Title: Thoracoscopic Right Intrapericardial Pneumonectomy

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Glossary

3D Three-dimensional

CT Computed tomographic

PA Pulmonary artery

PET Positron emission tomographic

RATS Robotic-Assisted Thoracoscopic Surgery

TEE Transesophageal echocardiogram

VATS Video-Assisted Thoracoscopic Surgery

Central Picture Legend
Intrapericardial VATS approach yields safer hilar dissection.

Central message

VATS pneumonectomy challenges caused by tedious hilar dissections, surgeons’ inexperience, and vascular injury risks are offset by enhanced retractors, optics, and intrapericardial exposures.

INTRODUCTION

Video or Robotic Assisted Thoracoscopic Surgical (VATS or RATS) approaches for lobectomy have increased steadily to become preferred over open thoracotomy. However, minimally invasive approaches for more challenging procedures like chest wall resection and airway reconstruction are still in development. Adoption of VATS pneumonectomy was slowed by case availability since total lung removal is appropriately avoided. Also, difficult hilar dissections for centrally located tumors risk unexpected vessel injury. Generally these challenges are from tumor girth, associated inflammation, and fibrosis from previous cancer treatments. Some can be overcome by intrapericardial dissections in unaffected tissues. Preoperative imaging may be predictive, but the ultimate decision to proceed with an intrapericardial approach is made intraoperatively based on the ability to safely dissected hilar structures.

MATERIALS and METHODS

Our technique for performing a safe and reproducible intrapericardial right pneumonectomy is described in 11 reproducible steps, each accompanied by narrated video with graphical annotation. We described previously our general approach to advanced resections.
Briefly, the highly adaptable technique requires flexible 5mm or 10mm (3D) optics (Olympus Endoeye™, Center Valley, PA) optics and numerous thin shaft retractor instruments (Sontec, Centennial, CO) often filling the same ports (Figure 1). We use a 3-incision upper lobe approach achieving the key elements of pleural exploration, adequate proximal PA exposure, sequential structure divisions (bronchus last), lymphadenectomy and stump coverage.

RESULTS

Preoperative Considerations

A parenchymal sparing operation including VATS sleeve resection is preferred if possible and oncologically valid. In this case, a bronchus intermedius squamous cell carcinoma extending proximally to encase the upper lobe airway mandated pneumonectomy.

Patients routinely undergo frailty screening, CT/PET imaging, pulmonary function testing, split lung perfusion scans, and echocardiograms (Figure 2). Right heart catheterization and TEE are occasionally useful to assess PA occlusion tolerance but were not necessary in this case.

DISCUSSION

Central tumors (and inflammation from preoperative chemoimmunotherapy or radiation) complicate hilar dissections and increase thoracoscopic pneumonectomy risks. As in this video, dissection was eased by an intrapericardial approach. While physiologic risk is uncertain, some VATS benefits associated with lessor resections might translate to pneumonectomy. We reported a retrospective 11-year experience of 67 VATS pneumonectomies with 82% of cases in the second half of the series performed successfully without conversion. Using the techniques
described in this article, there were no intraoperative deaths from catastrophic PA bleeding or
other technical mishaps. Survival curves by stage and perioperative outcomes were similar using
an intent to treat analysis. Interestingly, we found that the pain reduction compared to
thoracotomy associated with VATS was delayed by months and this was recently replicated by
others. Now that minimally invasive lung resection has become the standard of care, more
complex operations naturally follow with larger series also having no evidence of impaired
outcomes.

Loss of vascular control should a proximal vessel injury occur concerns most physicians.
Besides a latex-free (relatively stiff plastic) catheter stapler leader (used first as a sling to aid PA
dissection), catastrophic artery tears are avoided by preserving the bronchus. Dividing the
bronchus early is tempting because it is accessible and obscuring PA access, but it acts as a
robust protective tether to oppose the dangerous force of large specimen retraction on the
delicate vessel. Experience with main PA control comes with preparing for possible bleeding
during difficult lobectomy cases. By encircling the artery with a double looped silicone sling,
the vessel will close completely if retracted. Similar PA control was routine practice for open
lung resection cases performed in the era of TB surgery.

Whole lung specimen extraction can be difficult given the large size comparable to small
VATS incisions and could be a mechanism behind delayed pain improvement noted above. A
wide interspace in the axillary region is good access incision for pneumonectomy and lung
specimens can be aligned so that the more malleable lobe is extracted first. About 10% of cases
experience a rib fracture that can be plated. Though this is not mandatory, increasing stability of
the fracture potentially helps with postoperative pain and respiratory mechanics. Alternative
extraction incisions can also be used. We also note cases where the access incision stretched by
specimens (and without the rib approximation sutures used in thoracotomies) facilitates air egress and mediastinal shift. We currently use the patch technique described, but there are other methods to seal this opening. Also, it may not be needed depending on patient anatomy and extent of mediastinal fixation from radiation or other treatment effects.

CONCLUSIONS

For suitable patients without parenchymal sparing options, thoracoscopic pneumonectomy is safe and feasible with possible long-term reduced pain.

VIDEO SEGMENTS

1. Positioning, Port/Incision Positioning

After double lumen endotracheal intubation, the patient is moved to left lateral decubitus position (Video 1). Standard VATS lobectomy incisions are created in the 8th intercostal space in the posterior axillary line, the seventh intercostal space more anteriorly, and a 4 cm access incision in the 4th intercostal space. An Alexis (Applied Medical, Rancho Santa Margarita, CA) access wound protector retracts the chest wall soft tissues. Pleural metastases are excluded with camera viewing from the posterior inferior incision. Intercostal nerve blocks are performed early to reduce central nociceptive sensitization related chronic pain. The inferior pulmonary ligament is then divided with energy while retracting the lower lobe superiorly. The anterior and posterior hilar pleurae is then opened with a bipolar sealer. At this point, dissection of Levels 9, 10 (inferior hilar), 7, 8 lymph nodes can be performed.

2. Inferior Pulmonary Vein Isolation
Circumferential inferior pulmonary vein dissection is then performed with both blunt dissection and energy while retracting the lung superiorly (Video 2). A vessel loop is placed around it to facilitate passing the stapler, but division is delayed until the superior vein is isolated as well. A camera swap is performed, and lung traction is exchanged from the access incision to the former camera port.

3. **Isolation of the superior pulmonary vein (intrapericardial)**

Before dividing the inferior vein, the superior pulmonary vein is dissected. This occasionally reduces lung vascular congestion during prolonged hilar dissection in tumors with high bronchial artery perfusion (Video 3). In our case, local tumor hilar fibrosis necessitated intrapericardial vein dissection. A long handle 15-blade scalpel is used to gently score the pericardium posterior to the phrenic nerve, which is then opened and extended using VATS scissors. While not mandatory, we find the scalpel to be the most useful instrument for the initial opening of the pericardium. The superior pulmonary vein is isolated within the opened pericardium and encircled with a vessel loop.

4. **Sequential division of pulmonary veins**

Using vessel loop control, the upper and lower pulmonary veins are divided in rapid succession with surgical stapler vascular loads (Video 4). Some peribronchial tissue is dissected from the airway at this point to improve hilar mobility.

5. **Pulmonary artery isolation**

Dissection of right main pulmonary artery from the right mainstem bronchus is then performed (Video 5). Level 7 lymph nodes are also dissected to facilitate the isolation of the pulmonary artery. Peribronchial airway tissue and pulmonary artery
attachments are divided carefully with energy. Attention is turned to the anterior hilum to further dissect the pulmonary artery. After some initial dissection between the airway and main pulmonary artery, retraction of the whole lung can be greatly aided by using a 5 mm laparoscopic flexible liver retractor such as the Diamond-Flex™ (Carefusion, San Diego, CA) through the anterior inferior incision. In addition to aiding arterial dissection, this retractor efficiently exposes the carina later in the case for lymph node dissection.

6. Division of the right main pulmonary artery

A red rubber catheter is positioned in between the artery and airway (Video 6). If controlling the airway, it can be swung around the pulmonary artery (reverse exclusion technique). Such a sling applies gentle arterial traction while dissecting away other thickened tissues (lymphatics or residual pericardium) that impair stapler function. Lastly, the red rubber catheter acts as a leader to facilitate safe passage of the endoscopic vascular stapler anvil behind the main pulmonary artery. A plastic latex-free catheter is stiffer yielding more reliable anvil guidance. Prior to dividing the artery, the stapler is closed to assess for any hemodynamic compromise caused by inadvertent main pulmonary artery narrowing or cardiac decompensation.

7. Division of the bronchus

Any remaining peri-bronchial attachments of lymphatics are divided while retracting the lung superiorly (Video 7). Lung retraction is again facilitated with the liver retractor which helps leave the shortest bronchial stump possible, especially for left sided pneumonectomy. The stapler is brought in from the posterior incision for division of the bronchus.

8. Specimen extraction
Extraction of the whole lung specimen can be difficult through the access incision (Video 8). To allow for maximal rib flexion, the pleura and intercostal muscles are divided as much as possible under the skin incision. We prefer a 15 mm Anchor tissue retrieval system (Anchor Products Co, Addison, IL) but some specimens require the larger 8x10 inch traditional pouch.

9. Lymph node dissection

The right paratracheal lymph node tissue packet is removed (Video 9). Hemostasis is achieved with Aquamantys (Medtronic, Minneapolis, MN) and topical hemostatic agents. Though a debate on the merits of lymph node dissection versus sampling is beyond the scope of this paper, minimizing the possibility of ischemia of the bronchial stump is important in preventing the dreaded complication of delayed bronchopleural fistula.

10. Bronchial stump coverage

The pericardial and residual thymic fat were mobilized with the LigaSure™ on a superior pedicle and secured to the bronchial stump with interrupted absorbable sutures to the pleural reflection (Video 10). For non-infected and non-irradiated cases, this is optional.

11. Chest wall seal

To limit post-pneumonectomy space air egress into subcutaneous tissue, the access incision site is closed using a double layer of Vicryl mesh by interrupted horizontal 0 Vicryl mattress sutures to the superior and inferior rib margins (Video 11). A chest tube is connected to a balanced pneumonectomy drainage system.
References


Figure Legends

Figure 1. Flexible 3D optics (A) and low-profile retractors including the Sontec thoracoscopic (B) and Diamond-Flex™ laparoscopic (C) retractors. By virtue of 5mm round (rather than ovoid) shaft cross-sections, multiple instruments can share the same port (D) to enable the complex traction-countertraction needed to dissect large tumors with hilar fibrotic changes. With permission.¹

Figure 2. Initial imaging for presented case demonstrating Coronal CT (A), PET (B), and Split Lung Radionuclide findings supporting pneumonectomy.

Video 1. Positioning, Port/Incision Positioning
Video 2. Inferior Pulmonary Vein Isolation
Video 3. Isolation of the superior pulmonary vein (intrapericardial)
Video 4. Sequential division of pulmonary veins
Video 5. Pulmonary artery isolation
Video 6. Division of the right main pulmonary artery
Video 7. Division of the bronchus
Video 8. Specimen extraction
Video 9. Lymph node dissection
Video 10. Bronchial stump coverage
Video 11. Chest wall seal