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ORIGINAL ARTICLE

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Mid-term survival outcome of single-port video-assisted thoracoscopic anatomical lung resection: a two-centre experience

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Abstract

OBJECTIVES: Single-port video-assisted thoracoscopic surgery (SPVATS) anatomical resection has been shown to be a feasible technique for lung cancer patients. Whether SPVATS has equivalent or better oncological outcomes for lung cancer patients remains controversial. The purpose of this study was to evaluate the perioperative and mid-term survival outcomes of SPVATS in 2 different medical centres.

METHODS: We retrospectively reviewed patients who underwent SPVATS anatomical resections between January 2014 and February 2017 in Coruña University Hospital's Minimally Invasive Thoracic Surgery Unit (Spain) and Chang Gung Memorial Hospital (Taiwan). Survival outcomes were assessed by pathological stage according to the American Joint Committee on Cancer (AJCC) 7th and 8th classifications.

RESULTS: In total, 307 patients were enrolled in this study. Mean drainage days and postoperative hospital stay were 3.90 ± 2.98 and 5.03 ± 3.34 days. The overall 30-day mortality, 90-day morbidity and mortality rate were 0.7%, 20.1% and 0.7%, respectively. The 2-year disease-free survival and 2-year overall survival of the cohort were 80.6% and 93.4% for 1A, 68.8% and 84.6% for 1B, 51.0% and 66.7% for 2A, 21.6% and 61.1% for 2B, 47.6% and 58.5% for 3A, respectively, following the AJCC 7th classification. By the AJCC 8th classification, these were 92.3% and 100% for 1A1, 73.7% and 91.4% for 1A2, 75.2% and 93.4% for 1A3, 62.1% and 85.9% for 1B, 55.6% and 72.7% for 2A, 47.1% and 64.2% for 2B and 42.1% and 60.3% for 3A.

CONCLUSIONS: Our preliminary results revealed that SPVATS anatomical resection achieves acceptable 2-year survival outcomes for early-stage lung cancer and is consistent with AJCC 8th staging system 2-year survival data. For advanced stage non-small-cell lung cancer patients, further evaluation is warranted.

Keywords: Single-port video-assisted thoracoscopic surgery • Mid-term survival outcome • Lung cancer • American Joint Committee on Cancer 7th edition • American Joint Committee on Cancer 8th edition

INTRODUCTION

Lung cancer is the leading cause of cancer-related death all over the world. Surgery is the treatment of choice for patients with early-stage non-small-cell lung cancer (NSCLC) and selected Stage IIIA patients [1–3]. Roviaro *et al.* [4] first described video-assisted thoracoscopic surgery (VATS) lobectomy in 1992. Thereafter, VATS mushroomed rapidly and has spread all over the world. Over the last 2 decades, minimally invasive thoracoscopic anatomical lung resection with lymph node dissection has become widely accepted as a safe and sound oncological treatment option [5, 6]. The evolution of minimally invasive VATS has driven the development of sophisticated instruments and varied concepts to cope with the demands of working through smaller and fewer incision wounds. Single-port video-assisted thoracoscopic surgery (SPVATS) is now being used for an ever-growing number of applications [7–11], even including major lung resection for lung cancer [7]. However, the majority of the single-port VATS-related studies are only related to its perioperative outcomes and feasibility. There are, as yet, few studies reporting its oncological results [9–11]. The objective of this study was not only to evaluate the perioperative outcomes but also to discuss the mid-term oncological outcome, as observed through our experience from 2 medical centres.

MATERIALS AND METHODS

Patients

A retrospective observation study was performed in patients undergoing an SPVATS for major pulmonary resections in the Minimally Invasive Thoracic Surgery Unit at Coruña Hospital

(CHUAC, Spain) and Chang Gung Memorial Hospital (CGMH, Taiwan) between January 2014 and February 2017. This study was approved by the review board of Coruña University Hospital's Minimally Invasive Thoracic Surgery Unit and Chang Gung Memorial Hospital, Linkou branch (IRB: 2013/092, 201700805B0). The indication for SPVATS anatomical resection for primary lung cancer included (i) clinical Stage I–II patients, (ii) selected clinical Stage IIIa patients who presented with single resectable N2 station metastasis, subject to patient request and evaluation by multidisciplinary committee and (iii) N2 patients who received neoadjuvant therapy followed by intention to treat by surgery.

A total of 442 patients received SPVATS, but 78 patients were excluded from this study due to secondary lung cancer or benign lung lesion, and a further 57 patients who received neoadjuvant therapy were also excluded. Finally, a total of 307 patients were enrolled in this study. The preoperative workup included chest radiography, bronchoscope, spirometry, chest tomography and a detailed search for distant metastasis, using positron emission tomography and brain images. Bone scan was used optionally for patients with suspected bone metastasis. All enrolled patients had clinical nodal staging with positron emission tomography. Clinical $cT_{1-2}N0$ patients without mediastinal lymph node emission did not undergo an invasive mediastinal procedure, such as mediastinal scope or endobronchial ultrasound fine-needle aspiration. A selective mediastinoscopy or endobronchial ultrasound fine-needle aspiration was performed on patients with either positron emission tomography-positive mediastinal lymph node or when the multidisciplinary team had recommended exclusion of multiple N2 station metastasis disease. Clinical records of each patient were reviewed for demographic and clinical data including age, gender, body mass index, smoking status, preoperative pulmonary function, Eastern Cooperative Oncology Group (ECOG) performance status, associated comorbidities and clinical stage. In addition, records were reviewed for perioperative and pathological data, including surgical approach, 30-day operative mortality (defined as death during the same hospitalization or within 30 days after the operation), 90-day morbidity and mortality (defined as death within 90 days after surgery), duration of drainage, length of postoperative hospital stay, tumour size, histology, lymph node dissection numbers and pathological stage.

Surgical techniques

The surgical technique is the same as that described in previous articles [7, 9]. The surgeon and the assistant were both in front of the patient in order to have the same thoracoscopic view. An incision was made in the 5th intercostal space, and without rib spreading, vision was obtained through a 30° thoracoscope and instruments with proximal and distal articulation were used to perform the procedure. Vessels were divided using endostaple or vascular clips if the angle was not favourable for endostapler. Resected lung specimen was retrieved through a plastic retrieving bag. Sometimes the incision wound was enlarged to retrieve the specimen completely with the whole plastic retrieving bag, especially for those patients with tumours >5 cm. The eligibility criteria for SPVATS segmentectomy included ground-glass opacity lesion <2 cm without clinical evidence of hilar or mediastinal lymph node metastasis. During the operation, we sent segmental or hilar lymph node samples for intraoperative frozen examination. If lymph node metastasis was highly suspected, such as fixed or enlarged lymph node, we shifted the operation method to lobectomy. In general, the choice of lobectomy, bilobectomy or pneumonectomy depended on the size and location of the tumour. Systemic lymph node dissection was performed for all patients. Postoperative complications were all gathered and classified in a scale from I to V according to the Clavien–Dindo classification [12]. Grades I and II represented minor complications requiring no therapy or pharmacological intervention. Grades III and IV represented major complications requiring surgical intervention or life support. Grade V complications implied death. If a patient had multiple concurrent complications, only the most severe complication was considered. Details are given in Table 1.

Follow-up

Patients returned to the outpatient clinics every 3 months for 2 years and then every 6 months annually up to 5 years. Upon each visit, a chest plain film was taken. If chest plain film revealed abnormal findings, restaging examination and biopsy would be arranged sequentially. Otherwise, chest tomography would be arranged annually for each patient if there was no abnormal finding on annual surveillance. The date of recurrence was defined as the date of positive findings on imaging.

Statistics

All collected clinicopathological factors were analysed by SPSS (version 19, Chicago, IL, USA). Overall survival (OS) was defined as the time from surgery until death from any cause, while patients who did not die during the study period were censored at the date of the last available follow-up. Disease-free survival (DFS) was defined as the time from surgery until disease relapse during the study period. If disease did not recur during the study period, patients were censored at the date of the last follow-up.

DFS and OS were estimated using the Kaplan–Meier method. The log-rank test was used to determine significance of survival distributions. A *P*-value <0.05 was considered statistically significant.

Table 1: Postoperative complications classification

Variables	Description
Minor complications	
Grade I	Adverse events without intervention
Grade II	Pharmacological treatment or minor intervention required
Major complications	
Grade III_a	Surgical, radiological, endoscopic treatment without general anaesthesia
Grade III_b	Surgical, radiological, endoscopic treatment with general anaesthesia
Grade IV_a	Intensive care unit care for single-organ dysfunction required
Grade IV_b	Intensive care unit care for multiple-organ dysfunction required
Grade V	Death

RESULTS

Perioperative outcomes

Between January 2014 and February 2017, 307 patients, comprising 215 men (70%) and 92 women (30%), underwent SPVATS anatomical resection for NSCLC (CHUAC: 234, CGMH: 73). Segmentectomy was used in 23 patients, lobectomy was used in 263 patients, bilobectomy was used in 12 patients and pneumonectomy was used in 9 patients. The clinical and demographic characteristics of the patients are presented in Table 2. Mean operation room time for the single-port major lung resection was 201.69 ± 61.32 min. Regarding mediastinal lymphadenectomy, the mean number of resected N1 and N2 lymph nodes was 5.74 ± 3.12 and 9.02 ± 5.32, respectively (Table 2). Conversion was necessary in 8 (2.6%) cases. Open thoracotomy was undertaken in 6 cases because of vascular injury or dense adhesion around the mediastinal surface. Two cases were converted to 2-port VATS to shorten the operative time (Table 3). Mean drainage days and postoperative hospital stay were 3.90 ± 2.98 and 5.03 ± 3.34 days, respectively. The overall 30-day mortality, 90-day morbidity and mortality rate was 0.7%, 20.1% and 0.7%, respectively.

Mid-term disease-free survival and overall survival outcome

The majority of the cases were subtypes of adenocarcinoma (59.6%). Most patients had clinical Stage I disease (81.8%). Seventy percent (217/307) of patients had pathological Stage I disease (IA, 125 and IB, 92), and in 16.3% (50) of patients, the severity of disease was upstaged (Table 2). The mean tumour size was 3.00 ± 1.68 cm (range 0.7–10.2 cm), while 15% of patients had unexpected metastatic nodal disease, 5.5% (17) of patients had occult N2 disease and 29.7% of patients received adjuvant cytotoxic chemotherapy. The detailed clinical and pathological staging shift paragraph is given in Supplementary Material, File S1. The 2-year DFS and 2-year OS of the cohort were 80.6% and 93.4% for 1A, 68.8% and 84.6% for 1B, 51.0% and 64.2% for 2A, 21.6% and 61.1% for 2B and 47.6% and 58.5% for 3A, respectively, with a median follow-up of 16 months. After changing the stage classification system to the American Joint Committee on Cancer (AJCC) 8th lung cancer stage classification, the 2-year DFS and 2-year OS were 92.3% and 100% for 1A1, 73.7% and 91.4% for 1A2, 75.2% and 93.4% for 1A3, 62.1% and 85.9% for 1B, 55.6% and 72.7% for 2A, 47.1% and 64.2% for 2B, 42.1% and 60.3% for 3A, respectively. Two 3A patients had stage migration to 3B under the AJCC 8th classification. Due to lack of sufficient follow-up time, 2-year DFS and OS were omitted. The 2-year OS for the study group was 84.6%. Stage-specific DFS and OS by the AJCC 7th and 8th classifications are shown in Fig. 1A–D, and the details for the AJCC 7th and AJCC 8th DFS and OS Stage 1 are shown in Fig. 2A and B (Supplementary Material, File S2).

DISCUSSION

Numerous reports from high-volume centres have shown that SPVATS anatomical resection can be a feasible and safe alternative compared with traditional VATS anatomical resection with regard to short-term outcomes with potential benefits that include similar lymph node dissection numbers [13–16], specific and effective postoperative pain control [17], decreased acute postoperative pain, shorter length of chest tube duration and hospital stay [14–16]. As for chest tube duration and postoperative hospital stay, our current 2-centre experience was consistent with the above-mentioned reports [14–16]. When it came to postoperative morbidity and in-hospital mortality rates, our cohort showed that SPVATS has acceptable in-hospital mortality and complication rates compared to the operative approach (Table 4). Although the postoperative complication rate was 20.1%, the majority of the complications were minor complications, including prolonged air leakage, arrhythmia and so on. In a comparative study of lung cancer patients who received VATS or thoracotomy, Boffa *et al.* [18] found that the postoperative complication rate of the VATS group was 30% in their series, which is better than the thoracotomy group in clinical Stage I lung cancer. Furthermore, in a national database analysis matching thoracotomy, VATS and robotic-assisted thoracoscopic surgery (RATS), postoperative complication rates were 54.1%, 45.3% and 43.8%, respectively. Thus, our complication rate was acceptable compared with other operative approaches [19]. Major complications occurred in 8 (2.6%) patients. One of the deceased patients was an HIV carrier and developed thrombocytopenia. He had no choice but to receive the operation after discussion with the cancer committee. After the operation, he died due to severe sepsis and thrombocytopenia. The other deceased patient had received previous thoracic surgery and developed pulmonary hypertension on the 7th day after SPVATS lobectomy. He died due to multiple-organ failure. The rate of conversion to multiport VATS or open thoracotomy was consistent with the reported largest series of multiport VATS, RATS [20–24], where the conversion rate varied from 2.5% to 10% (Table 4). There were 16 patients with bleeding accidents during the operation, but only 4 catastrophic bleeding episodes required conversion to open surgery. Most of the bleeding episodes could be adequately managed through a single-port surgical technique as mentioned in our previous report [25].

In addition to our perioperative outcomes, our study had several unique aspects that previously published series seldom mentioned. First, since 2011, when the first experience of SPVATS lobectomy was published [7], suspicion regarding its feasibility and doubts about its safety have gradually diminished with the mushrooming of published reports from all over the world. However, the most important aspect of the surgery is the oncological result. Limited by the state of the art of our time, SPVATS surgeons are always vigilant and prudent about the survival outcome for lung cancer patients, while adopting new procedures under the same principle of oncology. Previously, Xie *et al.* [10] and Ng *et al.* [11] published their series about survival outcomes in relatively homogenous patient populations. Here, we present a preliminary report on DFS and OS for NSCLC patients from 2 different centres. Even though patient demography and ethnicity were different for the 2 centres, there was no significant difference in OS between the 2 hospitals for the AJCC 7th and AJCC 8th Stage I patients ($P = 0.089$, $P = 0.133$, Supplementary Material, File S3). So we might believe that SPVATS anatomical resection as a treatment option provides a therapeutic effect that is in line with the current average 2-year survival results for early-stage lung cancer patients [26–28]. The OS and stage-specific 2-year survival are consistent with that of large series [26–27] and external validation [27–28], whether or not it is under the definition of the AJCC 7th or AJCC 8th stage classification. For locally

Table 2: Patient characteristics and perioperative outcomes

Variables	CHUAC ($n = 234$)	CGMH ($n = 73$)	Total (%) ($n = 307$)	*P*-value
Age (years), mean ± SD	66.52 ± 11.16	63.19 ± 9.85	65.73 ± 10.94	0.023
Gender				<0.001
Male	179	36	215 (70)	
Female	55	37	92 (30)	
Smoking status				<0.001
No	50	51	101 (32.9)	
Former	94	12	106 (34.5)	
Current	90	10	100 (32.6)	
ACS history				0.373
Yes	39	9	48 (15.4)	
No	195	64	259 (84.6)	
COPD				0.103
Yes	37	6	43 (14)	
No	197	67	264 (86)	
Additional primary malignancy				0.592
Yes	45	12	57 (18.6)	
No	189	61	250 (81.4)	
Body mass index, mean ± SD	26.36 ± 3.85	24.04 ± 2.68	25.79 ± 3.73	<0.001
ECOG				0.092
0	148	54	202 (34.2)	
1	86	19	105 (65.8)	
FEV_1, mean ± SD	2.33 ± 0.65	2.19 ± 0.59	2.26 ± 0.64	0.008
FEV_1 (%), mean ± SD	81.04 ± 19.39	87.66 ± 15.40	82.64 ± 18.69	0.008
Previous thoracic surgery				0.135
Yes	7	0	7 (2.3)	
No	227	73	300 (97.7)	
Tumour location				0.679
RUL	85	25	110 (35.8)	
RML	15	6	21 (6.8)	
RLL	41	16	57 (18.5)	
LUL	54	13	67 (21.7)	
LLL	40	13	53 (17.2)	
Clinical stage				0.432
I	188	63	251 (81.8)	
II	32	8	40 (13)	
III	14	2	16 (5.2)	
Operation method				0.002
Segmentectomy	11	12	23 (7.5)	
Lobectomy	203	60	263 (85.7)	
Bilobectomy	11	1	12 (3.9)	
Pneumonectomy	9	0	9 (2.9)	
Operation time, mean ± SD	202.08 ± 60.74	200.45 ± 63.54	201.69 ± 61.32	0.843
Tumour size, mean ± SD	3.14 ± 1.79	2.56 ± 1.19	3.00 ± 1.68	0.010
Lymph node dissection number, mean ± SD				
N1	5.08 ± 1.95	7.78 ± 4.78	5.74 ± 3.12	<0.001
N2	7.59 ± 2.83	13.48 ± 8.10	9.02 ± 5.32	<0.001
Number of N2 station dissection	3	3	3	1
Pathological stage AJCC 7th edition				0.485
IA	92	33	125 (40.7)	
IB	69	23	92 (30.0)	
IIA	29	9	38 (12.4)	
IIB	14	1	15 (4.9)	
IIIA	30	7	37 (12.0)	
Pathological stage AJCC 8th edition				0.386
1A1	10	7	17 (5.5)	
1A2	52	15	67 (21.8)	
1A3	30	11	41 (13.4)	
1B	59	22	81 (26.4)	
2A	10	1	11 (3.6)	
2B	32	10	42 (13.7)	
3A	39	7	46 (14.9)	
3B[a]	2	0	2 (0.7)	
Histology				<0.001
Adenocarcinoma	120	63	183 (59.6)	
Squamous cell carcinoma	56	8	64 (20.8)	
Other[b]	58	2	60 (19.6)	
Lymphovascular invasion				<0.001
Yes	124	7	131 (42.7)	
No	110	66	176 (57.3)	

Continued

Table 2: Continued

Variables	CHUAC ($n = 234$)	CGMH ($n = 73$)	Total (%) ($n = 307$)	P-value
Visceral pleural invasion				<0.001
P0	177	49	226 (73.6)	
P1	27	22	49 (16)	
P2	39	2	41 (10.4)	
Drainage duration, mean ± SD	3.97 ± 3.15	3.69 ± 2.39	3.90 ± 2.98	0.492
Postoperative hospital stay, mean ± SD	5.15 ± 3.56	4.68 ± 2.50	5.03 ± 3.34	0.305

[a]3B patients in AJCC 8th classification were the result of stage shift by the new classification.
[b]Other type of histology included adenosquamous cell carcinoma, typical carcinoid tumour, atypical carcinoid tumour, lymphoepithelioma-like carcinoma and large-cell neuroendocrine carcinoma.
AJCC: American Joint Committee on Cancer; ACS: acute coronary syndrome; COPD: chronic obstructive pulmonary disease; CGMH: Chang Gung Memorial Hospital; CHUAC: Minimally Invasive Thoracic Surgery Unit at Coruña Hospital; ECOG: Eastern Cooperative Oncology Group; FEV1: forced expiratory volume in 1 s; LLL: left lower lobe; LUL: left upper lobe; RLL: right lower lobe; RML: right middle lobe; RUL: right upper lobe; SD: standard deviation.

Table 3: Reasons for conversion to thoracotomy and 90-day postoperative complications

Reason for conversion	Number
Mediastinal surface total adhesion	2
Vessel bleeding	
Truncus anterior artery	2
Interlobar artery	1
Pulmonary vein	1
Complications	**Number**
Minor complications	
Grade I	
Atelectasis	2
Subcutaneous emphysema	3
Prolonged air leakage (>5 days)	32
Grade II	
Arrhythmia	11
Bradycardia	1
Wound haematoma	1
Chylothorax	1
Pneumonia	4
Major complications	
Grade III_b	
Prolonged air leakage	3
Postoperative bleeding	2
Stroke	1
Grade V	
Death	2

advanced NSCLC patients (Stage II and III), our initial treatment result is worth looking into, in future. However, due to the relatively limited case numbers, further observation is warranted.

Second, our study is based on a 2-centre, international experience with 1 centre in Spain and 1 in Taiwan using similar staging criteria, surgical techniques and postoperative follow-up protocol to evaluate perioperative and mid-term outcomes of these relatively new surgical techniques. All included patients were free from neoadjuvant therapy and had adequate pulmonary function reserve. In terms of surgical technique, all of the surgeons used the same techniques as previously described by Gonzalez *et al.* [7]. Each author performed systemic hilar and mediastinal lymph node dissection, however, despite using the same principle of lymph node dissection, lymph node harvesting numbers were quite different between the 2 centres (7.6 vs 13.5). Riquet *et al.* [29] found that the number of removed lymph nodes was normally distributed with high inter-individual variability. Moreover, our 2 patient cohorts were from different geographical areas and differed ethnically. A complete hilar and mediastinal lymphadenectomy is more important than harvesting numbers of lymph nodes.

Third, our study used a relatively large population of SPVATS anatomical resections reported to date. Although we previously published our experience of bleeding control techniques by SPVATS [25], cohort evidence was lacking to prove its feasibility. Our report was the first to describe such experience in 2 different centres.

Limitations

However, some limitations should be taken into account when the results are considered. First, lack of sufficient case numbers and unified adjuvant regimen of locally advanced NSCLC patients made it difficult to arrive at a more solid conclusion about the therapeutic effect with regard to mid-term survival outcome, although our initial results were on par with the average survival rate. For example, in our limited numbers of Stage 2B patients by the AJCC 7th classification, the 2-year DFS was lower than in 3A patients, which might reflect the heterogeneity of our 2B patients. We further analysed the AJCC 7th Stage 2B patients in our cohort. Forty-six percent (9/15) of patients had a tumour >7 cm with costal pleural invasion. Two patients had a tumour >5 cm with hilar lymph node metastasis, and 4 other patients had mediastinal pleural invasion. Three patients could not tolerate postoperative radiotherapy and received adjuvant chemotherapy only. Jeon *et al.* [30] found the combined T_3 descriptors group had a poorer prognosis than those with T_3 centrally located lesion, poorer than patients without complete adjuvant therapy. This could partially explain why the 2-year DFS of our AJCC 7th 2B patients was inferior to 3A stage. In addition, adjuvant chemotherapy also plays an important role in DFS and OS of locally advanced patients. Cisplatin-based doublet adjuvant chemotherapy has been used for pathological Stage II and Stage III patients in Spain and Taiwan, except the AJCC 7th Stage IB (T2aN0M0) patients. However, lack of unified adjuvant regimen might have introduced bias into the survival analysis. Further evaluation is warranted. Second, between different centres, there inevitably exists some bias among patient characteristics and differences in

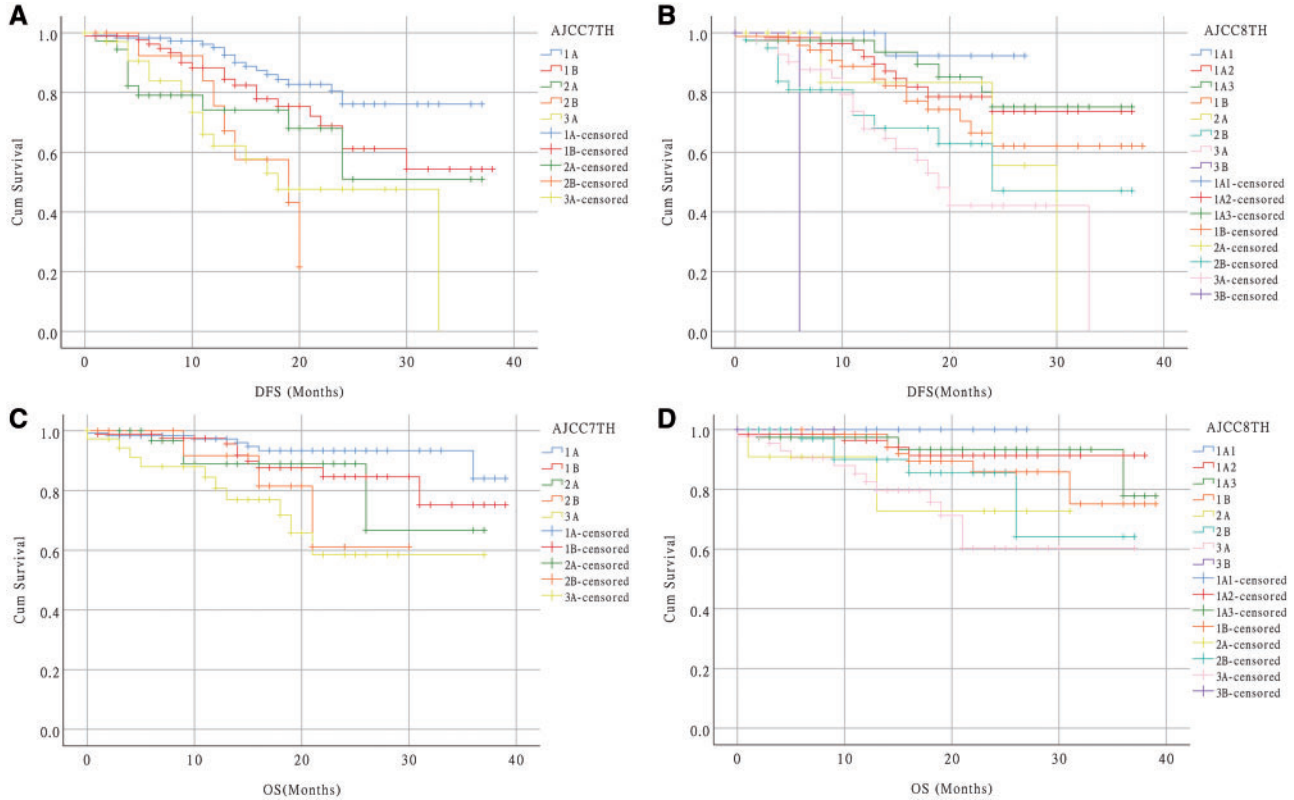

Figure 1: DFS and OS of the whole study group. (**A**) DFS according to the 7th edition. (**B**) DFS according to the 8th edition. (**C**) OS according to the 7th edition. (**D**) OS according to the 8th edition. AJCC: American Joint Committee on Cancer; DFS: disease-free survival; OS: overall survival.

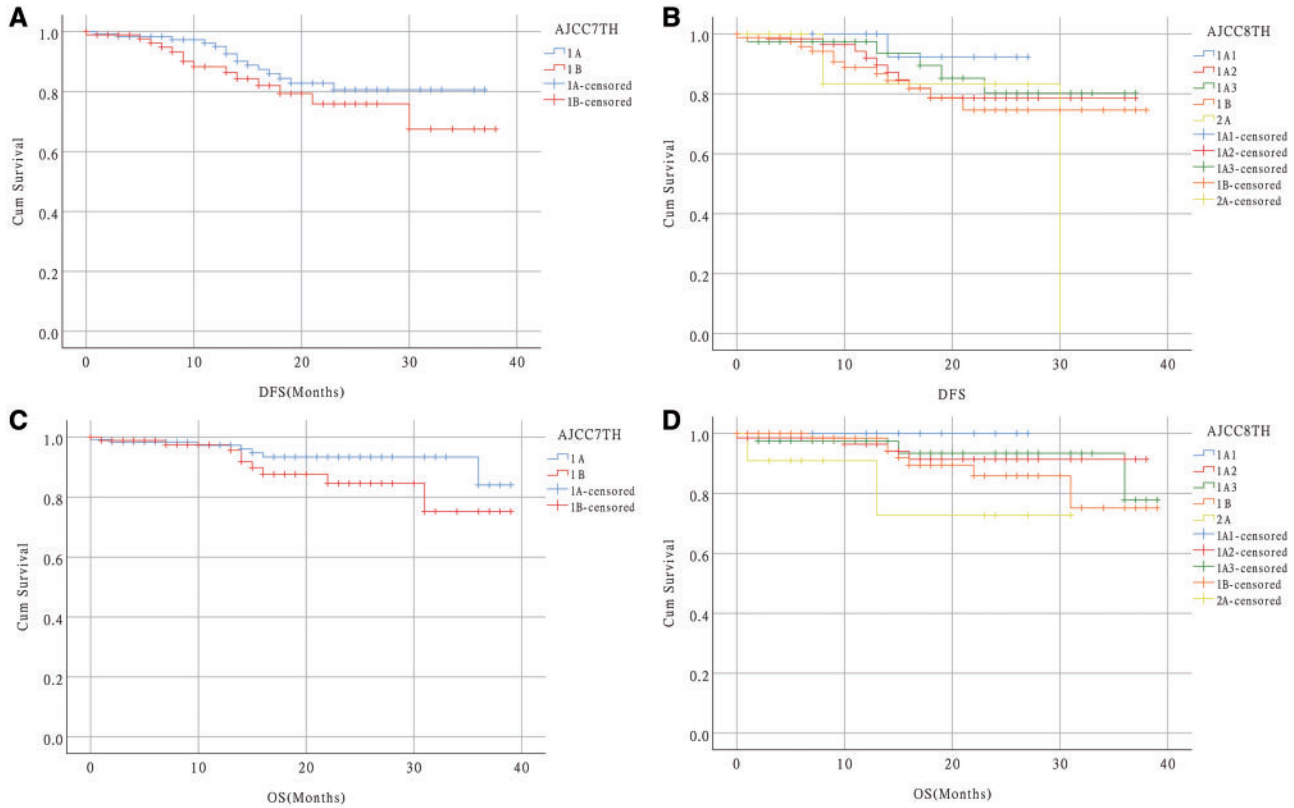

Figure 2: DFS and OS of Stage 1 lung cancer patients. (**A**) DFS according to the 7th edition. (**B**) DFS according to the 8th edition. (**C**) OS according to the 7th edition. (**D**) OS according to the 8th edition. AJCC: American Joint Committee on Cancer; DFS: disease-free survival; OS: overall survival.

Table 4: Summary of reports on minimally invasive surgery (VATS and RATS) conversion rates, morbidity and mortality outcomes

References	No. of cases	Conversion (%)	Morbidity (%)	Mortality (%)
McKenna *et al.* [20]	1100	2.5	15.3	0.8
Onaitis *et al.* [21]	500	1.6	23.2	1
Marty-Ané *et al.* [22]	410	6.1	20.5	1.2
Nasir *et al.* [24]	394	10	27	0.5
Present study	307	2.6	20.1	0.7

VATS: video-assisted thoracoscopic surgery; RATS: robotic-assisted thoracoscopic surgery.

surgeon technique and proficiency. Although there was no significant survival difference for early-stage lung cancer patients between the 2 centres (Supplementary Material, File S3), such retrospective study bias might have had an effect on mid-term survival outcome. We still need a longer observation time to validate the therapeutic role of SPVATS anatomical resection for lung cancer patients. Third, lack of comparative information on multiport VATS, RATS or thoracotomy anatomical resection makes SPVATS for NSCLC patients less persuasive. It would be very important for us to conduct further study to distinguish perioperative and survival outcomes among multiport VATS, RATS and thoracotomy surgery.

CONCLUSION

In summary, our study showed that SPVATS anatomical resection is a feasible and safe procedure with low in-hospital mortality and morbidity rate, and acceptable mid-term DFS and OS outcomes for early-stage NSCLC patients. For locally advanced stage NSCLC patients, we need more patients and more time to confirm its therapeutic role in future.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

Conflict of interest: none declared.

REFERENCES

[1] Yang HX, Woo KM, Sima CS, Bains MS, Adusumilli PS, Huang J *et al.* Long-term survival based on the surgical approach to lobectomy for clinical stage I nonsmall cell lung cancer: comparison of robotic, video-assisted thoracic surgery, and thoracotomy lobectomy. Ann Surg 2017; 265:431–7.

[2] Chen K, Wang X, Yang F, Li J, Jiang G, Liu J *et al.* Propensity-matched comparison of video-assisted thoracoscopic with thoracotomy lobectomy for locally advanced non-small cell lung cancer. J Thorac Cardiovasc Surg 2017;153:967–76.

[3] Iwasaki A, Shirakusa T, Shiraishi T, Yamamoto S. Results of video-assisted thoracic surgery for stage I/II non-small cell lung cancer. Eur J Cardiothorac Surg 2004;26:158–64.

[4] Roviaro G, Rebuffat C, Varoli F, Vergani C, Mariani C, Maciocco M. Videoendoscopic pulmonary lobectomy for cancer. Surg Laparosc Endosc 1992;2:244–7.

[5] Yang CF, Adil SM, Anderson KL, Meyerhoff RR, Turley RS, Hartwig MG *et al.* Impact of patient selection and treatment strategies on outcomes after lobectomy for biopsy-proven stage IIIA pN2 non-small cell lung cancer. Eur J Cardiothorac Surg 2016;49:1607–13.

[6] Berry MF, D'Amico TA, Onaitis MW, Kelsey CR. Thoracoscopic approach to lobectomy for lung cancer does not compromise oncologic efficacy. Ann Thorac Surg 2014;98:197–202.

[7] Gonzalez-Rivas D, Paradela M, Fieira E, Velasco C. Single-incision video-assisted thoracoscopic lobectomy: initial results. J Thorac Cardiovasc Surg 2012;143:745–7.

[8] Wu CF, Gonzalez-Rivas D, Wen CT, Liu YH, Wu YC, Chao YK *et al.* Comparative short-term clinical outcomes of mediastinum tumor excision performed by conventional VATS and single-port VATS: is it worthwhile? Medicine (Baltimore) 2015;94:e1975.

[9] Gonzalez D, de la Torre M, Paradela M, Fernandez R, Delgado M, Garcia J *et al.* Video-assisted thoracic surgery lobectomy: 3-year initial experience with 200 cases. Eur J Cardiothorac Surg 2011;40:e21–8.

[10] Xie D, Wang H, Fei K, Chen C, Zhao D, Zhou X *et al.* Single-port video-assisted thoracic surgery in 1063 cases: a single-institution experience. Eur J Cardiothorac Surg 2016;49(Suppl 1):i31–6.

[11] Ng CS, Kim HK, Wong RH, Yim AP, Mok TS, Choi YH. Single-port video-assisted thoracoscopic major lung resections: experience with 150 consecutive cases. Thorac Cardiovasc Surg 2016;64:348–53.

[12] 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.

[13] Liu CC, Shih CS, Pennarun N, Cheng CT. Transition from a multiport technique to a single-port technique for lung cancer surgery: is lymph node dissection inferior using the single-port technique? Eur J Cardiothorac Surg 2016;49(Suppl 1):i64–72.

[14] Dai F, Meng S, Mei L, Guan C, Ma Z. Single-port video-assisted thoracic surgery in the treatment of non-small cell lung cancer: a propensity-matched comparative analysis. J Thorac Dis 2016;8:2872–8.

[15] Mu JW, Gao SG, Xue Q, Mao YS, Wang DL, Zhao J *et al.* A propensity matched comparison of effects between video assisted thoracoscopic single-port, two-port and three-port pulmonary resection on lung cancer. J Thorac Dis 2016;8:1469–76.

[16] Shen Y, Wang H, Feng M, Xi Y, Tan L, Wang Q. Single- versus multiple-port thoracoscopic lobectomy for lung cancer: a propensity-matched study. Eur J Cardiothorac Surg 2016;49(Suppl 1):i48–53.

[17] Hsieh MJ, Wang KC, Liu HP, Gonzalez-Rivas D, Wu CY, Liu YH *et al.* Management of acute postoperative pain with continuous intercostal nerve block after single port video-assisted thoracoscopic anatomic resection. J Thorac Dis 2016;8:3563–71.

[18] Boffa DJ, Dhamija A, Kosinski AS, Kim AW, Detterbeck FC, Mitchell JD *et al.* Fewer complications result from a video-assisted approach to anatomic resection of clinical stage I lung cancer. J Thorac Cardiovasc Surg 2014;148:637–43.

[19] Kent M, Wang T, Whyte R, Curran T, Flores R, Gangadharan S. Open, video-assisted thoracic surgery, and robotic lobectomy: review of a national database. Ann Thorac Surg 2014;97:236–42.

[20] McKenna RJ Jr, Houck W, Fuller CB. Video-assisted thoracic surgery lobectomy: experience with 1,100 cases. Ann Thorac Surg 2006;81:421–5.

[21] Onaitis MW, Petersen RP, Balderson SS, Toloza E, Burfeind WR, Harpole DH Jr *et al.* Thoracoscopic lobectomy is a safe and versatile procedure: experience with 500 consecutive patients. Ann Surg 2006;244:420–5.

[22] Marty-Ané CH, Canaud L, Solovei L, Alric P, Berthet JP. Video-assisted thoracoscopic lobectomy: an unavoidable trend? A retrospective single-institution series of 410 cases. Interact CardioVasc Thorac Surg 2013;17: 36–43.

[23] Cerfolio RJ, Bess KM, Wei B, Minnich DJ. Incidence, results, and our current intraoperative technique to control major vascular injuries during minimally invasive robotic thoracic surgery. Ann Thorac Surg 2016;102: 394–9.

[24] Nasir BS, Bryant AS, Minnich DJ, Wei B, Cerfolio RJ. Performing robotic lobectomy and segmentectomy: cost, profitability, and outcomes. Ann Thorac Surg 2014;98:203–8.

[25] Gonzalez-Rivas D, Stupnik T, Fernandez R, de la Torre M, Velasco C, Yang Y *et al.* Intraoperative bleeding control by uniportal video-assisted thoracoscopic surgery. Eur J Cardiothorac Surg 2016;49(Suppl 1):i17–24.

[26] Goldstraw P, Chansky K, Crowley J, Rami-Porta R, Asamura H, Eberhardt WE *et al*. The IASLC lung cancer staging project: proposals for revision of the TNM stage groupings in the forthcoming (eighth) edition of the TNM classification for lung cancer. J Thorac Oncol 2016;11:39–51.

[27] Chansky K, Detterbeck FC, Nicholson AG, Rusch VW, Vallières E, Groome P *et al*. The IASLC lung cancer staging project: external validation of the revision of the TNM stage groupings in the eighth edition of the TNM classification of lung cancer. J Thorac Oncol 2017;12:1109–21.

[28] Wu CF, Fu JY, Yeh CJ, Liu YH, Hsieh MJ, Wu YC *et al*. Recurrence risk factors analysis for stage I non-small cell lung cancer. Medicine (Baltimore) 2015;94:e1337.

[29] Riquet M, Legras A, Mordant P, Rivera C, Arame A, Gibault L *et al*. Number of mediastinal lymph nodes in non-small cell lung cancer: a Gaussian curve, not a prognostic factor. Ann Thorac Surg 2014;98:224–31.

[30] Jeon JH, Kim MS, Moon DH, Yang HC, Hwangbo B, Kim HY *et al*. Prognostic differences in subgroups of patients with surgically resected T3 non-small cell lung cancer. Ann Thorac Surg 2016;102:1630–7.