Elective and Emergency Surgical Management of Adrenal Gland Tumors: 60 Cases (1999–2006)

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ABSTRACT

Sixty-one adrenal gland tumors were surgically removed from 60 dogs. Fifty-two dogs underwent elective adrenalectomy and 8 dogs underwent emergency adrenalectomy for acute adrenal hemorrhage. Size of adrenal tumors ranged from 10 mm to 80 mm. Histopathology confirmed a diagnosis of adrenocortical tumor in 47 dogs, 26 of which were malignant. Pheochromocytoma was diagnosed in 11 dogs. Six dogs had tumor invasion of the caudal vena cava. Of the seven dogs that did not survive the perioperative period, four underwent emergency adrenalectomy. No dogs with tumor invasion of the caudal vena cava died perioperatively. Perioperative morality rates were 5.7% for dogs that underwent elective adrenalectomy and 50% for dogs that underwent emergency adrenalectomy for acute adrenal hemorrhage. Median survival time was 492 days for the 53 dogs that survived the perioperative period. Of the factors analyzed, only adrenal tumor size and the presence of acute adrenal hemorrhage had predictive values for perioperative mortality. Those dogs that survived the perioperative period had extended survival times of up to 1,590 days. The mortality rate associated with elective adrenalectomy in dogs may be lower than previously reported. Dogs with very large tumors or acute adrenal hemorrhage may have a more guarded prognosis.
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Introduction

Primary adrenal tumors have been reported to account for 1–2% of all canine neoplasias.[1] Adrenalectomy has been recognized as the treatment of choice for both adrenocortical tumors and pheochromocytomas since successful surgery was reported to yield a good long-term prognosis, with median survival times extending years.[2–6] However, adrenalectomy may not always be recommended due to previously reported perioperative mortality rates ranging from 19% to 60%.[2–8] Fortunately, improvements in anesthetic, surgical, and nursing protocols appear to have resulted in lower perioperative mortality rates after adrenalectomy than have been reported in the past. Previous studies investigated factors that may influence the outcome of adrenalectomy and concluded that tumor size, tumor type, presence of caval thrombus, and histopathology were not good predictors of outcome.[2,3,8] Because it has generally been accepted that long-term prognosis was good after adrenalectomy, providing the perioperative period was survived, identifying factors that currently influence perioperative mortality may be helpful in guiding therapeutic recommendations.

Acute adrenal tumor hemorrhage has been reported and thought to be secondary to tumor growth-related rupture of the adrenal capsule.[9–11] Acute adrenal tumor hemorrhage has been found to lead to significant peritoneal and/or retroperitoneal blood loss.[9–11] The rich vascular supply of the adrenal gland and the neovascularization often seen with adrenal tumors may make adrenal tumor hemorrhage even more serious. Little has been published regarding acute adrenal hemorrhage in dogs. The management of two dogs after adrenal tumor rupture was described.[10,11] In one case report, four dogs presented with signs of cardiovascular collapse and were taken to surgery for adrenalectomy.[9] Three of the four dogs survived surgery, and the authors concluded that adrenalectomy was indicated for ruptured adrenal tumors and

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ACTH *adrenocorticotropic hormone;* CI *confidence interval;* CRI *continuous rate infusion;* PO *per os*

that short-term prognosis might have been good if hemorrhage could be controlled and the mass removed. The authors also stated that local recurrence and metastasis might be long-term concerns in these patients due to incomplete excision or intraperitoneal seeding. However, extended follow up was unavailable to appreciate long-term prognosis.

Up to 25% of adrenal tumors have been reported to invade the phrenicoabdominal vein and caudal vena cava, complicating tumor excision.[3,4,12,13] Previous studies have indicated that the presence of a tumor thrombus does not preclude adrenalectomy or significantly increase perioperative morbidity or mortality.[3] Long-term survival even after resection of locally extensive disease has been reported as good.[3,4] However, adrenalectomy may not be recommended in patients with tumor invasion due to preconceptions of increased risk of complications or death. Additional data supporting the lack of increased perioperative mortality in patients with tumor thrombi may be helpful in reinforcing to veterinarians that patients with tumor invasion can have a good outcome after adrenalectomy.

The purpose of this retrospective study was to examine the medical records of 60 dogs taken to surgery for one or more adrenal tumors, and determine which factors affected perioperative survival. Factors evaluated included tumor size, histopathologic diagnosis, anesthetic and operative times, presence of acute adrenal tumor hemorrhage, and presence of tumor invasion into the caudal vena cava. Perioperative mortality was reported to provide current information regarding mortality associated with canine adrenalectomy. Survival times were also reported for those dogs surviving the perioperative period.

Materials and Methods

Medical records were reviewed from all dogs that underwent adrenalectomy between January 1999 and February 2006. Criteria for case selection included patients that underwent adrenalectomy and had complete medical records available for review, including histopathologic diagnosis. Owners and referring veterinarians were interviewed to obtain long-term follow-up information. Necropsy was not routinely performed.

Preoperative Data Collection

Signalment and clinical signs at presentation were obtained from the medical records.

Diagnostic Testing

Before surgery, each dog was evaluated by physical examination, complete blood count, biochemical profile, and thoracic radiographs. When clinically indicated, dogs suspected of having hyperadrenocorticism underwent adrenocortical axis evaluation via adrenocorticotropic hormone (ACTH) stimulation test, endogenous ACTH levels, low-dose dexamethasone suppression test, and/or high-dose dexamethasone suppression test. Abdominal ultrasound was performed before surgery in all dogs that underwent elective adrenalectomy. Adrenal glands >7 mm in width that exhibited asymmetry were considered abnormal.[14] In dogs presenting with acute adrenal tumor hemorrhage and requiring emergent adrenalectomy, abdominal ultrasound, abdominocentesis, electrocardiography, and abdominal radiographs were variably performed.

Procedures

Anesthesia

Anesthetic times were defined as the period from induction to extubation. An anesthetic protocol was determined for each dog based on information obtained via physical examination and diagnostic testing. All dogs received premedication consisting of an opioid and benzodiazepine. General anesthesia was induced with propofol (4–6 mg/kg IV) or etomidate (2 mg/kg IV) with midazolam (0.2 mg/kg IV). After orotracheal intubation with a cuffed endotracheal tube, anesthesia was maintained with inhalant anesthetics (sevofluorane or isofluorane) delivered in oxygen via a circle breathing system and precision vaporizer. Vaporizer settings were adjusted to maintain an adequate plane of anesthesia. Ventilation was controlled to maintain an end tidal carbon dioxide of 35–45 mm Hg. Analgesia was provided intraoperatively (hydromorphone 0.05 mg/kg IV or a fentanyl continuous rate infusion [CRI] of 3–6 μg/kg/min). Appropriate intravenous fluid support was provided to all dogs intraoperatively; the volume of intravenous fluid each dog received was based on assessment of blood loss, heart rate, pulse quality, mucous membrane color, capillary refill time, femoral pulse quality, and blood pressure (direct or indirect). Colloidal support, blood products, and neuromuscular blocking agents were used on a case selective basis. Monitoring of neuromuscular blockade was undertaken using the train of four technique.[15] Normothermia was promoted during the perioperative period using heated circulating water blankets and a forced warm air convection system. Anesthetic monitoring included pulse and respiratory rates, pulse quality, temperature, continuous lead II electrocardiogram, pulse oximetry, end tidal carbon dioxide, hemotocrit, plasma protein, blood gas, and electrolyte assessments. Arterial blood pressure was continuously monitored directly by intra-arterial catheter or indirectly by oscillometric or Doppler systems. Intraoperative hypotension was treated with crystalloids (Normosol R[a] 10–80 mL/kg IV) or colloids (hetastarch[b] 5–20 mL/kg IV). Inotropic support was provided on a case-by-case basis utilizing dopamine (3–10 μg/kg/min CRI),

dobutamine (2–10 μg/kg/min CRI), or epinephrine (0.05–0.2 μg/kg/min CRI). Refractory intraoperative hypertension was treated with sodium nitroprusside (1–15 μg/kg/min CRI). Ventricular arrhythmias were treated with lidocaine (1–2 mg/kg IV bolus followed by a 25–75 μg/kg/min CRI) or procainamide (6–8 mg/kg IV followed by a 25–30 μg/kg/min CRI). Supraventricular tachycardia was treated with esmolol (0.05–0.1 mg/kg IV to total dose of 0.5 mg/kg followed by a 50–200 μg/kg/min CRI).

Surgical Procedures

Operative times were defined as the period from initial incision to skin closure. A ventral midline exploratory laparotomy was performed in all dogs. Adrenal tumors were identified; side, tumor size, presence of tumor invasion into the vena cava, evidence of metastatic disease, and presence of peritoneal and/or retroperitoneal hemorrhage were assessed. Tumor invasion limited to the phrenicoabdominal vein was not recorded.

Routine adrenalectomy was performed using a combination of blunt and sharp dissection and commonly used electrocautery for hemostasis.[16] The phrenicoabdominal vein and other prominent vascular supply to the adrenal gland were either ligated or occluded by vascular clips. When the adrenal tumor was found to invade the vena cava, the tumor was dissected until its only attachment was via the extension into the caudal vena cava, typically through the phrenicoabdominal vein. Vascular clamps were placed across the vena cava, cranial and caudal to the tumor thrombus. A venotomy was performed in the vena cava and the tumor thrombus was removed. The ostia of the phrenicoabdominal vein was often included in the venotomy to insure that the tumor attachment was excised. The venotomy was closed with 5-0 monofilament suture (polydiaxanone[c] or polypropylene[d]) in a continuous cruciate pattern.

In those dogs with acute adrenal tumor hemorrhage, peritoneal blood was evacuated from the abdominal cavity to identify the source of hemorrhage. Some degree of retroperitoneal hemorrhage was present around the adrenal tumor in all dogs. The retroperitoneal fascia surrounding the adrenal tumor was bluntly explored and the tumor remnants and capsule were removed. The phrenicoabdominal vein and other sources of hemorrhage were identified and ligated.

Postoperative Treatment and Data Collection

Management

All dogs received fluid therapy, opioid analgesics (fentanyl 3–6 μg/kg/hr CRI) and intravenous broad-spectrum antibiotics (typically cefazolin 22 mg/kg IV *q* 8 hr). Colloids, vasopressors, blood products, antiarrhythmics, and antiemetics were administered on a case selective basis. Postoperative monitoring included heart rate, pulse strength, respiratory rate and effort, temperature, systemic blood pressure, packed cell volume, total protein, and electrolytes. For dogs with suspected or confirmed hyperadrenocorticism, dexamethasone (0.15 mg/kg total dose) was administered as a CRI for 6 hr postoperatively, followed by subcutaneous injections of dexamethasone (0.15 mg/kg subcutaneously *q* 12 hr) until the animals were eating, at which time oral prednisone (1 mg/kg *per os* (PO) *q* 12 hr) was begun. The prednisone dosage was tapered over 9–12 wk, then discontinued.[17] For the one dog that underwent a bilateral adrenalectomy, prednisone was decreased to and maintained at the lowest possible daily maintenance dosage, and mineralocorticoid (desoxycorticosterone pivalate) was administered every 28 days.

Complications

Hypotension was treated with crystalloids (Normosol R 10–80 mL/kg IV), colloids (hetastarch 5–20 mL/kg IV bolus followed by 10–20 mL/kg/day CRI), and/or vasopressors (dopamine, dobutamine, or epinephrine as previously described). Ventricular arrhythmias were treated with antiarrhythmics as necessary (lidocaine, procainamide as previously described, or sotalol 0.5–2 mg/kg PO *q* 12 hr). Vomiting was treated with famotidine (1 mg/kg IV *q* 24 hr), omeprazole (0.5–1 mg/kg PO *q* 24 hr), metoclopramide (1 mg/kg/day CRI), and/or ondansetron (0.1 mg/kg IV *q* 8–24 hr).

Statistical Analysis

A statistical consulting service[e] and software packages[f,g] were used to evaluate the data. Survival time was defined as the interval between surgery and death. The perioperative period was defined as days 1–28 postoperatively. Perioperative mortality was defined as death or euthanasia that occurred in the period from surgery to 28 days postoperatively. The relationship between risk factors and perioperative mortality was assessed using exact logistic regression. Each of the potential risk factors (tumor size, histopathologic diagnosis, anesthetic and operative times, tumor thrombus, and hemoperitoneum) was tested separately against the response (perioperative survival). Kaplan-Meier survival curves were created assuming a Weibull distribution for overall survival time. For dogs that were still alive at last known follow up, observed survival time was considered to be censored.

Results

During the 7 yr study period, 60 patients were identified that met inclusion criteria. Sixty-one adrenal tumors were removed from these 60 dogs, and 8 dogs required emergency adrenalectomy to stop potentially fatal blood loss.

Preoperative Data Collection

Signalment

The median age for dogs that underwent adrenalectomy was 11 yr (range, 6–16 yr). Thirty dogs (50%) were spayed females, 28 (47%) were neutered males, and 2 (3%) were intact males; no intact females were operated. The median weight was 21 kg (range 4–48.6 kg). No gender predisposition was noted. Breeds represented included: Labrador retriever (n=7), mixed breed (n=20), shih tzu (n=3), German shepherd (n=2), boxer (n=2), American Eskimo (n=2), beagle (n=2), dachshund (n=2), and one each of the following breeds: cockapoo, Jack Russell terrier, West Highland white terrier, golden retriever, chow chow, rottweiler, collie, Pekingese, Maltese, border collie, Bedlington terrier, Lhasa apso, Pomeranian, Shetland sheepdog, Belgian Mallinois, rat terrier, Scottish terrier, English springer spaniel, wirehaired terrier, and Siberian husky.

Clinical Signs

Clinical signs were present in 95% of dogs operated. Presenting complaints in the 47 dogs with an adrenocortical tumor included polyuria and polydyspsia (n=25), polyphagia (n=4), panting (n=4), lethargy (n=12), weakness (n=2), anorexia (n=7), vomiting and diarrhea (n=5), and alopecia or recurrent pyoderma (n=5). Presenting complaints in the 11 dogs with a pheochromocytoma that underwent elective adrenalectomy included polyuria and polydypsia (n=5), panting (n=2), lethargy (n=2), anorexia (n=2), pain (n=2), and vomiting and diarrhea (n=3). Adrenal tumors were incidental findings during abdominal ultrasound in two dogs during geriatric screenings (one adrenocortical tumor, one pheochromocytoma). In the eight dogs that presented with ruptured adrenal tumors, acute clinical signs were present in all dogs and included collapse (n=6), lethargy (n=2), vomiting (n=2), and pain (n=2).

Diagnostic Testing

Twenty-five dogs were diagnosed preoperatively with hyperadrenocorticism. Thoracic radiographs did not provide evidence of pulmonary metastasis in any dog in this study. Abdominal ultrasound was performed in 54 of 60 dogs preoperatively; of the 8 dogs that presented with acute hemoperitoneum, only 2 had abdominal ultrasound performed. An adrenal gland mass was observed in 100% of the patients imaged. Tumor invasion of the vena cava was observed in 10 of 54 (19%) dogs by abdominal ultrasound; 6 had tumor invasion confirmed at surgery. The sensitivity and specificity for ultrasonographic detection of tumor invasion into the caudal vena cava were 100% and 91.6%, respectively. The adrenal tumors, when measured by abdominal ultrasound, ranged in size from 9.6 mm to 80 mm. In the eight dogs that presented with acute adrenal hemorrhage, abdominocentesis in all dogs revealed nonclotting hemorrhagic effusion. These eight dogs all exhibited loss of abdominal and/or retroperitoneal detail on abdominal radiographs, and all were anemic (packed cell volume $<32\%$). Electrocardiography was performed in the eight dogs that presented for acute adrenal hemorrhage; all dogs had tachycardia (heart rate >140 beats/min), and four of eight had ventricular arrhythmias.

Anesthesia

No dogs died during the anesthetic period. Eighteen dogs (35%) that underwent elective adrenalectomy and all eight dogs (100%) that underwent emergency adrenalectomy had intraoperative complications. Complications that developed intraoperatively included hypotension (n=13), hypertension (n=1), tachycardia (n=24), ventricular arrhythmias (n=4), and hemorrhage (n=16). Anesthetic times ranged from 60 to 240 min (median 100 min). Anesthetic times were not predictive of outcome.

Surgical Procedures

Fifty-nine dogs underwent unilateral adrenalectomy, and one dog underwent bilateral adrenalectomy. Fifty-two dogs underwent elective adrenalectomy and eight dogs underwent emergency adrenalectomy. Operative times ranged from 40 min to 135 min (median, 60 min). Operative times were not predictive of outcome.

Concurrent surgical procedures were performed in 36 of 60 dogs (60%). Liver biopsy was performed in 14 dogs. Liver lobectomy was performed in three dogs for masses (two diagnosed as concurrent hepatocellular carcinoma and one as hepatocellular hyperplasia), in two dogs for adhesion or invasion of right adrenocortical carcinoma into the caudate lobe, and in one dog for a biliary cyst. Nephrectomy was performed in three dogs due to tumor encompassing the renal vein (two left adrenocortical carcinoma, one right adrenocortical carcinoma), in one dog due to presence of tumor in the kidney (left Grade 3 fibrosarcoma), and in one dog due to inadvertent laceration of the renal vein (left adrenocortical carcinoma). Cholecystectomy was performed in two dogs due to the presence of a mucocele. Splenectomy was performed in two dogs for nodules diagnosed as lymphoid hyperplasia and in one dog for lymphoma. Gastrotomy was performed in one dog for removal of a foreign body. A partial gastrectomy was performed in one dog for a palpable mass effect diagnosed as chronic ulceration. Intestinal biopsies were obtained in three dogs. Lastly, a cystotomy was performed in one dog for removal of cystic calculi.

Adrenal tumors were identified in all 60 dogs. Thirty-two (52.4%) of the tumors were in the left adrenal gland (7 pheochromocytomas, 23 adrenocortical tumors, 1 fibrosarcoma,

1 lymphoma) and 29 (47.5%) were in the right adrenal gland (4 pheochromocytomas, 24 adrenocortical tumors, 1 pheochromocytoma and adrenocortical carcinoma). The one dog with bilateral adrenal tumors had an adrenocortical adenoma of the left adrenal gland and an adrenocortical carcinoma of the right gland. Location of the tumor was not predictive of outcome.

Tumor invasion into the caudal vena cava was identified in six dogs (10%) (**Figure 1**). Four invasive masses (67%) were left adrenal tumors (three pheochromocytomas, one adrenocortical tumor) and two (33%) were right-sided tumors (two pheochromocytomas). All dogs with tumor thrombus present survived the perioperative period. The presence of tumor invasion was not predictive of outcome.

Acute adrenal hemorrhage was present in eight (13%) dogs secondary to a ruptured adrenal tumor; left- and right-sided tumors were equally represented (**Figure 2**). Seven of the ruptured tumors were adrenocortical in origin (four carcinomas, two adenomas, and one hyperplasia with capsule rupture) and one was medullary in origin (pheochromocytoma). The presence of acute adrenal hemorrhage had a negative effect on outcome.

Postoperative Data Collection

Complications

In the 60 dogs that underwent adrenalectomy, postoperative complications developed in 30% of dogs. Complications that developed included hypotension (n=3), bradycardia (n=1), ventricular arrhythmias (n=8), tachypnea (n=7), vomiting (n=7), and cardiopulmonary arrest (n=2). Dogs with acute adrenal hemorrhage developed postoperative complications more frequently (7/8; 88%) than those dogs that did not have acute adrenal hemorrhage (11/52; 21%).

FIGURE 1 *Photograph of an excised right adrenal gland tumor (*right*) and associated caval thrombus (*left*).*

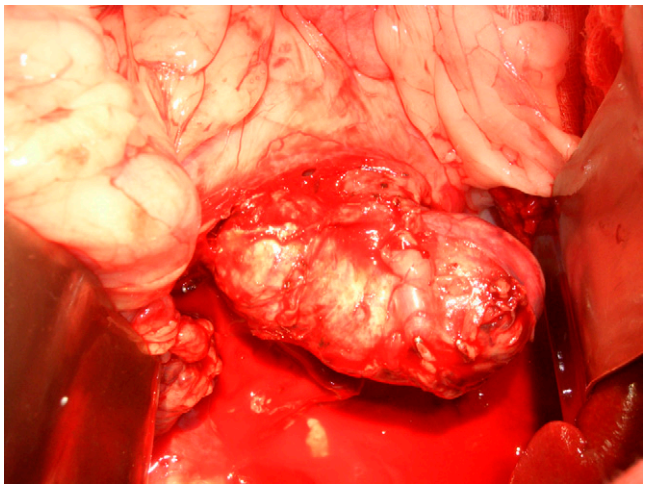

FIGURE 2 *Intraoperative dissection of a ruptured left adrenal gland tumor.*

Histopathologic Diagnosis

Adrenocortical tumors were diagnosed in 78.3% (47/60) of dogs; 26 were carcinomas (43%), 15 were adenomas (25%), and 6 (10%) were cortical hyperplasia. Pheochromocytoma was diagnosed in 11 (18%) dogs. Lymphoma was diagnosed in one dog, and fibrosarcoma was diagnosed in one dog. In the dog that underwent bilateral adrenalectomy, adenoma was diagnosed in one adrenal gland and adrenocortical carcinoma in the other. One dog that underwent unilateral adrenalectomy had a tumor demonstrating both adrenocortical carcinoma and pheochromocytoma and was excluded from the analyses.

Liver biopsy or lobectomy was performed in 20 dogs; 12 were diagnosed with hepatocellular vacuolization, 4 with hepatocellular hyperplasia, 2 with concurrent hepatocellular carcinoma, and 1 dog with a biliary cyst. One dog had histopathologically confirmed intra-abdominal adrenocortical carcinoma metastasis to the liver.

Outcome

No dogs died intraoperatively. Median hospitalization time was 1.5 days for dogs that underwent elective adrenalectomy and 4 days for dogs that underwent emergency adrenalectomy. Fifty-three (88%) dogs survived the perioperative period. No dog that had a tumor invasion of the vena cava died in the perioperative period. Of all dogs that died in the perioperative period, six of seven

(85.7%) were diagnosed with adrenocortical carcinoma and one was diagnosed with pheochromocytoma.

Three of the seven dogs that died in the perioperative period underwent elective adrenalectomy; of those dogs, two were diagnosed with adrenocortical carcinoma and one with pheochromocytoma (**Table 1**). Tumor sizes for the three dogs that died that underwent elective adrenalectomy were 39, 40, and 60 mm. For dogs that underwent elective adrenalectomy, anesthetic and operative times, histopathologic diagnosis, and presence of tumor invasion into the vena cava were not predictive of outcome. Tumor size was found to significantly influence perioperative mortality in dogs that underwent elective adrenalectomy. Each 1 mm increase in tumor size was associated with a 7.9% increase in odds of perioperative mortality (95% confidence interval [CI], 2.5%–15.3%; P=0.0025).

Four of the seven dogs (57%) that died in the perioperative period had acute adrenal hemorrhage secondary to ruptured adrenocortical tumors and underwent emergency adrenalectomy; all four were diagnosed with adrenocortical carcinoma (Table 1). Tumor sizes for the four dogs with ruptured tumors that died in the perioperative period were 50, 50, 60, and 70 mm. It appeared that tumor size was significantly related to the chances of developing acute adrenal hemorrhage; each 1 mm increase in tumor size was associated with a 6% increase in odds of acute adrenal hemorrhage (95% CI, 2–11%; P=0.008). Four of the eight dogs (50%) that presented with acute adrenal hemorrhage died in the perioperative period. Of the four dogs with acute adrenal hemorrhage that did not survive the perioperative period, one dog was euthanized for progressive dyspnea and suspect pulmonary thromboembolism, one dog was euthanized for progressive pulmonary edema, one dog was euthanized for intractable seizures, and one dog died of acute cardiopulmonary arrest. Dogs with acute adrenal hemorrhage were found to have a significantly increased risk of perioperative mortality (P=0.034) compared with dogs that underwent elective adrenalectomy.

Median follow-up time was 510 days (**Figure 3**). Median survival time for all dogs that had elective adrenalectomy was 375 days (range, 1–1,590 days). In those dogs that survived the perioperative period after elective adrenalectomy, median survival time was 492 days (95% CI 366–660 days). Death was considered related to the adrenal tumor in six dogs that survived the perioperative period (one dog had intra-abdominal fibrosarcoma metastasis, one dog had intra-abdominal lymphoma progression, one dog with adrenocortical carcinoma had pulmonary metastasis, and two dogs with adrenocortical carcinoma and one dog with cortical adenoma had recurrence of clinical signs).

Median survival time for all dogs with acute adrenal hemorrhage was 208 days (range, 1–1,020 days); dogs surviving the perioperative period had a median survival time of 844 days (95% CI. 258–2,758 days; range, 450–1,020 days). In the dogs that survived the perioperative period after emergency adrenalectomy, death was not known to be related to the adrenal tumor. Two dogs were alive at last follow up (450 and 1,020 days), one dog was euthanized for pneumonia (510 days), and one dog was euthanized for liver failure (540 days).

Discussion

The perioperative mortality rate of the 52 dogs in this study that underwent elective adrenalectomy (6%) was substantially lower than the mortality rates of previously reported studies (19–60%).[2–8] Even when dogs that underwent emergency adrenalectomy for acute adrenal hemorrhage were considered, the perioperative mortality rate of the present study (12%) compared favorably with previous reports. Furthermore, in this study, the median survival

TABLE 1

Summary Data for Seven Dogs That Died in the Perioperative Period After Adrenalectomy

Dog	Breed	Age, yrs	Diagnosis	Tumor side	Size	Acute adrenal hemorrhage	Cause of death	Survival time
1	Labrador retriever mix	13	Adrenocortical carcinoma	Right	70 mm	+	Euthanized:suspect pulmonary thromboembolism	2 days
2	Collie	7	Adrenocortical carcinoma	Left	60 mm	+	Euthanized:progressive pulmonary edema	4 days
3	German shepherd	11	Adrenocortical carcinoma	Left	60 mm	−	Died acutely at home	6 days
4	Mixed breed	9	Adrenocortical carcinoma	Left	50 mm	+	Euthanized: refractory seizures	2 days
5	Beagle	14	Adrenocortical carcinoma	Right	50 mm	+	Acute cardiopulmonary arrest	1 day
6	Dachschund	14	Adrenocortical carcinoma	Right	39 mm	−	Acute cardiopulmonary arrest	1 day
7	Boxer	9	Pheochromocytoma	Left	40 mm	−	Refractory ventricular arrhythmias, acute cardiopulmonary arrest	1 day

+, acute adrenal hemorrhage present and emergency adrenalectomy performed; −, acute adrenal hemorrhage absent and elective adrenalectomy performed.

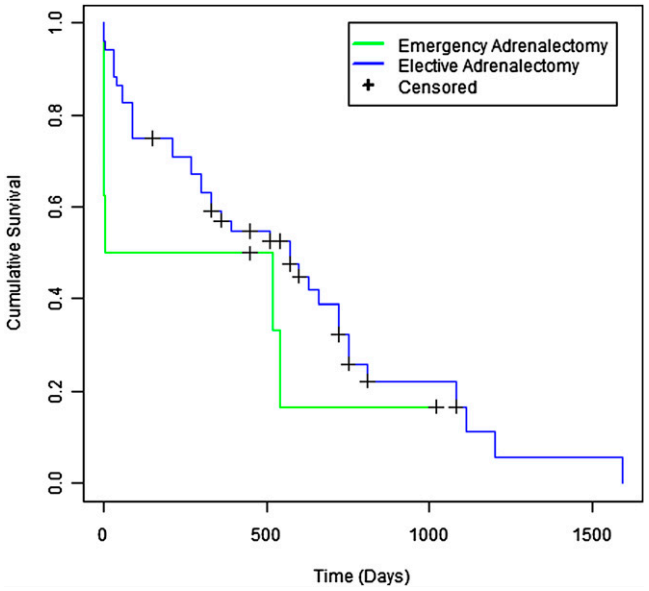

FIGURE 3 *Kaplan-Meier survival analysis for 60 dogs that underwent adrenalectomy.* Blue line *indicates dogs that underwent elective adrenalectomy.* Green line *indicates dogs with acute adrenal hemorrhage that underwent emergency adrenalectomy.*

time of the dogs that underwent elective adrenalectomy that survived the perioperative period (492 days) substantiated previous reports that successful adrenalectomy in dogs with adrenal tumors was associated with good long-term survival.[2,4,6,7,11]

The eight dogs with acute adrenal hemorrhage requiring emergency adrenalectomy had a perioperative mortality rate of 50%. The mortality rate in dogs that underwent emergency adrenalectomy in the present study did not vary markedly from the mortality rate of the one previously reported series of four dogs with acute adrenal hemorrhage.[9] Consistent with these findings, the presence of hemoperitoneum secondary to adrenal tumor hemorrhage was associated with a significantly higher incidence of postoperative complications and mortality rate in the dogs in this study. Dogs that underwent emergency adrenalectomy were more likely to require blood transfusions, treatment of arrhythmias and hypotension, and required longer periods of hospitalization (median 4 days) compared with dogs that underwent elective adrenalectomy (median 1.5 days). Of the four dogs with acute adrenal hemorrhage that did not survive the perioperative period, three were euthanized for progressive clinical deterioration and one dog died acutely of cardiopulmonary arrest. However, survival time was good (range, 450–1,020 days) if dogs with acute adrenal hemorrhage survived the perioperative period. No dog that had acute adrenal hemorrhage and survived the perioperative period was reported to have died or been euthanized due to recurrence of clinical signs or metastatic disease. Two dogs were alive at last follow up (450 and 1,020 days) and two dogs were euthanized (510 and 540 days); one dog was euthanized for pneumonia and one dog was euthanized for progressive liver failure. Although necropsy was not performed in the two dogs that were euthanized, the results suggested that dogs with acute adrenal hemorrhage that underwent emergency adrenalectomy might not be at increased risk for local recurrence or metastasis.

Of the three dogs that underwent elective adrenalectomy and died in the postoperative period, one dog had sick sinus syndrome, one dog died suddenly at home 6 days postoperatively, and one dog died in the hospital from refractory ventricular arrhythmias and subsequent cardiopulmonary arrest. Because only three dogs that underwent elective adrenalectomy died in the perioperative period, it was difficult to draw conclusions regarding risk factors that increase postoperative mortality. The one factor analyzed for dogs that underwent elective adrenalectomy and appeared to have an effect on outcome was tumor size. An increase in tumor size of 1 mm was associated with an 8% increase in odds of postoperative mortality. It was interesting to note that an increase in tumor size of 1 mm was also associated with a 6% increase in odds of adrenal tumor hemorrhage. Subjectively, it appeared that smaller adrenal tumors had less invasion into surrounding tissues, less intraoperative hemorrhage, shorter anesthetic and operative times, and fewer postoperative complications. These findings suggested that early detection and removal of adrenal tumors might be associated with greater postoperative survival.

For those dogs that underwent elective adrenalectomy, six developed clinical signs consistent with recurrence or metastatic disease and were euthanized (12%). One dog had a diagnosis of fibrosarcoma, one lymphoma, three dogs had a diagnosis of adrenocortical carcinoma, and one dog had a diagnosis of adrenocortical adenoma. In this study the metastatic rate for adrenal tumors was lower than previously reported; however, necropsy was not performed and actual metastatic rate might have been higher.[2,5,7,13] Biopsies of other organs were obtained in 31 dogs (20 liver, 5 kidney, 2 spleen, 1 stomach, 3 intestine). Because only approximately one half of the dogs in this study had additional organs biopsied, it was possible the metastatic rate was underestimated. It was also possible that dogs with suspected metastatic disease were not operated and thus not included in this study, resulting in a falsely low metastatic rate.

Tumor thrombus in the caudal vena cava was present in 10% of the dogs in this study. Dogs that had tumor thrombus confined to the phrenicoabdominal vein were not included in reporting venous invasion in this study. Although the surgical

procedure of adrenalectomy and venotomy for thrombus removal was more technically demanding than adrenalectomy alone, none of these six dogs died in the postoperative period and their survival times ranged from 42 days to 1,020 days. Kyles et al reported a frequency of adrenal tumors with venous invasion of 25% and a postoperative mortality rate of 30% for dogs that underwent adrenalectomy and venotomy for thrombus removal.[3] Kyles et al included dogs with thrombus present in the phrenicoabdominal vein in reporting venous invasion, a technically simpler surgery.[3] The present data supported previously reported low morbidity and mortality rates associated with thrombectomy and reinforced that patients with tumor invasion could have a good outcome after adrenalectomy. This study also corroborated previous reports suggesting that invasion of the vena cava was more common with pheochromocytoma (83%) than adrenocortical tumors (17%).[3]

Limitations of this study were consistent with those of other retrospective studies. Data and follow up were not always complete and cause of death was not always known. The metastatic rate might have been underestimated because necropsy was not routinely performed, and there might have been a case selection bias influenced by owner and surgeon decisions regarding a patient's suitability for surgery.

Conclusion

The perioperative mortality rate improved and survival rate was greater after elective adrenalectomy than was documented in previous studies. In those patients surviving the postoperative period, there was good long-term survival. The presence of acute adrenal hemorrhage had a significant negative effect on perioperative survival, but not long-term outcome for those patients surviving the perioperative period. Larger tumors were more likely to result in tumor rupture and had a higher perioperative mortality rate, arguing that earlier surgical intervention might have improved prognosis for these patients. Tumor invasion of the caudal vena cava did not affect perioperative survival or long-term outcome.

FOOTNOTES

[a] Normosol-R; Hospira Inc., Lake Forest, IL

[b] Hespan; Braun Medical Inc, Irvine, CA

[c] PDS; Ethicon Inc., Somerville, NJ

[d] Prolene; Ethicon Inc., Somerville, NJ

[e] Ohio State University Statistical Consulting Service; Columbus, OH

[f] Minitab 15 Statistical Software (2007); Minitab, Inc., State College, PA

[g] SAS/STAT software, Version 9.2; SAS Institute Inc., Cary, NC

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