



Simplified synchronous disconnection of pulmonary arteries and veins for right upper lobectomy

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Abstract

Background Video-assisted thoracoscopic lobectomy with lymphadenectomy is considered one of the most effective treatments for early non-small cell lung cancer. We developed a novel approach for lobectomy in patients with right upper lung cancer through simplified synchronous disconnection of pulmonary arteries and veins. This study aimed to evaluate the feasibility, efficacy, safety, and cost-effectiveness of this minimally invasive technique in managing right upper lobectomy.

Patients and methods From March 2016 to September 2017, 62 patients with right upper lung cancer underwent lobectomy via simplified synchronous disconnection of pulmonary arteriovenous by video-assisted thoracoscopic surgery. All patients were followed up for 6–12 months after the procedure through clinic visits or telephone/e-mail interviews.

Results Of the 62 patients (mean age, 57.2 ± 8.7 years), 28 were men (45.2%) and 34 (54.8%) were women. All procedures were successfully performed by thoracoscopy, with a mean operating time of 66.2 ± 9.0 min. The mean blood loss was 40.3 ± 19.5 mL. Only 1 (1.61%) patient required blood transfusion. The mean number of endoscopic linear stapling devices used was 2.6 ± 0.7 . The mean number of lymph nodes harvested was 16.0 ± 1.6 . Postoperative pneumonia was encountered in 4 (6.45%) patients. There was no postoperative mortality. The mean length of hospital stay was 5.3 ± 1.3 days. Six-month follow-up revealed an excellent clinical result and degree of satisfaction.

Conclusions Simplified synchronous disconnection of pulmonary arteries and veins is a feasible, economical, safe, and effective therapeutic procedure for right upper lung carcinoma. This novel procedure shows promise as a viable surgical approach for right upper lobectomy.

Keywords Non-small cell lung cancer · Synchronous disconnection · Thoracoscopy · Video-assisted thoracoscopic surgery

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Video-assisted thoracoscopic pulmonary lobectomy with systematic lymphadenectomy is considered one of the most effective treatments for early non-small cell lung cancer (NSCLC) [1, 2]. In most institutions, the procedure is usually performed through conventional three-port video-assisted thoracoscopic surgery (cVATS) [3]. cVATS operative steps for right upper lobectomy (RUL) treat the pulmonary arteries and veins separately, including the superior pulmonary vein, posterior segmental artery, and anterior and apical segmental trunk. As the truncus intermedius artery lies just behind the superior pulmonary vein, it is easy to damage the truncus intermedius artery and cause massive hemorrhage when exposing the superior pulmonary vein. The posterior segment of the upper lobe pulmonary veins is often located above the interleaf pulmonary artery and is liable to cause injury and bleeding during the separation process. Therefore, cVATS for RUL may occasionally cause vessel injury and massive hemorrhage.

Considering the disadvantages of these pulmonary lobectomy procedures, in March 2016 we designed a simplified synchronous disconnection of pulmonary arteries and veins (SSDPAV) for RUL at our hospital. In this article, we report our initial experience with SSDPAV for RUL.

Patients and methods

Patient selection

From March 2016 to September 2017, a total of 62 patients with initial stages of NSCLC underwent SSDPAV for RUL by means of VATS at our institution. The patients' characteristics are listed in Table 1. Clinical stage of NSCLC was based on UICC staging (2017, 8th Edition). This study was approved by the Institutional Review Board and Ethics Committee of the First Affiliated Hospital of Fujian Medical University (No. 2016-03, March 2016). All patients underwent a preoperative routine blood examination, cardiologic consultation, pulmonary function measurement, chest computed tomography (CT) scan, abdominal ultrasonography, bone scintigraphy scan, and magnetic resonance imaging (MRI) of the brain to rule out the extrathoracic spread of disease prior to surgery. Pathologic evidence of lung cancer was obtained in all patients by transbronchial biopsy, sputum cytology, transcutaneous biopsy under CT guidance, or lung biopsy under VATS [4]. A detailed medical history was also documented. All patients granted their informed consent at least 1 day before surgery after careful explanation of the procedure and the goals of the study.

Table 1 Clinical, surgical, and oncological characteristics of patients ($N=62$)

Variables	
Age (years)	57.2 ± 8.7
Sex (M/F)	28:34
Associated disease (n)	
Chronic obstructive pulmonary disease (Gold guidelines)	2
Diabetes mellitus	1
Current smoker	1
Oncological stage (pTNM) (n)	
pIA	13
pIB	29
pIC	18
pIIA	2
Pathological characteristics (n)	
Squamous cell carcinoma	6
Adenocarcinoma	53
Adenosquamous carcinoma	3

Inclusion criteria were: initial stages of NSCLC T1N0 to 1M0, or isolated single N2 lymphadenectomy of phase IIIA; and no history of right thoracic surgery or severe chest wall deformity; age below 75 years; preoperative lung function: FEV1% and MVV % of predicted more than 50%, FEV1 more than 1L; quit smoking for at least 2 weeks before the operation for smoker. Exclusion criteria were: tumor invasion of the large vessels of the mediastinum, or important nerves such as the recurrent laryngeal nerve; tumor invasion of the protuberance or trachea; tumor invasion of large chest walls requiring reconstruction; multi-station lymphatic metastasis; mediastinal lymphoid tuberculosis; indistinct borderline between peripheral blood vessels; bronchial female patients and bronchial branches; history of right chest surgery or serious pleuritis; severe chest wall deformity; upper airway and maxillofacial injury or deformity; lung, pleural, or heart disease.

Surgical procedure

All patients were positioned on the operating table in the lateral decubitus position and underwent healthy side one-lung ventilation (Fig. 1A). A 1.0-cm incision for the camera port was made through the 6th or 7th intercostal space in the anterior axillary line. We used a 1.0-cm 30° thoracoscope (Karl Storz, Tuttlingen, Germany) to observe the thoracic cavity. If the adhesion was firm in the thoracic space, VATS lobectomy was converted to open thoracotomy. Such converted cases were excluded from this study. When the lesions were identified and adhesions were minimal, a 3.0-cm port was placed along the anterior axillary line in the 4th intercostal space as the main access port, and a 0.5-cm Disposable Laparoscopic Puncture (Surgaid, Xiamen, China) was placed through the 7th intercostal space at the posterior axillary line as the auxiliary access port. A wound protector (Endo Keeper; NELIS, Bucheon, Korea) was fixed on the incision window (Fig. 1B, C). SSDPAV for RUL proceeded as follows. First, the horizontal fissure was dissociated from anterior to posterior to expose the right upper bronchus (Fig. 2A, B), and one endoscopic linear stapling device (ENDO-GIA; Covidien, Medtronic, MN, USA) was inserted into the window for structures of the right upper bronchus (Fig. 2C, D). In case the horizontal fissure was slightly incomplete, the use of energy device was preferred. If the horizontal fissure was poorly developed or completely undeveloped, the use of stapler could be considered, or convert to traditional or single-direction thoracoscopic lobectomy [5], such converted cases were also excluded from this study. Second, after freeing the pulmonary hilar pleura, group 10 and 11 lymph node dissection was performed (Fig. 2E, F). Third, another stapler was used to perform SSDPAV (Figs. 3, 4). Fourth, lymph node dissection was performed for groups 2, 4, 7, 8, and 9 (Fig. 5A–D). Fifth, when pleural irrigation and lung expansion showed no air leakage or active hemorrhage, a 26F

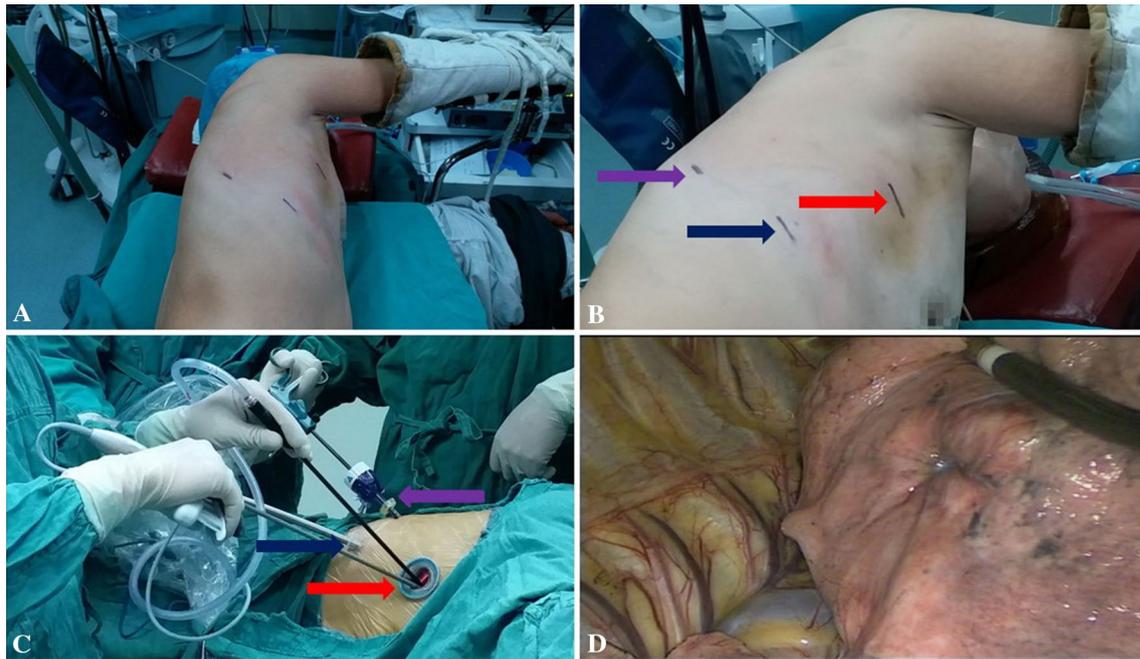


Fig. 1 **A** The lateral decubitus used during surgery. **B** Chest incision marked before operation. The colored arrows indicate the following: red, the main operational incision; purple, incision for the camera port; blue, the auxiliary access portion. **C** Simplified synchronous disconnection of pulmonary arteries/veins for RUL procedure. The

colored arrows indicate the following: red, ultrasonic knife, endoscopic suction apparatus, and wound protector; blue, 1.0-cm 30° thoracoscope and trocar; purple, 0.5-cm disposable laparoscopic puncture and endograsper. **D** Endoscopic view of right thoracic cavity. (Color figure online)

chest tube was placed directly through the incision. The chest tube was removed [6] when: (1) the lung was fully expanded without pleural effusion on chest radiography, (2) there was no air leakage through the chest tube, and (3) the amount of drainage was less than 100 mL per day.

Data collection and follow-up

The operating time, intraoperative bleeding, number of lymph nodes harvested, hospital stay, drainage time, pain score, and complications were recorded. The patients were followed up for 6–12 months by hospital visits (41 cases, 66.1%), telephone (16 cases, 25.8%), or e-mail (5 cases, 8.06%). The mean duration of follow-up was 8.7 ± 2.5 months. Patients were required to fill out a detailed questionnaire (Table 2). The data collected include cosmetic scores, satisfaction scores, postoperative dyspnea, residual pain, and incidence of tumor recurrence or metastasis.

Results

All procedures were successfully performed in all patients, with a mean operating time of 66.2 ± 9.0 min. There was no surgical mortality and no conversion to open procedure for massive bleeding during the operation. The mean blood loss

was 40.3 ± 19.5 mL. Only 1 (1.61%) patient required blood transfusion for postoperative hemoglobin < 70 g/L. The mean number of endoscopic linear stapling devices used was 2.6 ± 0.7 , and the mean number of lymph nodes harvested was 16.0 ± 1.6 . The mean drainage time was 3.2 ± 0.8 days, with an average drainage of 87.6 ± 25.3 mL/day. The mean length of postoperative hospital stay was 5.3 ± 1.3 days, with 38 patients (61.3%) discharged on the fourth or fifth postoperative day and the remainder discharged on the sixth to tenth day. Postoperative pneumonia was encountered in 4 (6.45%) patients. This diagnosis was achieved by chest radiography findings combined with clinical and laboratory data. Among these patients, two were long-term male smokers and were diagnosed with mild chronic obstructive pulmonary disease before surgery, one was a current smoker, and the other had a history of diabetes for more than 3 years, for which insulin was used to control blood sugar before surgery. All of these cases were resolved by intravenous antibiotics and did not require further intervention. No wound infection was observed in any patient.

Follow-up evaluations were completed by all participants. Forty-five patients (72.6%) returned the questionnaire immediately, and 17 patients (27.4%) returned it after a reminder or repeated e-mailing. Outcomes of follow-up after surgery are shown in Table 5. The response rates at the time of discharge and 6–12 months postoperatively were 100%. There

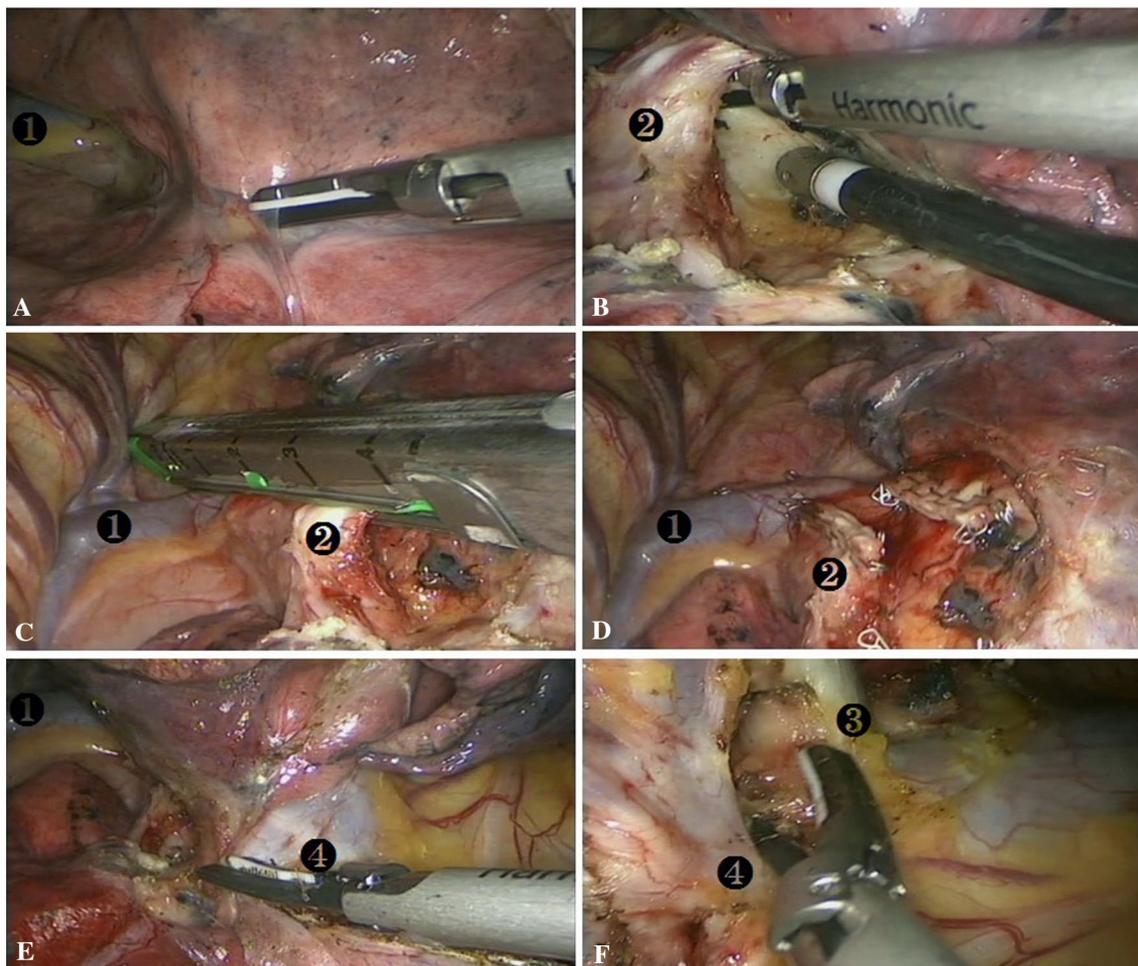


Fig. 2 **A** and **B** Dissociating the horizontal fissure from anterior to posterior to expose the right upper bronchus. **C** and **D** Cutting off the right upper lung bronchus with an endoscopic linear stapling device. **E** and **F** Upon freeing pulmonary hilar pleura, group 10 and 11 lymph

node dissection was performed. Dingbat negative circled one—arch of azygos vein; Dingbat negative circled two—right upper lobe bronchus; Dingbat negative circled three—truncus anterior; Dingbat negative circled four—right upper pulmonary vein

was no postoperative mortality, no tumor recurrence, and no metastasis within the follow-up period. Postoperative pain affected 15 patients (24.2%) at the time of discharge. According to a visual analog scale (VAS) pain score, 12 cases (80.0%) were considered mildly painful (mean VAS score 2.43 ± 0.58) and 3 (20.0%) were considered moderately painful (mean VAS score 5.72 ± 0.59). No patient required analgesia. None of the patients complained about postoperative pain 6 months after surgery. Our procedure showed an excellent clinical result (Tables 3, 4) and degree of satisfaction (Table 5) during follow-up.

Discussion

We successfully performed SSDPAV for RUL in all 62 patients and yielded some useful preliminary outcome data. There was no postoperative mortality, and no tumor

recurrence or metastasis over a minimum follow-up of 6 months. The mean operating time was 66.2 ± 9.0 min, mean blood loss 40.3 ± 19.5 mL, and mean length of postoperative hospital stay 5.3 ± 1.3 days (Table 2), all of which are less than or similar to the results of previous studies [7, 8]. The mean number of harvested lymph nodes in our series was 16.0 ± 1.6 , which was within the range of rates reported in previous studies [7]. The procedure resulted in a short hospital stay, minimal blood loss, no major complications, an excellent clinical outcome, and no tumor recurrence or metastasis over a minimum 6-month follow-up. SSDPAV therefore carries several advantages compared with traditional RUL treatment techniques.

Over the past half century, lung cancer has become the most commonly diagnosed cancer as well as the leading cause of cancer death in males worldwide [9, 10]. Surgical resection with lymphadenectomy remains the mainstay option for resectable lung cancer [11, 12]. Since VATS for

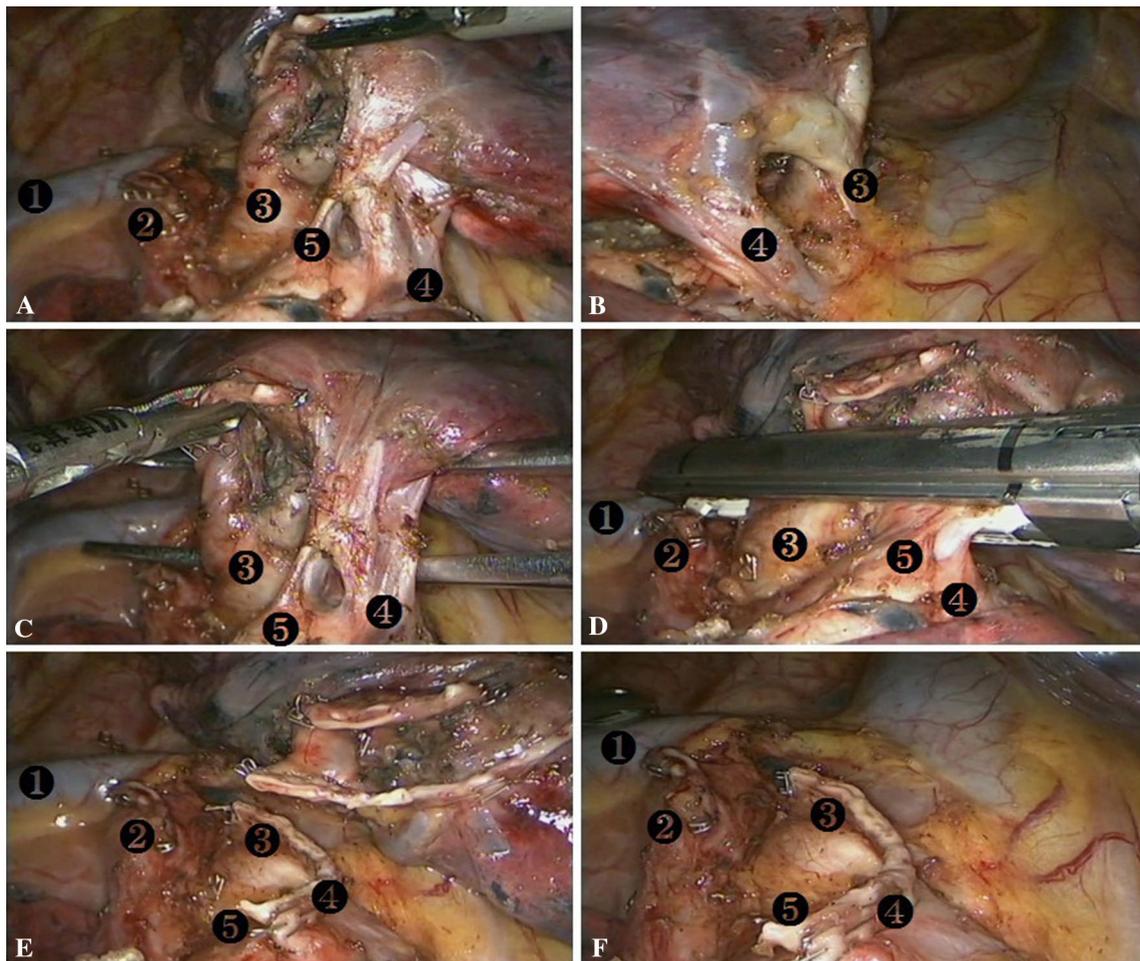


Fig. 3 **A** Lateral, posterior view of the right upper pulmonary arteries and veins. **B** Lateral, anterior view of right upper pulmonary arteries and veins. **C** Probing the right upper pulmonary arteries and veins with an oval forceps. **D–F** Synchronous disconnection of the right upper pulmonary arteries and veins. Dingbat negative circled one—

arch of azygos vein; Dingbat negative circled two—right upper lobe bronchus; Dingbat negative circled three—truncus anterior; Dingbat negative circled four—right upper pulmonary vein; Dingbat negative circled five—posterior ascending artery

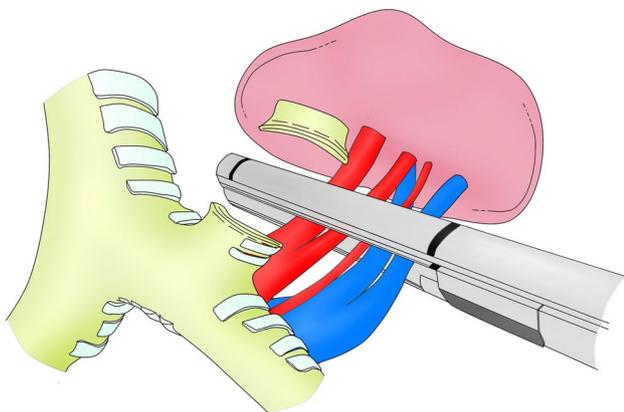


Fig. 4 Synchronous pulmonary arteriovenous disconnection for RUL procedure

lung resection was first described by Lewis in 1992 [13], its application has grown worldwide. Nowadays, cVATS lobectomy with lymphadenectomy is becoming popular and considered one of the most effective treatments for early NSCLC. Although RUL with lymphadenectomy under cVATS is widely accepted as the standard procedure for early-stage right upper lobe NSCLC in most institutions [14], this technique has some imperfections.

First, the operative protocol of cVATS for RUL is to treat pulmonary arteries and veins separately, including the superior pulmonary vein, posterior segmental artery, and anterior and apical segmental trunk. As the truncus intermedius artery lies just behind the superior pulmonary vein, it is easy to damage the truncus intermedius artery and cause massive hemorrhage when exposing the superior pulmonary vein. As the posterior segment of the pulmonary vein of the upper lobe is often located above the interleaf pulmonary artery,

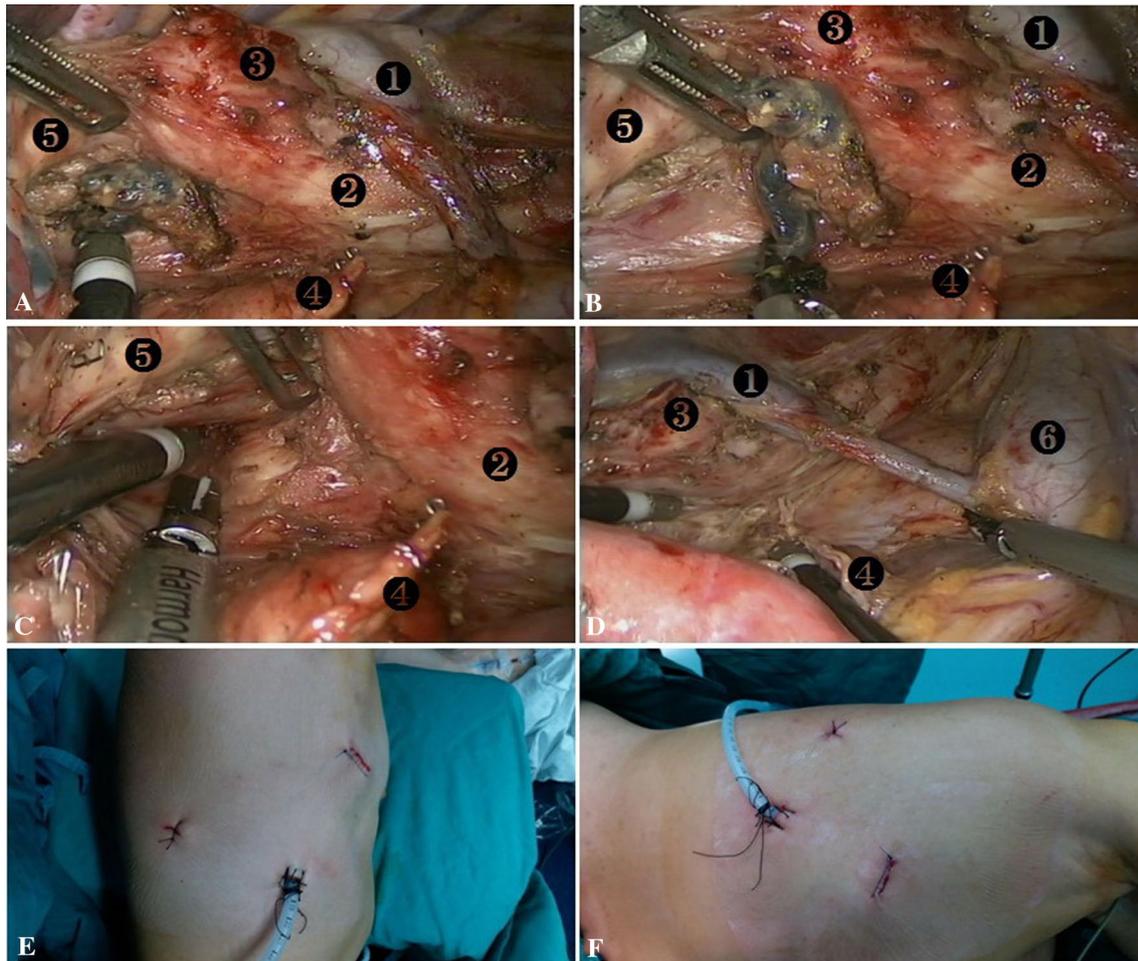


Fig. 5 **A** and **B** Anterior technique for subcarinal lymphadenectomy. **C** and **D** View of mediastinum after lymph node dissection. **E** and **F** Postoperative view of incisions. Dingbat negative circled one—arch of azygos vein; Dingbat negative circled two—right main bronchus;

Dingbat negative circled three—right upper lobe bronchus stump; Dingbat negative circled four—pulmonary arteriovenous stump; Dingbat negative circled five—right intermediate bronchus; Dingbat negative circled six—superior vena cava

Table 2 Perioperative outcomes

Characteristics	
Mean total operative time (min)	66.2 ± 9.0
Intraoperative bleeding (mL)	40.3 ± 19.5
Mean no. of endoscopic linear stapling devices used	2.6 ± 0.7
Mean no. of lymph nodes harvested	16.0 ± 1.6
Mean drainage (mL/day)	87.6 ± 25.3
Mean drainage time (days)	3.2 ± 0.8
Mean postoperative hospital stay (days)	5.3 ± 1.3

it is liable to cause injury and bleeding during the separation process. Therefore, the incidence of hemorrhage in the cVATS for RUL is relatively high. Second, subcarinal lymphadenectomy is usually performed by a posterior technique in cVATS. This dissection is risky as it takes place deep and adjacent to the esophageal plexus, necessitating forward

Table 3 Postoperative complications

Characteristics	n (%)
Prolonged air leakage (> 5 days)	0
Arrhythmia	2 (3.22)
Chylothorax	0
Hypoxia	1 (1.61)
Pneumonia	4 (6.45)
Atelectasis	0
Cerebrovascular accident	0

retraction of the remaining lung (currently with additional endoscopic retractors) [15]. The posterior dissection can damage the esophageal plexus and the bronchial microvasculature, often causing gastric hypomotility [16], bronchial necrosis, and bronchopleural fistula [17]. Third, in cVATS, a 1.0- to 3.0-cm skin incision must be made for the second

Table 4 Follow-up questionnaire

Nature of question
Response
1. Cosmetic results
Verbal response scale (VRS): 1 dissatisfied/2 accepted/3 satisfied/4 perfect
2. Postoperative pain
Visual analog scale (VAS) pain score: from 0 “no pain” to 10 “worst pain imaginable”
3. Postoperative dyspnea
No/yes
Frequency: very frequently/often/occasionally/never
Degree ^a : mild/moderate/severe/extremely severe
4. Tumor recurrence or metastasis
No/yes
Location: left lung/right lung/liver/epinephros/brain/bone/other
5. Satisfaction
VAS: very satisfied (9–10)/satisfied (6–8)/dissatisfied (3–5)/very dissatisfied (0–2)

^aThe degree of dyspnea was classified as follows: mild, dyspnea occurs only when walking fast or climbing up a gentle slope; moderate, walking slower than their peers because of dyspnea or need of halfway rest when walking on a flat surface; severe, dyspnea occurs when walking on a flat surface for about 100 m or a few minutes, and need of halfway rest for breathing; extremely severe, cannot leave the house or change clothes because of obvious dyspnea

Table 5 Outcomes of postoperative follow-up

Demographics	Discharge	≥ 6 months
Mean cosmetic score, VRS	3.8 ± 0.6	5.3 ± 0.7
Degree of postoperative pain, <i>n</i> (%)		
Mild	17 (27.4)	1 (1.61)
Moderate	4 (6.45)	0
Severe	0	0
Degree of dyspnea, <i>n</i> (%)		
Normal	12 (19.4)	56 (90.3)
Mild	47 (75.8)	6 (9.68)
Moderate	3 (4.84)	0
Severe	0	0
Extremely severe	0	0
Tumor recurrence or metastasis	0	0
Degree of satisfaction, <i>n</i> (%)		
Very satisfied	53 (85.5)	59 (95.2)
Satisfied	9 (14.5)	3 (4.84)
Dissatisfied	0	0
Very dissatisfied	0	0

operation hole through the 6th to 8th intercostal space at the posterior axillary line, where the chest wall muscles are thick and the intercostal space is narrow [18]; this often induces troublesome deep intramuscular bleeding. Moreover, frequent import and export of instruments through this incision can easily induce intercostal nerve injury, which results in numbness or paresthesia as well as postoperative wound-related pain [6]. Fourth, separate disconnection of pulmonary arteries and veins also requires more endoscopic

linear stapling devices, which is not only stapler-consuming but also makes the RUL a time-consuming process. Heavy use of endoscopic consumables will add to the financial burden of patients, especially if uninsured and financially disadvantaged. Moreover, a long operation increases the risk of postoperative complications such as pneumonia, arrhythmia, and cerebrovascular accident, which will ultimately prolong the length of hospital stay and increase the total medical costs.

Attempts at improving the cosmetic outcome have resulted in the development of a series of minimally invasive surgical procedures [6]. Reduced-port surgery has been reported as one such option. For single utility port VATS, Chu et al. [19] reported the technical feasibility and advantages of its minimal invasiveness in 2010. Single-port VATS was first reported by Migliore for the treatment of noncomplex pleural disease in 2003 [20]. In 2011, Gonzalez-Rivas shared his personal experience in using single-port VATS lobectomy [21, 22]. However, reduced-port surgery, including single-port VATS, is not widely used because of its relatively poor maneuverability and the requirement for highly experienced thoracoscopic surgeons or expensive special devices. Moreover, the operation time is often doubled or even tripled [23].

To address the disadvantages associated with early-stage NSCLC treatments, we designed SSDPAV for VATS RUL whereby the pulmonary arteries and veins were simultaneously disconnected during the procedure.

SSDPAV for VATS RUL presents several potential advantages. First, the procedure of RUL is simplified. Typical cVATS procedural steps for RUL include the upper vein,

anterior and apical segmental trunk, posterior segmental artery, upper bronchus, and fissure. By contrast, in SSDPAV for RUL the steps are simplified to involve fissure, upper bronchus, and SSDPAV. As the origin of the upper lobe bronchi of the right lung is relatively constant and the anatomic variation is narrow, it is easy to identify and perform disconnection of upper lobe bronchi of the right lung, which facilitates SSDPAV because the mobility of the right lung is increased. The simplified procedure not only saves operation time but also makes the surgery easier to master, especially for inexperienced thoracic surgeons. Second, injury to blood vessels is common and troublesome in total thoroscopic lobectomy, often leading to conversion to thoracotomy [24–26]. Unless the treatment is timely or appropriate, such injury can even jeopardize the patient's life. SSDPAV greatly reduces the likelihood of vascular injury, which often leads to severe intraoperative hemorrhage during the separation of the pulmonary arteriovenous process, thus making it a safe and feasible procedure. Third, for subcarinal lymphadenectomy we use an anterior technique (Fig. 5A, B), which is atraumatic, simple, and quick. We have encountered no bronchial complications in more than 60 cases. Fourth, the 0.5-cm Disposable Laparoscopic Puncture used as the auxiliary access port simplified the creation of an incision. It is more minimally invasive than a conventional incision, not only facilitating surgical cooperation but also reducing the postoperative pain. Fifth, as the operative steps are simplified, the number of endoscopic linear stapling devices used in this procedure numbers just one, compared with 2–4 devices used otherwise, which also reduces the cost of medical consumables and eases the financial burden of poorer patients. Lastly, simplified, rapid, and safe operative steps are helpful in reducing the postoperative complications (PCs) of patients. It is reported that the incidence of PCs after cVATS lobectomy is still very high, ranging from 17 to 37% [27], leading to prolonged hospitalization and intensive care unit stay, increased rate of rehospitalization, and significantly increased perioperative mortality [28]. A study conducted by Geller et al. also pointed out that complications, both major and minor, contribute significantly to the total direct hospital cost of lobectomy for early-stage NSCLC [29]. PCs are also important factors associated with long-term prognosis [30]. The incidence of PCs after SSDPAV for RUL was 11.3%, less than was reported in previous studies; PCs were also relatively mild in our study. We believe that this simplified procedure is beneficial to patients because it shortens the operation time and lowers the amount of repeated pulmonary turnover during the operation, thus reducing the incidence of PC.

There are, however, three limitations to this study. First, the number of patients involved was relatively small because the lobe type and initial stages of NSCLC were limited. Meanwhile, they were relatively young (lung cancer surgery

normal 60–65 years in middle), have no comorbidities like COPD, which may also contribute to the good result of this study. Second, the results were from a single medical center; multicenter, randomized controlled trials will be required to confirm the advantages of SSDPAV for RUL. Third, this study only focuses on RUL; application of SSDPAV for the resection of other lobes still remains to be explored.

Conclusions

SSDPAV lobectomy is a feasible, economical, safe, and effective therapeutic procedure for right upper lung cancer. This novel procedure shows promise as a viable surgical approach to RUL.

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Compliance with ethical standards

Disclosures Jian-Bo Lin, Ming-Lian Qiu, Chun-Jin Lin, Xu Li, Jian-Feng Chen, Fan-Cai Lai and Bo Liu have no conflicts of interest or financial ties to disclose.

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