

complex segmentectomy was a safe operation that provided acceptable outcomes for the treatment of lung cancer [9, 10]. In contrast, the perioperative results of clinical trial JCOG0802/WJOG4607L demonstrated that a complex segmentectomy was associated with increased complications [8]. In the studies just described, the perioperative outcomes of uniportal versus multiportal thoracoscopic approaches were not reported for simple and complex segmentectomy procedures, respectively. Therefore, it is still important to determine the efficacy of UTS compared with MTS in patients with early stage lung cancer and discuss the potential impacts of simple and complex procedures.

PATIENTS AND METHODS

Patient selection

This study was approved by the ethics committee of Shanghai Pulmonary Hospital (No. K19-030Y). As demonstrated in Fig. 1, the study was conducted using the data set comprising 12 538 consecutive patients surgically treated for lung cancer at Shanghai Pulmonary Hospital between January 2014 and December 2015. Clinical cases were included in the analysis if the following criteria were met: pathologically confirmed stage IA lung cancer, based on the eighth American Joint Committee on Cancer staging system, and patients who underwent uniportal or MTS [11]. Patients who had a resection that included more than 2 segments were excluded. Histological type was described according to the World Health Organization classification of lung cancer [12]. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guideline.

Surgical procedures

Segmentectomy was performed if the following criteria were met: (i) <3 cm with subsolid nodule or radiologically non-invasive appearance (consolidation/tumour ratio <0.5) in preoperative high-resolution CT; (ii) located at the outer third of the lung parenchyma; (iii) general condition and respiratory function adequate for lobectomy; (iv) patient age 18–79 years old; (v) no prior chemotherapy or radiation therapy for any malignant diseases; and (vi) patient's agreement. In addition, segmentectomy was preferred for patients at our institution who could not tolerate a lobectomy.

The multiportal VATS in our study included only a 2-port VATS. This technique was defined as no rib spreading and a maximum length of 8 cm for the utility incision [13]. Uniportal VATS

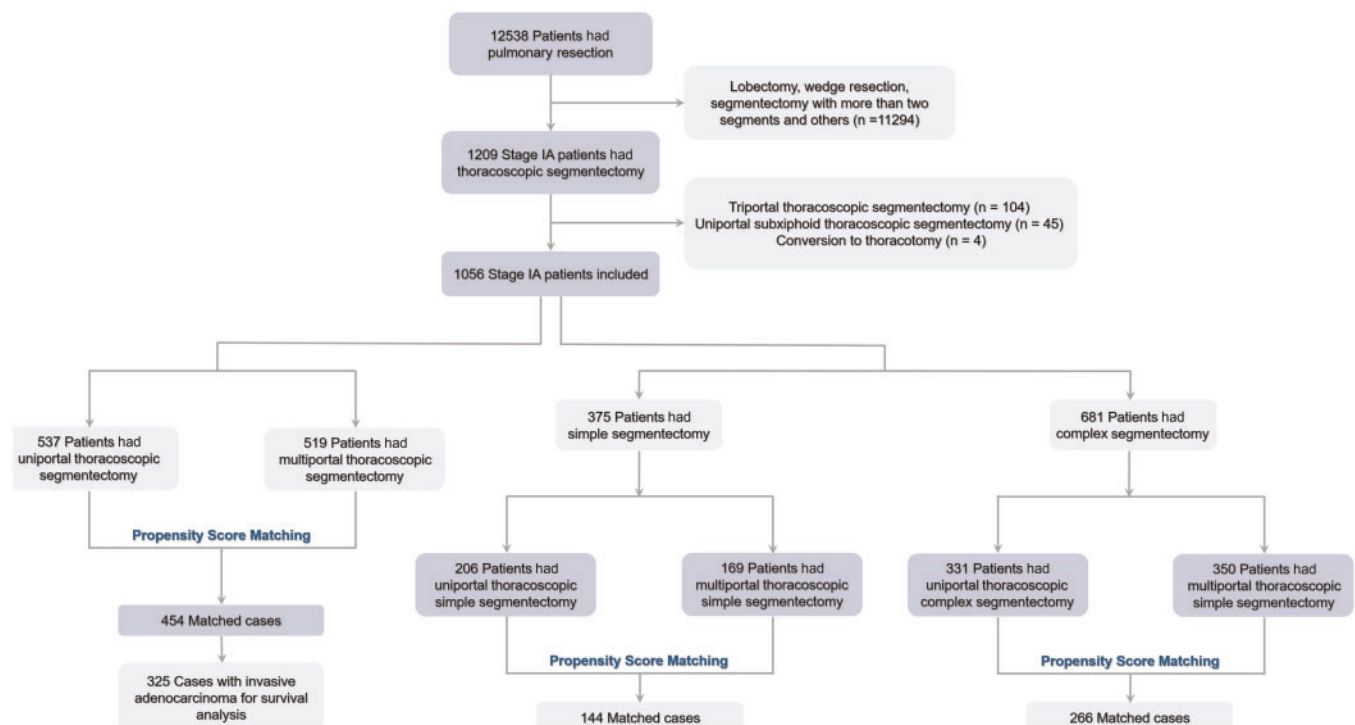


Figure 1: Diagram for creation of study cohorts.

was defined as inserting the effective instruments inside the chest cavity through a single incision (<4 cm) [14]. The details of the surgical procedures are described in the [Supplementary Materials](#). In the segmentectomy, we would dissect the affected segment or both the adjacent segments together with an adequate surgical margin (R0) and routinely explore the mediastinal, hilar and segmental lymph nodes to intraoperatively confirm N stages. The cases included in this study were performed by 14 senior surgeons. Based on the technical aspects, the relatively easier procedure that created 1 linear intersegmental plane was considered a simple segmentectomy. The procedure that created several intricate intersegmental planes would be classified as a complex segmentectomy. The segments of simple and complex segmentectomies can be found in [Supplementary Material, Table S1](#).

Statistical analyses

Complications were documented for each patient according to the Common Terminology Criteria for Adverse Events version 5.0. Perioperative mortality included any death within the first 30 days after the operation or during the hospitalization. Ninety-day mortality was also recorded. Disease-free survival (DFS) was defined as the time from the initial operation to the date of the lung cancer-related recurrence. Overall survival (OS) was considered as the time from the initial operation to death.

To minimize bias, a propensity score matching analysis (1:1) was performed between the UTS and MTS on the basis of non-random allocation. Propensity scores were calculated by a logistic model that included the following variables: age, sex, body mass index (BMI), Charlson comorbidity index, smoking status, ratio of forced expiratory volume in 1 s to forced vital capacity, tumour size and surgical type. Each patient who received UTS was automatically matched with a patient who received MTS,

with the closest estimated propensity score on the logistic model. Afterwards, the matching analysis was also performed between the uniportal and the MTS groups and between the simple and complex segmentectomy groups, respectively.

All the patients were characterized by demographic and clinical variables, such as age, sex, BMI and the Charlson comorbidity index. The perioperative outcomes included operative time, estimated blood loss, length of stay, drainage duration, complications and lymph nodes retrieved. The summarized data are presented as number (percentage) or median and interquartile range. Differences in patient characteristics and postoperative outcomes were evaluated using χ^2 tests for categorical variables and an independent Wilcoxon rank-sum test for continuous variables. To investigate the predictors of complications with grade ≥ 2 , the odds ratios (ORs) and their 95% confidence intervals (CIs) were estimated using a logistic regression model. DFS and OS were estimated using the Kaplan-Meier method and compared across groups using univariate and multivariate Cox proportional hazards models. The statistical analyses of this research were based on R software (version 3.1; R Development Core Team, R Foundation for Statistical Computing, Vienna, Austria). All statistical tests were 2-sided, with a significance level at 0.05.

RESULTS

Patient characteristics

In total, 1056 cases fitted the criteria for inclusion in this study: 537 uniportal and 519 multiportal segmentectomies ([Supplementary Material, Table S2](#)). In the unmatched set, 61.6% of patients with UTS had complex segmentectomies compared with 67.4% of patients with MTS ($P=0.049$). In the UTS group, the median age and forced expiratory volume in 1 s to forced

Table 1: Clinical characteristics of matched patients who had segmentectomies

Characteristics	Thoracoscopic segmentectomy			Simple segmentectomy			Complex segmentectomy		
	UTS (n = 454)	MTS (n = 454)	P-value	UTS (n = 147)	MTS (n = 147)	P-value	UTS (n = 266)	MTS (n = 266)	P-value
Age (years)			0.783			0.948			0.709
Median	58.0	58.0		58.0	58.0		57.0	57.0	
IQR	50.0–64.0	50.0–64.0		49.0–65.0	51.0–63.0		49.0–64.0	48.0–64.0	
Sex, n (%)			0.946			0.631			0.929
Male	174 (38.3)	178 (39.2)		54 (36.7)	58 (39.5)		102 (38.3)	101 (38.0)	
Female	280 (61.7)	276 (60.8)		93 (63.3)	89 (60.5)		164 (61.7)	165 (62.0)	
BMI			0.693			0.569			0.241
Median	23.1	23.0		22.5	23.1		23.3	22.9	
IQR	21.1–25.2	21.2–24.8		20.9–25.2	21.3–24.6		21.2–25.0	21.1–24.8	
CCI			0.794			0.763			0.612
Median	2.0	2.0		2.0	2.0		2.0	2.0	
IQR	1.0–2.0	1.0–2.0		1.0–2.0	1.0–2.0		1.0–2.0	1.0–2.0	
Smoking status, n (%)			0.824			0.567			0.462
Current or ever	46 (10.1)	44 (9.7)		12 (8.2)	15 (10.2)		28 (10.5)	23 (8.6)	
Never	408 (89.9)	410 (90.3)		135 (91.8)	132 (89.8)		238 (89.5)	243 (91.4)	
FEV1 %			0.583			0.982			0.453
Median	92.9	92.9		92.9	92.9		93.5	92.9	
IQR	85.4–99.6	85.6–99.5		84.4–99.2	82.6–99.6		85.4–99.4	87.2–99.5	
Surgical type, n (%)			0.488						
Simple	166 (36.6)	156 (34.4)							
Complex	288 (63.4)	298 (65.6)							
Histological analysis, n (%)									
Invasive adenocarcinoma	152 (33.5)	173 (38.1)	0.146	54 (36.7)	55 (37.4)	0.904	82 (30.8)	90 (33.8)	0.458
Non-invasive adenocarcinoma	292 (64.3)	268 (59.0)	0.101	90 (61.3)	89 (60.6)	0.905	181 (68.0)	168 (63.2)	0.235
Other	10 (2.2)	13 (2.9)	0.526	3 (2.0)	3 (2.0)		3 (1.1)	8 (3.0)	0.128
Tumour size (cm)									
Median	0.9	1.0	0.278	1.0	1.0	0.571	0.9	0.9	0.558
IQR	0.6–1.3	0.6–1.2		0.6–1.4	0.7–1.4		0.6–1.2	0.6–1.2	

BMI: body mass index; CCI: Charlson comorbidity index; FEV1 %: ratio of forced expiratory volume in 1 s to forced vital capacity; IQR: interquartile range; MTS: multiportal thoracoscopic segmentectomy; UTS: uniportal thoracoscopic segmentectomy.

vital capacity were 58.0 years old and 92.9%, respectively. In addition, median tumour sizes were 0.8 cm in the UTS and 1.0 cm in the MTS groups ($P=0.001$). The surgeons who performed the UTS and MTS are listed in [Supplementary Material, Table S3](#). The pathological classifications of 1025 adenocarcinomas are showed in [Supplementary Material, Table S4](#). After propensity score matching, 454 cases with thoracoscopic segmentectomy were included in each surgical group (908 total). In addition, 147 and 266 patients were selected from unmatched patients and classified into simple and complex segmentectomy groups, respectively. Patient and disease characteristics are summarized in [Table 1](#) and were well balanced in the matched groups.

Perioperative outcomes of matched thoracoscopic segmentectomies

No patient died within 90 days of surgery in this study. In the unmatched set, all the perioperative indicators, such as the operative time (125 vs 127 min; $P=0.836$) and complications (10.2% vs 12.1%; $P=0.328$) were comparable between the 2 cohorts ([Supplementary Material, Table S5](#)). Moreover, a similar trend of perioperative results could be observed between UTS groups matched with MTS groups in [Table 2](#). Multivariable analysis revealed that the only predictor of surgical complications (grade ≥ 2) was tumour size (OR 1.497, 95% CI 1.067–2.098; $P=0.019$) ([Supplementary Material, Table S6](#)). Complications are listed in [Supplementary Material, Table S7](#). The most frequent postoperative complications among the 2 cohorts of patients were pneumonia and prolonged air leak.

Comparison of simple and complex segmentectomies

After previously paired thoracoscopic segmentectomy cases were subdivided into simple and complex segmentectomies, a shorter operative time was observed in the patients with simple segmentectomy who had both the UTS (105 vs 140 min; $P<0.001$) and the MTS groups (119 vs 132 min; $P=0.011$) ([Supplementary Material, Table S8](#)). The analysis of the matched complex segmentectomy cohort for perioperative outcomes showed significant differences in operative time (141 vs 133 min; $P=0.016$) between the UTS and the MTS groups ([Table 2](#)). In the simple segmentectomy set, reduced operative time (180 vs 119 min, $P=0.007$) and reduced drainage duration (4 vs 4 days, $P=0.010$) were noted in the UTS group. In addition, perioperative data, such as complications ($P=0.493$) and mediastinal ($P=0.174$) and intrapulmonary ($P=0.124$) dissected lymph nodes, were comparable among the UTS and MTS groups who had complex segmentectomies.

Survival comparison in propensity score matched patients

In the survival analysis, only patients with invasive adenocarcinoma ($n=325$) were included from the matched cohorts. The median follow-up time was 52.0 months for all included cases. As demonstrated in [Fig. 2](#), recurrence occurred in 9 and 16 patients for the UTS and MTS groups [hazard ratio (HR) 1.620, 95% CI

Table 2: Perioperative outcomes of matched patients who underwent segmentectomy

Perioperative data	Thoracoscopic segmentectomy			Simple segmentectomy			Complex segmentectomy		
	UTS (n = 454)	MTS (n = 454)	P-value	UTS (n = 147)	MTS (n = 147)	P-value	UTS (n = 266)	MTS (n = 266)	P-value
Operative time (min)	126 (95–162)	127 (99–155)	0.883	108 (80–138)	119 (94–150)	0.007	141 (111–177)	133 (102–1157)	0.016
Blood loss (ml)	50 (50–100)	50 (50–100)	0.172	50 (50–100)	50 (50–100)	0.365	50 (50–100)	50 (50–100)	0.073
Length of stay (days)	4 (3–5)	4 (4–5)	0.592	4 (4–5)	4 (4–6)	0.285	4 (3–5)	4 (4–5)	0.662
Drainage duration (days)	4 (3–5)	4 (4–5)	0.088	4 (3–5)	4 (3–5)	0.010	4 (3–5)	4 (4–5)	0.303
Complications	48 (10.6)	51 (11.2)	0.749	19 (12.9)	19 (12.9)	1	24 (9.0)	29 (10.9)	0.493
Mediastinal lymph nodes retrieved	5 (4–8)	5 (4–8)	0.361	5 (4–8)	5 (4–8)	0.826	4 (4–8)	4 (4–8)	0.174
Intrapulmonary lymph nodes retrieved	3 (3–5)	3 (3–5)	0.385	3 (3–5)	3 (3–5)	0.975	3 (3–5)	3 (3–5)	0.124
Mediastinal lymph nodes stations	3 (2–4)	3 (2–4)	0.742	3 (2–4)	4 (2–4)	0.137	3 (2–4)	3 (2–4)	0.329
Intrapulmonary lymph nodes stations	2 (2–3)	2 (2–3)	0.636	2 (2–3)	2 (2–4)	0.188	2 (2–3)	2 (2–3)	0.326

Data are presented as median (interquartile range) or n (%).
MTS: multiportal thoracoscopic segmentectomy; UTS: uniportal thoracoscopic segmentectomy.

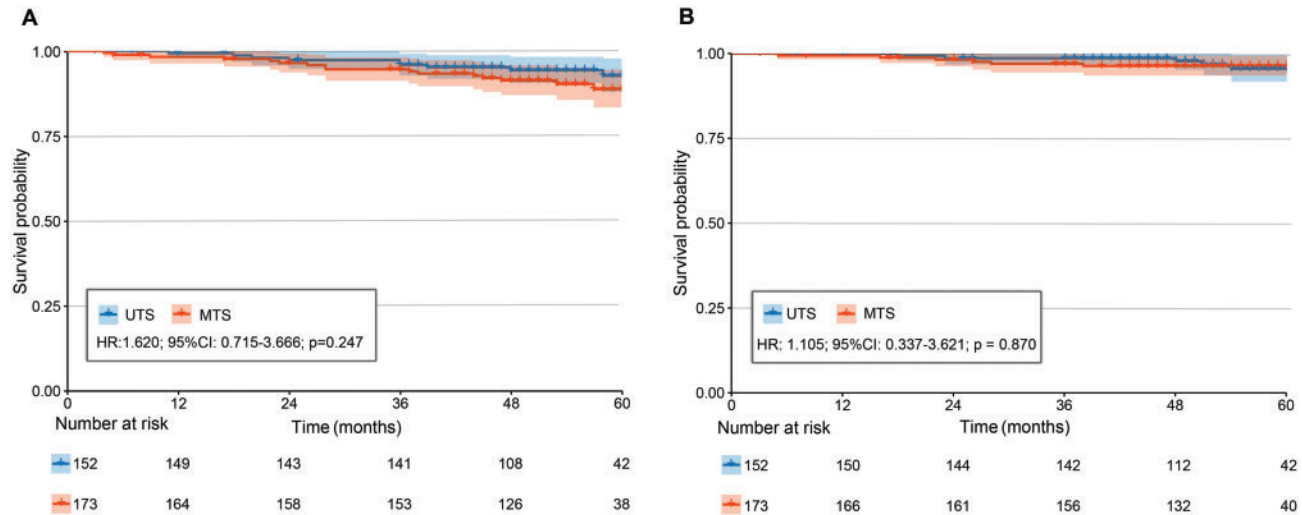


Figure 2: Kaplan-Meier survival estimates for (A) disease-free survival and (B) overall survival between propensity score matched patients with invasive adenocarcinoma undergoing segmentectomy. CI: confidence interval; HR: hazard ratio; MTS: multiportal thoracoscopic segmentectomy; UTS: uniportal thoracoscopic segmentectomy.

0.715–3.666; $P=0.247$], respectively. The 5-year OS was 96.7% and 96.5% (HR 1.105, 95% CI 0.337–3.624; $P=0.870$), respectively. Tumour size ($P=0.010$) and histological diagnosis ($P<0.001$) were confirmed as independent prognostic factors for DFS in univariate analysis (Supplementary Material, Table S9). Furthermore, only histological diagnosis ($P=0.001$) had an independent prognostic value for DFS in the multivariate analysis (Table 3).

DISCUSSION

Uniportal thoracoscopic surgery is a modified technique based on the multiportal approach, and the incision is sufficient for the surgeon to operate accurately [15]. Based on the propensity score matched method, we performed a large-scale retrospective study

with 1056 patients to evaluate perioperative results and demonstrate survival outcomes of UTS and MTS, information that has not been reported previously. Furthermore, we are the first to investigate the feasibility and safety of UTS and MTS in simple and complex segmentectomies, respectively. In general, UTS yields acceptable perioperative outcomes and therapeutic effects equivalent to those of MTS.

In recent years, accumulated evidence supported the view that uniportal thoracoscopic surgery possessed comparable perioperative outcomes. Gonzalez-Rivas *et al.* [16] described the initial results of uniportal thoracoscopic lobectomy in 2012. Afterwards, they reported uniportal VATS for the superior segment and concluded that UTS was a feasible and safe procedure [17]. In 2013, Wang *et al.* [18] presented their perioperative results of uniportal thoracoscopic lobectomy and segmentectomy with 19 cases. In addition, we reported on the single-institutional

Table 3: Multivariate Cox proportional hazards regression model analysis for disease-free survival and overall survival

Variable	DFS		OS	
	HR (95% CI)	P-value	HR (95% CI)	P-value
Age (years)			1.057 (0.987–1.133)	0.114
Tumour size (cm)	1.671 (0.968–2.885)	0.065	1.816 (0.797–4.138)	0.156
Histological analysis		0.001		0.084
Lepidic	1		1	
Papillary/acinar	1.749 (0.695–4.401)	0.235	3.080 (0.716–13.244)	0.131
Micropapillary/solid	7.041 (2.506–19.785)	0.008	6.008 (0.982–36.740)	0.052

CI: confidence interval; DFS: disease-free survival; HR: hazard ratio; OS: overall survival.

experience with uniportal thoracoscopic lobectomy ($n=569$) and segmentectomy ($n=162$) [7]. Gradually, the applications of uniportal VATS were extended to other types of thoracic surgical procedures, such as double sleeve bronchovascular and carinal resections [19, 20].

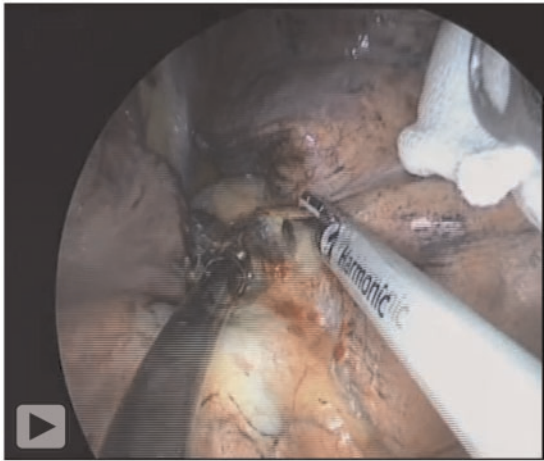
One of the major challenges with UTS was whether we could guarantee the quality of the operative procedure, especially the adequate dissection of lymph nodes. Because the patients who were considered for segmentectomy had subsolid nodules on the CT scans, lymph node sampling was routinely performed in our department. Guidelines published by the European Society of Thoracic Surgeons recommended resection of at least 6 nodes to guarantee proper pathological classification [21]. In our procedure, the median number of dissected lymph nodes was 8 for both UTS and MTS. This result was consistent with those of previous studies, which reported a mean of 5–10 dissected lymph nodes with a segmentectomy [22, 23]. This factor did not affect the 5-year DFS (HR 1.005, 95% CI 0.695–1.453; $P=0.980$) and OS (HR 1.105, 95% CI 0.803–1.518; $P=0.540$) in the univariate analysis.

The segmentectomy procedure was more complicated because of the intricate process of creating linear intersegmental planes and dissecting the fragile vessels and bronchus. Our perioperative results confirmed that the operative time was comparable between UTS and MTS, based on the propensity score matched method. This trend was inconsistent with that in some previous studies. For example, Wang *et al.* [5] performed a propensity matched analysis with 92 corresponding cases and stated that uniportal VATS lobectomy and segmentectomy were associated with reduced operative times (169.9 vs 191.2 min; $P=0.029$) and less estimated blood loss (53.04 vs 95.33 ml; $P=0.017$). Similarly, Liu *et al.* [24] reported that the operative time was significantly increased in the multiport lobectomy set ($P<0.001$). However, it was not observed in the segmentectomy set ($n=96$ cases, 3.34 vs 3.45 h; $P=0.542$). Collectively, the advantage of a shorter operative time in UTS was not supported by our results.

Although the perioperative indicators were comparable between UTS and MTS, the applications of UTS still needed to be discussed in detail due to the variety of segmentectomies. Suzuki *et al.* [8] reported that complex segmentectomy (versus lobectomy) (OR 2.07, 95% CI 1.11–3.88; $P=0.023$) was related to the occurrence of air leak and empyema (grade ≥ 2). Our logistic regression model showed that complex segmentectomy (versus simple) was not a risk factor for complications (OR 0.753, 95% CI 0.492–1.152; $P=0.191$). They speculated that the procedure of

creating a fissure could be the reason for more complications in the complex segmentectomy, which included cautery, a stapler or a stapler and cautery. The detail of creating a fissure has not been documented in our surgical records. Generally, we created a fissure depending on the stapler or the stapler and less cautery (Video 1). Our results also suggested that the operative time was longer in the complex segmentectomy in both UTS and MTS. It was consistent with the research of Handa *et al.* [10], who reported a significantly longer operative time (180 vs 143.5 min; $P<0.001$) for the complex segmentectomy based on hybrid surgical techniques. This result might imply that the segmentectomy was inevitably harder to complete with the increased numbers of intersegmental planes in the surgical procedure. Moreover, the possibility of external and internal instruments fighting in the uniportal VATS might result in the longer operative time for the segmentectomy [15]. Interestingly, our analysis indicated that MTS and UTS possessed statistical advantages in the operative time in the complex and simple segmentectomies, respectively. However, this minor statistical difference in the operative time (11 and 8 min) was clinically irrelevant. Uniportal VATS did not compromise the outcomes in the relatively difficult segmentectomy. At the same time, the uniportal technique had the advantage of avoiding the side view because the camera was inserted through a lower intercostal space, thereby achieving the 'baseball-diamond' instrument setting for the complete dissection [5].

The multi-institutional clinical trial Cancer and Leukemia Group B 39802 prospectively presented the technical safety and feasibility of thoracoscopic surgery for early stage lung cancer [25]. Nevertheless, long-term survival comparisons among uniportal and multiportal thoracoscopic resections are lacking in the current literature. Based on results from previous studies, we included patients with a pathological tumour size ≤ 3 cm and a consolidation tumour ratio <0.5 [22, 23]. The long-term survival outcomes of patients with stage IA invasive adenocarcinoma treated with uniportal and multiportal thoracoscopic segmentectomies were demonstrated for the first time. Other than UTS versus MTS, a less differentiated histological diagnosis showed an independent prognostic value in DFS. The 5-year DFS and OS outcomes were consistent with those of large series, regardless of whether the definitions of the American Joint Committee on Cancer seventh or American Joint Committee on Cancer eighth stage classification were considered [26, 27]. Therefore, we might believe that UTS as a treatment option could provide an oncological effect that is comparable with the current average long-term survival results for stage IA adenocarcinoma.



Video 1: The uniportal thoracoscopic segmentectomy of the apicoposterior segment (S1-2) of the right upper lobe.

Limitations

The main study limitations must also be considered. First, selection bias existed due to the retrospective nature of the study. Although propensity matching could reduce the bias, it could not eliminate it. Prospective clinical trials are necessary to further validate the application of uniportal and multiportal thoracoscopic segmentectomies. Second, although previous studies had stated that postoperative pain would be reduced as the numbers of incisions decreased [28, 29], our study lacked analysis of postoperative pain because we did not record the pain score before June 2015. In addition, our analysis was based on Asian populations who have lower BMI and smoke less. However, there was no definite evidence that a high BMI or a history of smoking would reduce the feasibility and safety of uniportal thoracoscopic surgery. Although some studies compared the perioperative indicators of those treated with biportal and 3- to 4-port VATS and showed comparable results [30], the evidence was not strong enough. The lack of a comparison between uniportal and 3- to 4- port VATS may be a weakness in our study. The last limitation is that we could not explore the influence of the surgeon's experience because of the relatively low number of cases of UTS per surgeon in our study.

CONCLUSION

During the era of minimally invasive surgery, the use of UTS has remarkably increased without compromising outcomes in patients with early stage lung cancer. This study confirms that similar perioperative and long-term outcomes could be observed between UTS and MTS. In particular, the minor advantage of UTS is seen in the simple segmentectomy. MTS possesses a less obvious advantage in a complex segmentectomy. Nevertheless, these differences are clinically irrelevant. In conclusion, UTS deserves to be continuously popularized, and more advanced and personalized treatment strategies should be developed.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

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Conflict of interest: The authors have no conflicts of interest to declare.

Author contributions

Dong Xie: Conceptualization; Data curation; Formal analysis; Investigation; Validation; Writing—original draft; Writing—review & editing. **Junqi Wu:** Data curation; Formal analysis; Investigation; Methodology; Visualization; Writing—original draft. **Xuefei Hu:** Data curation; Formal analysis; Investigation; Methodology; Writing—original draft. **Diego Gonzalez-Rivas:** Methodology; Writing—review & editing. **Yunlang She:** Formal analysis; Investigation; Methodology; Software. **Qiankun Chen:** Data curation; Writing—review & editing. **Yuming Zhu:** Data curation; Resources; Writing—review & editing. **Gening Jiang:** Data curation; Resources. **Chang Chen:** Conceptualization; Funding acquisition; Project administration; Resources; Supervision; Writing—review & editing.

Reviewer information

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