Original Article

Thoracoscopic double sleeve lobectomy in 13 patients: a series report from multi-centers

Jun Huang[1,2,3]*, Jingpei Li[1,2,3]*, Yuan Qiu[1,2,3], Xin Xu[1,2,3], Dmitrii Sekhniaidze[4], Hanzhang Chen[1,2,3], Diego Gonzalez-Rivas[5,6], Jianxing He[1,2,3]

[1]Department of Thoracic Surgery, Guangzhou Medical University First Affiliated Hospital, Guangzhou 510120, China; [2]Guangzhou Institute of Respiratory Disease, Guangzhou 510120, China; [3]Key cite of National Clinical Research Center for Respiratory Diseases, Guangzhou 510120, China; [4]Thoracic Surgery Department, Regional Oncological Center, Tyumen, Russian Federation; [5]Department of Thoracic Surgery, Coruña University Hospital, Coruña, Spain; [6]Minimally Invasive Thoracic Surgery Unit (UCTMI), Coruña, Spain

*These authors contributed equally to this work.

Correspondence to: Professor Jianxing He, MD, PhD, FACS. Department of Cardiothoracic Surgery, The First Affiliated Hospital of Guangzhou Medical University, 151 Yanjiang Road, Guangzhou 510120, China. Email: drjianxing.he@gmail.com.

Background: This study aims to explore the feasibility and safety of video-assisted thoracic surgery (VATS) double sleeve lobectomy in patients with non-small lung cell cancer (NSCLC).

Methods: Between June 2012 and August 2014, 13 NSCLC patients underwent thoracoscopic double sleeve lobectomy and mediastinal lymphadenectomy at three institutions. A retrospective analysis of clinical characteristics, operative data, postoperative events and follow-up was performed.

Results: Thirteen NSCLC patients (median age, 60 years; range, 43-67 years) underwent thoracoscopic double sleeve lobectomy. There were no conversions to thoracotomy. Left upper lobectomy was most frequently performed (eleven patients). Median operative time was 263 minutes (range, 218-330 minutes), and median blood loss was 224 mL (range, 60-400 mL). The learning curve revealed reductions in both operative times and blood loss of ten cases from one center. Median data were duration of blocking pulmonary artery (PA) 72 minutes (range, 44-143 minutes), resected lymph nodes 24 (range, 10-46), stations of retrieved lymph nodes 6 (range, 5-9), thoracic drainage 1,042 mL (range, 500-1,700 mL), duration of thoracic drainage 5 days (range, 3-8 days), postoperative hospital stay 10 days (range, 7-20 days), and ICU stay 1 day (range, 1-2 days). One patient (1/13, 7.70%) suffered from pneumonia after surgery. There were no deaths at 30 days. Median duration of follow-up was 6 months (range, 1-26 months). And no local recurrences or distant metastasis were reported.

Conclusions: Thoracoscopic double sleeve lobectomy is a technically challenging, but feasible procedure for NSCLC patients and it should be restricted to skilled VATS surgeons.

Keywords: Non-small lung cell cancer (NSCLC); video-assisted thoracic surgery (VATS); sleeve lobectomy; learning curve

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Introduction

Cao and his colleagues (1) reported that video-assisted thoracic surgery (VATS) lobectomy for non-small lung cell cancer (NSCLC) can yield similar long-term survival outcomes with conventional open lobectomy. With the widely application of VATS technique, the indication of this procedure has been greatly broadened, and the technical barriers have been constantly broken (2,3). As an less invasive alternative procedure to total pneumonectomy in patients with locally advanced tumors involving the pulmonary artery (PA) and bronchus (4), sleeve lobectomy by conventional thoracotomy, especially double sleeve

lobectomy (vascular and bronchial) is still the preferred approach due to high difficulty in operation and potentially undesirable complications, even when performed by skilled VATS surgeons.

Since the first reported VATS bronchial sleeve lobectomy was published (5), more and more technical challenges have become reality, which would be VATS angioplasty (6-8), uniportal VATS bronchial sleeve lobectomy (9,10), and even thoracoscopic double sleeve lobectomy (11-13). However, all of these reports were single center experiences, and most series were less than five patients. Hence, the thoracic society urged for a multi-center data of thoracoscopic double sleeve lobectomy to addresses the feasibility and safety of this operation. In this study, we present the first multi-center experiences of thoracoscopic double sleeve lobectomy.

Patients and methods

The medical ethics board of all participating hospitals approved the study. Between June 2012 and August 2014, 13 patients underwent a thoracoscopic double sleeve lobectomy including mediastinal lymphadenectomy for primary NSCLC at the First Affiliated Hospital of Guangzhou Medical University (Guangzhou, China), Coruña University hospital (Coruña, Spain) and Tyumen Regional Cancer Center (Tyumen, Russia). Clinical records of the patients were retrospectively analyzed.

All patients were diagnosed with NSCLC by bronchoscopy. Preoperative staging was determined mainly by enhanced thoracic computerized tomography, brain magnetic resonance or computed tomography (CT), and bone scintigraphy, except that one patient received positron emission tomography/CT (PET-CT). Physical examination, standard laboratory tests, electrocardiograms, and lung function tests were performed in all patients.

There were two patients with clinic N2 disease, and both received induction chemotherapy. One patient with squamous cell carcinoma had four cycles of paclitaxel + cisplatin before surgery (case 6), the other patient with adenocarcinoma had six cycles of pemetrexed + cisplatin (case 11). Two patients rejected to receive adjuvant chemotherapy.

Surgical technique

All patients received a combination of epidural and general anesthesia before the operation. The patients were placed in a lateral decubitus position. All 13 procedures were performed via 3-4 ports, or uniportal. The detailed port design for different methods was described in *Table 1*.

Before dissection, the mediastinal pleura were inspected to assess the mobility of the tumor and its invasion into surrounding structures. Once radical surgery (*Figure 1*) was guaranteed, the superior or inferior pulmonary vein would be dissected and then transected with endostapler (Ethicon Endo-Surgery, Johnson & Johnson, Cincinnati, OH, USA). The main bronchus and distal bronchus were transected with a long handle blade and scissor (*Figure 1A*).

After the main PA was dissected, there were four methods with different port design to clamp the PA: (method A) two patients (case 1-2) underwent three ports thoracoscopic double sleeve lobectomy (*Table 1*). One pair of vascular blocking forceps was placed through the operative port (3.5 cm) on the proximal PA, and the other pair of forceps was placed through the left port (10 mm) on the distal PA (*Figure 2*); (method B) one patients (case 3) underwent three ports thoracoscopic double sleeve lobectomy (*Table 1*). One pair of vascular blocking forceps was placed through the operative port (3.5 cm) on the proximal PA. Different with method A, the other pair of forceps was placed through the camera port (10 mm) on the distal PA (*Figure 3*); (method C) seven patients (case 4-10) underwent four ports thoracoscopic double sleeve lobectomy (*Table 1*). One pair of vascular blocking forceps was placed through a 5-mm port located in anterior chest wall at the level of the proximal PA, and the other pair of forceps was placed through the posterior axillary line port (10 mm) on the distal PA (*Figure 4*); (method D) three patients (case 11-13) underwent uniportal thoracoscopic double sleeve lobectomy (*Table 1*). A bulldog clamp was used for the distal PA while the vascular blocking forceps were used to clamp the proximal PA (*Figure 5*). After the PA clamp was completed, the invasive part of main PA was resected (*Figure 1B*). The surgical technique for PA circumferential sleeve resection is similar to previous reports (11,14). The wedge anastomosis for uniportal approach would only be applied if the tumor invasion was less than 1/3 of the circumference and 2 cm width of the basilar part. After confirming the resected margin of PA, the PA was reconstructed with a primary closure using 4-0 Prolene (Ethicon, Somerville, NJ, USA) (*Figure 1C*). A standard needle holder and a pair of forceps were inserted to complete running suture through the 3.5-5 cm operative port (*Table 1*). After the bronchial margins were confirmed as negative by intraoperative frozen section, the bronchial sleeve reconstruction was performed

Table 1 The ports design of thoracoscopic double sleeve lobectomy

Method	Case	Ports	Camera port	Operative port	VBF port 1	VBF port 2
A	Case 1-2	3	Midaxillary line/7th ICS/10 mm	Preaxilary line/4th ICS/3.5 cm	Postaxillary line/7th ICS/10 mm	–
B	Case 3	3	Postaxillary line/7th ICS/10 mm	Preaxilary line/4th ICS/3.5 cm	Midaxillary line/7th ICS/10 mm	–
C	Case 4-10	4	Midaxillary line/7th ICS/10 mm	Preaxilary line/3th ICS/3.5 cm	Postaxillary line/7th ICS/10 mm	Anterior chest/ PA level/5 mm
D	Case 11-13	1	Preaxilary line/4th or 5th ICS/4-5cm			

VBF, vascular blocking forcep; ICS, intercostal space; PA, pulmonary artery.

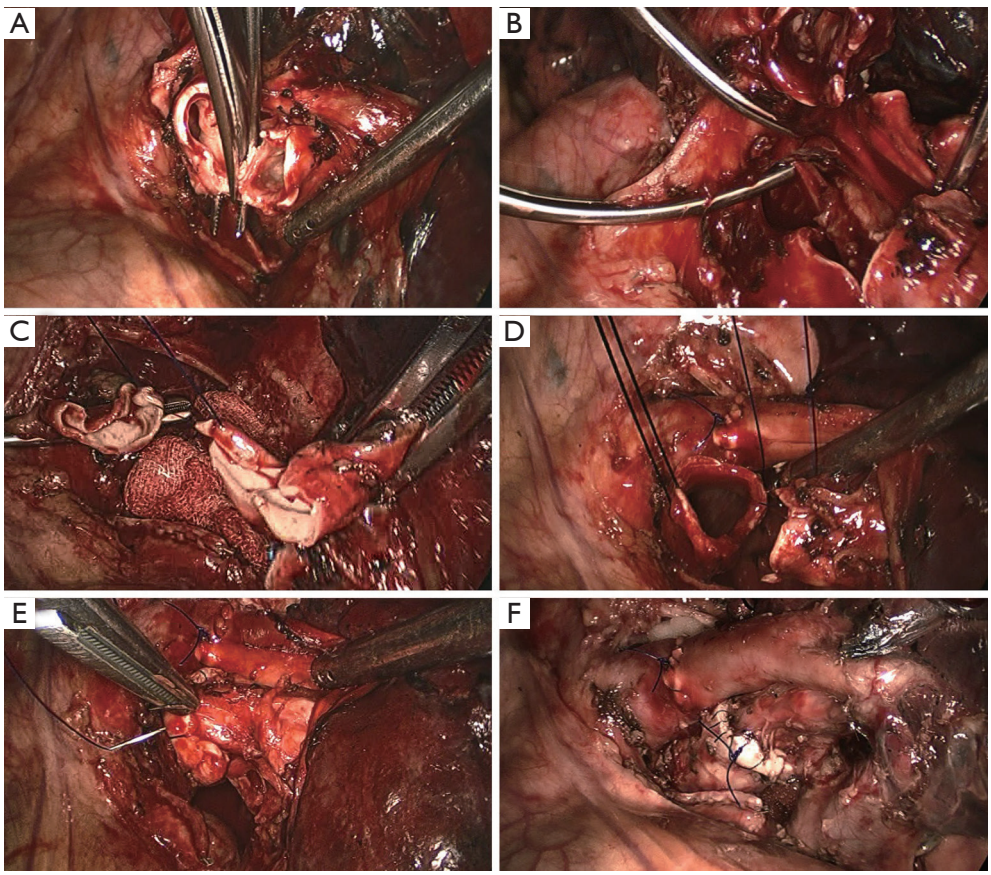

Figure 1 Surgical technique of thoracoscopic double sleeve lobectomy. (A) Transecting the main bronchus; (B) sleeve resecting the blocked PA; (C) sleeve reconstructing the blocked PA; (D) completed vascular reconstruction and starting sleeve bronchial reconstruction; (E) sleeve reconstructing the bronchus; (F) over view of double sleeve reconstruction. PA, pulmonary artery.

by using a 3-0 Prolene (Ethicon, Somerville, NJ, USA) for cartilaginous and membranous portions (*Figure 1D,E*). The residual lobe was inflated and no air leakage was detected underwater. Then, the distal clamp was removed before tying the arterial sutures to remove the intravascular air. The proximal clamp was finally removed to ensure hemostasis of the sewn PA (*Figure 1F*).

During uniportal thoracoscopic double sleeve lobectomy, bronchial sleeve reconstruction was completed before angioplasty to avoid traction on the arterial suture. In three cases (case 1, case 3 and case 6), pericardium, pleura and other tissue were used to separate the PA and bronchus to

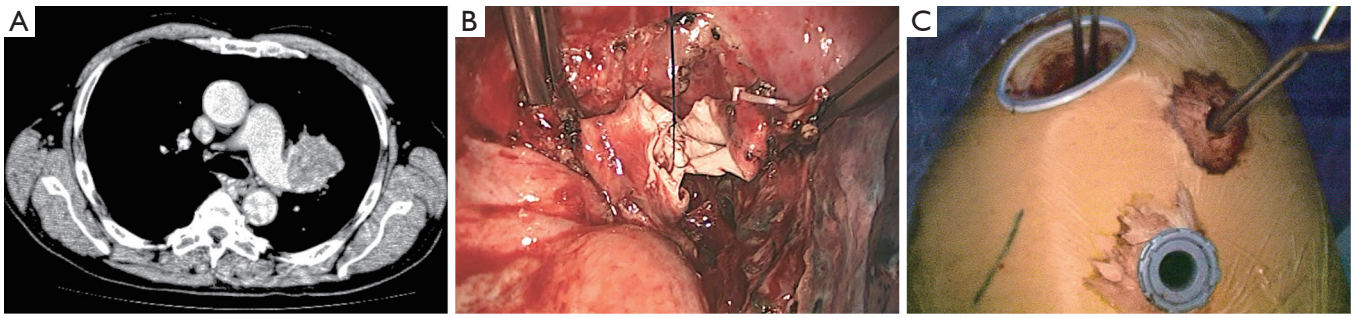

Figure 2 Method A: ports design of thoracoscopic double sleeve lobectomy.

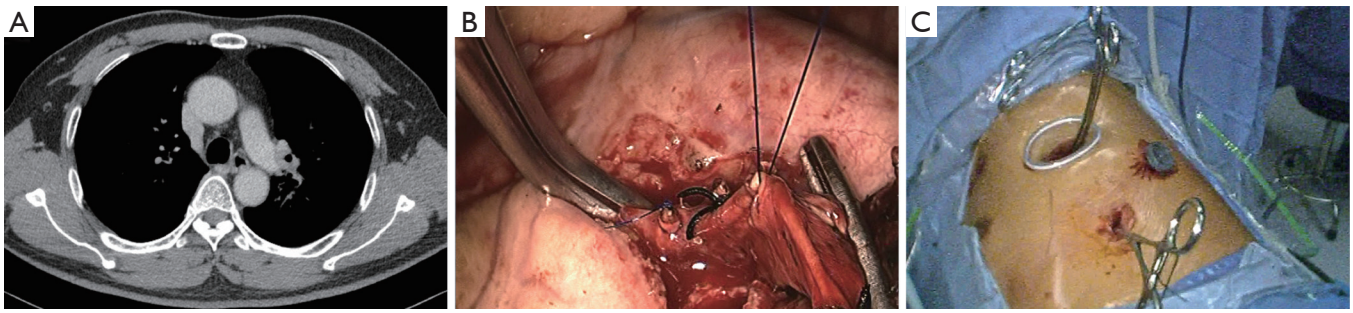

Figure 3 Method B: ports design of thoracoscopic double sleeve lobectomy.

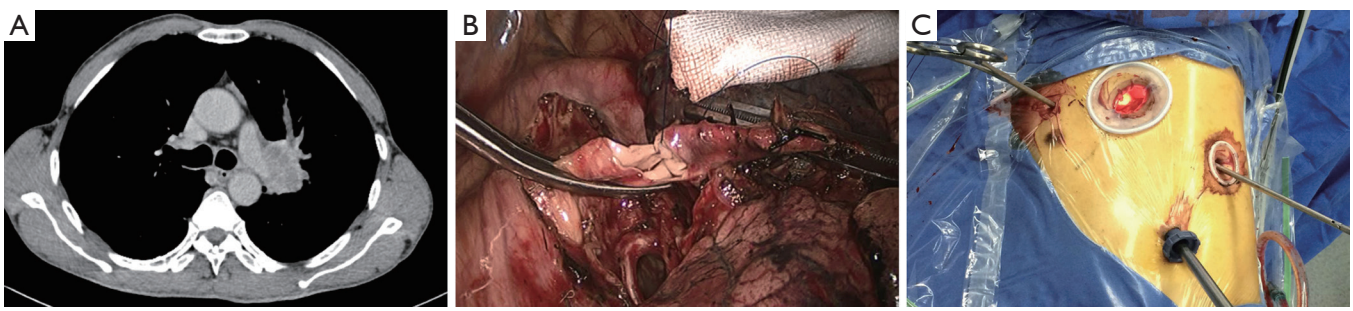

Figure 4 Method C: ports design of thoracoscopic double sleeve lobectomy.

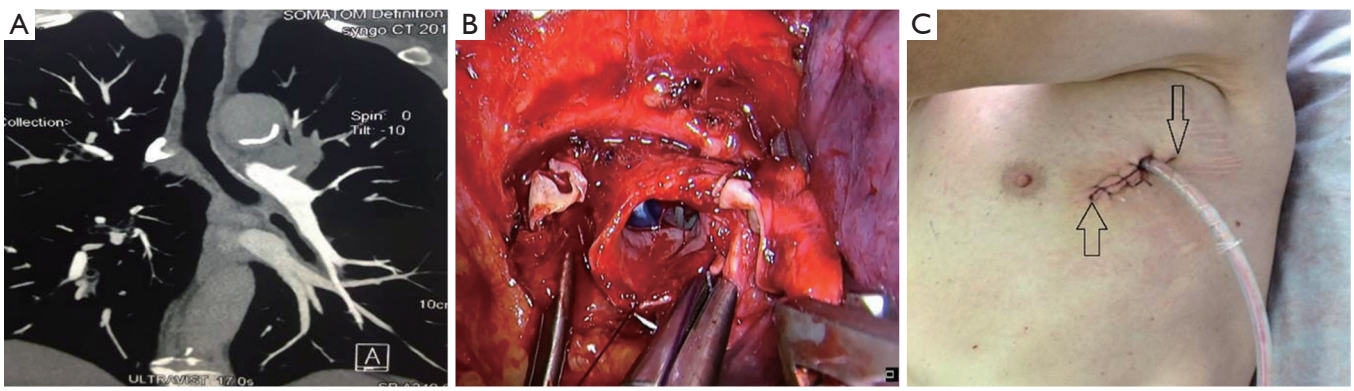

Figure 5 Method D: ports design of thoracoscopic double sleeve lobectomy.

prevent bronchial artery fistula.

Thoracic surgery was completed by placement of one or two intercostal drainage tubes and closure of the thoracic incisions. Postoperative bronchoscopy is then performed to clear the airways of blood and secretions before extubation.

Statistical analysis

Clinical information was recorded in Microsoft EXCEL (Microsoft Corp, Redmond, WA, USA) for further processing. Enumeration data were presented with frequencies and percentages. Measurement data were presented with median and range.

Results

The clinical characteristics of all patients were summarized in *Table 2*. All thirteen patients were males. Median age was 60 years (range, 43-67years). Twelve patients (12/13, 92.3%) had a smoking history. Ten patients (10/13, 76.9%) were diagnosed as squamous carcinoma, while two patients (2/13, 15.4%) were adenocarcinoma, and one patient (1/13, 7.7%) was adenosquamous carcinoma. The location of the tumors was as follow: eleven left upper lobe (LUL) (11/13, 84.6%), one right upper lobe (RUL) (1/13, 7.7%), and one left lower lobe (LLL) (1/13, 7.7%). There were ten invasion of main PA (10/13, 76.9%), and two invasion of branch PA (2/13, 15.4%).

The operative data of all patients were shown in *Table 3*. There were no conversions to thoracotomy. The median operative time was 264 minutes (range, 218-330 minutes). The median blood loss was 224 mL (range, 60-400 mL). There were reductions in both operative times and blood loss of ten cases from one center, which were from 298.5 to 253 minutes, and 300 to 150 mL separately (*Figure 6*). The median duration of blocking PA was 72 minutes (range, 44-143 minutes); the median duration for PA anastomosis time was 45 minutes (range, 26-75 minutes); the median duration for bronchial anastomosis was 31 minutes (range, 15-50 minutes); the median length of resected PA was 2 cm (range, 1-3 cm); the median length of resected bronchus was 2 cm (range, 1.5-3 cm). The median numbers of resected lymph nodes were 24 (range, 10-46), and the median stations of retrieved lymph nodes were 6 (range, 5-9).

Postoperative events were summarized in *Table 4*. One patient suffered from pneumonia after surgery, and no patients died at 30 days. The median postoperative hospital stay was 10 days (range, 7-20 days). The median ICU stay was 1 day (range, 1-2 days). The median duration of thoracic drainage was 5 days (range, 3-8 days); the median thoracic drainage was 1,042 mL (range, 500-1,700 mL). The median duration of follow-up was 6 months (range, <1-26 months). Eight patients had completed four cycles platinum-based adjuvant chemotherapy, the chemotherapy treatment of the remaining three patients is still ongoing. Two patients received at least four cycles of neoadjuvant chemotherapy, and so, did not receive adjuvant chemotherapy. To date, no local recurrences or distant metastasis were reported.

Discussion

In this retrospective multi-center series report, thoracoscopic double sleeve lobectomy was successfully performed to thirteen NSCLC patients. There were no conversions to thoracotomy. The median operative time was 263 minutes. The median blood loss was 224 mL. The reductions in operative times and blood loss of ten cases from one center were promising. The median numbers of resected lymph nodes were 24. The median postoperative hospital stay was 10 days. The median duration of follow-up was 6 months. To date, no local recurrences or distant metastasis were reported.

Although VATS lobectomy has been widely applied (15), double sleeve lobectomy is still a contraindication to VATS in most medical centers (16). To offer potential benefits of VATS to more NSCLC patients, progressively technical innovations have been made, and several institutes have reported their initial experiences of thoracoscopic double sleeve lobectomy (11-13). However, all of these recent reports were same series, or even single patients from one medical center, and they mainly focused on technical feasibility instead of general safety.

Technically, though there were separate methods of clamping the PA for uniportal or multiport procedures, each method was equally effective in blocking PA. In the uniportal procedure, a bulldog clamp is placed inside the chest cavity to clamp the distal artery, which allowed surgeons more operative space. Additionally, once the proximal PA was cut, the exposure and reconstruction of the bronchus could be more convenient through the 4-5 cm operative port, based on the relative anatomical position of the PA and bronchus. For bronchial anastomosis eased subsequent PA reconstruction and reduced vascular tension at the same time. In multiport procedure, an additional 5 mm incision greatly eased the surgical performance, which has already been reported in major thoracic pulmonary

Table 2 Patient characteristics

Character	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12	Case 13
Age (years)	60	67	58	57	54	63	62	67	60	43	65	66	52
Gender	Male	Male	Male	Male	Male	Male	Male	Male	Male	Male	Male	Male	Male
Smoking history	40 y, 40/d	30 y, 20/d	35 y, 20/d	35 y, 60/d	25 y, 60/d	50 y, 60/d	40 y, 20/d	30 y, 20/d	40 y, 40/d	No	31 y, 40/d	40 y, 40/d	32 y, 40/d
Histology	Sqa	Ad-Sqa	Sqa	Sqa	Sqa	Sqa	Sqa	Sqa	Sqa	Ade	Ade	Sqa	Sqa
Tumor size	4.5×3.4	5.7×5.3	3.0×2.2	5.8×4.8	4.3×3.2	3.8×2.2	4.8×4.3	3.6×3.5	1.6×1.1	7.6×7.4	7.5×7.5	5	5
Pathological stage	T3N1M0	T3N1M0	T3N0M0	T3N0M0	T3N1M0	T3N1M0	T3N2M0	T3N0M0	T3N2M0	T3N1M0	T3N0M0	T3N1M0	T2aN0M0
Location	LUL	LUL	LUL	LUL	LUL	LUL	LLL	LUL	RUL	LUL	LUL	LUL	LUL
PA invasion	Main	Main	Branch	Main	Main	Main	Main	Main	Branch	Main	Main	Main	–
Pulmonary function													
FEV_1	2.71	2.58	2.67	2.98	2.73	1.79	2.48	2.32	1.86	3.35	NA	NA	NA
FEV_1%	93.33	87.61	88.73	89.17	74.00	63.15	87.52	92.97	69.58	92.53	109	NA	NA
MVV	120.6	88.86	78.43	109.4	100.7	80.9	102.58	96.3	99.51	125.9	NA	NA	NA

Sqa, squamous carcinoma; Ad-Sqa, adenosquamous carcinoma; Ade, adenocarcinoma; LUL, left upper lobe; LLL, left lower lobe; RUL, right upper lobe; PA, pulmonary artery; NA, no available; FEV_1, forced expiratory volume in first second; MVV, maximal ventilatory volume; y, years.

Table 3 The operative data

Character	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12	Case 13
Blood loss (mL)	200	400	400	60	70	400	200	300	100	200	80	300	200
Operative time (min)	274	323	253	218	222	274	230	256	230	276	260	330	280
Duration of blocking PA (min)	68	108	76	44	45	55	50	60	60	143	110	70	50
Duration of angioplasty (min)	44	60	30	26	35	40	45	41	35	75	60	60	40
Duration of bronchialplasty (min)	35	32	42	30	25	15	30	23	30	24	40	50	30
Length of resected PA (cm)	2	3	1	1	3	2	1	1	1	2	3	3	3
Length of resected bronchus (cm)	2	2	2	1.5	2	1.5	1.5	2	1.5	1.5	1.5	3	3
Numbers of resected LN	37	26	20	46	27	21	19	20	34	24	10	12	13
Stations of retrieved LN	7	7	6	7	9	5	6	7	6	6	5	5	5

PA, pulmonary artery; LN, lymph nodes.

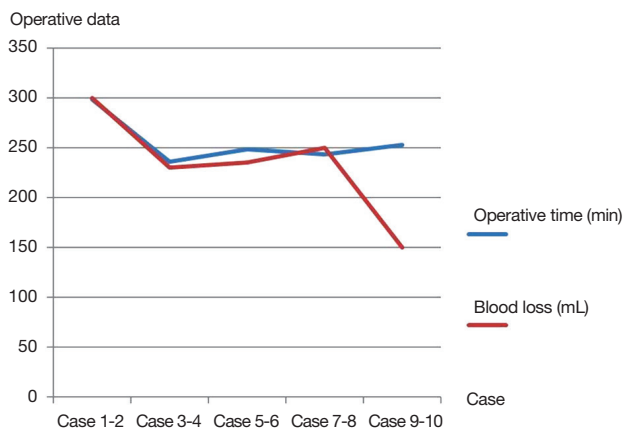

Figure 6 Promising reductions in operative times and blood loss of ten cases from one center.

resection (17) and minimally invasive cardiac surgery (18,19). Although the choice involving the numbers of port during the procedure is simply based on the surgeons' preference and experience, it is not a key issue when it comes to the success of thoracoscopic double sleeve lobectomy.

As for surgical trauma, the median operative time and blood loss of this study were 264 minutes and 224 mL, which were consistent with previous reports of thoracoscopic double sleeve lobectomy (11,13,14). And the *Figure 6* also revealed promising reductions in both operative times and blood loss of ten cases from one center, which were from 298.5 to 253 minutes, and 300 to 150 mL separately. Hence, it indicated that thoracoscopic double sleeve lobectomy could be easily done by skilled VATS surgeons with progressive accumulation of surgical experience.

In this series, the median duration of blocking PA was 60 minutes (range, 44-110 minutes) and no complications associated with clamp of the PA occurred. The longest duration of blocking PA among these patients was 143 min, postoperative recovery was uneventful, and no reperfusion injury or thrombosis occurred. Jiang and his colleagues (20) reported a pulmonary vessel blocking model in rabbits that underwent a block of the PA and veins compared to block of the PA alone and found that it might be safe to block the pulmonary vessels up to one hour during pulmonary surgery. In our experience, with satisfactory blocking PA, the arterial reconstruction would be safer and easier during the operation. Since there were no surgical reports

Table 4 Postoperative events

Character	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12	Case 13
Morbidity	–	–	–	–	–	–	–	–	–	–	Pneumonia	–	–
Postoperative hospital stay (d)	7	10	12	8	7	15	8	9	7	13	20	12	9
ICU stay (d)	1	1	1	1	1	1	1	1	1	1	1	2	1
Duration of thoracic drainage (d)	3	6	6	5	3	8	5	4	5	6	5	4	2
Thoracic drainage (mL)	700	1500	1,500	1,330	835	1,700	950	1,100	850	680	700	NA	NA
Adjuvant chemotherapy	TXT/ TO	TXT/ LOP	PAX/ LOP	PAX/ DDP	PAX/ LOP	–	PAX/ DDP	PAX/ DDP	–	–	–	VP-16/ DDP	–
Chemotherapy cycles	4	4	4	4	4	–	4	4	On	On	–	4	On
Follow-up duration (month)	26	15	9	7	4	3	3	3	2	<1	3	6	1
Status	Live	Live	Live	Live	Live	Live	Live	Live	Live	Live	Live	Live	Live

TXT, docetaxe; TO, oxaliplatin; LOP, lobaplatin; PAX, paclitaxel; DDP, cisplatin; VP-16, etoposide; NA, no available.

concerning this issue, we appeal for further research to determine the proper time for this procedure.

With regard to postoperative complications, only one significant complication was observed and was attributed to effects from the second line of treatment: pneumonia was diagnosed in a patient who received six cycles of neoadjuvant chemotherapy. This suggests that neoadjuvant chemotherapy patients can successfully undergo the operation, but postoperative management needs more attention, especially in regards to anti infection, and nutrition. There were no significant complications observed in the remaining 12 patients. However, there are also several limitations to our study. First, there were only 13 patients in this series, and most tumors of these patients were located in LUL. This might contribute to the surgeons' preference and experience. Second, the median duration of follow-up was only 6 months, and there were still three patients on chemotherapy. The potential long-term benefit of this operation is still unclear. Hence, further experience of both short-term and long-term benefit of thoracoscopic double sleeve lobectomy is needed to be accumulated.

Conclusions

Thoracoscopic double sleeve lobectomy is safe and feasible when performed by a skilled VATS surgeon, although further investigations are needed to confirm this conclusion.

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