Compendium

Minimally Invasive Abdominal and Thoracic Surgery: Techniques

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Abstract: Laparoscopy, thoracoscopy, and other endoscopic-assisted procedures have many uses in veterinary medicine. Diagnosis and biopsy are currently the most common uses of minimally invasive techniques, but popularity for procedures such as ovariectomy, cancer staging, lung lobectomy, and pericardectomy is rising. This article touches on basic surgical procedures and describes some more advanced techniques.

Laparoscopy is defined as the exploration of the abdominal cavity and its organs with a rigid endoscope. Similarly, thoracoscopy is defined as exploration of the pleural cavity and its organs with a rigid endoscope. Both procedures are indicated for many diagnostic and surgical procedures (BOXES 1 and 2), with examination and biopsy of viscera currently being the most common use.1–3 Specimens acquired by laparoscopic and thoracoscopic biopsy are generally superior to those acquired by other percutaneous biopsy methods because the mass or tissue of interest is directly visualized and a relatively large sample can be obtained.4,5 In addition, due to the magnification and intense lighting provided by the endoscope, small lesions not easily seen by other diagnostic methods (e.g., transcutaneous ultrasonography) are more apparent. For this reason, laparoscopy and thoracoscopy are particularly indicated in oncology to help diagnose and stage primary or metastatic lesions.

More recently, laparoscopy and thoracoscopy have been used to perform a variety of surgical procedures. The number and type of procedures that can be performed using minimally invasive techniques in small animals are only limited by imagination, innovation, and instrumentation.

Laparoscopy

Patient Preparation

Patients should be clipped and surgically prepared as for an open procedure. All clients should be aware that if complications arise, or if it is warranted, traditional open surgery may be performed. Ideally, the patient should be fasted for 6 to 12 hours and the bladder emptied to prevent iatrogenic penetration of the gastrointestinal (GI) tract or urinary bladder during trocar placement and to provide more working space.

Dorsal recumbency with a midline approach is the most commonly used position for bilateral diagnostic and for surgical procedures. This approach offers good visualization of the liver, gallbladder, pancreas, stomach, intestines, urinary system, reproductive system, and spleen, as well as thoracic structures.6 One disadvantage of this position is that in obese animals the falciform ligament may obscure the cranial abdomen, but this can be removed easily with monopolar electrocautery on scissors or another coagulation and cutting device (e.g., LigaSure, Valleylab, Boulder CO, USA; Harmonic Scalpel, Cincinnati, OH, USA). The most common location for the camera portal in animals in dorsal recumbency is on or adjacent to midline near the umbilicus. Placing the portal 1 cm caudal to the umbilicus helps to avoid entering through the falciform ligament. Approaches are modified slightly for each individual patient and organ of interest to provide adequate working space.

Left lateral recumbency with a right lateral approach is also a commonly used position for diagnostic procedures. It is recommended for evaluation of the liver,

Key Points

- Patients should be clipped and surgically prepared as for an open procedure in case conversion is required or warranted.
- Dorsal recumbency with a midline abdominal approach provides excellent ability to perform bilateral diagnostics and surgeries.
- Abdominal insufflation can be performed using either a Veress needle or a mini-open approach (Hasson technique). The latter reduces the risk of iatrogenic organ puncture and has a short learning curve.
Box 1. Diagnostic and Surgical Laparoscopic Procedures

**General**
- Abdominal exploration
- Biopsy of abdominal viscera (liver, pancreas, spleen, kidney, intestine, adrenal gland), peritoneum, lymph nodes

**Liver and Biliary Systems**
- Liver lobectomy
- Cholecystectomy
- Cholecystectomy/cholecystostomy tube placement
- Biliary rerouting procedures
- Mesenteric and lymphatic angiography
- Extrahepatic portosystemic shunt identification and attenuation

**Gastrointestinal Tract**
- Prophylactic gastropexy
- Treatment of gastric dilatation and gastric dilatation–volvulus
- Gastric and intestinal feeding tube placement
- Gastric and intestinal foreign-body removal

**Urinary and Reproductive Tract**
- Cystotomy
- Cystectomy
- Cystostomy tube placement
- Nephrectomy
- Ovariectomy and ovariohysterectomy
- Cryptorchid castration
- Vasectomy

**Other**
- Adrenalectomy

*Generally an endoscopic-assisted procedure.

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gallbladder, right limb of the pancreas, duodenum, right kidney, and right adrenal gland. The left lateral approach is not generally used due to the location of the spleen, which lies directly under the normal location for portals. The risks of iatrogenic splenic rupture and poor ability to visualize structures are high with this approach.

**Abdominal Insufflation**

Before the endoscope and instrument portals can be placed, pneumoperitoneum must be created. Carbon dioxide (CO₂) is used to insufflate the peritoneal cavity. Historically, other gases have
been used, but CO₂ is the safest for the patient and the operating team. Initial insufflation of the abdominal cavity can be provided either via a Veress needle, which is sharp and blind, or via placement of a cannula, which is blunt and open, through a mini-celiotomy (Hasson technique). Both approaches have advantages and disadvantages that are important to consider for each patient.

The Veress needle consists of a blunt obturator spring-loaded within a sharp cutting tip. The obturator retracts as the needle is advanced through the skin and then advances beyond the sharp tip after penetration into the abdominal cavity, thereby protecting abdominal organs. The Veress needle can be placed either on the ventral midline or in the caudal abdomen to the right of midline (FIGURE 1). Once the surgeon is confident that the needle is in the abdomen, insufflation with CO₂ is started. Some surgeons perform a test injection with saline into the Veress needle to make sure it is in the abdomen. The injection should be easily performed, with no resistance. Once insertion of the needle into the peritoneal cavity is confirmed, tubing connected to the automatic CO₂ insufflator is attached to the hub of the needle and pneumoperitoneum is created. Pressure should be kept below 15 mm Hg, with 10 mm Hg being adequate for most procedures in small animals.1 (See the companion article for more information about appropriate intraabdominal pressures.) After sufficient abdominal insufflation, a sharp trocar–cannula system is blindly inserted through the abdominal wall in the location predetermined for the endoscope. The main advantage of the Veress technique over the Hasson technique is that it is usually quick to perform; however, gas administration is slower and it requires blind introduction of the first trocar, which carries the risk of iatrogenic rupture of abdominal organs.

We prefer to make a "mini-open" approach into the abdominal cavity, place a cannula bluntly, and then insufflate the abdomen via the cannula (Hasson technique; FIGURE 1). A ~5-mm stab incision is made through the skin and subcutaneous tissue, and the linea alba or fascia is grasped with Adson-Brown forceps and elevated. At this point, two stay sutures can be placed at either end of the incision through the fascia and used to elevate the fascia. A stab incision is made through the fascia into the peritoneal cavity, and a blunt trocar–cannula system is advanced into the abdominal cavity. The trocar should be aimed laterally and ventrally toward the right side of the patient (away from the spleen) and should slide with a slight twisting motion into the abdomen without resistance. Once positioned, the inner blunt trocar is removed from the outer sheath. CO₂ is then rapidly infused into the abdomen. The abdomen should distend evenly (like blowing up a balloon) without pocketing or a sudden increase in pressure. Uneven insufflation, slow rates, and/or very high pressures may indicate that the subcutaneous space or organs are being insufflated.

Once the abdomen is sufficiently distended, the endoscope (connected to the camera) can be placed into the abdomen safely. The stay sutures can be kept in place to help reduce the size of the incision if it exceeds 5 mm (or 10 mm for 10-mm cannulae) and to facilitate closure after completion of the procedure. There is a short learning curve with the Hasson technique, and we have found this technique to be safer than the Veress technique in terms of preventing inadvertent insufflation or puncture of the GI tract or abdominal viscera, as well as preventing the insufflation of the subcutaneous space instead of the abdominal cavity, which can be frustrating and prolong surgical time. The main advantages of the Hasson technique are its relative safety and the capacity for rapid gas insufflation. Both the Hasson and Veress insufflation techniques have similar complications: iatrogenic damage of organs (usually the spleen or small intestine), introduction of CO₂ into the subcutaneous tissues, and fatal air embolism if CO₂ is infused into a mass, vessel, or organ.2

Maintaining an airtight seal at the portal sites allows for constant and appropriate insufflation, thereby enabling good visualization and a safer, faster procedure.

**General Technique**

After insufflation and placement of the first cannula, the endoscope is placed into the abdomen. Often, the endoscope becomes blurred on initial entrance into the abdomen (regardless of insufflation technique), usually due to either condensation on the lens from a temperature change or contamination from blood or other fluid while passing through the cannula. Gently wiping the tip of the endoscope on the intestine may clean the lens. If it remains soiled, the endoscope should be removed and wiped with a warm, saline-soaked sterile gauze square or commercially available sterile anti-fog solution. Prewarming the scope in saline while placing the camera port may also help to reduce fogging.

With the camera in place, a 360° general exploration can be done to identify any contraindication to pursuing further laparoscopic intervention (e.g., adhesions, large masses, iatrogenic damage to bowel or other viscera). Ideally, the abdomen should be explored in a routine manner to avoid missing a subtle lesion.

Determination of instrument portal site locations is the next step and is vital to successful surgery. Choosing sites that will triangulate the camera and instruments toward the organ(s) of most interest is paramount. After the creation of pneumoperitoneum, instrument portals can be safely introduced using direct visualization with the endoscope and camera. The easiest way to locate a cannula site is to depress the body wall repeatedly over the potential site until the location can be seen within the abdominal cavity.
with the endoscope. The light source can be used to illuminate the body wall from within to help avoid blood vessels (FIGURE 2). The sharp trocar–cannula unit is then advanced with a screwing action (just pushing does little to advance the trocar). At this time, the camera should follow and visualize the trocar point (FIGURE 2). The most frequent complication in laparoscopy is laceration of abdominal viscera (intestines or spleen) during trocar placement. This can usually be avoided with direct visualization of the trocar point because appropriate redirection or retraction of the trocar can be performed as needed. In addition, patient positioning (head-down or head-up; see the companion article for more information about patient positioning) can be used to allow gravity to move vital structures out of the way. Once the endoscope is in place, instruments should never leave or enter the abdomen without direct visualization. Additionally, instruments not in use should not remain unseen within the abdomen. Cannulae may need to be stabilized during switching of instruments to prevent their inadvertent premature removal from the body. If this does happen, a blunt trocar can be placed into the dislodged cannula and the unit replaced through the previous incision under direct visualization with the endoscope.

Once the endoscope and accessory portals are in place, the abdomen can be fully explored. Use of a palpation probe during the exploration can help to maneuver and “feel” organs as needed. After completion of the laparoscopic procedure, the endoscope and instruments are removed and the pneumoperitoneum is allowed to deflate. This is done initially by stopping the insufflation and opening the valves on the cannula. As the inflation recedes, the cannulae are removed and the remaining gas is allowed to leak from the incisions. The abdomen should be gently depressed to release trapped pockets of gas. The incisions are then closed routinely. If stay sutures have been placed, they can be used to close the incision. Local infiltration of the cannula sites with bupivacaine (1 mg/kg), with or without systemic analgesics (based on patient status and procedure performed), is recommended.

Complications
General complications of laparoscopy include iatrogenic damage to abdominal organs (spleen, GI tract, urinary bladder), portal site seroma formation, and tumor seeding at portal sites. Complications specific to each procedure are discussed in the following sections. Basic skills such as suturing and knot tying are presented in depth in several excellent references and are recommended for surgeons in training.10

Liver Biopsy
Laparoscopic liver biopsy is technically easy to perform, provides adequately sized and lesion-specific tissue samples for histopathologic analysis and other tests (e.g., culture, heavy metal analysis), and permits visual inspection of small or subtle lesions as well as adjacent structures. Using a right lateral approach exposes most of the liver surface and extrahepatic biliary system for examination. Alternatively, dorsal recumbency can be used.

Evaluation of coagulation parameters before liver biopsy is recommended, but coagulation status does not necessarily predict bleeding after biopsy. Abnormal coagulation profiles are not, in our opinion, an absolute contraindication to laparoscopic liver biopsy; in fact, laparoscopy may be preferable to a more invasive, open approach in a coagulopathic animal. Nonetheless, knowledge of abnormal parameters allows the surgeon and anesthetist to be prepared for bleeding with available blood products, plasma products, and volume control. After the liver is explored with a palpation probe, a 5-mm oval cup biopsy forceps is used to take samples from the edge of the liver, including normal- and abnormal-appearing tissue. The forceps is opened over the liver edge and closed, holding the liver for up to 30 seconds (FIGURE 3). The forceps is then pulled away from the liver and withdrawn from the body. The biopsy site is monitored for bleeding, which is minimal in most cases. If hemorrhage is a concern, the palpation probe can be used to apply pressure, or hemostatic agents such as gel foam can be placed into the biopsy site. Magnification of bleeding can make hemorrhage look more significant than it is. Several biopsy samples should be taken, depending on the tests required. Occasionally, lesions are deeper or the edges of the liver are too rounded from disease to use the biopsy forceps appropriately. In these cases, a core biopsy needle can be used. Hemostasis is confirmed before completion of the procedure.

Pancreatic Biopsy
A right lateral approach is generally used for evaluation and biopsy of the pancreas. This approach allows visualization of the right limb of the pancreas, the duodenum, the extrahepatic biliary system, and the liver. One or two samples are generally taken from the edge of the pancreas, away from the pancreatic ducts. A 2002 study evaluating laparoscopic pancreatic biopsy in healthy dogs found no postoperative complications or secondary pancreatitis.11
Laparoscopic evaluation followed by biopsy, jejunostomy tube placement, and abdominal lavage is a reasonable diagnostic and therapeutic option in dogs with apparent pancreatitis. Chronic pancreatitis in cats can also be diagnosed using laparoscopy.6

Renal Biopsy
Biopsy of the right kidney is technically easier than the left due to the greater mobility of the left kidney and the location of the spleen relative to potential cannula sites. Laparoscopy permits direct visualization of the biopsy site, as well as monitoring of bleeding. Core biopsy punches are used instead of forceps due to the inability to grasp the rounded organ and obtain deep tissue samples with forceps (FIGURE 4). A right lateral, midabdominal approach is used to sample the right kidney. A second portal is placed for a palpation probe, which is used to stabilize the kidney and tamponade hemorrhage if necessary. A small incision is made in the skin to directly advance the biopsy needle. This site should be determined using endoscopic guidance and located to allow direct access to the kidney. It should be placed caudal to the last rib to prevent leakage of the pneumoperitoneum through the diaphragm resulting in iatrogenic pneumothorax. As with renal biopsies using an open approach, the sample should be taken from the cranial or caudal pole, to avoid the arcuate vessels, and the needle should not be directed into the corticomedullary junction. Moderate hemorrhage is expected (FIGURE 4). We allow the site to bleed for 3 to 5 seconds and then provide pressure to reduce the amount of blood that collects just under the renal capsule. One to three samples are generally taken. Not uncommonly, renal core biopsies are nondiagnostic (regardless of technique), so the surgeon should make an effort to seat the biopsy needle well and evaluate the sample before removing the endoscope.

Intestinal Biopsy
With the animal in dorsal recumbency and the endoscope located 2 to 3 mm caudal to the umbilicus, two instrument portals can be established to completely inspect (“run”) the bowel using a combination of two atraumatic Babcock forceps or hook retractors to determine the section of bowel to be biopsied. The bowel can be run orally by first locating the cecum or ileum, or aborally from the pylorus. Intestinal biopsy is an endoscopic-assisted procedure and, thus, should be done last because pneumoperitoneum will be lost when the bowel is exteriorized. After the portion of bowel to be biopsied is determined, either an instrument portal can be enlarged with a blade (under visualization of the endoscope) and the bowel exteriorized, or the bowel can be exteriorized through the original cannula portal when the grasping instruments holding the bowel and the cannula are removed as one (en bloc). Stay sutures are placed through the submucosa to allow an assistant to hold the section of bowel (approximately 3 to 5 cm). A sample is taken and sutured as in an open abdominal approach; the incision is lavaged; and the bowel is replaced into the abdomen. To obtain multiple intestinal biopsy samples, the incision in the body wall can be clamped with towel clamps and covered with gauze or an assistant’s hand to create a seal to allow recreation of pneumoperitoneum. The next site is located, and the bowel is removed through the same incision. Insufflation should be suspended during work outside the body to prevent gas wastage.

Other Diagnostic Techniques
Biopsy or removal of lymph nodes for cancer staging can be performed using a punch-type or grasping biopsy instrument or a combination of sharp and blunt dissection with electrocautery or tissue-ablating instruments. As long as the lymph node can be visualized appropriately and surrounding vital structures avoided, the biopsy can be done safely. Collection of abdominal effusion from small pockets within the abdomen can also be performed to obtain samples for culture and cytologic examination. Dedicated laparoscopic suction devices, sterilized equine insemination pipettes, regular Poole suction tips, or a long needle on a syringe can be used to collect effusion under laparoscopic guidance.

Feeding Tube Placement
Several techniques have been described for the placement of feeding tubes.7,12,13 These are generally endoscopic-assisted procedures performed by using laparoscopy to exteriorize the section of bowel and then placing the tubes externally. For duodenostomy feeding tubes, the distal duodenum is located by running the bowel with two atraumatic grasping forceps orally. The duodenum is then grasped firmly on the antimesenteric border and brought close to the cannula via which it is to be exteriorized. The skin incision is extended with a scalpel under laparoscopic visualization. The grasped intestine, forceps, and cannula are removed en bloc. A similar procedure is used for jejunostomy tubes, except that a proximal part of the jejunum is selected. It is important in both cases to maintain correct orientation so that the feeding tube can be directed aborally. Gastrostomy tube placement is the same, except that a small part of the body of the stomach is exteriorized through the left abdominal wall.

Three to four centimeters of intestine or stomach wall should be exteriorized and stabilized outside the body by four stay sutures. The tube is then placed as in an open technique. As with intestinal biopsy, feeding tube placement should be performed as the last procedure because pneumoperitoneum is lost. Intestinal foreign bodies can be removed using a similar technique with variations based on the size and location of the foreign body.
Gastroscopy

Gastroscopy is typically an endoscopic-assisted procedure. With the animal in dorsal recumbency, laparoscopy is used to locate the pyloric antrum and exteriorize it through the right abdominal wall. The endoscope portal is placed on midline at the level of the umbilicus, and a single instrument portal is placed on the right side 2 cm caudal to the last rib at approximately mid-rib level. The pyloric antrum is grasped with anatraumatic grasping forceps midway between the lesser and greater curvature. If tension is too great, the antrum may need to be regrasped or some of the pneumoperitoneum released. As with feeding tube placement and biopsy, the area is brought close to the cannula, the incision extended under laparoscopic visualization, and everything removed en bloc. Stay sutures are used to stabilize the stomach wall, and an incisional gastroscopy is performed (FIGURE 5). The serosal and muscularis layers are incised approximately 5 cm and sutured to the transverse abdominal muscle. The external and internal oblique muscles are then closed over the gastroscopy. Subcutaneous tissue and skin are closed in a routine manner.

Ovariectomy and Ovariohysterectomy

Ovariectomy and ovariohysterectomy can be performed with the patient in dorsal recumbency with its head tilted down or in lateral recumbency, during which the animal must be switched from one side to the other. Ideally, a table that permits quick and easy tilting is used. The benefit of performing this procedure with the patient in dorsal recumbency is that there is no need to move the tower to complete the procedure.

When the patient is in dorsal recumbency, the endoscope portal is located cranial to the umbilicus on the midline. Two instrument portals are placed at the level of the umbilicus on either side at the edge of the rectus abdominus. Intestine and omentum covering the uterine horn are removed, and the horn is grasped to expose the ovarian pedicle. For ovariectomy in sexually immature dogs, the ovary can be removed entirely with Metzenbaum scissors and electrocautery or with a tissue ablation unit. The entire ovary can be visualized so that no tissue is missed. In older dogs, it may be necessary to dissect fat surrounding the ovary first or use 5- or 10-mm vascular clips or suture on the ovarian pedicle if it is well developed. For ovariohysterectomy, the suspensory ligament is transected with Metzenbaum scissors, with or without electrocautery or a tissue ablation unit. Making a hole through the mesovarium isolates the ovarian pedicle, and two vascular clips are placed. The same procedure is performed on the opposite side. As in the open procedure, the mesovarium is broken down with scissors and electrocautery or torn with forceps. To perform the hysterectomy, a preformed suture loop (Endoloop, Roeters knot) is brought into the abdomen through one of the cannulae and the uterine horns and body of the uterus are placed through the loop to the level of the cervix. The loop is tightened, and the long end is cut with scissors. The cervix is transected with Metzenbaum scissors cranial to the loop, leaving approximately 1 cm of tissue to prevent slippage of the ligature. All three surgical sites are inspected for bleeding, and additional suture(s) or vascular clips are placed as needed. One of the cannula sites is enlarged just enough to remove the uterus and ovaries. The enlarged cannula site should have the abdominal fascia sutured in a separate layer. The other cannulae only require subcutaneous tissue and skin closure.

Cryptorchid Surgery

Laparoscopy provides excellent visualization for removal of intraabdominal cryptorchid testicles in most cases. Animals are placed in dorsal recumbency with the head tilted down. The endoscope portal is located cranial to the umbilicus, and instrument portals are placed as for ovariohysterectomy, at the level of the umbilicus at the edge of the rectus abdominus. The internal inguinal rings should be visualized first because if the vas deferens and testicular arteries are present, then the testicle is not in the abdomen. It is either in the inguinal region and can be removed through an external abdominal wall incision, or the animal has been castrated. If the vas deferens and testicular arteries are not present, the testicle can be located anywhere from the internal inguinal ring to the caudal pole of the kidney. The gubernaculum can be followed cranially to locate the testicle if it is not immediately apparent. Intestines may need to be moved to find the testicle, which does not usually cross the midline. Once the testicle is located, the gubernaculum is transected with Metzenbaum scissors and electrocautery. The vascular pedicle and vas deferens are ligated with vascular clips or pretied suture. The testicle is removed through a portal. Often, the testicle is small enough to be removed through the cannula; other times, the incision is extended just enough to pull the testicle through. Unless a tumor is suspected, laparoscopic retrieval bags are not routinely used.

Cystotomy

Cystotomy is an endoscopic-assisted procedure that is indicated primarily in male dogs when rigid cystoscopy is not feasible. It is used to examine the bladder and proximal urethra, take culture or biopsy samples, and remove cystic calculi. The laparoscope is
used to locate the bladder and, using techniques similar to intestinal surgery, bring it to the body wall. A cannula is placed directly over the area where the bladder is to be exteriorized and used to present anatraumatic grasper to pull the bladder to the body wall. The incision is extended under laparoscopic guidance just enough to expose the bladder. The apex of the bladder is exteriorized and stabilized with stay sutures. Urine is drained from the bladder, and the laparoscope is removed from the abdomen and placed into the bladder through a small incision. After completion of the procedure, the bladder is flushed and closed in a routine manner and placed back into the abdomen. Any incision greater than 10 mm should have the fascia closed prior to the subcutaneous tissue and skin.

**Other Laparoscopic Procedures**

Numerous other procedures have been performed in single or small numbers of cases. Laparoscopic colon resection was described in a 10-year-old female Labrador retriever. Careful case selection and a circular stapler and a reloadable linear stapler are needed for this procedure. Laparoscopic cholecystectomy has also been performed. Using advanced techniques and instrumentation, this has been shown to be a safe means of removing the gallbladder for uncomplicated gallbladder mucocles. Laparoscopic and endoscopic techniques to thoroughly evaluate the patency of the extrahepatic biliary tract will be an important consideration when using MIS to remove the gallbladder in small animals. Anecdotally, laparoscopy has been used in our hospital to determine whether external bite wounds or other superficial traumatic injuries have penetrated body cavities (thoracic and abdominal), to remove a foreign body (abdominal sponge), to evaluate and identify the presence of acquired extrahepatic portosystemic shunts after attenuation of a single congenital extrahepatic portosystemic shunt, and to monitor and restage abdominal tumors after resection.

**Thoracoscopy**

In general, thoracoscopy is easier to perform than laparoscopy because there are fewer organs to manipulate and because pneumothorax is easier to induce than pneumoperitoneum. Thoracoscopy has many advantages over open thoracotomy. The magnification and intense lighting provide excellent visualization of lesions, including those that are submacroscopic. Thoracoscopy also permits access to previously difficult-to-reach structures and removes the physical difficulty of working in a deep-chested dog (“working in a hole”). The recovery differences between dogs undergoing open thoracotomy versus thoracoscopy can be profound. We particularly prefer using thoracoscopy for cancer staging in older dogs because the recovery is usually excellent. Thoracoscopy should be attempted in all cases in which it is not known whether an open approach is necessary, such as in penetrating chest wounds to determine the extent of the injury and in spontaneous pneumothorax when diffuse disease may be present and an open approach may not provide any definitive treatment. Thoracoscopy can easily be converted to an open median sternotomy, or, after definitive diagnosis of the affected side, the patient can be turned to perform a lateral thoracotomy.

**Patient Preparation**

Patients are placed in dorsal, slightly oblique dorsal (sternum slightly away from the surgeon), or lateral recumbency. The area to be prepared for thoracoscopy should be as wide or wider than that for open thoracotomy to provide enough space to triangulate portals and place a chest tube. For dorsal procedures, patients should be clipped from the thoracic inlet cranially to the cranial one-third of the abdomen caudally and the ventral half of the thorax. For ventral procedures, the thoracic inlet approach. The lateral intercostal and paraxiphoid portal should be inserted either to the left or right of midline in the angle between the xiphoid and last rib. A blade is used to make a 2- to 3-cm incision through the skin and subcutaneous tissue, and a hemostat is used to widen the hole and penetrate the pleura. A blunt trocar cannula unit is inserted and aimed cranially, slightly laterally, and ventrally to avoid the mediastinum. Once the trocar is in place, air is provided to enter the chest cavity, producing a pneumothorax. The camera is inserted into the thorax, and the hemithorax is explored. Normal mediastinum will appear as a thin, transparent sheet with blood vessels and fat running through it (FIGURE 7). It may have
Under direct visualization with the camera, the first instrument portal can be placed into one hemithorax. The trocar–cannula unit should not be tunneled, as the extra tissue will limit instrument maneuverability. An instrument can then be inserted into the hemithorax and the mediastinum broken down. It is ideal to use a coagulation or vessel-sealing instrument to break down the mediastinum, as there can be vessels that hemorrhage and reduce visualization following transection of the tissue, particularly abnormal tissue; however, normal mediastinum can be transected with Metzenbaum scissors without much bleeding (Figure 7). Once both sides of the thorax are exposed, second and third instrument portals can be placed into the opposite hemithorax. The creation of a bilateral pneumothorax increases working space and exposure of thoracic organs. Hemithorax procedures can be performed with the patient in lateral recumbency.

Figure 7. Normal mediastinum. (a) Note the transparent, curtain-like appearance of the mediastinum with small vessels and fat as seen from the left hemithorax. (b) A hole has been made with Metzenbaum scissors in a nonvascular area to provide access to the opposite hemithorax. m = mediastinum, ms = Metzenbaum scissors, pp = palpation probe.

Methods of increasing the working space during thoracoscopy include thoracic insufflation with CO₂ to between 4 and 6 mm Hg, creating a bilateral pneumothorax passively, and one-lung ventilation or one-bronchus intubation. Thoracic insufflation is not recommended because it not only adds an unnecessary step to the procedure but also increases the risk of tension pneumothorax. The creation of a bilateral pneumothorax is routine during thoracoscopy procedures and is considered to be relatively safe. The use of endobronchial blockade devices for one-lung ventilation is becoming more common in veterinary medicine and greatly increases the working space within the thorax. Obviously, with one-lung ventilation, an experienced anesthesia team and advanced monitoring equipment are needed.

When the procedure is complete, the cavity can be flushed and suctioned, a chest tube placed under thoracoscopic visualization and secured in place in a routine fashion, and portals removed and closed in layers. Depending on the procedure performed, chest tubes are left in place for immediate postoperative evacuation of air until they are no longer clinically needed. If the tubes are to be used long-term, they should not be placed through an existing portal site because it will be difficult to achieve an airtight seal.

Thoracoscopy has shown great promise in veterinary medicine. The ability to visualize and access lesions is markedly improved compared with open procedures, recovery time is rapid, and hospitalization time, time in the intensive care unit, and need for heavy analgesia and sedation in the postoperative period are all decreased. All of these benefits make thoracoscopy a very attractive surgical option.

Complications
Complications of thoracoscopy include iatrogenic damage to viscera (lungs and heart), vessel laceration (intercostal and internal thoracic vessels), portal site seroma formation, and tumor seeding at portal sites. One case report demonstrated seeding of portal sites with mesothelioma after biopsy and partial pericardectomy for recurrent pericardial and pleural effusion composed of fluid with cellular changes consistent with an exfoliating carcinoma. This report supports the use of endoscopic retrieval bags in cases in which neoplasia is suspected. As seeding has been reported with fine-needle aspiration as well as open procedures, owners should be warned of the risk regardless of the technique used. There is also a case report of accidental entrapment of an endobronchial blocker in a staple line.

Pericardial Window
Thoracoscopy can provide excellent information in cases of chronic pleural effusion, pericardial effusion, or pyothorax. With very little trauma to the patient, fluid can be removed, structures examined under magnification, biopsy samples obtained, and surgical staging performed.

Thoracoscopy for treatment of pericardial effusion with a pericardial window is easy to perform and has benefits that far outweigh those of open procedures. Animals can undergo diagnosis and potentially definitive treatment through three small incisions and can be expected to recover the same day. Animals are placed in dorsal recumbency with a paraxiphoid portal for the endoscope. Based on the surgeon’s preference, the instrument portals can be placed both on the right side, or one on the right and one on the left side. If both are on the right side, they can go between the fifth to seventh and ninth to 10th intercostal spaces, and if they are on each side, sites between the ninth and 10th intercostal spaces generally work well. The portals should be placed ventral to the costochondral junction. A right lateral approach can also be used, particularly if evaluation of the right atrial appendage or aortic root is warranted. This approach places the endoscope portal in the ventral third of the sixth or seventh intercostal space. The instrument portals are placed at midpoint of the fourth and eighth intercostal spaces.

With both techniques, the phrenic nerve can be visualized before the incision is made. The mediastinum should be removed first to improve visualization and maneuverability, preferably with a coagulation device to avoid dripping of blood onto the endoscope. The cranial mediastinum should be evaluated for enlarged lymph nodes and a biopsy sample obtained if necessary. The pericardium is grasped with grasping forceps and pulled up to be
cut with Metzenbaum scissors. After the initial cut, pericardial fluid can be suctioned; the grasping forceps are then repositioned so that a patch of pericardium about 3 × 3 cm can be removed (large enough to prevent healing, but small enough to prohibit herniation of the heart).

**Subtotal Pericarrectomy**

Subtotal pericarrectomy is significantly more challenging than a window but can still be performed thoracoscopically with the animal in dorsal recumbency.16,17 The primary indication is restrictive pericarditis. The procedure generally requires two sets of two instrument portals and coagulation as needed. The same principles are followed as in an open technique with the preservation of the phrenic nerves. The procedure is started as for a pericardial window by grasping the pericardium and lifting it up to be cut with Metzenbaum scissors. The phrenic nerves can be elevated off the pericardium if more pericardium requires removal.

**Lung Biopsy and Partial Lung Lobectomy**

For bilateral procedures or when the diseased side cannot be determined, dorsal recumbency is used. The paraxiphoid portal can be used, with the remaining portal sites determined by the location of the affected lobe. If the side of the diseased lobe can be determined before surgery, lateral recumbency is preferred because access is greater. Small peripheral lesions or tissue samples for chronic lung disease can be removed with a loop suture. Endoscopic stapling devices are ideal, but they are expensive and are unnecessary for small masses. If an endoscopic stapling device is used, the largest stapler available is recommended to limit the need for more than one staple line.

**Lung Lobectomy**

Thoracoscopic lung lobectomy has been described in healthy dogs21 and dogs with lung tumors.22 Generally, small masses located away from the hilus are easily removed. Large masses located at the hilus can limit visualization and restrict appropriate placement of the stapling device. One-lung ventilation is recommended, and lateral recumbency usually provides the best access. The basic principles of triangulation are used, with the endoscope and two instrument portals placed depending on the lobe to be removed. The pulmonary ligament is sharply cut with Metzenbaum scissors to remove caudal lung lobes (FIGURE 8). The stapling device is placed over the vein, artery, and bronchus without dissecting them individually. A 65-mm cartridge with 3.5-mm staples is recommended.16 The cut surface should be monitored for leakage, although it is expected that the stapling device will occlude both the airways and vessels. After the stapling device is discharged, it is closed and removed from the cavity, and an endobag can be introduced to help with removal of the lobe. The lobe can be removed through a minithoracotomy or by extension of one of the instrument portals. Lymph nodes should be evaluated before completion of the procedure and removed or sampled if indicated. A chest tube is placed and ports closed as described above.

**Hilar Lymph Node Biopsy and Removal**

The hilar lymph nodes can be seen if they are enlarged. With the lungs partially collapsed, the nodes can usually be seen between the lung lobes after gentle manipulation of the lungs with a blunt probe. The nodes can be sampled (with attention to the close association with the aorta) with a double-spoon, grasping-type biopsy forceps (FIGURE 9) or removed with a combination of sharp and blunt dissection.

**Thoracic Duct Occlusion**

Chylothorax can be a frustrating disease that ultimately requires multiple bicavitary approaches for controversial procedures such as thoracic duct ligation, pericarrectomy, and cisterna chyli ablation, with unpredictable efficacy. Thoracoscopy offers minimal trauma and superior visualization of the thoracic cavity and thoracic duct in these patients. Injection of the popliteal lymph node with...
new methylene blue can help elucidate the thoracic duct, which can then be either clipped or ablated. Clip application is restricted to large dogs and requires dissection of the pleura for proper placement. Tissue ablation is recommended in cats and small dogs and can be performed through the pleura without dissection down to the duct.¹⁶

Because of differences in anatomy, dogs are placed in sternal, left lateral, or dorsal recumbency, whereas cats are placed in sternal or right lateral recumbency. Portals are placed at the midpoint of the seventh or eighth intercostal space for the endoscope, and the instrument portals are placed at the sixth and ninth intercostal spaces midway between the endoscope and dorsal end of the ribs. This procedure can be combined with pericardectomy, but multiple portals may be required to achieve appropriate ventral access to the pericardium.

**Future Directions**

Dogs and other species are used routinely as animal models to explore new instrumentation as well as techniques for use in human patients. For this reason, some veterinarians and human surgeons have highly advanced knowledge and skills in MIS for animals. For example, laparoscopic subtotal splenectomy has been evaluated in dogs for use in humans to treat splenic trauma, portal hypertension, and other diseases.²¹ This technique could have a role in small animals with splenic trauma as well as for biopsy or small mass removal. Diaphragmatic plication via thoracoscopy has been described in a canine model for treatment of unilateral diaphragm paralysis in humans.²² Although the disease may not be relevant, this technique may be useful with modification for treatment of hiatal hernia in dogs. A technique for performing isolated lung perfusion via thoracoscopy for treatment of unresectable lung malignancies has also been developed.²³ With some adaptations, this may be a usable technique in veterinary cancer patients. Other more advanced techniques are currently being used on a very small scale in veterinary patients. For example, laparoscopic ultrasonography has been described in six dogs.²⁶ This tool allows an ultrasonic probe to be placed directly onto an organ, permitting biopsy of nonsuperficial lesions and previously inaccessible organs. In addition, color Doppler can be used before biopsy to minimize bleeding.²⁶

It is our hope that veterinary surgeons will acquire and build on the existing knowledge to bring new techniques to small animal patients via advanced training. Clinical use of MIS in veterinary patients is limited only by level of skill and by imagination.

**References**

1. Compared with the Veress needle technique, the Hasson (mini-open) technique
   a. is easier.
   b. allows more rapid gas insufflations.
   c. reduces the risk of iatrogenic splenic rupture.
   d. all of the above

2. When the endoscope becomes blurred on entering a cavity, it should not be cleaned by
   a. rubbing the tip gently on a nearby organ.
   b. rubbing the tip with a finger.
   c. removing the scope and cleaning it with a moistened sterile gauze square.
   d. applying commercially available anti-fog solution to the tip.

3. The most common complications of laparoscopy include
   a. iatrogenic rupture of the spleen.
   b. portal site seroma.
   c. inability to complete the procedure using minimally invasive technique.
   d. a and b

4. Hemorrhage from liver biopsies can be controlled by all of the following except
   a. applying a Babcock forceps to the area.
   b. waiting for the small amount of hemorrhage to clot.
   c. applying pressure with a blunt probe.
   d. applying a hemostatic agent such as gel foam.

5. Intestinal biopsy is
   a. an endoscopic-assisted procedure.
   b. not possible via laparoscopy.
   c. nondiagnostic via laparoscopy.
   d. easily performed entirely within the abdominal cavity.

6. Laparoscopic-assisted gastropexy is
   a. performed with the patient in dorsal recumbency.
   b. performed at the pyloric antrum.
   c. essentially an incisional gastropexy.
   d. all of the above

7. For bilateral thoracic procedures, the first cannula is placed
   a. right lateral.
   b. left lateral.
   c. paraxiphoid.
   d. at the thoracic inlet.

8. Which statement regarding thoracoscopic creation of a pericardial window is false?
   a. It is easy to perform.
   b. It cannot be combined with thoracic duct ligation.
   c. It can be diagnostic and therapeutic.
   d. It can be performed with animals in dorsal recumbency.

9. Which statement(s) regarding lung lobectomy is/are true?
   a. It should not be performed via thoracoscopy.
   b. It has been performed via thoracoscopy in dogs.
   c. It is best performed for small masses away from the hilus.
   d. b and c

10. Thoracoscopic procedures performed in dogs include
    a. liver biopsy.
    b. subtotal pericardectomy.
    c. gastropexy.
    d. persistent left aortic arch correction.