Current Concepts in Minimally Invasive Surgery of the Abdomen

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KEYWORDS

• Laparoscopy • Dog • Cat • Minimally invasive • Biopsy • Ovariectomy
• Cisterna chyli ablation • Adrenalectomy

KEY POINTS

- Laparoscopic and laparoscopic-assisted procedures are well established in veterinary surgery, with novel minimally invasive approaches and procedures described regularly in the peer-reviewed literature.
- Advances in preoperative work-up (eg, abdominal CT and/or MRI) have facilitated more appropriate patient selection for minimally invasive surgical procedures, allowing more focused dissections and less surgical trauma.
- As the field advances, advantages related to magnification, visualization, and accessibility are expected to establish laparoscopic and laparoscopic-assisted procedures as superior to traditional open surgery for certain procedures.
- Developing advances, such as single-incision laparoscopic surgery (SILS) and/or natural orifice transluminal endosurgery, are actively pursued in veterinary patients.

INTRODUCTION: NATURE OF THE PROBLEM

Minimally invasive surgery of the abdomen is an area of veterinary medicine that continues to progress, paralleling advances in instrumentation, technology, and increasing familiarity of the procedures by newly trained surgeons. Laparoscopic and laparoscopic-assisted procedures are becoming increasingly available to veterinary patients, both in the referral and nonreferral settings, with the American College of Veterinary Surgeons incorporating training in minimally invasive surgery as a required aspect of a residency program. Consequently, many excellent review articles and

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books exist within the veterinary literature, providing detailed equipment descriptions and procedural information related to laparoscopy.[1–5] The purpose of the present article is to supplement these sources by providing readers with an update on more recent developments in the field veterinary laparoscopy and laparoscopic-assisted procedures. Basic equipment setup and procedures are referenced briefly to allow a greater focus on more contemporary procedures and advances in the field.

INDICATIONS/CONTRAINDICATIONS

Indications for laparoscopy include biopsies of almost all organs that can be achieved by laparotomy (**Box 1**). Laparoscopy is also a minimally invasive way to perform several surgical procedures, with more procedures performed as experience and expertise increases (**Box 2**). Ancillary surgical procedures, such as placement of feeding tubes to optimize recovery or to help stabilize patients before procedures, also can be performed (**Box 3**), along with a complete abdominal explore for oncologic staging purposes. Organs and pathology are better seen laparoscopically due to magnification and light source.[5] Targeted biopsies of specific lesions can be performed, obtaining larger samples than could otherwise be achieved percutaneously. Sample procurement via laparoscopy decreases patient morbidity, pain, infection rate, and time compared with a standard laparotomy.[6–9] Other advantages include the ability to document pathology of organs, which is advantageous for developing treatment plans and medical record keeping; monitoring chronic conditions; and education with clients and veterinary colleagues involved in the care of patients.[5]

There are few contraindications to laparoscopy due to the minimally invasive nature of this technique, especially if a traditional laparotomy is warranted. Unstable patients have contraindications for laparoscopy similar to those of laparotomy. Patients with diaphragmatic defects (eg, hernias) should not undergo laparoscopy because insufflated CO_2 expands into the pleural space causing respiratory compromise. Large tumors or mass removals may be best performed with the traditional open approach or surgeries where an obvious conventional surgical approach is warranted. Lack of surgeon experience is a contraindication with laparoscopic procedures, with a steep initial learning curve for this technique. Some surgeons choose to use a predetermined time limit before conversion to traditional methods. Laparoscopy needs specialized surgical equipment, the lack of which is a contraindication.

Box 1
Abdominal organs readily biopsied via laparoscopy

- Liver
- Spleen
- Pancreas
- Lymph nodes
- Kidney
- Adrenal gland
- Peritoneum
- Cholecystocentesis (transhepatic)
- Prostate

Box 2
Established small animal laparoscopic surgical procedures

- Abdominal exploratory
- Ovariectomy, ovariohysterectomy, and/or ovarian remnant removal
- Abdominal cryptorchid testicle removal
- Adrenalectomy
- Cholecystectomy
- Liver lobectomy
- Splenectomy
- Nephrectomy
- CC ablation
- EHPSS attenuation
- Mesenteric lymph node extirpation
- Cystoscopic calculi removal
- Artificial urethral sphincter placement

TECHNIQUE/PROCEDURE

Preparation

Preoperative patient preparation for minimally invasive surgery of the abdomen has many similarities to traditional open abdominal surgery. Preparation includes a routine preoperative fast and use of perioperative antibiotic prophylaxis depending on the planned procedure and patient status. Additional preparation steps include evacuation of the urinary bladder and performing a wider hair clip than might be utilized for a traditional ventral midline laparotomy. Evacuation of the urinary bladder allows for increased physical space within the peritoneal cavity during the laparoscopic procedure as well as minimizing the risk of accidental trauma to the bladder during establishment of laparoscopic portals. A wider hair clip allows for more laterally positioned laparoscopic portal placement to facilitate appropriate instrument triangulation.

Patient Positioning

Patient position for minimally invasive surgery of the abdomen largely depends on the planned procedure. By varying a patient's position, a surgeon can use passive retraction of the abdominal viscera by gravity to facilitate exposure to the anatomic structures of interest for a particular procedure. This position may need to be changed during the procedure, requiring an operating table that can be adjusted to the desired angles. For procedures involving the retroperitoneal space, it is often advantageous to

Box 3
Laparoscopic tube placement options

- Gastrostomy tube
- Jejunostomy tube
- Cystostomy tube
- Cholecystostomy tube

position patients in sternal recumbency, with the pelvis supported, allowing abdominal viscera to passively fall away from retroperitoneal structures of interest.[10]

An ideal operating table for use with minimally invasive surgery allows tilting the table side to side (eg, to provide sequential access to each side of the reproductive tract) as well as the front and back ends of the table (eg, Trendelenburg position to maximize exposure to the caudal abdomen). It is important to carefully secure patients to the table to prevent inadvertent slipping or falling during the procedure. Commercially available tabletop add-on patient positioning platforms are becoming more common through veterinary laparoscopic supply companies. These devices offer the ability to retrofit an existing nontilting surgical table for laparoscopic use.

Approach

The surgical approach for minimally invasive surgery of the abdomen varies depending on the planned procedure. Even for a single specific procedure, the number of planned portals may vary depending on surgeon preference, which may dictate changes in the specific port placement. In general, many laparoscopic procedures use portals along the ventral aspect of the abdomen in a baseball field configuration to help with triangulation of instruments. Alternative approaches for specific procedures to facilitate exposure for particular organs are, however, important to consider. For example, a paralumbar approach may be used for adrenalectomy and greatly facilitates exposure of the gland during the procedure.[10] Use of a 0° telescope inserted into a screw-in threaded trocar as it is being established is useful for direct identification of tissues/organ the port is advancing toward.

Technique/Procedure

Basic technical and equipment-related information is available in excellent review articles, both previously published in this series as well as in other sources.[1–5] This review emphasizes modern port options and instruments necessary for some of the newer and evolving minimally invasive surgical procedures performed in the abdominal cavity.

Laparoscopic instruments portals have evolved beyond the traditional Veress needle and/or Hasson methods. Portals that accommodate variable instruments sizes are commercially available (**Fig. 1**) and greatly facilitate swapping of instruments and telescopes of different sizes during a procedure. Optical trocars that allow direct visualization of tissues as they are penetrated during portal placement are helpful, especially

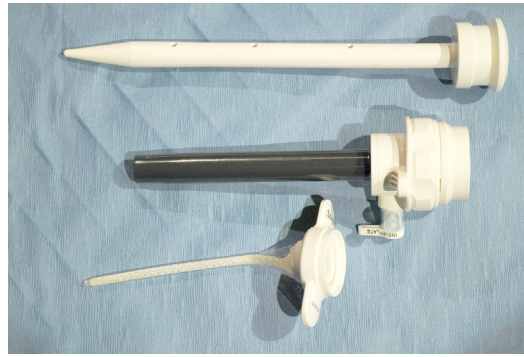

Fig. 1. A laparoscopic portal that automatically accommodates and seals around instruments or telescopes ranging from 5 mm to 12 mm in diameter.

when placing a portal through a nontraditional location (eg, paracostal portal placement for an adrenalectomy). Portals that warm, clean, and defog the telescope during insertion are available as well. Finally, simple blunt-tip screw-in trocars (Fig. 2) allow for safer entry into the abdomen without creation of a larger body wall defect or a need for retention sutures as required with the traditional Hasson technique. Wound retraction devices for laparoscopic-assisted procedures are available to facilitate exposure through a relatively small surgical incision.[11]

As more advanced and diverse laparoscopic procedures are described for small animal veterinary patients, the selection of instruments that are necessary is also increasing. For example, laparoscopic cotton-tipped dissectors (Fig. 3) and both 5-mm and 10-mm laparoscopic right-angled forceps (Fig. 4) are invaluable for dissection of adrenal tumors and gall bladders. New tip options for the LigaSure vessel sealing device (Covidien, Mansfield, Massachusetts) have facilitated dissection of tissues using the same instrument notably faster and easier (eg, Dolphin tip and/or Maryland jaw instruments).

A summary of laparoscopic and laparoscopic-assisted procedures is provided.

Liver biopsy

Indications for a liver biopsy include unexplained laboratory or abnormal imaging findings. Diagnosing liver dysfunction is normally achieved by histopathology, ensuring that liver biopsy is a common procedure performed. The liver is a simple and easily accessible organ to be laparoscopically biopsied.[3,5,12] A coagulation panel should be considered before biopsy. Generally, a 2-port position is used: ventral midline for the camera and either a right or left cranial quadrant paramedian instrument portal. Both sides of the liver can be biopsied through either side. A 5-mm × 10-mm oval cup biopsy forceps is the easiest way, obtaining a sample from the edge of the lobe or from the central liver parenchyma. The tissue is grasped gently and held for 10 to 30 seconds before it is either gently tugged or twisted away. The biopsy area should be visualized until the bleeding has ceased. If bleeding is prolonged, pressure can be applied to the biopsy site with a cotton-tipped applicator or a piece of gelatin sponge, or oxidized regenerated cellulose can be placed over the biopsy site. A third port can be placed on the contralateral side to use either a coagulation device or a pretied loop

Fig. 2. A blunt-tip screw-in trocar. Inset shows a close-up view of the tip.

Fig. 3. Cotton-tipped laparoscopic dissecting wand.

ligature or extracorporeally assembled loop ligature in patients with coagulopathy. Multiple sites should be biopsied from multiple lobes for best chance of diagnostic accuracy.

Cholecystocentesis

Aspiration of bile for culture and analysis is often needed when assessing hepatopathies. An 18G or 20G long needle with an inner stylet (eg, cerebrospinal fluid collection needle) is used. The needle should enter caudal to the last rib to prevent puncture of the diaphragm and pneumothorax. The gall bladder should be punctured by first advancing the needle through the quadrate lobe of the liver, so, if leakage occurs, it drains back into the liver. Often, abdominal insufflation pressures need to be reduced to allow the needle to reach the gall bladder.

Pancreatic biopsy

Indications for pancreatic biopsy include differentiation of acute pancreatitis versus acute liver disease and visualization of both organs.[13,14] The tip of the right limb of the pancreas is usually the most accessible area. The pancreas needs to be visualized to determine if this is a representative sample; however, the left limb of the pancreas is challenging to assess completely.[5] A 5-mm × 10-mm oval biopsy cup forceps can be used on the periphery to ensure that the pancreatic ducts and the blood supply to pancreas and the duodenum are not compromised. Either a ventral or right lateral laparoscopic approach can be used. Laparoscopic-assisted biopsy of the pancreas can be

Fig. 4. Right-angle laparoscopic forceps, 5 mm (*bottom*) and 10 mm (*top*).

used by externalizing the descending duodenum through an incision for gastrointestinal biopsies. Other methods include a pretied loop, a LigaSure device, harmonic scalpel, and hemostatic clips.[5] Pancreatitis as a complication of pancreatic biopsy is low.[15]

Spleen biopsy and splenectomy

There are few indications for splenic biopsy, with the procedure generally performed to assess for neoplasia.[16] Diffuse splenomegaly is generally the indication, instead of splenic masses; 5-mm × 10-mm oval cup biopsy forceps are used. A coagulation profile should be performed before biopsy. A ventral or left lateral midabdominal approach should be used. If splenomegaly is suspected, caution should be taken when entering the abdomen with either approach. Coagulation through the use of a piece of gelatin sponge or oxidized regenerated cellulose can be placed over the biopsy site.

Laparoscopic splenectomy has been reported using a 3-port technique with patients in dorsal recumbency and rolled into right lateral recumbency or with a SILS Port (Covidien, Mansfield, Massachusetts).[17,18] A vessel sealant device is used to perform a hilar splenectomy. A specimen retrieval bag should be used to prevent seeding of the abdomen, and incisions may need to be enlarged to the remove the spleen.

Lymph node extirpation

Detection of an enlarged lymph node during laparoscopy or by imaging is an indication for biopsy, along with nondiagnostic cytology aspirates, and during staging of canine oncologic patients. Three-mm or 5-mm oval cup biopsy forceps are used, and patient positioning depends on other laparoscopic procedures performed concurrently or on which node is sampled.

Laparoscopic medial iliac lymph node (MILN) extirpation has been reported.[19] Indications include diagnostic staging of canine oncologic patients. A lateral 3-portal caudal abdominal approach can be used for the ipsilateral lymph nodes. MILNs are identified by incising the retroperitoneum caudal to the deep circumflex iliac artery and vein and dorsal to the external artery or vein using a vessel sealant device. This technique was successful in 8 purpose-bred hounds with normal MILNs. The contralateral MILN was not able to be seen or biopsied from this approach. Also, the hypogastric and sacral lymph nodes cannot be visualized or sampled. Complications include hemorrhage and tearing of lymph node capsule. Further work is necessary before this technique becomes a routinely clinically feasible option.

Kidney biopsy and nephrectomy

Kidney biopsies are generally obtained only when they change the course of treatment. Examples of such scenarios may include the need to obtain a specific diagnosis, define the extent of disease, and determine the reversibility of renal disease. Laparoscopic-assisted biopsies are obtained with a needle core biopsy instrument (14G or 16G) under visualization.[3,5] Osmotic diuretics that improve renal blood flow should be discontinued before biopsy, and a coagulation profile should be assessed. Port placement can be ventral midline with patients rotated slightly, with the kidney to be biopsied up or in a midabdominal location away from the falciform fat on midline. The needle core biopsy instrument should enter near the kidney, relatively high on the lateral body wall. The angle of the needle needs to be tangential to the kidney to obtain a cortical biopsy, and the throw of the needle biopsy instrument needs to be considered to avoid injury to surrounding structures. After the biopsy is taken, the tip of a palpation probe or cotton-tipped applicator should be placed over the biopsy site for 1 minute.[3] The major complication of kidney biopsy is hemorrhage, and patients likely have hematuria for the next 24 to 48 hours. Fluid diuresis should be used postbiopsy to prevent blood clot formation and obstruction.[5]

Laparoscopic left nephrectomy has been described in an experimental series of 16 dogs.[20] Dogs were placed in dorsal recumbency in a 15° Trendelenburg position and a 3-port technique used. The animals were then rolled onto the right side to start the dissection. The renal vessels were be ligated with ligating clips and sectioned. The kidney were freed from the peritoneum and the ureter was mobilized. The ureter was ligated and divided at the level of the iliac vessels. The kidney was removed with a specimen retrieval bag and needed to be morselized. This technique has also been performed in a clinical series of 9 dogs.[21] This method differed by early dissection of the ureter which aids in retraction and elevation of the kidney for dissection and division of the ureter near its insertion into the bladder instead of near the iliac vessels. Complications include visual obstruction due to hydroureter and hemorrhage. Conversion to an open approach may be necessary.

Laparoscopic-assisted gastrointestinal biopsies

Biopsies of the small intestine can be performed in a laparoscopic-assisted manner.[22] The animal is placed in dorsal recumbency and standard midline portals are established. The jejunum can be atraumatically grasped and exteriorized through an enlarged portal incision. Standard intestinal samples then can be obtained. Wound retraction devices can be used to aid in larger segments of intestinal exteriorization, also allowing the duodenum and ileum to be sampled more easily.

Laparoscopic ovariectomy, ovariohysterectomy, or ovarian remnant removal

Laparoscopic ovariectomy or ovariohysterectomy is a common procedure and one many veterinary surgeons begin their laparoscopic career with. Advantages over a traditional open approach include enhanced visualization and faster recovery.[9] Patients are placed in dorsal recumbency, on a table that has the ability to tilt to the left and right; 1-, 2-, and 3-port techniques have all been described. The 1-port technique relies on having an operating scope, consisting of a 10-mm operating scope with an operating channel that accommodates 5-mm instruments. A common technique is a 2-port technique, where a subumbilical port is placed, and second port is placed either cranial or caudal to the subumbilical port. Patients are rotated into right or left lateral recumbency, opposite to the side of ovariectomy, and the ovary is identified. It is then held up to the body wall and suspended to the body wall by a percutaneous swaged-on needle with suture or laparoscopic hook. A vessel sealant device may be used to remove the ovary. If the ovary is suspended by a suture, the ovary can remain in place and be removed after the contralateral ovariectomy, or it may be removed immediately if a laparoscopic hook is used. A 3-port technique can be used where all 3 ports are placed in midline, with 2 caudal to the umbilicus and 1 cranial to the umbilicus.[23] This method does not involve suspending the ovary from the abdominal wall.

The 3-port technique can be used to perform an ovariohysterectomy.[5] Bilaterally, the ovarian pedicles are transected and the broad ligament is also transected close to the uterus to decrease number of blood vessels as well as to minimize potential damage to the ureters and gastrointestinal tract with the electrosurgical device. This is performed from cranial to caudal, with constant traction on the proper ligament. The ovaries and uterus are exteriorized through the caudal incision, where the body of the uterus is ligated and transected in a routine manner. Complications include hemorrhage and other standard laparoscopic complications.

Ovariohysterectomy for pyometra also can be performed using the 3-port technique.[24] A wound retractor device can be used in the caudal portal to facilitate removal of the uterus. Careful case selection is warranted, with guidelines suggested for dogs less than 10 kg with a uterine horn diameter less than 2 cm, or dogs greater than 10 kg

with a uterine horn diameter less than 4 cm. Potential complications include uterine rupture and hemorrhage. The authors have performed laparoscopic ovarian remnant removals using both 2- and 3-port techniques.

Laparoscopic cryptorchid testicle removal

The laparoscopic cryptorchid testicle removal procedure is indicated after identification of an abdominally located testis.[22,25] Patients should be placed in Trendelenburg position and can be rolled into left and right lateral recumbency depending on location of testicle. A subumbilical port is placed and the retained testicle is found. A 2-port technique can be used by placing the second port over the testicle and using Babcock forceps or an aggressive grasper to elevate the testicle outside the body wall after extending the second port incision and ligating the vasculature and vas deferens routinely.[25] Alternatively, a 3-port technique can be used to ligate the vasculature intra-abdominally, with either a vessel sealant device or hemoclips.[5] The portal site still needs to be enlarged to remove the testicle.

Laparoscopic adrenalectomy

Laparoscopic adrenalectomy has been described in canine patients.[3,10,26] Appropriate case selection is paramount to success due to the pertinent anatomy of the gland near large vascular structures and an adrenal gland tumor's ability to invade these structures. Imaging of adrenal masses is important preoperatively, with vessel invasion a contraindication for laparoscopic removal along with large size (>6 cm). Unstable patients should have an open approach. The standard work-up for an adrenal mass should be performed as per open adrenalectomy, along with appropriate medications before surgery is performed. Dogs can be placed either in lateral recumbency with elevation of the erector spinae muscle group or in sternal recumbency with 2 cushions placed to elevate the chest and the pelvic area to leave the abdomen unsupported.[10,26] A 3- or 4-port technique should be used, in the paralumbar fossa, caudal to the last rib on a virtual half circle triangulating the approximate position of the adrenal gland. A fourth port can be used dorsally for retraction if needed. The laparoscope may be placed in the middle port, with instruments on either side, or at either the cranial or caudal ports, depending on individual anatomy. For exposure, the kidneys need to be retracted caudally or dorsally and, for right adrenalectomy, the right lateral hepatic lobe needs to retracted cranially. After exposure of the adrenal gland and dissection through the peritoneum dorsolateral to the gland, the phrenicoabdominal vein should be ligated. A combination of a vessel sealant device, bipolar electrocautery, and dissecting forceps should be used to circumferentially dissect the gland. Careful dissection is needed to ensure that the capsule stays intact. Once the gland is dissected free, the adrenal gland and tumor can be placed in a specimen retrieval bag and removed. Potential complications include lost visualization during minor bleeding or lymphatic vessel damage, profuse bleeding requiring immediate conversion to an open approach, and rupture of the adrenal gland and mass.

Laparoscopic cisterna chyli ablation

The laparoscopic cisterna chyli (CC) ablation procedure is indicated as an adjunct procedure for idiopathic chylothorax treatment. CC ablation may reduce backpressure in the thoracic duct and may reduce the force driving recanalization. Dogs are placed in sternal recumbency with the pelvis elevated. This technique can be performed with 2 portals placed 2- to 3-cm caudal to the 13th rib on the left side in the dorsal third of the abdomen, or with a transdiaphragmatic portals placed in the dorsal third of the left 10th or 11th intercostal space (use of nonvalved port is critical to prevent tension pneumothorax).[27] Initial dissection is through the craniolateral aspect of the

peritoneum between the lateral margin of the left kidney and the dorsolateral body wall. The renal artery is identified and followed to the aorta. The CC is located dorsal to the aorta in the region of the left renal artery. The sternal positioning allows the kidney to displace ventrally during dissection. To facilitate identification of the CC, the popliteal lymph node is injected with methylene blue. The ablation is performed by blunt tearing of the wall of the CC. Complications include inability to locate the CC, tension pneumothorax, and diaphragmatic tears in the transdiaphragmatic approach and aortic laceration. Only surgeons experienced with laparoscopy should attempt this procedure.

Laparoscopic cholecystectomy

Indications for laparoscopic cholecystectomy are uncomplicated gall bladder mucoceles.[3,28] Complicated mucoceles, such as cases of coagulopathies, bile peritonitis, extrahepatic biliary tract obstruction, and small body size (<4 kg), are contraindications, along with surgeon inexperience. Patients should be placed in dorsal recumbency and a 4-port technique is generally used: a subumbilical port, a left cranial quadrant port, and 2 right cranial quadrant ports, triangulated around the anticipated position of the gall bladder. A Trendelenburg position should be adopted. A fan retractor should be placed in the left port, the laparoscope in the right-sided port closest to midline and the other right port along with the subumbilical port for instruments controlled by the surgeon. The cystic duct needs to be dissected round, proximal to the first hepatic duct. The duct is then ligated either with hemoclips or suture and then the gall bladder is dissected off the hepatic fossa. If any leakage of bile occurs or hemorrhage, an open approach should be performed. The gall bladder should be placed in a specimen retrieval bag for removal. Complications include cystic duct rupture, potential for confusion between the cystic and common bile duct, and bile spillage from the cystic duct ligation. Recommendations are to double ligate the cystic duct with monofilament suture by extracorporeal or intracorporeal knots. A liver biopsy for bacterial culture and histopathology along with a bile culture should be performed.

Laparoscopic extrahepatic portosystemic shunt ligation

Laparoscopic extrahepatic portosystemic shunt (EHPSS) ligation is indicated for patients with a single congenital EHPSS.[5,29] Patients are placed in dorsal recumbency, on a table that is able to be tilted head up and from left to right. A 4-portal ventral abdominal technique is used: 1 portal caudal to the umbilicus, left and right paramedian (also called midabdominal by some investigators) portals, and a portal in the right caudal quadrant equidistant from the umbilicus and pubic bone. Gastric traction sutures should be used to aid in elevation of the stomach for identification of the shunt. The animal can be rotated into left lateral recumbency to aid the visualization of the epiploic foramen by elevating the descending duodenum. The animal can be rotated into right lateral recumbency to assess the left abdominal gutter and the diaphragm, to assess for portoazygous or portophrenic shunts. The omental bursa can be assessed with patients in dorsal recumbency. Once the vessel is identified, it is dissected out and cellophane with ligating clips is placed. The pancreas and the jejunum should be visualized to assess for signs of portal hypertension.

Laparoscopic-assisted cystoscopic calculus removal

Urinary calculi can be removed through laparoscopic-assisted cystoscopy.[30–33] Patients should be placed in the Trendelenburg position. The camera portal should be placed 2- to 3-cm caudal to the umbilicus, with a second site caudally on midline for female patients and paramedian or midline for male patients. The apex of the bladder is grasped with Babcock forceps through the caudal port and used to retract

the bladder to the abdominal wall where a ventral cystotomy can be made just large enough to allow removal of the largest cystolith. The bladder is temporarily sutured to the abdominal wall and a cystocope or laparoscope can be used to visualize the bladder lumen, remove cytsoliths, and take biopsies for histopathology or culture. Alternatively, the cystoliths can be removed by flushing saline into the bladder at 300 mm Hg and removed via suction after temporary cystopexy to avoid urine contamination into the abdominal cavity. The proximal urethra should be evaluated for remnant uroliths. The bladder wall then can be closed primarily.

Gastropexy

Prophylactic gastropexy can be performed either laparoscopically or with a laparoscopic-assisted procedure, with pexy tensile strengths comparable to open gastropexy methods and ultrasonographically documented intact gastropexies at more than 1 year postoperatively.[34,35] With the laparoscopic procedure, the creation of the pexy is performed either via intracorporeal suturing or with laparoscopic stapling devices.[36,37] A modified laparoscopic technique has been described in experimental dogs using extracorporeal percutaneous full-thickness body wall sutures to hold a cauterized gastric serosa against a cauterized peritoneal surface.[38] Most recently, laparoscopic gastropexy has been described using single-port access with articulating instruments and angled telescopes.[39] Laparoscopic-assisted gastropexy is favored by some surgeons because it is technically simpler to perform and does not require specialized equipment beyond a basic laparoscopic set up.[34,37]

Feeding and/or drainage tubes

Laparoscopic and laparoscopic-assisted feeding and drainage tube placement has been described in experimental and clinical dogs. Laparoscopic-assisted enterostomy tube placement is an effective method for feeding tube placement in a minimally invasive manner.[40,41] Laparoscopic cystostomy tube placement, along with cystopexy, has been described using a 3-portal technique.[42] Temporary biliary drainage can be established via laparoscopic-guided percutaneous cholecystostomy tube placement using a locking-loop pigtail catheter and has been shown superior to ultrasound-guided techniques in a cadaver study.[43]

COMPLICATIONS AND MANAGEMENT

Potential complications of minimally invasive surgery of the abdomen depend on the specific procedure performed. Generally speaking, the types of complications that can be encountered are similar to those associated with traditional open surgical procedures (**Box 4**), with a few differences discussed later.

Complications specific to laparoscopic procedures early in a surgeon's career may arise from a lack of appropriate exposure or visualization, inappropriately rough tissue handling exacerbated by the lack of tactile feedback with long laparoscopic instruments, or general inexperience with the advanced procedures performed. For these reasons, it is important that a surgeon beginning laparoscopy seek appropriate training and guidance and progress in a stepwise fashion from simpler procedures and/or laparoscopic-assisted procedures to more advanced delicate procedures near critical anatomic structures. Electing to convert to an open approach to prioritize patient health and safety should not be viewed as a failure.

Other laparoscopic-specific complications are related to the generation of capnoperitoneum, often associated with excessive intra-abdominal pressures. Such pressures can cause impaired venous return to the heart and/or compression of the diaphragm with subsequent respiratory compromise. To avoid these issues, many

Box 4
Complications associated with minimally invasive surgery of the abdomen

- Hemorrhage
- Seroma
- Accidental penetration of an abdominal organ during portal placement
- Wound dehiscence
- Insufflation-related complications
  - Acid-base disturbances
  - Reduced venous return to the heart
  - Impaired diaphragmatic movement and reduced pulmonary function
- Procedure-specific complications (feeding or draining tube leakage, tumor seeding at portal locations, etc.)

surgeons prefer to use low intra-abdominal insufflation pressures (6–10 cm H_2O), with only brief periods of higher pressure as needed to perform specific brief maneuvers (eg, provide counterpressure against the force required to establish additional portals). At the completion of a laparoscopic procedure, the peritoneal cavity should be completely deflated to remove CO_2 gas.

POSTOPERATIVE CARE

- Monitoring
  - Baseline temperature, pulse, and respiration on completion of the procedure and every 6–8 hours thereafter
  - If concern for hemorrhage, packed cell volume/total solids and regular arterial blood pressure monitoring
  - Depending on patient status, consider monitoring electrolytes, acid-base status, specific organ parameters (eg, renal panel), corticotropin stimulation test postadrenalectomy, urination frequency and volumes, and respiratory status.
- Analgesics
  - Opioids (hydromorphone, fentanyl, buprenorphine, etc.)
    - Dose and frequency dictated by extent of the procedure and regular patient pain score assessment
  - If no contraindications, consider adding a nonsteroidal anti-inflammatory drug
    - May be used in combination with opioids
    - For less-invasive procedures, may be used alone or after a brief period of opioid analgesia
  - Local incisional blocks can reduce need for systemic analgesics
    - For example, bupivicaine at portal sites
- Supportive care
  - Nutritional support is an important consideration
    - If not eating well on own, consider feeding tube placement during anesthetic episode associated with the surgery
  - Maintain hydration status, typically with intravenous crystalloid and/or colloid fluids
    - Avoid overhydration
  - Prevent self-trauma (eg, via use of Elizabethan collars, as needed); restrict activity

REPORTING, FOLLOW-UP, AND CLINICAL IMPLICATIONS

Results from clinicopathologic samples and tests obtained during an abdominal minimally invasive procedure dictate the long-term follow-up plans and clinical implications. Referral to board-certified specialists may be indicated (eg, internal medicine specialist for a chronic hepatopathy documented via laparoscopic liver biopsy or medical oncologist for an adrenal cortical adenocarcinoma removed via laparoscopy). Other follow-up is best performed with a primary care veterinarian (eg, long-term dietary modification as dictated by urolith analysis results obtained during a laparoscopic-assisted cystoscopy).

OUTCOMES

Patient recovery after minimally invasive surgical procedures of the abdomen typically is rapid and, therefore, long-term outcomes usually depend on the underlying disease process rather than the surgery itself. Elective procedures, such as gastropexy and/or gonadectomy, are expected to yield excellent long-term outcomes. Conversely, biopsy results indicating a disseminated neoplastic process carry a worse prognosis; minimally invasive surgical procedures often can yield critical long-term prognostic information while sparing patients the increased morbidity associated with a traditional open procedure.

CURRENT CONTROVERSIES/FUTURE CONSIDERATIONS

SILS is becoming increasingly popular to reduce complications and surgical trauma of multiple sites. This technique can be achieved through a specialized operating telescope that has a working channel; however, only 1 instrument can be used at a time. The SILS Port is a multiple instrument port that allows the telescope, insufflation, and 2 instrument portals. The difficulty in using this instrument can arise from the inability to appropriately triangulate instruments. Articulating instruments are available that decrease the collision of instruments. SILS has been described in ovariectomy, gastropexy, splenectomy, and laparoscopic-assisted intestinal surgery.[18,23,39,44]

Lift laparoscopy is a feasible alternative to traditional capnoperitoneum laparoscopy and has been used in clinical dogs undergoing ovariohysterectomy.[45–47] A custom-made elliptical lift device is inserted into the peritoneal cavity via a ventral midline stab incision and traction is applied to provide a working space for the desired laparoscopic procedure. Lift location and number of lift devices (eg, 2 lift devices applied simultaneously with 1 in a more cranial location and the other placed caudally) may provide better access to different portions of the peritoneal cavity. This alternative method of providing physical space within the peritoneal cavity for laparoscopic procedures may be beneficial in a subset of critically ill patients who might not tolerate the potential physiologic alterations associated with capnoperitoneum.[45]

Natural orifice transluminal endoscopic surgery is an emerging technique that enables surgery to be performed on abdominal organs by access through the stomach, colon, or vagina. Ovariectomy via the stomach has been reported in research and clinical dogs.[48]

SUMMARY

Minimally invasive surgery of the abdomen continues to be an advancing field within the discipline of veterinary surgery. Many traditional procedures can now be performed in a minimally invasive manner, allowing for quicker patient recovery and less associated tissue trauma. Biopsies of most abdominal organs are readily

performed in a minimally invasive manner. As veterinary surgeons become more familiar with laparoscopy, advanced procedures are becoming increasingly commonplace. Certain laparoscopic procedures are expected to replace their corresponding traditional open surgeries.

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