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Laparoscopic adrenalectomy for resection of unilateral noninvasive adrenal masses in dogs is associated with excellent outcomes in experienced centers

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OBJECTIVE
To report the short- and long-term outcomes of laparoscopic adrenalectomy (LA) for resection of unilateral adrenal masses and to document risk factors for conversion and peri- and postoperative morbidity.

ANIMALS
255 client-owned dogs.

METHODS
Dogs were included if LA was attempted for resection of a unilateral adrenal mass. Medical records were evaluated and relevant data were reported, including complications, conversion, perioperative death, and long-term outcomes. Signalment, clinicopathological data, and surgical experience were factors statistically evaluated for possible associations with capsular penetration during surgery, conversion, surgical time, duration of hospital stay, death prior to discharge, mass recurrence, and survival time.

RESULTS
155 dogs had left-sided tumors, and 100 had right-sided tumors. Conversion to an open approach was performed in 9.4% of cases. Capsular penetration (19.2%) and major hemorrhage (5.4%) were the most prevalent intraoperative complications. Of the dogs operated on, 94.9% were discharged from the hospital. Lesion side, portion of the gland affected, and surgeon experience influenced surgical time. Conversion rate increased with increasing body condition score and lesion size. Risk of death prior to discharge increased with increasing lesion size. Risk of conversion and death prior to discharge were lower when performed by more experienced surgeons. Capsular penetration during LA increased the risk of tumor recurrence.

CLINICAL RELEVANCE
LA for resection of unilateral adrenal masses is associated with excellent outcomes in experienced centers. Surgeons with greater experience with LA have lower surgical times, conversion rates, and risk of death prior to discharge.

Laparoscopic adrenalectomy (LA) has been established as a safe and effective alternative to open celiotomy for resection of adrenocortical tumors and pheochromocytomas in dogs with modestly sized adrenal masses that do not invade the vena cava.[1–6] Results have been published from several small cohorts of dogs that have undergone LA and have reported short-term perioperative complications and conversion rates as well as mortality.[1–6] Hemorrhage and capsular penetration are cited as the most commonly encountered adverse events.[1–6] Conversion rates of 0% to 10% have principally been attributed to hemorrhage and

challenges associated with visualization of the operative field.[1–6] Mortality has been reported to occur in 0% to 28% of cases and is reported variably as mortality prior to discharge in some studies or mortality within 30 days of surgery in others.[1–6]

To date, there is no report evaluating the outcomes of LA in a large cohort of dogs. Studies published to date have also not been able to evaluate risk factors for complications, conversion, and perioperative mortality due to small case numbers. Furthermore, the role of surgical experience with LA has not been evaluated as a risk factor for complications or long-term outcomes. For this study, data on surgical outcomes of a large cohort of dogs undergoing LA in specialized centers with considerable experience in minimally invasive surgery were collected. The study aimed to document perioperative complications, conversion, and mortality rates as well as long-term outcomes and recurrence of adrenal tumors treated with LA. A secondary aim of the study was to document the effect of experience with LA on complication and conversion rates and long-term outcomes in dogs.

Methods

Animals

Medical records of dogs that underwent LA for resection of an adrenal mass between June 2007 and February 2022 at 1 of 7 veterinary institutions (6 academic teaching hospitals and 1 private specialty practice) were included in the study. Dogs in which vascular invasion into the phrenicoabdominal vein alone had been diagnosed by preoperative diagnostic imaging studies were retained, but dogs in which tumor thrombus extension into the vena cava or other vascular structures was present were excluded from the study. Dogs that underwent an open adrenalectomy (OA) were also excluded, although data from dogs in which an LA was attempted but converted to an open approach were retained in the study. This study includes some data on small cohorts of patients for which short-term outcomes were previously published in other manuscripts.[3–5]

Diagnostic evaluation

Medical records were evaluated for signalment, history, and the results of physical examination and diagnostic imaging. Due to the large case cohort, summary data are most often reported. The presence of adrenal or pituitary-dependent hyperadrenocorticism is reported based on endocrinological evaluation using urine creatinine-to-cortisol ratio, low-dose dexamethasone suppression testing, and endogenous adrenocorticotropic hormone assay, although results are not reported in detail. Suspicion for the presence of a pheochromocytoma was based on consistent clinical signs and/or the results of urine normetanephrine-to-creatinine and metanephrine-to-creatinine ratios where they were performed. Tumor size was measured as the maximal diameter of the tumor on either an abdominal ultrasonographic evaluation or contrast-enhanced CT (CECT). The side of the lesion (right, left) was recorded. Whether the adrenal tumor emanated principally from the cranial pole or the caudal pole or whether the whole gland appeared effaced was also recorded. In cases where details of mass location could not be reliably collected from recorded imaging studies, no entry was made for mass location. Vascular invasion into the phrenicoabdominal vein only was reported and these dogs were included in the study. Dogs with suspicion of vascular invasion into the vena cava or other vascular structures on preoperative diagnostic imaging were excluded.

Surgery

All dogs in this study underwent a unilateral transperitoneal LA using a technique similar to those previously described.[1–6] Dogs were positioned in lateral, lateral oblique, or sternal recumbency, and a 3- to 5-port technique was used. In all cases, the telescope port was placed 3 to 5 cm lateral to the umbilicus on the affected side, and instrument ports were positioned in the cranial and caudal quadrants on the affected side as has been previously described.[1–6] In some cases, a fourth or fifth portal was added as required for placement of additional instrumentation, principally if challenges were encountered in retracting surrounding organs. Surgical and anesthesia time was recorded for all procedures. Anesthesia time included time for all unrelated procedures and diagnostic imaging tests to be performed that occurred under the same anesthesia. Surgical time was recorded as the time from the initial skin incision to the termination of the LA procedure, and every attempt was made to exclude the surgical time necessary for other nonadrenal procedures to be performed. The results of histopathological evaluation of all resected and submitted masses are reported.

Complications, conversion, and recurrence

Complications were recorded for each procedure and classified using the Veterinary Cooperative Oncology Group—Common Terminology Criteria for Adverse Events (VCOG-CTCAE v2) scheme recently described.[7] Conversion to an open approach was recorded when it occurred along with the reason conversion was pursued. Conversions were graded from grades 1 to 4 based on a previously published classification system.[8] Briefly, grade 1 conversions are strategic due to anticipated surgical difficulty, grade 2 are reactive extensions of the incision or incisions due to non–life-threatening operative difficulty or error, grade 3 are conversions to an open approach due to non–life-threatening operative difficulty or error, and grade 4 are conversions to an open approach due to life-threatening operative error. Perioperative mortality was recorded as either intraoperative or within the postoperative hospitalization period. Long-term follow-up was obtained from the medical record or by email or telephone contact with the owner. Cases where recurrence of disease was diagnosed by reemergence of clinical signs and/or by further diagnostic imaging in the postoperative period were recorded. For dogs that were discharged

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from the hospital, median survival time (± range) was recorded for those dogs still alive at the time of writing as well as those that had died.

Statistical analysis

Risk factors for complications, conversion, and perioperative mortality were evaluated statistically using both logistic (dichotomous outcomes) and linear regression (continuous outcomes) analyses. Risk factors of interest were evaluated with univariate regression for inclusion in a main effects model, with a liberal P value of < .200. Factors with P < .200 were entered together into a main effects model, and a final model was built using backward selection with a significance level of P < .05. Before removal, risk factors were tested for confounding using a 20% change in coefficients as a cut point for inclusion.[9] Clinically relevant interactions were tested. Patient-specific factors including breed, age, sex, body weight, body condition score (BCS), presence of a functional tumor, and performance of additional surgical procedures at the time of LA were evaluated as potential risk factors. Tumor-specific risk factors entered into the model included tumor side (left vs right), principal tumor location within the gland (cranial pole, caudal pole, whole gland), tumor size (maximal diameter), and histologic tumor type (adrenocortical adenoma, carcinoma, pheochromocytoma). Surgeon experience with LA (dichotomized into surgeons who had performed < 10 or > 10 LA procedures) was also considered a potential risk factor for outcomes. Outcomes assessed included duration of surgery, conversion to an open approach, postoperative hours in the hospital, death before discharge, and local recurrence of a mass at the site of LA. Gross capsular penetration at the time of surgery was also assessed as a risk factor for local recurrence. Overall survival time was reported in a descriptive fashion. All analyses were conducted using Stata, version 15 (StataCorp LLC).

Results

Animals

Two hundred fifty-five dogs that underwent unilateral LA met the inclusion criteria and were enrolled in the study. The most common types represented were mixed-breed dogs (n = 62), Shih Tzu (15), Labrador Retriever (14), Dachshund (13), Beagle (11), Golden Retriever (11), Maltese (10), Poodle (9), Jack Russell Terrier (8), German Shepherd Dog (7), Cocker Spaniel (6), and Yorkshire Terrier (5). Fifty other breeds were represented with < 5 dogs/breed. One hundred twenty-four dogs were spayed females, 86 were castrated males, 32 were intact males, and 13 were intact females. The median age at the time of surgery was 126 months (range, 48 to 204 months). Median body weight was 12.1 kg (range, 3 to 96 kg). The median BCS (out of 9) was 6 (range, 3 to 9).

Diagnostic evaluation

Endocrine evaluation was performed in most dogs but was not complete in all cases. Of dogs where there was a suspicion of an endocrinopathy present based on clinical signs, preoperative biochemical and endocrine function testing, and diagnostic imaging, 141 dogs were suspected to have either pituitary- or adrenal-dependent hyperadrenocorticism, 31 were considered to be most compatible with having a pheochromocytoma, 3 were diagnosed with diabetes mellitus, and 2 were considered to have an aldosterone-secreting mass. Three further dogs were diagnosed with diabetes mellitus and hyperadrenocorticism, and 2 dogs were suspected to have hyperadrenocorticism and a pheochromocytoma. The remaining dogs (76) were suspected to have nonfunctional tumors.

Reports from thoracic radiographs (n = 145), abdominal ultrasound evaluation (207), and abdominal CT (219) were reviewed. Thoracic radiographs revealed nonspecific pulmonary nodules that were not biopsied in 2 dogs. Findings unrelated to the adrenal glands on abdominal diagnostic imaging are not summarized due to space limitations. One hundred fifty-five (61%) dogs had left-sided masses, and 100 (39%) dogs had right-sided masses removed. Descriptive data of left and right-sided lesions is summarized **(Table 1)**. In 80 (37%) dogs the mass effaced the entire gland, in 99 (45%) dogs the mass primarily occupied the cranial pole, and in 39 (18%) dogs the mass emanated primarily from the caudal pole. In the remainder, medical records did not specify where the gland primarily emanated from. Phrenicoabdominal vein tumor invasion without extension into the caudal vena cava was diagnosed in 31 (12%) dogs using ultrasonography or CECT evaluation. Of these 31 dogs, 17 had histologically confirmed pheochromocytoma, 9 had adrenocortical carcinoma, 4 had adrenocortical adenoma, and 1 had a nonspecific adrenal endocrine

Table 1—Lesion variables and select outcomes based on side operated for 255 dogs undergoing unilateral laparoscopic adrenalectomy.

Variable	Right-sided lesions (n = 100)	Left-sided lesions (n = 155)
Portion of gland affected[a]	Cranial pole: 34/84 (40.5%)	Cranial pole: 65/134 (48.5%)
	Caudal pole: 10/84 (11.9%)	Caudal pole: 29/134 (21.6%)
	Whole gland: 40/84 (47.6%)	Whole gland: 40/134 (29.9%)
Phrenicoabdominal vein invasion present	12/100 (12%)	19/155 (12.3%)
Maximal tumor diameter (cm)	2.5 cm (range, 1.3–5.5 cm)	2.6 cm (range, 0.9–14 cm)
Conversion	11/100 (11%)	13/155 (8.4%)
Surgical time (min)	110 (range, 35–290)	95 (range, 40–280)

[a]Only cases where enough data from imaging were available to reasonably categorize into principally cranial, caudal, or whole gland effaced were included.

tumor diagnosis. The maximal median tumor diameter was 2.5 cm (range, 0.9 to 14 cm).

Surgical procedures

A 3-port technique was used most commonly (n = 186), followed by a 4-port technique (54), a 2-port (single-port device plus 1 additional instrument port) technique (3), a single-port technique alone (2), and a 5-port technique (1). Vessel-sealing devices were used in all cases. The Ligasure/ForceTriad (Medtronic Inc) line of vessel-sealing devices was used most frequently (n = 198), followed by the Enseal (Ethicon Endosurgery; 16), the Harmonic Scalpel (Ethicon Endosurgery Inc; 15), the RoBi Plus (Karl Storz Inc; 15), and the Sonicision (Medtronic Inc; 2). Resected adrenal tumors were placed into a specimen-retrieval bag or the cut thumb of a sterile surgical glove. In 55 dogs, a total of 64 additional procedures were performed at the same time as LA and included laparoscopic liver biopsy (n = 29), laparoscopic splenectomy (10), dermal mass resection (8), castration (3), thoracoscopic lung lobectomy (2), lap-assisted cystotomy (2), and 1 each of thyroidectomy, parathyroidectomy, tail amputation, laparoscopic gastropexy, laparoscopic ovarian remnant resection, and partial liver lobectomy.

The median surgical time for the LA procedure was 100 minutes (range, 35 to 290 minutes). The median anesthetic time for all procedures performed at the time the LA was 210 minutes (range, 90 to 480 minutes).

Surgeon experience

Median number of LA procedures performed by 16 primary surgeons was 9 (range, 1 to 61). Eight surgeons had performed < 10 LA procedures (median number performed, 3; range, 1 to 7), and 8 surgeons had performed > 10 (median number performed, 21; range, 11 to 61).

Conversion

In total, 24 of 255 (9.4%) procedures resulted in conversion to an open celiotomy approach. Reasons for conversion included hemorrhage that affected hemodynamic stability and/or visualization of the surgical field (n = 18), poor visualization of anatomical structures (4), previously undetected vascular invasion into vena cava (1), and close adherence of tumor capsule to renal vein (1). In those that could be classified, conversions were grade 1 in 13 dogs, grade 3 in 4 dogs, and grade 4 in 6 dogs.[8]

Intraoperative complications

Capsular penetration during surgery occurred in 41 of 214 (19.2%) dogs in which this finding was reported in the surgery report. Major hemorrhage occurred in 14 of 255 (5.5%) dogs. The source of major hemorrhage was not noted in every case, but iatrogenic laceration of the ipsilateral renal vein occurred in 4 dogs, and laceration of the ipsilateral renal artery, aorta, and vena cava occurred in 1 dog each. Of the 5 dogs where major hemorrhage emanated from either the renal vein or artery, 3 of 5 had caudal pole tumors and 1 of 5 had a tumor affecting the whole gland. In 1 dog where renal vein laceration occurred, conversion to an open approach was pursued and nephrectomy was performed. Iatrogenic injury to the diaphragm occurred in 1 dog with a right-sided tumor, which did not result in conversion. In 1 dog, an initial Veress needle approach resulted in a pneumothorax. Three of 255 (1.1%) dogs died intraoperatively from hemorrhage (n = 2) and hypertension (1).

Postoperative complications and long-term outcome

Complications and severity grade, occurring in the first month postoperatively in the 252 dogs that survived the surgical procedure, are listed **(Table 2)**. Thirteen of 255 (5.1%) dogs died before being discharged from the hospital, and 242 (94.9%) dogs were discharged from the hospital. Causes of death during hospitalization were as follows: unknown

Table 2—Intraoperative and postoperative complications occurring in 255 dogs undergoing laparoscopic adrenalectomy for resection of unilateral adrenal masses.

Complication	Frequency	Incidence	VCOG-CTCAEv2 grade[7]
Intraoperative			
Capsular penetration	41/214	19.2%	Grade 1 (n = 41)
Major hemorrhage[a]	14/255	5.5%	Grade 4 (n = 12)
			Grade 5 (n = 2)
Iatrogenic injury to diaphragm	1/255	0.4%	Grade 4 (n = 1)
Pneumothorax	1/255	0.4%	Grade 3 (n = 1)
Hypertension	1/255	0.4%	Grade 5 (n = 1)
Postoperative			
Thromboembolic events	8/252	3.2%	Grade 5 (n = 7)
			Grade N/A (n = 1)
Port site wound infection	6/252	2.4%	Grade 2 (n = 6)
Suspected pancreatitis	5/252	2.3%	N/A
Regurgitation	5/252	2.3%	N/A
Aspiration pneumonia	5/252	2.3%	Grade 2 (n = 1)
			Grade 3 (n = 3)
			Grade 5 (n = 1)
Seizures	1/252	0.4%	Grade 5 (n = 1)
Gastric dilatation-volvulus syndrome	1/252	0.4%	Grade 4 (n = 1)
Severe vasculitis and skin necrosis	1/252	0.4%	N/A

[a]Lower grades of hemorrhage occurred in other cases but were not generally recorded and so were omitted here.
N/A = Not available.

(n = 6), intraoperative hemorrhage (3), suspected sepsis/systemic inflammatory response syndrome (2), bleeding auricular mass (1), and suspected thromboembolism (1). The median number of days spent in the hospital was 3 (range, 1 to 18 days). The median number of postoperative hours spent in the hospital was 48 (range, 10 to 288 hours). Recurrence of an adrenal mass was detected on abdominal imaging at the site of previous LA in 15 of 148 (10.1%) dogs that underwent subsequent abdominal imaging at various times postoperatively (exact timing of postoperative abdominal imaging was not noted in many cases and so is not reported). None of these dogs underwent a second adrenalectomy procedure. In 1 dog, recurrence was diagnosed at necropsy, at which time metastasis to the mediastinum was noted. Of the 242 dogs that were discharged from the hospital, 97 had died at a median of 18 months (range, 1 to 72 months) postoperatively, and 135 were still alive at a median of 12 months postoperatively (range, 1 to 68 months) at the time of this writing, with the remainder being lost to follow-up.

Histopathological analysis

In dogs where histopathological evaluation of submitted samples was available, the following diagnoses were made: adrenocortical carcinoma was diagnosed in 101 of 233 (43%) dogs, adrenocortical adenoma was diagnosed in 86 of 233 (37%) dogs, pheochromocytoma was diagnosed in 42 of 233 (18%) dogs, and both adrenocortical carcinoma and pheochromocytoma were present in the gland of 2 of 233 (1%) dogs. In 1 dog each, embryonal duct remnant and adrenal hyperplasia were diagnosed.

Risk factor analysis

A summary of the statistically significant risk factors for the outcomes evaluated is summarized **(Table 3)**. Surgical time was significantly affected by side of the lesion (right-sided tumors took 16 minutes [95% CI, 3.64 to 28.18 minutes] longer to resect), part of the gland affected (caudal pole tumors took 27.5 minutes [95% CI, 14.11 to 40.84 minutes] longer to resect than those effacing the entire gland), and surgeon experience (surgeons that had operated on < 10 cases took 22 minutes [95% CI, 1.89 to 41.30 minutes] longer to complete the surgery). Conversion to open surgery was affected by BCS (each 1/9 increase in BCS increased conversion risk by 1.7 times [95% CI, 1.06 to 2.71]), lesion size (for each 1-cm increase in lesion size, conversion risk increased 1.6 times [95% CI, 1.02 to 2.36]), and surgeon experience (surgeons who had performed < 10 procedures are 4.2 times as likely to convert

Table 3—Summary of risk factor analysis for a variety of outcomes for 255 dogs undergoing unilateral laparoscopic adrenalectomy. Only statistically significant results are listed here.

Effect	Risk factor	OR (for dichotomous outcomes)	β-Coefficient (for continuous outcomes)	SE	95% CI (LL to UL)	P value	Interpretation
Surgical time	Lesion side	—	15.91	6.22	3.64 to 28.18	.011	Right-sided lesions had longer surgical time compared to left-sided lesions
	Part of gland affected	—	–27.47	6.77	–40.84 to –14.10	< .001	Cranial pole lesions had shorter surgical times compared to lesions that affected the whole gland
	Surgeon experience	—	–21.59	9.99	–41.30 to –1.89	.032	More experienced surgeons had shorter surgical times
Conversion	BCS	1.69	—	0.41	1.06 to 2.71	.029	Conversion rate increases with increasing BCS
	Lesion size	1.55	—	0.33	1.02 to 2.36	.040	Conversion rate increased as lesion size increased
	Surgeon experience	0.23		0.15	0.06 to 0.83	.025	Conversion rate was lower for more experienced surgeons
Postoperative hours in hospital	Age	—	0.26	0.11	0.04 to 0.47	.021	As patient age increases, postoperative hours in the hospital increase
	Endocrinopathy: aldosteronoma	—	127.70	28.68	71.08 to 184.32	< .001	Dogs with nonfunctional tumors had shorter postoperative hospitalization compared to those with pheochromocytoma, aldosteronoma, or mixed tumors
	Endocrinopathy: hyperadrenocorticism and pheochromocytoma	—	112.17	29.56	53.80 to 170.53	< .001	
	Endocrinopathy: hyperadrenocorticism and diabetes mellitus	—	107.11	28.32	51.20 to 163.03	< .001	
	Surgeon experience	—	19.23	9.14	1.18 to 37.28	.037	Dogs operated by more experienced surgeons had greater postoperative hours in hospital
Death prior to discharge	Lesion size	0.66	—	0.11	0.47 to 0.91	.011	As lesion size increased, risk of death prior to discharge increased
	Surgeon experience	6.97	—	4.49	1.97 to 24.66	.003	Increased surgeon experience decreased risk of death prior to discharge
Local recurrence	Capsular penetration	6.48	—	4.14	1.86 to 22.64	.003	Recurrence higher in group that experienced intraoperative capsular penetration

BCS = Body condition score. LL = Lower limit. UL = Upper limit.

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[95% CI, 1.20 to 14.93]). Postoperative time in the hospital was increased by patient age (increasing age prolonged hospital stay) and surgeon experience (hospital stay was longer for surgeons who had performed > 10 procedures). Risk of death prior to discharge was affected by lesion size (as lesion size increased, risk of death prior to discharge decreased) and surgeon experience (dogs operated on by surgeons who had performed > 10 procedures were 7 times as likely to be discharged from the hospital [95% CI, 1.97 to 24.66]). Capsular penetration during surgery was a risk for local recurrence (odds of recurrence were 6.5 times as great in those with capsular penetration [95% CI, 1.86 to 22.64]). Of the 41 dogs with intraoperative capsular penetration, 7 experienced recurrence of a mass lesion at the operated site while 19 did not, and for the remaining 15, insufficient postoperative follow-up was available to know whether recurrence occurred.

Discussion

This study documents the surgical outcomes of a large cohort of dogs that underwent unilateral LA for resection of adrenal masses at 7 centers with considerable experience in veterinary minimally invasive procedures. Morbidity and mortality associated with LA compared favorably with reported outcomes of previous studies documenting the outcomes of OA performed through a celiotomy. Perioperative mortality for OA for treatment of noninvasive masses has been documented in the 3% to 25% range.[5,10-15] Perioperative morbidity is much harder to compare with historical controls, as reporting mechanisms vary so widely between studies and not all studies categorize data for noninvasive and invasive tumors separately. Care must always be taken in the interpretation of data from different studies, as a variety of biases, including variable case populations and surgeon experience levels, can affect outcomes and interpretation. In this study, 99% of dogs survived the surgical procedure, and 95% of dogs survived the perioperative procedure and were discharged from the hospital. Perioperative complication rates were also relatively low in this case population. Major hemorrhage was the most common intraoperative complication, occurring in 5.5% of cases, with damage to the ipsilateral renal vein being reported more frequently compared with other large blood vessels in the area. In 4 of 5 dogs in which major hemorrhage emanated from iatrogenic damage to either the renal vein or artery, a caudal pole tumor or a tumor effacing the entire gland was being operated on. Great care needs to be taken with tumors that affect the caudal pole, as their capsule can be closely adherent or compressing the renal vein and artery, and these masses may represent a population at higher risk for major hemorrhage. Preoperative CECT provides an excellent tool for anatomical assessment of the margins of the tumor and can aid in good case selection, especially for less experienced surgeons early in their experience curve. Suspected thromboembolism and pancreatitis were both uncommon

postoperative complications reported or suspected in 3.2% and 2.3% of dogs, respectively. Antemortem diagnosis of these conditions is, however, notoriously challenging, so it is possible that the incidence of these complications was underestimated.

One of the principal tenets of good technique in surgical oncology is preservation of the tumor capsule to prevent spillage of tumor cells and a potential increase in the incidence of local recurrence. The authors believe that the issue of capsular penetration has been highlighted in LA because of the excellent visualization of the surgical field that is afforded by the magnification the telescope provides. This hypothesis is given some credibility by the fact that few reports of OA mention capsular damage, although it almost certainly occurs with some regularity when OA is performed. In the first publication of LA by the author's group (some cases of which are also included in this study), a comparison between LA and OA in 2 smaller cohorts of dogs undergoing LA suggested a higher incidence of capsular penetration in the LA group, although it was pointed out that in most of the cohort of dogs undergoing OA, a detailed account of whether capsular penetration had occurred was lacking.[3] In the first-ever publication of LA in the veterinary literature,[1] capsular penetration was performed proactively after the authors noted the often delicate tumor capsule and necrotic center that make adrenal tumors very prone to rupture. Until this point, the clinical significance of capsular penetration had been uncertain. In the study of the present report, capsular penetration occurred in 19% of cases and was found to be a significant risk factor for recurrence. Dogs where capsular penetration occurred during dissection experienced 6.5 times the recurrence rate of dogs where capsular penetration didn't occur. This finding supports the recommendation that every attempt should be made to prevent capsular penetration by using delicate tissue dissection and avoiding the direct grasping of the adrenal tumor or tumor capsule during the procedure. It is important to note, however, that even in the population of dogs in which capsular penetration occurred, only 27% experienced recurrence, and none of these dogs were reoperated on. It is possible, however, that a lack of uniform follow-up with diagnostic imaging may have underestimated the incidence of recurrent local disease in this cohort.

A variety of factors were shown to have a significant effect on conversion rate for LA in this study. Increasing BCS increased conversion rate. This is an interesting finding that is mirrored in the human surgical literature, where body mass index has a significant effect on conversion also.[16,17] The adrenal gland often sits in a large fat pad cranial to the cranial pole of the kidney, and dissection of this fat pad is necessary to enable resection. When this fat pad is more pronounced, as presumably happens in dogs with a higher BCS, the dissection and visualization of tissue planes can be more challenging, leading to surgeon frustration and perhaps hastening the decision to convert by some surgeons. This hypothesis is backed up by the observation that loss of visualization was

the second most common cause for conversion in the 9.4% of dogs that were converted from LA to OA. When performing LA in dogs with high BCS, strategies for overcoming fat pad–related challenges such as aspiration of fat with a suction-irrigation probe or the use of extra instrument ports for placement of retractors might help mitigate these issues in some patients. Interestingly in humans, where higher morbidity and conversion have been reported for LA in obese patients, it has also been pointed out that LA should not be avoided in the overweight or obese cohort, as it is these very patients that might stand to benefit the most from the many advantages a minimally invasive approach provides.[18] Other factors associated with increasing conversion rate included lesion size and surgeon experience level. Increasing lesion size is a well-known risk factor for conversion, which also increases conversion risk in humans.[16,17] As lesions increase in size, visualization tends to become obscured, especially in smaller dogs. Neovascularization tends to be greater in larger tumors, and hemorrhage from the tumor capsule and surrounding tissues can be profound. Larger tumors may also increase the risk of major hemorrhage from surrounding large vessels due to displacement or compression of these structures, making identification and avoidance more challenging. In this study, for every 1-cm increase in mass diameter, the risk of conversion to an open approach increased by a factor of 1.6. There is no known cutoff for lesion size where the risk of conversion or intraoperative complications becomes unacceptably high, so every surgeon has to decide case selection criteria for themselves. The primary author considers maximal mass diameter of around 5 to 6 cm to be the upper limit for cases that will be attempted laparoscopically in dogs, but again this is a personal choice and will vary from surgeon to surgeon.

The effect of surgeon experience on outcomes of procedures can be challenging to study in smaller cohorts of patients. In this study, data from a large cohort of canine patients were available, and dogs were operated on by surgeons with widely differing experience levels (median number of LA performed per surgeon was 9, with a range of 1 to 61). The analysis of surgical experience could have been performed in several ways, but we elected to analyze outcomes data from those surgeons who had performed < 10 cases and compare it with those who had performed 10 or more. Ten LA procedures represented the midpoint of experience, as 8 surgeons had performed < 10 and 8 had performed ≥ 10 LA procedures. Greater surgeon experience with the procedure was shown to decrease surgical time, conversion rate, and risk of death prior to discharge. Operating time and conversion rate have also been shown to decrease in humans as surgeon experience increases.[19] In 1 study in humans,[20] the learning curve for transperitoneal LA has been evaluated in relation to surgical time using the cumulative sum method. In that study, the authors identified 3 general phases of the learning curve, with phase 1 (learning period) involving the first 34 procedures, phase 2 (acquiring competence phase) involving procedures 35 to 51, and finally phase 3 (mastering phase) involving procedures after the 52nd case, where operating time started to decrease. Where the plateau occurs after which veterinary surgeons would enter their mastering phase for operating time and conversion rate for canine LA would likely be difficult to calculate for the patient cohort in this study given that only 3 surgeons in this study had performed > 34 LA procedures and only 1 surgeon had performed > 52. These analyses could also have been biased by a variety of factors, including different surgeons' criteria for case selection, the quality of surgical equipment available to them, the level of experienced mentorship available, surgeons' personal tolerance for extended surgical times, or the logistical challenges at different institutions that might make conversion to an open approach a more rapidly reached surgical decision in dogs compared with human patients.

There are a variety of limitations to this study. As with all retrospective studies, certain elements of the medical history were incomplete for some cases, and variation between case management protocols at different institutions in different countries cannot be easily accounted for with this study design. For assessment of the effect of surgeon experience, cases contributed by surgeons who had performed > 10 cases also included case data from the first 10 cases that those more experienced surgeons had performed, and this was not accounted for in the statistical model design. The authors could have excluded the more experienced surgeons' first 10 cases, but this would have significantly reduced the size of the case cohort available for evaluation and possibly increased the possibility of a type II error.

In conclusion, results of this study demonstrated, using data from a large cohort of dogs undergoing LA, that resection of unilateral adrenal masses without caval invasion is associated with low perioperative morbidity and mortality. The study has furthermore provided tools for surgeons and pet owners to aid in stratifying risk to make better case selection decisions for their pets in the future.

Acknowledgments

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