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CLINICAL RESEARCH

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Laparoscopic resection of pancreatic masses in 12 dogs

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Abstract

Objective: To describe the surgical management and outcome of dogs undergoing laparoscopic pancreatic mass resection (LPMR).

Study design: Retrospective study.

Animals: Twelve client-owned dogs.

Methods: Data collected from medical records of dogs that underwent LPMR between 2012 and 2023 included signalment, clinical signs, mass location within pancreas, preoperative diagnostic imaging, laparoscopic approach, number of portals and device type used for LPMR, operating time, complications and clinical outcome.

Results: Pancreatic tumors were located in the left lobe (7), in the right lobe (4) and in the body of the pancreas (1). A 3- or 4-port technique was used in nine and three dogs, respectively. LPMR was performed with the Ligasure in nine dogs, a harmonic scalpel in two dogs and an endoscopic stapler in one dog. The procedure was performed successfully, with no conversion to open laparotomy, in all cases with a median operating time of 69 min. Postoperative complications occurred in four dogs, which resolved with medical treatments. All dogs survived the surgical procedure, were discharged from the hospital and alive a minimum of 90 days postoperatively. The final follow-up time ranged between 105 and 245 days (median 147). Histopathological diagnosis included insulinoma (9) and pancreatic carcinoma (3).

Conclusion: LPMR was performed successfully using a 3- or 4-port technique and was associated with a low complication rate and a good clinical outcome.

Clinical significance: LPMR may be considered as an alternative to open celiotomy in dogs, particularly for small tumors located in the distal aspect of the pancreatic lobes.

1 | INTRODUCTION

Laparoscopic pancreatic resection in humans is a surgical procedure indicated for the treatment of inflammatory disease, trauma, congenital abnormalities, pancreatic tumors and neoplasms of the duodenum, ampulla of Vater and lower bile duct.[1–3] In human medicine, laparoscopic distal pancreatectomy has become a safer and

more feasible procedure compared with open distal pancreatectomy. The reported benefits include decreased blood loss, shorter hospital stays, decreased analgesic requirements and a more rapid return to a regular diet, with no increase in the postoperative complication rate or effect on oncologic outcome.[4] Nevertheless, the selection of appropriate case criteria plays an important role in improving the postoperative outcome of pancreatic resection achieved with a minimally-invasive technique.[5–7] Compared with open surgery, laparoscopic procedures are associated with less postoperative pain and surgical stress and offer the advantages of image magnification and quicker postoperative recovery.[8–11] However, the cost of the equipment, the potentially longer surgery time and the associated learning curve are all among its disadvantages.[8] In an experimental study, the recovery of the gastrointestinal transit and the stress response in dogs undergoing laparoscopic and conventional distal pancreatectomy were compared.[12] The laparoscopic procedure resulted in a more rapid recovery of gastrointestinal transit and less stress for the dogs.[12] Laparoscopic partial pancreatectomy (LPP) was used with a good clinical outcome and no surgical complications for the treatment of a pancreatic β cell tumor located in the left lobe of the pancreas in a dog.[13] A 3-port technique for LPP was recently described in a cat with exocrine pancreatic carcinoma.[14] The objective of the present study was to determine the success of laparoscopic pancreatic resection mass (LPMR) in dogs, to describe three different laparoscopic approaches in relation to the location of the tumor and to evaluate complications and outcomes. We hypothesized that LPMR could be performed successfully in dogs, particularly for masses located in the right or the left limb of the pancreas.

2 | MATERIALS AND METHODS

2.1 | Case selection and medical record information

Medical records from five referral veterinary hospitals were searched to identify dogs diagnosed with pancreatic tumors from 2012 to 2023. The surgical procedures were performed by four different veterinary surgeons (E.P, F.J.L.A, D.G.R, F.J.P.D) and one board-certified surgeon (F.C.). The criteria for inclusion in the study were dogs with comprehensive clinical records and a pancreatic tumor identified via computed tomographic angiography (CTA) or abdominal ultrasonography (AUS) excised laparoscopically. Dogs that underwent open pancreatectomy were excluded, but this did not include dogs that underwent conversion of the laparoscopic approach. In dogs with insulinomas, only those classified as stage I, with no evidence of metastases, assessed via CTA or AUS were included; dogs with stage II or III insulinomas were excluded.[15] Data retrieved from the clinical records included signalment, clinical history, age, bodyweight, clinical signs, mass location, mass size measured with CTA or AUS, pre- and postoperative glucose concentration, laparoscopic approach and patient positioning in relation to the location of the mass, number of portals, device type used for LPMR, operating time, intra- and postoperative complications and clinical outcome. Intraoperative complications, surgery duration and postoperative complications were recorded. Complications were classified as minor when medical or surgical treatment was not needed and major when medical or surgical treatment was required. All dogs underwent a clinical examination and AUS within the first 12 h postoperatively (median time 6 h; range 3–12 h) to check for signs of pancreatitis or peritoneal reactivity. The choice of postoperative medication depended on the surgeon's preference and included an analgesic (methadone 0.2 mg/kg intravenous every 4–6 h for 48 h), an acid reducer (ranitidine 1 mg/kg intravenous every 12 h for 1 week), an antiemetic (maropitant 1 mg/kg every 24 h subcutaneously) and in few cases antibiotics (amoxicillin and clavulanic acid, 12.5 mg/kg orally every 12 h for 1 week).

Additional clinical rechecks that included physical examination and AUS were performed within 90 days (within 1 week and every 30 days until 90 days postoperatively) after surgery in all dogs. When possible, the survival time of the dogs was determined during appointment dates for physical examination and/or telephone conversations with the owners.

2.2 | Surgical technique

2.2.1 | Laparoscopic technique for resection of pancreatic masses of the right lobe

The skin was aseptically prepared and the dog was initially positioned in dorsal recumbency to facilitate the establishment of the first portal. The other two portals were placed with the dog in left lateral recumbency. Alternatively, all the ports were placed with the dog positioned directly in left lateral recumbency; positioning depended on the surgeon's preference (Figure 1).

A 3-portal laparoscopic technique was used. Abdominal access was obtained using a sutureless modified Hasson technique. A 5 mm incision through the skin and subcutaneous tissues was made 2 cm caudal to the umbilicus. A 5 mm laparoscopic cannula (Kii Sleeve with Advanced Fixation, Applied Medical or Ternamian

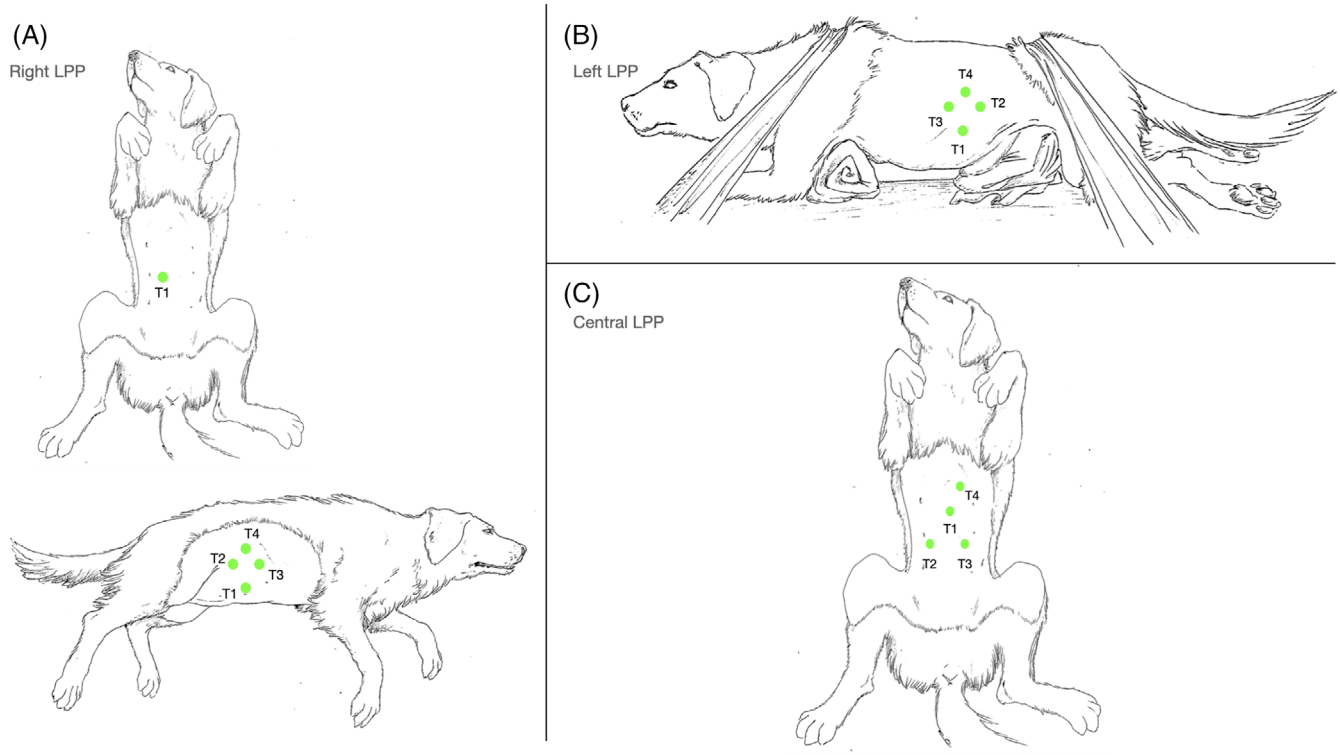

FIGURE 1 (A) Placement of portals and positioning of dogs for laparoscopic partial pancreatectomy of the right lobe. Dogs were first positioned in dorsal recumbency to establish the telescope portal T1 and then repositioned in left lateral recumbency for placement of the other portals in the right flank (right paramedian approach); T1 telescope portal, T2 left-hand portal, T3 right-hand portal, T4 retraction portal. (B) Placement of portals and positioning of dogs for laparoscopic partial pancreatectomy of the left lobe. Dogs were positioned in sternal recumbency and two cushions were used to elevate the chest and the pelvic area (left flank approach); T1 telescope portal, T2 right-hand portal, T3 left-hand portal, T4 retraction portal. (C) Placement of portals and positioning of dogs for laparoscopic partial pancreatectomy of the body of the pancreas. Dogs positioned in dorsal recumbency (ventral approach); T1 telescope portal, T2 left-hand portal, T3 right-hand portal, T4 retraction portal.

EndoTIP cannula Karl Storz Endoscopy-America) was introduced into the abdomen, and insufflation with CO_2 was started with an intra-abdominal pressure of 8 mmHg. Intra-abdominal pressure ranged from 6 to 8 mmHg, depending on the surgeon's preference. The dog was then repositioned in left lateral recumbency, and the right lobe of the pancreas was visualized laparoscopically using a 5-mm 30° laparoscope (Hopkins Forward-Oblique Telescope, Karl Storz, Tuttlingen, Germany). The second and third portals (two 5 mm cannulae, Kii Sleeve with Advanced Fixation, Applied Medical or Ternamian EndoTIP cannula Karl Storz Endoscopy-America) were positioned under laparoscopic guidance. T2 (left-hand portal) and T3 (right-hand portal) were placed in the right lateral abdomen in a triangulating pattern around the pancreatic mass. T2 was placed in the caudal abdominal quadrant 5–8 cm below and 5–10 cm lateral to the telescope portal in the lower right quadrant. T3 was placed 5–8 cm cranial and 5–10 cm lateral to the telescope portal and just caudal to the ipsilateral costal arch. When required, a fourth portal (5 mm cannulae, Kii Sleeve with Advanced Fixation, Applied Medical or Ternamian EndoTIP cannula Karl Storz Endoscopy-America) was placed 5–8 cm dorsal to T1. After laparoscopic visualization of the mass, the pancreas was manipulated with atraumatic laparoscopic grasping forceps (Clickline Grasping forceps, Karl Storz, El Segundo, CA or Epix Laparoscopic Grasper, Applied Medical), and the mass was carefully separated from the surrounding tissues with a harmonic scalpel blade (Ultracision Harmonic Scalpel, Ethicon Endo-Surgery, Cincinnati, Ohio) or Ligasure sealing device (LigaSure 5 mm sealer and divider connected to a LigaSure or Force Triad generator; Covidien, Mansfield, Massachusetts). The ultrasonically activated scalpel was set at a power level of 3 (75% of full power) in the knife mode.[16] A large part of the right limb of the pancreas where the mass was located was then freed from the duodenum and mesoduodenum. When resection of the mass from the right pancreatic limb caused a mesenteric defect large enough to result in a transmesenteric internal hernia, it was closed with a 4–0 monofilament absorbable suture in an intracorporeal simple

interrupted suture pattern. The abdomen was inspected for hemorrhage. The mass was placed in the specimen retrieval device for abdominal removal (Figure 2). The cannula was withdrawn from the body wall, and the specimen retrieval bag containing the mass was exteriorized through the portal incision.

After evacuation of the pneumoperitoneum, the portals were closed routinely using a monofilament absorbable suture material in a simple continuous suture pattern in the muscular fascia and in an intradermal suture pattern in the skin.

2.3 | Laparoscopic technique for resection of pancreatic masses of the left lobe

Preoperative surgical preparation of the dogs was the same as previously described. The dog was positioned in sternal recumbency, supported by two cushions. One cushion was placed between the pelvic limbs to support the pelvis and the other cushion was placed under the sternum to elevate the chest, as described by Naan et al.[17] Creation of T1 was done using either with the Verres needle technique immediately caudal to the last rib in the ipsilateral paralumbar fossa or with a modified Hasson technique. T1 was positioned in the middle of the left lateral flank, 2–3 cm under the epaxial abdominal muscles. Next, a 5 mm 30° telescope (Hopkins Forward-Oblique Telescope, Karl Storz, Tuttlingen, Germany) was introduced through T1 and abdominal insufflation with CO_2 was started. The cannulae application and the method for abdominal CO_2 insufflation were the same as previously described. All cannulae used in the procedure were 5 mm in diameter. T2 and T3 were placed in cranial and caudal positions, respectively, slightly dorsal to T1. When required, T4 was placed 5–8 cm dorsal to T1 (Figure 1B). A nasogastric tube was introduced through the nose of the dog and advanced to the stomach to remove gas, thereby creating a larger working space. After abdominal exploration, the omental sac was opened to gain access to the left limb of the pancreas, which is located deep and medial to the left kidney. Manipulation of the pancreas was performed with atraumatic laparoscopic grasping forceps (Clickline Grasping forceps, Karl Storz, El Segundo, CA or Epix Laparoscopic Grasper, Applied Medical). After the caudal part of the left pancreatic lobe was visualized, it was freed from the

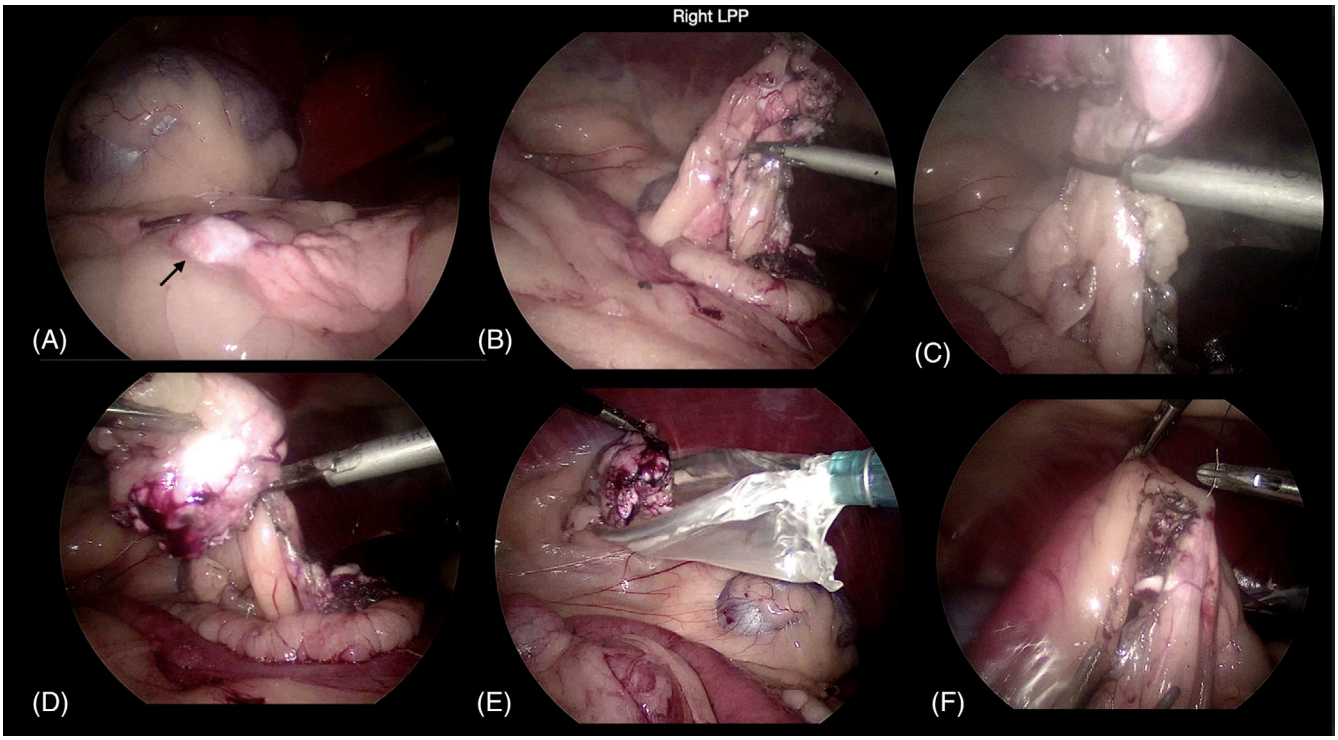

FIGURE 2 Laparoscopic technique for resection of pancreatic masses of the right lobe: (A) Laparoscopic visualization of a neoplasm located in the pancreatic lobe (black arrow). (B) Initial dissection of the parenchyma around the mass with an ultrasonically activated scalpel. (C) Dissection of the mass from the mesenteric tissue with an ultrasonically activated scalpel. (D) Final resection of the tumor with an ultrasonically activated scalpel. (E) Positioning of the mass in the specimen retrieval bag. (F) Intracorporeal suturing of the mesenteric defect.

surrounding tissues using the Ligasure vessel sealing device. The mass attached to the left lobe of the pancreas was suspended with atraumatic laparoscopic grasping forceps, and the left lobe of the pancreas was excised with the Ligasure device. The abdomen was inspected for hemorrhage, and the excised part of the pancreas containing the mass was placed in a specimen retrieval device. Removal of the cannulae, evacuation of the pneumoperitoneum and closure of the portals were done as previously described (Figure 3).

2.4 | Laparoscopic technique for resection of a neoplasm located in the body of the pancreas

Preoperative surgical preparation of the dogs was the same as previously described. The dog was positioned in dorsal recumbency. T1 was placed 1 cm caudal to the umbilicus using a modified Hasson technique. A 5 mm 30° telescope (Hopkins Forward-Oblique Telescope, Karl Storz, Tuttlingen, Germany) was then introduced through T1 and the abdomen was insufflated with CO_2 starting with an intra-abdominal pressure of 8 mmHg. T2 was placed 3 cm lateral to and to the left of the camera portal and T3 was positioned 4 cm lateral to and to the right of the camera portal, in a triangulating pattern. When required, T4 was placed in a subxiphoid position (Figure 1C). T1, T2 and T4 were 5 mm portals and T3 was a 12 mm portal. All the types of cannulae used in this procedure were the same as previously described. To completely explore the body of the pancreas, it was necessary to open the greater omentum by dissecting the tissues with 5 mm laparoscopic Maryland forceps (Clickline Maryland forceps, Karl Storz). Once the mass was visualized, it was freed from the surrounding tissues. The tissues around the mass were then grasped with laparoscopic Babcock forceps (Clickline Babcock forceps, Karl Storz), and two 30-mm endoscopic linear staplers containing 2.5-mm staples (Endo GIA; Medtronic) were used to resect the mass from the body of the pancreas (Figure 4). The abdomen was inspected for hemorrhage, and the mass was placed in a specimen retrieval device. Removal of the cannulae, evacuation of the

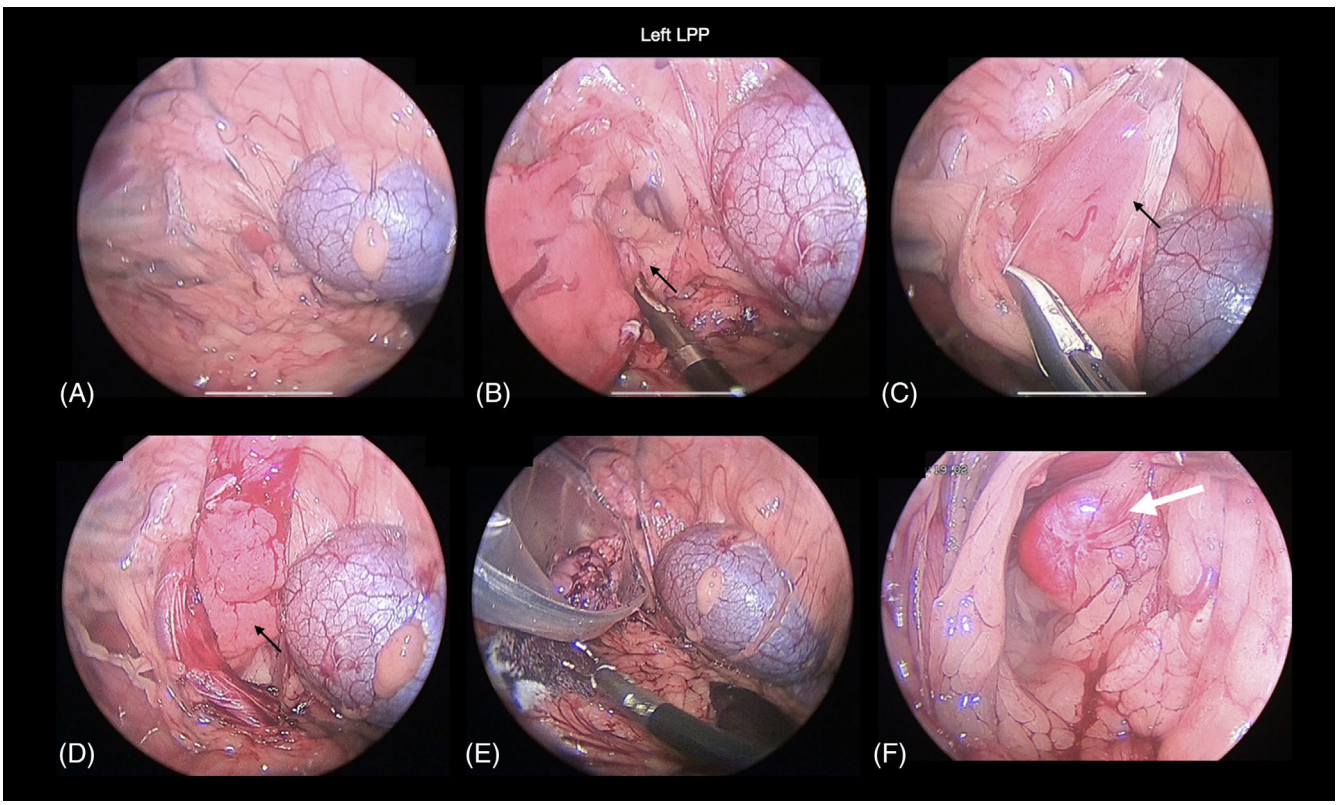

FIGURE 3 Laparoscopic technique for resection of pancreatic masses of the left lobe. (A) Initial laparoscopic view of the approach to the left lobe of the pancreas. (B) Visualization of a tumor in the left lobe of the pancreas (black arrow). (C) Fine dissection of the tissues surrounding the left lobe of the pancreas using Ligasure sealing device. (D) Complete dissection of the left lobe of the pancreas (black arrow). (E) Positioning of the neoplasm in the specimen retrieval bag. (F) Visualization of an enlarged lymph node of the pancreas (white arrow) before extirpation.

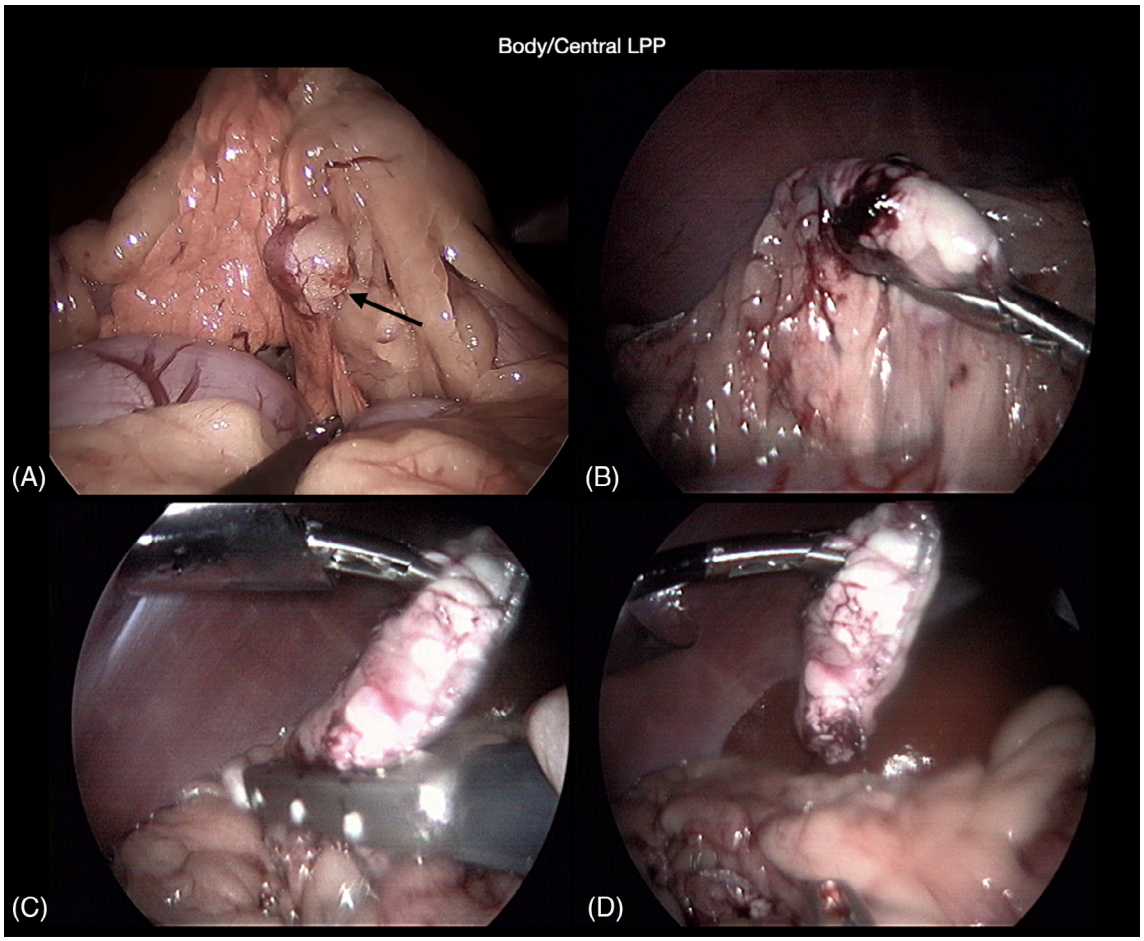

FIGURE 4 Laparoscopic technique for resection of a neoplasm located in the body of the pancreas. (A) Laparoscopic visualization of a neoplasm located in the body of the pancreas (black arrow). (B) Suspension and isolation of the mass with atraumatic grasping forceps. (C) Resection of the tumor with a 30-mm endoscopic linear stapler. (D) Visualization of the resected mass.

pneumoperitoneum and closure of the portals were performed as described above.

3 | RESULTS

3.1 | Population data, clinical signs, and diagnostic investigations

A total of 12 dogs met the inclusion criteria for the study. Two other dogs were excluded from the study because they had stage II insulinoma. There were six intact male and six spayed female dogs. At the time of the surgery, the median age was 112 months (range, 92–156 months) and the median bodyweight was 23.1 kg (range, 7–42 kg). The breeds included Poodle (2/12), mixed breed (2/12), Boxer (1/12), Australian Shepherd (1/12), Labrador retriever (1/12), Great Dane (1/12), Cocker Spaniel (1/12), Greyhound (1/12), Griffon (1/12), and Brittany Spaniel (1/12). On physical examination, abdominal palpation elicited mild pain in two dogs (2/12). Clinical signs included weakness (9/12), seizures (7/12), collapse (6/12), ataxia (6/12), vomiting (5/12), tremors (4/12), anorexia (3/12) and exercise intolerance (3/12). Preoperative hematological analysis was carried out in all dogs and included a complete blood cell count and serum biochemistry that included the concentration of glucose (median 36 mg/dL, range 22–59 mg/dL), fructosamine (median 232 μmol/L, range 215–260 μmol/L), and insulin (median 37.1 mlU/L, range 10.5–40.2 mlU/L). Preoperative diagnostic imaging included AUS in one dog (1/12) and CTA in eight dogs (8/12), while AUS was performed first followed by CTA in the other 3 dogs (3/12). The pancreatic tumor was located in the distal part of the right lobe in four dogs (4/12), in the distal left limb of the pancreas in seven dogs (7/12) and in the body of the pancreas in one (1/12) dog (Table 1). A three-portal technique was used in nine dogs (3 with a tumor in the right lobe and 6 with a tumor in the left lobe). The remaining three dogs (1 with a tumor in the left lobe, 1 with a tumor in the

TABLE 1 Surgical procedures, conversions, complications, and follow-up in 12 dogs undergoing laparoscopic resection of pancreatic mass.

Case	Pancreatic mass location	Imaging modality	Metastatic lesions	Number of ports	Vessel sealing device	Complications	Liver biopsy (LB)/ lymphadecetomy (LA)	Surgery Time (min)	Lesion size (mm)	Histopathological diagnoses	Clinical Follow-up (days)
1	Right lobe distal	CTA + AUS	No	3	Ligasure	None	No	50	31	Insulinoma	122
2	Left lobe distal	CTA + AUS	No	3	Ligasure	None	LA	55	33	Insulinoma	153
3	Left lobe distal	CTA + AUS	No	4	Ligasure	Transitional hyperglycemia	LA	55	29	Insulinoma	122
4	Left lobe distal	AUS	No	3	Ligasure	Vomiting	No	35	30	Pancreatic carcinoma	121
5	Right lobe distal	CTA	No	3	Ligasure	None	LB	41	24	Pancreatic carcinoma	124
6	Body	CTA	No	4	Stapler suture	None	LB	100	12	Insulinoma	120
7	Right lobe distal	CTA	No	4	Harmonic scalpel	None	No	60	65	Insulinoma	244
8	Left lobe distal	CTA	No	3	Ligasure	None	No	93	32	Insulinoma	245
9	Left lobe distal	CTA	No	3	Ligasure	Seizures	No	82	33	Insulinoma	122
10	Left lobe distal	CTA	No	3	Ligasure	None	No	100	25	Insulinoma	183
11	Left lobe distal	CTA	No	3	Ligasure	None	No	90	33	Insulinoma	107
12	Right lobe distal	CTA	No	3	Harmonic scalpel	Pancreatitis	LB	70	32	Pancreatic carcinoma	105

right lobe and 1 with a tumor in the body of the pancreas) underwent a 4-portal technique. The laparoscopic approach for resection of the pancreatic mass was possible in all cases. Resection of the tumor was done with the Ligasure 5 mm sealer and divider connected to a Ligasure or Force Triad generator (Covidien) in nine dogs (2 with a tumor in the right lobe and 3 with a tumor in the left lobe). A harmonic scalpel (Ultra Cision, Smithfield, Rhode Island, USA) was used in two dogs with a tumor in the right lobe and two charges of an endoscopic 30-mm linear stapler with 2.5-mm staples (Endo GIA; Medtronic) were used in one dog with a tumor in the body of the pancreas. The mesenteric defect was considered large enough to result in internal herniation in one case (1/12) and was therefore sutured using an intracorporeal simple interrupted suture pattern. In two dogs (2/12) with enlarged lymph nodes (Figure 3F), laparoscopic excision of local lymph nodes was done as previously described.[18] Three dogs (3/12) underwent laparoscopic liver biopsy after LPMR as described by Singh.[19] The median surgery time for LPMR in this study population was 69 min (range 35–100 min) (Table 1).

3.2 | Complications and outcome

LPMR was performed successfully in all 12 cases with minor intraoperative complications in three (3/12) dogs, and all the dogs survived the surgical procedure. Mild bleeding during dissection of the pancreatic parenchyma, which was immediately controlled with the vessel sealing device occurred in two (2/12) dogs. In (1/12) another dog, a defective cannula caused a momentary loss of the pneumoperitoneum, which was resolved by replacing the cannula with a new one. All the dogs underwent a clinical examination and AUS within the first 12 h postoperatively (median time 6 h; range 3–12 h) to check for signs of pancreatitis or peritoneal reaction. In 11 dogs (11/12) AUS revealed the presence of free gas in the abdomen and mild edema and reaction at the surgical site of the pancreas without diffuse peritoneal hyperechogenicity. In one dog (1/12) AUS showed diffuse edema and hyperchogenicity in most of the pancreas parenchyma with mild peritoneal hyperechogenicity and free gas in the abdomen. Postoperative blood glucose concentration was measured in all dogs (median 88 mg/dL, range 80–165 mg/dL).

Minor postoperative complications occurred in two dogs. One had several episodes of vomiting, which resolved themselves 24 h after surgery. The other dog developed transient hyperglycemia (165 mg/dL), which was controlled without medical treatment and normalized 24 h postoperatively (115 mg/dL).

Major complications in the postoperative period occurred in two dogs (2/12). The first dog had idiopathic seizures, which were treated with a benzodiazepine (diazepam 0.4 mg/kg) administered intravenously. The second dog had signs of pancreatitis, including vomiting, anorexia and abdominal pain, and AUS showed signs of diffuse pancreatic and peritoneal hyperechogenicity. This dog was treated with maropitant (1 mg/kg), administered subcutaneously, every 24 h and methadone (0.2 mg/kg), administered intravenously, every 4–6 h, and the complication resolved 1 week postoperatively. The other eight dogs (8/12) had no clinical signs of pancreatitis or other complications, hospitalization was uncomplicated and AUS revealed only mild reactions of the surgical site without signs of diffuse pancreatic or peritoneal hyperechogenicity. Eleven (11/12) dogs were discharged 48 h after surgery in good clinical conditions. The dog (1/12) with signs of pancreatitis in the postoperative period was discharged from the hospital 1 week after surgery in good clinical condition. Histopathological examination of the excised pancreatic mass revealed stage I insulinoma in nine (9/12) dogs and pancreatic carcinoma in three (3/12) dogs. In addition, the pancreatic tumors were completely resected with clear margins in all of the dogs. The median tumor size measured with CTA or AUS was 32 mm (range 12–65 mm). Histopathological examination of the liver and lymph node biopsy samples did not reveal metastatic disease and the lesions were classified as benign. A clinical follow-up that included physical examination and AUS was done a minimum of 90 days postoperatively in all the dogs. The final follow-up ranged between 105 and 245 days (median 147 days) postoperatively. Survival time was determined by telephone conversations with the owners of eight dogs (8/12), and during appointment dates for physical examination for the other four dogs (4/12). The surgical wounds healed completely with no complications in all (12/12) of the dogs. The median survival time of all 12 dogs was 10.8 months (median 11.6 months for the 9 dogs with insulinoma and 8.7 months for the 3 dogs with carcinoma). At the time of writing, nine of the 12 dogs were still alive and three had died for reasons not associated with their oncological disease (1 dog died after a road traffic accident, 1 for neurological reasons and 1 after anticoagulant rodenticide poisoning).

4 | DISCUSSION

Our hypothesis that LPMR can be carried out successfully in dogs with masses in the left and right lobes and central regions of the pancreas was accepted. Our results were in agreement with other reports that suggest LPMR

is a feasible and safe technique for the removal of pancreatic neoplasms in humans.[2,20] In recent years, advanced technology and increased experience in laparoscopic surgery have enabled a wider application of minimally-invasive surgical techniques in veterinary medicine. The main advantages of laparoscopic surgery include image magnification and reduced stress, postoperative pain and hospitalization time in patients. In agreement with other studies, we found that the laparoscopic atraumatic graspers and the vessel sealing devices allowed for gentle manipulation of the pancreas.[8–11]

In 2002, Naitoh et al. compared gastrointestinal transit and the stress response in dogs that underwent laparoscopic and conventional distal pancreatectomy. Gastrointestinal transit was significantly delayed in the group of dogs that underwent traditional open distal pancreatectomy, even though the operating time was greater in the laparoscopic procedure. Furthermore, in the dogs that underwent laparoscopic distal pancreatectomy, the serum IL-1 level was significantly lower and the blood cortisol concentration returned to normal more rapidly compared with dogs that had conventional distal pancreatectomy. The authors concluded that the laparoscopic approach was associated with a more rapid recovery, less stress, and a faster return to normal gastrointestinal transit than the conventional procedure.[12]

The imaging modality of choice is CTA because of its high sensitivity for the detection of pancreatic masses, although the specificity of CTA for the detection of metastatic lesions is low.[21] In our study, CTA was the preoperative imaging procedure of choice, although one dog underwent AUS examination only. In this case, the surgery was performed because there was no evidence of enlarged lymph nodes or other metastases at AUS examination; however, this should not be recommended as a gold standard diagnostic work-up for patients undergoing laparoscopic resection of pancreatic masses, leaving CTA as the best option for preoperative staging.

In the present study, the pancreatic masses ranged in diameter from 12 to 65 mm, and in 11 of 12 cases the neoplasms were located in the distal part of the affected lobe of the pancreas. In all cases, LPMR was performed successfully. Our results support the indications described by Buishand et al. and allowed us to use case selection criteria similar to those reported in human medicine.[22] The body mass index of the patient, previous surgical history and the size of the tumor are selection criteria for laparoscopic excision of pancreatic masses in humans.[23] When pancreaticoduodenectomy is required in human patients, masses <30 mm can be excised via a laparoscopic approach, but open distal pancreatectomy is recommended for masses >50 mm.[5,23] However, another human study concluded that minimal invasive surgery should not be withheld from patients based on selection factors such as tumor size.[24]

In our study, neoplasms >60 mm in diameter were considered to be large. Eleven dogs had small tumors that were < 34 mm in diameter, and only one dog had a large tumor, which was 65 mm and located in the right limb of the pancreas. The latter tumor had no adhesions or vascular invasion of surrounding organs and LPMR was performed without any intraoperative complications and with a good clinical outcome. Despite the fact that only one case had a large tumor (>60 mm) in our study, a cut-off of 60 mm could be taken into consideration, as a feasibly laparoscopically resectable tumor in dogs. However, it should be considered that large tumors (>60 mm) located in the left limb or in the body of the pancreas could be more challenging to excise using laparoscopy, and an open approach should be considered.

Another important aspect that had to be considered before performing LPMR was the size of the dog. In the present study, the size of the dogs varied with bodyweights ranging from 7 kg to 42 kg. The smallest dog had a 25 mm neoplasm located in the left limb of the pancreas. Performing LPMR was expected to be more challenging in small dogs than in medium-sized or large dogs because of the limited working space. However, magnification of the surgical area and the choice of different sizes (5 and 3.5 mm) of laparoscopic atraumatic graspers and dissection forceps allowed for precise and gentle manipulation of the pancreas in small dogs. Moreover, LPMR seems to be more challenging for masses located in the pancreatic body than in the right or left pancreatic lobe because of reduced accessibility to this part of the pancreas and the proximity of the pancreatic ducts. In the dog that had a small (12 mm) mass in the body of the pancreas, laparoscopic enucleation was successful because the lesion was small with noninvasive features and did not involve the pancreatic ducts. This selection criterion appears to agree with studies in human medicine on the approach to pancreatic neoplasms located near the main pancreatic ducts.[3,25,26]

Several studies in human medicine have shown that bipolar vessel sealing devices are safe and reliable for maintaining hemostasis and minimizing the risk of hemorrhage during laparoscopic pancreatectomy.[27,28] The Ligasure sealing device, which safely seals vessels up to 7 mm in diameter, was used in nine of our 12 cases. This device enables the sealing and the dividing of minor blood vessels without prior dissection, which reduces surgical time and eliminates complications caused by ligature slippage and collateral bleeding during dissection.[29] In two (2/12) dogs of the current study, laparoscopic pancreatectomy was performed with an ultrasonically activated scalpel, set at a power level of 3 (75% of full power)

in the knife mode. Takao et al. used an ultrasonically activated scalpel in an experimental study in dogs and found that it was an effective tool to perform biliary-pancreatic surgery. The main advantage of this type of instrument is that it provides simultaneous cutting and hemostasis with minimal injury to the pancreatic stump.[16] In one (1/12) other case in the present study, enucleation of a neoplasm in the body of the pancreas was done using an endoscopic linear stapler with 2.5-mm staples. In human medicine, the use of an endoscopic linear stapler is a well-described alternative to laparoscopic pancreatectomy and allows safe and rapid ligation and transection of the pancreatic parenchyma.[1,2,4,30] Merchant et al. reported that the pancreatic parenchyma must be thick and firm at the site of resection when using an endoscopic stapling device to avoid increasing the risk of pancreatic fistula.[2] The use of a linear stapling device for partial pancreatectomy has also been described in dogs.[31]

Only one case report in veterinary medicine has described LPP for the removal of an insulinoma in a dog. The dog was positioned in dorsal recumbency and a 3-port technique was used for laparoscopic resection of a nodule in the left limb of the pancreas.[13] Another recent report described a 3-port technique for laparoscopic resection of an exocrine carcinoma in the left limb of the pancreas in a cat, which was also positioned in dorsal recumbency.[14] In our experience, it was easier to approach the left limb of the pancreas using a left lateral approach with the dog in sternal recumbency. We reasoned that with the dog in sternal recumbency, the organs moved away from the pancreas resulting in a larger working space with minimal need for tissue retraction and better exposure of several anatomical structures including the splenic artery and local lymph nodes. In contrast, a ventral approach with the dog in dorsal recumbency, as described by Mcclaran et al., necessitated retraction of the duodenum and manipulation of part of the parenchyma of the pancreas to reach the left limb of the pancreas. In addition, the working space was limited and the three ports were positioned along the midline; T1 was located 2 cm caudal to the umbilicus and T2 and T3 were approximately 3 cm and 6 cm cranial to the umbilicus, respectively. In contrast, our portal placement allowed for direct exposure of the left limb of the pancreas and facilitated dissection of the pancreas from the surrounding tissues.[13] For neoplasms located in the right limb of the pancreas dogs could be positioned in left lateral recumbency for a right flank approach. Alternatively, the dogs were placed in dorsal recumbency for the placement of T1 and then repositioned in left lateral recumbency for placement of the remaining ports in the right flank, depending on the surgeon's preference. In the author's experience it was easier to establish the camera portal T1 with the dog in dorsal recumbency. In contrast with the dog in left lateral recumbency, the placement of T1 was more challenging, but it did not necessitate repositioning the patient. Furthermore, a left lateral recumbency allowed a gravitational displacement of abdominal organs improving the access and the visualization of the right limb of the pancreas with minimal tissue retraction. In contrast, a complete ventral approach with the dog in dorsal recumbency necessitates pulling the duodenum ventromedially or grasping and lifting it upward to expose the right limb of the pancreas.[32] Postoperative therapy included administration of an analgesic, acid reducer, antiemetic and in a few cases antibiotics depending on the surgeon's preference. However, there are no indications in laparoscopic pancreatic surgery for the use of prophylactic antibiotics. Only in rare cases of febrile patients with septic complications of pancreatitis should prophylactic antibiotics be used, and an open approach is preferable to laparoscopic surgery in these cases.[22]

Pancreatitis is one of the most frequent postoperative complications of pancreatic surgery.[33,34] Trifonidou et al. reported postoperative pancreatitis in 10% of 51 dogs with insulinoma. Other possible complications of partial pancreatectomy for the treatment of insulinoma include bleeding, sepsis, leukopenia and syncope.[33,35–37] In our study, one dog had transient hyperglycemia, one had vomiting and a third had idiopathic seizures; only the latter required medication. One (1/12) dog had signs of mild pancreatitis postoperatively and was treated successfully with medical therapy. A physical examination and AUS were performed within 90 days (within 1 week and again at approximately 30, 60, and 90 days) of surgery in all the dogs (12/12). Those follow-up examinations aimed to monitor the dogs for signs of pancreatitis and other postoperative complications associated with the surgery. In the first clinical recheck 1 week after surgery, none of the dogs had signs of pancreatitis or other postoperative complications. The final follow-up performed 105–245 days postoperatively in all dogs revealed that medications were no longer required and none had abnormal clinical signs. Based on those results, we concluded that LPMR had a good clinical outcome and was associated with a low risk of postoperative pancreatitis and severe postoperative complications.

This study had several limitations, one of which was the inclusion of cases from multiple institutions. This may have increased the variability of the surgical outcome and the postoperative management of the dogs. The small number of cases was another important limitation of the study, which may have affected statistical analysis.

We concluded that LPMR could be carried out using a 3- or 4-portal technique and may be a viable alternative to open celiotomy in dogs. The criteria that should be considered when selecting cases for LPMR include small (<60 mm in diameter) neoplasms in the right or left pancreatic lobe that have not invaded vital structures or metastasized. Enucleation of neoplasms in the body of the pancreas may also be possible in selected dogs. Additional studies are required to better standardize animal selection criteria, further assess the suitability of LPMR and improve the technique.

AUTHOR CONTRIBUTIONS

Poggi E, DVM, GpCert (SASTS), PGCert VEaMIS: Conception of the study, study design, collected the data, data analysis and interpretation, primarily drafted and revised the work, performed surgical procedure. Lillo-Araya FJ, DVM, DMI, PhD: Study design, data acquisition, and draft revision, performed surgical procedures. Garcia Rubio, D, DVM, PGCert VEaMIS, Accre. AVEPA (Soft Tissue Surgery): Study design, data acquisition, and draft revision, performed surgical procedures. Pérez Duarte, FJ, DVM, PhD: Study design, data acquisition, and draft revision, performed surgical procedures. Gutiérrez del Sol, J. DVM: Study design, data acquisition, and draft revision. Izzo F, DVM, MSc (Oncology), GPCert (SAS): Study design, data acquisition, and draft revision. Cinti F, DVM, PhD, GpCert (SASTS), Dipl. ECVS, MRCVS: Conception of the study, study design, collected the data, data analysis and interpretation, primarily drafted and revised the work, performed surgical procedure.

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CONFLICT OF INTEREST STATEMENT

The authors declare no potential conflicts of interest with respect to the research, authorship or publication of this article.

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