JAVMA

Thoracoscopic removal of cranial mediastinal masses in dogs is associated with a low conversion rate, excellent survival to discharge, and good long-term outcome

Kenneth A. Carroll, BVetBiol/BVSc, DACVS[1]; Philipp D. Mayhew, BVM&S, DACVS[1]*; William T. N. Culp, VMD, DACVS[1]; Federico Massari, DVM, DECVS[2]; Manuel Jiménez Peláez, LV, DECVS[3]; Michele A. Steffey, DVM, DACVS[1]; Michelle Giuffrida, DVM, DACVS[1]; Ingrid M. Balsa, DVM, DACVS[1]; Erin A. Gibson, DVM, DACVS[1]; Makayla A. Farrell, DVM[4]; Ameet Singh, DVM, DACVS[4]; Nicole Buote, DVM, DACVS[5]; Valery F. Scharf, DVM, DACVS[6]; Herve Brissot, DMV, DECVS[7]; Chris Thomson, DVM, DACVS[8]

[1]Department of Surgical and Radiological Sciences, School of Veterinary Medicine, University of California-Davis, Davis, CA
[2]Clinica Veterinaria Nervianese, Nerviano MI, Italy
[3]AUNA Especialidades Veterinarias, Valencia, Spain
[4]Department of Clinical Studies, Ontario Veterinary College, University of Guelph, Guelph, ON, Canada
[5]Department of Clinical Sciences, College of Veterinary Medicine, Cornell University, Ithaca, NY
[6]Department of Clinical Sciences, College of Veterinary Medicine, North Carolina State University, Raleigh, NC
[7]Pride Veterinary Referrals, Derby, Derbyshire, UK
[8]Veterinary Specialty Hospital, North County, San Marcos, CA

*Corresponding author: Dr. Mayhew (philmayhew@gmail.com)

OBJECTIVE
To report the complications and outcomes associated with thoracoscopic cranial mediastinal mass resection in dogs.

ANIMALS
49 client-owned dogs that underwent thoracoscopic cranial mediastinal mass removal.

METHODS
This was a retrospective cohort study (January 1, 2014, to July 31, 2023), and the medical records of 49 client-owned dogs that underwent thoracoscopic cranial mediastinal mass removal were reviewed. The signalment, history, clinicopathologic features, perioperative complications, and long-term outcome were recorded.

RESULTS
Preoperative myasthenia gravis (MG) and megaesophagus (ME) were identified in 17 of 49 (35%) dogs and 11 of 49 (22%) dogs, respectively. The median maximal tumor diameter on CT images was 4.7 cm (range, 2.7 to 8.5 cm). Nonemergent conversion to an open procedure was necessary in 4 of 49 (8%) dogs, and dogs with conversion to an open procedure had a significantly larger median maximal CT tumor diameter than dogs without conversion (P = .03). The most common tumor type was thymoma (37/49 [76%]). The overall median survival time for dogs with thymoma was 1,102 days (95% CI, 482 to upper bound not reached). The median survival time for dogs with thymoma and concurrent presurgical MG was 182 days (95% CI, 14 to upper bound not reached). Presurgical diagnosis of MG (P = .44) or ME (P = .69) was not associated with survival time.

CLINICAL RELEVANCE
Thoracoscopic removal of cranial mediastinal masses was associated with low conversion and complication rates. Long-term survival is possible, and thoracoscopic removal should be considered for select cases.

Keywords: thoracoscopic, thymoma, mediastinal, computed tomography, thoracic

The cranial mediastinum is an uncommon location for the development of neoplasia in small animals.[1,2] While thymoma is the most common diagnosis,[1,3,4] other tumors have also been reported, such as ectopic thyroid carcinoma,[2,5] lymphoma,[6,7] and thymic carcinoma.[6,7] More benign etiologies include branchial cyst[8–10] and organizing hematoma.[10] For thymoma, ectopic thyroid carcinoma, and thymic carcinoma, the therapeutic standard of care consists of cranial mediastinal mass extirpation, most commonly via a median sternotomy or intercostal thoracotomy.[11,12] For more benign etiologies, serial monitoring may be appropriate and surgical

Received December 6, 2023
Accepted June 17, 2024
Published online July 17, 2024

doi.org/10.2460/javma.23.12.0679

intervention is determined on the basis of clinical signs and/or involvement of local mediastinal structures.

Thoracoscopic removal of cranial mediastinal masses has been reported previously in dogs.[13–16] Strict selection criteria must be applied with consideration of patient and tumor size, as well as absence of regional organ and vascular invasion.[17] The tumor size must be assessed in relation to patient size, and it must not be too large to interfere with appropriate visualization and triangulation of instrumentation within the thorax.[15] To assist with working space, 1-lung ventilation or alternating ventilation may be necessary.[17] Regardless of the approach, the goal of cranial mediastinal mass surgery is complete removal of the mass without violation of the tumor capsule, and any technique that jeopardizes principles of surgical oncology should be avoided.

Thoracoscopic surgery is commonly performed in humans and is associated with improved patient morbidity and shorter hospitalization than traditional open surgery.[18] To the authors' knowledge, only 1 study[15] has evaluated the long-term outcome of dogs undergoing thoracoscopic cranial mediastinal mass removal. While a negative prognostic relationship was established between thoracoscopic thymoma removal and perioperative myasthenia gravis (MG) and megaesophagus (ME), experience from larger cohorts of cases has not been reported to date.[15] The objective of this study, therefore, was to report intraoperative and postoperative adverse events as well as short- and long-term outcomes associated with thoracoscopic cranial mediastinal mass resection in a large cohort of dogs.

Methods

Inclusion criteria

Dogs that underwent thoracoscopic cranial mediastinal mass removal between January 1, 2014, and July 31, 2023, with a minimum of 4 weeks of postoperative follow-up, were included. A retrospective search of the medical record was performed at 8 veterinary clinics (4 academic referral hospitals and 4 private referral hospitals). Dogs that required a median sternotomy or intercostal thoracotomy were only included if a thoracoscopic approach was initially attempted for cranial mediastinal mass removal. Cases without a complete surgical or anesthetic report were excluded from the study.

Data collection

For each dog included in the study, data were collected from the medical record including signalment, weight (kg), clinical signs, laboratory tests (CBC, biochemistry, and urinalysis), diagnostic imaging findings (radiography, ultrasonography, and CT), cytological analysis, preoperative medical treatment, anesthesia protocol, intubation technique, use of 1-lung ventilation, surgical findings, port and patient positioning, concurrent procedures, instrumentation, tumor size, duration of anesthesia and surgery, intraoperative and postoperative adverse events, duration of indwelling thoracostomy tube, duration of hospitalization, histological results, adjuvant therapy, date of last follow-up, and date and cause of death (if applicable).

Duration of surgery was defined as the interval from first skin incision to placement of the last suture. Duration of anesthesia was defined as the interval from intubation to extubation of the patient. Presence or absence of MG was based on clinical signs and a positive anti-AChR antibody titer test. Maximal tumor diameter based on CT was recorded on the basis of historical radiological reports or, if not within the medical record, retrospectively measured and subsequently reported.

Adverse events were recorded for each procedure and classified by use of the Veterinary Cooperative Oncology Group–Common Terminology Criteria for Adverse Events scheme.[19] Major intraoperative adverse events were defined as any complication resulting in death or emergent conversion to an open thoracic procedure. Major postoperative adverse events included aspiration pneumonia and any other complication resulting in dog death or the need for another surgery. Minor postoperative adverse events were defined as any complication that resolved with medical therapy or was self-limiting. If conversion was performed, method of conversion (intercostal thoracotomy or median sternotomy) along with the reason for conversion was reported. Conversions were graded from 1 to 4 on the basis of a previously published classification system.[20] Final histological diagnosis was determined by a board-certified veterinary pathologist from the original histopathology report. Long-term outcomes were obtained by evaluation of the medical record and/or follow-up with the referring veterinarian and dog owner. Survival time was defined as the interval between the date of surgery and date of last follow-up or death.

Statistical analysis

All analyses were performed with a commercially available statistical software program (Stata, version 16.1; StataCorp). Clinical data including breed, sex, age, and weight were summarized with descriptive statistics (median with range; mean ± SD). Wilcoxon rank sum tests were used to compare surgical and anesthetic times across groups and to compare tumor measurements by institution type. Logistic regression was used to identify variables associated with surgical times longer than 90 minutes. Variables were tested for univariable associations, and those with $P < .2$ were tested for inclusion in a multivariable model, with variables retained if $P < .05$ or identified as confounders (change in OR > 20%). The Kaplan-Meier product limit method was used to estimate overall survival time with animals alive or lost to follow-up censored at their last known alive date. Log-rank tests were used to test unadjusted associations between prognostic variables and overall survival. All tests were 2-sided, and values of $P < .05$ were considered statistically significant.

Results

Animals

Forty-nine dogs met the inclusion criteria and were included in the analysis. All dogs were operated on by a board-certified small animal surgeon with experience in thoracoscopy and assisted by a small animal surgery resident and/or fellow candidate in minimally invasive surgery. Breeds represented included 10 mixed-breed dogs, 5 Labrador Retrievers, 4 Golden Retrievers, 4 Akita Inus, 3 Beagles, 2 Collies, and 1 each of Australian Shepherd, Blue Heeler, Boxer, Cocker Spaniel, Dachshund, Doberman, English Bulldog, French Bulldog, German Shepherd Dog, Hound, Kelpie, Maremma, Mastiff, American Pitbull Terrier, Podenco, Portuguese Water Dog, Rottweiler, Shih Tzu, Spanish Water Dog, Standard Poodle, and West Highland White Terrier. Twenty-nine dogs were male (5 intact and 24 neutered) and 20 were female (1 intact and 19 spayed). Median weight was 26.1 kg (range, 6 to 60.8 kg), and median age was 10 years (range, 4 to 14 years).

Clinical signs and laboratory tests

At presentation, the most common clinical signs included anorexia (31/49 [63%]), exercise intolerance (23/49 [47%]), and cough (18/49 [37%]). Ataxia and proprioceptive deficits were noted in 14 of 49 (29%) dogs. Horner syndrome was present as the only clinical sign in 1 of 49 (2%) dogs. Myasthenia gravis and ME were identified in 17 (35%) and 11 (22%) of 49 dogs, respectively. Concurrent MG and ME was seen in 11 of 49 (22%) dogs. Serum biochemical abnormalities included elevated ALP activity (13/49 [27%]), elevated ALT activity (11/49 [22%]), and elevated AST activity (6/49 [12%]). Complete bloodwork abnormalities included anemia (5/49 [10%]), neutrophilia (4/49 [8%]), leukocytosis (3/49 [6%]), leukopenia (2/49 [4%]), and thrombocytopenia (2/49 [4%]). On urinalysis, hematuria was identified in 4 of 49 (8%) dogs, proteinuria in 3 of 49 (6%) dogs, and struvite crystalluria in 1 of 49 (2%) dogs.

Diagnostic imaging and cytological examination

Three-view thoracic radiography was performed in 37 of 49 (76%) dogs. Of these dogs, a soft tissue opacity within the cranial mediastinum was noted in all 37 (100%) patients. Abdominal ultrasonography was performed in 11 of 49 (22%) dogs. Common abdominal ultrasonography findings included cholecystic debris (4/11 [36%]), nonspecific liver nodules (3/11 [27%]), cystoliths (2/11 [18%]), cavitated splenic mass (1/11 [9%]), and enteritis (1/11 [9%]). Thoracic contrast-enhanced CT imaging was performed in all 49 (100%) dogs. A cranial mediastinal mass was noted in all dogs (49/49 [100%]). The median maximal CT tumor diameter was 4.7 cm (range, 2.7 to 8.5 cm), and the median maximal CT tumor diameter to body weight ratio was 0.20 (range, 0.08 to 0.59). Neither of these differed significantly by practice type (academic referral hospital vs private referral hospital; $P = .78$ and $P = .16$, respectively).

Vascular and/or regional tissue invasion was not identified in any dog. Additional CT findings included sternal lymphadenopathy (29/49 [59%]), ME (11/49 [22%]), alveolar pulmonary pattern (3/49 [6%]), interstitial pulmonary pattern (3/49 [6%]), ossifying pulmonary metaplasia (2/49 [4%]), pulmonary bullae (2/49 [4%]), and pleural effusion (2/49 [4%]). Ultrasound-guided fine-needle aspiration of the cranial mediastinal mass was performed in 13 of 49 (27%) dogs. Cytology was consistent with thymoma in 11 of 13 (85%) dogs and neuroendocrine carcinoma in 2 of 13 (15%) dogs.

Preoperative medical treatment

Thirteen of the 17 (76%) dogs with MG were treated preoperatively with pyridostigmine. The mean dose of pyridostigmine prescribed was 1 ± 0.28 mg/kg PO every 8 hours, and all dogs were on this medication for at least 2 weeks prior to presentation. Four of 49 (8%) dogs were treated preoperatively with prednisone. The mean dose of prednisone prescribed was 0.9 ± 0.14 mg/kg PO every 24 hours; only 25% (1/4) of these dogs had concurrent MG.

Anesthesia and surgical procedure

Anesthesia was performed at the discretion of the attending anesthesiologist. One-lung ventilation was performed in 8 of 49 (16%) dogs: 7 of 8 (88%) with an endobronchial blocker (Arndt endobronchial blocker; Cook Medical Inc) and 1 of 8 (12%) with a double-lumen endobronchial tube (Teleflex Medical Inc). Seven of the 8 (88%) cases that utilized 1-lung ventilation were performed at academic referral hospitals.

After induction of general anesthesia, all dogs were positioned in dorsal recumbency. Thoracoscopy was performed with a multiport approach, as described elsewhere.[13–15] Briefly, a telescope was inserted in a subxiphoid position and accompanied by 2 intercostal cannulas in 40 of 49 (82%) dogs, 3 intercostal cannulas in 8 of 49 (16%) dogs, and 4 intercostal cannulas in 1 of 49 (2%) dogs. For surgical dissection, a LigaSure (Medtronic Inc), Enseal (Ethicon Endosurgery Inc), and Harmonic scalpel (Ethicon Endosurgery Inc) were used in 40 of 49 (82%), 6 of 49 (12%), and 3 of 49 (6%) dogs, respectively. Following surgery, a thoracostomy tube was placed in all dogs, with a median duration of indwelling placement of 18 hours (range, 4 to 54 hours).

The overall median surgical time was 80 minutes (range, 30 to 245 minutes). Median surgical time was 110 minutes (n = 18; range, 65 to 245 minutes) at academic referral hospitals and 60 minutes (31; range, 30 to 100 minutes) at private referral hospitals ($P < .0001$). Surgical time > 90 minutes occurred in 13 of 18 (72%) academic referral hospital cases and 3 of 31 (10%) private referral hospital cases ($P < .0001$). Among all procedures performed at academic referral hospitals, the median surgical time of cases with 1-lung ventilation (n = 7) did not differ significantly from those without 1-lung ventilation (11; $P = .36$). Upon univariable and multivariable analyses, only institution type was associated with surgical time, with cases performed in academic referral hospitals having a 25 times greater odds of lasting over 90 minutes ($P < .001$; **Table 1**).

Table 1—Univariable and multivariable analysis of predictors associated with surgical time over 90 minutes in 49 dogs undergoing thoracoscopic cranial mediastinal mass removal between January 1, 2014, and July 31, 2023.

Variable	Univariable analysis OR (95% CI)	*P* value	Multivariable analysis OR (95% CI)	*P* value
Age (y)	0.99 (0.75–1.32)	.96	—	—
Male (sex)	2.82 (0.75–10.59)	.12	—	—
Weight (kg)	1.02 (0.98–1.08)	.28	—	—
One-lung ventilation	4.55 (0.93–22.28)	.06	0.85 (0.11–6.39)	.98
LigaSure (Medtronic)	0.96 (0.21–4.47)	.96	—	—
Academia	24.27 (5.02–117.26)	< .001	25.75 (4.478–148.16)	< .001
Maximal CT tumor diameter (cm)	0.96 (0.65–1.42)	.83	—	—
Maximal tumor diameter to body weight ratio	0.15 (0.00–27.89)	.48	—	—
Myasthenia gravis	1.20 (0.35–4.16)	.77	—	—
Megaesophagus	1.24 (0.30–5.05)	.77	—	—
Conversion to open surgery	2.21 (0.28–17.35)	.45	—	—

The overall median anesthetic time was 150 minutes (range, 70 to 400 minutes). Median anesthetic time was 250 minutes (n = 18; range, 180 to 400 minutes) at academic referral hospitals and 120 minutes (31; range, 70 to 180 minutes) at private referral hospitals ($P < .0001$). In academic referral hospitals, the median additional anesthetic time (before and after surgery) was 127 minutes (range, 70 to 285 minutes) compared to 60 minutes (range, 25 to 135 minutes) in private referral hospitals ($P < .0001$). Among all procedures performed at academic referral hospitals, the use of 1-lung ventilation (n = 7) was not associated with longer additional anesthetic time, when compared to cases without 1-lung ventilation (11; $P = .81$).

Adverse events

No major intraoperative adverse events were reported. Nonemergent conversion to an open procedure was necessary in 4 of 49 (8%) dogs, and each was classified as a grade 3 conversion according to a previously published classification system.[20] Excessive adhesions were identified to the left cranial lung lobe in 2 dogs and to the cranial vena cava in 1 dog. All cases with adhesions (n = 3) were converted to a median sternotomy, whereas poor visualization of the cranial mediastinal mass resulted in conversion to a lateral thoracotomy in 1 dog. In the 4 cases of grade 3 conversion, a thoracostomy tube was placed with a median duration of indwelling placement of 30 hours (range, 14 to 41 hours).

Dogs with conversion to an open procedure had a significantly larger median maximal CT tumor diameter (6.2 cm; range, 6 to 8 cm) than dogs without conversion (4.5 cm; range, 2.7 to 8.5 cm; $P = .03$). In contrast, the median maximal CT tumor diameter to body weight ratio was not significantly different in dogs with (0.26; range, 0.16 to 0.53) and without (0.20; range, 0.08 to 0.59) conversion to an open procedure ($P = .23$). Other than the 4 dogs that required conversion to an open procedure, all cranial mediastinal masses were extirpated by use of a specimen retrieval bag (45/49 [92%]). Intraoperative hypothermia (< 37.2 °C for > 5 minutes), hypotension (mean blood pressure < 70 mm Hg for > 5 minutes), and hypoventilation (end-tidal CO_2 > 50 mm Hg) occurred in 9 of 49 (18%), 9 of 49 (18%), and 7 of 49 (14%) dogs, respectively.

Major postoperative adverse events occurred in 5 of 49 (10%) dogs. Four of 49 (8%) dogs were secondary to aspiration pneumonia, which was confirmed on thoracic radiography, and each dog was treated medically with antimicrobial therapy. Three of 4 (75%) dogs with aspiration pneumonia subsequently died or were euthanized at a median of 19 days (range, 2 to 28 days) postoperatively. Pulmonary thromboembolism occurred in 1 of 49 (2%) dogs. This patient became acutely tachypneic and oxygen dependent 4 days following surgery, and thromboembolism was confirmed via necropsy. Two of 49 (4%) dogs did not survive to hospital discharge: 1 dog with aspiration pneumonia and 1 dog with pulmonary thromboembolism. The most common minor postoperative adverse events was continued MG (5/49 [10%]). For each of these dogs, postoperative pyridostigmine was prescribed at a mean dose of 1.2 ± 0.10 mg/kg PO every 8 hours. Other minor postoperative adverse events included incisional skin infections (2/49 [4%]) and gastric ileus (1/49 [2%]). Both resolved with medical intervention (antimicrobial and prokinetic therapy).

Histological examination and adjuvant therapy

On histological evaluation, cranial mediastinal masses included thymoma (37/49 [76%]), ectopic thyroid carcinoma (5/49 [10%]), thymic carcinoma (2/49 [4%]), thymic branchial cyst (1/49 [2%]), and organizing hematoma (1/49 [2%]). The final histopathology report was not available for 3 of 49 (6%) cases, and these tumors were not defined. Chemotherapy was initiated in 3 of 49 (6%) dogs following surgery. Carboplatin (300 mg/m^2, IV, q 3 wk for 6 total doses) was given to 1 dog with thymic carcinoma, and toceranib phosphate (2.5 to 2.75 mg/kg PO, q 48 h for 6 months) was prescribed to 2 dogs with ectopic thyroid carcinoma.

Postoperative survival

All dogs survived the thoracoscopic cranial mediastinal mass removal procedure. Prior to hospital discharge, 2 of 49 (4%) dogs died of adverse events including aspiration pneumonia (n = 1) or pulmonary thromboembolism (1). Forty-seven of 49 (96%) dogs survived to hospital discharge. Median duration of hospitalization for dogs discharged from the hospital was 2 days (range, 1 to 9 days).

Six of 49 (12%) dogs were lost to follow-up. Four of 49 (8%) dogs were euthanized due to aspiration pneumonia, and 7 of 49 (14%) dogs were euthanized for reasons unrelated to their primary cranial mediastinal mass, including humeral osteosarcoma (2/7 [29%]), splenic hemangiosarcoma (2/7 [29%]), hepatic hemangiosarcoma (1/7 [14%]), tracheal and bronchial collapse progression (1/7 [14%]), and pelvic limb liposarcoma (1/7 [14%]). During the follow-up period, there was 1 case of local intrathoracic recurrence (1/49 [2%]) and no cases of port site metastases, although loss of follow-up and the lack of postoperative diagnostic imaging might be causes of underreporting of these events.

The overall median survival time (MST) for 37 dogs with thymoma was 1,102 days (95% CI, 482 to upper bound not reached). Dogs with thymoma had a 1- and 2-year survival rate of 78% and 57%, respectively. The MST for the 16 dogs with thymoma with a presurgical diagnosis of MG was 182 days (95% CI, 14 to upper bound not reached) versus 1,102 days (95% CI, 482 to upper bound not reached) for the 21 dogs without MG, which did not differ significantly (P = .20). The MST for the 5 dogs with ectopic thyroid carcinoma was 358 days (95% CI, 19 to upper bound not reached). Presurgical diagnosis of MG (P = .44) or ME (P = .69) were not associated with survival time. Tumor type (thymoma vs other) was not associated with survival time (P = .97). Institution type (academic referral hospitals vs private referral hospitals) was not associated with survival time (P = .83). Postoperative MG (P = .94) or aspiration pneumonia (P = .17) was not associated with survival time.

Discussion

Thoracoscopy is feasible and can be used safely for the surgical removal of cranial mediastinal masses in dogs. All dogs survived surgery in our study, and emergent conversion to an open procedure was not performed in any dog. Although intraoperative and postoperative adverse events are possible, the risk in our study was relatively low with appropriate preoperative diagnostic imaging, patient selection, and surgeon experience with thoracoscopy.

Findings in the present study agreed with epidemiological findings of previous reports.[13–15] Tumors were mostly from mixed-breed animals (10/49 [20%]), the median age was 10 years, the most common histopathological diagnosis was thymoma (37/49 [76%]), and sex distribution was similar between males (29/49 [59%]) and females (20/49 [41%]). Clinical signs were mostly attributed to the presence of an intrathoracic mass, with exercise intolerance (23/49 [47%]) and coughing (18/49 [37%]) commonly identified, as well as secondary paraneoplastic syndromes such as MG (17/49 [35%]).

Both MG and ME have previously been found to be negative prognostic indicators in dogs undergoing thymectomy.[3,12] Specifically for thoracoscopic thymoma removal, the MST for dogs with concurrent MG and ME was reported in 1 study[15] to be 20 days, in comparison to ≥ 60 days for dogs with thymoma without paraneoplastic syndromes. In that study, 7 of 18 (39%) dogs were diagnosed with MG and ME and 4 of 7 (57%) dogs were treated with pyridostigmine prior to surgery.[15] Comparably, in our study, 13 of 17 (76%) dogs with MG were treated with preoperative pyridostigmine and the MST for dogs with thymoma and concurrent presurgical MG was 182 days (95% CI, 14 to upper bound not reached). Presurgical diagnosis of MG (P = .44) or ME (P = .69) were not associated with survival time. The improved MST in this study might have been secondary to the increased usage of preoperative pyridostigmine. Pyridostigmine, an acetylcholinesterase inhibitor, is the mainstay of treatment for canine MG.[4] Pyridostigmine has the potential to minimize the risk of postoperative myasthenic decompensation and thus reduce the risk of aspiration pneumonia.[15] Aspiration pneumonia was documented in a minority of dogs (4/49 [8%]), of which half had preoperative MG and ME diagnosed. Preoperative recommendations for humans with MG prior to thymoma removal include serial plasma exchange and corticosteroid administration.[15,21,22] In our study, 4 of 49 (8%) dogs were treated with preoperative prednisone, and it has been reported that corticosteroids are associated with improved clinical outcomes in humans with MG undergoing cranial mediastinal mass removal.[23] No dogs were treated preoperatively with serial plasma exchange, and the veterinary application of this treatment modality for MG is still emerging. A recent study[24] demonstrated the efficacy of serial plasma exchange in 3 dogs with acquired MG and advocated it as a reasonable adjunct therapy to acetylcholinesterase inhibitor drugs in cases that are not responding to medical management alone. Regardless of the therapy (pyridostigmine and/or corticosteroids and serial plasma exchange), the authors recommend that appropriate preoperative treatment for MG and ME is implemented for at least 2 weeks prior to surgical intervention. Other possibilities for the improved MST in our study include unmeasured or unreported differences between study populations at the different referring veterinary hospitals, such as variations in the anesthetic protocol, surgical technique, or perioperative management (excluding pyridostigmine).

A tumor volume of ≤ 300 cm^3 or tumor diameter < 8 cm in dogs weighing > 20 kg has been recommended for successful thoracoscopic cranial mediastinal mass removal in dogs.[15] In our study, the median maximal CT tumor diameter was 4.7 cm (range, 2.7 to 8.5 cm), and the median maximal CT tumor diameter to body weight ratio was 0.20 (range, 0.08 to 0.59). A tumor volume was not calculated due to

the retrospective nature of our study and the difficulties in obtaining CT images from referring institutions. Rather than estimating an approximate tumor volume on the basis of a sphere ($4/3\pi r^3$) as previously reported,[15] we reported a median maximal tumor diameter. On the basis of the CT, all tumors were measured in 3 dimensions (length, height, and width), with the largest diameter being recorded. Most cranial mediastinal masses are nonspherical in nature, and this was demonstrated by a wide variability in measurements obtained for the same tumor in our study.

Thoracoscopy was performed with a primary subxiphoid telescope port and a combination of intercostal cannulas for surgical instrumentation. To help assist with visualization, 1-lung ventilation was performed in 8 of 49 (16%) dogs, and most of these cases were performed at academic referral hospitals (7/8 [88%]). One-lung ventilation is commonly used in humans for thoracoscopic surgery[25,26] and has been recommended for minimally invasive thymectomy in dogs.[27] This technique allows for improved visibility of intrathoracic structures and minimizes the risk of iatrogenic lung injury.[25,26] While 1-lung ventilation offers multiple benefits for thoracoscopic surgery, successful placement of endobronchial blockers and double-lumen endotracheal tubes does require additional training, skills, and equipment such as a bronchoscope or fluoroscopy.[25,28] For these reasons, it is uncommonly performed for dogs with cranial mediastinal masses. However, the use of 1-lung ventilation in academic referral hospitals (n = 7) was not associated with longer additional anesthetic time in our study when compared to cases without 1-lung ventilation (11; $P = .81$). On the basis of these results, the role of 1-lung ventilation in these cases remains unclear and further studies regarding its utility may be required.

Nonemergent conversion to an open procedure was necessary in 4 of 49 (8%) dogs. Conversion to an open procedure is commonly required during a thoracoscopic procedure. Reported conversion rates for thoracoscopic surgery in dogs range from 20% to 44% for lung lobectomy,[29,30] 6% for pericardiectomy,[31] and 11% for cranial mediastinal mass removal.[15] The most common reason for conversion within this population was presence of adhesions, followed by poor visualization. In our study, dogs with conversion to an open procedure had a significantly larger median maximal CT tumor diameter than dogs without conversion ($P = .03$). It appears that a large tumor size may not necessarily be prohibitive of successful thoracoscopy but within this cohort was associated with excessive adhesion formation. Adhesions can be challenging to manage thoracoscopically and are often difficult to identify on preoperative CT. Regardless of the procedure (thoracoscopic vs nonemergent conversion), all dogs survived the cranial mediastinal mass removal procedure and 47 of 49 (96%) dogs survived to hospital discharge. The 2 dogs that did not survive the immediate postoperative period died secondary to complications from aspiration pneumonia (n = 1) and pulmonary thromboembolism (1).

Of the 49 cases in our multi-institutional study, 18 (37%) were from academic referral hospitals and 31 (63%) were from private referral hospitals. Due to this variety in case distribution, significant differences were identified for various parameters when compared between the 2 sectors. For example, the median surgical time was 110 minutes (n = 18; range, 65 to 245 minutes) at academic referral hospitals and 60 minutes (31; range, 30 to 100 minutes) at private referral hospitals ($P < .0001$); cases performed in academic referral hospitals had a 25 times greater odds of lasting over 90 minutes ($P < .001$; Table 1). Previously reported surgical times for thoracoscopic cranial mediastinal mass removal range from 90 to 117 minutes.[13,15] It is suggested that most cases at an academic referral hospital would involve more intensive didactic teaching throughout the procedure for the resident and/or fellow candidate. In comparison, private practice surgeons do not always have direct mentorship responsibilities and can often proceed through a procedure without pausing for resident and/or fellow candidate feedback and training. In addition to surgical time, anesthetic time was also significantly different between academic and private institutions ($P < .0001$). Specifically, the median anesthetic time was 250 minutes (n = 18; range, 180 to 400 minutes) at academic referral hospitals and 120 minutes (31; range, 70 to 180 minutes) at private referral hospitals. Longer surgical time was not the only driving factor in academic referral hospital cases having longer anesthetic times, as cases performed also had significantly longer anesthetic exposure beyond the operative time. In academic referral hospitals, the median additional anesthetic time (before and after surgery) was 127 minutes (range, 70 to 285 minutes) compared to 60 minutes (range, 25 to 135 minutes) in private referral hospitals ($P < .0001$). Again, we postulate that the additional time for anesthesia (before and after surgery) occurred secondary to the didactic teaching nature of academic referral hospitals. Not only the surgical house officers but also veterinary students and other ancillary services such as the anesthesia team are being trained.

The most common tumor type in our study was thymoma (37/49 [76%]), and the overall MST for the dogs with thymoma was 1,102 days (95% CI, 482 to upper bound not reached). On the basis of previous literature, the MST for thymectomy in dogs ranges from 617 to 790 days. Moreover, no significant associations were identified for survival time in our study (eg, presurgical diagnosis of MG and ME, tumor type, institutional type, postoperative MG, and aspiration pneumonia). Further prospective controlled studies should be focused on assessment of whether preoperative patient therapy (eg, pyridostigmine for dogs with MG) as well as minimally invasive surgical approaches can decrease patient morbidity and improve recovery times and short- and long-term outcomes.

Several limitations were associated with this study. As it was a retrospective, multi-institutional study, variation was inherent within the study population. Not only were there differences in perioperative management, anesthetic protocols, and surgeon

experience for each of the 8 veterinary institutions, there were also discrepancies in the data that were recorded and reported for cases, especially in terms of long-term follow-up information. Moreover, the study was constrained by a limited sample size. Another limitation of the study involved the measurement of tumor size. As CT scans were not readily available from each referring institution, we decided to calculate a maximal median CT tumor diameter measurement. Commercially available software is routinely used in humans to calculate a CT-rendered volumetric calculation of tumor size, and this would have been our preference for this study.[32]

In conclusion, this study provides evidence to support the feasibility of thoracoscopic cranial mediastinal mass removal in dogs. To the knowledge of the authors, this is the largest retrospective study to date evaluating the feasibility of this minimally invasive technique in dogs. The study demonstrates that thoracoscopy is a safe technique with a low conversion rate and provides good short- and long-term outcomes for dogs after cranial mediastinal mass removal. With appropriate preoperative medical management, presurgical diagnosis of MG and ME are not contraindications for thoracoscopic surgery in dogs with cranial mediastinal masses.

Acknowledgments

None reported.

Disclosures

The authors have nothing to disclose. No AI-assisted technologies were used in the generation of this manuscript.

Funding

The authors have nothing to disclose.

ORCID

K. A. Carroll https://orcid.org/0000-0002-0977-1261
W. T. N. Culp https://orcid.org/0000-0001-6132-156X
M. A. Steffey https://orcid.org/0000-0003-0852-0644
A. Singh https://orcid.org/0000-0002-8095-9339
N. J. Buote https://orcid.org/0000-0003-4623-3582

References

1. Day MJ. Review of thymic pathology in 30 cats and 36 dogs. *J Small Anim Pract*. 1997;38(9):393–403. doi:10.1111/j.1748-5827.1997.tb03492.x
2. Liptak JM, Kamstock DA, Dernell WS, Ehrhart EJ, Rizzo SA, Withrow SJ. Cranial mediastinal carcinomas in nine dogs. *Vet Comp Oncol*. 2008;6(1):19–30. doi:10.1111/j.1476-5829.2007.00133.x
3. Robat CS, Cesario L, Gaeta R, Miller M, Schrempp D, Chun R. Clinical features, treatment options, and outcome in dogs with thymoma: 116 cases (1999–2010). *J Am Vet Med Assoc*. 2013;243(10):1448–1454. doi:10.2460/javma.243.10.1448
4. Forgash JT, Chang YM, Mittelman NS, et al. Clinical features and outcome of acquired myasthenia gravis in 94 dogs. *J Vet Intern Med*. 2021;35(5):2315–2326. doi:10.1111/jvim.16223
5. Constantino-Casas P, Rodríguez-Martínez HA, Gutiérrez Díaz-Ceballos ME. A case report and review: the gross, histological and immunohistochemical characteristics of a carcinoma of ectopic thyroid in a dog. *Br Vet J*. 1996;152(6):669–672. doi:10.1016/s0007-1935(96)80120-5
6. Martano M, Buracco P, Morello EM. Canine epithelial thymic tumors: outcome in 28 dogs treated by surgery. *Animals (Basel)*. 2021;11(12):3444. doi:10.3390/ani11123444
7. Burgess KE, DeRegis CJ, Brown FS, Keating JH. Histologic and immunohistochemical characterization of thymic epithelial tumours in the dog. *Vet Comp Oncol*. 2016;14(2):113–121. doi:10.1111/vco.12072
8. Levien AS, Summers BA, Szladovits B, Benigni L, Baines SJ. Transformation of a thymic branchial cyst to a carcinoma with pulmonary metastasis in a dog. *J Small Anim Pract*. 2010;51(11):604–608. doi:10.1111/j.1748-5827.2010.01006.x
9. Liu S, Patnaik AK, Burk RL. Thymic branchial cysts in the dog and cat. *J Am Vet Med Assoc*. 1983;182(10):1095–1098.
10. Ruby J, Secrest S, Sharma A. Radiographic differentiation of mediastinal versus pulmonary masses in dogs and cats can be challenging. *Vet Radiol Ultrasound*. 2020;61(4):385–393. doi:10.1111/vru.12859
11. Atwater SW, Powers BE, Park RD, Straw RC, Ogilvie GK, Withrow SJ. Thymoma in dogs: 23 cases (1980–1991). *J Am Vet Med Assoc*. 1994;205(7):1007–1013. doi:10.2460/javma.1994.205.07.1007
12. Zitz JC, Birchard SJ, Couto GC, Samii VF, Weisbrode SE, Young GS. Results of excision of thymoma in cats and dogs: 20 cases (1984–2005). *J Am Vet Med Assoc*. 2008;232(8):1186–1192. doi:10.2460/javma.232.8.1186
13. Mayhew PD, Friedberg JS. Video-assisted thoracoscopic resection of noninvasive thymomas using one-lung ventilation in two dogs. *Vet Surg*. 2008;37(8):756–762. doi:10.1111/j.1532-950X.2008.00447.x
14. Alwen SG, Culp WT, Szivek A, Mayhew PD, Eckstrand CD. Portal site metastasis after thoracoscopic resection of a cranial mediastinal mass in a dog. *J Am Vet Med Assoc*. 2015;247(7):793–800. doi:10.2460/javma.247.7.793
15. MacIver MA, Case JB, Monnet EL, et al. Video-assisted extirpation of cranial mediastinal masses in dogs: 18 cases (2009–2014). *J Am Vet Med Assoc*. 2017;250(11):1283–1290. doi:10.2460/javma.250.11.1283
16. Griffin MA, Sutton JS, Hunt GB, Pypendop BH, Mayhew PD. Video-assisted thoracoscopic resection of a noninvasive thymoma in a cat with myasthenia gravis using low-pressure carbon dioxide insufflation. *Vet Surg*. 2016;45(S1):O28–O33. doi:10.1111/vsu.12504
17. Case JB, Fox-Alvarez WA, Culp WT. Thoracoscopic mediastinal mass resection. In: Fransson BA, Mayhew PD, eds. *Small Animal Laparoscopy and Thoracoscopy*. 2nd ed. Wiley Blackwell; 2022:407–414. doi:10.1002/9781119666912.ch37
18. Chetty GK, Khan OA, Onyeaka CV, Ahmad F, Rajesh PB, Waller DA. Experience with video-assisted surgery for suspected mediastinal tumours. *Eur J Surg Oncol*. 2004;30(7):776–780. doi:10.1016/j.ejso.2004.05.004
19. LeBlanc AK, Atherton M, Bentley RT, et al. Veterinary Cooperative Oncology Group–Common Terminology Criteria for Adverse Events (VCOG-CTCAE v2) following investigational therapy in dogs and cats. *Vet Comp Oncol*. 2021;19(2):311–352. doi:10.1111/vco.12677
20. Follette CM, Giuffrida MA, Balsa IM, et al. A systematic review of criteria used to report complications in soft tissue and oncologic surgical clinical research studies in dogs and cats. *Vet Surg*. 2020;49(1):61–69. doi:10.1111/vsu.13279
21. Chiu HC, Chen WH, Yeh JH. The six year experience of plasmapheresis in patients with myasthenia gravis. *Ther Apher*. 2000;4(4):291–295. doi:10.1046/j.1526-0968.2000.004004291.x
22. Yeh JH, Chiu HC. Optimal volume of processed plasma and total number of selective plasmapheresis sessions in the treatment of patients with severe generalized myasthenia

gravis. *J Clin Apher*. 1999;14(4):177–180. doi:10.1002/(sici)1098-1101(1999)14:4<177::aid-jca4>3.0.co;2-l
23. Berrih-Aknin S, Le Panse R. Myasthenia gravis: a comprehensive review of immune dysregulation and etiological mechanisms. *J Autoimmun*. 2014;52:90–100. doi:10.1016/j.jaut.2013.12.011
24. Vitalo A, Buckley G, Londoño L. Therapeutic plasma exchange as adjunct therapy in 3 dogs with myasthenia gravis and myasthenia-like syndrome. *J Vet Emerg Crit Care (San Antonio)*. 2021;31(1):106–111. doi:10.1111/vec.13022
25. Bauer C, Winter C, Hentz JG, Ducrocq X, Steib A, Dupeyron JP. Bronchial blocker compared to double-lumen tube for one-lung ventilation during thoracoscopy. *Acta Anaesthesiol Scand*. 2001;45(2):250–254. doi:10.1111/j.1399-6576.2001.450218
26. Slinger PD. Optimizing one-lung ventilation: moving beyond tidal volume. *J Cardiothorac Vasc Anesth*. 2018;32(6):2673–2675. doi:10.1053/j.jvca.2018.04.034
27. Mayhew PD, Culp WT, Pascoe PJ, Kass PH, Johnson LR. Evaluation of blind thoracoscopic-assisted placement of three double-lumen endobronchial tube designs for one-lung ventilation in dogs. *Vet Surg*. 2012;41(6):664–670. doi:10.1111/j.1532-950X.2011.00979.x
28. Gil MG, Pérez EB, Plumed RM. Flexible and rigid bronchoscopy in thoracic anesthesia. In: Cohen E, ed. *Cohen's Comprehensive Thoracic Anesthesia.* Elsevier; 2022:171–181. doi:10.1016/B978-0-323-71301-6.00013-5
29. Scott JE, Auzenne DA, Massari F, et al. Complications and outcomes of thoracoscopic-assisted lung lobectomy in dogs. *Vet Surg*. 2023;52(1):106–115. doi:10.1111/vsu.13886
30. Lansdowne JL, Monnet E, Twedt DC, Dernell WS. Thoracoscopic lung lobectomy for treatment of lung tumors in dogs. *Vet Surg*. 2005;34(5):530–535. doi:10.1111/j.1532-950X.2005.00080.x
31. Atencia S, Doyle RS, Whitley NT. Thoracoscopic pericardial window for management of pericardial effusion in 15 dogs. *J Small Anim Pract*. 2013;54(11):564–569. doi:10.1111/jsap.12138
32. Nishino M, Guo M, Jackman DM, et al. CT tumor volume measurement in advanced non-small-cell lung cancer: performance characteristics of an emerging clinical tool. *Acad Radiol*. 2011;18(1):54–62. doi:10.1016/j.acra.2010.08.021