Thoracoscopy: Common Techniques in Small Animals

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Abstract: Thoracoscopy is gaining popularity in small animal surgery as an alternative to thoracotomy for an increasing variety of cases. This article discusses the details of some of the most frequently performed thoroscopic procedures in small animal practice: diagnostic biopsy of pleural, mediastinal, pericardial, and lung tissue; thoracoscopic pericardial window creation and subphrenic pericardectomy; lung lobectomy; thoracic duct ligation; and cranial mediastinal mass resection. A companion article that presented the instrumentation, anesthesia challenges, and approaches for thoracoscopic procedures in small animals was published in the January 2013 issue.

Thoracoscopic Pericardectomy

Pericardectomy is indicated for treatment of various cardiac and noncardiac diseases. Creation of a pericardial window can relieve clinical signs associated with idiopathic or neoplasia-associated pericardial effusion.1–4 Subphrenic pericardectomy (SPP) is the treatment of choice to relieve the signs associated with constrictive pericarditis1,2,5,6 and has been used as an adjunctive therapy in patients with idiopathic chylothorax.7 For surgical access to tumors of the atrial appendage, a large pericardial window has been used to gain access to the base of the right auricle.8 Newer evidence suggests that SPP may also have certain advantages for management of idiopathic effusion.9

In general, no increase in working space is necessary during the creation of a thoracoscopic pericardial window, so carbon dioxide insufflation or one-lung ventilation (OLV) are not required. The exception may be in dogs with very low thoracic depth-to-width ratios (flat-chested dogs such as English bulldogs) where very little working space exists in the thoracic cavity; OLV can be helpful in these cases. Pericardial disease is less common in cats; however, thoracoscopic partial pericardectomy has recently been described as an adjunctive treatment for idiopathic chylothorax in two cats.10

For thoracoscopic SPP, techniques with and without OLV have been described.5,6 The need for OLV in thoracoscopic SPP is debatable, but OLV may allow a maximal amount of pericardium ventral to the phrenic nerve to be removed while minimizing the possibility of iatrogenic damage to surrounding organs.

Patient Positioning and Port Placement

For pericardial window creation and SPP, dogs are generally positioned in dorsal recumbency as described here, although a pericardial window technique has also been described with dogs positioned in lateral recumbency.4 The viewing monitor and tower are positioned at the head of the patient on the left side. A three-port technique is used for both pericardial window creation and SPP. Depending on available telescope and instrument sizes, 5- to 10-mm cannulae are used. Thoracoscopic access is achieved...
Thoracoscopic Pericardial Window Technique\textsuperscript{3,4}

A good, unobstructed view of the apex of the heart needs to be established before beginning creation of a pericardial window. Initiating penetration of the pericardium over the apex can be challenging. If significant pericardial effusion is present, incision into the pericardium is usually easier and safer, as the fluid acts as a protective barrier to help avoid iatrogenic damage to the underlying epicardium and coronary vessels. Generally, the pericardium is elevated using Kelly or Babcock forceps and laparoscopic scissors are used to incise the pericardial sac (\textit{VIDEO 1*}). This initial incision can also be made with the fine-tipped end of a vessel-sealing device (e.g., Ligasure V, Covidien Inc, Mansfield, MA). Once the pericardium is penetrated, any existing effusion will pour out. The grasping forceps should then be repositioned to grasp and elevate one edge of the pericardial incision. Scissors or, preferably, the tip of a vessel-sealing device are inserted into the pericardial defect and used to excise an approximately 4 × 4–cm window of pericardium over the apex of the heart (\textit{FIGURE 1}). Whichever device is used to create the window, care should always be taken to avoid damage to the underlying coronary vessels and epicardium by elevation of the pericardium during sectioning. Suction is useful at this point, as significant pericardial/pleural effusion may be present. In cases with possible neoplastic lesions, resected pericardial tissue should be removed from the thoracic cavity either through a large cannula (10 to 12 mm) or in a specimen retrieval bag to minimize the risk of port-site metastasis.

Thoracoscopic Subphrenic Pericardectomy Technique\textsuperscript{5,6}

For SPP, the pericardium is initially penetrated as described for creation of a pericardial window. The vessel-sealing device is inserted through the established pericardial incision and used to continue sectioning the pericardium in a caudodorsal direction to the level of the phrenic nerve. OLV can be initiated at this point, with deflation of the lung on whichever side of the pericardium is to be sectioned first. Tilting the table away from the side being operated on may also aid in visualization. Once dissection down to the subphrenic level is complete, the thoracoscope is removed from the subxiphoid port and placed into the instrument port on the side initially being dissected. The vessel-sealing device is then placed in the subxiphoid port, and Babcock forceps are placed into the contralateral instrument port to allow the cut edge of the pericardium to be retracted medially, thus improving visualization of the phrenic nerve (\textit{VIDEO 2*}). The pericardium is sectioned along a line parallel to the phrenic nerve in a caudal to cranial direction. In order to avoid iatrogenic damage, care should be taken to identify the atrial appendage, which generally comes into view during this part of the dissection. This procedure can also be helpful for inspecting or gaining surgical access to atrial appendage tumors.

When pericardial resection is complete on one side, the collapsed lung is reinflated and the contralateral side is collapsed if necessary. The table is tilted to the opposite side and the procedure repeated on that side until only a small cranial attachment of the pericardium remains. The thoracoscope is then replaced into the subxiphoid port. The Babcock forceps are replaced into one instrument port and the vessel-sealing device placed into the other so that final sectioning of the remaining cranial attachment of the pericardium can be accomplished. Pericardial tissue with associated fat is then placed into a specimen retrieval bag and removed through one of the port incisions. If OLV was used, reinflation of both lungs is visually verified after termination of the procedure and a chest tube is placed to evacuate the pneumothorax. Port closure is performed routinely.

Complications

Hemorrhage from the intercostal arteries and veins is a potential complication with any thoracoscopic intervention, and the cause of any ongoing hemorrhage should be carefully inspected before closure. Iatrogenic damage to the phrenic nerve is possible. In dogs, phrenic nerve damage is unlikely to result in clinical signs if unilateral but may lead to hypventilation if it occurs bilaterally or in animals that have preexisting respiratory compromise. In dogs...
with constrictive pericarditis, adherence between the pericardium and epicardium is possible, making subphrenic pericardectomy impossible or at least more challenging. Epicardial stripping is possible and can be associated with a high complication rate but has rarely been described in dogs. Profuse hemorrhage from a bleeding cardiac mass is possible after pericardial window creation, as in some cases, the pericardium is likely to be providing a tamponade effect on intrapericardial hemorrhage. Iatrogenic damage to pulmonary parenchyma is possible, and the areas of lung located close to the port sites are at particular risk for iatrogenic trauma during instrument exchanges. Inspection of these areas before closure is recommended.

Thoracoscopic Lung Biopsy and Lobectomy

Lung biopsies are usually indicated for the diagnosis of chronic diffuse lung disease. Lung lobectomy is indicated for treatment of primary or metastatic lung neoplasia, bullae/bleb formation, chronic consolidation, major trauma, pulmonary abscessation, or lung lobe torsion. Traditionally, the approach to a lung biopsy or lobectomy has been via either intercostal thoracotomy or median sternotomy. In veterinary medicine, both thoracoscopic-assisted and totally thoracoscopic techniques have been described for lung lobectomy. Both have advantages and disadvantages. In general, the thoracoscopic-assisted technique may be used in cases in which the thoracic mass is modestly sized and located somewhat peripherally within the lobe and requires larger thoracic wall incisions to safely exteriorize the affected lobe. The totally thoracoscopic technique allows resection of somewhat larger masses closer to the hilum, although the easiest cases involve masses that are modestly sized and peripheral. In my practice, total thoracoscopic lung lobectomy is generally performed for masses up to 3 to 4 cm in diameter in dogs weighing 15 kg, masses up to 4 to 6 cm in dogs weighing 15 to 30 kg, and masses up to 8 to 9 cm in dogs that weigh >30 kg.

Many primary lung tumors may be diagnosed on plain radiography. However, advanced imaging may be beneficial to aid in surgical planning and to rule out metastatic disease.

Thoracoscopic-assisted biopsy or lung lobectomy can be performed without the use of OLV. However, in most cases that require a totally thoracoscopic partial or complete lobectomy, OLV is mandatory to provide adequate visualization of the pulmonary hilum.

Patient Positioning and Port Placement

For lung biopsy, dorsal or lateral recency can be used. I prefer dorsal recency, as a more complete examination of both hemithoraces is possible from this approach. For lung lobectomy, most patients that have a well-circumscribed, single pulmonary mass are positioned in left or right lateral recency depending on mass location. Dorsal recency can be used for patients with spontaneous pneumothorax or in rare cases in which two masses might be present in lung lobes in both hemithoraces, but access to the pulmonary hilum is significantly more difficult from this approach.

Port positioning for thoracoscopic lung biopsy is not critical if diffuse disease is present and a biopsy sample from any lobe is acceptable. If the patient is in dorsal recency, a subxiphoid camera port is usually established along with two other instrument ports placed on the right and left sides to give access to the periphery of one lung lobe. If the patient is in lateral recency, it is important to place the ports in a triangulating pattern around the lobe to be biopsied. If lung biopsy will be performed with a loop ligature, 5-mm ports can be used. If a stapler is to be used, at least one 12-mm port must be placed to accommodate the stapler (e.g., EndoGIA, Covidien).

Port positioning for thoracoscopic lung lobectomy depends on lesion location. Ideal port positions for the different lobes have not been described. However, it is important not to place the ports too close to the lung lobe in question. Therefore, for a caudal lobe resection, the ports are usually placed cranially (third or fourth intercostal space), whereas for a cranial lobe, the ports are placed caudally (seventh to ninth intercostal space) in a triangulating pattern around the anticipated location of the pulmonary hilum. Placing the instrument ports too close to the lung lobe to be resected makes it difficult to open the stapler cartridge within the thorax, especially in smaller animals. If this problem is encountered, it may be necessary to place another instrument port in a location more distant from the mass.

Surgical Techniques

Lung Biopsy

A thoracoscopic lung biopsy sample can be harvested in a number of ways. One of the easiest and least expensive is to place a loop ligature around the periphery of one of the lung lobes to be biopsied. A 5- or 10-mm Kelly or Babcock forceps is placed into one of the instrument ports to aid in manipulating the loop ligature around the tip of the lung lobe. With the ligature in place, the area to be biopsied is gently grasped with the forceps and retracted. This allows the loop ligature to slide up the lobe and prevents the loop from slipping off the lung as it is tightened. Once the loop is tight, endoscopic scissors are used to cut the tissue distal to the ligature and the tissue is removed through one of the instrument ports. Alternatively, a stapler can be used to harvest the sample. With the help of Babcock forceps to stabilize the periphery of a lung lobe, the stapler is placed across the lung parenchyma and deployed. One stapler (EndoGIA) places three lines of staples on either side of the cut line, thus providing very secure closure of all airways and blood vessels within the lung tissue.

Partial or Complete Lung Lobectomy

Once the cannulae are in position and OLV is established, an attempt should be made to visualize the mass, using a blunt probe to manipulate the lung lobe. If the mass cannot be easily visualized, it may be safer to attempt a full lung lobectomy to ensure that the mass is not missed. In the case of the caudal lung lobes, the pulmonary ligament, which attaches the caudal lung lobes to the mediastinum, must be sectioned in a caudal to cranial direction up to a point close to the pulmonary vessels. The endoscopic stapler is used for
sectioning the pulmonary artery, pulmonary vein, and bronchus. Several cartridge lengths (30, 45, and 60 mm) and staple sizes (2.0, 2.5, 3.5, and 4.8 mm) are available. For lung lobectomy in dogs, use of 60-mm long cartridges and 3.5-mm staples is generally recommended. The EndoGIA stapler comes in a linear configuration or in a “rotating” version that allows the tip of the cartridge to be angled to either 22° or 45°. This is a very useful feature when attempting to maneuver the stapler into position around the base of a pulmonary hilum.

The endoscopic stapler is passed through one of the 12-mm instrument portals. A good, unfogged view of the lung lobe in question should be maintained at all times. If a partial lung lobectomy is to be performed, the stapler is positioned across the lung lobe once the tips of the cartridge have been opened. For a complete lung lobectomy, the cartridge is placed across the pulmonary artery, pulmonary vein, and bronchus together (VIDEO 3). Once the stapler is in the correct position, the tips are closed, the staples dispensed, and the cartridge reopened and carefully pulled back and out of the cannula. Care should be taken during this maneuver, as the cartridge often adheres slightly to the stapled tissue; abrupt removal can cause tearing of lung tissue. If the cartridge used was not long enough to section the entire length of the lung lobe, a second cartridge can be used to complete the transection of the lung parenchyma or pulmonary hilum. If a small piece of lung remains attached, an endoloop, intracorporeally tied ligature, or laparoscopic hemoclip can be used. This is often the case in medium to large dogs, in which even a 60-mm cartridge is usually not enough to transect the entire length of the hilum.

Once the lung lobectomy is completed, the cut surface of the pulmonary hilum is closely visualized for hemorrhage or air leakage. Saline can be dripped onto the site or enough saline instilled to submerge the staple line if suspicion for air leakage is high. The resected lung lobe should then be placed in a specimen retrieval bag and the bag removed through one of the portal incisions (VIDEO 3*). At this point, inspection of the pulmonary hilum for any lymph node enlargement should be attempted. If lymphadenopathy is present, aspiration of the nodes and/or resection can be attempted. Knowledge of potential metastatic spread to lymph nodes has significant prognostic and therapeutic implications.

In the thoroscopic-assisted technique, the telescope is placed as described above. Once the mass has been identified, a minithoracotomy incision is created over the hilum of the lobe to be resected. This incision can be retracted open using a small Finocchietto retractor or an Alexis wound retractor (Applied Medical Inc.) device. The lung lobe in question is exteriorized through this assist incision and is resected using conventional or endoscopic stapling devices. The port incisions and minithoracotomy are closed in routine fashion.

Complications

Several important intra- and postoperative complications can be associated with thoroscopic lung lobectomy. Significant postoperative hemorrhage from intercostal vessels has been reported. Hemorrhage or air leakage from the pulmonary hilum can also occur if the stapler does not function correctly or is incorrectly placed. Iatrogenic damage to surrounding structures (especially lung tissue) can occur, and great care should be taken when passing instruments through thoracic cannulae. The most common reasons for conversion of a thoroscopic lung lobectomy to a conventional thoracotomy are failure of OLV and hemorrhage. In one study, conversion to an open approach was necessary in four of nine dogs, although this likely represents the early phase of a learning curve.

Thoroscopic Thoracic Duct Ligation

Chylothorax is a complex disorder that results in accumulation of chylous fluid within the thoracic cavity. In some cases, it is associated with an underlying disease process, but in many cases, it is idiopathic. Medical management of chylothorax is rarely successful, and it is considered a surgical disease by most clinicians. Although many different surgical procedures have been used for management of chylothorax, the combination of thoracic duct ligation (TDL) and SPP has been associated with some of the highest success rates reported in the veterinary literature, albeit in small populations of dogs. The outcome of a minimally invasive approach for TDL and SPP has now been described in a small cohort of dogs, and these early data suggest that the success rate may be similar to that achieved when this combination of procedures is performed using an open approach. The minimally invasive surgical approach can obviate the need for single or double intercostal thoracotomy, which has often been used for management of chylothorax.

The SPP technique is the same as that described for thoroscopic pericardectomy above and uses different portals from those used for TDL. Therefore, the two techniques are largely performed in sequence as two individual procedures during the same anesthetic episode.

Patient Positioning and Port Placement

For TDL, different approaches have been described, with dogs being positioned in both sternal and left lateral recumbency. The first thoracic portal for the telescope is placed on the right side at the mid- to dorsal third thoracic level in the eighth or ninth intercostal space, allowing visualization of the caudal mediastinal area. Two more instrument portals are placed at the seventh or eighth and ninth or tenth intercostal spaces in a slightly more dorsal location and in a triangulating pattern around the caudal mediastinum. In cats, the surgical approach is generally performed at similar locations, but on the left side; two cases of thoracoscopic TDL in cats have recently been reported.

Surgical Technique

When performed with the patient in lateral recumbency, once port placement is complete, a 3- to 4-cm laparotomy incision is made in the right cranial abdominal quadrant. Some surgeons perform lymphangiography by injecting a contrast agent directly into a mesenteric lymph node or into a catheterized mesenteric lymphatic vessel in the base of the mesentery (although this is challenging...
through a small paracostal incision). For better intraoperative visualization of the thoracic duct branches in the thorax, mesenteric lymph nodes in the area of the ileoceleocolic junction are exteriorized through the paracostal incision, and methylene blue dye diluted 1:1 with sterile saline is slowly infused into a lymph node to a dose not exceeding 0.5 mg/kg. Methylene blue coloration of the thoracic duct can also be achieved using a popliteal lymph node injection.\(^{13,16}\) As soon as the methylene blue is visualized in the thoracic duct branches, blunt dissection around the duct branches in the mediastinal root dorsal to the aorta is initiated (FIGURE 3). A space between vertebral arterial branches is selected for dissection and clip placement, as far caudal within the thoracic cavity as possible. As much dissection across the mediastinal base as possible is performed, and all visualized thoracic duct branches are clipped using a laparoscopic clip applier (FIGURE 3). The thoracic duct branches can also be occluded using extracorporeal or intracorporeal suture ligation techniques. Biopsy of the mediastinum, pleura, and pericardium may also be helpful in these cases to rule out underlying disease.

**Complications**

The most significant complication of this technique is likely to be persistence of chylous pleural effusion leading to postoperative continuation of clinical signs. Persistent effusion after TDL in combination with pericarpectomy has been reported to occur in up to 40% of patients when either open or minimally invasive approaches are used.\(^{7,13—15}\) Due to the incomplete understanding of the pathophysiology of chylothorax, it may be difficult to identify the underlying reason for treatment failure. In some cases, incomplete ligation of all thoracic duct branches may result in ongoing effusion. When treatment failures occur, other techniques (described elsewhere) can be attempted.

**Thoracoscopic Cranial Mediastinal Mass Resection**

Cranial mediastinal masses in dogs are most frequently diagnosed as either thymomas or lymphomas, with ectopic thyroid carcinomas, branchial cysts, and chemodectomas being much less common. If thymoma is confirmed by cytology or histopathology, surgical resection is usually recommended. Many thymomas are too large to be amenable to a minimally invasive approach, although those that are up to 5 to 6 cm in diameter in medium-sized to large dogs and are not invading surrounding organs may be amenable to thoracoscopic resection (FIGURE 4).\(^{17}\)

Surgical anatomy of these masses is quite variable, and a preoperative computed tomography scan can be very helpful in clinical decision making. OLV may also be very helpful during the procedure to maximize visualization and potentially reduce iatrogenic damage to pulmonary parenchyma during dissection.

**Patient Positioning and Port Placement**

The dog is placed in dorsal recumbency, and a telescope portal is established in a subxiphoid location. A 3-cm incision is made at the left fourth intercostal space at the level of the dorsal third of the thorax in an area adjacent to the mass. (If the mass is more right-sided, which is less common, this incision can be made on the right side.) A finger can be placed through this incision into the thoracic cavity to aid in manipulating the mass during dissection and also to remove the mass at the termination of the surgery. A second instrument portal is usually placed on the right side at the sixth to ninth intercostal space in the ventral third of the thoracic cavity.

**Surgical Technique**

Once all ports are in place, a blunt grasping instrument, blunt probe, or gloved finger is used to manipulate the mass and a vessel-sealing
device is used to initiate dissection of the mass from the surrounding tissue planes. In some cases, the mass can be attached to the internal thoracic artery; careful dissection is required to separate these two structures from each other. Every effort should be made to resect the mass without penetrating the tumor capsule. Once completely resected, the mass is placed into a specimen retrieval bag and removed through the cranial left-sided portal (VIDEO 4*).

Complications
Potential complications include hemorrhage from surrounding vascular structures. Phrenic nerve damage should also be avoided. If significant hemorrhage occurs or if the size or location of the mass makes thoracoscopic resection very difficult, conversion to an open approach should be performed.

Miscellaneous Procedures
Biopsy of the pleura and mediastinum can easily be performed in conjunction with the procedures mentioned or as a diagnostic procedure performed for investigation of pleural effusion or pleural/mediastinal masses or thickening.18 Biopsy of these tissues is generally performed using 5-mm cup or punch biopsy forceps. Small samples are collected, and the site(s) is/are inspected for hemorrhage before closure.

Conclusion
As greater experience with thoracoscopic surgery is obtained, it is likely that more procedures will become feasible using the techniques discussed here. Appropriate patient and equipment selection, along with consideration of referral to a specialty center, is vital for all of these procedures and will help maximize the chance of success and help lower the incidence of conversion to an open approach.

References
1. Subphrenic pericardectomy is the treatment of choice for which of these conditions?
   a. constrictive pericarditis
   b. diaphragmatic hernia
   c. persistent right aortic arch
   d. all of the above

2. Potential complications associated with thoracoscopic subphrenic pericardectomy include
   a. damage to the pulmonary parenchyma.
   b. damage to the phrenic nerve.
   c. hemorrhage from intercostal vessels.
   d. all of the above

3. Which of the following is not an indication for lung lobectomy?
   a. chronic consolidation
   b. pulmonary abscess
   c. diffuse lung disease
   d. lung lobe torsion

4. In a dog weighing <15 kg, thoracoscopic lung lobectomy can be performed to remove masses up to _______ cm in diameter.
   a. 1
   b. 3 to 4
   c. 8 to 9
   d. 6 to 10

5. When performing a thoracoscopic lung biopsy, positioning a patient in dorsal recumbency can offer what advantage?
   a. It facilitates more complete examination of both hemithoraxes.
   b. It makes OLV easier.
   c. It increases the effectiveness of mechanical ventilation.
   d. all of the above

6. Postoperative complications associated with thoracoscopic lung lobectomy include
   a. hemorrhage from the pulmonary hilum.
   b. air leakage from the pulmonary hilum.
   c. intercostal vascular hemorrhage.
   d. all of the above

7. For thoracoscopic thoracic duct ligation, patient positioning options include _______ recumbency.
   a. right lateral
   b. sternal
   c. dorsal
   d. all of the above

8. When performing thoracoscopic thoracic duct ligation, what is the advantage of injecting diluted methylene blue dye into a mesenteric lymph node?
   a. The dye improves visualization of the thoracic duct.
   b. The presence of the dye reduces lymph flow through the thoracic duct.
   c. The dye decreases the risk of hemorrhage.
   d. all of the above

9. Persistent chylous effusion after thoracic duct ligation in combination with pericardectomy has been reported to occur in up to _______ of patients when either open or minimally invasive approaches are used.
   a. 15%
   b. 25%
   c. 40%
   d. 75%

10. Cranial mediastinal masses in dogs are most frequently diagnosed as
    a. hemangiosarcoma.
    b. chondrosarcoma or hemangiopericytoma.
    c. thymoma or lymphoma.
    d. histiocytoma.