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Long-term survival after treatment of idiopathic lung lobe torsion in 80 cases

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Abstract

Objective: To report outcomes of dogs treated for lung lobe torsion (LLT) and to determine prognostic factors for survival.

Study design: Retrospective multicenter study from four veterinary teaching hospitals.

Animals: Dogs (n = 80) with LLT.

Methods: Medical records were reviewed for clinical and histopathological findings. Long-term outcome was assessed with an owner questionnaire. Lung lobe torsion was classified as idiopathic or secondary on the basis of the etiology.

Results: The most represented breeds were pugs (47.5%) and sighthounds (16.2%). The cause of the LLT was considered primary in 77%, secondary in 21%, and unknown in 2% of dogs. Postoperative complications were recorded in 14% of dogs. Overall, 95% of dogs survived to discharge, and median follow-up was 1095 days (range, 7-3809). Owners assessed outcomes and quality of life as excellent in 93% and 89% of dogs, respectively. Primary LLT was associated with a longer survival (median not reached in the study) compared with secondary LLT (921 days; range, 7-2073; $P = .001$).

Conclusion: Overall long-term survival after lung lobectomy for LLT was excellent. Primary LLT was associated with longer survival compared with secondary LLT. Long-term owner evaluation of clinical outcome for dogs undergoing lung lobectomy for LLT was considered excellent.

Clinical impact: Dogs with primary LLT undergoing lung lobectomy have a longer survival time compared with dogs with secondary LLT and have an excellent postoperative outcome.

1 | INTRODUCTION

Lung lobe torsion (LLT) is a potentially life-threatening condition in dogs and cats,[1-4] consisting of a lobar rotation of the bronchovascular pedicle at the hilus. This condition results in airway obstruction and vascular compromise.[1,4-6] The incidence of LLT remains unclear in small animals but in man ranges between 0.09% and

0.4%. In addition, LLT is a postoperative complication reported in 0.2% to 0.4% of lung lobectomies.[5,7]

The pathophysiology of LLT has not be elucidated in any species but has been linked to changes in the spatial relationship between lung lobes as well as bronchial cartilage dysplasia. These factors are believed to increase mobility of lung lobes within the thorax, thereby predisposing to LLT.[2,3,5] In human patients, postoperative, posttraumatic, and spontaneous occurrence due to an underlying pneumonic process have been described.[5,8] Overall, most cases of LLT occur after a lung lobectomy, with the right middle lung lobe being the most affected after right upper lobectomy.[5,8,9] In dogs, the etiology is primary (spontaneous or idiopathic) or secondary to an underlying process such as pulmonary (eg, neoplasia) or pleural disease (eg, pleural effusion).[4] Unlike the terminology used in human medicine, *primary*, *idiopathic*, and *spontaneous* are terms used interchangeably to describe LLT in animals when no predisposing factors can be identified.[1,2,10-12]

Large deep-chested dogs, such as Afghan hounds as well as other smaller breeds (eg, pugs), are overrepresented. However, LLT has been also documented in a diversity of breeds ranging from Chihuahuas to Newfoundlands.[1-4,11-19] It has been reported that small breed dogs are typically affected by secondary LLT,[4] whereas primary LLT is more common in pugs; large breed dogs are equally affected by primary and secondary LLT.[1-4]

The treatment of LLT is surgical, with lung lobectomy considered the gold standard in animals, whereas controversy still exits regarding the optimal treatment in human medicine. Resection of the nonviable tissue avoiding a reperfusion insult is the typical treatment in both dogs and human patients, but repositioning, with or without pexy, seems to represent a feasible option according to the findings in some studies in man.[5,8,20-22] Mortality associated with LLT in human patients ranges from 8.3% to 16%.[5,6,21] Reported mortality rate in dogs ranges from 31% to 61%[1,2]; however, more recent reports described a lower rate ranging from 8% to 14%.[4,19]

An important prognostic factor affecting survival in human patients with LLT is the extent of the lung torsion, but survival is not affected by the underlying cause or by surgical techniques (reposition vs resection).[5] Similarly, the underlying cause of the torsion (idiopathic vs secondary) does not appear to affect survival to discharge; however, dogs with left cranial LLT seem more likely to survive to discharge compared with dogs with concurrent right cranial and right middle LLT.[4] Pugs have been found to have a better prognosis compared with other breeds, with a survival rate to discharge ranging from 86% to 92% compared with 50% for nonpugs[2]; however, this has been questioned in more recent studies in which no survival advantage was found.[4,19] Because of the conflicting reports regarding postoperative outcomes in dogs with LLT, the rarity of the disease, and the poorly understood pathophysiology, additional large-scale studies are always beneficial to determine risk factors affecting the outcome in these dogs.

The objective of this study was to describe short- and long-term outcomes of dogs presented for LLT and to identify factors associated with survival by using a large scale multicenter study. We hypothesized that the outcome for pugs and dogs with idiopathic LLT was better compared with other affected breeds or causes.

2 | MATERIALS AND METHODS

2.1 | Study design and eligibility criteria

This retrospective observational study used anonymized clinical data and was approved by the Liverpool Veterinary School Research Ethics Committee (VREC601). Electronic records from four small animal referral university hospitals in the United Kingdom (University of Liverpool, University of Bristol, Royal Veterinary College, University of Edinburgh) were searched to identify all dogs in which LLT had been diagnosed between 2007 and 2018. Dogs in which LLT had been diagnosed during the study period that had comprehensive clinical records were included in the study. Affected dogs that presented for a second surgery to address another postoperative lobar torsion were not classified as new cases and were not included in the statistical analysis.

Information retrieved from the records included signalment, clinical history, examination findings, preoperative blood test results, preoperative diagnostic findings, location of the LLT, time from presentation to surgery, surgical treatment, surgical and anesthetic time, pleural fluid analysis and histopathological findings, time from surgery to thoracic drain removal, time from surgery to discharge, bacteriology results, concomitant surgical procedures under the same general anesthetic, survival to hospital discharge, and recurrence of LLT. The inciting cause of LLT was determined on the basis of clinical, diagnostic, and histopathological findings. The occurrence of any intraoperative and postoperative complication was recorded as well as the requirement of additional surgical intervention or medical treatment. Complications were classified as minor, defined as complications that did not require additional surgical or medical treatment to resolve, and major, defined as complications or associated morbidity that required additional surgical or medical treatment to resolve. To evaluate outcome, a questionnaire was designed (Questionnaire S1), and owners were requested to answer six questions about their dog's outcome and quality of life.

2.2 | Statistical analysis

Descriptive statistics were computed for all variables. Continuous explanatory variables assessed included age, body weight, duration of clinical signs, time from presentation to surgery, anesthetic time, surgical time, time from surgery to thoracic drain removal, time from surgery to discharge, and survival. According to results from Shapiro–Wilk test, none of these data sets were likely to be from a normal distribution ($P < .001$ for all), so they are reported as median (range). Categorical variables assessed were sex, neuter status, breed (pug vs sighthounds; pug vs other breeds; sighthounds vs other breeds), location of the lobar torsion (left side vs right side and left cranial vs right middle), concomitant procedures, etiology, and occurrence of complications.

For each dog, disease-specific survival time was determined to be the time elapsed from the date of surgery to the date of death or censorship (Figure 1). Dogs were censored from survival analysis when they were alive at the time of analysis or lost to follow-up. The Kaplan–Meier method and Cox proportional hazards analysis were used to determine the association of a range of variables with the survival time. The outcome variable was survival time, and the explanatory variables were those previously listed. All variables were initially tested separately via univariate Cox proportional hazards analysis, and a multivariate Cox proportional hazards model was then built, which initially included the variables identified as $P < .2$ on univariate analysis. Cox proportional hazards analysis results are reported as odds ratios, 95% confidence intervals, and the associated *P*-value. With regard to the breed distribution, a χ^2 test was initially used to determine any significant association between etiology and breeds. When a significant association was found, Fisher's exact test was then used to characterize the results, in particular whether pugs were more likely to experience primary LLT compared with sighthounds and other breeds as well as whether sighthounds were more likely to experience primary LLT compared with other breeds. The level of statistical significance was set at $P < .05$ for two-sided analyses.

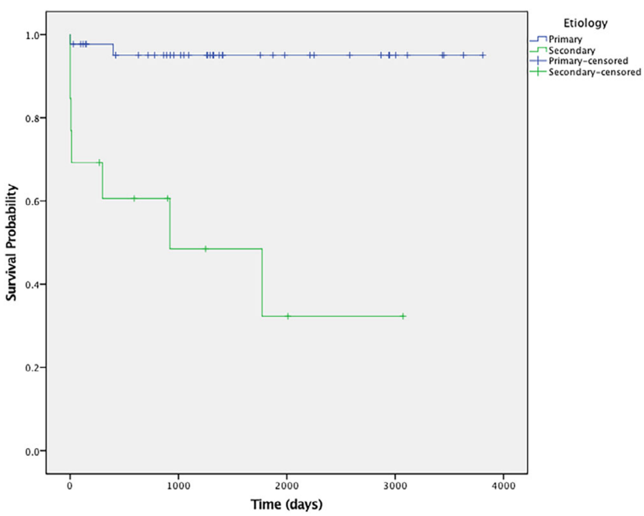

FIGURE 1 Kaplan–Meier survival curve for dogs with primary (n = 43) and secondary (n = 11) lung lobe torsion treated by lung lobectomy

3 | RESULTS

3.1 | Population data, clinical presentation, and diagnostic investigations

In total, 84 dogs met the eligibility criteria, but four dogs were excluded because of incomplete medical records, leaving a study population of 80 dogs. The most represented breeds were pugs (38 [47.5%]) and sighthounds (13 [16.2%] including five whippets, four greyhounds, three lurcher and one saluki), followed by Labrador retriever (9), shih tzu (3), border collie (2), and others.

The population included 49 male dogs (31 neutered and 18 intact) and 31 female dogs (19 neutered and 12 intact), with a male-to-female ratio of 1.6:1. At the time of the surgery, the median age was 31.5 months (range 2.5-130), and median weight was 10 kg (range 1-61.9). There were 15 juvenile (≤12 months old) dogs, 11 of which were pugs.

Median duration of clinical signs was 4 days, ranging from less than 24 hours prior to presentation to 90 days. Respiratory signs including dyspnea, tachypnea, increased respiratory effort, and excessive panting were reported in 66 (82%) dogs. Cough was described in 30 (37%) dogs, in particular in four dogs presented for hemoptysis. Other clinical signs reported were lethargy (45 [56%]), anorexia/hyporexia (26 [32%]), pyrexia (18 [22%]), and exercise intolerance (8 [10%]). In nine (11%) dogs presented for lethargy, anorexia, gastrointestinal signs such as vomiting, regurgitation or diarrhea, pigmenturia with suspected lower urinary tract infection, abdominal, spinal or generalized pain, no clinical signs associated with the respiratory system were reported. In most dogs, a combination of clinical signs was reported.

Findings at physical examination included increased respiratory effort (33 [41%]), tachypnea (23 [29%]), pyrexia (13 [16%]), dyspnea (9 [11%]), panting (9 [11%]), upper respiratory sounds (4 [5%]), shallow breathing (2 [2.5%]), and paradoxical breathing (2 [2.5%]). Cardiothoracic auscultation revealed attenuated pulmonary sounds (36 [45%]), attenuated cardiac sounds (11 [14%]), adventitial pulmonary sounds (8 [10%]), increased lung sounds (2 [2.5%]), and heart murmur (1 [1.2%]). Pyrexia was documented in 13 (16%) dogs, cranial abdominal pain was documented in four (5%) dogs, and kyphosis was documented in one (2%) dog. In seven (9%) dogs, physical examination revealed no abnormalities.

Complete blood count (CBC) was available in 63 dogs, and abnormalities included neutrophilia ($>12 \times 10^9$/L) in 44 (70%) dogs, with band neutrophils in 10 (16%) dogs, leukocytosis ($>18 \times 10^9$/L) in 30 (47%) dogs, monocytosis ($>1.2 \times 10^9$/L) in 28 (44%) dogs, anemia (hematocrit <35%) in 22 (35%) dogs, lymphopenia ($<1.2 \times 10^9$/L) in 10 (16%) dogs, lymphocytosis ($>3.8 \times 10^9$/L) in six (9.5%) dogs, and thrombocytopenia ($<150 \times 10^9$/L) in three (4.7%) dogs. In nine (14%) dogs, CBC was within reference limits.

Serum biochemistry was available in 67 dogs. Hypoproteinemia and hypoalbuminemia were each present in 10 (15%) dogs. Alkaline phosphatase levels were increased (>119 U/L) in 34 (51%) dogs, and alanine aminotransferase (>125 U/L) and creatine kinase levels were elevated in seven (10%) dogs. Hypercholesterolemia (cholesterol >8.3 mmol/L) was present in 11 (16%) dogs, hyperbilirubinemia (total bilirubin >15 μmol/L) was present in eight (12%) dogs, hyperlactatemia (lactate >2.5 mmol/L) was present in eight (12%) dogs, hyperglycemia (glucose >6.6 mmol/L) was present in six (9%) dogs, hyponatremia (<144 mmol/L) was present in six (9%) dogs, hypokalemia (<3.5 mmol/L) was present in seven (10%) dogs, hypocalcemia (<2.13 mmol/L) was present in eight (12%) dogs, and hypochloremia (109 mmol/L) was present in six (9%) dogs. In 13 (19%) dogs, serum biochemistry was within normal limits.

Computed tomography was the most common diagnostic tool used to diagnose LLT. It was performed in 69 (86%) cases. The most common abnormalities described were obliteration or tapering of the main bronchus (47 [68%]), pleural effusion (45 [65%]), vesicular pattern of the affected lung lobe (41 [59%]), lung consolidation (19 [27%]), local lymphadenopathy (12 [17%]), atelectasis (9 [13%]), and emphysema (7 [10%]). Thoracic radiography was performed in 19 (24%) cases, and the most commonly reported features were an increased radiopacity and vesicular pattern compatible with consolidation and suspected torsion of a lung lobe, pleural effusion, and pneumothorax.

Thoracic ultrasound was used in four (5%) cases, echocardiography was performed in two (2.5%; one with pulmonary stenosis) dogs because of suspected cardiac disease, and bronchoscopy was used in two (2.5%) dogs.

The left cranial lung lobe was affected in 40 (50%) dogs, followed by right middle (28 [35%]), right cranial (13 [16%]), and accessory (1 [1%]) lobes. Two cases were presented with the torsion of two lung lobes: left cranial/right middle and right cranial/right middle. In pugs, the left cranial lung lobe was the most affected (25 [66%]), followed by the right cranial (10 [26%]) and the right middle (3 [8%]) lobes. For sighthounds, the right middle lung lobe was the most commonly affected (10 [77%]), followed by the left cranial (2 [15%]) and right cranial (1 [8%]) lobes.

3.2 | Surgical procedures

Four dogs died or were euthanized before surgery including three dogs presented with severe respiratory compromise that experienced cardiopulmonary arrest before surgery and one dog in which LLT secondary to a pulmonary adenocarcinoma was diagnosed and for which the owner elected euthanasia. These four cases were included in the initial descriptive analysis but there were not included in survival analysis.

Seventy-six dogs underwent surgery that included resection of the affected lung lobe; in none of the cases was de-rotation with or without pexy attempted. Median surgical time was 75 minutes (range, 40-250), and median anesthetic time was 180 minutes (range, 90-330). An intercostal thoracotomy was used as the surgical approach in 73 cases, and median sternotomy was performed in the remaining three cases. Time from diagnosis to surgery ranged from less than 24 hours to 5 days, with 64 (83%) dogs undergoing surgical treatment less than 24 hours after initial presentation.

Lung lobectomy was performed with a stapling device in 70 dogs (in six cases, the surgical site was reinforced with sutures); sutures only were used in six cases, and, in two of the cases, hemoclips were also added (1-kg pug and 2.7-kg papillon).

A thoracic drain was placed in all but two dogs, and it was removed from a range of less than 12 hours to a maximum of 15 days in one doge with persistent chylothorax. In 39 (51%) dogs, the drain was removed within the first 24 hours.

Postoperative hospitalization for monitoring, thoracic drain management, and analgesia ranged from 72 hours to 20 days (median, 96 hours). Eleven concomitant surgeries were performed in eight dogs including rhinoplasty, palatoplasty, and laryngeal sacculectomy for BOAS (2); subtotal pericardiectomy with thoracic duct ligation (1); subtotal pericardiectomy (2); subtotal pericardiectomy, thoracic duct ligation, cisterna chyli ablation, and pleural access port placement (1; PleuralPort; Norfolk Vet Products, Skokie, Illinois); mediastinal biopsies (1); mediastinal mass biopsies (1); partial mediastinectomy (1); partial lung lobectomy of the left caudal lung lobe due to adhesions from the left cranial and left caudal lung lobe (1); and rib resection to remove the affected lung lobe due to adhesions from the right middle lung lobe and the parietal pleura (1). Antibacterial and analgesia therapy was prescribed postoperatively at the discretion of the surgeon, 30 (39%) dogs received prophylactic antibiotic postoperatively.

3.3 | Clinicopathological results

Aerobic and anaerobic bacterial culture and antimicrobial susceptibility testing from the pleural effusion or lung parenchyma were performed in 39 dogs. In four cases, bacterial culture was positive, including mixed growth of *Escherichia coli* and *Staphylococcus intermedius*, suspected *Nocardia* spp or *Actinomyces* spp, *Bacillus* spp, and *β-hemolytic Streptococcus* spp. Histopathological evaluation was available in 68 cases. The most common findings included necrosis (58 [87%]), hemorrhage (55 [82%]), thrombosis (16 [24%]), fibrosis (14 [21%]), pleural fibroplasia (7 [10%]), pleuropneumonia (6 [9%]), pleuritis (5 [7%]), and suppurative pneumonia (2 [3%]). In two cases, pulmonary adenocarcinoma was diagnosed.

In 61 (77%) dogs, cause of the LLT was not found, so a diagnosis of idiopathic LLT was made; 35 (57%) idiopathic LLT were found in pugs. Two pugs were pregnant at the time of diagnosis; it is unknown if the pregnancy could have been an inciting factor for the torsion. In the remaining 17 (21%) dogs with an available diagnosis, the condition was deemed secondary to chylothorax (9), concomitant pyothorax (2), trauma (2), pulmonary adenocarcinoma (2), congenital lobar emphysema (1), pyogranulomatous pericarditis and mediastinitis (1), eosinophilic pleural effusion (1), or mesothelioma (1). In two cases (2%), one pug (1%) and one (1%) Pyrenean mountain dog, the cause could not be verified because the dogs died before the surgical procedure. The distribution of primary and secondary LLT related to breeds is reported in Table 1. No difference was found between pugs and sighthounds ($P = .054$) or between sighthounds and other breeds ($P = .434$); however, a difference was found between pugs and other breeds ($P = .001$).

TABLE 1 Breed distribution of primary and secondary lung lobe torsion[1]

	Pugs[a,b,d]		Sighthounds[a,b,c]		Other breeds[a,c,d]	
Etiology	n	%	n	%	n	%
Primary	35	92	9	69	17	59
Secondary	2	5	4	31	11	38
Unknown	1	3	0	0	1	3

[a] $P = .034$, χ^2 test.
[b] $P = .054$, Fisher's exact test.
[c] $P = .434$, Fisher's exact test.
[d] $P = .001$.

3.3.1 | Complications

Surgery was uncomplicated in 74 of 76 cases. Two dogs (3%) had intraoperative complications recorded; one dog experienced hemorrhage after de-rotation of the lung lobe, which did not require blood-product transfusion; and, in one dog that also had pulmonic valve stenosis, a patch-graft was planned but abandoned because of a sudden deterioration related to the general anesthetic. All dogs survived the surgical procedures.

In the postoperative period, 12 complication events occurred in 11 (14%) dogs. Five complications were considered minor: hypoxemia requiring oxygen supplementation (2), continued pleural effusion (2), and hypoalbuminemia, peripheral edema, and seroma of the surgical site in one dog. Seven complications were classified as major: pyothorax (2), chylothorax (3), aspiration pneumonia (1), and hemoglobinuria and nonregenerative anemia requiring transfusion in one dog. Among these dogs, LLT was diagnosed in 8, whereas secondary LLT was diagnosed in three. No difference was found between the LLT etiology and the risk of postoperative complications ($P = .413$).

Specifically, among the three dogs that developed chylothorax postoperatively, two dogs underwent a second surgical intervention, and one dog was euthanized. A 4-year-old greyhound developed chylothorax 2 days post–lung lobectomy, and conservative treatment was attempted but failed, so a second surgery including thoracic duct ligation, subtotal pericardiectomy, and pleural access port placement (PleuralPort; Norfolk Vet Products) was performed 13 days after lung lobectomy. The dog recovered uneventfully, and clinical signs ceased after surgery. A 3-year-old saluki developed chylothorax 3 days after surgery, and a pleural access port (PleuralPort; Norfolk Vet Products) was placed, but the dog was euthanized 11 months after surgery because of lack of improvement and failure of the pleural port. Finally, a 4-year-old Labrador developed chylothorax 13 days after lung lobectomy and was euthanized at the owner's request. These three dogs had spontaneous torsion of the right middle lung lobe.

3.3.2 | Outcomes

Among all dogs presented for LLT, 76 of 80 (95%) dogs survived to discharge, and, among all dogs that underwent surgical treatment, 75 of 76 (99%) dogs survived to discharge.

Follow-up was available for 56 (70%) dogs and ranged from 7 to 3809 days (median, 1095). Eleven (20%) dogs died or were euthanized during the follow-up period between 7 and 2910 days, five (9%) of which were for reasons unrelated to the cause of the LLT. Intestinal lymphoma was diagnosed in an 8-year-old pug, which was euthanized 3 years after surgery, and epitheliotropic lymphoma was diagnosed in a 3-year-old whippet, which was euthanized approximately 1 year after surgery. A 1-year-old pug was euthanized after the occurrence of seizure. Finally, two dogs were euthanized for reasons unrelated to LLT, the specific cause was not indicated by their owners.

Six (11%) dogs died or were euthanized for causes related to their secondary LLT, four for chylothorax, one for pulmonary carcinoma, and one for mesothelioma. A 7-year-old Doberman in which pulmonary adenocarcinoma was diagnosed was euthanized 9 months after surgery because of metastatic disease and subsequent deterioration. A 9-year-old Weimaraner with a preexistent chylothorax and pyothorax was euthanized by owner request 7 days after lung lobectomy because of persistent pleural effusion and lack of improvement.

Three dogs in which chylothorax was diagnosed had chylothorax recurrence 13 days, 11 months, and 12 months after surgery, and the owners elected euthanasia; one of the dogs was an 18-month-old whippet in which a second LLT (left cranial lung lobe) was also diagnosed. Finally, a 5-year-old pug in which spontaneous left cranial LLT was initially diagnosed required regular pleural fluid drainage. A diagnosis of mesothelioma was confirmed 11 months after the initial surgery, and the dog was euthanized.

Forty-five (56%) owners completed questionnaires. Long-term issues were reported in only four (9%) cases; three dogs had chylothorax, and one had recurrent eosinophilic pleural effusion, requiring occasional drainage. All dogs returned to full exercise, and, subjectively, none seemed to be affected by the surgery.

The overall outcome of the surgery was described as excellent in 42 (93%) cases, good in two (4.5%) cases, and poor in one dog (2.5%) with chylothorax that required repeated thoracocentesis postoperatively. The quality of life of the dogs was described as excellent in 40 (89%) cases, good in four (9%) cases, and poor in the dog with chylothorax that was eventually euthanized.

3.3.3 | Risk factors associated with survival of surgery for LLT

Overall median disease-specific survival rate for dogs undergoing lung lobectomy for LLT as estimated for all 56 dogs was not reached. Based on Kaplan–Meier estimates, the 1-, 2-, and 5- year disease-specific survival rates were 93% (51/55), 91% (50/55), and 88% (49/55), respectively.

TABLE 2 Prognostic factors for duration of survival after surgical treatment of lung lobe torsion in dogs, derived from univariate logistic regression

	Lung lobar torsion survival		
Logistic regression	**OR**	**95% CI**	***P* value**
Age	1.01	0.99-1.02	.086*
Sex	1.55	0.46-5.17	.471
Neuter status	0.62	0.17-2.32	.487
Body weight	1.00	0.99-1.00	.212
Breed			
pug vs sighthounds	0.29	0.04-2.07	.218
pug vs other breeds	1.79	0.03-0.86	.032*
sighthounds vs other breeds	0.60	0.12-2.90	.526
Duration of clinical signs	0.99	0.96-1.03	.971
Time from presentation to surgery	0.57	0.07-4.59	.601
Surgical time	1.01	0.98-1.04	.234
Anesthetic time	1.00	0.99-1.02	.376
Location of the torsion			
Left vs right	1.00	0.29-3.46	.997
Left cranial vs right middle	0.72	0.19-2.70	.632
Intraoperative complications	2.55	0.31-20.95	.381
Postoperative complications	2.11	0.42-10.65	.362
Concomitant procedures	12.61	2.54-62.62	.002*
Etiology	14.76	3.05-71.47	.001*

Abbreviations: 95% CI, 95% confidence interval; OR, odds ratio (reference category used in logistic regression).
*$P < .20$, qualified for inclusion in the multiple regression analysis.

TABLE 3 Prognostic factors for duration of survival after surgical treatment of lung lobe torsion in dogs, derived from multivariate logistic regression

	Complications		
Logistic regression	**OR**	**95% CI**	***P* value**
Age	1.00	0.98-1.02	.460
Breed (pug vs others)	0.44	0.03-7.22	.570
Concomitant procedures	5.94	1.05-33.40	.063
Etiology, idiopathic vs secondary	9.37	1.45-45.36	.002

Abbreviations: 95% CI, 95% confidence interval; OR, odds ratio.

Logistic regression analysis was used to determine factors associated with survival when possible confounding factors were taken into account (Table 2). After the initial model was refined by backward-stepwise elimination, the best-fit model was one that included four variables (age, breed [pug vs other breeds], concomitant procedures, and etiology). In the final multiple-regression model (Table 3), the only factor associated with a decreased risk of death included having an idiopathic LLT ($P = .002$). Dogs with secondary LLT had a median disease-specific survival time of 921 days (range, 7-3073), whereas, the median disease-specific survival time was not reached in those with idiopathic LLT.

4 | DISCUSSION

In this study, dogs with idiopathic LLT lived longer after lung lobectomy than those with secondary disease, leading us to accept our first hypothesis that outcome for dogs with idiopathic LLT was better compared with other causes. However, we reject our second hypothesis because pugs with idiopathic LLT did not have a better outcome compared with other breeds.

Lung lobe torsion can affect dogs at any age and of any size despite occurring more frequently in young and small breed dogs.[1,2,4,18,19] Fifteen (19%) juvenile dogs were reported in this study, and 73% of them were pugs. Latimer et al[3] reported similar findings, describing LLT in seven juvenile dogs, of which five were pugs. As previously reported, pugs were overrepresented with 47.5% of dogs; sighthound dogs accounted for most of the remaining population. In pugs, left cranial lung lobe was the most commonly affected lobe, followed by the right cranial and the right medial lobes, which is in line with findings in the study by Park et al.[4]

Pugs have been found to have a higher incidence of bronchomalacia, which causes flaccidity of the supportive cartilage, hypotonia of myoelastic fibers, and loss of integrity of the bronchial wall predisposing to bronchial collapse.[23,24] In this study, the occurrence of LLT in pugs was identical to the reported distribution of bronchomalacia and bronchial collapse, with the left cranial bronchus most affected, followed by the right cranial and the right middle bronchus.[25] Factors contributing to this particular distribution included thoracic conformation and anatomical features of individual bronchi and lung lobes.[23-26] This could explain the overrepresentation of pugs for LLT because bronchomalacia could cause bronchial collapse leading to atelectasis of the lung lobe, altering the spatial conformation of lung lobes and increasing their mobility.[2,4,11,13,25] Histopathological and genetic studies with analysis of the fibers of the bronchus of the torsed lung lobe would be required to confirm this hypothesis and the prevalence of this condition. On the other hand, sighthounds were presented mainly for the torsion of the right middle lobe. This is believed to be because of its narrow shape and relative increased mobility potentially contributing to its torsion.[4,27]

Previously, pugs and other small breed dogs were found to have better prognoses compared with other breeds.[1,18] However, in our study, we failed to find an association between survival and any of the variables related to the signalment of our population even when pugs were tested separately from the rest of the population. This finding is in line with large, more recently published studies.[4,19] For the first time, a strong association was found between the etiology of the LLT and survival; dogs experiencing idiopathic LLT that underwent surgical intervention were more likely to have a successful outcome compared with dogs with secondary LLT. We can speculate that idiopathic LLT has a more benign course, and, thus, these dogs are less likely to have long-term sequelae after surgical intervention.

In human patients, LLT is observed after thoracic surgery, with torsion of the right middle lobe after right upper lobectomy.[5,28,29] Lung lobectomy is not considered a risk factor for a subsequent lobar torsion in small animals; it is sporadically reported and, in our population, none of the dogs had previous thoracic surgery. Recurrence of LLT has been reported only occasionally, ranging from 3% to 7% of cases, occurring usually between 5 and 180 days after the original presentation.[4,18,19] In our population, only one dog re-presented for a second LLT after initial lung lobectomy; however, persistent chylothorax was suspected to be the inciting cause for both the torsions. This was also described in a report of a recent study in which the four cases of LLT recurrence had continued pleural effusion postoperatively.[4] It was speculated that continued pleural effusion in conjunction with the increased available space in the thorax after the previous lung lobectomy predisposed these dogs to recurrence of LLT.[4] Because of the paucity of reports in the literature of cases with recurrent LLT, no specific risk factors for recurrence of torsion have been elucidated.

In human patients, resection or de-rotation (with or without pexy) are both acceptable surgical options, although there is with controversy regarding which is the best treatment; re-positioning can retain pulmonary function, but direct resection avoids a reperfusion insult.[5] A recent systematic review found no differences in survival between the two proposed treatments; factors involved in the treatment choice were the presence of arterial flow preoperatively, the lack of hemorrhagic infarctions, and the subjective visual assessment of the pulmonary parenchyma.[5] It is unlikely that de-rotation and pexy will be considered in small animals because the excision of the affected lung lobe is well tolerated.

Complications after lung lobectomy performed because of LLT range from 8% to 24%, with no standardized criteria to evaluate the complications described among the reports.[1,4,18,19,30] In our population, only 3% of dogs had intraoperative complications, and 14% had postoperative complications. Occurrence of postoperative complications was not associated with a shorter survival time. Because of the variety of encountered complications, it would be misleading to try and draw additional conclusions; however, in our population, the occurrence of chylothorax was associated with poorer outcome. Three dogs developed chylothorax after lung lobectomy and either died or were euthanized in the first 3 months after surgery. Chylothorax is thought to develop after disruption or obstruction of the thoracic duct or thoracic lymphatics, resulting in lymphangiectasia[1,4,27,31] and has been reported as a possible cause of LLT as well as a complication after lung lobectomy for LLT.[4,19,31] If spontaneous resolution of the chylothorax is not achieved in the short postoperative period, surgical treatment should be considered. In cases of preexistent chylothorax, corrective surgery can be performed at the time of lung lobectomy.[4] After considering the cases reported in this study, we recommend a prompt and aggressive approach for cases of chylothorax, and a more guarded prognosis should be given to the owners.

The main limitation of this study is its multi-institutional retrospective nature, which can increase the variability in management and treatment of cases. Medical records were occasionally incomplete, and follow-up data were inconsistent. The low number of dogs with a negative status (dead or euthanized) could preclude a reliable statistical analysis, limiting the precision of the effects of the different variables. This is supported by the wide confidence intervals for the odds ratios in this study. The measures of outcome of the dogs in our study were based entirely on a subjective questionnaire (Questionnaire S1); this assessment may be less reliable, leading to an incorrect perception by the owner. The follow-up period ranged from 7 to 3809 days; this could have resulted in recall bias in which owners who completed the questionnaire a longer period of time after their dog's surgery had a less accurate recall of their dog's clinical outcome, resulting in less reliable questionnaire scores compared with owners who completed the questionnaire within a shorter period of time after their dog's surgery.

In conclusion, the current study provides evidence that dogs undergoing lung lobectomy for idiopathic LLT have a better prognosis with a longer survival time compared with dogs experiencing secondary LLT.

CONFLICT OF INTEREST

The authors do not have any affiliation, financial, support or conflicts of interest with the technique or products used in this work.

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REFERENCES

1. Neath PJ, Brockman DJ, King LG. Lung lobe torsion in dogs: 22 cases (1981-1999). *J Am Vet Med Assoc.* 2000;217:1041-1044.
2. Murphy KA, Brisson BA. Evaluation of lung lobe torsion in pugs: 7 cases (1991-2004). *J Am Vet Med Assoc.* 2006;228:86-90.
3. Latimer CR, Lux CN, Sutton JS, Culp WTN. Lung lobe torsion in seven juvenile dogs. *J Am Vet Med Assoc.* 2017;251:1450-1456.
4. Park KM, Grimes JA, Wallace ML, Sterman AA, Thieman Mankin KM, Campbell BG, et al. Lung lobe torsion in dogs: 52 cases (2005–2017). *Vet Surg.* 2018;47:1002-1008.
5. Dai J, Xie D, Wang H, He W, Zhou Y, Hernandez-Arenas LA, et al. Predictors of survival in lung torsion: a systematic review and pooled analysis. *J Thorac Cardiovasc Surg.* 2016;152:737-745.
6. Cable DG, Deschamps C, Allen MS, Nichols FC, Trastek VF, Pairolero PC. Lobar torsion after pulmonary resection: presentation and outcome. *J Thorac Cardiovasc Surg.* 2001;122:1091-1093.
7. Larsson S, Lepore V, Dernevik L, Nilsson F, Selin K. Torsion of a lung lobe: diagnosis and treatment. *Thorac Cardiovasc Surg.* 1988;36:281-283.
8. Ternes T, Trump M, de Christenson MR, Howell G, Stewart J. Spontaneous middle-lobe torsion. *Radiol Case Rep.* 2013;8:812.
9. Shorr RM, Rodriguez A. Spontaneous pulmonary torsion. *Chest.* 1987;91:927-928.
10. White RN, Corzo-Menendez N. Concurrent torsion of the right cranial and right middle lung lobes in a whippet. *J Small Anim Pract.* 2000;41:562-565.
11. Rooney MB, Lanz O, Monnet E. Spontaneous lung lobe torsion in two pugs. *J Am Anim Hosp Assoc.* 2001;37:128-130.
12. Hofeling AD, Jackson AH, Alsup JC, O'Keefe D. Spontaneous midlobar lung lobe torsion in a 2-year-old Newfoundland. *J Am Anim Hosp Assoc.* 2004;40:220-223.
13. Spranklin DB, Gulikers KP, Lanz OI. Recurrence of spontaneous lung lobe torsion in a pug. *J Am Anim Hosp Assoc.* 2003;39:446-451.
14. Choi J, Yoon J. Lung lobe torsion in a Yorkshire Terrier. *J Small Anim Pract.* 2006;47:557.
15. Davies JA, Snead EC, Pharr JW. Tussive syncope in a pug with lung-lobe torsion. *Can Vet J.* 2011;52:656-660.
16. Kurach LM, Nykamp SG, Ringwood PB. What is your diagnosis? *J Am Vet Med Assoc.* 2012;241:1149-1151.
17. Agut A, Carrillo JD, Seva J, Soler M, Laredo FG. What is your diagnosis? *J Am Vet Med Assoc.* 2013;243:333-335.
18. Benavides KL, Rozanski EA, Oura TJ. Lung lobe torsion in 35 dogs and 4 cats. *Can Vet J.* 2019;60:60-66.
19. Wainberg SH, Brisson BA, Reabel SN, Hay J, Hayes G, Shmon CL, et al. Evaluation of risk factors for mortality in dogs with lug lobe torsion: a retrospective study of 66 dogs (2000-2015). *Can Vet J.* 2019;60:167-173.

20. Uramoto H, Takenoyama M, Hanagiri T. Simple prophylactic fixation for lung torsion. *Ann Thorac Surg*. 2010;90:2028-2030.
21. Yang EM, Song ES, Jang H, Jeong IS, Choi YY. Lung torsion after tracheoesophageal fistula repair in an infant. *Korean J Pediatr*. 2013;56:186-190.
22. Childs L, Ellis S, Francies O. Pulmonary lobar torsion: a rare complication following pulmonary resection, but one not to miss. *BJR Case Rep*. 2017;2:20160010.
23. Johnson LR, Pollard RE. Tracheal collapse and bronchomalacia in dogs: 58 cases (7/2001-1/2008). *J Vet Intern Med*. 2010;24:298-305.
24. Adamama-Moraitou KK, Pardali D, Dai MJ, Prassinos NN, Kritsepi-Kostantinou M, Patsikas MN, et al. Canine bronchomalacia: a clinicopathological study of 18 cases diagnosed by endoscopy. *Vet J*. 2012;191:261-266.
25. De Lorenzi D, Bertoncello D, Drigo M. Bronchial abnormalities found in a consecutive series of 40 brachycephalic dogs. *J Am Vet Med Assoc*. 2009;235:835-840.
26. Bottero E, Bellino C, De Lorenzi D, Ruggiero P, Tarducci A, D'Angelo A, et al. Clinical evaluation and endoscopic classification of bronchomalacia in dogs. *J Vet Intern Med*. 2013;27: 840-846.
27. Lord PF, Greiner TP, Greene RW, DeHoff WD. Lung lobe torsion in the dog. *J Am Anim Hosp Assoc*. 1973;9:473-482.
28. Wagner RB, Nesbitt JC. Pulmonary torsion and gangrene. *Chest Surg Clin North Am*. 1992;2:839-852.
29. Banki F, Velmahos GC. Partial pulmonary torsion after thoracotomy without pulmonary resection. *J Trauma*. 2005;59: 478-481.
30. Follette C M, Giuffrida M A, Balsa I M, Culp WTN, Mayhew PD, Oblak ML, 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*. 2019;1-9. doi.org/10.1111/vsu.13279.
31. Johnston GR, Feeney DA, O'Brien TD, Klausner JS, Polzin DJ, Lipowitz AJ, et al. Recurring lung lobe torsion in three Afghan hounds. *J Am Vet Med Assoc*. 1984;184:842-845.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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