Feasibility Investigation of Ipsilateral Reoperations by Thoracoscopy for Major Lung Resection

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Abstract

Background Video-assisted thoracoscopic surgery (VATS) has become the preferred approach for minimizing harm from thoracic operations. There is no report, however, which has discussed the feasibility of VATS in ipsilateral reoperation of major lung resection.

Methods The present study included patients who had undergone ipsilateral reoperation of major lung resection by VATS from October 2009 to May 2017. Referring clinical data were recruited for analysis.

Results Fourteen patients were recruited in the present study, including nine patients who underwent lobectomy and five who underwent segmentectomy during the second operation. Different hila were found in 6 patients, and pleural adhesions appeared in 10 patients. The average intraoperative blood loss was 203.6 ± 121.7 mL, and the mean operating room time was 2.2 ± 0.5 hours. There were no intraoperative deaths, and only one patient required conversion to thoracotomy. The average drainage time was 5.9 ± 4.6, and the mean hospital stay was 6.7 ± 4.2 days.

Conclusion Though it is technically demanding to safely handle the changed hilum structure caused by the last operation, major lung resection by VATS is feasible for ipsilateral reoperation in appropriate candidates.

Keywords
- thoracoscopy
- major lung resection
- hilum
- management

Introduction

In light of surgical technology and equipment development, surgery using video-assisted thoracoscopic surgery (VATS) has been successfully applied in many challenging situations consisting of sleeve and double sleeve lobectomies, pneumonectomy, and even tracheal and carinal plastic surgery.[1–4] In addition to less intraoperative blood loss and comparable operating times,[5] the VATS technique has also demonstrated equivalent oncological results. Hanna et al[6] reported that there was no difference between VATS and thoracotomy in terms of disease-free, cancer-specific, and 5-year overall survivals. Furthermore, Paul et al[7] pointed out that lobectomy with VATS was associated with a lower rate of postoperative complications such as arrhythmias, reintubation, and anemia requiring blood transfusion.

Despite all of these advancements and the popularization of VATS technique, ipsilateral reoperation remains a prohibited area. The technical restrictions come from both dense pleural adhesions[8,9] and difficult hila (distorted hilum anatomical structure with fibroplastic proliferation in a high degree) after the primary operation.[10] Among these circumstances, safe management of difficult hila has become one of the greatest challenges, even for thoracotomy.[11] Given the limited operative field and weakened haptic feedback, these situations would be trickier during thoracoscopic operations. The essential framework of the difficult hilum consists of contorted anatomical structures and fibroplastic

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proliferation,[12] which pose a high risk of pulmonary artery injury during surgery. Subsequent massive bleeding frequently results in unplanned surgical conversion.[13,14] Nevertheless, as far as we know, there are still no available articles that report the use of VATS for difficult hila.

Herein, the present study aimed to share some pointers for handling difficult hila and demonstrating the feasibility of ipsilateral reoperative major lung resection by VATS.

Patients and Methods

Patients Selection

The present study included lung nodule patients who underwent second ipsilateral major lung resections (lobectomy or segmentectomy but excluding pneumonectomy) with VATS from 2009 through 2017. We excluded patients who had neoadjuvant radiotherapy before the later surgery. As a retrospective study, the approval was waivered by the ethical committee of Shanghai Pulmonary Hospital and The First Affiliated Hospital of Zhejiang University.

Preoperative Evaluation

Preoperative evaluation was undertaken in all of the patients. Enhanced chest computed tomography (CT) scans and previous surgical history were utilized to evaluate lung lesion resectability. Due to suspected lung cancer diagnoses, brain magnetic resonance imaging, abdominal ultrasonography/CT scan, and bone scanning were performed to rule out distant metastasis. Pulmonary function tests, echocardiography, and blood gas analyses were routinely performed to assess cardiopulmonary functional reserve. Perfusion–ventilation scans were additionally required in patients with lung function impairment with the aim of obtaining more precise calculations of predicted postoperative lung functions.

Operative Process

Each patient was intubated using a double lumen and placed in the lateral decubitus position after general anesthesia. One or more (two/three) port techniques were chosen according to preference of the operating surgeon. The manipulation port was made at the fourth/fifth intercostal space of the anterior axillary line, while the additional ports at the seventh/eighth intercostal space for camera (mid-axillary line) and auxiliary operation (linea scapularis). Upon entering the pleural space, sharp dissection with cautery, instead of blind blunt dissection, was always appropriate for dissecting out pulmonary adhesions to avoid more pulmonary injuries. This was usually a safe and effective way in conditions that the incision was surrounded by dense pleural adhesions.

Hilum dissection was the most difficult step in successful reoperation using VATS. Based on hilum structure as observed through thoracoscopy, patients were divided into two groups in this study. If there was no obvious alteration in hilum anatomy, the patient was categorized into Group A. In this situation, dissection around the hilum was usually easy, and thus, the ligating sequence depended on surgeon's experience and specific conditions. If severe scar formation subsequent to the prior operation existed, however, the anatomy of hilum would consequently be altered (Group B). Differing from Group A, a strict ligating sequence (veins first and arteries last) would become necessary. For accurately differentiating, target bronchus and pulmonary arteries from dense adherence tend to be challenging, while pulmonary vein anatomy usually remained relatively intact without too many handling difficulties.

The patients were extubated postoperatively and then transferred back to the wards. Chest tubes were removed once there was no air leakage upon cough. All resected specimens were sent for pathological analysis, and the results were used to determine postoperative management.

Results

Basic Information of Patients

A total of 14 cases were enrolled into present study, which included 4 males and 10 females. These patients underwent second ipsilateral resection with VATS. The median age was 63 years (range, 33–73 years). A majority of the patients (11 patients) were operated on the right side and only 3 on the left side. The main reason might be the lobectomy-to-lobectomy at the left side means completion pneumonectomy which would be excluded from the present study.

Surgical Options and Results of First Operations

All patients underwent VATS lung resection during the first-time surgery, in which five patients had surgery with single ports, six with double, and three with triple. There were 6 of 14 patients managed with lobectomy, 6 of 14 with wedge resection, and 2 of 14 with segmentectomy. One patient who received lobectomy had an additional resection of a mediastinal tumor during the same surgery. Systemic lymphadenectomy was adopted in 12 patients with 80 resected lymph nodes in total. The patient receiving wedge resection for biopsy (one), and the patient with adenocarcinoma in situ (AIS) (one) did not undergo lymphadenectomy.

According to the records of the first operation, the mean volume of intraoperative blood loss was 178.6 ± 124.6 mL. No patient had operative conversion or extended resection. The mean operative time was 2.2 ± 0.5 hours during the first surgery. The average lesion size was 19.4 ± 13.3 mm. The pathological results consisted of 10 invasive adenocarcinoma (AD), 1 AIS, 1 neurilemmoma, 1 metastatic neuroectodermal tumor, and 1 metastatic hepatocellular carcinoma. Resected lymph nodes were all proven to be negative.

Surgical Options and Results of Second Operations

The median time interval between the two operations was 19.5 months (range, 4–73 months). No patient underwent chemotherapy after the first operation. According to preoperative lung function testing and blood gas analysis, the average forced expiratory volume in one second % predicted (FEV1%pred) was $83 \pm 8.7\%$, and the mean oxygen saturation was $96.7 \pm 1.6\%$. Before the operation, all patients were initially diagnosed with suspected lung cancer.

During the second-time operations, most of the patients (seven) underwent single-port thoracoscopy followed by who received triple and double ports at 4 and 3, respectively. There

Table 1 Intraoperative data of later operation

Variables	Later operation ($n = 14$)
Reoperation time (h)	2.2 ± 0.5
Intraoperative bleeding (mL)	203.6 ± 126.3
Intraoperative mortality	0
Conversion to thoracotomy	7% (1/14)
Obvious pleural adhesion	71% (10/14)
Difficult hilum[a]	43% (6/14)

[a]Distorted hilum anatomical structure with fibroplastic proliferation in a high degree.

were five patients who were managed with segmentectomy, including one patient with both upper segmentectomy and lower wedge resection, while the rest of them (nine patients) underwent lobectomy. From intraoperative records, six patients encountered difficult hila. Obvious pleural adhesions were found in 10 patients. The average intraoperative blood loss was 203.6 ± 121.7 mL. No intraoperative emergency happened, but one patient suffered operative conversion to thoracotomy due to a severe pleural adhesion. The mean operating room time was 2.2 ± 0.5 hours. Intraoperative data of later operations are presented in ►**Table 1**.

Fifteen lesions were resected lesions, including 10 AD, 2 desmoplasia, 1 minimally invasive adenocarcinoma, 1 metastatic hepatocellular carcinoma, and 1 pulmonary carcinoid tumor (spindle cell carcinoma). The average lesion size was 18.6 ± 11 mm, and the mean distance to pleura was 3.4 ± 4.9 mm. Five lesions were close to the pleura locally (no distance to pleura). All patients underwent lymphadenectomy, through which 77 lymph nodes were excised. No lymph node metastasis was found. Lesion characteristics are summarized in ►**Table 2**.

Postoperative complication was prolonged air leaks which were found in 5 of 14 patients, making it the most common postoperative complication. No patient had any special treatment for air leaks. The average hospitalization time was 6.7 ± 4.2 days with the mean drainage time of 5.9 ± 4.6 days. Patients' postoperative information is listed in ►**Table 3**.

Discussion

With improvement of surgical technique and surgical instrument, VATS has been widely applied over the past several years, gradually becoming a treatment mainstay in thoracic surgery.[15,16] The contraindications recognized previously have been partly overcome.[17–19] In this study, we first reported experiences of major lung resection (ipsilateral reoperation) with complete VATS. Through the dense pleural adhesions and the hilum structure changing presented such difficulties during the reoperation using VATS, results showed that the complication rate, hospitalization time, and drainage time were comparable with conventional thoracotomy.[7]

The key to this surgery is safe management of difficult hila. First, at the field between target bronchi and arteries, it is advisable to perform dissection with sharp scissors over energy platforms such as harmonic devices. Blunt dissection would be dangerous if scar formation has appeared. Any unintentional traction to crisp scars may tear arteries, thus inducing a massive bleeding emergency. Second, ensuring that the dissection occurs close to the bronchi and removed from the pulmonary arteries should be done. Artery rupture tends to bring more severe consequence besides bronchus injury. Third, accurate recognition of hidden landmarks (such as the stapler line) would help surgeons confirm the site of target bronchi and avoid the detoured vessels.

Although the appearance of artery rupture would obviously have decreased with the previously described methods, patients with difficult hila still suffered a higher risk of rupture. Once artery rupture occurred, temporary trunk blockade (with Prolene suture) is usually an effective way to repair them. However, the feasibility of blockade depends on whether or not a frozen extrapericardium has appeared, which can be easily recognized according to regional scar formation and observed in thoracoscopy. In conditions in which trunk blockade is not feasible, a bronchus-before-artery maneuver might be a great alternative with cutting target bronchus first, ligating, and severing the remaining tissue with staplers.

Despite all these experiences, a backup plan B should be prepared for unplanned conditions. As mentioned earlier, certain clinical techniques available to handle artery rupture exist, but if the amount of bleeding is too massive to handle with thoracoscopy, operative conversion to thoracotomy would become inevitable. Additionally, perioperative emergencies were not the only reason for surgical conversion to another technique. To prevent intraoperative and/or postoperative complications, either dense adhesions or interference by lymph nodes should be considered as a significant cause for operative conversion,[20] and one patient in the present study encountered conversion due to pleural adhesions.

Ipsilateral reoperation using VATS is feasible when the hilum structure is relatively intact after the first operation. If upper hilum had been involved during the first surgery, there would be such a dense adhesion that clear recognition of artery trunks tends to be difficult. Thus, it is necessary in most cases (four of five in our study) to open the pericardium and expose the intrapericardial pulmonary arteries for possible trunk blockade. In this situation, if station 4L (trachea–bronchial) lymph nodes had also been previously removed, the consequent extrapericardial adhesions between the aorta and other artery trunks would further impede safe

Table 2 Characteristics of lesions

Information of lesions	Later operation
Malignant lesion[a]	80% (12/15)
Size (mm)	18.6 ± 11
Margin distance (mm)	14 ± 6.6
Distance to pleura (mm)	3.4 ± 4.9
Visceral pleura invasion	27% (4/15)

[a]Excluding pulmonary carcinoid tumor.

Table 3 Postoperative information of per patient

Patient	Frist operation	Reoperation	Intraoperative bleeding (mL)	Reoperation time (h)	Hospital stay (d)	Drainage time (d)
1	RUW	RUL	100	2	4	3
2	RUS	RUL	200	2.5	3	3
3	RUL	RML	200	2	5	6
4	RUL	RML	200	2	5	3
5	LUL	LLS	200	1.5	7	8
6	RML	RUL[a]	200	2	5	3
7	RML[b]	RUL	600	3	4	3
8	RUW	RUL	150	2	8	8
9	LLW	LUS	200	2	9	8
10	RLL	RUS	150	2.5	6	3
11	RLS	RMS	100	1.5	2	2
12	RLW	RLL	150	2	20	20
13	RLW	RLL	300	3.5	7	3
14	LLW	LLL	100	2	9	9

Abbreviations: LLL, left lower lobectomy; LLS, left lower segmentectomy; LLW, left lower wedge resection; LUL, left upper lobectomy; LUS, left upper segmentectomy; RLL, right lower lobectomy; RLS, right lower segmentectomy; RLW, right lower wedge resection; RML, right middle lobectomy; RMS, right middle segmentectomy; RUL, right upper lobectomy; RUS, right upper segmentectomy; RUW, right upper wedge resection.
[a]Both upper segmentectomy and wedge resection.
[b]Middle lobectomy and resection of mediastinal mass.

dissection. Hence, the performance of completed thoracoscopic resection tends to become extremely difficult on the left side. Actually, meticulous preoperative evaluations and surgical experience was of great significance for a favorable surgical effect.

Prominent complication after ipsilateral consecutive operations was prolonged air leakage (36% in this study). The leading cause was a result of pulmonary tears caused by separation of pleural adhesions. Other than careful surgery, several novel pathways have been proven to be effective to prevent prolonged air leakage. Fleece-bound sealing (TachoSil) might be beneficial to hasten air leakage healing in these cases.[21,22] Marta et al[23] pointed out that patients treated with TachoSil had less postoperative air leakage duration than those who received standard treatment after lung lobectomy. Additionally, Baysungur et al[24] reported that patients managed by the autologous pleural buttressing (staple lines) had earlier chest tube removal for lung bullae surgery. A meta-analysis ($n = 1,335$) by Malapert et al[25] revealed that assistive methods (such as sealants and buttressing) effectively reduced prolonged air leakage risk following wedge resection or lobectomy. Additionally, as the ipsilateral reoperation is rare in clinical situation and remains a relative contraindication for VATS, there were only 14 cases within 8 years. But with limited simple size, we could preliminarily prove the feasibility of thoracoscopic reoperation. The prospective clinical trial needs to be performed to address this limitation in the future.

In conclusion, with clinical experience, VATS may serve as a feasible approach to perform ipsilateral reoperative major lung resection. The keys to a successful VATS reoperation are correct management of difficult hila, backup plan B setting, accurate patient selection, and prolonged air leak avoidance.

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Conflict of Interest
None.

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References

1 Gonzalez-Rivas D, Delgado M, Fieira E, Fernandez R. Double sleeve uniportal video-assisted thoracoscopic lobectomy for non-small cell lung cancer. Ann Cardiothorac Surg 2014;3(02):E2
2 Santambrogio L, Cioffi U, De Simone M, Rosso L, Ferrero S, Giunta A. Video-assisted sleeve lobectomy for mucoepidermoid carcinoma of the left lower lobar bronchus: a case report. Chest 2002; 121(02):635–636
3 Augustin F, Maier H, Lucciarini P, Bodner J, Klotzner S, Schmid T. Extended minimally invasive lung resections: VATS bilobectomy, bronchoplasty, and pneumonectomy. Langenbecks Arch Surg 2016;401(03):341–348
4 Gonzalez-Rivas D, Yang Y, Sekhniaidze D, et al. Uniportal video-assisted thoracoscopic bronchoplastic and carinal sleeve procedures. J Thorac Dis 2016;8(Suppl 2):S210–S222
5 Handy JRJ Jr, Asaph JW, Douville EC, Ott GY, Grunkemeier GL, Wu Y. Does video-assisted thoracoscopic lobectomy for lung cancer

provide improved functional outcomes compared with open lobectomy? Eur J Cardiothorac Surg 2010;37(02):451–455

6 Hanna WC, de Valence M, Atenafu EG, et al. Is video-assisted lobectomy for non-small-cell lung cancer oncologically equivalent to open lobectomy? Eur J Cardiothorac Surg 2013;43(06): 1121–1125

7 Paul S, Altorki NK, Sheng S, et al. Thoracoscopic lobectomy is associated with lower morbidity than open lobectomy: a propensity-matched analysis from the STS database. J Thorac Cardiovasc Surg 2010;139(02):366–378

8 Komatsu K, Fujii A, Higami T. Haemostatic fleece (TachoComb) to prevent intrapleural adhesions after thoracotomy: a rat model. Thorac Cardiovasc Surg 2007;55(06):385–390

9 Izumi Y, Takahashi Y, Kohno M, Nomori H. Cross-linked poly (gamma-glutamic acid) attenuates pleural and chest wall adhesions in a mouse thoracotomy model. Eur Surg Res 2012;48(02): 93–98

10 Omasa M, Date H, Takamochi K, Suzuki K, Miyata Y, Okada M. Completion lobectomy after radical segmentectomy for pulmonary malignancies. Asian Cardiovasc Thorac Ann 2016;24(05): 450–454

11 Pettiford BL, Schuchert MJ, Abbas G, et al. Anterior minithoracotomy: a direct approach to the difficult hilum for upper lobectomy, pneumonectomy, and sleeve lobectomy. Ann Surg Oncol 2010;17(01):123–128

12 Alpert JB, Godoy MC, Degroot PM, Truong MT, Ko JP. Imaging the post-thoracotomy patient: anatomic changes and postoperative complications. Radiol Clin North Am 2014;52(01):85–103

13 Samson P, Guitron J, Reed MF, Hanseman DJ, Starnes SL. Predictors of conversion to thoracotomy for video-assisted thoracoscopic lobectomy: a retrospective analysis and the influence of computed tomography-based calcification assessment. J Thorac Cardiovasc Surg 2013;145(06):1512–1518

14 Flores RM, Ihekweazu U, Dycoco J, et al. Video-assisted thoracoscopic surgery (VATS) lobectomy: catastrophic intraoperative complications. J Thorac Cardiovasc Surg 2011;142(06):1412–1417

15 Whitson BA, Groth SS, Duval SJ, Swanson SJ, Maddaus MA. Surgery for early-stage non-small cell lung cancer: a systematic review of the video-assisted thoracoscopic surgery versus thoracotomy approaches to lobectomy. Ann Thorac Surg 2008;86(06):2008–2016, discussion 2016–2018

16 Yang SM, Hsu HH, Chen JS. Recent advances in surgical management of early lung cancer. J Formos Med Assoc 2017;116(12): 917–923

17 Fan J, Yao J, Wang Q, Chang Z. Safety and feasibility of uniportal video-assisted thoracoscopic surgery for locally advanced non-small cell lung cancer. J Thorac Dis 2016;8(12):3543–3550

18 Nakajima T, Watanabe A, Nakazawa J, Higami T. Transmanubrial approach with video-assisted thoracoscopic surgery for left superior sulcus tumour with dense adhesion after replacement of descending thoracic aorta. Interact Cardiovasc Thorac Surg 2012;14(06):906–908

19 Huang J, Xu X, Chen H, et al. Feasibility of complete video-assisted thoracoscopic surgery following neoadjuvant therapy for locally advanced non-small cell lung cancer. J Thorac Dis 2013;5(Suppl 3): S267–S273

20 Li Y, Wang J, Yang F, et al. Indications for conversion of thoracoscopic to open thoracotomy in video-assisted thoracoscopic lobectomy. ANZ J Surg 2012;82(04):245–250

21 Lang G, Csekeö A, Stamatis G, et al. Efficacy and safety of topical application of human fibrinogen/thrombin-coated collagen patch (TachoComb) for treatment of air leakage after standard lobectomy. Eur J Cardiothorac Surg 2004;25(02):160–166

22 Anegg U, Lindenmann J, Matzi V, Smolle J, Maier A, Smolle-Jüttner F. Efficiency of fleece-bound sealing (TachoSil) of air leaks in lung surgery: a prospective randomised trial. Eur J Cardiothorac Surg 2007;31(02):198–202

23 Marta GM, Facciolo F, Ladegaard L, et al. Efficacy and safety of TachoSil® versus standard treatment of air leakage after pulmonary lobectomy. Eur J Cardiothorac Surg 2010;38(06):683–689

24 Baysungur V, Tezel C, Ergene G, et al. The autologous pleural buttressing of staple lines in surgery for bullous lung disease. Eur J Cardiothorac Surg 2010;38(06):679–682

25 Malapert G, Hanna HA, Pages PB, Bernard A. Surgical sealant for the prevention of prolonged air leak after lung resection: meta-analysis. Ann Thorac Surg 2010;90(06):1779–1785