Oesophageal pneumatosis: computed tomographic characteristics in three dogs (2018–2021)

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Abstract

Background: Oesophageal pneumatosis (OP) is defined as the presence of gas within the oesophageal wall. The description of this condition in veterinary medicine is currently lacking. The pathogenesis of alimentary tract pneumatosis remains unclear. Current literature describes that access of gas into the oesophageal wall may occur by one or a combination of the following mechanisms: mucosal disruption, increased intra or extra-luminal pressure or dissection of gas from an extra-oesophageal source.

Objectives: The aim of this multi-centric case series was to describe the computed tomography (CT) findings of OP in dogs.

Methods: Three adult dogs were included. One dog presented with gastrointestinal signs and general malaise while the other two presented with spontaneous facial and cervical subcutaneous emphysema.

Results: CT revealed different degrees of intramural gas along the oesophageal wall in all cases. The first dog was diagnosed with emphysematous gastritis based on the presence of gastric pneumatosis paired with compatible clinicopathological and endoscopic findings. This dog was successfully treated with antibiotics. The remaining two dogs were diagnosed with spontaneous pneumomediastinum and required no surgical or medical treatment.

Conclusions: In all cases with OP, there was concurrent gastric pneumatosis. Gas extensively and circumferentially distributed with a banded shape along the oesophageal wall was present in patients with presumed mural gas dissection because of pneumomediastinum. Conversely, a focal and mild amount of mural gas with a tubular shape was identified in the distal segment of the oesophagus in the patient with emphysematous gastritis.

Keywords: alimentary tract pneumatosis, canine oesophagus, intramural oesophageal gas, oesophageal wall
1 | INTRODUCTION

Oesophageal pneumatosis (OP) is the term used to describe the presence of gas within the oesophageal wall (Studdert & Gay, 2012). In human medicine OP is rarely described and may be idiopathic or secondary to a specific underlying condition (Neal & Jha, 2020). Pneumatosis of the alimentary tract can occur from the oesophagus to rectum secondary to a wide spectrum of conditions. Benign conditions include immune-mediated, infectious, pulmonary, gastrointestinal, iatrogenic and idiopathic diseases. It has been described also with life-threatening conditions such as traumatic, mechanical and ischemic processes (Aste et al., 2005; Bakkali et al., 2014; Chelimilla & Makker, 2013; Fisk & Allen-Durrance, 2019; Grassi et al., 1995; Ho et al., 2007, Fischetti et al., 2004; Keklik et al., 2016; Lang et al., 2011; Lefor, 2008; Mitsuyoshi et al., 2015; Tewari et al., 2017; Tixedor et al., 1998; Torres et al., 2018). These two groups of conditions have different clinical management and prognosis, but they can have similar imaging findings. Therefore, distinguishing between these conditions is clinically relevant, but remains a challenge for the radiologist in daily practice. Published literature describes that gas access into the oesophageal wall may occur due to one or a combination of the following mechanisms: increased intraluminal pressure, mucosal disruption, and/or dissection of gas from an extra-oesophageal source (Neal & Jha, 2020).

Diagnostic imaging is essential for the diagnosis of OP, with computed tomography (CT) being the gold standard in human medicine due to its high sensitivity evaluating the oesophageal wall compared to other imaging modalities (Neal & Jha, 2020). In humans, alimentary tract pneumatosis may course with gastrointestinal signs, although some patients remain asymptomatic (Ho et al., 2007). CT findings of OP may vary depending on the amount of intramural gas as well as the underlying aetiology. The gas within the oesophageal wall is usually seen as multi-focal intramural gas collections with a linear or banded shape distributed circumferentially. When a large amount of intramural gas is detected, it may completely surround the oesophageal mucosa producing an ‘air donut’ sign (Neal & Jha, 2020). Partial or complete collapse of the thin oesophageal mucosa secondary to intramural expansion has also been described in humans, resulting in different geometric mucosal shapes (Neal & Jha, 2020).

At the time of this study, according to our review of literature, there are no published peer-review reports describing OP and its imaging characteristics in veterinary patients. The main objective of the current study is to describe the clinical and CT characteristics in a group of dogs with OP.

2 | METHODS

This was a multi-centric, retrospective, case series study design. The databases of three veterinary hospitals were reviewed: ‘Pride Veterinary Centre’ (PVC; Derby, UK), ‘Hospital Veterinario de la Universidad Católica de Valencia’ (HV-UCV; Valencia, Spain) and ‘Hospital Veterinari Ca nis Girona’ (HVC-G; Girona, Spain). The databases were searched for dogs with a radiologic diagnosis of OP and a CT study performed during the diagnostic work-up. The keywords used in the radiology database and in the medical records database of the three hospitals were ‘oesophageal pneumatosis’, ‘intramural oesophageal gas’ or ‘gas within the oesophageal wall’. Permission to use clinical and diagnostic imaging data for research was provided through informed consent from the owners at the time of admission.

Inclusion criteria for the present study were as follows: canine cases with CT images of diagnostic quality, available endoscopy, histology results or, otherwise, resolution of OP on subsequent imaging examination, complete patient history and available haematological and serum biochemical analyses. All decisions regarding inclusion or exclusion were made based on a consensus of the first author (first-year small animal imaging resident; MOP European College of Veterinary Diagnostic Imaging [ECVDI]) and a board-certified veterinary radiologist (CA European College of Veterinary Diagnostic Imaging [E CVDI]).

Recording and analysis of medical data were supervised by two specialist board-certified veterinary radiologists (CF and CA, European College of Veterinary Diagnostic Imaging [ECVDI]), a specialist double board-certified veterinarian in emergency and critical care (VJHB, American College of Veterinary Emergency Critical Care [ACVECC] and European College of Veterinary Emergency Critical Care [ECVECC]) and an experienced veterinary radiologist (JDVB, PhD). The following information was retrospectively reviewed, if available, by the first author (MOP), aware of final diagnosis and working at the Pride Veterinary Centre at the time of data recording: signalment, anamnesis, clinical signs, physical examination, haematology, biochemistry, diagnostic imaging (CT and ultrasound) features, endoscopic findings, histological and bacteriological results, as well as the outcome.

Abdominal B-mode ultrasonographic examinations (General Electric LOGIQ S7, Seongnam, Korea) were performed on transverse and sagittal planes using electronic microconvex (10C) and electronic linear (ML6–15) probes, with frequencies ranging between 8 and 15 MHz.

The CT studies of the head, neck, and thorax (extending the field of view approximately up to the third lumbar vertebra), were performed under general anaesthesia in all dogs. Due to the multi-centric character of the study, the studies were obtained using two different 16-slice CT scanners (General Electric Medical Systems, BrightSpeed, Chicago, IL, USA and Siemens SOMATOM Scope, Siemens Healthcare Diagnostics, IL, USA) with two patients positioned in sternal and one in dorsal recumbency. Anaesthetic protocols varied in each institution according to the attending clinician. Acquisition parameters were as follows: helical scan mode, 0.625–2.5 mm slice thickness, a pitch of 0.8–1.75, 56–80 mAs tube current, 120–130 kV tube voltage, 512 × 512 matrix, and a soft tissue and bone reconstruction algorithm. Window width and level were appropriately adjusted and multi-planar reformattting was used whenever necessary for optimal evaluation. For all dogs, CT images were acquired prior to and after 45 s following administration of iohexol at 600 mgI/kg. When available, the contrast was injected at a rate of 2–3 ml/s via a cephalic catheter by an angiographic pressure injector (Nemoto Dual Shot Alpha 7, Tokyo, Japan). In one of the cases an injector was not available, therefore, contrast injection was manually performed and images were acquired approximately 45 s following bolus injection.
CT studies were reviewed by two ECVDI-certified veterinary radiologists (CF and CA), an experienced veterinary radiologist (JDBV), and two first-year ECVDI residents (MOP and AO). All observers were aware of the presenting clinical signs at the time of interpretation. They were not aware of the endoscopic findings (presence/absence of mucosal wall lesions), final patient outcome, or other results (e.g. histologic diagnosis). Disagreements were resolved through a consensus reading by all reviewers. CT studies were reviewed using an image analysis workstation and a commercially available open-source DICOM imaging viewing analysis software (Horos®, https://horosproject.org). The following CT characteristics were recorded based on a final consensus among the observers: location, distribution and amount of intramural gas along the included alimentary tract (the amount was classified subjectively as mild, moderate or marked), oesophageal and gastric wall enhancement, presence of regional peripheral fat stranding pattern, pneumoperitoneum, pneumomediastinum or gas accumulated in the subcutaneous space or other organs/vasculature, presence of cavitary (thoracic-abdominal) effusion and lymphadenopathy. The location of the intramural gas along the alimentary tract was defined as oesophageal and/or gastric depending on the affected organs. The radiological diagnosis of oesophageal and/or gastric pneumatosis was based on detection of these intramural gas collections. Fat stranding, as described in the literature, was used as criteria of peritoneal inflammation and considered compatible with peritonitis, steatitis, vasculitis or oedema (Thornton et al., 2011). Free subcutaneous, abdominal or mediastinal gas was considered as gas non-contained in hollow viscus or parenchymatous organs and defined as subcutaneous emphysema, pneumoperitoneum/pneumoretroperitoneum or pneumomediastinum respectively. Mural contrast enhancement was subjectively assessed as either normal or absent. Lymphadenopathy was assessed comparing the available literature data on canine lymph node measurements (Beukers et al., 2013; Iwasaki et al., 2016; Milovancev et al., 2017; Stehlik et al., 2020; Teodori et al., 2021). Additional CT findings were also recorded when considered relevant by the authors (e.g. pulmonary, hepatic or vascular abnormalities).

The referring veterinary surgeons were contacted for the clinical records post-diagnosis of the patients. The follow-up duration and outcome data were retrieved from the clinical notes provided by the referring practices. Outcome was classified as ‘deterioration’ in patients where examination revealed clinical deterioration from the clinical signs at presentation, ‘no improvement’ in patients where examination remained unchanged compared to presentation, ‘improving’ in patients demonstrating improvement with some remaining clinical signs, and ‘normal’ for all patients demonstrating an unremarkable examination at the time of re-examination.

3 | RESULTS

3.1 | Clinical findings

Three dogs met the inclusion criteria, one from each institution. Patient 1 was a 4-year-old intact male Beagle, patient 2 a 6-year-old female spayed Border Collie and patient 3, a 9-year-old female spayed Lhasa Apso.

Patient 3 presented with lethargy, anorexia and neutrophilic leukocytosis, as well as gastrointestinal signs including vomiting and diarrhoea. The other two patients (1 and 2) did not present any gastrointestinal signs nor evidence of systemic abnormalities. Their presenting complaint was facial and cervical subcutaneous emphysema. Physical examination was unremarkable on presentation in both animals apart from the emphysema. Complete blood counts and serum biochemistry profiles were normal. No history of a trauma or recent anaesthetic procedure were reported in any of the patients.

3.2 | Imaging findings

Reasons for imaging studies were either investigation of the gastrointestinal signs (patient 3) or assessment of a potential origin for the facial and cervical subcutaneous emphysema (patients 1 and 2).

Abdominal ultrasound was performed only in patient 3. On the initial ultrasonographic study, the gastric wall was considered normal. Clinical deterioration of the patient leads to a second ultrasonographic examination prior to the CT study. Marked diffuse and irregular gastric wall thickening with partial loss of the wall layering was detected. There were also multiple intramural gas collections along the wall and extending to the area of the lower oesophageal sphincter, producing a marked reverberation artefact. There was neither intraluminal gas within the intrahepatic or extrahepatic portal vasculature, nor presence of pneumoperitoneum.

CT studies revealed different degrees of intramural gas along the oesophageal and gastric wall in all dogs (Figures 1–3). In the oesophagus of patients 1 and 2, there were multi-focal, circumferentially distributed collections of parietal gas with a banded shape (Figure 2). Conversely, in patient 3, there was a mild amount of intramural gas seen as a focal collection in the distal segment of the oesophagus with a tubular shape (Figure 3). In all dogs, there was moderate amount of gas present within the gastric wall. Intramural gas was not observed in the rest of the intestinal tract included in the field of view in any patient. The oesophageal and gastric mural enhancement was considered within normal limits in all dogs. Moderate to marked facial and cervical emphysema (Figure 4) and pneumomediastinum (Figure 5) was present in patients 1 and 2 as well as mild pneumoperitoneum. Mild pneumoretroperitoneum was seen only in patient 2. Streaky peritoneal fat (fat stranding pattern) was seen only in patient 3. The vasculature (including thoracic, mesenteric and portal vessels) was considered within normal limits in all dogs. Additional relevant findings were a millimetric pleural bleb in patient 1 and mild amount of bilateral pleural effusion in patient 3. No other relevant findings were seen in patient 2. No evident lymphadenopathy was detected in any of the patients.

3.3 | Endoscopy, histology and bacteriology

Oesophagogastroscopy and tracheobronchoscopy were performed in patient 1 after the CT study. Both were considered unremarkable.
Patient 3 also had an oesophagogastroscope after the CT study. It revealed superficial ulcerations and severe multi-focal hyperaemic lesions affecting the entire gastric mucosal surface. The oesophagus was unremarkable. Endoscopic biopsies of the gastric mucosa were performed, and samples were submitted for histopathology and bacterial culture. Histopathology of the stomach revealed an oedematous, haemorrhagic and fibrotic mucosa, with increased clear spaces, representing air pockets embedded within the connective tissue. Scattered intraepithelial lymphocytes and plasma cells were seen throughout the superficial lamina propria. Multiple spiral-shaped bacteria were
**FIGURE 3** Post-contrast CT images of a patient with oesophageal pneumatosis and concurrent emphysematous gastritis. Sagittal plane (a), dorsal plane (b) and transverse plane (c). The white arrow is pointing the gas in the oesophageal lumen. There is a small amount of oesophageal intramural gas pointed by the arrow head with a tubular appearance. In the dorsal image (b) the dashed arrow is pointing the intramural gastric gas. Medium frequency algorithm for soft tissue window with window level $= 40$ HU and window width $= 350$ HU.

**FIGURE 4** Transverse pre-contrast CT images of a patient with facial (a) and cervical (b) subcutaneous emphysema. The white arrows are pointing the marked amount of gas accumulated and scattered throughout the subcutaneous tissue. High-frequency algorithm for bone window with window level $= 110$ HU and window width $= 1946$ HU.

**FIGURE 5** Transverse post-contrast CT images at the level of the cranial mediastinal reflection of two different patients with pneumomediastinum. The white arrows are pointing the marked amount of gas present in the mediastinum surrounding the mediastinal organs and structures. High-frequency algorithm for lung window with window level $= -500$ HU and window width $= 1400$ HU.
visualised along the mucosal surface. No evidence of mucosal necrosis was identified. Culture of the gastric wall isolated *E. coli*, *Proteus* sp. and *Enterococcus* sp. This patient was diagnosed with emphysematous gastritis based on the presence of gastric intramural gas, systemic abnormalities and compatible endoscopic and clinicopathological findings.

### 3.4 Treatment and outcome

Patient 3 diagnosed with emphysematous gastritis, improved on antibiotic therapy. Clinical improvement was achieved after 1 week with ultrasonographic resolution of the gastric pneumatosis. Medical management was continued for a month and there has been no relapse of clinical signs to date.

The dogs presumptively diagnosed with spontaneous pneumomediastinum, oesophageal and gastric emphysema (dogs 1 and 2) required no treatment. Close monitoring, a rest period with restricted exercise and the use of a harness rather than a collar during walking were recommended to the owners. Complete resolution of pneumomediastinum, oesophageal and gastric pneumatosis was confirmed on a follow-up CT study 1 month after presentation in both patients. Thereafter, all patients were followed at their respectively referring veterinary centres without recurrence of signs related to alimentary tract pneumatosis. No relapse of the presenting clinical signs has been reported to date.

### 4 DISCUSSION

The present study describes the clinical and imaging findings in three adult dogs with intramural oesophageal gas. According to the literature reviewed during the present study, these are the first cases of canine OP reported so far, with the first description of its CT features.

The pathogenesis of alimentary tract pneumatosis remains unclear. In human medicine, two main theories attempt to explain its aetiology proposing an infectious or mechanical origin (Mitsuyoshi et al., 2015). Alimentary tract pneumatosis may occur due to bacterial infiltration of the mucosa leading intramural gas production, or secondary to mural or extra-luminal pressure (e.g. blunt trauma, vomiting or presence of gas in the mediastinum/peritoneum). The other process refers to a relatively intact mucosa due to increased intraluminal pressure was ruled out in all patients. Additionally, gastric or intestinal pneumatosis, often associated with ischemic processes, can directly enter into the oesophageal wall (Lin et al., 2015; Mitsuyoshi et al., 2015; Neal & Jha, 2020; Pasquali et al., 2017).

In our case series no history of a trauma, choking or recent anaesthesia was reported in any of the patients. Therefore, the possibility of increased intraluminal pressure was ruled out in all patients. Additionally, in those where oesophagoscopy was performed after the CT study, the oesophageal mucosa was normal, thus a macroscopic primary oesophageal-related disease was unlikely. In patients 1 and 2, the gastric mucosa was unremarkable, but there was enough amount of pneumomediastinum potentially triggering the dissection of gas through the oesophageal wall according to the mechanical theory. In patient 3, the detected gastric alterations could potentially lead to gastric pneumatosis with secondary gas dissection from the gastric to the oesophageal wall, according to the previous published data in humans (Lin et al., 2015; Mitsuyoshi et al., 2015; Neal & Jha, 2020; Pasquali et al., 2017). In patients 1 and 2, the cause of pneumomediastinum was not identified by CT or endoscopy and therefore considered idiopathic. The lumen of the trachea and bronchi was endoscopically visualised, along with the digestive tract from the oral cavity to the gastric lumen, without detecting lesions that justified the alterations seen in the CT.

According to human literature, oesophageal intramural gas is usually not detected on survey radiographic or fluoroscopic studies, even retrospectively (Neal & Jha, 2020). Therefore, CT is the gold standard imaging modality for the detection of gas in the oesophageal wall. It also offers additional advantages over radiography such as superior contrast resolution without superimposition. In addition, CT may help diagnose potential origin for OP that cannot be identified using radiography alone. The authors recommend the use of CT instead of other imaging modalities for detection of canine oesophageal pneumatosis.

Gastric pneumatosis can be divided into two separate clinical entities with similar imaging findings: emphysematous gastritis and gastric emphysema. Emphysematous gastritis is a life-threatening condition and gastric emphysema is a relatively benign entity
The term ‘emphysematous oesophagitis’ is documented in affected patients. OP is also an imaging finding rather than a definitive diagnosis. The term ‘emphysematous oesophagitis’ is documented in the human medicine literature (Li et al., 2018) but at the time of this study, no published reports describing or using the term ‘oesophageal emphysema’ were found. Distinguishing between emphysematous oesophagitis and oesophageal emphysema was beyond the scope of this case series. Given the lack of an histopathological analysis of the oesophageal wall, both entities were included under the umbrella term OP.

In our case series, the patient diagnosed with emphysematous gastritis (patient 3) had gastrointestinal signs and concurrent systemic clinical abnormalities, whereas patients presumably diagnosed with gastric emphysema (patient 1 and 2) do not have gastrointestinal signs or evidence of systemic abnormalities. The observed gastric pneumatosis in these two cases resolved promptly with no treatment. In human medicine, conservative treatment is recommended in cases of alimentary tract pneumatosis where there is no evidence of ischemia (e.g. absence of elevated serum lactate and normal mural enhancement on imaging) (Spektor et al., 2014; Treyaud et al., 2017). In patients 1 and 2, the supportive treatment was the treatment of choice. Most of the alterations detected by CT had resolved rapidly, indicating a benign condition with good favourable prognosis.

This is the first case series documenting the presence of canine OP. CT allowed characterisation of lesions previously not reported in veterinary medicine. CT findings are like those reported in human medicine. There was different amount of intramural oesophageal gas depending on the aetiology. Gas extensively and circumferentially distributed with a banded shape along the oesophageal wall was present in patients with presumed mural gas dissection because of a pneumomediastinum (Figures 1 and 2). Conversely, a focal and mild amount of mural gas with a tubular shape was identified in the patient with emphysematous gastritis (Figure 3).

The main limitation of the present study is the reduced number of cases. Further studies including histopathological analysis of the oesophageal wall and comparison to image findings are warranted. None of the dogs in the present study died or were subjected to euthanasia, and therefore histopathological analysis of the oesophageal wall was not available for any of the included cases.

In conclusion, the authors suggest that the presence of moderate to marked amount of diffusely distributed intramural oesophageal gas could be triggered by increased extra-luminal pressure, such as in case of pneumomediastinum, whereas a mild focal amount could be related to direct extension from an adjacent source (e.g. extension of gastric pneumatosis). Imaging studies can be ancillary in the diagnosis and ruling out concurrent primary diseases. Further studies with larger patient populations are needed to better characterise oesophageal pneumatosis (OP), and to determine if this can be actually subdivided in emphysematous oesophagitis and oesophageal emphysema as two separate clinical entities.

**Author Contributions**

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**Conflict of Interest**

The authors declare no conflict of interest.

**Data Availability Statement**

The data that support the findings of this study are available on the request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

**Ethical Statement**

As a retrospective case series, no ethical approval was required.

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