Adrenalectomy is indicated for the resection of a variety of neoplastic lesions in dogs. Traditionally, adrenal tumors have been resected either through an open ventral celiotomy approach or a paracostal approach, both of which have advantages and disadvantages. Laparoscopic adrenalectomy has been performed in humans since the early 1990s and has been described in a small number of veterinary patients. Major advantages of laparoscopic adrenalectomy over an open approach for treatment of benign disease of the adrenal gland in humans include significant decreases in the occurrence of postoperative pneumonia, sepsis, renal insufficiency, wound infection, and cardiac arrest as well as shorter hospital stays, lower intensive care unit admission rates, and lower cost. Controversy still surrounds laparoscopic resection of adrenocortical carcinoma in the human literature. Some studies have demonstrated excellent results in these cases; however, others suggest that recurrence and disease-free interval may be inferior to results obtained with open surgery. These results must be interpreted carefully, given that adrenocortical carcinoma is a more aggressive neoplasm in humans, with nodal metastases present in 26.5%, distant metastasis present in 21.6%, and 5-year survival rate of only 38.6% documented in a large study. In dogs, adrenocortical carcinoma is a less malignant tumor, with distant metastasis reported to occur in only 5% to 14% of cases. Several studies were unable to detect a difference in disease-free interval and survival time between dogs with adenomas versus adenocarcinomas.

Only small numbers of laparoscopic adrenalectomies have been described in the veterinary literature to date. To our knowledge, no comparative studies have evaluated the perioperative outcomes in cohorts of dogs with adrenocortical tumors resected with an open versus laparoscopic approach.
The aims of the study reported here were to describe a technique for laparoscopic adrenalectomy in dogs with adrenocortical masses and compare the outcomes of these patients with those of dogs with comparable lesions treated by open adrenalectomy. We hypothesized that laparoscopic adrenalectomy would be associated with a low perioperative complication rate and a low conversion rate for resection of noninvasive adrenocortical masses.

**Materials and Methods**

**Case selection**—Medical records of dogs that underwent laparoscopic adrenalectomy for resection of an adrenal mass at the University of Pennsylvania (June 1, 2007, through September 17, 2008) or the University of California-Davis (August 25, 2010, through October 16, 2013) were identified and reviewed. Only dogs with an adrenocortical mass (hyperplasia, adenoma, or carcinoma) diagnosed on the basis of histologic evaluation were included. Similarly, medical records from the University of California-Davis were searched to identify dogs that underwent open adrenalectomy in the 7 years prior to initiation of the laparoscopic adrenalectomy technique at that facility (January 22, 2003, through July 10, 2009); only records for dogs that would have been reasonably considered appropriate candidates for laparoscopic adrenalectomy on the basis of the following criteria (determined on the basis of the authors’ experience) were included in the study: no vascular invasion into the caudal vena cava on preoperative diagnostic imaging evaluations (abdominal ultrasonographic) were included. Similarly, medical records from the University of California-Davis were searched to identify dogs that underwent open adrenalectomy in the 7 years prior to initiation of the laparoscopic adrenalectomy technique at that facility (January 22, 2003, through July 10, 2009); only records for dogs that would have been reasonably considered appropriate candidates for laparoscopic adrenalectomy on the basis of the following criteria (determined on the basis of the authors’ experience) were included in the study: no vascular invasion into the caudal vena cava on preoperative diagnostic imaging evaluations (abdominal ultrasonographic examination, CT, or both), maximal lesion diameter ≤ 5 cm, and no obvious peritumoral hematoma or tumor invasion into periadrenal organs.

For all dogs that underwent a CT scan, tumor volume was calculated by use of a commercially available imaging analysis software package and recorded as total tumor volume as well as a ratio of tumor volume to body weight. Dogs were excluded from either group if they had vascular invasion into the caudal vena cava, had lesions > 5 cm in maximal diameter, or did not have a histopathologic diagnosis consistent with an adrenocortical mass.

To ensure that dogs undergoing open adrenalectomy were an appropriate control population for dogs undergoing laparoscopic adrenalectomy, the following data were recorded for comparison between groups: age, sex, body weight, body condition score (on a scale of 1 to 9), phenoxycbenzamine or trilostane pretreatment, presence or absence of hyperadrenocorticism (adrenal or pituitary dependent or both), lesion side (left or right adrenal gland), maximal tumor diameter (assessed by CT or ultrasonography), and tumor type (hyperplasia, adenoma, or adenocarcinoma).

**Diagnostic evaluation**—All dogs underwent a thorough diagnostic evaluation. Each received an endocrinologic evaluation, which in most cases, comprised multiple laboratory tests for hyperadrenocorticism including one or more of the following: determination of urine cortisol-to-creatinine concentration ratio, ACTH stimulation test, endogenous ACTH assay, low-dose dexamethasone suppression test, and high-dose dexamethasone suppression test. On the basis of laboratory test results, either functionally active cortisol-secreting masses (adrenal-dependent hyperadrenocorticism) or nonfunctional masses were diagnosed. In some dogs, pituitary-dependent Cushing’s disease could not be ruled out entirely on the basis of diagnostic evaluation, in which case, for statistical purposes, they were recorded only as having hyperadrenocorticism (pituitary or adrenal dependent).

**Patient preparation and anesthesia**—Most dogs with functional cortisol-secreting tumors received trilostane for 2 to 3 weeks before surgery. Among dogs for which pheochromocytoma could not be ruled out before surgery, in some cases, phenoxycbenzamine hydrochloride was administered for 2 to 3 weeks before adrenalectomy. On the day of the adrenalectomy, patients underwent general anesthesia with a nonstandardized protocol at the discretion of the attending anesthesiologist.

**Laparoscopic adrenalectomy**—Dogs were positioned on the operating table in dorsal recumbency and then rolled into lateral recumbency (earlier cases) or were initially positioned in lateral recumbency (later cases) with the affected adrenal gland uppermost. In all procedures, mechanical tilt tables were used so that the dog could be rotated into a more sternal position by rotating the table toward the side on which the surgeon stood. The surgeon and surgical assistant stood on the side of the table closest to the ventral aspect of the patient’s abdomen, with the endoscopic tower placed directly across from the surgeon on the other side of the patient.

A 3- or 4-port technique was used for laparoscopic adrenalectomy in all dogs. In some cases, a fourth port was placed to aid in retraction of surrounding organs. The first 3 dogs that underwent laparoscopic adrenalectomy had a subumbilical camera portal established on the ventral midline via a modified Hasson technique. Subsequently, a camera portal was established 3 to 5 cm lateral to the umbilicus on the affected side to improve visualization of the tumor; either the modified Hasson technique or a modified Veress needle technique was used. Briefly, in the latter procedure, a 0.5- to 1-cm-long incision was made through the skin and subcutaneous tissues. Dissection was advanced through the muscle layers of the abdominal wall until the peritoneum could be elevated. A disposable Veress needle was then inserted with counterpressure provided by peritoneal elevation with forceps adjacent to the location of the Veress needle. Once the Veress needle had been advanced into the peritoneal cavity, a mechanical insufflator was attached to the hub of the needle to create a pneumoperitoneum of 8 to 12 mm Hg pressure with CO₂. A 0° or 30° 29-cm telescope was then placed through the cannula into the abdominal cavity. Under direct observation, 2 additional instrument ports were then created with 6-mm trocarless threaded cannulae or an 11-mm conical-tipped cannula. The cranial quadrant instrument port was placed 3 to 10 cm cranial to and 5 to 8 cm lateral to the telescope port in a location just caudal to the costal arch ipsilateral to the lesion. A second instrument port was placed in the caudal quadrant, cranial to and 5 to 7 cm lateral to the telescope port in a location just caudal to the costal arch ipsilateral to the lesion. A second instrument port was placed in the caudal abdominal quadrant 5 to 10 cm caudal and 5 cm lateral to and 5 to 8 cm lateral to the telescope port in a location just caudal to the costal arch ipsilateral to the lesion.
to 8 cm lateral to the telescope port in the lower left quadrant (Figure 1). If a fourth port was placed, it was placed over the location of the kidney to aid in retraction of more cranially located tissues.

Once all ports had been established, the peritoneal cavity was briefly explored to evaluate for intercurrent pathological changes or signs of metastasis. Periadrenal tissues adjacent to the tumor were manipulated with a blunt probe, Babcock or Kelly forceps, or laparoscopic surgical retractor to initiate the dissection of the tumor.

Dogs received supplemental corticosteroid treatment at the point of tumor manipulation during surgery to avoid a hypoadrenocortical episode in the recovery period. Dexamethasone sodium phosphate (0.1 to 0.2 mg/kg [0.05 to 0.09 mg/lb], IV), prednisolone sodium succinate (1 to 2 mg/kg [0.45 to 0.91 mg/lb], IV), or hydrocortisone sodium succinate (2 mg/kg, IV) was administered. A bipolar or ultrasonic vessel-sealing device was used to develop all of the dissection planes around the tumor and, in most cases, was used to ligate and section the phrenicoabdominal artery and vein. In the first 3 procedures performed, the phrenicoabdominal vein and artery were clipped with a laparoscopic clip applier.1 Interruptent suctioning of small amounts of blood as well as fat around the gland was performed with either a disposable or nondisposable suction irrigator. After dissection of the tumor was complete, the tumor was placed into the inverted thumb of a large-sized surgical glove or into a commercially available specimen retrieval device. The surgical site was lavaged with sterile saline (0.9% NaCl) solution and closely inspected for ongoing hemorrhage.

Port site closure was performed in a routine fashion after free gases had been evacuated from the peritoneal cavity. Interrupted sutures of 2-0 to 3-0 polydioxanone were placed in the deep fascia of the body wall. Subcutaneous tissues were generally closed with poliglecaprone 25 in either a simple interrupted or simple continuous pattern. Intradural closure was performed with 3-0 to 4-0 poliglecaprone 25 in a simple continuous pattern. For some patients, skin sutures were placed with 3-0 to 4-0 nylon in a simple interrupted or cruciate pattern.

Open adrenalectomy—All dogs in the open adrenalectomy group underwent adrenalectomy via ventral celiotomy approach with a technique similar to those previously described.1–6 Supplemental corticosteroid treatment was administered at the point of tumor manipulation as described for laparoscopic adrenalectomy. Adrenal tumors were removed by careful dissection of all peritumoral attachments with a combination of sharp and blunt dissection. Hemostasis was achieved with combinations of monopolar or bipolar electrosurgery, surgical clips, and suture material. Vessel-sealing devices were not used in any patients undergoing open adrenalectomy. Closure of the celiotomy incision was routine in all cases.

Postoperative care—All dogs were carefully monitored as they recovered from surgery in an intensive care setting. Analgesic protocols were instituted according to the discretion of the attending clinician. Generally, this consisted of intermittent IV administration or constant rate infusion of an opioid drug: hydromorphone hydrochloride (0.1 mg/kg, IV q 4 h), oxymorphone hydrochloride (0.1 mg/kg, IV q 4 h), buprenorphine hydrochloride (0.01 mg/kg [0.005 mg/lb], IV q 6 h), or fentanyl citrate (2 to 10 µg/kg/h [0.9 to 4.5 µg/lb/h], IV). On discharge, tramadol hydrochloride was prescribed (2 to 4 mg/kg [0.91 to 1.82 mg/lb], PO, q 8 h for 3 to 5 days) for most dogs. Dogs in which hyperadrenocorticism was not suspected were administered NSAIDs: either deracoxib (1 mg/kg, PO, q 24 h for 3 to 7 days) or carprofen (2.2 mg/kg [1.0 mg/lb], PO, q 24 h for 3 to 7 days).

Outcome assessment—Surgical variables compared between laparoscopic adrenalectomy and open adrenalectomy groups included surgical time from initial skin incision to placement of the last closing suture (if dogs had other procedures performed concurrently, only the time for the surgical approach, adrenalectomy time, and closure time were recorded), peripheral organ injury; and incidence of gross tumor capsular rupture. Clinical findings related to hemorrhage (subjectively assessed as minor or severe on the basis of the medical record) were also reported.

Postoperative variables compared between the 2 groups included hospitalization time (in hours from the end of surgery to discharge time), incidence of postoperative pancreatitis (determined on the basis of clinical suspicion and results of laboratory and diagnostic imaging tests), postoperative pneumonia, thromboembolism (suspected on the basis of clinical signs and diagnostic imaging findings), and wound infection. Postoperative mortality rate (proportion of dogs that died or were euthanized within the postoperative hospitalization period) was also compared between groups. An attempt was made to follow-up on all patients for ≥ 1 month after surgery.

Statistical analysis—A series of comparisons were made to determine baseline (preoperative) differences between dogs of the laparoscopic adrenalectomy and open adrenalectomy groups. Ordinal characteristics were analyzed with Student’s t tests when the data were normally distributed or could be transformed to normality; otherwise, Mann-Whitney tests were used. Categorical
characteristics were analyzed for independence with χ² tests. Outcomes were compared for group differences, with adjustment for the side on which adrenalectomy was performed. Additional analyses added an adjustment for log-transformed body weight, tumor diameter, or body condition score to determine whether the significance of the group effect was affected by these possible confounding factors. For continuous responses, these analyses were performed with ANCOVA models, after transforming the dependent variable appropriately. For significance of the group effect was affected by these possible confounding factors. For continuous responses, these analyses were performed with ANCOVA models, after transforming the dependent variable appropriately. For analyses were performed with ANCOVA models, after transforming the dependent variable appropriately. For continuous responses, these analyses were performed with ANCOVA models, after transforming the dependent variable appropriately. For continuous responses, these analyses were performed with ANCOVA models, after transforming the dependent variable appropriately. For significant results consistent with a diagnosis other than adrenocortical disease. Twenty-five dogs that underwent open adrenalectomy for similar lesions in the 7 years prior to institution of the laparoscopic adrenalectomy technique at the University of California-Davis were included as control dogs. There were no differences between dogs in the laparoscopic adrenalectomy and open adrenalectomy groups with regard to age, sex, body condition score, trilostane or phenoxybenzamine pretreatment, presence or absence of hyperadrenocorticism, lesion side, maximal tumor diameter, or tumor type. Dogs in the open adrenalectomy group were significantly (P = 0.04) heavier than dogs in the laparoscopic adrenalectomy group.

Laparoscopic adrenalectomy group—Twelve dogs were spayed females, 10 were castrated males, and 1 was a sexually intact male. Median age of dogs was 11 years (range, 6 to 16 years). Breeds represented included 6 mixed-breed dogs and 1 each of Bichon Frise, Cairn Terrier, Cocker Spaniel, Dachshund, English Springer Spaniel, German Shepherd Dog, Great Pyrenees, Greyhound, Labrador Retriever, Miniature Dachshund, Miniature Pinscher, Miniature Schnauzer, Rhodesian Ridgeback, Samoyed, Shih Tzu, Shetland Sheepdog, and West Highland White Terrier. Median weight of these dogs was 16.6 kg (36.5 lb; range, 6.4 to 43.6 kg [14.1 to 95.9 lb]). Median body condition score was 6 of 9 (range, 4 to 8).

Trilostane was administered to 14 dogs at a median dosage of 1.1 mg/kg (0.5 mg/lb; range, 0.5 to 4.0 mg/kg [0.23 to 1.82 mg/lb], PO, every 12 hours for 2 to 4 weeks before surgery. Phenoxybenzamine was administered to 5 dogs at a median dosage of 0.8 mg/kg (0.36 mg/lb; range, 0.5 to 1.2 mg/kg [0.23 to 0.55 mg/lb]), PO, every 12 hours for 2 to 4 weeks before surgery. Nine dogs had right-sided masses and 14 dogs had left-sided masses resected. In 1 dog, bilateral adrenal masses were present but only the larger left-sided lesion was resected in this dog during the study period. Hyperadrenocorticism was preoperatively diagnosed in 16 dogs and not suspected in 7 dogs on the basis of preoperative biochemical analysis, endocrine function testing, and diagnostic imaging results.

Historical findings in this cohort of dogs included polydipsia and polyuria (n = 16), lethargy (6), polyphagia (6), excessive panting (3), weight loss (1), weight gain (1), vomiting (1), urinary incontinence (1), and coughing (1). In 1 dog with no clinical signs, an incidental finding of hepatic enzyme activities above the upper reference limits during a wellness examination prompted further diagnostic evaluation. Physical examination findings in these dogs included bilateral flank hair thinning or alopecia (n = 5), a pendulous abdomen (2), and a heart murmur (1).

Thoracic radiographs for 19 of 23 dogs were available for review, and a thoracic CT scan was performed in 1 of 23 dogs. Imaging results were considered normal except for the following findings: left atrial enlargement (n = 1 dogs), ill-defined opacity in right caudal lung lobe (1), and diffuse mild interstitial lung pattern (1). No obvious metastatic lesions were detected in the thorax of any dog.

Abdominal ultrasonography was performed in all 23 dogs. Unilateral adrenal masses were found in 22 dogs, and bilateral adrenal masses were detected in 1 dog. In 1 dog, there was suspicion of phrenicoabdominal vein and caval vena caval invasion on ultrasonography, but caval invasion was subsequently ruled out by CT evaluation. Other findings detected on abdominal ultrasonography included hepatomegaly (n = 8 dogs), 1 or more splenic nodules (5), 1 or more hepatic nodules (4), bilateral pyelectasia (2), bladder urethra (1), and trigonal mass of the urinary bladder (1). Contrast-enhanced CT scans of the abdomen were performed in 20 of 23 dogs. Adrenal masses were detected in all patients. In 5 dogs, CT examination revealed phrenicoabdominal vein invasion but in no dogs were caval vena caval thrombi visualized. Median maximal diameter of the resected adrenal masses was 2.8 cm (range, 1.1 to 4.3 cm). Median tumor volume from CT scans in 20 of 23 dogs was 12.1 cm³ (range, 2.2 to 35.6 cm³). Ratio of tumor volume to body weight was a median of 0.64 (range, 0.1 to 3.9).

In 18 dogs, 3 ports were used, and in 5 dogs, 4 ports were used. Four of the 5 dogs with 4 ports placed had left-sided lesions, and 1 had a right-sided lesion. The bipolar sealing device was used in 22 of 23 dogs, and an ultrasonic vessel sealer was used in 1 dog. In 1 of 23 dogs, conversion to an open adrenalectomy was performed because of inability to control hemorrhage from a blood vessel at the cranial pole of the tumor. Although the bleeding was not considered severe, the primary surgeon felt that the safer course of action was to convert to an open approach to avoid excessive blood loss. The patient did not require transfusions for hemodynamic support, and control of the bleeding was rapidly achieved after conversion. Data from this dog were retained in the statistical analysis of baseline group variables but excluded from the analyses of outcome data between groups.

Intraoperative complications included minor hemorrhage from the phrenicoabdominal artery on the lateral aspect of the tumor in 2 of 22 dogs that was easily controlled with the vessel sealing device, minor hemorrhage from the renal capsule in 1 dog that did not require specific treatment, and minor tumor capsule rupture or impingement in 7 dogs (5 with right-sided lesions...
and 2 with left-sided lesions). Median surgery time for laparoscopic adrenalectomy was 90 minutes (range, 40 to 150 minutes). Other procedures performed concurrently with adrenalectomy included laparoscopic liver biopsy (n = 3 dogs), laparoscopic splenectomy (1), and laparoscopic-assisted cystotomy (1).

Histologic evaluation revealed adenocortical carcinoma in 13 dogs and adrenocortical adenoma in 9 dogs. One dog had a diagnosis of adrenocortical hyperplasia on histologic examination.

Postoperative complications that were confirmed or suspected included pneumonia (n = 1 dog) and wound infection at 1 port site (1). All dogs in the group were discharged from the hospital and survived ≥ 1 month after surgery.

Open adrenalectomy group—Seventeen dogs were spayed females and 8 dogs were castrated males. Median age was 10 years (range, 6 to 13 years). Breeds represented included mixed (n = 6), Rhodesian Ridgeback (2), Boxer (2), Labrador Retriever (2), and 1 each of Brussels Griffon, Basset Hound, Border Collie, Chesapeake Bay Retriever, Dalmatian, German Shepherd Dog, Lhasa Apso, Pit Bull Terrier, Pembroke Welsh Corgi, Rottweiler, Scottish Terrier, Shiba Inu, and West Highland White Terrier. Median body weight was 20.7 kg (65.3 lb; range, 8.5 to 52.3 kg [18.7 to 113.1 lb]). Median body condition score was 6 of 9 (range, 3.5 to 9).

Trilostane was administered to 10 dogs at a median dosage of 1.05 mg/kg (0.48 mg/lb; range, 0.9 to 2.9 mg/kg [0.41 to 1.32 mg/lb]) every 12 hours for 2 to 4 weeks before surgery. Phenoxycobenzamine was administered to 8 dogs at a median dosage of 0.66 mg/kg (0.3 mg/lb; range, 0.22 to 2.5 mg/kg [0.10 to 1.14 mg/lb]) every 12 hours for 2 to 4 weeks before surgery.

Right-sided lesions were present in 16 dogs, whereas 9 dogs had left-sided lesions. Preoperative endocrine testing confirmed hyperadrenocorticism to be present in 18 dogs, and nonfunctional tumors were suspected in 7 dogs.

Historical findings in this cohort of dogs included polydipsia and polyuria (n = 18), lethargy (8), polyphagia (11), excessive panting (10), coughing (2), weight gain (1), urinary incontinence (1), and paraparesis (1). Physical examination findings in these dogs included a pendulous abdomen (n = 10), bilateral flank hair thinning or alopecia (9), subcutaneous masses (3), heart murmur (3), tachyarrhythmia (1), and paraparesis (1).

Thoracic radiographs for 22 of 25 dogs were available for review. No dogs had evidence of metastatic disease in the thorax. Other relevant findings on thoracic radiography included moderate diffuse bronchiointerstitial pattern (n = 2), possible bronchitis or bronchiectasis (1), and mild left cranial lung lobe infiltration most likely consistent with pneumonia (1). Abdominal ultrasonography revealed a unilateral adrenal mass in all dogs. Other findings included hepatomegaly (n = 8 dogs), bladder wall thickening (2), hepatic nodule (1), splenomegaly (1), splenic nodule (1), bilateral pyelectasia (1), and mesenteric lymphadenopathy (1). There was suspicion of phrenicoabdominal vein invasion on abdominal ultrasonography in 2 dogs, and this was also detected on a subsequent CT scan of one; in the second dog, a CT scan following ultrasonography was suggestive of renal vein invasion, although this was not found to be present at surgery. Median maximal tumor diameter was 3.2 cm (range, 1.3 to 4.4 cm). Contrast-enhanced CT scans of the abdomen were performed in 6 of 25 dogs. Median tumor volume from CT scans was 8.9 cm³ (range, 3.3 to 14.2 cm³). Median ratio of tumor volume to body weight was 0.47 (range, 0.1 to 0.62).

A ventral midline celiotomy was performed in all dogs that underwent open adrenalectomy. Intraoperative complications included severe hemorrhage in 1 dog from a branch of the renal vein that was ligated and tumor capsular penetration in 1 dog with a particularly friable tumor that was removed piecemeal. Detailed surgical reports were lacking for some of these dogs, and capsular rupture or impingement may not have been recorded for all surgeries in which it occurred. Surgical time was documented in the medical records of 18 of 25 dogs. Median surgery time for open adrenalectomy was 120 minutes (range, 75 to 195 minutes). Histologic evaluation of the resected adrenal mass revealed adenocortical adenocarcinoma and adenoma in 14 and 10 dogs, respectively. The diagnosis for the remaining dog was adrenocortical hyperplasia.

Postoperative complications that were confirmed or suspected on the basis of clinical findings and diagnostic evaluation included pancreatitis (n = 2 dogs), aspiration pneumonia (2), and thromboembolism (1). Two dogs died within 3 days after surgery, prior to discharge; one of these dogs became very hypoxic (determined on the basis of low partial pressures of arterial oxygen on blood gas analysis) in the postoperative period, and thromboembolism was suspected. The second dog became lethargic and dyspneic 3 days after surgery and had cardiopulmonary arrest. Necropsy revealed severe pancreatitis and hepatitis. The remaining 23 dogs were discharged from the hospital. Of these 23 dogs, 15 were known to have survived ≥ 1 month, whereas the remaining 8 were lost to follow-up.

Comparison of outcomes—Results of statistical comparisons for outcomes of interest between groups were summarized (Table 1). The incidence of gross tumor capsular rupture or impingement was confirmed in 24 of 25 dogs (Table 1). One of 23 dogs in the laparoscopic adrenalectomy group, conversion to an open adrenalectomy was performed because of inability to control hemorrhage from a blood vessel at the cranial pole of the tumor. Data from this dog were retained in the statistical analysis of other group comparisons but excluded from the analyses of outcome data.

Table 1—Results of outcome variable analysis for 48 client-owned dogs that underwent laparoscopic adrenalectomy (n = 23) at the University of California-Davis or the University of Pennsylvania between June 1, 2007, and October 16, 2013, or open adrenalectomy (25) at the University of California-Davis between January 22, 2003, and July 10, 2009.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Laparoscopic adrenalectomy</th>
<th>Open adrenalectomy</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumor capsule rupture or impingement</td>
<td>7/22</td>
<td>1/25</td>
<td>0.01</td>
</tr>
<tr>
<td>Pancreatitis</td>
<td>0/22</td>
<td>2/25</td>
<td>0.09</td>
</tr>
<tr>
<td>Thromboembolism</td>
<td>0/22</td>
<td>1/25</td>
<td>0.32</td>
</tr>
<tr>
<td>Wound infection</td>
<td>1/22</td>
<td>0/25</td>
<td>0.34</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>1/22</td>
<td>2/25</td>
<td>0.58</td>
</tr>
<tr>
<td>Surgery time (min)†‡</td>
<td>95 (40–50)</td>
<td>120 (75–195)</td>
<td>0.001</td>
</tr>
<tr>
<td>Days in hospital*</td>
<td>3 (1–4)</td>
<td>4 (2–6)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Postoperative time in hospital (h)†‡</td>
<td>48 (22–70)</td>
<td>66 (27–77)</td>
<td>0.001</td>
</tr>
<tr>
<td>Perioperative death</td>
<td>0/22</td>
<td>2/25</td>
<td>0.07</td>
</tr>
</tbody>
</table>

For 1 of 23 dogs in the laparoscopic adrenalectomy group, conversion to an open adrenalectomy was performed because of inability to control hemorrhage from a blood vessel at the cranial pole of the tumor. Data from this dog were retained in the statistical analysis of other group comparisons but excluded from the analyses of outcome data.

†Values reported as median (range). †Data reported for 22 of 23 dogs in the laparoscopic adrenalectomy group, respectively. †Data for 2 dogs that died in the postoperative period were excluded from analysis of postoperative hospitalization time.
capsular rupture was greater, whereas surgical time, total hospital stay, and number of hours hospitalized after surgery were all significantly ($P < 0.05$) shorter in the laparoscopic adrenalectomy group, compared with the open adrenalectomy group.

**Discussion**

The laparoscopic approach to adrenalectomy is a complex intervention that requires considerable experience and the availability of specialized equipment to complete. The procedure has been previously described in 16 dogs$^{10,12}$ and 1 cat, generally with excellent results reported. In the present study, a cohort of a further 23 dogs that underwent this procedure had successful outcomes, with little perioperative morbidity, no deaths, and only 1 conversion to an open approach.

Despite the relatively small numbers of case descriptions in the literature, it is becoming evident from multiple centers that this intervention can be performed successfully in dogs of various sizes if appropriate case selection is considered. In the first report$^{10}$ of laparoscopic adrenalectomy in the veterinary literature, results from 7 dogs with hyperadrenocorticism and adrenal tumors ranging in size from 24 to 48 mm were described. The principal technical challenge reported was rupture of the tumor capsule that occurred in the first 2 surgeries and prompted the authors of that study to prophylactically penetrate the capsule and aspirate the contents in future patients. Although en bloc resection is ideal, these tumors often have delicate capsules, and penetration can occur easily. No obvious recurrence of clinical signs occurred in that group of 7 dogs, suggesting that tumor regrowth was unlikely to have occurred within the follow-up period, although the ramifications of this complication would require further study.$^{10}$ In a subsequent report by Naan et al.,$^{12}$ 9 dogs with adrenocortical tumors treated by this method also had little surgical morbidity. Of those 9 patients, tumor capsule rupture occurred in 2, and 1 dog developed a pneumothorax from inadvertent Veress needle penetration of the thoracic cavity.$^{12}$ In the present study, 7 of 22 dogs had minor tumor capsular rupture noted by the surgeon, and rupture in 5 of these 7 occurred during right-sided mass resection. For tumors of the right adrenal gland, the capsule of the tumor is often continuous with the external tunic of the vena cava, making these tissues generally harder to dissect away from each other. Histologically, capsular penetration cannot easily be evaluated because, during exteriorization of the tumor with a specimen retrieval device, it is common to disrupt the tumor capsule during forced exteriorization through the small port incision. Despite a significantly increased incidence of capsular rupture in dogs that underwent laparoscopic adrenalectomy versus open adrenalectomy, these results should be interpreted with caution. Although data for patients that underwent laparoscopic adrenalectomy were prospectively entered into a database by the authors, data for dogs that had open adrenalectomy were retrospectively collected from surgical reports, which in some cases may have neglected to describe capsular rupture. It may also be possible that capsular rupture is detected less frequently during open adrenalectomy because the magnification provided by the laparoscope allows easy detection of even subtle capsular penetration. It is unlikely that capsular rupture commonly leads to tumor regrowth, considering that few cases have been reported in the literature and recurrence of clinical signs in dogs with hyperadrenocorticism after adrenalectomy has not been described to the authors’ knowledge. Our study did not include long-term follow-up of patients, so the importance of capsular rupture in these dogs remains unknown.

Dogs in this study were positioned in lateral recumbency with the spinal column partially elevated relative to the ventral aspect of the abdomen by use of a mechanical tilt table. In the authors’ opinion, this positioning gave excellent access to the lesions and vitally provided very good visibility of the major vascular dissection planes between the mass and the caudal vena cava as well as renal veins and arteries. We found that retraction of organs was not necessary in most patients, especially for right-sided lesions. In only 1 patient with a right-sided lesion was a fourth port necessary for insertion of a retractor. For lesions on the left side, it is possible that there may be some impingement on the surgical field by the stomach (especially if it is very gas filled) or the spleen. In 4 of 14 dogs with left-sided lesions, a fourth port was placed to aid in retraction of surrounding organs. Tilting of the table to facilitate a more sternal position was found to help with retraction of these organs in some cases. Although true sternal recumbency was found to be potentially advantageous in preventing organ interference with surgical dissection in 1 study$^{12}$ that evaluated this positioning in dogs, it was still necessary to place a fourth port in 2 of 5 healthy dogs, and investigators of that study felt that this positioning was more challenging with right-sided lesions. It is possible that ideal patient positioning may vary depending on specific patient and lesion characteristics. No studies have prospectively compared these 2 positions for laparoscopic adrenalectomy in dogs. In the present study, we always draped the linea alba into the sterile field, thus allowing conversion to a ventral midline celiotomy approach should conversion become necessary. Intraoperative complications in the laparoscopic adrenalectomy group were limited to 1 patient, in which a bleeding vessel at the cranial pole of the tumor could not easily be controlled and led to the decision to convert to an open approach. In 2 other patients, minor hemorrhage from the phrenicoabdominal artery on the lateral aspect of the lesion occurred, but rapid control of the hemorrhage was possible with a vessel-sealing device. In the authors’ experience, with the aid of a suction device that functions to improve visibility of the surgical field during minor bleeding, many intraoperative sources of minor bleeding from the tumor capsule or phrenicoabdominal vessels can be sealed without conversion to an open approach. However, surgeons should not hesitate to convert to an open approach if bleeding is profuse or cannot be completely controlled intraoperatively.

To our knowledge, this is the first study to compare postoperative complications, surgical time, and hospitalization times between dogs undergoing laparoscopic adrenalectomy and open adrenalectomy. In humans, many advantages have been reported in outcomes for

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Laparoscopic adrenalectomy over open adrenalectomy, including lower incidences of postoperative pneumonia, sepsis, renal insufficiency, wound infection, and cardiac arrest as well as shorter hospital stays.\textsuperscript{9,13,18} Surgical time in humans has also been reported to be longer for open adrenalectomy, compared with laparoscopic adrenalectomy.\textsuperscript{9} Data for the present study represent a much smaller cohort of dogs, compared with the number of patients in most human studies. However, we were able to draw some of the same conclusions. Surgical time for the laparoscopic procedure was significantly (\(P = 0.03\)) shorter than for open adrenalectomy. Many factors affect surgical time, including surgeon experience, lesion type, and availability of surgical equipment. All surgeries for the patients in the present study were performed in a veterinary teaching hospital environment, with board-certified surgeons and residents in training involved as primary or assistant surgeons. It would be difficult to retrospectively quantify surgeon experience between groups when multiple clinicians were involved in the procedures and when different primary surgeons would have had variable degrees of experience with open and laparoscopic adrenalectomy procedures. Lesions were matched between the laparoscopic adrenalectomy and open adrenalectomy groups, and there was no difference in maximal diameter of the lesion between groups. There were more right-sided lesions in the open adrenalectomy group, compared with the laparoscopic adrenalectomy group, although this difference was not significant. One factor that may have played a role in the duration of surgery is that in all patients that underwent laparoscopic adrenalectomy, dissection was performed with the aid of a vessel-sealing device, whereas the open adrenalectomy procedures were performed prior to the acquisition of a vessel-sealing device. Vessel-sealing devices are known to improve surgical time in laparoscopic adrenalectomy in humans,\textsuperscript{19} and this may have in part driven this difference; however, we hypothesize that the magnitude of this difference was not driven by the impact of vessel-sealing devices alone.

Hospitalization times (both total days in hospital and postoperative hours in hospital) were significantly (\(P \leq 0.001\)) lower in the laparoscopic adrenalectomy group, a finding that has been reported in several human studies.\textsuperscript{9,13} This difference may in part be driven by a reduced need for prolonged opioid-based analgesic regimens in the postoperative period, although no study has confirmed this finding in veterinary patients. It may also be attributable to a reduction in other morbidities, such as pneumonia and pancreatitis, compared with that in patients undergoing open adrenalectomy. In the present study, all postoperative morbidity rates in dogs were low. Pancreatitis is always a concern in postadrenalectomy patients, and it may be hypothesized that laparoscopic adrenalectomy provides an advantage over open adrenalectomy in that minimal or no pancreatic retraction is necessary with this procedure. In our study, 2 of 25 dogs in the open adrenalectomy group had postoperative pancreatitis, which proved fatal in 1 dog. This difference between groups was not significant (\(P = 0.09\)). However, if larger populations of dogs undergoing these procedures are assessed in future studies, it may become possible to confirm this hypothesis. There were no postoperative deaths in the laparoscopic adrenalectomy group, whereas 2 dogs in the open adrenalectomy group died in the postoperative period: one of confirmed pancreatitis and the other of suspected pneumonia and thromboembolic disease. Larger numbers of clinical patients would be required to prove a difference in postoperative mortality rates between groups.

Care should be taken in comparing these results to general retrospective studies of adrenalectomy that do not exclude dogs with very large or invasive tumors. The open adrenalectomy and laparoscopic adrenalectomy groups in the present study excluded these higher-risk patients and thus results appear favorable, compared with those of studies in which all adrenalectomy patients have been grouped together.

Case selection is a critical step in the development of advanced laparoscopic techniques and can aid in ensuring optimal outcomes and low complication and conversion rates. The role of advanced imaging is considered important by the authors in ruling out vascular invasion in any adrenalectomy patients but especially those undergoing laparoscopic adrenalectomy, where intraoperative assessment of the vasculature may be impaired by the inability to palpate the regional anatomic structures. It has been reported that contrast-enhanced CT has a higher sensitivity and specificity for detection of vascular invasion, compared with ultrasonography,\textsuperscript{2–20} and because of this, CT has become the standard modality for preoperative assessment of laparoscopic adrenalectomy candidates in the authors’ institution. In the study reported here, 5 dogs were found to have phrenicoabdominal vein invasion on CT but still underwent adrenalectomy via a laparoscopic approach. Because the phrenicoabdominal vein is sectioned directly at the point of entry into the caudal vena cava, we do not consider phrenicoabdominal vein invasion in isolation as a contraindication to laparoscopic adrenalectomy. However, if invasion into the caudal vena cava is suspected, we would recommend an open approach. Lesion size is commonly cited in the human literature as an important case selection criterion, and in the authors’ experience, lesions up to approximately 5 cm seem amenable to a laparoscopic approach. Adrenal masses > 5 cm often have more invasive characteristics and thus may not be candidates for laparoscopic adrenalectomy, but it is possible that removal of noninvasive lesions > 5 cm will be amenable to a laparoscopic approach in the future. In many adrenal masses, either the cranial pole or the caudal pole of the lesion is affected by the tumor, and the authors have observed that cranial pole lesions are often much simpler to remove laparoscopically, compared with caudal pole lesions, which are often closely adherent to the renal vein. Surgeons should consider this in the early part of their learning curve as they select suitable cases for laparoscopic adrenalectomy.

Our results supported that laparoscopic adrenalectomy can be a feasible intervention in canine patients with modestly sized noninvasive adrenal masses. In this study, we found that laparoscopic adrenalectomy reduced surgical time and hospitalization time, compared
with open adrenalectomy. Future studies with greater case numbers are required to evaluate more thoroughly the effect of laparoscopic adrenalectomy on postoperative morbidity and mortality rates and to evaluate the long-term oncological outcomes in these patients.

a. OsiriX, version 4.1.2, Pixmeo, Bernex, Switzerland.
b. C-Arms International Inc, San Diego, Calif.
d. Hopkins II laparoscope, Karl Storz Veterinary Endoscopy, Goleta, Calif.
e. Endostip, Karl Storz Veterinary Endoscopy, Goleta, Calif.
f. 11-mm trocar/cannula assembly 30103, Karl Storz Veterinary Endoscopy, Goleta, Calif.
g. Endopeanut, Covidien Inc, Mansfield, Mass.
h. Ligasure, Covidien Inc, Mansfield, Mass.
i. Harmonic Scalpel, Ethicon Endo-Surgery Inc, Cincinnati, Ohio.
j. M/L-10, Microline Surgical, Beverly, Mass.
l. Suction wand with trumpet valve, Karl Storz Veterinary Endoscopy, Goleta, Calif.
m. Monarch Applied Medical Inc, Rancho Santa Margarita, Calif.

References