Extended pleurectomy and decortication: Video atlas of operative steps

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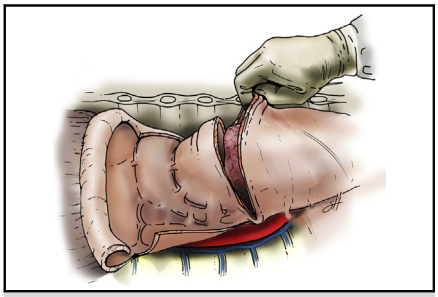

Removal of malignant pleural mesothelioma by extended pleurectomy and decortication.

CENTRAL MESSAGE

The operative steps for an extended pleurectomy and decortication are described with a video atlas. An ePD can achieve a macroscopic complete resection for MPM with preservation of the lung.

See Commentary on page 331.

Video clip is available online.

Feature Editor Note—*Video Atlas Articles (VAAs) are peer-reviewed descriptions of an operative procedure distilled into a series of steps, with each step taught to the reader through its own narrated video and short corresponding text. The purpose of the VAA is to provide continuing surgical education in a format that is quality-assured, easily accessible, and high impact. Much of the excitement around our new series of VAAs surrounds robotic and thoracoscopic/laparoscopic procedures. Our field has progressed rapidly into one in which robotic and thoracoscopic surgery have improved clinical outcomes, and we drive much of the innovation in minimally invasive surgical platforms and technique. The ability to record high-resolution video during the routine conduct of robotic and thoracoscopic/laparoscopic surgery has facilitated this opportunity in structured, peer-reviewed, expert instruction of index cases in thoracic surgery and is the bedrock for the VAA initiative. Open surgery, however, has become less frequent in our training programs, and operations that are performed open are now more likely to be complex rather than routine cases. This highlights a gap in surgical training that can be narrowed with novel methods of continuing surgical education. In this VAA, the authors describe an extended pleurectomy/decortication procedure for malignant pleura mesothelioma in a structured and comprehensive series of 12 steps. High-resolutions videos recorded from a surgeon's headlight camera are provided for each step and allow the reader to experience the conduct of each step of this complex, open operation from the surgeon's perspective. This is the first VAA of an open procedure and showcases the potential of this format to advance continuing surgical education for open thoracic surgery.*

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Malignant pleural mesothelioma (MPM) is the most common type of malignant mesothelioma, which arise from the pleural, peritoneum, pericardium, and tunica vaginalis. The incidence of MPM is about 3000 patients per year in the United States. The etiology of the majority of cases is asbestos exposure. Surgery with chemotherapy results in long-term survival in some patients.[1] Surgery has a role in the diagnosis, staging, and treatment, with both palliative and curative intents.[2] The National Comprehensive Cancer Network, the European Society for Medical Oncology, and American Society of Clinical Oncology have guidelines

that recommend surgery for MPM for both diagnosis and treatment.[3-5]

A macroscopic complete resection is the goal of curative-intent surgery.[6,7] Negative microscopic margins (R0 resection) are not feasible since MPM covers all surfaces of the thoracic cavity and resection of these structures is not possible. The National Cancer Institute, the International Association for the Study of Lung Cancer, and the Mesothelioma Applied Research Foundation have helped standardize the operations for MPM. To achieve a macroscopic complete resection, either a lung-sparing surgery called an extended pleurectomy/decortication (ePD) or a lung-sacrificing surgery called an extrapleural pneumonectomy is performed.[8] A visceral and parietal pleurectomy includes the "extended" descriptor when resection of the diaphragm and/or pericardium are performed. Whether a partial diaphragm resection should be included as an ePD is questionable, but despite differences in the operations, the goal of an ePD is to remove all visible, palpable, or viable tumor while sparing the lung.

This article outlines the steps to perform an ePD. This approach is surgeon-specific, and alternatives to most aspects of this operation exist. Extensive training is necessary before performing this operation independently.

PREOPERATIVE EVALUATION

An extensive evaluation is necessary to determine whether a patient is an operative candidate. The evaluation includes diagnostic and subtype confirmation, establishment of clinical stage, and assessment of cardiopulmonary status. Patients are evaluated for a treatment plan that may include surgery, chemotherapy, immunotherapy, radiotherapy, palliation, and clinical trial eligibility. Presentation at multidisciplinary tumor board helps finalize recommendations.

Video-assisted thoracoscopic surgery (VATS) or computed tomography (CT)-guided biopsies establish the diagnosis. Confirmation of the diagnosis or subtyping requires rebiopsy or review of the pathology once referred to a center specializing in MPM. Repeated VATS biopsies may be required. After diagnosis, positron emission tomography scans, CT scans, and occasionally magnetic resonance imaging help establish clinical staging. The positron emission tomography scan evaluates the thoracic cavity, mediastinal lymph nodes, and potential metastatic sites. Magnetic resonance imaging assists with identifying local invasion but does not contribute significantly more than CT.

Staging with mediastinoscopy and diagnostic laparoscopy helps to identify a subset of patients with advanced disease that is not noted on imaging.[9,10] Diagnostic laparoscopy reveals disease in 17% of patients. Mediastinoscopy may exclude marginal operative candidates, but it does not fully evaluate lymph node metastases because pleural disease can spread to nodes other than the peritracheal nodes. Repeated VATS biopsies, mediastinoscopy, and diagnostic laparoscopy can be performed during the same operation.

Assessment of cardiopulmonary status is necessary to lower perioperative risk. Pulmonary function tests and ventilation/perfusion nuclear scans are performed. Postoperative predicted pulmonary volumes are calculated to determine eligibility for an extrapleural pneumonectomy even when an ePD is planned. The diffusion-limited carbon monoxide is important to identify restricted pulmonary diffusion that occurs with asbestosis. An absolute threshold for pulmonary function tests or ventilation/perfusion values in which an ePD should not be performed is debatable; however, when the numbers are particularly low, the lung will likely not regain significant function. An echocardiogram and an electrocardiogram are performed. Right heart catheterization may be necessary, given that echocardiogram does not adequately estimate right heart pressure; however, cardiology consultation is advisable for most patients especially with comorbidities.

OPERATIVE APPROACH

Preoperative Planning and Positioning

An epidural catheter, arterial line, central venous catheters, nasogastric tube, and urinary catheter are placed. A pulmonary artery catheter is rarely necessary. A central venous catheter is inserted in the internal jugular vein; however, femoral vein access is an acceptable alternative. Blood loss is normally 300 to 500 mL. Injury to vessels such as the superior vena cava may result in larger-volume blood loss, and femoral access may be helpful for rapid resuscitation. Epidural catheters may be eliminated and regional anesthetic agents used, which may prevent exacerbation of hypotension from unilateral sympathectomy. A flexible bronchoscopy is unnecessary; therefore, a double-lumen endotracheal tube is placed to start. Two-lung ventilation is maintained as long as possible to decrease barotrauma, including during the initial pleurectomy. After the operation, the double-lumen tube is changed to a single-lumen tube and a therapeutic flexible bronchoscopy is performed to remove secretions. The operation is performed in standard lateral decubitus position with slight anterior rotation of the hip.

Operative Steps

Step 1. Video 1 and 2: Incision and development of the extrapleural plane. An extended posterolateral thoracotomy is performed with the incorporation of previous VATS port sites if feasible. The latissimus dorsi and serratus anterior are mobilized and spared. The sixth rib is removed with a subperiosteal dissection to spare the intercostal muscles, which are approximated during closing. The extrapleural space is developed circumferentially from the resected

rib. The incision is extended once lack of chest wall invasion is determined. Hemostasis is continually obtained with packing areas while working elsewhere and coagulation with Aquamantys Bipolar Sealers (Medtronic, Minneapolis, Minn) or argon plasma coagulation (instrument list: Table 1 and Table E1).

Step 2. Video 3: Anterior extrapleural dissection. The anterior pleural dissection removes the parietal pleural from the chest wall into the pericardiosternal recess. Internal mammary and pericardial fat pad nodes are removed. When the dissection reaches the pericardium, the pleura is peeled off the fibrous pericardium to the pulmonary veins if the disease does not invade the pericardium. If the disease invades the pericardium, separation of the fibrous and serous pericardium may complete the dissection. Alternatively, the anterior dissection is stopped and the pericardium is resected later in the operation.

Step 3. Video 4: Apical extrapleural dissection. The apical pleural dissection removes the disease from the chest wall and apex. Dissection is continued along the mediastinal pleura by pushing the structures into the mediastinum to avoid traction injuries to the recurrent laryngeal nerves, the lymphatics, vessels, and airways. Once the azygous vein (aortic arch/left side) is identified, this dissection is completed. The apical dissection will connect to the anterior dissection at the superior vena cava.

Step 4. Video 5: Posterior extrapleural dissection. The posterior pleural dissection is developed from the chest wall over the azygous and the esophagus to posterior hilum. During left-sided operations, the pleurectomy continues over the aorta; avoiding a dissection behind the aorta is critical to prevent injury to the segmental branches. Sharp dissection of fibrous adhesions is required to mobilize the parietal pleura to the visceral pleura; complete mobilization facilitates the visceral dissection later. Below the inferior pulmonary vein, the posterior dissection continues to the diaphragm along the inferior mediastinum. The lymph node dissections from levels 7, 8, and 9 are performed.

Step 5. Video 6: Lymph node dissection. The level 7 lymph node dissection is completed. Although not shown, lymph node dissections include levels 3, 4R, 5, 6, 8, 9, 10, 11, 12, and internal mammary nodes depending on the side of the operation. These are performed during dissections in the respective areas. Lymph nodes within the intercostal muscles are also retrieved.

Step 6. Video 7: Diaphragm resection. Preservation of portions of the diaphragm is feasible depending on extent of disease. Anteriorly, removal of the diaphragmatic disease exposes the angle between the diaphragm and pericardium and, posteriorly, the disease is peeled off above the esophagus on the right and the aorta on the left. Often, resection of the diaphragm is easier from the abdominal side; therefore, the diaphragm is opened at the most lateral point and this opening is extended to the mediastinum while preserving as much muscle as possible. The peritoneum at the base of the diaphragm is scored about 1 to 2 cm lateral to the mediastinum. The diaphragm medial to this line becomes a cuff to attach the diaphragm patch to prevent herniation.

Step 7. Video 8: Pericardial resection. During the anterior parietal dissection at the point in which the pleura cannot be peeled off the pericardium, it is opened. The pericardiectomy is extended superiorly to the great vessels, inferiorly to the diaphragm, posteriorly to the pulmonary veins, and anteriorly to the pleura of the contralateral lung. Complete transection is easier from an intrapericardial approach. Stay sutures are placed to prevent retraction of the pericardium to the contralateral side with subsequent hemodynamic instability.

Step 8. Video 9: Visceral decortication. The operative lung is inflated and an incision is performed through the pleura; often both the visceral and parietal pleura with the thickened disease are fused. With one hand that provides retraction, the lung is separated from the visceral pleura by both blunt and sharp dissections. The disease may be too adherent for decortication. The lingula or right middle lobe may require resection and wedge resections often facilitate pleurectomy at difficult angles. The fissure is approached by performing the visceral pleural dissection from each lobe to the base of the fissure. With complete fissures, this dissection may require dissection off the pulmonary arteries. Completion of the visceral pleurectomy is obtained when this dissection connects to the parietal pleural dissection.

TABLE 1. Unique instrumentation for extended pleurectomy and decortication

Instrument	Company
Matson Rib Double Ended Elevator and Stripper Raspatory	Novo Surgical Inc
Stille-Luer-Type D/A 10MM Curved Jaws	Cen-Med Enterprises Inc
Alexander Periosteotome- Sharp	Novo Surgical Inc
Doyen Coastal Elevator: Cobb, Right, and Left Blade, Heavy Duty Round Handle	Superior Instruments
Cobb Elevator	Novo Surgical Inc
Handpiece Interpulse w/Coaxial High Flow	Stryker
Aquamantys 6.0 Bipolar Sealer	Medtronic
Argon Beam Coagulator	Valleylab Inc.
ProTack 5-mm Fixation Device	Medtronic
LIGACLIP Endoscopic Rotating Multiple Clip Applier	Johnson & Johnson
Carter-Tomason Suture Passer	CooperSurgical
Gore-Tex Dual Mesh 20 cm × 30 cm × 1.0 mm	W. L. Gore & Associates
Endo GIA Ultra Universal Stapler	Covidien

Step 9. A: Video 10: Diaphragm reconstruction (part I). A nonabsorbable, 1- to 2-mm patch is placed in the native position at the eighth intercostal space (ICS) anteriorly, ninth ICS laterally, and tenth ICS posteriorly. Alternatively, reconstruction with a biological material such as an acellular dermal matrix may decrease infection rate caused by air leaks. No. 2 polyglactin 910 sutures are sewn through the chest wall, into diaphragm patch as a vertical mattress with the edge everted into the chest cavity, and back through the chest wall one interspace higher. A suture-passing device may help. Sutures to the erector spinae muscles are inserted.

B: Video 11: Diaphragm reconstruction (part II). Once the lateral diaphragm patch is secured, the size and tautness of the patch are based on the sutures along the mediastinum. Anteriorly, a portion of the muscular diaphragm is usually preserved between the chest wall and pericardium which is sewn to the anterior edge of the patch with non-absorbable sutures. Next, the patch is attached to the base of the pericardium, which provides more rigidity to the reconstruction compared with the anterior muscular diaphragm. The medial border of the patch is secured from the pericardium to the residual cuff of the diaphragm. The reconstruction is completed over the vertebral bodies with a ProTack 5-mm fixation device (Medtronic).

Step 10. A: Video 12: Pericardial reconstruction (part I). The pericardial reconstruction prevents herniation and torsion. The pericardium is reconstructed with a 0.1-mm polytetrafluoroethylene patch that is attached with 2-0 nonabsorbable sutures. Alternatively, polyglactin 910 mesh or bovine pericardium is used, which may decrease infectious complications. Over the great vessels, the pericardium does not need to be closed. The pericardium is reconstructed starting with horizontal mattress sutures in the anterior pericardium that are parachuted into the chest.

B: Video 13: Pericardial reconstruction (part II). The inferior pericardial patch is secured to the confluence of the diaphragm and pericardium through diaphragm patch. Avoiding compression of the inferior vena cava is critical during this reconstruction. The patch is secured to the posterior pericardium along the inferior pulmonary vein (IPV) and superior pulmonary veins. The placement of these sutures will determine the size of the patch, given that the anterior sutures are already in place; if the patch is too tight, restriction may occur. The patch is fenestrated to prevent tamponade.

Step 11. Video 14: Povidone–iodine scrub. Several intraoperative therapies are available that may decrease ipsilateral recurrences. Povidone–iodine is administered to the intrathoracic cavity after complete resection and reconstruction of diaphragm and pericardium with protocol modified from Lang-Lazdunski and colleagues (Table 2).[11] Other intraoperative adjuncts include chemotherapy, photodynamic therapy, hydrogen peroxide, and argon beam coagulation. No therapy has proven efficacy or benefit over another.

TABLE 2. Procedure for the administration of povidone–iodine

Step	Procedure
1	Prepare: hyperthermic (40°C-41°C) 3 L of saline with 10% povidone–iodine
2	Scrub incision and chest with 10% pure povidone–iodine
3	Allow to bathe for 5 min in chest
4	Irrigate and bathe with water for 5 min
5	Administer 3 L of hyperthermic povidone–iodine with handpiece
	Interpulse with Coaxial High Flow (Stryker)
6	Allow to bathe for 5 min in chest
7	Repeat scrub incision and chest with 10% pure povidone–iodine
8	Allow to bathe for 5 min in chest
8	Irrigate and bathe with water for 5 min
9	Assess thoroughly for hemostasis

Step 12. Video 15: Final anatomy. Overview of the anatomy of the residual thoracic cavity after pleurectomy.

Operative Considerations

- The latissimus dorsi and the serratus anterior can be mobilized without transection. If residual space in the chest results in an empyema or persistent air leaks, these muscles are available as pedicled muscle flaps. This approach requires subcutaneous drain placement to avoid seroma formation. In addition, if the muscle does not seal the chest completely, the subcutaneous space can communicate with the residual thoracic cavity.
- The sixth rib is removed in a periosteal plane. When closing the chest after resection of this rib, the intercostal sutures do not pull the ribs completely together to help decrease postoperative pain. The intercostal bundles are sutured together and the muscle flaps are parachuted into the incision to prevent fluid shift through the chest wall. Alternatively, the seventh rib may be removed for better exposure of the diaphragm.
- Once the rib is removed, chest wall invasion is assessed during the initial pleurectomy to determine resectability. Chest wall biopsy with rapid pathological assessment (frozen section) can help determine whether chest wall invasion is present. However, frozen section only augments gross findings for confirmation.
- Dissection of the pleura off vascular, lymphatic, and nerve tissue is performed by pushing the mediastinum off the pleura rather than pulling the pleura off the mediastinum to decrease traction injuries.

- Identifying the IPV and performing the pleurectomy from the posterior pleura below the vein to the pericardium anteriorly will help identify the diaphragm to create a cuff for the reconstruction.
- Dissection of the parietal pleural across the hilar vessels onto the pulmonary parenchyma will facilitated completion of the visceral pleurectomy.
- With large tumors, the visceral decortication can be performed before completion of the parietal pleurectomy. This maneuver will facilitate the safe approach to the mediastinum and hilum, especially between the IPV and the diaphragm.
- For thin visceral pleura without gross disease, ablation of the pleura is acceptable if the visceral pleura cannot be adequately decorticated.
- When removing the diaphragm, holes in the peritoneum are closed whenever possible.
- Either avulsing or transecting the diaphragm and removing it from the peritoneal surface is often simpler than resection of the diaphragm from the thoracic cavity secondary to the bulky pleural disease.
- Creation of a cuff of diaphragm along the mediastinum over the aorta and esophagus helps reconstruct the diaphragm patch and prevent herniation. If disease is involved, this area can be decorticated and spared.
- Traction on the phrenic vein is critical to avoid because tearing this vein can track onto the inferior vena cava and into the abdomen.
- During reconstruction of the pericardium, the patch must remain loose and have fenestrations to prevent restriction and tamponade.
- Four chest tubes are placed in anterior, lateral, diaphragm, and posterior positions. Suction on the tubes may result in significant loss of tidal volume secondary to air leaks.

CONCLUSIONS

Extended pleurectomy and decortication can achieve a macroscopic complete resection of malignant pleural mesothelioma with the preservation of the lung. Outlined herein are the steps to perform this operation.

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TABLE E1. Instrument list for extended pleurectomy and decortication

Instrument
Retractors
1. Abdominal Balfour Retractors
2. Finochietto Rib
3. Davidson Scapula
4. Allison
5. Kelly
6. Richardson
7. Malleable Ribbon
8. Cushing Nerve and Vein
9. USA Double Ended
Clamps
1. Mosquito Halsted
2. Artery Crile
3. Hemostatic Crile
4. Rochester-Pean
5. Hemostatic Gemini
6. Classic Rochester-pean
7. Thoracic Mixter
8. Artery Ochsner
9. Tissue Allis 5X6 Teeth
10. Towel Backhaus
11. Sponge Foerster
12. Sponge Holding Serr Jaws
13. Thoracic Willauer-Allis
14. Tissue Thoracic Babcock
15. Judd-Allis
16. Harken CVD DeBakey Jaw
17. Surgery Deep Bridge Str Jaws
18. Surgery Deep Bridge Delicate
Stille-Giertz Rib Shear
Forceps
1. Tissue Vascular DeBakey
2. Cooley Vascular
3. Tissue Adson Standard
4. Tissue
5. Tissue Bonney
6. Dressing Serr
7. Tissue Vascular DeBakey Standard Jaw insulated
8. DeBakey Thoracic Tissue Straight 3-mm tip
9. Schnidt Hemo Half Curved Jaws
10. Vanderbilt Un Vessel
11. Judo-Allis Tissue 3 × 4 Teeth
Holders
1. Instrument Single Link
2. Needle Holder
a. Classic Plus Sarot
b. Mayo Hegar Classic Plus
c. Microvasc Classic Plus
d. Classic Plus Crile Wood
e. Mayo Hegar
Scissors
1. Classic Mayo Curved Round Blade
2. Classic Mayo Straight Round Blade

(Continued)

TABLE E1. Continued

Instrument
3. Tonsil Metzenbaum Delicate Curved 4. Classic Plus Metzenbaum Delicate Curved 5. Classic Plus Nelson Delicate Curved 6. Wexler Heavy Thoracic Curved 7. Universal Standard 8. Dissecting 11″ Nelson Vital Curved Regular
Edna Non-Perforating Towel Clip
Knife handle 1. Surgical No. 3 Stainless Steel 2. Surgical No. 3L Stainless Steel 3. Surgical No. 7 Stainless Steel
Harken Rib Spreader-Frame, Arm, Crank, and Blade
Matson Rib Double-Ended Elevator and Stripper Raspatory
Pin Heavy Cutter
Stille-Luer-Type D/A 10MM Curved Jaws
Bailey Rib Contractor
Coastal Alexander Periosteotome- Sharp
Doyen Costal Elevator- Cobb, Right, and Left Blade, Heavy Duty Round Handle
Andrews-Pynchon Suction Tube
Handpiece Interpulse w/Coaxial High Flow
Aquamantys 6.0 Bipolar Sealer
Argon Beam Coagulator
ProTack 5-mm Fixation Device
LIGACLIP Endoscopic Rotating Multiple Clip Applier
Suture Passer 10-12 mm guide
Dual Mesh 20 cm × 30 cm × 1.0 mm
Endo GIA Ultra Universal Stapler
Sutures 1. ETHIBOND 0 CT-1 30 2. Silk 0 MH 3. VICRYL 1TP-1 4. VICRYL 0 UR-6 5. VICRYL 2-0 CT-1 6. VICRYL 3-0 7. MONOCRYL 4-0 PS-2