

# Surgical approach and presence of preoperative pleural effusion impact thoracostomy tube usage in dogs and cats following thoracic surgery for suspected neoplasia

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## OBJECTIVE

To assess factors associated with increased pleural fluid and air evacuation, longer duration of thoracostomy tube usage, and longer hospitalization in dogs and cats following surgery for thoracic neoplasms.

## ANIMALS

62 dogs and 10 cats.

## METHODS

Medical records were reviewed for dogs and cats undergoing thoracic surgeries between August 1, 2019, and June 30, 2023, for resection of suspected neoplasia in which a thoracostomy tube was placed. Data collected included patient signalment, type of procedure performed, histologic diagnosis of the primary mass removed, volume of fluid and air evacuated from the thoracostomy tube, and time in hospital.

## RESULTS

Median sternotomy was associated with increased total fluid evacuation (median, 12.1 mL/kg; IQR, 15.4 mL/kg;  $P = .012$ ), whereas rib resection was associated with increased total air evacuation (median, 2.1 mL/kg; IQR, 13.6 mL/kg;  $P = .06$ ). The presence of preoperative pleural effusion was associated with higher total fluid evacuation (20.6 mL/kg; IQR, 32.1 mL/kg;  $P = .009$ ), longer duration with a thoracostomy tube in place (42.5 hours; IQR, 41.9 hours;  $P = .027$ ), and longer hospitalization period (61 hours; IQR, 52.8 hours;  $P = .025$ ). Cats had a thoracostomy tube in place for a longer time compared to dogs (median, 42.6 hours; IQR, 23.5 hours;  $P = .043$ ).

## CLINICAL RELEVANCE

Animals undergoing median sternotomy and rib resection may be expected to have higher fluid and air volumes, respectively, evacuated postoperatively. This often leads to an increased duration of thoracostomy tube usage and a longer period of hospitalization.

**Keywords:** thoracostomy tube, neoplasia, air evacuation, fluid evacuation, thoracic surgery

**S**urgical excision is often the recommended treatment for thoracic neoplasms in dogs and cats.<sup>1,2</sup> These tumors can affect any tissue within the thoracic cavity, requiring different methods for surgical excision.<sup>1</sup> A lateral thoracotomy is typically performed for unilateral primary pulmonary neoplasms, whereas a median sternotomy is preferred for mediastinal tumors or tumors affecting both hemithoraces.<sup>1,3</sup> A transdiaphragmatic approach can be considered for caudal thoracic lesions, especially if a celiotomy is being performed for concurrent abdominal pathology.<sup>1,4</sup> If a neoplasm affects the thoracic wall, a rib resection

can be performed to excise the mass.<sup>5,6</sup> Regardless of surgical approach, thoracostomy tubes are frequently placed to monitor and quantify pleural space fluid and air accumulation and used to prevent significant pleural effusion or pneumothorax development postoperatively.<sup>7,8</sup> Thoracostomy tubes are associated with postoperative complications with complication rates between 22% and 44% in animals that had a thoracostomy tube placed.<sup>8,9</sup> The duration of time a thoracostomy tube is left in place has been associated with an increased risk of complications in veterinary species, including the development of a pyothorax.<sup>8,10</sup> This is not unique to veterinary medicine, with human literature reporting thoracostomy tube complication rates up to 19%.<sup>11</sup> In humans, postoperative thoracostomy tubes have also been found to increase postoperative pain levels, limit postoperative movement, and slow overall recovery for patients.<sup>12</sup>

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While thoracostomy tubes are commonly used following thoracic procedures in dogs and cats, the appropriate timing for thoracostomy tube removal remains uncertain. Historically, guidelines have recommended that fluid evacuation from the thoracostomy tube be  $< 2 \text{ mL/kg/d}$  ( $0.08 \text{ mL/kg/h}$ ) before the tube is removed.<sup>13</sup> This is due to the normal production and absorption of pleural fluid, which is  $0.1$  to  $0.2 \text{ mL/kg/h}$  in dogs.<sup>14</sup> More recent studies have found that dogs and cats may tolerate higher postoperative pleural fluid volumes than historically believed.<sup>15-17</sup> With uncertainty about time for appropriate removal, it is possible that thoracostomy tubes are being left in place for longer than clinically needed in dogs and cats following thoracic procedures, resulting in longer hospitalization times and increased postoperative pain.

Factors associated with higher volumes of fluid or air evacuation following thoracic surgeries for animals with thoracic neoplasia have not been previously evaluated. Bleakly et al<sup>3</sup> compared short-term outcomes associated with median sternotomy and lateral thoracotomy for lung lobectomy in dogs and found increased fluid evacuation associated with a median sternotomy. This study did not assess other surgical approaches or neoplasms that were not associated with the lungs.<sup>3</sup> Understanding associations that may affect fluid and air evacuation leading to longer thoracostomy tube usage and hospitalization can help establish clinical expectations for both the owner and clinician. The main objective of this study was to assess factors contributing to increased fluid or air evacuation following thoracic surgeries for suspected neoplasia that may result in a longer duration of thoracostomy tube usage and a longer hospitalization period in dogs and cats.

## Methods

### Data collection

Electronic medical records were searched for billing triggers for thoracostomy tubes between August 1, 2019, and June 30, 2023, and associated records reviewed. Animals were initially excluded if tube placement was not related to thoracic surgery or the animal had a tube placed following surgery without suspicion for neoplasia. The remaining animals were included in the study if they had records related to volume evacuated through the thoracostomy tube, timing of thoracostomy tube removal, and time to hospital discharge. Exclusion criteria were cardiopulmonary arrest intraoperatively during or after thoracostomy tube placement, arrest postoperatively before the thoracostomy tube could be removed, or if postoperative records were not complete or available.

Data collected from records included patient signalment at the time of surgery. Reports written by board-certified radiologists of preoperative imaging, either thoracic CT or thoracic radiographs, were assessed for the presence of pleural effusion or a pneumothorax. Surgical details were collected, including

approach (lateral thoracotomy, medial sternotomy, rib resection, or transdiaphragmatic), if lymphadenectomy was performed, complications associated with thoracostomy tube placement, and timing of tube placement. The histopathologic diagnosis of excised masses was confirmed by a board-certified veterinary anatomic pathologist, and animals were divided into groups by diagnosis, consisting of pulmonary carcinoma, thymoma, metastatic neoplasia, hemangiosarcoma, body wall sarcoma, histiocytic sarcoma, lymphoma, benign neoplasia, and other benign pathology.

The treatment sheets from the duration of hospitalization were assessed for volume of fluid and air evacuated following anesthetic recovery and 8, 12, and 24 hours postoperatively as well as the remaining duration of thoracostomy tube usage if longer than 24 hours. Fluid and air evacuation was calculated at each time point by dividing the volume in milliliters of fluid or air produced by the body weight in kilograms and the length of time in hours postoperatively. The duration the thoracostomy tube was in place was calculated as the time between anesthetic recovery and tube removal. The length of total hospitalization post-thoracostomy tube placement was calculated as the time between anesthetic recovery and time of hospital discharge. Any complications following thoracostomy tube removal within the hospitalization period were also recorded if they were noted in the animal's record.

Complications associated with thoracostomy tube placement were those that occurred intraoperatively resulting in failure to achieve negative pressure following closure or those necessitating tube replacement. Complications following thoracostomy tube removal were those that occurred between tube removal and hospital discharge consisting of tachypnea or decreased oxygenation following tube removal that warranted intervention. Any interventions secondary to these complications were recorded.

### Thoracostomy tube placement

Thoracostomy tubes were placed at the end of the surgical procedure using small-bore, 12-gauge, wire-guided thoracostomy tubes. All dogs and cats received the same gauge of thoracostomy tube regardless of body weight. Only 1 thoracostomy tube was placed in each animal. All tubes were placed in the modified Seldinger technique. Tubes were placed either before closure and visualized to be in the correct location or after closure with correct placement determined by ability to drain fluid or air from the chest until negative pressure was achieved. Once ideal placement was confirmed, the tube was secured in place.

### Statistical analysis

Once initial postoperative results were compiled, the volume of fluid and air evacuated and the length of hospitalization were assessed for significant association between species, age at surgery, preoperative presence of pleural effusion or pneumothorax, surgical approach, whether lymphadenectomy was performed during

surgery, and histologic diagnosis of the mass excised. For each variable, a Shapiro-Wilk test was performed to assess for normal distribution. To evaluate the effect of each variable on fluid and air evacuation, length of thoracostomy tube usages, and length of hospitalization, a Mann-Whitney *U* test or Kruskal-Wallis test was performed for data with a minimum of 5 entries. For tests with multiple comparisons, a Bonferroni correction was performed to adjust for multiple comparisons. A *P* value < .05 was considered significant for all results. All analyses were conducted using commercial software (SPSS Statistics for Windows, version 29.0; IBM Corp).

## Results

A total of 75 thoracic surgeries (65 dogs, 10 cats) were included. Of those, 2 dogs were excluded due to death during the procedure. One was due to cardiopulmonary arrest and the second due to intraoperative euthanasia secondary to carcinomatosis found on initial thoracic explore. A third dog was excluded due to incomplete postoperative records. One cat was presented twice during this period for 2 median sternotomies. The surgeries were over a year apart and were therefore counted separately. Therefore, 72 animals met the criteria for this study, including 62 dogs and 10 cats. Dogs were commonly reported as mixed breed (*n* = 24), and cats were most commonly reported as domestic shorthair (8). Further breakdown of other breeds is presented in **Table 1**. The dogs consisted of 1 intact male, 31 castrated males, and 30 spayed females. The cats consisted of 5 castrated males and 5 spayed females. The median age of the dogs at the time of surgery was 10 years (range, 2.4 to 14.5 years). The median age of the cats was 8.4 years (range, 3.8 to 12.9 years).

All animals received preoperative imaging in the form of thoracic CT (*n* = 71) or thoracic radiographs (1). Preoperative imaging reports found pleural effusion in 11 dogs and 3 cats and a pneumothorax in 1 dog. One cat with preoperative pleural effusion had a chylothorax. The remaining animals with pleural effusion had a small volume of effusion without associated clinical signs. Lateral thoracotomy was the most common surgical approach to the thorax in both cats and dogs. Lymphadenectomy was performed in 18 animals. Lymphadenectomy was performed in 10 animals undergoing lateral thoracotomy and 8 animals undergoing median sternotomy. The most common

histologic diagnosis was pulmonary carcinoma in dogs and thymoma in cats (**Supplementary Table S1**).

Thoracostomy tube placement was not associated with complications besides in 1 dog necessitating a lung lobectomy and tube replacement secondary to an air leak secondary to pulmonary damage from intraoperative thoracostomy tube placement. All other cases had routine placement with no obvious complications noted at the time. Following placement, thoracostomy tubes were evacuated until negative pressure was achieved following closure and again following anesthetic recovery. Thoracostomy tubes were aspirated every 8 hours or as needed on the basis of clinical signs of dyspnea, tachypnea, or poor oxygen saturation on pulse oximetry. Of the dogs, thoracostomy tubes were in place for a median of 22.1 hours (IQR, 8.3 hours), and dogs were hospitalized for a median of 42.3 hours (IQR, 23.4 hours). In cats, tubes were in place for a median of 42.6 hours (IQR, 23.5 hours), and cats were hospitalized for a median of 68.2 hours (IQR, 39.3 hours; **Table 2**). The median fluid evacuation at the time of thoracostomy tube removal was 0.73 mL/kg/d (IQR, 1.7 mL/kg/d; range, 0 to 7.8 mL/kg/d), with 56 (77.8%) animals having fluid evacuation < 2 mL/kg/d prior to thoracostomy tube removal. Only 2 animals had complications following tube removal (1 dog and 1 cat). Both developed increased respiratory rate and effort after tube removal; the cat responded to oxygen supplementation without evidence of pleural effusion on point-of-care ultrasound, while the dog required thoracocentesis with removal of approximately 400 mL (20 mL/kg) of fluid from the pleural space. Both cases resolved without replacement of a thoracostomy tube.

Cats were found to have a thoracostomy tube in place for a longer duration than dogs (median, 42.6 hours vs 22.1 hours in dogs; *P* = .043). Species was not found to be associated with increased fluid (*P* = .909) or air (*P* = .177) evacuation at any time point after surgery and was also not associated with a significantly longer period of hospitalization (*P* = .190). The presence of preoperative pleural effusion was associated with an increased fluid evacuation rate in the first 8 (median, 0.4 vs 0.2 mL/kg/h; *P* = .005) and 12 (median, 0.5 vs 0.2 mL/kg/h; *P* = .009) hours postoperatively as well as higher total fluid evacuation (median, 20.6 vs 6.3 mL/kg; *P* = .009). Preoperative pleural effusion was also associated with delayed thoracostomy

**Table 1**—Animal demographics, including sex, age at time of surgery, whether pleural effusion was present preoperatively, surgical approach, and whether lymphadenectomy was performed for 62 dogs and 10 cats undergoing thoracic surgery for removal of suspected thoracic neoplasia.

Parameter	Overall population ( <i>n</i> = 72)	Dogs ( <i>n</i> = 62)	Cats ( <i>n</i> = 10)
Sex (MI/CM/FI/SF)	1/36/0/35	1/31/0/30	0/5/0/5
Age (y) <sup>a</sup>	9.9 (3.9)	10 (3.9)	8.4 (4.3)
Presence of preoperative pleural effusion (Y/N)	14/58	11/51	3/7
Surgical approach (LT/MS/RR/TD)	43/22/5/2	37/19/4/2	6/3/1/0
Lymphadenectomy performed (Y/N)	18/54	17/45	1/9

CM = Castrated male. FI = Female intact. LT = Lateral thoracotomy. MI = Male intact. MS = Median sternotomy. N = No. RR = Rib resection. SF = Spayed female. TD = Transdiaphragmatic. Y = Yes.

<sup>a</sup>Data are presented as median (IQR).

**Table 2**—Summary of fluid and air production, duration of thoracostomy tube placement, and length of hospitalization following thoracic surgery for 62 dogs and 10 cats with suspected thoracic neoplasia.

Parameters	Overall population (n = 72)	Dogs (n = 62)	Cats (n = 10)
Fluid evacuation postoperatively			
First 8 h (mL/kg/h) <sup>a</sup>	0.2 (0.4)	0.2 (0.5)	0.2 (0.3)
First 12 h (mL/kg/h) <sup>a</sup>	0.3 (0.3)	0.3 (0.3)	0.3 (0.5)
Second 12 h (mL/kg/h) <sup>a</sup>	0.2 (0.4)	0.2 (0.4)	0.2 (0.3)
Total fluid production (mL/kg) <sup>a</sup>	6.7 (9.9)	6.7 (8.4)	9.8 (25.0)
Air evacuation postoperatively			
First 8 h (mL/kg/h) <sup>a</sup>	0 (0.1)	0 (0.1)	0.1 (0.2)
First 12 h (mL/kg/h) <sup>a</sup>	0 (0.1)	0 (0)	0.1 (0.2)
Second 12 h (mL/kg/h) <sup>a</sup>	0 (0)	0 (0)	0 (0)
Total air evacuation (mL/kg) <sup>a</sup>	0.1 (1.6)	0.1 (1.2)	1.1 (15.2)
Hospitalization data			
Duration of TT placement (h) <sup>a</sup>	22.3 (20.9)	22.1 (8.3)	42.6 (23.5)
Hospitalization post-TT removal (h) <sup>a</sup>	8.1 (19.6)	8.0 (19.1)	22.8 (18)
Duration of hospitalization (h) <sup>a</sup>	42.7 (26)	42.3 (23.4)	68.2 (39.3)

TT = Thoracostomy tube.

<sup>a</sup>Data are presented as median (IQR).

tube removal (median, 42.5 vs 21.9 hours;  $P = .027$ ) and a longer hospitalization period (median, 61 vs 42.1 hours;  $P = .025$ ; **Table 3**). The surgical approach affected both fluid and air evacuation postoperatively (**Table 4**). Median sternotomy was associated with higher fluid evacuation within the initial 8 hours postoperatively when compared to a lateral thoracotomy (median, 0.5 vs 0.17 mL/kg/h, respectively;  $P = .004$ ) as well as higher total fluid evacuation when compared

to a lateral thoracotomy (median, 12.1 vs 6.7 mL/kg for lateral thoracotomy;  $P = .012$ ). Total fluid evacuation was not statistically significant between median sternotomy and rib resection ( $P = 1.000$ ) and rib resection and lateral thoracotomy ( $P = .351$ ). Rib resection was associated with higher air evacuation rates within the initial 8 hours (median, 0.2 vs 0 mL/kg/h for both lateral thoracotomy [ $P = .023$ ] and median sternotomy [ $P = .049$ ]) and 12 hours (0.2 vs 0 mL/kg/h for lat-

**Table 3**—Summary of fluid evacuation, duration of thoracostomy tube usage, and duration of hospitalization associated with the presence (n = 14) and absence (58) of preoperative pleural effusion in 62 dogs and 10 cats following thoracic surgery for suspected thoracic neoplasia.

Parameter	Pleural effusion present	No pleural effusion present
Fluid evacuation postoperatively		
First 8 h (mL/kg/h) <sup>a</sup>	0.4 (0.3)	0.2 (0.4)
First 12 h (mL/kg/h) <sup>a</sup>	0.5 (0.4)	0.2 (0.3)
Second 12 h (mL/kg/h) <sup>a</sup>	0.3 (0.4)	0.2 (0.3)
Total fluid production (mL/kg) <sup>a</sup>	20.6 (32.1)	6.3 (8.2)
Hospitalization data		
Duration of TT placement (h) <sup>a</sup>	42.5 (41.9)	21.9 (7.6)
Hospitalization post-TT removal (h) <sup>a</sup>	16.8 (22.6)	7.8 (18.9)
Duration of hospitalization (h) <sup>a</sup>	61 (53.8)	42.1 (21.5)

<sup>a</sup>Data are presented as median (IQR).

**Table 4**—Summary of fluid and air evacuation, duration of thoracostomy tube usage, and duration of hospitalization following lateral thoracotomy (n = 43), median sternotomy (22), and rib resection (5) in 60 dogs and 10 cats with suspected thoracic neoplasia.

Parameter	Lateral thoracotomy	Median sternotomy	Rib resection
Fluid evacuation postoperatively			
First 8 h (mL/kg/h) <sup>a</sup>	0.17 (0.4)	0.5 (0.4)	0.2 (0.2)
First 12 h (mL/kg/h) <sup>a</sup>	0.2 (0.4)	0.4 (0.5)	0.2 (0.2)
Second 12 h (mL/kg/h) <sup>a</sup>	0.2 (0.3)	0.3 (0.4)	0.2 (0.4)
Total fluid evacuation (mL/kg) <sup>a</sup>	6.7 (9.9)	12.1 (15.4)	7.6 (8.2)
Air evacuation postoperatively			
First 8 h (mL/kg/h) <sup>a</sup>	0 (0)	0 (0.1)	0.2 (0.6)
First 12 h (mL/kg/h) <sup>a</sup>	0 (0)	0 (0.1)	0.2 (0.4)
Second 12 h (mL/kg/h) <sup>a</sup>	0 (0)	0 (0)	0.1 (0.6)
Total air evacuation (mL/kg) <sup>a</sup>	0.1 (1.0)	0.1 (1.1)	2.1 (13.6)
Hospitalization data			
Duration of TT placement (h) <sup>a</sup>	21.2 (7.2)	34.5 (29.2)	27.4 (25.1)
Hospitalization post-TT removal (h) <sup>a</sup>	7.6 (17.3)	14.8 (22.8)	22.4 (14.5)
Duration of hospitalization (h) <sup>a</sup>	40.4 (19.3)	52.2 (33.9)	49.8 (7.7)

<sup>a</sup>Data are presented as median (IQR).

eral thoracotomy [ $P = .040$ ]) postoperatively, as well as higher total air evacuation (median, 2.1 vs 0.1 mL/kg for both lateral thoracotomy [ $P = .006$ ] and median sternotomy [ $P = .012$ ]). Animals that underwent a lateral thoracotomy had a shorter duration of hospitalization when compared to a median sternotomy (median, 40.4 vs 52.2 hours;  $P = .014$ ). The duration of hospitalization was not significantly different between lateral thoracotomy and rib resection ( $P = .752$ ) and medial sternotomy and rib resection ( $P = 1.000$ ). Animal sex and histologic diagnosis were not associated with increased fluid ( $P = .713$  and  $.051$ ) or air ( $P = .711$  and  $.072$ ) evacuation during the postoperative period, a longer duration with a thoracostomy tube in place ( $P = .845$  and  $.252$ ), or a longer duration in hospital ( $P = .323$  and  $.840$ ).

## Discussion

This study found that the surgical approach and presence of preoperative pleural effusion did impact the volume of fluid and air evacuated, duration of thoracostomy tube usage, and duration of hospitalization in this population of dogs and cats. Surprisingly, cats were also found to have a longer duration of thoracostomy tube usage, despite having similar fluid and air evacuation and total hospitalization time compared to dogs. Factors such as histologic diagnosis, lymph node extirpation, animal sex, and animal age did not impact postoperative fluid and air evacuation, thoracostomy tube usage, or length of hospitalization. This may be secondary to the small sample size or may represent that these factors truly do not impact thoracostomy tube usage following thoracic surgery in cats and dogs.

Preoperative pleural effusion was associated with increased fluid evacuation at all time points except the 12-hour postoperative period; however, median overall fluid evacuation rates were still higher in those with preoperative pleural effusion at this time point (0.3 vs 0.2 mL/kg/h). Several factors may confound the effects of preoperative pleural effusion on postoperative pleural fluid evacuation rates. Most notably, the etiology of the pleural effusion may dictate whether it is likely to resolve with surgery alone.<sup>18</sup> The presence of chylothorax is associated with the evacuation of significantly higher fluid volumes at the time of thoracostomy tube removal and the presence of pleural effusion 2 weeks after thoracostomy tube removal.<sup>18</sup> Animals with chylothorax may have higher volumes of fluid evacuated secondary to inflammation of the pleura if the effusion is chronic or there is failure to resolve the primary cause of the chylothorax.<sup>19,20</sup> In the case of most animals with chylothorax secondary to neoplasia, this is caused by obstruction of lymphatic drainage most commonly secondary to a mediastinal mass.<sup>20</sup> In this study population, only 1 cat had a large volume of pleural effusion preoperatively with a chylothorax secondary to a large mediastinal mass. The remaining animals in this population with pleural effusion noted preoperatively were noted to have small volumes of effusion secondary to thoracic neoplasia. The nonchylous pleural effusions seen with thoracic

neoplasia can also be associated with inflammation of the pleura, resulting in increased fluid production and decreased absorption.<sup>21</sup> This inflammation may explain an increase in postoperative fluid production in this population.<sup>21</sup> Animals with preoperative pleural effusion also had a thoracostomy tube in place and were hospitalized for a longer period, likely secondary to the increased fluid evacuation postoperatively.

Dogs and cats in this population were more likely to have higher fluid volumes evacuated after a median sternotomy. This has been previously documented in dogs and humans following median sternotomy for lung lobectomy and cardiac surgery, respectively, when compared to a lateral thoracotomy.<sup>3,22</sup> Production of pleural effusion postoperatively is most associated with exudation from damaged tissue or damage to local lymphatic drainage.<sup>16</sup> This may be secondary to the longer incision length necessary for this approach, the manipulation and dissection of the mediastinal pleura, or the extensive dissection necessary to remove some mediastinal tumors.<sup>3</sup> The mediastinum does contain a large lymphatic network in comparison to other structures in the thoracic cavity, which may make it more influential in the clearance of pleural effusion outside of thoracostomy tube evacuation.<sup>14,23</sup> Minimizing disruption of tissue intraoperatively may therefore help limit the volume of fluid evacuated postoperatively by retaining normal lymphatic drainage of fluid within the pleural space.

Rib resection procedures were associated with higher rates and volume of air evacuated postoperatively throughout the duration a thoracostomy tube was in place in this population. Due to the nature of this procedure, this is likely secondary to air leakage from the external environment through the closure or movement of air pockets present in the pleural space following surgery instead of pulmonary air leaks.<sup>3,24</sup> Air leaks following lung lobectomy are commonly reported in human patients associated with damaged pulmonary tissue.<sup>25</sup> These are reported to be commonly self-limiting in human patients, with most reaching resolution within 7 days of surgery.<sup>25</sup> Air leaks have been reported in an experimental canine model following partial lung lobectomy but otherwise have not been reported associated with lung lobectomy in dogs.<sup>26,27</sup> This may be due to the potential self-limiting nature of the leak postoperatively, as seen in humans.<sup>25</sup> Air leaks may be secondary to pulmonary barotrauma following mechanical ventilation and pulmonary re-expansion or surgeon trauma to the pulmonary parenchyma during body wall closure.<sup>1,4</sup>

Cats in this study had a thoracostomy tube in place longer than dogs despite having similar fluid and air evacuation rates at all time points in the hospital and no significant difference in hospitalization length. The small number of cats in this study may have reduced the ability to determine statistical significance for the length of hospitalization, as the median hospitalization period was longer in cats than dogs. As for the longer duration of thoracostomy tube usage, there is no obvious explanation in this population. It may be secondary to clinician bias on

timing to thoracostomy tube removal in cats, difficulty in assessing cats postoperatively, and concern for development of clinical signs secondary to premature tube removal. Hospitalized cats are reported to have tachycardia and tachypnea compared to cats in their home environment.<sup>28</sup> Postoperative pain may also play a part in tachycardia and tachypnea in cats and may be challenging to assess accurately in a cat that is fearful or stressed in the hospital.<sup>29,30</sup> Higher respiratory rates postoperatively may influence a clinician to leave a thoracostomy tube in place longer despite having fluid and air evacuation appropriate for tube removal. This may prove to be counterintuitive for cats, as thoracostomy tubes are reported to cause significant pain in human patients and may be the cause of the clinical abnormalities in these cats.<sup>12</sup>

The results of this study should be interpreted in light of the study limitations. The retrospective nature of this study was susceptible to inaccuracies in the volume of pleural fluid and air evacuated at different time points as well as time to discharge, as this was reliant on accurate medical record documentation. The retrospective nature may also have led to an underestimation of complications associated with thoracostomy tube placement in this population of animals. Additionally, there would have been heterogeneity in the surgeries and postoperative management with many different clinicians working at an academic teaching hospital over the study period. This could have led to differences in the duration of thoracostomy tube placement and hospitalization associated with different clinician preferences. Due to the small population size and wide range of diagnoses with variable presence of pleural effusion, the effects of all independent variables together on fluid and air evacuation, thoracostomy tube usage, and hospitalization length could not be assessed.

In conclusion, surgical approach and presence of preoperative pleural effusion were associated with a higher volume of fluid or air evacuation postoperatively. Both were associated with longer hospitalization. Preoperative pleural effusion and species were also associated with longer thoracostomy tube usage. Understanding trends in thoracostomy tube usage can help to guide postoperative expectations for both the owner and the clinician. This also highlights the need for further prospective research evaluating thoracostomy tube usage in cats and better evaluation of cats in hospital to ensure that thoracostomy tubes are not left in place longer than is clinically needed. Further prospective research is needed in a larger population of dogs and cats to evaluate further factors that may impact thoracostomy tube usage and the best timing for thoracostomy tube removal.

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## Supplementary Materials

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