Veterinary Surgery
37:444–453, 2008

Laparoscopic Adrenalectomy for Treatment of Unilateral Adrenocortical Carcinomas: Technique, Complications, and Results in Seven Dogs

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Objective—To investigate the feasibility of, and outcome after, laparoscopic adrenalectomy in dogs with unilateral adrenocortical carcinoma.
Study Design—Case series.
Animals—Dogs (n = 7) with Cushing's syndrome caused by unilateral adrenocortical carcinoma.
Methods—Laparoscopic adrenalectomy with the dog in lateral recumbency on the unaffected side. Three 5-mm portals (1 laparoscopic portal, 2 instrument portals) were placed in the paralumbar fossa. A fourth instrumental portal (5–12 mm) was placed above the kidney. After dissection and hemostatic control of the phrenicoabdominal vein, the adrenal gland was carefully dissected or when there was capsule fragility, necrotic content was partially aspirated. The remaining glandular tissue was removed through the 12-mm trocar site.
Results—Dogs with unilateral adrenocortical carcinoma (3 right-sided, 4 left-sided) without invasion of the caudal vena cava were successfully operated by laparoscopic approach. There were no significant intraoperative complications; 2 dogs died within 48 hours of surgery because of respiratory complications. Five dogs were discharged 72 hours after surgery, and signs of hyperadrenocorticism disappeared thereafter (survival time ranged from 7 to 25 months).
Conclusions—Laparoscopic adrenalectomy is feasible in dogs with either right- or left-sided adrenocortical carcinoma not involving the caudal vena cava.
Clinical Relevance—When performed by experienced surgeons, laparoscopic adrenalectomy offers a minimally invasive alternative to open laparotomy or retroperitoneal surgery for the treatment of unilateral adrenocortical carcinoma in dogs.

INTRODUCTION

SPONTANEOUS HYPERCORTISOLISM (Cushing's syndrome) is a common endocrinopathy in middle-aged to old dogs resulting from hyperadrenocorticism. In 80–85% of affected dogs, hypercortisolism is caused by excessive secretion of the adrenocorticotropic hormone (ACTH) by the pituitary gland, resulting in bilateral adrenal hyperplasia. Adrenocortical tumors account for the remaining 15–20% of cases of spontaneous hyperadrenocorticism in dogs. Bilateral adrenal tumors occur rarely in the dog, and are more frequently unilateral (adenomas in 40–50%; carcinomas in 50–60%).[1,2] Currently, adrenalectomy is the treatment of choice for adrenal tumors, unless metastatic lesions are encountered preoperatively.[1–3]

Some of the more common techniques used for open adrenalectomy in dogs include ventral median celiotomy

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Presented in part at the 15th Annual Scientific Meeting of the European College of Veterinary Surgeons, Sevilla, Spain, July 2006.
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Submitted July 2007; Accepted November 2007

0161-3499/08
doi:10.1111/j.1532-950X.2008.00410.x

and retrocostal or flank laparotomy.[3–8] Selection of approach is based on adrenal gland size, surgeon's preference, affected side, and presence of neoplastic invasion of the caudal vena cava. Pros and cons of various approaches have been reported.[4–9] A retroperitoneal approach via flank incision is usually recommended for small lesions within the right adrenal gland in the absence of invasion of the caudal vena cava. The left adrenal gland can be exposed without much difficulty by flank or ventral median approaches. The latter approach is recommended for large tumors, pheochromocytomas, or tumors extending in the caudal vena cava, regardless of lateralization.[4–10]

Laparoscopic adrenalectomy in humans was reported in 1992[11,12] and is most often used for benign functional and nonfunctional tumors (< 12 cm in size) of the adrenal glands.[13–16] Laparoscopic adrenal surgery may offer several advantages including fewer wound complications, reduced morbidity, improved comfort and cosmetic appeal, reduced bleeding, better observation of abdominal organs, shorter hospital stays, and faster recovery periods.[14–34] Advantages of minimally invasive surgical procedures in dogs compared with open surgical procedures have been reported and laparoscopic ovariohysterectomy reduces postoperative pain and surgical stress compared with the open technique.[35–37]

Given the promising results in humans and well-known advantages of minimally invasive surgery in dogs, studying the feasibility and efficacy of laparoscopic adrenalectomy in dogs with unilateral adrenal tumors seemed warranted. We report our experience with 7 dogs and procedural details for minimally invasive laparoscopic adrenalectomy in dogs with unilateral adrenal tumors that have not invaded the caudal vena cava.

MATERIALS AND METHODS

Inclusion Criteria

Medical records (Centre Hospitalier Vétérinaire Frégis, November 2004–September 2005; Veterinärmedizinische Universität Wien, November 2005–July 2006) of dogs with Cushing's syndrome caused by unilateral adrenal tumor, referred for surgical treatment were reviewed. Dogs that had neoplastic invasion of the caudal vena cava were excluded. Recorded variables were age, body weight, breed, clinical signs, location and size of the affected adrenal gland, surgical time, complications, and clinical outcome.

Diagnostic Evaluation

Upon admission, clinical signs and endocrine tests (urine cortisol/creatinine ratio, ACTH stimulation, low- and high-dose dexamethasone tests) performed by the referring veterinarians were consistent with hyperadrenocorticism associated with adrenal gland tumors in dogs included in this report. Complete blood count (CBC), serum biochemical profile, thoracic radiographs and abdominal ultrasonography were performed in all dogs before surgery. One dog had an abdominal computed tomography (CT) scan.

Anesthesia

Dogs were premedicated with either morphine hydrochloride (0.1 mg/kg subcutaneously [SC]) and diazepam (0.2 mg/kg intravenously [IV]) at the Centre Hospitalier Vétérinaire Frégis, or methadone (0.1 mg/kg IV) and midazolam (0.2 mg/kg IV) at the Veterinärmedizinische Universität Wien. Anesthesia was induced with propofol (6 mg/kg IV) and maintained with isoflurane in 100% oxygen. Controlled ventilation was provided and ECG, noninvasive or invasive (Veterinärmedizinische Universität Wien) blood pressure, capnography and pulse oximetry were monitored. Dexamethasone (0.2 mg/kg IV) was administered immediately after anesthetic induction.

Surgical Technique

The caudal aspect of the hemithorax and the lateral abdomen on the affected side were clipped and prepared for aseptic surgery. Dogs were positioned in lateral recumbency on the unaffected side, with a cushion placed under the *erector spinae* muscle group to raise the spine towards the surgeons who stood against the animal's ventral side (Fig 1). The video monitor was positioned in front of the surgeons on the dorsal side of the dog.

A 5-mm, 30° or 0° laparoscope (Stryker Endoscopy, 93290 Tremblay, France or Karl Storz Endoskop, 1030 Wien) was connected to a video camera (Stryker Endoscopy or Karl Storz Endoskope) and a light source (Quantum 4000 Stryker Endoscopy or Xenon Nova 300 Karl Storz Endoskope). Images were viewed on a video monitor and recorded. The endoscopic equipment included an irrigation–suction unit

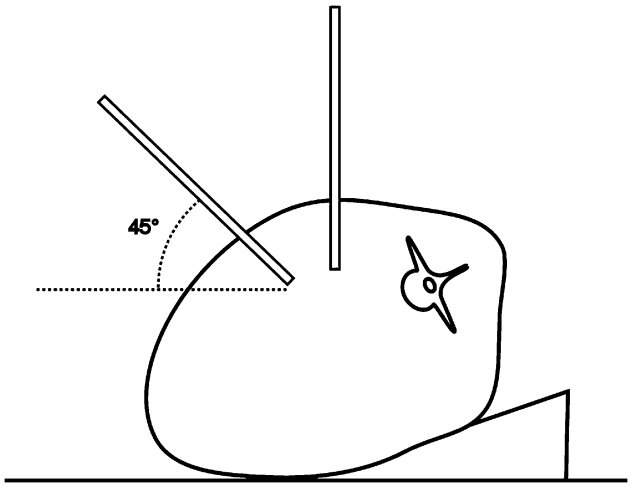

Fig 1. Schematic representation of the dog's surgical position (lateral recumbency) and orientation of the portals. A triangular cushion was placed under the *erector spinae* muscle group in order to raise the spine towards the surgeons standing by the animal's ventral side.

(SURGIWAND II, Tyco Healthcare, 78990 Elancourt, France), a self-retaining retractor (ENDO RETRACT II, Tyco Healthcare), bipolar forceps (BIPOLAR-ZANGEN 5 mm, Karl Storz Endoscope, 51100, Reims, France), grasping forceps (ENDO GRASP, Tyco Healthcare), scissors (ENDO SHEARS, Tyco Healthcare) and dissectors (ENDO DISSECT, Tyco Healthcare) connected to an electrosurgical unit, as well as endoclips (ENDO CLIP II ML, Tyco Healthcare). In 2 dogs, a LigaSure® device (LigaSure™ Lap, LigaSure Atlas™, Valleylab, Tyco Healthcare, 2345 Brunn am Gebirge, Austria), a feedback-controlled, bipolar vessel-sealing system used to achieve hemostasis was used.

After draping, a Verres needle was inserted at a level just caudal to the 13th rib in the paralumbar fossa ipsilateral to the affected side. The abdomen was inflated with CO_2 until an intra-abdominal pressure of 8–10 mm Hg was achieved. Inflation was adjusted according to the dog's size and physiologic variables.

Four portals were located in the paralumbar fossa. Three 5-mm portals were made along a virtual half-circle with kidney of the affected side as the center point. The half-circle radius was determined subjectively, according to dog and instrument size (Fig 2). The laparoscope was inserted through portal 1 and the instruments through portals 2 and 3. A fourth instrumental portal (5–12 mm) for the self-retaining retractor and suction device was located above the kidney.

Laparoscopic examination of tissues surrounding the affected adrenal gland and partial examination of the liver (incomplete because of the lateral position) was performed. Absence of liver macrometastases and macroscopic vascular invasion into the caudal vena cava was confirmed in all dogs.

Exposure and dissection of the adrenal glands were performed differently on the right and left sides because of anatomic differences.

Right Adrenalectomy. To achieve wide exposure of the right adrenal gland, the right lateral hepatic lobe was retracted cranially whereas the kidney was retracted dorsally. Because dogs were positioned in lateral recumbency with a cushion under the erector spinae muscle group (Fig 1), the descending duodenum or other organs were displaced by gravity. Dissection between the right adrenal gland and the caudal vena cava was carefully performed using an endoscopic dissector.

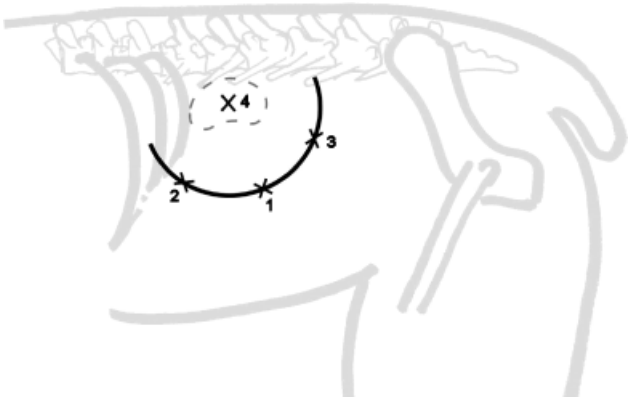

Fig 2. Positions of the surgical portals along the paralumbar fossa (no. 1 = laparoscope; nos. 2–4 = instruments).

Left Adrenalectomy. For exposure of the left adrenal gland, the descending colon was reflected medially, the left kidney was reflected dorsally, and the spleen ventrally.

Immediately after exposure of the adrenal gland, careful dissection and hemostasis of the phrenicoabdominal vein was achieved on both sides by the use of either bipolar electrocautery, haemostatic endoclips, or the LigaSure®. To minimize manipulation of the adrenal gland, the peritoneum was incised lateral to the adrenal gland (Fig 3). Additionally, the periadrenal tissue was grasped using a blunt grasper to facilitate complete circumferential dissection of the gland using either bipolar dissection or the LigaSure® device. The renal blood supply was retracted medially to avoid accidental hemorrhage during dissection. Further hemostasis of vessels on the caudal and cranial parts of the gland was achieved using bipolar electrocautery or the LigaSure® device.

When the gland was friable and under tension, or in the case of spontaneous rupture, a small window in the capsule was used to aspirate the necrotic semiliquid content at the center of the gland by using an irrigation–suction unit. After careful dissection, the remaining glandular tissue was progressively entirely removed in small pieces through the 12-mm protected trocar to prevent abdominal wall contamination. The abdomen was inspected for hemorrhage, and the adrenalectomy site was locally rinsed with small volumes of warmed lactated Ringer solution and concurrent use of close suction to avoid abdominal contamination with neoplastic cells. After abdominal deflation the laparoscopic portals were closed.

Excised adrenal tissue was submitted for pathologic examination.

Postoperative Care

Morphine hydrochloride (0.1 mg/kg SC) or buprenorphine hydrochloride (0.01 mg/kg IV) were administered for postoperative analgesia every 4–6 hours for 24–36 hours. Cefalexine

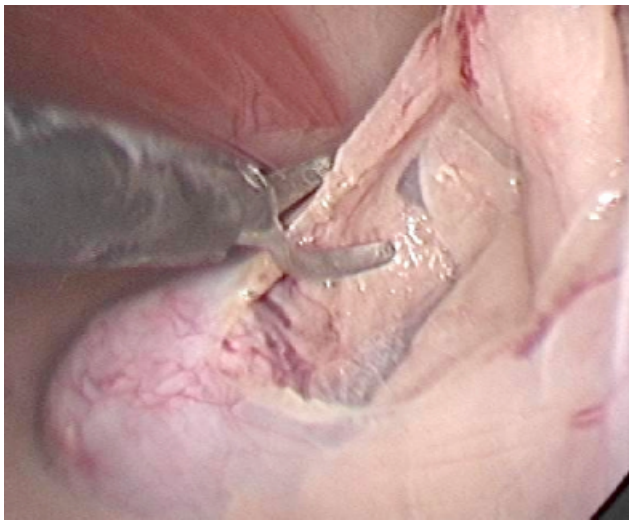

Fig 3. Laparoscopic intraoperative view: distant dissection of a left adrenal gland through the peritoneum.

(15 mg/kg orally every 12 hours) was administered for 5–10 days. IV fluids (0.9% NaCl) with dexamethasone (0.05 mg/kg IV every 6 hours) were administered during the first 24–36 hours. Desoxycorticosterone acetate (DOCA; 0.2 mg/kg intramuscularly [IM] once daily) was also administered until hospital discharge (3 days).

When dogs began eating and drinking, prednisolone (0.2 mg/kg orally every 12 hours) was used instead of dexamethasone. Dosage of prednisone was tapered (0.1 mg/kg orally) over 4–6 weeks, and then discontinued. One IM DOCA injection every 2–3 days was administered between the second and the fourth weeks. Rest and leash walk were recommended for 3 weeks after surgery. We recommended an ACTH stimulation test within 3 weeks after surgery.

Outcome

Dogs were re-evaluated either by the operating surgeons or by the referring veterinarian. All owners and referring veterinarians were contacted via telephone to obtain follow-up information.

RESULTS

Clinical Findings (Table 1)

Dogs had a mean age 11 years (range, 9–14 years) and weight of 19 kg (range, 7–37 kg). No pulmonary metastases were identified and ultrasonography (Table 1) or CT scan confirmed the presence of unilateral adrenal tumor not involving the caudal vena cava. Tumors were left-sided in 4 dogs and right-sided in 3 dogs. Mean diameter of the affected adrenal gland was 25 mm (short-axis; range, 16–20 mm), and 37 mm (length; range, 24–48 mm). Contralateral adrenal glands were within normal limits in all dogs (Table 1). In dog 6, the abdominal CT scan confirmed the presence of an enlarged right adrenal gland with multiple hyperdense calcifications proximal to, but not infiltrating, the medially displaced caudal vena cava (Fig 4).

Surgical Findings

Affected adrenal glands were removed successfully via laparoscopic approach without need for celiotomy. Mean surgical time from Verres needle insertion to complete closure was 113 minutes (range, 90–150 minutes; Table 2). Mean surgical time for the right adrenal gland was 133 minutes (range, 120–150 minutes) and for the left adrenal, 99 minutes (range, 90–110 minutes). Iatrogenic injury because of trocar placement or Verres needle insertion did not occur.

In all dogs, the adrenal gland appeared friable under tension, and was partially suctioned before excision in small pieces. Despite careful manipulation, the capsule of the gland was accidentally ruptured in the first 2 dogs. In the next 5 dogs, a small window was opened in the capsule with concurrent closely positioned suction and the

Table 1. General Characteristics of Dogs Treated by Laparoscopic, Unilateral Adrenalectomy

Dog	Signalment	Signs	Abnormal Findings on CBC and Serum Chemistry (Reference Range)	Size of the Affected Gland*: Localization Other Ultrasound Abnormalities
1	14-year-old, M, 30 kg Briard	PD/PD, polyphagia, abdominal enlargement, alopecia	None	30 × 45 mm Left Mild hepatomegaly, urinary bladder distention
2	11-year-old, SF, 37 kg Labrador Retriever	Calcinosis cutis, alopecia	ALP = 4712 U/L (10–80)	29 × 36 mm: Right None
3	9-year-old, M, 13 kg Poodle	PD/PD, polyphagia, abdominal enlargement, alopecia, thin skin	Blood white cells = 22 × 10^{10}/L (6–13) ALP = 3281 U/L (10–80) Cholesterolemia = 3 g/L (0.2–2.5) Lipemia = 1.7 g/L (<0.5)	25 × 35 mm: Right Mild hepatomegaly, cholecystitis
4	10-year-old, M, 7 kg Yorkshire Terrier	PU/PD	None	38 × 38 mm: Left None
5	13-year-old, M, 20 kg Mixed Breed	PU/PD, polyphagia, abdominal enlargement, calcinosis cutis	ALP = 3423 U/L (10–80) ALT = 473 U/L (10–50)	23 × 37 mm: Left Mild hepatomegaly
6	12-year-old, SF, 12 kg Mixed Breed	PU/PD, polyphagia, abdominal enlargement	None	24 × 48 mm: Right Mild hepatomegaly
7	10-year-old, SF, 14 kg Tibetan Terrier	PU/PD, hematuria, stranguria, weakness/lethargy	Blood white cells = 18 × 10^{10}/L (6–13) ALP = 2907 U/L (10–80)	17 × 24 mm: Left Mild hepatomegaly, enlarged spleen

*Reference range for adrenal gland size: short axis 3–7.5 mm; long axis <2.4 mm.[54,55]

M, male; SF, spayed female; PU/PD, polyuria/polydipsia; ALP, alkaline phosphatase; ALT, alanine aminotransferase.

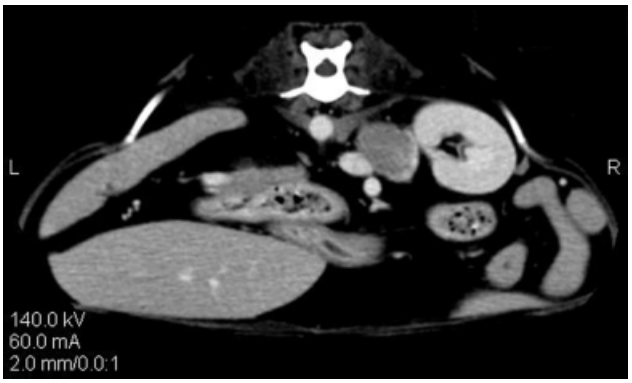

Fig 4. Preoperative computed tomography scan of dog 6 with an enlarged right adrenal gland.

necrotic semiliquid content aspirated. This technique was exploited to minimize the risk of intrasurgical rupture of the gland, with subsequent spillage of neoplastic cells. All grossly visible adrenal gland tissue was then removed. Mild hemorrhage occurred in dog 2 during dissection and was controlled by bipolar cauterization. No other perioperative complications occurred.

Postoperative Complications

In 3 dogs (dogs 1, 2, 5) subcutaneous cellulitis around the surgical portals occurred after 24 hours and resolved with hot packing within 5 days (Table 2). Dogs 3 and 4 died 2 days after surgery from respiratory complications (Table 2). Thoracic radiographs showed the presence of alveolar infiltrates and pleural effusions in both dogs; their owners declined necropsy.

Outcome

Five dogs were discharged within 3 days. Survival times for dogs 1, 2, 5–7 ranged from 7 to 25 months (mean survival time, 15.4 months). All dogs had marked improvement of clinical signs of Cushing's syndrome. Polyuria and polydipsia (dogs 1, 5–7) as well as polyphagia (dogs 1, 5, 6) recovered rapidly within the first 4 weeks after surgery. Alopecia (dogs 1, 6), and calcinosis cutis (dogs 2, 5) recovered gradually to a subnormal level within the first 2–3 months. Abdominal enlargement (dogs 1, 5, 6) improved partially. Signs of cystitis and weakness/lethargy in dog 7 resolved within 2 weeks.

Despite our recommendations, ACTH stimulation tests were not performed after surgery because of logistic reasons. Dog 1 died 7 months after surgery from unknown cause. Notably, this dog had no evidence of thoracic metastases nor clinical signs of Cushing's syndrome. Dog 2 was euthanatized 12 months after surgery because of radiographic evidence of pulmonary metastases. Dogs 5–7 were still alive at 25, 19, and 14 months (mean survival time, 19 months) after the last follow-up visit (Table 2).

Histology Findings

Adrenocortical carcinoma was diagnosed in all dogs. Histologic evidence of neoplastic emboli (vascular and/or lymphatic invasion) was observed in the adrenal gland tissue of dogs 2, 4–6.

DISCUSSION

We were able to successfully perform laparoscopic unilateral adrenalectomy without need for conversion to

Table 2. Perioperative Data and Clinical Outcome of 7 Dogs with Adrenocortical Carcinomas Treated by Laparoscopic Adrenalectomy

Dog	Surgical Complications	Postoperative Complications	Surgical Time (minutes)	Follow-up and Clinical Outcome
1	Gland rupture	Subcutaneous cellulites around portals	100	7 months Died*
2	Mild hemorrhage, gland rupture	Subcutaneous cellulites around portals	130	12 months Euthanatized†
3	None	Severe respiratory distress	120	2 days Died‡
4	None	Severe respiratory distress	90	2 days Died‡
5	None	Subcutaneous cellulites around portals	95	25 months Alive
6	None	None	150	19 months Alive
7	None	None	110	14 months Alive

*Died of causes unrelated to adrenal tumor.
†Euthanatized because of pulmonary metastasis.
‡Died of severe respiratory distress.

open laparotomy in 7 dogs with unilateral adrenal tumors (3 right-sided, 4 left-sided) without neoplastic invasion of the caudal vena cava.

Comparative human studies have shown the benefits of minimally invasive techniques for removal of benign adrenal tumors (either functional or nonfunctional) of <12 cm in size.[13–16] Potential benefits of minimally invasive approaches include decreased requirements for analgesics, fewer adrenalectomy-related complications, improved patient satisfaction, shorter hospital stays, and faster recovery periods when compared with open surgery.[14–34] Interestingly, laparoscopic ovariohysterectomy in dogs is associated with reduced postoperative pain and surgical stress compared with an open technique.[35–37] Moreover, a significantly higher nociceptive threshold as assessed by the tolerated palpation pressure was evident in dogs treated laparoscopically compared with those that had median celiotomy.[36] Finally, dogs treated with celiotomy may have significantly higher plasma cortisol levels at 1–2 hours after surgery.[36,37] It is thus posited that laparoscopic adrenalectomy may offer other potential advantages over an open technique, including limited manipulation of other abdominal organs, decreased surgical wound complications, improved postoperative comfort, as well as an excellent view of abdominal structures. This magnification could be especially useful during dissection between the right adrenal gland and the caudal vena cava.

Although transabdominal or retroperitoneal approaches have been described for human laparoscopic adrenalectomy, the lateral transabdominal approach remains the most widely used technique. Accordingly, it offers a large field of view that enables good orientation and an optimal observation of landmarks familiar from open surgical approach.[14,16–18,21,22,31,33] The retroperitoneal approach provides more direct access to the adrenal gland and can avoid abdominal adhesions in patients with previous abdominal surgery; however, dissection and exposure are more difficult, the working space is limited, and this approach does not allow a full abdominal exploration.[19,22,30,38] In the light of these caveats, as well as for body size, we chose the transabdominal laparoscopic approach for our dogs. As in human surgery,[14,19,21,22,24] our dogs were placed in lateral recumbency on the unaffected side, with a cushion placed under the *erector spinae* muscle group to raise the spine towards the surgeons standing on the dog's ventral side.

The surgical portals were placed along the paralumbar fossa using a transperitoneal approach (Fig 2), which allowed excellent exposure of the adrenal gland, as well as optimal viewing during dissection. This could be especially useful when performing dissection between the right adrenal gland and caudal vena cava that is essential to avoid entering the gland or disrupting the caudal vena cava. This is especially difficult, risky, and challenging to achieve especially for right-sided tumors, inasmuch as the right adrenal gland is extremely close to the caudal vena cava and its capsule is medially continuous with the tunica adventitia of the vein.[39]Although this complication was not observed in the 3 dogs with right-sided tumors, the possible occurrence of life-threatening hemorrhage resulting from the effraction of the caudal vena cava during right adrenal gland dissection must be seriously considered. This operative complication should be carefully discussed with owners and special precautions such as preoperative blood typing are highly recommended.

Dissection of the phrenicoabdominal vein must be carefully performed to avoid bleeding and gland trauma. We performed hemostasis of the right phrenicoabdominal vein at its junction with the caudal vena cava. Because the left phrenicoabdominal vein enters the left renal vein and does not join directly with the caudal vena cava,[39] its dissection is easier to perform. Mild hemorrhage occurred in dog 2 during the dissection of the right phrenicoabdominal vein but it was quickly controlled with bipolar cauterization without the need of blood transfusion.

Bleeding is the most common complication during and after laparoscopic adrenalectomy in humans, and accounts for $\sim 40\%$ of all complications.[16] Nonetheless, blood transfusions are required in $<5\%$ of patients.[16] In dogs 6 and 7, the use of the LigaSure® device proved useful for bleeding prevention. Accidental rupture of the adrenal capsule occurred in the first 2 dogs despite extremely careful manipulation during dissection. Whether this phenomenon occurred from lack of experience, the nature of the tumor, or both, remains unclear. Adrenal carcinomas are very friable, and ruptures have been reported even with the conventional open technique.[7] In the 5 subsequent dogs, we decided to create a little window in the capsule to perform immediate intracapsular suction of the semiliquid content, thereby avoiding the potential risks of accidental gland rupture. It should be noted, however, that this method may result in tumor seeding. Immediate close suction was thus performed thereafter. Excision of the entire gland or small pieces of all visible adrenal tissue through the 12-mm protected trocar was achieved in all dogs. Use of retrieval bags has been recommended to prevent tumor cell spillage during laparoscopic removal of tumors. In our dogs, the overall fragility of the gland would have warranted the use of retrieval bag and should be considered in the future.

The clinical consequences of tumor spillage in adrenal carcinoma remain unclear. Even in the presence of microscopic invasion into the blood vessels, regrowth is generally slow and clinical recurrence may take several years to develop.[7,40] Van Sluijs et al[7] reported a disease-free survival of 8 and 48 months for 2 of 5 dogs with a

ruptured capsule. Despite capsule gland effraction, none of the dogs had clinical signs of recurrent hyperadrenocorticism compared with 9% (2 of 22) and 29% (8 of 28) in 2 other reports.[7,40] Additionally, our data suggest that capsule gland effraction does not seem to influence the clinical outcome. Dogs 5–7 are still alive at 25, 19, and 14 months after surgery. In dog 2, death was likely because of tumor-related causes (lung metastases 12 months after surgery). In future studies, more distant dissection and the use of surgical devices as Harmonic Scalpel® or LigaSure® may help to avoid this issue.

We did not have to revert to open surgical technique. Conversion to an open procedure occurs in $\sim 2\%$ of human cases (range, 0–13%), the main indication for conversion being uncontrollable bleeding (40% of all complications).[16,41] The second most common reason for conversion to an open procedure is the presence of malignancy with local and vascular invasion as detected upon laparoscopic exploration.[16,41]

In humans, postoperative complications after laparoscopic adrenalectomy include bleeding, wound infection or hematoma, as well as thromboembolic, urinary, gastrointestinal, pulmonary, and cardiovascular problems.[16,20–27,30] Injury to peritoneal and retroperitoneal organs (liver parenchyma, spleen, pancreas, colon, lymphatic system, and adrenal gland) accounts for $<5\%$ of all complications.[15,32,33] In dogs, minor spleen injury and controllable bleeding are the most common complications being reported during laparoscopic procedures.[35,36,42] Acute pancreatitis with peritonitis has been reported to be responsible for 8–25% of mortality rates after open adrenalectomy, especially with the ventral median approach.[5,7] In our dogs, pancreatitis did not occur; however, further investigations are needed to evaluate the potential impact of this minimally invasive surgical approach on the occurrence of pancreatitis in dogs. Iatrogenic injury from trocar or Verres needle insertion did not occur in our dogs.

Causes of death after laparoscopic adrenalectomy in people include massive hemorrhage, necrotizing pancreatitis, pulmonary embolism, sepsis, and cardiopulmonary failure.[16,41] When compared with open adrenalectomy, the laparoscopic approach has been found to reduce the likelihood of perioperative complications in people undergoing adrenalectomy.[25] A positive impact of laparoscopy on intraoperative bleeding and postoperative pulmonary complications has been previously demonstrated.[19] The overall mortality rates in people vary between 0.2% and 1.2% at 30-day follow-up.[16,41] In our dog, perioperative mortality rate was 28% (2 of 7 dogs, both deaths occurring postoperatively). Although this rate may seem quite high, it is comparable with the rates of 19% (4/21),[8] 21% (6/28),[40] 28% (10/36),[7] and 60% (15/25)[5] reported previously in dogs. The major postoperative complication observed in our dogs was severe respiratory distress in 28% (2 of 7) of dogs. Both animals died 48 hours after surgery without a definitive diagnosis. Clinical signs and thoracic radiographs were compatible with pulmonary thromboembolism and/or pneumonia, both being well-known postoperative complications occurring in animals and humans suffering from hyperadrenocorticism.[1–3]

Dogs with hyperadrenocorticism undergoing adrenalectomy are at an increased risk of developing pulmonary thromboembolism.[1,2] It should be noted, however, that we were unable to perform necropsy to determine the exact causes of death. In humans, thromboembolic complications can be reduced by perioperative anticoagulation.[43] Although we did not perform routine anticoagulation in dogs with Cushing's syndrome, administration of low-dose heparin for several days after surgery may help to reduce the occurrence of embolic events. It should be noted, however, that pulmonary thromboembolism has been also reported to occur in a series of dogs administered heparin during and after open adrenalectomy.[40] To the best of our knowledge, no studies on the potential usefulness of heparin to prevent pulmonary thromboembolism in the dog have been published. Further studies are also needed to establish whether intermittent positive pressure ventilation or pneumoperitoneum may increase the likelihood of thromboembolism in Cushing's patients, regardless of the surgical procedure used. In people, laparoscopy has been shown to induce specific pathophysiologic changes in response to pneumoperitoneum, which may in turn predispose to the development of deep venous thrombosis.[44,45] We are unaware of similar studies in dogs. Given the gap of information on the incidence of venous thromboembolism after laparoscopic procedures in dogs, we believe that the need for thromboprophylaxis cannot be firmly established. Further studies are needed to understand venous thromboembolism, after cancer surgery, which remains a common and severe complication in humans.[16,41]

Laparoscopic surgery is likely to be less painful than open surgery because of smaller incision size and decreased skin and muscular trauma. Although pain scores were not evaluated in our dogs, all were standing up the day after surgery and palpation of the abdomen was not painful. Dogs were discharged 72 hours after surgery and no dog required analgesic drugs during home stay. Moreover, no wound complications other than mild cellulitis were observed even in the presence of some severe preexisting skin lesions. Notably, abdominal incision dehiscence has been reported to occur in 10% of cases after open adrenalectomy.[40]

Disadvantages or problems associated with laparoscopic adrenalectomy may include increased surgical time, the need for specific instrumentation, technical difficulties, and the occurrence of intraoperative compli-

cations during dissection (mild bleeding and gland rupture). As for other laparoscopic techniques, laparoscopic adrenalectomy has longer surgical times and is more technically demanding than the conventional open techniques, at least until the learning curve allows the surgeon's full confidence. In our dogs, mean surgical time for laparoscopic adrenalectomy (from Verres needle insertion to complete closure) was 113 minutes (range, 90–150 minutes). Given differences in anatomic location, mean surgical time for the right adrenal gland (133 minutes; range, 120–150 minutes) was longer than for the left adrenal gland (99 minutes; range, 90–110 minutes). Surgical time with an open approach may be shorter and reportedly ranges between 100 and 180 minutes.[4,6] As for any minimally invasive procedure, laparoscopic adrenalectomy requires specific and more expensive surgical instrumentation; however, use of reusable instruments may decrease instrumentation costs.

In human surgery, the role of laparoscopy in the management of adrenocortical cancer remains controversial. Because these tumors are usually very large, open adrenalectomy is still preferred by some surgeons. On the other hand, laparoscopic adrenalectomy is regarded by other surgeons as the "gold standard" for treatment of adrenal tumors (adrenocortical carcinoma and malignant pheochromocytoma) in humans, at least in the absence of either local or vascular invasion.[13–16,24,26,27,31,33,34,46,47]

Portal site tumor recurrence and occurrence of intra-abdominal carcinomatosis from laparoscopic adrenalectomy have been repeatedly reported with malignant adrenal tumors.[48–50] In contrast, other authors have not reported local or portal site recurrence after laparoscopic adrenalectomy in malignant tumors with negative margins.[51] In patients with adrenocortical cancer, a 60% locoregional recurrence rate has been reported, which is similar to the rate reported for open adrenalectomy.[52] Despite the opening of the gland capsule in our dogs, no clinical signs related to hyperadrenocorticism because of either a local or a portal site recurrence were observed.

Adrenocortical carcinoma was diagnosed in all of our dogs. Histologic evidence of neoplastic emboli in the adrenal gland tissue analyzed (vascular and/or lymphatic invasion) was observed in 4 dogs (dogs 2, 4–6). It is worth noting, however, that this phenomenon does not seem to influence clinical outcome. Preoperative differentiation between adrenocortical adenoma and carcinomas is often difficult in the absence of metastases or obvious invasion. No imaging test can be consistently used to distinguish between benign and malignant adrenal tumors in dogs.[53]

Out of 5 discharged dogs (1, 2, 5–7), 2 survived for 7 and 12 months surgery (dogs 1, 2), and 3 are still alive (dogs 5–7) at 24, 19 and 14 months after surgery, respectively (mean survival time, 19 months). Mean published survival time for adrenocortical tumors treated by adrenalectomy in the dog is 20–22 months.[3,4,6–10] Given the small number of dogs in our series, however, these results must be interpreted cautiously.

Ideal candidates for laparoscopic adrenalectomy are dogs with adrenal masses and confined tumors, in the absence of caudal vena cava or surrounding tissues involvement, without respiratory or vascular problems, and no evidence of metastasis. Potential contraindications to the laparoscopic approach may include the presence of large and/or invasive tumors, small animal size (<7 kg), presence of obesity, evidence of metastasis, concomitant lung and/or heart disease, lack of surgical experience. Theoretically, large noninvasive tumors may be excised by experienced laparoscopic surgeons by using retrieval bags and a surgical mixer.

We conclude that laparoscopic adrenalectomy is feasible in dogs with unilateral adrenal tumors not involving the caudal vena cava. Although the technique gave promising results even in the presence of gland rupture, technical progresses should be keenly pursued to avoid capsule effraction. Compared with traditional open surgery, laparoscopic adrenalectomy may offer several advantages including decreased pain, better observation, reduced risk of dehiscence and postoperative wound complications, as well as shorter hospitalization times. Further studies in dogs are warranted to compare the short- and long-term results of laparoscopic adrenalectomy with either the ventral median or retrocostal open approaches.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Dominique Heripret, Dr. F. Zeugzwetter, and Dr. Laurent Findji for their participation in the study series, and Dr. Enzo Emanuele for expert editorial assistance.

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