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*Patent pending design

Radiograph provided by Professor Filippo Martini, Parma – Italy
Perioperative Complications and Outcome of Laparoscopic Cholecystectomy in 20 Dogs

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Objective: To report the complications and outcome of dogs undergoing laparoscopic cholecystectomy for uncomplicated gall bladder disease.

Study Design: Multi-institutional case series.

Animals: Client-owned dogs (n = 20).

Methods: Medical records of dogs that underwent laparoscopic cholecystectomy were reviewed and signalment, history, clinical and ultrasound examination findings, surgical variables, and complications were collated. Laparoscopic cholecystectomy was performed using a multiport approach. Data were compared between dogs with successful laparoscopic cholecystectomy and dogs requiring conversion to open cholecystectomy.

Results: Six dogs (30%) required conversion from laparoscopic to open cholecystectomy due to inability to ligate the cystic duct (3), evidence of gall bladder rupture (1), leakage from the cystic duct during dissection (1), and cardiac arrest (1). Cystic duct dissection was performed in 19 dogs using an articulating dissector (10), right angle forceps (7), and unrecorded (2). The cystic duct was ligated in 15 dogs using surgical clips (5), suture (6), or a combination (4). All dogs were discharged from the hospital and had resolution of clinical signs, although 1 dog developed pancreatitis and 1 dog required revision surgery for bile peritonitis. There was no significant difference in preoperative blood analysis results, surgical technique, or duration of hospitalization between dogs undergoing laparoscopic cholecystectomy and cases converted to open cholecystectomy.

Conclusion: Laparoscopic cholecystectomy can be performed successfully for uncomplicated gall bladder disease in dogs after careful case selection. The surgeon considering laparoscopic cholecystectomy should be familiar with a variety of methods for cystic duct dissection and ligation to avoid difficulties during the procedure.

Laparoscopic surgery has become popular in veterinary medicine¹ and is associated with faster return to function, improved visualization, possible reduction in surgical site infections, and reduced postoperative pain for selected surgical procedures in dogs.²⁻⁸

In people, laparoscopic cholecystectomy is performed for symptomatic cholecystolithiasis and is associated with a significantly shorter hospital stay and shorter convalescence compared with open cholecystectomy.⁹⁻¹ⁱ Recent reports cite a conversion rate of 5–10% for multiport laparoscopic cholecystectomy in people,⁹⁻¹¹ most often due to adhesions obscuring visualization, iatrogenic biliary duct injury, and hemorrhage.¹⁰,¹³

Laparoscopic cholecystectomy has been described in a clinical report of uncomplicated gall bladder mucoceles in 6 dogs without evidence of biliary tract rupture or obstruction.¹⁴ All dogs had successful laparoscopic cholecystectomy without conversion to an open procedure, and all dogs showed improvement or postoperative resolution of clinical signs.¹⁴

For advanced laparoscopic procedures such as laparoscopic cholecystectomy, careful case selection is important.¹⁴⁻¹⁷ Appropriate case selection for laparoscopic cholecystectomy in dogs and factors that may indicate the need for conversion to an open cholecystectomy are not clearly identified. The objective of this study was to report the complications and perioperative outcome of dogs undergoing laparoscopic cholecystectomy and describe details of the laparoscopic procedure, including surgery duration and conversion rate.
MATERIALS AND METHODS

Case Selection

Medical records of dogs that underwent laparoscopic cholecystectomy for uncomplicated gall bladder disease at the participating institutions from July 15, 2008 to July 15, 2015 were identified and reviewed. All dogs that underwent laparoscopic cholecystectomy with or without conversion to an open cholecystectomy were included. Candidates for laparoscopic cholecystectomy were approximately based upon previously published recommendations. Dogs with clinical signs, persistent total serum bilirubin concentration elevations or evidence of gall bladder rupture, abdominal effusion, or extra-hepatic biliary obstruction on ultrasound examination were not considered candidates for laparoscopic cholecystectomy.

Data retrieved from medical records included age, body weight, sex, breed, clinical history, current medications, concurrent comorbidities, and physical examination findings. Complete blood count, serum biochemistry analysis, coagulation parameters, and urinalysis from the perioperative period were recorded. Results of abdominal ultrasound examination and results of any additional diagnostic imaging was recorded and reviewed. Data for surgery included operative technique, intraoperative findings, surgery and general anesthesia duration, results of bacterial culture, and histologic findings of gall bladder and liver biopsies. Perioperative complications, medications prescribed at hospital discharge, recurrence of clinical signs, and duration of postoperative hospitalization were noted.

Laparoscopic Cholecystectomy

Following induction of general anesthesia, dogs were positioned in dorsal recumbency and the ventral abdomen was aseptically prepared. Abdominal access was obtained using a Hasson or modified Hasson technique. A 5 mm incision was made through the skin, subcutaneous tissues and linea alba, 10 mm caudal to the umbilicus to allow introduction of a 30° laparoscope (Karl Storz Endoscopy, Goleta, CA). A stab incision was made into the linea alba and a 6 or 12 mm smooth, trocar/cannula assembly (Karl Storz Endoscopy) was introduced into the abdomen. The abdomen was insufflated with CO₂ to a maximum of 8–12 mmHg using a pressure regulating mechanical insufflator (Karl Storz Endoscopy). Three instrument portals (3.5–12 mm) were established under laparoscopic guidance in locations described by Mayhew et al. One portal was placed in the left cranial quadrant, just caudal to the costal arch for the introduction of a retraction device to elevate the gall bladder and allow visualization of the cystic duct. Two portals were placed in the right middle and cranial quadrant for the introduction of dissection forceps, taking care to triangulate all ports around the anticipated location of the gall bladder (Fig 1). Based on surgeon preference, a commercially available multiple channel, single access port (SILS™ port, Covidien Inc, Mansfield, MA) was used (Fig 2). The SILS™ port was inserted into the abdomen as described. Briefly, a 25 mm incision was created 10 mm caudal to the umbilicus through the skin, subcutaneous tissues, and linea alba. Two apposing stay sutures were placed into the rectus sheath at the incision margins. Digital insertion through the incision was...
performed to liberate the falciform ligament. Two adjacently placed Carmalt forceps were attached to the multichannel single access port in a staggered manner allowing for its insertion into the abdomen. When a single access port was used, an additional 5 mm instrumental portal was placed in the left cranial abdominal quadrant for insertion of a retraction device for gall bladder elevation.

Laparoscopic cholecystectomy was performed as described. Briefly, following establishment of pneumoperitoneum and creation of instrument portals, the gall bladder was elevated using either a blunt probe or a 5 or 10 mm fan retractor placed in the left sided instrument portal. The cystic duct was visualized, and, if present, adhesions were transected using a vessel-sealing device (Ligasure™, Covidien Inc) through a right-sided instrument portal. Dissection of the cystic duct was performed using a laparoscopic articulating dissector (Karl Storz Endoscopy) or 5 mm right-angled forceps (Fig 3A). When using the articulating dissector for cystic duct dissection, the instrument was placed through the right-sided instrument portal and deflected to create a $90^\circ$ angle in the shaft of the instrument to provide an optimal dissection angle behind the cystic duct (Fig 3B). The deflection angle was alternated between right and left to allow for dissection from both sides of the cystic duct. Once dissection was complete, the cystic duct was ligated using 10 mm metallic clips (Endo Clip™, Covidien Inc), extracorporeal or intracorporeal ligation, pretied ligature loop (Surgitie™, Covidien Inc) or a combination of these methods (Fig 3C). The cystic duct was transected using laparoscopic Metzenbaum scissors (Karl Storz Endoscopy). Laparoscopic Babcock forceps were used to grasp the cystic duct remnant on the gall bladder and a combination of blunt dissection and vessel-sealing devices were used to dissect the gall bladder free from the hepatic fossa. The gall bladder was temporarily deposited in the lateral aspect of the abdomen and the hepatic fossa was inspected and lavaged (Suction wand with trumpet valve, Karl Storz Endoscopy). In selected cases, a pretied ligature loop was inserted through the left instrument portal and laparoscopic Babcock forceps were inserted through the right instrument portal through the loop and grasped the cystic duct stump allowing for ligature placement. Liver biopsy was obtained with laparoscopic cup biopsy forceps inserted through an instrument portal. A specimen retrieval bag (Endo Catch™, Covidien Inc) was inserted through a 10 mm portal to retrieve the gall bladder in some dogs. In other dogs, the gall bladder was retrieved through the subumbilical port site incision without the use of a specimen retrieval bag. The gall bladder and liver biopsy were submitted for histologic examination, and bacterial culture and susceptibility testing of gall bladder contents was performed.

Open Cholecystectomy
Conversion to open laparotomy was performed if the cystic duct was unable to be securely ligated or if there was evidence of gall bladder rupture. Following ventral midline celiotomy, the gall bladder was dissected from the hepatic fossa using a combination of sharp and blunt dissection. The cystic duct was ligated using 2–0 polydioxanone circumferential ligatures. The celiotomy incision was then closed.

Complications
Complications were defined as major if they necessitated conversion to open cholecystectomy or required revision.
surgery and minor if they were transient with no intervention required.

Outcome
Follow-up phone conversations and/or clinical examination with owners determined short-term (<14 days postoperative) and long-term (>30 days) outcomes. If the dog had died or was euthanized, the cause of death was recorded.

Statistical Analysis
Age, body weight, serum total bilirubin concentration, serum alkaline phosphatase, alanine transaminase, and
gamma-glutamyl transferase activities, white blood cell count, platelet count, surgical technique, surgery duration, anesthesia duration, hospitalization duration, and postoperative stay were categorized by conversion status (laparoscopic cholecystectomy vs. conversion to open cholecystectomy). Surgical technique was described by the total number of ports placed, the use of SILSTM port compared to multiple single ports, method of cystic duct dissection (right-angled forceps and articulating forceps), method of cystic duct ligation (suture, metallic clips, and combination), and the method of gall bladder dissection (blunt probe, vessel-sealing device, and combination). Normality of continuous variables was confirmed using a Shapiro–Wilk test. Categorical variables were compared with a Fisher’s exact test, and continuous variables were compared with a Student’s t-test for normally distributed data. Nonparametric data were tested with a Wilcoxon rank-sum test. P \leq .05 was considered statistically significant.

RESULTS

Cases

Twenty dogs were identified in the study period and included. Breeds included Shetland Sheepdog (8), Mixed-breed (3), Dachshund (2) and 1 each of a Jack Russell, Pom-eranian, Cock Spaniel, Cairn Terrier, West Highland White Terrier, Bichon Frise, and an Italian Greyhound. The age at diagnosis ranged from 5 months to 14.7 years (median 10.4). The body weight ranged from 3.8 to 16.3 kg (median 9.4). There were 10 spayed females (50%), 9 castrated males (45%), and 1 intact male (5%). There was no significant difference in sex (P = .55), age (P = .27), or body weight (P = .48) between dogs undergoing laparoscopic cholecystectomy vs. cases requiring conversion to open cholecystectomy. Comorbidities included valvular heart disease (7), hypothyroidism (3), diabetes mellitus (2), hyperadrenocorticism (2), cardiac arrhythmia (1), tracheal collapse (1), immune-mediated thrombocytopenia (1), immune-mediated hemolytic anemia (1), seizures (1), and oral melanoma (1).

Preoperative Findings

Fourteen dogs (70%) presented with clinical signs (Table 1). Six dogs (30%) had evidence of gall bladder disease on abdominal ultrasound examination that was an unexpected finding. There was no significant difference in preoperative serum total bilirubin concentration, serum alkaline phosphatase, alanine transaminase and gamma-glutamyl transferase activities, white blood cell count, or platelet count between dogs undergoing laparoscopic vs. cases requiring conversion to open cholecystectomy (Table 2). Coagulation parameters (prothrombin time, partial thromboplastin time) were assessed in 6 dogs and were within reference intervals.

Three-view thoracic radiographs were obtained prior to surgery in 10 dogs and were considered normal, except in 1 dog with mild left atrial enlargement. Abdominal ultrasound examination was performed for all dogs. There was evidence of mucocele development with echogenic bile sludge and stellate bile patterns in 18 dogs.20 Cholelithiasis was present in 3 dogs but choledocho lithiasis was not observed in any dog. A well circumscribed echogenic mass was seen in the lumen of the gall bladder in 2 dogs and gall bladder neoplasia was suspected.

The gall bladder length and width were reported in the ultrasound examination for 12 dogs and ranged from 72 × 37 mm to 16 × 14 mm (Table 3). Subjective assessment of size was reported for 10 dogs and considered severely distended (1), prominent (1), moderately distended (4), mildly distended (3), and not dilated (1). Cystic duct diameter was recorded for 6 dogs, ranging from 3 to 7 mm (median 6). One dog had multifocal small intestinal muscularis and

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Number of dogs (%) with clinical signs at presentation in dogs undergoing laparoscopic cholecystectomy or conversion to open cholecystectomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical signs</td>
<td>Laparoscopic Median (n=14)</td>
</tr>
<tr>
<td>None</td>
<td>4 (31%)</td>
</tr>
<tr>
<td>Vomiting</td>
<td>6 (46%)</td>
</tr>
<tr>
<td>Anorexia</td>
<td>6 (46%)</td>
</tr>
<tr>
<td>Lethargy</td>
<td>5 (38%)</td>
</tr>
<tr>
<td>Polyuria/ polydipsia</td>
<td>1 (8%)</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>2 (15%)</td>
</tr>
<tr>
<td>Abdominal pain</td>
<td>3 (23%)</td>
</tr>
<tr>
<td>Depression</td>
<td>1 (8%)</td>
</tr>
<tr>
<td>Panting</td>
<td>1 (8%)</td>
</tr>
</tbody>
</table>

Table 2 | Comparison of preoperative serum biochemistry and hematology for dogs undergoing laparoscopic cholecystectomy or conversion to open cholecystectomy |
<table>
<thead>
<tr>
<th>Parameter (reference interval)</th>
<th>Laparoscopic Median (range) n=16</th>
<th>Converted cases Mean (range) n=6</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total bilirubin (0–0.2 mg/dL)</td>
<td>0.3 (0.06–1.9)</td>
<td>0.7 (0.06–3.7)</td>
<td>0.79</td>
</tr>
<tr>
<td>ALP (23–143 U/L)</td>
<td>357.6 (56–738)</td>
<td>607.6 (128–1095)</td>
<td>0.51</td>
</tr>
<tr>
<td>ALT (19–107 U/L)</td>
<td>277.2 (37–1464)</td>
<td>236 (37–788)</td>
<td>0.97</td>
</tr>
<tr>
<td>GGT (0–7 U/L)</td>
<td>20.4 (0–125)</td>
<td>18.6 (6–31)</td>
<td>0.22</td>
</tr>
<tr>
<td>White blood cell count (4.9–15.4 × 10⁹/L)</td>
<td>10.4 (5.7–19.5)</td>
<td>14.3 (5.5–35.6)</td>
<td>0.32</td>
</tr>
<tr>
<td>Platelet count (117–418 × 10⁹/L)</td>
<td>411.5 (215–784)</td>
<td>404.7 (231–530)</td>
<td>0.91</td>
</tr>
</tbody>
</table>

ALP, alkaline phosphatase; ALT, alanine transaminase; GGT, gamma-glutamyl transferase.
submucosal thickening. Four dogs had course hepatic parenchyma and 2 dogs had mild bilateral adenomegaly. Two dogs had mild bilateral chronic renal degenerative changes and 1 dog had hypoechoic nodules within the spleen.

Laparoscopic Cholecystectomy

Various surgical approaches and instrumentation was used, according to surgeon preference. All procedures used a multi-port technique. Procedures used 4 portals, 14,19 (11), 3 portals (1), 2 portals (1), and SILS™ port (7). The subumbilical camera port was a 12 mm port (11), 6 mm port (1), or 3.5 mm port (1). The left instrument port was a 12 mm port (6) or 6 mm port (14). The right instrument port used a 6 mm port (18) or 3.5 mm port (1). A second instrument portal was placed in the left cranial quadrant rather than the right cranial quadrant in 1 dog. A 3 port technique, omitting the second right sided instrument portal, was used in 1 dog and 2 ports were placed with a 12 mm port as the subumbilical camera port and a 12 mm port as the left instrument port in 1 dog. The most common port placement combined with the SILS™ port in 6/7 dogs was to place the SILS™ port in the subumbilical location, with the placement of two 6 mm instrument portals paramedian in the right and left cranial abdominal quadrants. In 1/7 SILS™ port applications, there was only 1 additional instrument port in the left cranial quadrant for placement of the fan retractor for gall bladder elevation. The use of multiple, single ports compared to the multi-channel single access port device did not significantly affect the conversion rate ($P=1.0$), nor did the total number of ports placed ($P=.4$).

The gall bladder was elevated towards the ventral body wall with an instrument placed in the left cranial abdominal instrument portal in all dogs. Elevation was performed using a 5 mm fan retractor (13), a 10 mm fan retractor (6), or a blunt probe (1).

Surgery was converted to open cholecystectomy in 1 dog after initial exploratory revealed bile leakage and gall bladder rupture. Cystic duct dissection prior to dissection of the gall bladder from the hepatic fossa was performed in 18 dogs. In 1 dog, the gall bladder was dissected from the hepatic fossa prior to cystic duct dissection, which resulted in moderate hemorrhage and a dependent gall bladder. This obscured visualization of the cystic duct and required conversion to open cholecystectomy. The method of cystic duct dissection was not recorded (1), by articulating forceps (10) or 5 mm right-angled forceps (7). Conversion was required during cystic duct dissection due to mild iatrogenic biliary leakage or an inability to safely ligate the cystic duct in 3 dogs. The cystic duct spread to a width >10 mm, precluding the use of the surgical clips and requiring conversion in 2/3 dogs.

Cystic duct ligation during laparoscopic cholecystectomy was successfully performed in the remaining 15 dogs using metallic clips (9) of which 4 were augmented with extracorporeal techniques (Roeder knot) or suture alone (6) with either intracorporeal or extracorporeal techniques (modified 4S Roeder knot). Two or more ligatures remained on the proximal end of the duct following transection in all dogs. There was no significant association between the material or method of ligation used between laparoscopic and converted cases ($P=1.0$).

<table>
<thead>
<tr>
<th>Group</th>
<th>Descriptive</th>
<th>Width $\times$ length (cm)</th>
<th>Wall thickness (cm)</th>
<th>Width (cm)</th>
<th>Common bile duct size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Converted to Open Cholecystectomy</td>
<td>1 Mild distension</td>
<td>0.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Prominent</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Severe distension</td>
<td>2.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4.4</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>7.2</td>
<td>0.6</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Laparoscopic</td>
<td>1</td>
<td>0.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Mild distension</td>
<td>&lt;0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Mild distension</td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Rounded</td>
<td>6.4</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>5</td>
<td>5</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Moderate distension</td>
<td>3.6</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>7</td>
<td>Moderate distension</td>
<td>3.4</td>
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<tr>
<td></td>
<td>8</td>
<td>3.2</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>9</td>
<td>Moderate distension</td>
<td>2.6</td>
<td></td>
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<tr>
<td></td>
<td>10</td>
<td>1.6</td>
<td>0.3</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>1.3</td>
<td>0.6</td>
<td></td>
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<tr>
<td></td>
<td>12</td>
<td>Moderate distension</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Not dilated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>4.2</td>
<td>3.1</td>
<td>0.6</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 | Preoperative appearance and dimensions of the gall bladder and bile ducts on ultrasound examination of dogs undergoing laparoscopic cholecystectomy or conversion to open cholecystectomy

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The gall bladder was dissected free from the hepatic fossa during laparoscopic cholecystectomy in 15 dogs using a bipolar vessel-sealing device (7), harmonic scalpel (4) or blunt dissection alone (4). The method of gallbladder dissection was not significantly different between laparoscopic and converted cases ($P=1.0$). Intraoperative bleeding was considered mild (14) and moderate (1) during dissection.

A specimen retrieval bag inserted through the 10 mm subumbilical port was used in 8 dogs, and not used in 6, with only mild spillage of bile during extraction in 1/6.

Laparoscopic cholecystectomy was successfully completed in 14 dogs (70%) and conversion to open cholecystectomy was required in 6 dogs (30%) due to cystic duct anatomy precluding secure ligation (2), evidence of gall bladder rupture (1), leakage from cystic duct during dissection (1), cardiac arrest (1), and dissection of the gall bladder initially prior to cystic duct dissection, which obscured visualization of the cystic duct (1). The anesthesia and surgery duration for laparoscopic cholecystectomy ranged from 120 to 285 minutes (median 175) and 72 to 180 minutes (median 108), respectively. There were significantly more intraoperative complications (yes/no) in the cases converted to open cholecystectomy ($P=.023$). The anesthesia and surgery duration for the converted open cholecystectomy cases was 135–285 minutes (median 205) and 75–175 minutes (median 103), respectively. There was no significant difference in anesthesia or surgery duration between laparoscopic cholecystectomy and cases requiring conversion to open cholecystectomy.

**Histologic and Microbiologic Findings**

Histologic examination of the gall bladder was performed in all dogs and showed evidence of mucosal cystic hyperplasia, cholecystitis or mucocele formation in 18 dogs with 3/18 having concurrent cholelithiasis. The remaining 2 dogs had a papillary adenoma in the gall bladder (1) and mural hemorrhage and fibrosis consistent with previous rupture or infarction (1). Both these dogs had successful laparoscopic cholecystectomy. Liver biopsy was performed in 18 dogs with cholestasis with biliary hyperplasia, portal hepatitis, and cholangitis (17) and no abnormalities (1). Bacterial culture of the gall bladder contents resulted in no growth (8), *Enterococcus* sp. (2), *Escherichia coli* (2), *Lactobacillus acidophilus* (1), or *Clostridium* sp. (1).

**Postoperative Complications**

One minor and 2 major complications were noted postoperatively and there was no significant difference in the frequency of postoperative complications between the laparoscopic and converted cases ($P=1.0$). One dog undergoing laparoscopic cholecystectomy had marked bruising of the ventral abdomen 4 days postoperative, despite normal coagulation parameters at the time of presentation. No intervention was required and the bruising resolved by 10 days postoperative. One dog undergoing open cholecystectomy developed pancreatitis and ketosis, which resolved with medical management. The third dog had undergone laparoscopic cholecystectomy and required surgical revision due to hepatic duct leakage and bile peritonitis 6 days postoperative. There had been no intraoperative complications noted during the initial procedure in this dog except for mild bleeding from the quadrate lobe which resolved without intervention. Two modified Roeder extracorporeal knots were used to ligate the cystic duct, prior to transection between them. An additional ligature was placed on the cystic duct following transection using a pretied ligature loop (Surgitie™). At revision, a partial quadrate liver lobectomy was performed to resolve a leaking hepatic duct. This dog recovered without further complication and, at 446 days postoperative, was clinically normal despite persistent elevations in serum alanine transaminase activity.

**Outcome**

Hospitalization duration ranged from 2 to 7 days (median 2) and all dogs were discharged from hospital. The hospitalization duration was not significantly different for dogs undergoing laparoscopic cholecystectomy vs cases requiring conversion to open cholecystectomy (laparoscopic: range 24–96 hours, median 27 hours, open: range 24–49 hours, median 27 hours; $P=.3$). All dogs were discharged with analgesics (tramadol, buprenorphine and/or meloxicam), and continued on ursodeoxycholic acid and s-adenosylmethionine/silybin supplements, if previously prescribed. Antibiotics were continued or started in 11 dogs (clindamycin, amoxicillin/clavulanic acid, enrofloxacin, metronidazole, and chloramphenicol).

Short-term outcome was available for 19 dogs (14 laparoscopic, 5 open) and long-term outcome for 16 dogs (12 laparoscopic, 4 open) with follow-up ranging from 10 to 900 days (median 268). All dogs with clinical signs attributable to gall bladder disease had resolution of these signs in 1–14 days, except for the dog that represented 6 days after laparoscopic cholecystectomy for acute abdominal pain due to bile peritonitis. The duration until resolution of clinical signs was significantly shorter for dogs undergoing laparoscopic cholecystectomy vs cases requiring conversion to open cholecystectomy ($P=0.047$). Follow-up serum biochemistry at 2 days to 3 months showed persistent elevation of liver enzyme activity in 12 dogs. Long-term outcomes were reported for 19 dogs with survival to follow-up in 14 dogs (74%), euthanasia or death for unrelated disease in 5 dogs (hepaticobdome, urinary bladder transitional cell carcinoma, renal failure, progressive endocrine disease, and thrombocytopenia). There was no significant difference in survival time for dogs undergoing laparoscopic cholecystectomy vs cases requiring conversion to open cholecystectomy ($P=.37$).

**DISCUSSION**

Laparoscopic cholecystectomy was performed successfully in 70% of dogs in this cohort using a multi-port technique and 95% of dogs that were discharged from hospital had resolution of clinical signs. Only 1 dog required revision.
surgery, in this case for hepatic biliary duct leakage. Previously described criteria for case selection for laparoscopic cholecystectomy recommended dogs have no evidence of biliary obstruction on abdominal ultrasound examination or on serum total bilirubin concentration.14 The current recommendation for open cholecystectomy is to ensure patency of the common bile duct with an enterotomy over the major duodenal papilla and the introduction of a catheter to flush the common bile duct.19 During laparoscopic cholecystectomy, the patency of the common bile duct cannot be assessed, although this is done during laparoscopic cholecystectomy in people.34 Thus, it is important for surgeons considering laparoscopic cholecystectomy in dogs, to be confident that there is no obstruction of the common bile duct. Malek et al reported no significant association on survival for dogs undergoing open cholecystectomy for gall bladder mucocele where the common bile duct was catheterized to ensure patency compared to those dogs where common bile duct patency was not assessed.25 However, these results may be biased based on intraoperative findings.25 In our study, 6 dogs had elevated serum total bilirubin concentration; however, postoperative complications related to biliary obstruction were not observed. There was no difference in the serum total bilirubin concentration for dogs undergoing laparoscopic cholecystectomy vs. dogs requiring conversion to open cholecystectomy. Multiple studies have failed to find significant differences in serum total bilirubin concentration, and serum alkaline phosphatase, alanine transaminase and gamma-glutamyl transferase activities, in dogs undergoing open cholecystectomy, regardless of outcome.25,46 The findings of previous studies along with the results of our study suggest that dogs with mild elevations in serum total bilirubin concentrations may be acceptable candidates for laparoscopic cholecystectomy.

Shetland Sheepdogs were overrepresented (8/20) in our study and the most common clinical signs at presentation for all dogs was vomiting, lethargy, and reduced food intake, all findings consistent with previous reports.21,23–26 Comorbidities were noted in the majority of dogs, including hyperadrenocorticism, hypothyroidism, and diabetes mellitus. There is a known association of gall bladder mucoceles with endocrinopathies although the pathogenesis remains unclear.24–26

The reports on findings of the abdominal ultrasound examination were inconsistent, prohibiting clear assessment of gall bladder size as selection criteria for laparoscopic cholecystectomy. Only 3/6 dogs that were converted to open cholecystectomy had gall bladder size recorded, all of which were marked enlarged. In comparison, most dogs undergoing successful laparoscopic cholecystectomy had mild enlargement of the gall bladder. Besso et al reported the average gall bladder volume of dogs with mucoceles was enlarged at 87 mL, compared to the approximated normal gall bladder volume in a medium sized dog of 15 mL.30 We did not document gall bladder volume. Gall bladder wall thickness is not a good indicator of mucosal hyperplasia or cholecystitis in dogs,20,26 although in people, gall bladder wall thickness can be predictive of laparoscopic operability.27,28 Two dogs that required open cholecystectomy had a gall bladder wall thickness greater than normal (2–3 mm).21,29

Preoperative abdominal ultrasound examination showed evidence of localized inflammation around the cystic duct in 1 dog. Initial laparoscopic exploration showed this dog had a gall bladder rupture and required immediate conversion to open cholecystectomy. Evidence of bile leakage during open cholecystectomy has no impact on survival and is usually a localized nonseptic bile peritonitis21,25,36 but correct identification preoperatively is important to determine appropriate laparoscopic cholecystectomy candidates.14 In people, the presence of pericholecystic fluid and acute cholecystitis is not a contraindication for laparoscopic cholecystectomy but is associated with higher conversion rates.9,13 This dog could have been ruled out as a candidate based on the preoperative ultrasound findings; however, another dog with evidence of hyperechoic fat and localized inflammation around the gall bladder on abdominal ultrasound examination did not have any evidence of gall bladder rupture or peritonitis and was discharged after laparoscopic cholecystectomy <32 hours postoperative. These dogs did, however, have different clinical signs on presentation; the former with vomiting and lethargy and moderate elevations in serum biochemistry parameters, the latter without clinical signs and minimal serum biochemistry changes. Ultrasound examination is considered a sensitive and specific tool in detecting bile peritonitis at 85.7 and 100%, respectively.24 but the outcomes of these 2 dogs with similar findings on ultrasound examination highlight the complexity of case selection for laparoscopic cholecystectomy. Clinical presentation must be considered in conjunction with findings on ultrasound examination (gall bladder size, gall bladder wall thickness, gall bladder wall integrity, and cystic duct size).

A case series of laparoscopic cholecystectomy in 6 dogs first described a surgical technique for laparoscopic cholecystectomy.14 Variations of this technique were used by different surgeons in our study but no method of approach, dissection or ligation was associated with conversion to open cholecystectomy. Single incision laparoscopic cholecystectomy in people is purported to improve cosmesis, reduce morbidity, and minimize hospital stay.31,32 Gonzalez-Gasch and Monnet reported on the SILS™ port system for elective laparoscopic procedures in dogs, citing reduced surgery duration and complication rate compared to a multi-port technique.33 Port placement, number and size was not associated with conversion; however, a 12 mm subumbilical camera portal and 12 mm instrument portal in the left cranial quadrant appeared beneficial for successful laparoscopic cholecystectomy. The 12 mm subumbilical portal allows insertion of a 5 mm laparoscope, an instrument for dissection if the angle is advantageous and a specimen retrieval bag for gall bladder extraction through incisional enlargement on ventral midline. The introduction of a 10 mm fan retractor in the left paramedian portal for gall bladder elevation subjectively appeared to improve visualization of the cystic duct. The shift from using a 5 to a 10 mm fan retractor was made as we gained experience, and this assisted in elevation of moderately distended gall bladders, without damage to...
adjacent liver parenchyma. The larger width of the 10 mm fan blades may create less pressure and tearing of hepatic parenchyma than the 5 mm blades. The use of a SILSTM port may minimize surgery duration and morbidity through a reduction in portal incisions33 while allowing for extraction of the gall bladder without further extension of an instrument portal. The SILSTM port was used with a left paramedian portal in 7 dogs, which the authors believe is essential for gall bladder elevation.

We believe the use of articulating forceps, initially designed for use in the SILSTM port to reduce instrument clashing during cystic duct dissection, improved the angle for cystic duct dissection compared with straight 5/10 mm right angle forceps. By deflecting the forceps to 70–90°, a safe angle for dissection around the cranial aspect of the cystic duct was created and allowed the entire width of the duct to be encompassed, especially in dogs where the duct was >5 mm. While the articulating forceps are helpful, straight right-angled forceps can also be used for safe dissection of the cystic duct.

Iatrogenic injury of a biliary duct during dissection is reported in 0.3–2.7% of people undergoing laparoscopic cholesctomy.10,34 Risk factors include aberrant anatomy, inflammation, and surgeon inexperience.34 Multiple imaging modalities are proposed to facilitate dissection including intraoperative cholangiography, intraoperative laparoscopic ultrasound examination, and near-infrared fluoroscopic cholangiography.10,35 None of these imaging modalities were used in this study but may be examined in the future.

If biliary duct injury is identified intraoperatively, it should be addressed immediately, which in people involves direct laparoscopic repair.33 Cystic duct leakage was observed in 1 dog during cystic duct dissection. This leak was mild, identified quickly and well contained. Although not required, this could have been addressed during laparoscopy with the placement of ligatures or endoscopic clips.

The occurrence of intraoperative complications was significantly more frequent in dogs undergoing open cholecystectomy. This is not unexpected since the reason for open conversion was a complication during laparoscopy. To determine an unbiased frequency of complication for laparoscopic vs. open cholecystectomy, a prospective, randomized trial, controlling for case complexity, would be required. We had a 30% conversion rate to open cholecystectomy but believe this rate could be further reduced with careful case selection and familiarity with multiple techniques for laparoscopic cystic duct ligation. We used metallic clips or suture material to occlude the cystic duct. In people, the use of a self-locking polymer clip (Hem-O-Lok clipTM Weck, Research Triangle Park, NC) is preferred over concern for migration or dislodgement of the metallic clips.36–38 The polymer clip has not been evaluated in laparoscopic cholecystectomy in dogs, but clinical reports have been favourable.39 The use of a biodegradable polymer clip (Laparo clipTM Covidien Inc) has also been investigated,40 which may be preferential to avoid potential nidus stone formation in the cystic duct.40 The best method of cystic duct ligation cannot be discerned from our study or others due to the lack of randomized control trials.41 Bile peritonitis did develop 6 days postoperative in 1 dog undergoing laparoscopic cholecystectomy but was due to inadvertent hepatic duct trauma rather than suture slippage from the transected cystic duct. While suture or surgical clips appears appropriate for ligation of the cystic duct during laparoscopic cholecystectomy in dogs, the laparoscopic surgeon should be capable of performing other methods of cystic duct ligation, especially for very dilated cystic ducts. It is imperative that whatever method of cystic duct ligation is performed results in complete occlusion of the entire width of the duct, which is not always possible with laparoscopic surgical clips.42 Conversion to open cholecystectomy was required in 2 dogs due to spreading of the cystic duct beyond the capacity of a 10 mm surgical clip. Had intracorporeal or extracorporeal suture techniques or a self-locking polymer clip been used, conversion may have been avoided. The use of a vessel-sealing device on the ligation and transection of cystic ducts in healthy canine cadavers is comparable to 10 mm metallic surgical clips.42 The vessel-sealing device is a rapid and effective way to ligate and transect the cystic duct but in vivo investigation is required.

The gall bladder was dissected free from the hepatic fossa prior to cystic duct isolation and dissection in 1 dog during laparoscopy. This fundus-first technique is usually performed in open cholecystectomy19 and is used in people during laparoscopy where excessive adhesions make access to the cystic duct difficult.43,44 Differences in the pathology of gall bladder disease in dogs19,22 compared to people2–12 make this less viable since most dogs present for cholecystectomy of gall bladder mucocele, where the gall bladder is engorged and heavy with inspissated bile. The weight of the free gall bladder after dissection, combined with the difficulty of retracting the heavy gall bladder ventrally and the presence of hemorrhage from the hepatic fossa, make access to the cystic duct difficult. We recommend a blunt instrument (fan retractor, blunt probe and Cuschieri retractor) be used for gall bladder elevation when dissecting the cystic duct because of the fragile gall bladder wall, especially for gall bladder mucoceles. This is in contrast to the approach in people where the gall bladder is suspended with a transabdominal suture or grasping instrument.10,32,34

One dog had a cardiac arrest during cystic duct ligation. This dog was stable preoperative with clinical signs of abdominal pain and mild changes on preoperative serum chemistry analysis. Some dogs with hepatobiliary disease are poor anesthetic candidates due to hypotension associated with vagal response during gall bladder manipulation, and endotoxemia secondary to extra-hepatic biliary obstruction.45,46 Subjects with postoperative hypotension are reported with poorer outcomes25,30,46 but a recent retrospective study did not find anesthetic complications in dogs undergoing cholecystectomy to be any different from dogs undergoing other hepatic surgery.45 Whether the dog in our study had a vagal-induced bradycardic event or an anesthetic-related event is unknown.

The specimen retrieval bag was used in only 8 dogs, although it is recommended for the extraction of the gall bladder to minimize spillage of bile, and allow aspiration of bile contents once partially exteriorized to collapse the
gall bladder and allow it to be removed through a smaller incision.\textsuperscript{14}

Extended surgery duration is referenced as a disadvantage of some laparoscopic procedures.\textsuperscript{2,3,5,8}\ Expertise impacts surgery duration in laparoscopic cholecystectomy in people\textsuperscript{47,48} but duration is also related to severity of disease. Duration of surgery in our study was comparable to previous reports for laparoscopic\textsuperscript{14} and open cholecystectomy.\textsuperscript{25}

People have a faster convalescence and shorter hospital stay after laparoscopic cholecystectomy.\textsuperscript{11,49} The duration of hospitalization in our study was not different for dogs undergoing laparoscopic cholecystectomy compared to cases that were converted, although resolution of clinical signs was shorter for dogs undergoing laparoscopic cholecystectomy. Interpretation of these results is inconclusive as results may varying according to disease severity.\textsuperscript{24,50}

Predictive factors for conversion to open cholecystectomy in people include increased white blood cell count, ultrasound findings of pericholecystic fluid, low serum albumin, elevated serum total bilirubin, right cranial abdominal pain during ultrasound, being male, obesity, comorbidities, and the presence of a thickened gall bladder wall.\textsuperscript{13,28,31,49} Since the pathogenesis of disease differs in canines,\textsuperscript{9–12,19,22} extrapolation of risk factors from people is not possible; however, careful consideration of preoperative imaging and the clinical status of the dog is imperative for successful laparoscopic cholecystectomy. We did not find any factors related to conversion to open cholecystectomy in our study.

Four of 6 conversions in our study were related to technical issues, lack of confidence performing intracorporeal or extracorporeal suture techniques when the cystic duct was too wide for metallic clips, dissection of the gall bladder prior to the cystic duct imped ing visualization, and early conversion due to biliary leakage. These situations potentially represent a learning curve in the procedure and it is expected lower conversion rates for laparoscopic cholecystectomy can be expected as experience and technical aptitude improve.

This study is limited by possible bias introduced by surgeon preferences in case selection and surgical technique. Laparoscopic cholecystectomy is a relatively new procedure in veterinary medicine and various centers are developing and personalizing the technique. As such, we were only able to examine a small sample size which limits the power of comparisons.

We had good success with laparoscopic cholecystectomy in a small cohort of dogs. Our results demonstrate that laparoscopic cholecystectomy can be performed in dogs with uncomplicated gall bladder disease, with a low complication rate and an acceptable conversion rate. We expect conversion rates will decrease with gains in clinical experience and advances in training, as noted in human surgery.\textsuperscript{10,34}\ Appropriate case selection is imperative to ensure there is no evidence of extra-hepatic biliary obstruction or gall bladder leakage to limit the risk of conversion. The surgeon considering laparoscopic cholecystectomy should be familiar with a variety of methods for cystic duct dissection and ligation to avoid complications and reduce the rate of conversions.

**DISCLOSURE**

The authors declare no conflicts of interest related to this report.

**REFERENCES**


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