J Vet Sci. 2020 Nov;21(6):e84
https://doi.org/10.4142/jvs.2020.21.e84
pISSN 1229-845X·eISSN 1976-555X

Journal of Veterinary Science

Original Article
Medical Imaging

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Computed tomographic features of gastric and esophageal content in dogs undergoing CT myelography and factors influencing the presence of esophageal fluid

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Received: Jun 5, 2020
Revised: Aug 21, 2020
Accepted: Sep 9, 2020

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ABSTRACT

Background: Gastroesophageal reflux (GER) has been reported to be a common finding in dogs under general anesthesia.
Objectives: The aim of this retrospective study was to assess the esophageal and gastric contents in a population of dogs undergoing computed tomographic myelography (myelo-CT) examination and to evaluate the factors influencing the presence of esophageal fluid (gastric content, duration of anesthesia, body position, and intrinsic factors).
Methods: Esophageal and gastric contents of 83 non-brachycephalic dogs were retrospectively assessed based on plain and myelo-CT scans. Age, weight, breed, sex, and the time between the 2 computed tomography [CT] scans were included.
Results: Esophageal fluid was present in 19% (16/83) of the animals, and 14% (12/83) and 46% (37/83), respectively, had fluid or food material in their stomachs. The frequency of observing esophageal fluid on myelo-CT scans was significantly increased compared with plain CT scans ($p = 0.006$). The presence of gastric fluid was significantly associated with an increased frequency of observing esophageal fluid compared to other gastric contents ($p = 0.049$; odds ratio, 3.1). The presence of esophageal fluid was not correlated with alimentary gastric contents ($p = 0.17$). Increased body weight and duration of anesthesia were significantly associated with an increased frequency of observing esophageal fluid ($p = 0.022$, $p = 0.021$).
Conclusions: Unlike alimentary gastric contents, fluid gastric contents were correlated with the presence of esophageal fluid upon myelo-CT. The observation of fluid in the esophagus may be consistent with GER. This study provides data additional to pH monitoring studies of GER and may support previous studies recommending shorter pre-anesthetic fasting periods in dogs.

Keywords: Tomography; gastroesophageal reflux; anesthesia; myelography; dog

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Conflict of Interest
The authors declare no conflicts of interest.

Author Contributions
Conceptualization: Gatel L, Cerasoli I; Formal analysis: Gatel L, Chalvet-Monfray K; Methodology: Gatel L, Benzimra C; Resources: Couturier L, Rault D, Cauvin E; Supervision: Gatel L, Cerasoli I; Writing - original draft: Benzimra C; Writing - review & editing: Gatel L, Cerasoli I, Chalvet-Monfray K, Rault D, Cauvin E, Couturier L.

INTRODUCTION

Gastroesophageal reflux (GER) has been reported to be a common finding in dogs under general anesthesia, with incidence rates ranging from 66% [1] to 78% [2]. GER is caused by transient relaxation of the lower esophageal sphincter, and it can lead to esophageal inflammation, discomfort, and esophageal strictures [3,4]. Its assessment in dogs has mostly relied upon monitoring variations in the pH level in the lower esophagus [5-7]. In most previous studies, pH values below 4 or higher than 7.5 in the lower esophagus have been used as a threshold suggestive of GER [5,6]. The reported occurrence of GER in dogs during anesthesia varies among studies from 17% to 50% [3,5,6,8]. Several parameters are suspected to promote GER, such as fasting duration, anesthetic drugs used, recumbency position and positional changes, increased intra-abdominal pressure, and orthopedic surgeries [5,8,9]. Their relative contribution, however, remains a matter of debate [5,8,9].

The degree of distention of and the nature of the contents in the esophagus and stomach can be easily assessed with computed tomography (CT) at specific time points (corresponding to the time of the scan). The observation of fluid or alimentary contents on CT scans could be suggestive of GER [10]. In humans, real-time magnetic resonance imaging has been used to assess gastroesophageal sphincter function and gastrointestinal reflux [11], and CT can be used to assess indirect signs of GER [12]. However, CT is not a documented modality for the evaluation of GER in dogs. CT procedures often necessitate moving the anesthetized animal from the anesthesia room to the CT table. Furthermore, procedures such as computed tomographic myelography (myelo-CT) require prolonged anesthetic times compared to standard CT and additional positional changes to perform the intrathecal injection of nonionic iodinated contrast medium.

The aim of this study was to retrospectively assess the esophageal and gastric contents of dogs at the time they underwent initial plain CT and myelo-CT based on CT scans. Another aim was to evaluate if the presence of esophageal contents was influenced by the nature of the gastric contents, the duration of anesthesia, changes of position, age, weight, sex, and reproductive status of the dogs. We hypothesized that 1) the nature of the gastric contents has an impact on the presence of esophageal contents; 2) the combination of positional changes and the increased duration of anesthesia between the plain CT and the myelo-CT is associated with a higher frequency of observing esophageal fluid; and 3) intrinsic factors, such as weight, age, and sex, have an influence on the esophageal contents.

MATERIALS AND METHODS

Patient selection

For this retrospective analytical study, the electronic medical records and the radiology picture archiving and communication system of the AzurVet center were searched. All non-brachycephalic dogs that had undergone CT examination of the thoracolumbar spine (including plain CT and myelo-CT during the same period of anesthetization) between January 2018 and January 2020 were included. Examinations were performed using a 64-slice CT scanner (Toshiba Aquilion 64; American Medical System, USA), using the following acquisition parameters: for small dogs, 120 kVp, 200 mA, 1 mm slice thickness with a pitch factor of 0.656 mm, reconstructed using bone and soft tissue algorithms; for large dogs, 120 kVp, 300 mA, 2 mm slice thickness with a pitch factor of 0.656 mm, reconstructed using bone and soft tissue algorithms. Examinations in which the field of view did not allow visualization of the full thoracic path of the esophagus and the entire stomach were excluded. Age, weight, breed, sex, and reproductive status were recorded from the medical records. Except for patients admitted in emergency, all the dogs had fasted starting the previous night as a standard protocol recommendation. The premedication procedures were not fully recorded (all patients received butorphanol [0.2 mg/kg], buprenorphine [20 µg/kg], acepromazine [10–50 µg/kg], or medetomidine [5–10 µm/kg] alone or in combination). Inductions were performed using intravenous bolus administration of midazolam (0.2 mg/kg) followed by propofol to effect (up to 4 mg/kg). Following intubation, all orotracheal tubes (cuffed Rush red rubber endotracheal tubes) were secured in place and connected to a circle breathing system (Matrx VMS® small animal anesthesia machine). Anesthesia was maintained with isoflurane in 100% oxygen.

CT data records

All qualitative assessments were performed by a third-year ECVDI resident using a dedicated DICOM viewer (free open-source code software; Horos, USA). All dogs were placed in the dorsal recumbency position for the plain CT and myelo-CT scans, and the positions of all were changed between the 2 scans (as a standard protocol from the dorsal to the right lateral recumbency position) to administer the intrathecal injections. The caudal portion of the thoracic esophagus was evaluated from the base of the heart to the cardia. The presence of gas, fluid, or alimentary contents in the esophagus (**Fig. 1**) and in the stomach (**Fig. 2**) was

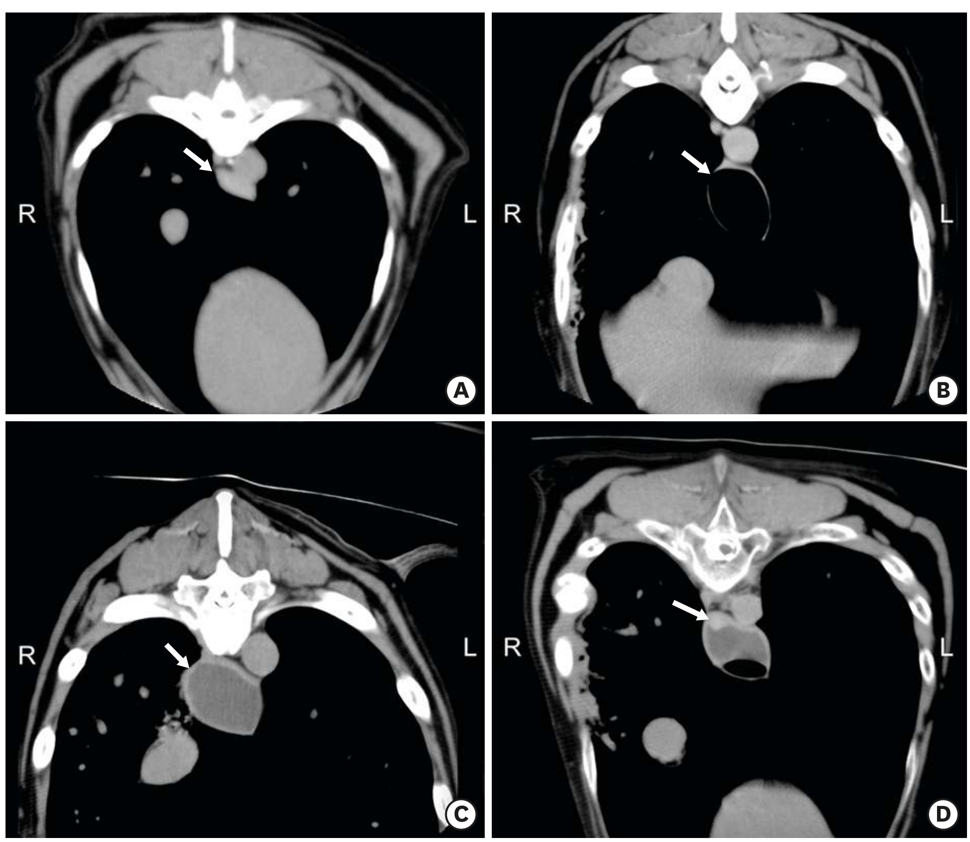

Fig. 1. Esophageal contents in different dogs. (A) Empty esophagus; (B) gas-filled esophagus; (C) fluid-filled esophagus; and (D) partially food-filled esophagus. Computed tomographic myelography images in transverse section using soft tissue window reconstructions are presented. The white arrows show the esophagus between the caudal vena cava and the aorta.

https://doi.org/10.4142/jvs.2020.21.e84

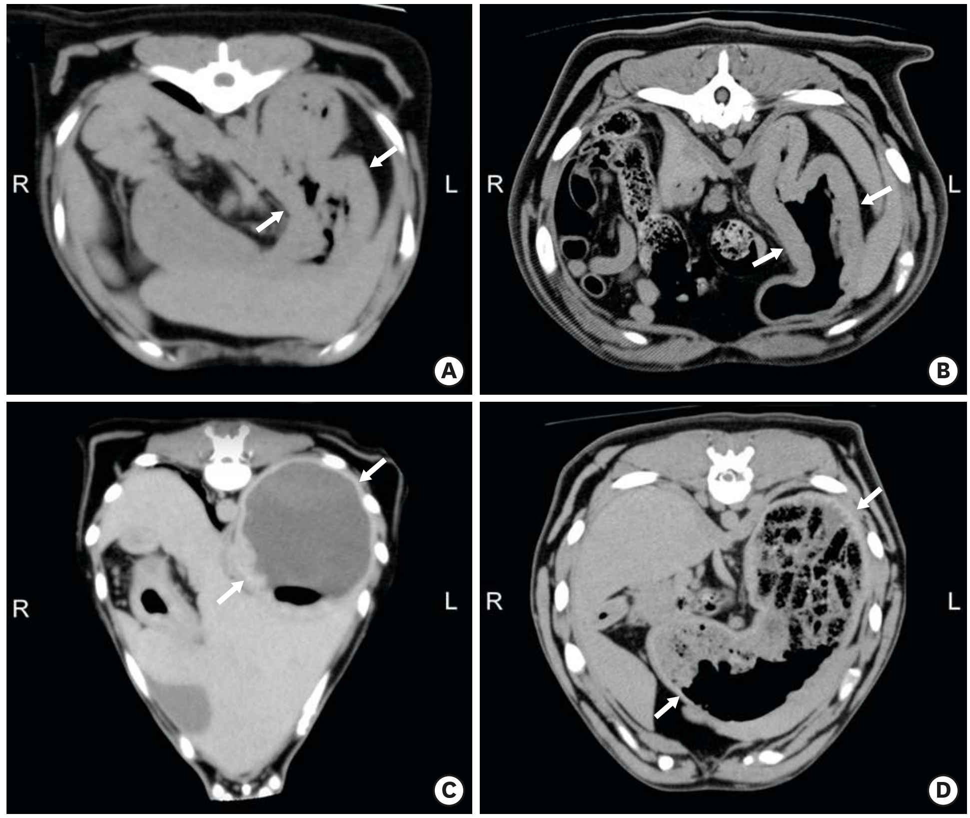

Fig. 2. Gastric contents in different dogs on plain computed tomography scans. (A) Empty stomach; (B) gas-filled stomach; (C) fluid-filled stomach; and (D) food-filled stomach. The gastric margins are delineated by the white arrows.

recorded. When mixed contents were noted, food was considered dominant over fluid and fluid dominant over gas. The degree of dilation of the stomach was subjectively scored from 0 to 3 (0 = empty, 1 = mild, 2 = moderate, 3 = marked) for each scan (**Table 1**). The time in min between the plain pre-contrast CT, and myelo-CT scans was also recorded for each dog. The time between scans was ranked in 3 categories: less than 40 min, between 41 and 70 min, and more than 71 min.

Statistical analysis

A statistical analysis was performed using a statistical software program (R Core Team 2019 software; R Foundation for Statistical Computing, Austria). Graphic evaluation of the data was conducted to appreciate the distribution of the quantitative variables. For all percentages calculated, a 95% confidence interval was provided with an exact binomial test. A univariate analysis was performed, and a Fisher's exact test was conducted to evaluate the presence of esophageal fluid in various conditions on the plain CT and myelo-CT scans: 1) empty versus distended stomach, 2) in stomach containing fluid versus gas or alimentary contents, 3) in

Table 1. Description of the subjective gastric scoring used to assess gastric volume on computed tomography scans

Gastric volume scoring
0: Empty—contact between mucosal folds in the smaller and greater curvatures, no or slight visible lumen.
1: Mild distention—gastric lumen visible, with gastric extension less or equal to 2 intercostal spaces.
2: Moderate distention—gastric extension exceeding 2 intercostal spaces but not extending beyond the costal arch.
3: Marked distention—gastric extension caudal to the costal arch.

https://doi.org/10.4142/jvs.2020.21.e84

stomach containing alimentary contents versus gas or fluid. A McNemar test was conducted to compare the number of cases presenting with esophageal fluid on the plain CT and myelo-CT scans. A Wilcoxon test was performed to compare the anesthetic time between the plain and myelo-CT scans and the presence or absence of esophageal fluid on the myelo-CT scan. The effect of weight and age on the presence or absence of esophageal fluid was investigated using a Wilcoxon test. A Fisher's exact test was performed to evaluate the presence of esophageal fluid in males versus females and in intact versus neutered dogs.

RESULTS

Population

Eighty-three dogs were included in the study. The median age was 8 years old (range, 0.5–15 years old; mean, 7.4 years old), and the median weight was 10 kg (range, 2–75 kg; mean, 17.8 kg). Nine intact females, 31 neutered females, 36 intact males, and 7 neutered males were included. There were 13 mixed-breed dogs, 10 chihuahuas, 4 Jack Russel terriers, 3 Australian shepherds, 4 cocker spaniels, 3 Coton de Tulear, 3 dachshunds, and 32 various other breeds (with 1 or 2 individuals representing each breed). All dogs were examined for clinical signs consistent with T3-L3 myelopathy using both plain CT and myelo-CT performed during the same anesthesia.

Esophageal CT findings

The dilation of the caudal esophagus was visible in 30 dogs in plain CT (36%, [26%, 47%]). The caudal esophagus was dilated with gas in 25 dogs (30%, [20%, 41%]) and with fluid in 5 dogs (6%, [2%, 14%]). The dilation of the caudal esophagus was visible in 42 dogs in myelo-CT (50%, [39%, 62%]. The caudal esophagus was dilated with gas in 26 dogs (31%, [22%, 42%]) and with fluid in 16 dogs (19%, [11%, 29%]) (**Fig. 3**). In one dog with fluid in the esophagus, a 3-mm mass (90 Hounsfield units) consistent with alimentary material (possibly kibble fragments) was observed within the pool of fluid. This dog was included in the group with fluid-filled esophagi. The number of dogs with esophageal fluid significantly increased based on myelo-CT compared to plain CT ($p = 0.006$), with a difference of 11 dogs (13%, [7%, 22%]) (**Fig. 4**).

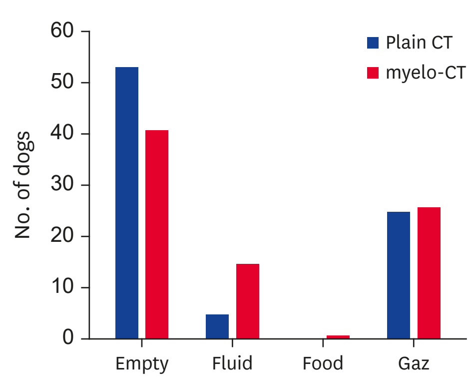

Fig. 3. Histogram representing the esophageal contents on plain CT and myelo-CT scans.
CT, computed tomography; myelo-CT, computed tomographic myelography.

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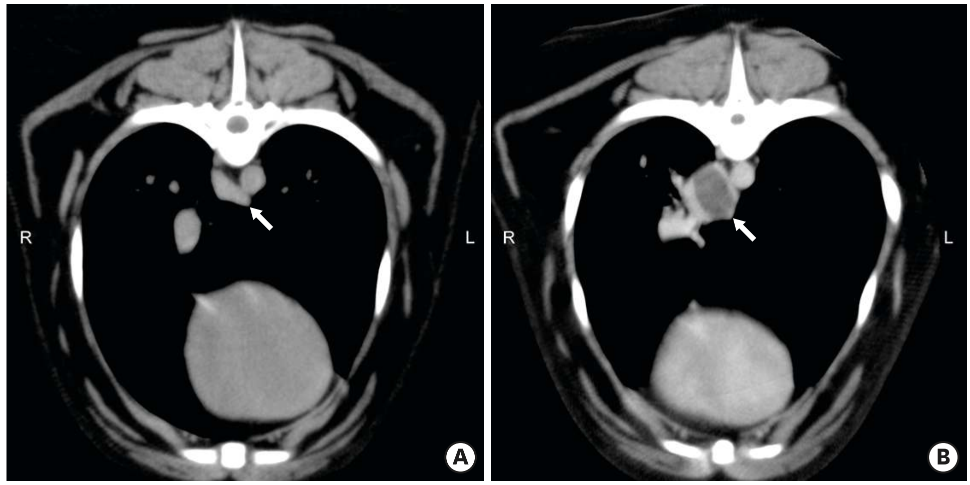

Fig. 4. Example of esophageal fluid in the caudal esophagus occurring between plain CT (A) and computed tomographic myelography (B) scans. Transverse CT images using soft tissue window reconstruction are presented. The white arrows show the esophagus between the caudal vena cava and the aorta.
CT, computed tomography.

Gastric CT findings

In plain CT and myelo-CT, 22 dogs (26%, [17%, 37%]) had an empty stomach and 61 dogs (74%, [63%, 83%]) had a full stomach. The stomachs were scored as mildly distended in 33 cases (40%, [29%, 51%]), moderately distended in 23 cases (28%, [19%, 39%]), and markedly distended in 5 cases (6%, [2%, 14%]). The stomach was dilated with gas in 12 dogs (14%, [8%, 24%]), with fluid in 12 dogs (14%, [8%, 24%]), and with food in 37 dogs (46%, [34%, 56%]).

Factors influencing the presence of esophageal fluid

Regarding the plain CT scans, the presence or absence of esophageal fluid was not significantly correlated with the presence or absence of gastric fluid ($p = 0.55$). The presence or absence of esophageal fluid was not significantly correlated with the presence or absence of a distended stomach (distended with fluid or alimentary contents) ($p = 0.15$). Regarding the myelo-CT scans, the presence or absence of esophageal fluid was not significantly correlated with the presence or absence of gastric contents (fluid or alimentary) ($p = 0.17$). Nevertheless, 5 dogs with fluid-filled stomachs presented with esophageal fluid (41%, [15%, 75%]), and 6 dogs with alimentary gastric contents had concurrent esophageal fluid (15%, [8%, 26%]). In fact, the presence of fluid in the stomach on plain CT was significantly correlated with the presence of esophageal fluid ($p = 0.049$ with an estimated odds ratio of 3.1 [1.1, 13.7]. The presence or absence of esophageal fluid was not significantly correlated with the degree of stomach distention ($p = 0.78$).

The median time between the 2 acquisitions was 43 min (range, 26–118 min). The median time between acquisitions in the group with esophageal fluid was 57 min (range, 31–118 min), which was significantly increased compared to the median time in the group without esophageal fluid (41 min; range, 26–72 min) ($p = 0.021$). The frequency of esophageal fluid as a function of the anesthetic time is presented in **Table 2**. The dog presenting with mixed fluid and alimentary esophageal contents was in the 41–70 min interval group.

The dogs with esophageal fluid at the time of the myelo-CT were significantly heavier (mean, body weight of 29 kg; median, 25 kg; range, 5–75 kg) compared with the dogs without

Table 2. Number of dogs presenting with esophageal fluid in the 3 groups of anesthetic duration

Duration of anesthesia between the 2 CT scans	0–40 min	41–70 min	> 70 min
Number of cases	31	47	5
Number of cases presenting esophageal fluid	4	9	3
Frequency of observing esophageal fluid	13%	19%	60%
CI	0–30%	9–33%	15–94%

The frequency of observing esophageal fluid in each group and the CIs are presented.
CT, computed tomography; CI, confidence interval.

esophageal fluid (mean, body weight 15 kg; median, 10 kg; range, 2–55 kg) ($p = 0.022$). The presence or absence of esophageal fluid on the plain CT or myelo-CT scans was not significantly correlated with age, sex, or reproductive status.

DISCUSSION

The frequency of observing fluid or food in the esophagus during the CT examination (plain CT followed by myelo-CT) was 19% in our population, which is consistent with the incidence of GER reported in previous studies [3,5,6,8]. Of the dogs in our study, only one had mixed alimentary and fluid content in the caudal esophagus on the myelo-CT scan. There was an increased frequency of observing esophageal fluid between the plain and myelo-CT scans, 6% and 19%, respectively. Only 39% of dogs had an empty stomach, and the majority had mild or moderate gastric distension. The frequency of observing esophageal fluid during the myelo-CT was significantly higher in dogs with a fluid-filled stomach. A longer anesthetic time between the plain CT and myelo-CT scans was associated with an increased frequency of esophageal fluid. Finally, dogs whose esophagus contained fluid were significantly heavier.

In the present study, 13% of dogs exhibited fluid in the caudal esophagus only at the time of the myelo-CT scan. The increased frequency of observing esophageal fluid on myelo-CT scans could be explained by the change of position necessary to administer the intrathecal injection, longer anesthetic time, or other unidentified factors. In the veterinary literature, the influence of recumbency on peri-anesthetic GER has been previously studied in dogs, with various conclusions ranging from an absence of influence [5] to increased reflux in association with changes in body position [7]. One study found that lateral recumbency and supination increased the incidence of GER [13]. In humans, sleeping in the right lateral recumbency position increases the risk of GER compared to sleeping in other positions [14]. In the present study, the intrathecal injections were performed while the dogs were in the right lateral recumbency as a standard protocol and due to the CT room configuration. The effect of positional changes on the presence of esophageal fluid cannot be clearly ascertained, as the accumulation of esophageal fluid between the 2 acquisitions could also be explained by the prolonged anesthetic time. The presence of a control group could have helped us to increase the specificity of this parameter. Furthermore, in our population, the observation of esophageal fluid on myelo-CT scans increased with increased anesthetic durations. These findings are in accordance with a previous study that showed the increase in median total anesthetic time was positively correlated with an increase in the frequency of observing GER with longer surgical procedures [7]. The true incidence of esophageal fluid in our population may be underestimated due to the discontinuous nature of the CT scans. Indeed, a previous study showed durations of reflux episodes in dogs ranging from 15–95 min [6]. Therefore, the delay necessary to perform the myelo-CT probably led to some underestimation of reflux episodes in our population.

In the present study, the majority of dogs had some fluid or food in their stomachs, with 44% presenting with alimentary material as the main gastric content. This finding may appear surprising, as the given recommendation was to stop food and fluid intake on the night before general anesthesia. This recommendation, which is generally accepted in veterinary medicine, arises from the 'nil by mouth from midnight' rule historically used in human medicine [15]. Gastric emptying times of 7–15 h have been reported in dogs [16]. However, several studies have shown that fasting does not necessarily result in an empty stomach [15]. Additionally, due to the retrospective nature of the case recruitment, we had no precise knowledge of the exact fasting duration for each case, and an unknown percentage of the examinations had been performed as emergency procedures because of acute signs of myelopathy. This will have decreased the mean fasting duration in our population. Moreover, due to the inclusion criteria, all the selected dogs presented with signs compatible with a T3-L3 myelopathy. Pain has been reported to increase sympathetic tone and decrease intestinal motility [17]; therefore, potential delayed gastric emptying secondary to pain or stress cannot be ruled out in our population. Moreover, physiologic responses to stress, including increased heart rate, blood pressure, and anxiety, have been suspected to increase abdominal pain and gastro abdominal symptoms in humans [18]. All these factors may have contributed to the various gastric distention states and contents in our cases. Nevertheless, the presence of fluid or food in the stomach allowed us to evaluate the frequency of observing esophageal fluid relative to the nature or type of gastric contents in our population and provided additional data compared to previous studies. One study investigated the relationship between fasting times, gastric volume, and gastric content pH without monitoring gastroesophageal pH [4]. However, most previous studies investigating GER have been based on fasted patients and consisted of monitoring lower esophageal pH [4-7] without knowledge of the residual gastric contents. The use of CT in the present study may help interconnect these reported data, even though pH monitoring was not available. The frequency of observing esophageal fluid did not appear to be increased in dogs whose stomachs contained food in our population, even though the presence of alimentary gastric contents could have raised concern about a greater risk of GER. This finding is consistent with several studies investigating the impact of pre-anesthetic fasting duration on the occurrence of GER in dogs [4-6,15]. Several studies have shown a significant decrease in GER in animals fed a light meal 3 h prior to anesthesia compared with dogs subjected to prolonged pre-operative fasting [15]. This may be due to a higher gastric pH in dogs with shorter fasting times [4], whereas low pH is suspected to promote relaxation of the distal esophageal sphincter [19]. Increased fluid gastric contents may be associated with a lower gastric pH, which in turn could increase the incidence of reflux, although this remains to be confirmed.

In our population, the mean body weight of dogs with esophageal fluid was significantly higher than that of the dogs without fluid in the esophagus, which is consistent with a previous study that showed an increased risk of regurgitation following general anesthesia in dogs weighing over 40 kg [20]. In humans, obesity is a known risk factor for GER and more generally for esophageal disorders, the incidence of which is correlated with increasing weight [21]. However, in the present study it is not clear whether increased gastroesophageal fluid in heavier dogs was related to increased body score or to the size or breed of dog.

The main limitation of our study was the lack of concurrent pH monitoring. The esophageal fluid observed on CT scans was strongly suspected to correspond to GER, especially when it was absent on the plain CT scan and present on the myelo-CT scan. However, a contribution of swallowed saliva or other secretions prior to the administration of anesthesia cannot be ruled out, especially for the plain CT scans. The observation of esophageal fluid on CT scans has been generally accepted to be consistent with regurgitation during anesthesia [10], even if, to the authors' knowledge, there have been no studies combining pH monitoring during esophageal reflux and the visualization of esophageal fluid on CT scans.

Another limitation of this study was its retrospective nature. One drawback was an often incompletely recorded anesthetic protocol. In particular, the use of medetomidine and its dose were unknown. Previous studies have produced contradictory conclusions relative to the impact of premedication drugs on the incidence of GER in dogs. Some studies have found a higher incidence of reflux with the use of xylazine or atropine compared with diazepam, pethidine, propionylpromazine, or acepromazine [5,6,22]. However, in a more recent study, premedication drugs such as midazolam, butorphanol, acepromazine, medetomidine, morphine, and buprenorphine were not associated with peri-operative GER, although non-opioid drugs were significantly less associated with post-operative vomiting [7]. Another study suggested there was no significant difference between anesthetic inhalant agents (isoflurane and halothane vs. sevoflurane) regarding the risk of GER [8].

Another flaw in our recruitment was the lack of standardization of the pre-anesthetic diet of our population, which has been previously documented to influence gastric volume in dogs [4]. Furthermore, complete medical records were not available for all the dogs in our study, including possible concurrent disorders that could have induced chronic or acute esophageal or gastric diseases. This could create a bias in the study. It cannot be ruled out that some animals in our population of non-brachycephalic dogs could have presented with pre-existing esophageal dilation. Pre-anesthetic thoracic radiographs could have been useful to avoid this bias. Brachycephalic dogs were excluded from our study because, although other studies have not shown brachycephalic dogs to be at greater risk of GER to date [23], they exhibit a high prevalence of esophageal and gastrointestinal abnormalities associated with brachycephalic syndrome [24]. A similar study of brachycephalic dogs could therefore be considered.

In conclusion, dogs undergoing myelo-CT are more likely to have esophageal fluid consistent with GER compared to plain CT examination. The majority of dogs undergoing myelo-CT presented with a non-empty stomach, despite general fasting period guidelines. However, only fluid gastric content increased the frequency of observing esophageal fluid. Higher body weight and prolonged anesthetic time seemed to significantly increase the likelihood of esophageal fluid in our population; however, the effect of body position could not be evaluated. Although CT may not be suitable as a primary technique to diagnose or monitor GER in dogs, due to radiation protection considerations and the need for general anesthesia, the detection of fluid or esophageal contents during CT examination should be mentioned and taken into consideration in the management of patients. This study provides additional and new data to the currently available literature investigating factors that influence GER in dogs, particularly the nature of gastric contents, and it may corroborate the results of previous studies that recommend shorter pre-anesthetic fasting periods for dogs.

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