Abstract

A lobectomy with a resection of the pulmonary artery (PA), if oncologically adequate, is less invasive than a pneumonectomy. However, it seems to be extremely difficult to perform this technique using video-assisted thoracic surgery with technical limitations because this technique is associated with an increased operative risk even in an open thoracotomy. Between April 2002 and December 2006, a curative video-assisted thoracic surgery lobectomy including a mediastinal lymphadenectomy was performed in 121 patients with primary non-small cell lung cancer. Five of those patients underwent a thoracoscopic lobectomy with the partial removal and reconstruction of the pulmonary artery. The causes of the pulmonary artery resection included two direct invasions of the artery, two invasions of the arterial branch, and one calcified lymphadenopathy involving the branch. No patients required a blood transfusion. No complications attributable to the technique or mortality were seen. No patients showed an abnormal blood flow through the reconstructed vessel. There were no local recurrences on the pulmonary artery. A video-assisted thoracic surgery lobectomy including a partial resection and reconstruction of the pulmonary artery is a complex procedure for patients with non-small cell lung cancer. It is feasible when all associated technical issues are properly addressed.

1. Introduction

A lobectomy with a resection and reconstruction of the pulmonary artery (PA), if oncologically adequate, is less invasive than a pneumonectomy because this technique allows patients to preserve the functioning pulmonary tissue. Although there have been several studies showing excellent results and reductions in operative risk [1, 2], this procedure is still not popular among thoracic surgeons because of the technical difficulties and the increased operative risk.

Although a video-assisted thoracic surgery (VATS) lobectomy is regarded as a minimally invasive procedure [3–5], it seems to be extremely difficult to perform angioplasty using VATS procedures due to various technical limitations. To date, there are no reports of a VATS lobectomy with a partial PA resection and reconstruction for non-small cell lung cancer (NSCLC) in the literature. Previously, very complex VATS major pulmonary resections including a contralateral VATS lobectomy in a single-lung patient [6] and a VATS completion pneumonectomy [7] have been successfully performed. This report documents the initial experience performing a VATS lobectomy with a partial resection and reconstruction of the PA in patients with NSCLC.

2. Materials and methods

2.1. Patients

Between April 2002 and December 2006, 121 patients underwent a curative VATS lobectomy including a mediastinal lymphadenectomy for primary NSCLC at this hospital. Of these 121 patients, five had a VATS lobectomy with a partial resection and reconstruction of the PA, and were retrospectively analyzed for this study. The eligibility for this study required a lobectomy with PA angioplasty performed totally using VATS procedures, in addition to the three definitions described by Cerfolio and Bryant [2]. The VATS procedures were performed without the use of a rib spreader while viewing a video monitor. This study excluded patients who underwent only a thoracoscopic suture of the PA for hemostasis. The combined bronchoplasties were also excluded. The Institutional Review Board of Clinical Research of the hospital ethically approved this study, and informed consent for this study was obtained from all patients.

The indications for a VATS lobectomy were based on the standard criteria for an open thoracotomy, including tumors up to 6 cm in diameter. The preoperative staging included a chest roentgenogram, computed tomography (CT) scan of the body with intravenous contrast, bronchoscopy, brain
magnetic resonance, and bone scintigraphy. Mediastinoscopy was not routinely performed, whereas positron emission tomography was frequently used.

2.2. Operative technique

All patients received epidural catheter anesthesia and general anesthesia with dual-lumen endotracheal tubes, and then positioned in the lateral decubitus position with the bed flexed to increase the intercostal spacing. A 7-cm utility thoracotomy incision was placed in the 3rd or 4th intercostal space (ICS). A silicone rubber wound protector (LapDisk, Hakko Shoji, Tokyo, Japan; or Alexis Wound Retractor, Applied Medical, Rancho Santa Margarita, CA) kept the utility thoracotomy wound open by retracting of the soft tissue. The remaining three incisions for the 12-mm trocars were used for a forceps, a retraction and a thoracoscope (Fig. 1). After the VATS exploration, the hilar dissection was performed while taking particular care to avoid nerve injury, as previously reported [6, 7]. The surgical procedures for the pulmonary vessels are described below.

2.3. Partial resection of the PA after applying the cross-clamps

The PA branches of the lobe to be removed without cancer invasion were first divided. After the superior pulmonary vein was divided to allow better viewing of the PA, the proximal and distal control of the PA was obtained using a silicone rubber tube with an external diameter of 8 mm (Kaneka, Osaka, Japan). After the unilateral tip of the Satinsky clamps 26–34 cm long was inserted into one end of the silicone rubber tube, the PA clamp was easily completed by adequate placement of the Satinsky clamps following the extraction of the other end of the tube. Specifically, on the right side, the proximal control was obtained anterior to the superior vena cava after division of the truncus anterior of the PA; and on the left side, it was obtained extrapericardially after separation of the ligamentum arteriosum. Satinsky clamps were placed through the utility incision on the proximal and distal PA (Fig. 2) after intravenous injection of 50 U/kg of sodium heparin. The partial PA that had cancer invading its surface was then resected using scissors. After confirming the lack of cancer invasion to the margin, the PA was reconstructed with a primary closure using 5-0 Prolene (Ethicon, Somerville, NJ) (Figs. 3 and 4). Through the utility incision, a standard needle holder 27 cm long was easily inserted in addition to two pairs of the Satinsky clamps (Fig. 5). Using a forceps 41 cm long with 1 mm DeBakey jaws (Scanlan, Saint Paul, MN) inserted through the anterior trocar, the vessel was grasped and the suture thread was retracted accordingly. The suture thread was handled with care to...
avoid tangling or entwining it with the clamps. After a completion of the running suture, the distal clamp was removed before tying the arterial sutures to help remove the intravascular air. The proximal clamp was then removed to ensure hemostasis of the sewn PA.

2.4. Partial resection of the PA after the side clamp

After attaining proximal and distal control of the PA, the affected branch of the PA was controlled using a silicone rubber tube. Employing the same technique as in the case of the cross-clamp, a silicone tube allowed the adequate placement of the Satinsky clamps (Figs. 6 and 7). After the side clamp was applied, the partial resection of the PA was performed using a knife. The peripheral side of the divided PA was not sutured. Sodium heparin was not administered.
The PA was reconstructed in the same fashion as described for the cross-clamp.

2.5. Operative technique after vascular repair

The bronchi were carefully dissected, stapled, and divided in the same manner as in an open thoracotomy. The bronchial stump with additional sutures at both ends was not reinforced with any viable tissue. After removal of the lung, a systematic dissection of the mediastinal nodes was performed. A single chest tube was inserted and the wounds were closed. No further anticoagulation was used postoperatively.

2.6. Data acquisition and follow-up

The reconstructed part of the PA was assessed using CT with intravenous contrast within six months postoperatively, or immediately when the event occurred. The complete follow-up data were obtained from the records of the post discharge visits and from the regular radiographic follow-up.

3. Results

The clinical details of the five patients are summarized in Table 1. The postoperative lung functions predicted on the basis of quantitative perfusion scans were tolerable in all patients, assuming that none required a pneumonectomy. Patient 4 underwent this surgery after a stage-down by induction chemotherapy, although patient 3, with a single station N2 disease, rejected the induction chemotherapy. The mean number of mediastinal node resected was 24.2 ± 8.1. Direct tumor invasion in two patients included one-eighth to one-fourth of the external wall of the PA. In another three patients, an affected lobe could not be separated from the PA because of tumor invasion or dense adenopathy of proximal part of the posterior ascending artery. In patient 2, the type of PA clamp was converted because of difficulty separating the tumor and vessel. The mean repair time of the PA was 28.0 ± 13.4 min. The prolonged operative time of patient 2 was due to a dense adhesion of the hilum and mediastinum, caused by the previous surgery (Table 1).

No patients required a blood transfusion during the surgery or the postoperative course. There were no operative deaths and no complications attributable to the technique. The mean hospital stay was 14.4 ± 9.0 days because a prolonged stay was necessary for two patients, who presented with complications (Table 1). All patients underwent a complete resection evidenced by the pathology and showed normal blood flow through the reconstructed PA on a postoperative CT-scan without any events related to the surgery. Although there were no local recurrences on the PA, one patient died of brain metastases 13 months postoperatively. Another died of pneumonia 23 months postoperatively despite the fact that there was no tumor recurrence. Three patients are presently alive without recurrence at 33 months mean follow-up (Table 1).

Table 1
Clinical details of the five patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patient 1</th>
<th>Patient 2</th>
<th>Patient 3</th>
<th>Patient 4</th>
<th>Patient 5</th>
</tr>
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<tbody>
<tr>
<td>Age (years)</td>
<td>57</td>
<td>72</td>
<td>67</td>
<td>69</td>
<td>79</td>
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<tr>
<td>Sex</td>
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<td>Male</td>
<td>Female</td>
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<td>Male</td>
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<tr>
<td>FEV1/FVC (%)</td>
<td>71</td>
<td>66</td>
<td>74</td>
<td>62</td>
<td>48</td>
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<tr>
<td>Past history</td>
<td>Tuberculosis</td>
<td>LUL for stage IB Sq and RUW for stage IA</td>
<td>Ad before this surgery</td>
<td>Hypertrophic cardiomyopathy</td>
<td>RLL for stage IB</td>
</tr>
<tr>
<td>Cause of PA resection</td>
<td>Dense adhesion of calcified lymph node</td>
<td>Direct tumor invasion of PA</td>
<td>Tumor invasion of PA branch</td>
<td>Direct tumor invasion of PA branch</td>
<td>Tumor invasion of PA branch</td>
</tr>
<tr>
<td>Type of PA clamp</td>
<td>Side</td>
<td>Side to Cross</td>
<td>Side</td>
<td>Side</td>
<td>Side</td>
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<td>Repair time of PA (min)</td>
<td>35</td>
<td>48</td>
<td>23</td>
<td>15</td>
<td>19</td>
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<td>Operative time (min)</td>
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<td>505</td>
<td>341</td>
<td>310</td>
<td>375</td>
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<td>Blood loss (ml)</td>
<td>160</td>
<td>565</td>
<td>120</td>
<td>270</td>
<td>355</td>
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<td>Postoperative complications</td>
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<td>Prolonged air leak</td>
<td>T4N2M0, stage IIb</td>
<td>Sputum retention</td>
<td>None</td>
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<tr>
<td>Outcome (months)</td>
<td>Alive, 65</td>
<td>Dead, 13</td>
<td>Alive, 45</td>
<td>Dead, 23</td>
<td>Alive, 20</td>
</tr>
</tbody>
</table>

FEV1, forced expiratory volume in one second; FVC, forced vital capacity; LUL, left upper lobectomy; Sq, squamous cell carcinoma; RUW, right upper wedge resection; Ad, adenocarcinoma; RLL, right lower lobectomy; RUL, right upper lobectomy; RUMB, right upper and middle bilobectomy; RLW, right lower wedge resection; PA, pulmonary artery.
4. Discussion

To assure the safety and reliability in the performance of a resection and reconstruction of the PA using the VATS procedure, the surgeon must achieve sufficient access to the main PA, gain proximal and distal control of the PA, properly manage the instruments and sutures, and also appropriately address the problem of anticoagulation therapy.

New instruments for thoracoscopic vascular clamping are still scarce. The use of a favorite clamp is still reliable for the control of the PA, even if the clamp is tricky to use because of small incision. Therefore, the utility of a thoracotomy incision requires the easy access to the main PA and a size of at least 7 cm or more for ease of operation of a standard needle holder in addition to the insertion of two pairs of the Satinsky clamps. Although direct vision of the operative field through the utility incision may not afford the surgeon sufficient view for the suture repair because of the cluttered wound, the thoracoscope can magnify the visual image of the repair. Reliable thoracoscopic instruments probably reduce the length of the utility incision.

Although attempts were made to perform a side clamp of the PA to reduce the number of clamps that must be inserted through the utility incision, a cross-clamp seems to be safer and more oncologically reliable than the side clamp because it provides easy separation between the tumor and vessel and an accurate diagnosis of affected area of the PA. A primary closure of the PA was performed in all patients because the tumor invasion of the PA wall did not exceed one-fourth of its external wall [2]. In the primary closure, a cross-clamp also may be easier than a side clamp because the repair time in patients who underwent a cross-clamping of the PA seemed to be shorter than that in case of a side clamp, as shown by Table 1.

The management of the instruments and sutures is more important in VATS than in an open thoracotomy. The grasp of the vessels using the forceps inserted through the trocar seems to be safe because of the infrequency of wobbling when the trocar site is regarded as a fulcrum. Manipulation of the needle holder might be much easier with the use of a robot like the da Vinci device [8]. Surgeons should thus take care to neither tangle the suture thread nor to entwine it with the clamps.

Rendina and colleagues reported an intravenous injection of 3000–5000 U of sodium heparin in aggressive PA resections, followed by 15,000 U/day of subcutaneous heparin for the first postoperative week [1]. Cerfolio and Bryant demonstrated that only an intraoperative dosage of 1500 U of heparin had no trouble with yielded no cessation of the flow of the PA in 10 sleeve and 38 partial PA resections [2]. In this study, only an intraoperative dosage of 50 U/kg of heparin was required with the PA clamping, although the clamping time was longer than expected. Low dosage of heparin may work well. A primary closure is thought to need no postoperative anticoagulation therapy.

To preserve the remaining lung function of the patient, a PA resection should be performed even if it requires an open thoracotomy, if the procedure is oncologically feasible. A VATS pneumonectomy should not be automatically selected. Although the limitations of this study include the small number of patients and the short-term of observation, the results support that a skilled surgeon may perform the VATS lobectomy with a partial PA resection and reconstruction if the requirements of this procedure are met.

In conclusion, a VATS lobectomy including a partial resection of the PA with a primary closure is therefore considered to be a feasible surgical modality when several technical issues can be appropriately addressed, even though it remains a complex procedure for the treatment of patients with NSCLC.

References