



Partial removal of the pulmonary artery in video-assisted thoracic surgery for non-small cell lung cancer

Keping Xu^{a,b}, Zhi Zhang^{a,c}, Jianqiang Zhao^{a,b}, Jianfeng Huang^c, Rong Yin^c, Lin Xu^c✉

^aDepartment of Thoracic Surgery, Nanjing Medical University, Nanjing, Jiangsu 210029, China;

^bDepartment of Thoracic Surgery, Huai'an First People's Hospital, Huai'an, Jiangsu 223300, China;

^cDepartment of Thoracic Surgery, Cancer Hospital Affiliated with Nanjing Medical University, Cancer Hospital of Jiangsu Province, Nanjing, Jiangsu 210009, China.

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Abstract

Lobectomy with partial removal of the pulmonary artery in video-assisted thoracic surgery (VATS) currently remains a challenge for thoracic surgeons. We were interested in introducing pulmonary vessel blocking techniques in open thoracic surgery into video-assisted thoracic surgery (VATS) procedures. In this study, we reported a surgical technique simultaneously blocking the pulmonary artery and the pulmonary vein for partial removal of the pulmonary artery under VATS. Seven patients with non-small-cell lung cancer (NSCLC) received lobectomy with partial removal of the pulmonary artery using the technique between December 2007 and March 2012. Briefly, rather than using a small clamp on the distal pulmonary artery to the area of invading cancer, we replaced a vascular clamp with a ribbon and Hem-o-lock clip to block the preserved pulmonary veins so as to prevent back bleeding and yield a better view for surgeons. The mean occlusion time of the pulmonary artery and pulmonary veins were 44.0 ± 10.0 and 41.3 ± 9.7 minutes, respectively. The mean repair time of the pulmonary artery was 25.3 ± 13.7 minutes. No complications occurred. No patients showed abnormal blood flow through the reconstructed vessel. There were no local recurrences on the pulmonary artery. In conclusion, the technique for blocking the pulmonary artery and veins is feasible and safe in VATS and reduces the risk of abrupt intraoperative bleeding and the chance of converting to open thoracotomy, and extends the indications of VATS lobectomy.

Keywords: video-assisted thoracic surgery (VATS), non-small-cell lung cancer (NSCLC), lobectomy, pulmonary artery reconstruction

INTRODUCTION

Lobectomy with video-assisted thoracic surgery (VATS) for tumor less than 3 cm in size has currently gained much more acceptance for most thoracic surgeons^[1]. However, when tumor invades the pulmonary

artery and pulmonary artery suture or reconstruction is inevitable, open thoracotomy is usually chosen by surgeons even if the tumor size is small. It seems to be extremely difficult to perform partial removal of the pulmonary artery by using VATS procedures due to various technical limitations. In addition, when lymph

✉ Corresponding author: Lin Xu, M.D., Department of Thoracic Surgery, Cancer Hospital Affiliated with Nanjing Medical University, Cancer Hospital of Jiangsu Province, Baiziting 42#, Nanjing, Jiangsu

210009, China. Tel(Fax):+86-25-83283571, E-mail:xulin83@vip.sina.com.

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nodes become tightly adherent to the pulmonary artery, there is the risk of abrupt intraoperative bleeding during dissection, which incurs high risk for patients. Therefore, both these two factors were previously considered as relative contraindications of VATS.

Although VATS technique is now popular and widely applied worldwide, few attempts on more complex VATS procedures have been reported until now. In terms of pulmonary artery reconstruction, only Nakanishi et al. showed their practical experiences of partial removal pulmonary artery in lobectomy with VATS^[2]. In the present study, we described our innovated technique for partial removal of the pulmonary artery in VATS lobectomy. Simultaneously blocking the pulmonary artery trunk and the preserved pulmonary veins was usually applied in pulmonary artery reconstruction in our open thoracotomy. This technique provided a clearer view and decreased blood loss as we previously described^[3]. We transplanted this idea into VATS procedures and developed this new technique clamping the pulmonary artery trunk

by a Satinsky clamp and blocking the preserved pulmonary veins by a ribbon and Hem-o-lock clip, and then partial removal of pulmonary artery and suture could be performed.

SUBJECTS AND METHODS

Subjects

Between December 2007 and March 2012, seven patients underwent VATS lobectomy with blocking both the pulmonary artery and veins at the authors' affiliated hospitals, and were retrospectively analyzed for this study. The eligibility for this study required a lobectomy with previously blocking both pulmonary artery and veins performed totally using VATS procedures. The VATS procedures were performed without rib spreader while viewing a video monitor. The study protocol was approved by the institutional review boards and ethics committees at the authors' affiliated institutions, and informed consent for surgery was obtained from all patients.

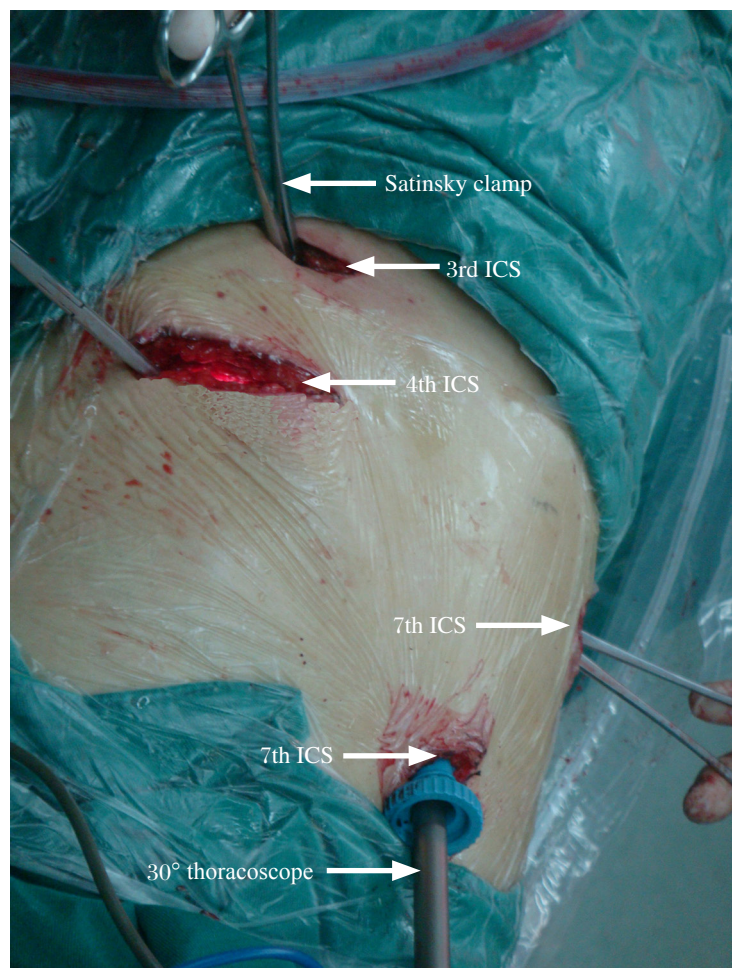


Fig. 1 A patient was put in the lateral decubitus position. An access incision (12 mm) was added for the center vascular clamp in the third intercostal space on the anterior axillary line. ICS: intercostal space.

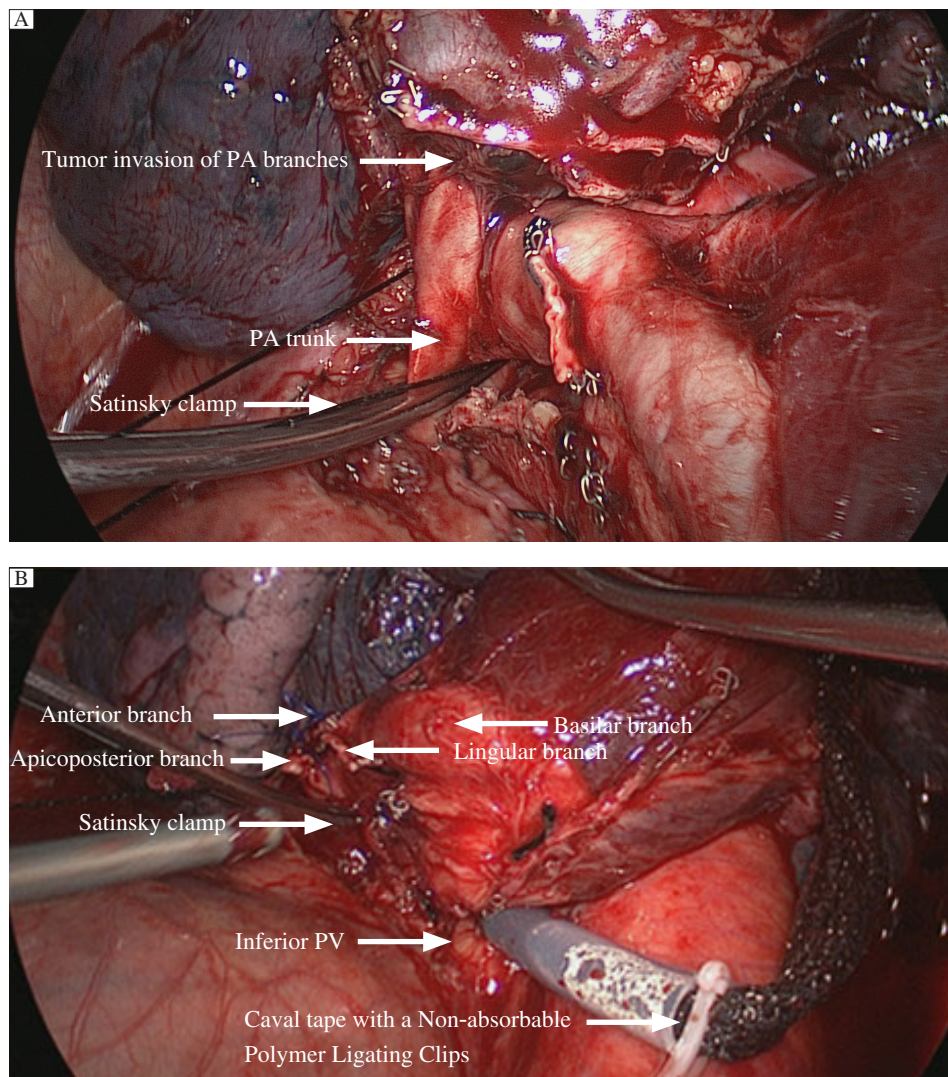


Fig. 2 The images of blocking the pulmonary vessels. A: left upper lobectomy with partial pulmonary artery anterior resection is depicted. The tumor invasion of pulmonary artery branches. B: The pulmonary artery branches (anterior branch and apicoposterior branch) were sutured directly with 4-0 Prolene. The handles of the clamps was placed on the main pulmonary artery and a caval tape secured with a 5 mm hem-o-lock non-absorbable polymer ligating clips to block the reserved pulmonary vein. PA: pulmonary artery; PV: pulmonary vein.

The indications for VATS lobectomy were based on the standard criteria for open thoracotomy, including tumors up to 4 cm in diameter. Preoperative staging included routine chest roentgenography, computed tomography (CT) of the thorax and abdomen, magnetic resonance imaging (MRI) of the brain, bone scintigraphy and bronchoscopy. Mediastinoscopy was not routinely performed whereas positron emission tomography (PET) was also selectively used. Cardiac evaluation and pulmonary function were performed.

Surgical technique

General anesthesia with selective lung ventilation was performed by the use of a double lumen endotracheal tube. All patients positioned in the lateral

decubitus position with the bed flexed to increase intercostal spacing. We placed an anterolateral mini-thoracotomy (40 mm) in the fourth intercostal space. A mastoid retractor kept the utility thoracotomy wound open by retracting the soft tissue. We added an access incision (12 mm) for the central vascular clamp in the third intercostal space on the anterior axillary line and placed two thoracoports (12 mm) in the seventh intercostal space on the posterior axillary line for the oval clamp and the mid-axillary line for a thoracoscope (**Fig. 1**). After the VATS exploration, hilar dissection was performed as previously reported^[4]. Surgical procedures for the pulmonary vessels are described below.

After each surgical procedure for the pulmonary vessels, the bronchi were encircled and then divided.

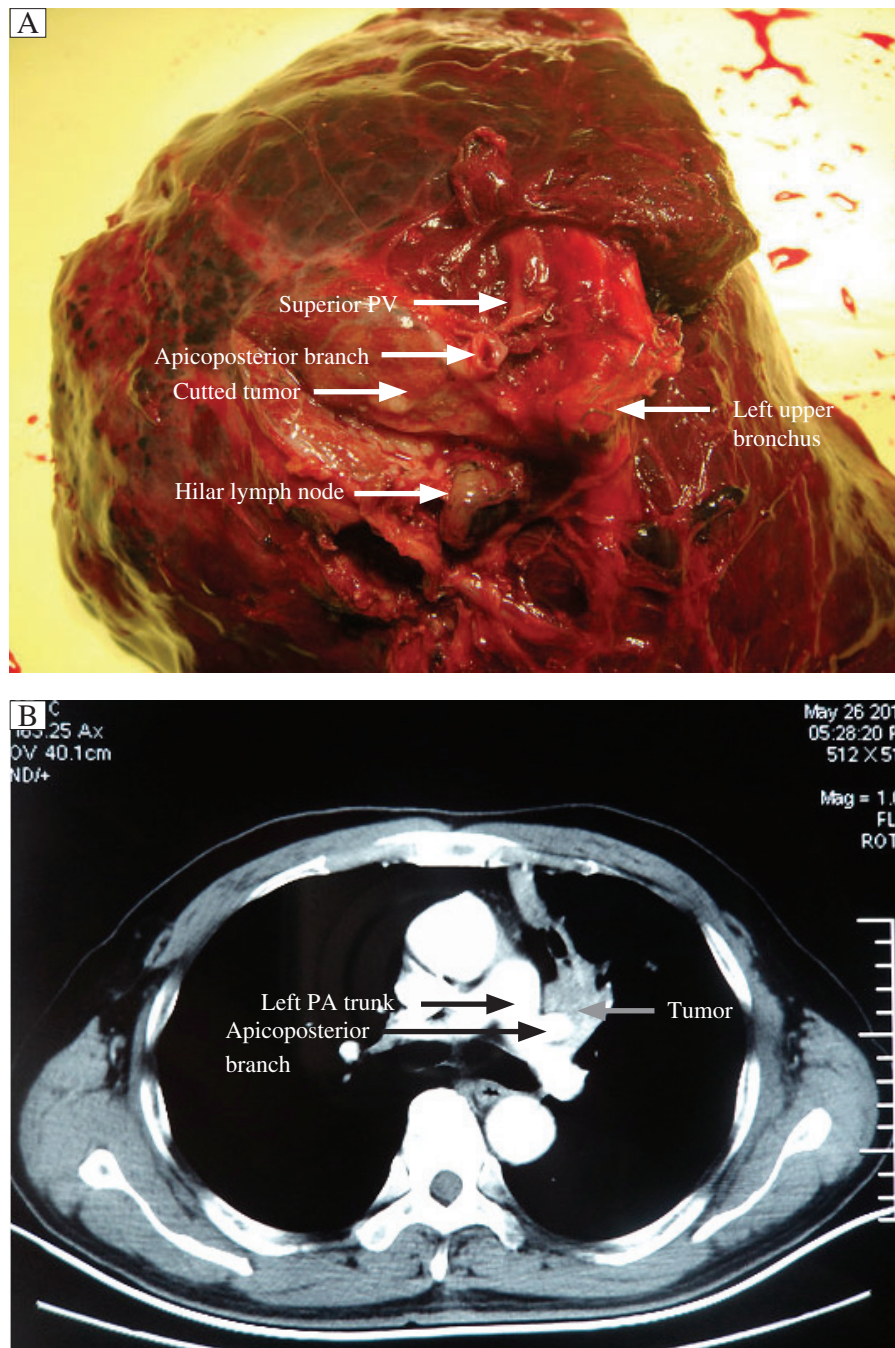


Fig. 3 The biopsy and typical CT examination of lung cancer. A: The specimen of lung cancer. B: Typical CT scan of a patient of a left upper lobe tumor with dense adhesion of tumor around apicoposterior branch. PV: pulmonary vein; PA: pulmonary artery.

We prefer stapling the pulmonary veins with a vascular stapler. Thereafter, the pulmonary artery branches without cancer invasion were stapled with vascular staplers or clipped with Hem-o-lock non-absorbable polymer ligating clips, and then the bronchus was cut with a stapler as well. The proximal pulmonary artery was controlled with a Satinsky clamp (Diener 06-240524) through the incision at the 3rd intercostal space (**Fig. 2A**) after intravenous injection of 3125 U sodium heparin. Rather than placing a clamp on the pulmonary artery distal to the area of invading can-

cer to prevent back bleeding^[2], we replaced a vascular clamp with a caval tape (tourniquet) to block the preserved pulmonary vein, and secured the caval tape with a 5 mm Hem-o-lock non-absorbable polymer ligating clips as shown in **Fig. 2A**, which shows a left upper lobectomy and a partial pulmonary artery reconstruction. This allowed more room for the operating surgeon to suture the pulmonary artery branches. The pulmonary artery branches with cancer invasion were resected with scissors, and then the lobe with the cancer was removed from the operative field. After confirmation

Table 1 Clinical characteristics of seven patients undergoing partial removal of the pulmonary artery in video-assisted thoracic surgery for non-small cell lung cancer

Variable	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7
Age (years)	67	65	70	65	63	62	72
Sex	Female	Female	Male	Male	Female	Female	Male
FEV1/FVC (%)	68	64	63	76	62	61	60
Performance status	0	1	2	1	1	2	1
Tumor size (mm)	38*35*30	39*35*28	35*32*32	31*32*24	40*24*25	34*32*31	35*32*30
Type of resection	RUL	LLL	LUL	LUL	LLL	RLL	RLL
Histologic type	Ad	Ad	Sq	Sq	Ad	Sq	Sq
Preoperative stage	T2N0M0	T2N1M0	T2N0M0	T2N1M0	T2N1M0	T2N2M0	T2N1M0
Postoperative stage	T2N0M0	T2N1M0	T2N1M0	T2N1M0	T2N0M0	T2N2M0	T2N1M0
Number of resected lymph nodes	30	12	31	29	18	35	21
Cause of blocking PA	Direct tumor invasion of PA	Dense adhesion of lymph node	Direct tumor invasion of PA	Direct Tumor invasion of PA branches	Dense adhesion of lymph node	Direct Tumor invasion of PA	Direct Tumor invasion of PA branches
Type of suturing PA	Suture PA	Suture PA branch	Suture PA	Suture PA branch	Suture PA branch	Suture PA	Suture PA branch
Repair time of the PA (min)	12	15	24	34	37	10	45
Occlusion time of PA (min)	35	46	45	50	48	27	57
Occlusion time of PV (min)	30	44	42	45	46	27	55
Operative time (min)	300	310	280	410	350	220	450
Blood loss (mL)	280	340	330	300	500	160	320
Postoperative complications	None	Arrhythmia	Prolonged air leak	Arrhythmia	None	None	None
Hospital stay	18	17	15	13	14	14	16
Outcome (months)	Alive, 30	Alive, 20	Alive, 7	Alive, 7	Alive, 6	Alive, 5	Alive, 2

FEV1: forced expiratory volume in one second, FVC: forced vital capacity, LUL: left upper lobectomy, LLL: left lower lobectomy, RLL: right lower lobectomy, RUL: right upper lobectomy, Sq: squamous cell carcinoma, Ad: adenocarcinoma, PA: pulmonary artery, PV: pulmonary vein.

that the resection margin of the pulmonary artery was tumor-free by intraoperative pathological examination, the partial pulmonary artery was sutured with 4/0 Prolene (Ethicon, Bracknell, UK) (**Fig. 2B**). The suture thread was handled carefully to avoid tangling or entwining with the clamp. Just before re-establishing the continuity of the pulmonary artery, the distal tape was loosened from the pulmonary vein before the arterial sutures were tied to help remove intravascular air. Then, the proximal pulmonary artery Satinsky clamp was removed to ensure hemostasis of the sewn pulmonary artery. An extensive dissection of the mediastinal and hilar lymph nodes was then performed.

Postoperative Care

No further anticoagulation was used postoperatively. The administration of intravenous fluids was also minimized to avoid volume overload and the possibility of pulmonary edema. Pain control was achieved in most cases by continuous patient controlled intravenous analgesia with tramadol or morphinics. Appropriate antibiotic coverage for five days was also required.

Follow-up of data acquisition

The complete follow-up data were obtained from the records of post discharge visits and from regular radiographic follow-up visits.

RESULTS

The clinical details of the seven patients are summarized in **Table 1**. The mean age of seven patients was 66.2 ± 3.6 years old. The causes of partial pulmonary artery removal with direct suturing included one direct tumor invasions of one-eighth of the external wall of the pulmonary artery, three lymph node invasions of the pulmonary artery branch and three direct tumor invasions of the arterial branch.

The mean repair time of the pulmonary artery was 25.3 ± 13.7 minutes.

The mean occlusion time of the pulmonary artery and pulmonary veins were 44.0 ± 10.0 and 41.3 ± 9.7 minutes, respectively. Patient 6, with a single station N2 disease, refused induction chemotherapy. The mean number of resected lymph nodes was 25.1 ± 8.3 . No patients required blood transfusion during the surgery and postoperatively. There were no operative deaths and no complications attributable to the technique. The mean hospital stay was 15.3 ± 1.8 days. All patients underwent a complete resection evidenced by pathology and showed normal blood flow through the reconstructed pulmonary artery on postoperative CT-scan without any events related to the surgery. All pa-

tients were alive without recurrence at a mean follow up duration of 11 months (**Table 1**).

DISCUSSION

A lobectomy with resection and reconstruction of the pulmonary artery has progressively gained acceptance as an alternative to pneumonectomy in lung cancer surgery^[5] because this technique allows patients to preserve functioning pulmonary tissue. VATS major pulmonary resection is reported to result in lower morbidity than that associated with thoracotomy^[6-8]. If equivalent operation can be achieved with VATS, some complications associated with thoracotomy may be avoided. However, it seems to be extremely difficult to perform partial removal pulmonary artery by using VATS procedures due to various technical limitations. With this background, we recently applied blocking of the pulmonary artery and veins in VATS as a novel strategy to treat patients with NSCLC at high cardiac or respiratory risk. This technique could shorten operation time, afford more operating space for surgeon and reduce blood loss due to the simplicity of the surgical procedure. Meanwhile, as it is difficult to control abrupt bleeding by VATS, VATS lobectomies for patients with severe adhesions that have a possibility of intraoperative bleeding are very risky. When there is uncontrolled sudden bleeding in a patient or a risk of sudden bleeding because of severe adhesions between the pulmonary artery and the hilar lymph nodes or tumor surrounding it (As shown in **Fig. 3**), most general thoracic surgeons opt to convert VATS to open thoracotomy. We applied this technique blocking both the pulmonary artery and veins in VATS for patients with severe adhesions because of lymph nodes or tumor at the lung hila to prevent sudden intraoperative bleeding, decrease the chance of converting to open thoracotomy and avoid pneumonectomy.

The proper design of incisions is very important for this new technique when pulmonary artery reconstruction is considered before operation. As described by the study of Nakanishi et al., it is important for a surgeon to achieve sufficient exposure of the pulmonary artery trunk, gain proximal and distal control of the pulmonary artery, properly manage the instruments and finally complete sutures^[2]. They placed a 7-cm utility thoracotomy incision in the third intercostal space, and placed the remaining three incisions for the 12-mm trocars in the sixth intercostal space on the anterior axillary line, on the auscultatory triangle, and in the seventh intercostal space on the posterior axillary line, respectively. Moreover, Mitsuhiro et al.^[9] placed the access incision for the central vascular clamp in the third intercostal space on the mid-axillary line and the

other access incision, for the distal clamp, in the sixth or seventh intercostal space on the posterior axillary line. In the conventional approach, the vascular clamp is inserted through an access incision so that they sometimes obstruct the limited visual field through the working port. Thus, we added an access incision (12 mm) for the central vascular clamp in the third intercostal space on the anterior axillary line. We placed an anterolateral mini-thoracotomy (40 mm) in the fourth intercostal space, and placed two thoracoports (12 mm) in the seventh intercostal space on the posterior axillary line and the mid-axillary line. It is unnecessary to place another access incision for claiming the pulmonary veins so as to afford a larger operative space and minor operative damage.

Our group previously reported that simultaneously blocking of the pulmonary artery and pulmonary veins in the open thoracotomy of locally advanced NSCLC was feasible^[3,10]. As compared with a simple pulmonary artery occlusion, clamping the distal reserved pulmonary veins can provide clearer surgical vision, greater operative space, simpler procedures and safer margin. Recently, we first applied this technique to lobectomy in VATS that did not necessarily require pulmonary artery resection but presented a difficult dissection of the pulmonary artery branches to avoid intraoperative uncontrolled bleeding. We found that this technique can shorten operation time and make operation safer. Therefore, we applied the technique to patients who required partial pulmonary artery resection with VATS. We thought that selected patients with severe adhesions between the pulmonary artery and the lung hilar lymph nodes or tumor surrounding it and at high cardiac or respiratory risk for open thoracotomy are the best candidates for these procedures.

In our study, the mean occlusion time of pulmonary artery and pulmonary veins were 40.6 ± 9.40 and 37.6 ± 8.44 minutes, respectively. As we all know, the exceedingly long occlusion time of the pulmonary vessels will induce serious lung ischemia-reperfusion injury (LIRI)^[11]. In the recently study^[12], we successfully established a rabbit model for blocking pulmonary artery and veins. We found that the characteristics of LIRI were similar when the pulmonary artery and veins were blocked compared with blocking of the pulmonary artery, which has been a common strategy applied in the surgical treatment of NSCLC for many years. Furthermore, LIRI induced by blocking the pulmonary artery and veins within one hour in this model was tolerable, but reversible. So we limited the occlusion time within one hour in VATS to avoid irreversible LIRI. There were no serious respiratory complications in our studies.

Finally, anticoagulant therapy for patients who have received pulmonary artery reconstruction remains controversial^[5, 13, 14]. According to our previous experience in open thoracotomy surgery^[3, 15], we considered that 3125 U intraoperative heparin should be safe and it is unnecessary to use any anticoagulation therapy postoperatively.

In conclusion, although the limitations of this study include the small number of patients and the short-term of observation, the results indicate that the surgical technique is feasible and safe in VATS. We recommend partial removal of the pulmonary artery under this technique for patients with difficulty on pulmonary artery dissection during VATS lobectomy. It is noteworthy that the procedure is technically difficult and time-consuming, so experienced surgeons are recommended to perform this procedure with proper selection of patients.

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