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PAPER

Documenting the prevalence of hiatal hernia and oesophageal abnormalities in brachycephalic dogs using fluoroscopy

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Objectives: To report the prevalence of abnormal fluoroscopic findings in brachycephalic dogs that were presented to a referral hospital for obstructive airway syndrome.

Methods: Hospital records between May 2013 and November 2015 identified 36 brachycephalic dogs investigated for obstructive airway disease: 21 French bulldogs, 6 bulldogs, 4 Boston terriers, 2 pugs, 2 boxers and 1 shih-tzu. The presence or absence of hiatal hernia, delayed oesophageal transit, gastro-oesophageal reflux and redundant oesophagus were recorded.

Results: Of the 36 dogs, 16 had hiatal hernia, all of which were French bulldogs; 31 dogs had delayed oesophageal transit time, 27 had gastro-oesophageal reflux, and 4 had redundant oesophagus.

Clinical Significance: The prevalence of hiatal hernia is higher than expected in the French bulldog, and there was a high prevalence of oesophageal disease in this group in general. These results suggest a need to investigate similar cases for evidence of gastrointestinal disease that may also require attention.

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INTRODUCTION

The oesophageal hiatus lies between the diaphragmatic crura and transmits the oesophagus, its vascular supply and the dorsal and ventral vagus trunks. It has a thicker muscular border compared with the rest of the diaphragm (Evans & de Lahunta 2012).

Hiatal hernia is defined as the protrusion or displacement of abdominal organs or structures through the oesophageal hiatus into the mediastinum. Four types of hiatal hernia have been documented in dogs. Type I (sliding hiatal hernia) occurs when the abdominal oesophagus and part of the stomach displace cranially through the oesophageal hiatus, resulting in the gastro-oesophageal junction lying within the thoracic cavity (Rahal *et al.* 2003). Type II is defined as a para-oesophageal hernia in which the caudal oesophageal sphincter remains in place at the hiatus, and part of the stomach herniates adjacent to this into the mediastinum. Type III has characteristics of both types I and II with concurrent axial and para-oesophageal herniation (Williams 1990). Type IV has only been reported once and is similar to type II or III but involves other organs (liver, stomach and small intestine) herniating adjacent to the oesophagus (Washabau 2012). The type I sliding hiatal hernia is the most common form documented in dogs (Llabres-Diaz *et al.* 2008).

Hiatal hernias may be either congenital or acquired. Congenital hernias have previously been reported in the Chinese shar pei, bulldog, French bulldog and chow chow breeds (Callan *et al.* 1993, Poncet *et al.* 2005, Washabau 2005, Cornell 2011, Washabau 2012). Congenital hernias occur due to a developmental abnormality of the oesophageal hiatus or phrenicoesophageal ligament (Jergens 2010). This then allows cranial displacement of abdominal structures into the thorax as described above.

There is relatively scant information within the veterinary literature regarding acquired hiatal hernias; they have been reported secondary to diaphragmatic repair, trauma, an oesophageal or upper respiratory tract disease or a neuromuscular disorder (Llabres-Diaz *et al.* 2008). In human medicine, one widely accepted theory is that an abnormal increase in abdominal pressure increases the pressure gradient between the abdominal and thoracic cavities, resulting in the displacement or "pushing up" of the gastro-oesophageal junction through a normal hiatus. There is no supporting experimental evidence for this theory despite its wide acceptance (Christensen & Miftakhov 2000).

This pressure differential is compounded when combined with an abnormal inspiratory effort, resulting in abnormally low intrathoracic pressure, and has been proposed as sufficient to induce a hiatal hernia (Bright *et al.* 1990, Pratschke *et al.* 1998, Sivacolundhu *et al.* 2002, Lecoindre & Richard 2004). A hiatal hernia has been documented in cases of abnormal respiratory effort, such as laryngeal paralysis, and following repair of chronic diaphragmatic hernia (Bright *et al.* 1990, Pratschke *et al.* 1998).

Documented sequelae to chronic hiatal hernia include gastro-oesophageal reflux, which allows either ingesta or fluid from the stomach to pass retrograde into the oesophagus. Oesophagitis is a common sequela because of exposure to gastric acid, pepsin, trypsin, bile salts and duodenal bicarbonate and may in turn lead to reduced oesophageal motility and, in severe cases, oesophageal stricture. The severity of the oesophagitis will relate to the frequency and content of the reflux (Washabau 2012). It is therefore advantageous to diagnose and manage cases as early as possible.

Diagnosis of a hiatal hernia may occasionally be made on plain radiography; radiographical findings include the identification of a rounded soft-tissue opacity or gas-filled viscus in the caudodorsal thorax overlying the diaphragm. This diagnosis may be aided with barium contrast radiography, which makes the delineation of the gastric and oesophageal margins clearer. Videofluoroscopy is more useful than plain radiography in cases in which the hernia is intermittent and can also be used to document gastro-oesophageal reflux, hypomotility and oesophageal redundancy (Washabau 2005, 2012, Llabres-Diaz *et al.* 2008, Cornell 2011). Endoscopy may document concurrent oesophagitis, gastro-oesophageal reflux and findings consistent with a hiatal hernia, such as cranial displacement of the caudal oesophageal sphincter and a large oesophageal hiatus (Washabau 2005, Cornell 2011). However, recently, it has been suggested that endoscopy may fail to diagnose some cases of gastro-oesophageal junction disorders because of the effects of endotracheal (ET) intubation and anaesthesia (Vangrinsven *et al.* 2015). This study also demonstrated that obstruction of the ET tube improves the detection of abnormalities of the gastro-oesophageal junction. Detection can be improved by using fluoroscopy in fully conscious animals, in which there will be normal airway pressures and which provides valuable information for the likelihood of reflux in brachycephalic patients with increased risk during general anaesthesia (Brodbelt *et al.* 2008).

The aim of the current study is to report the prevalence of hiatal hernia in brachycephalic breeds presented to a referral hospital for treatment of brachycephalic obstructive airway syndrome (BOAS).

MATERIALS AND METHODS

Diagnostic imaging records of fluoroscopy barium swallow studies performed on brachycephalic breed dogs at Langford Vets Small Animal Hospital, University of Bristol over a retrospective 30-month period between May 2013 and November 2015 were selected for review.

The routine protocol for a barium swallow study was as follows: (1) the dog stands with food placed in front of them in a raised food bowl; (2) room temperature food coated in barium sulphate powder (Vet-Way Ltd, York, UK) or 5 mL Iohexol 300 mg I/ml (Omnipaque, GE Healthcare, Cork, Ireland) was offered; and (3) dogs were offered soft food and kibble on separate occasions; the amount and specific brand of each food type was varied and tailored to patient appetite.

The food boluses were tracked from the oropharynx through to the stomach using videofluoroscopy at a rate of eight frames per second. Assessment of oral, pharyngeal, oesophageal and gastro-oesophageal phases was included. In all studies, pressure to the abdomen using paddles was routinely applied if no hiatal hernia was documented on the initial images. This application of pressure was performed immediately before screening; in order to comply with radiation safety; this was only performed if the person applying the pressure was at a safe distance from the primary beam. Two observers were always present: a radiographer and a radiologist (either a radiology resident or a board-certified diplomate). Video loops were saved for further review.

The videofluoroscopy studies for all of the patients were reviewed using proprietary software (Visbion Image Viewer, Visbion, Chertsey, Surrey, UK) by two reviewers: one board-certified radiologist (C Warren-Smith) and one second year radiology resident (E Reeve). The studies were reviewed with no knowledge of the signalment, presenting complaint or original study diagnosis. Agreement by consensus was reached for every patient. The original reports of the fluoroscopy studies were later reviewed to determine whether abdominal pressure had been used to identify a hiatal hernia.

Studies were assessed for the presence of a hiatal hernia, oesophageal redundancy, gastro-oesophageal reflux and poor oesophageal motility. These were defined as follows (following Gaschen 2012). A *hiatal hernia* was diagnosed if any portion of the stomach (usually the fundus) protruded cranial to the diaphragm accompanied by cranial movement of the remainder of the stomach towards the diaphragm. This is detected on videofluoroscopy by observing the soft-tissue opacity wall of the stomach as a separate structure located within the thorax cranial to the diaphragmatic crura at a level between the aorta and the caudal vena cava. *Gastro-oesophageal reflux* was defined as a retrograde motion of the positive, contrast-soaked ingesta from the stomach to the oesophagus. *Poor motility* was defined as failure of the bolus to progress smoothly and rapidly along the oesophagus due to either bolus retention at any location in the oesophagus after more than two subsequent swallow attempts, retrograde movement of the bolus of greater than 10 cm or increased transit time defined as greater than 10 s. *Oesophageal redundancy* was defined as a focal dilation of increased diameter or distension of the oesophagus cranial to, or at the level of, the thoracic inlet. This was delineated during videofluoroscopy study with focal accumulation of the positive, contrast medium-soaked food.

RESULTS

Forty-one fluoroscopy barium swallow studies were identified of 41 different dogs. Four studies were graded as being of poor quality due to reluctance or refusal to eat or too much movement of the patient; all such studies were discarded. In addition, one study was discarded because it was not available for review. Three studies had required a repeat attempt either later the same day or on a different date to obtain a diagnostic-quality fluoroscopy barium swallow. In all, therefore, 36 dogs met the inclusion criteria.

The breed, age and gender of the dogs are presented in Table 1. The findings from the study included delayed oesophageal transit time or reduced oesophageal motility, gastro-oesophageal reflux, hiatal hernia and a redundant oesophagus and are also presented in Table 1.

For all cases, the concurrent gastro-intestinal symptoms were chronic regurgitation of food, water or both. This was most often reported to occur either during, or immediately after, exercise. Occasionally, there were reports of intermittent vomiting in addition to regurgitation. Case 2 had additional episodes of nasal discharge, which were presumed most likely to be due to regurgitation into the nasopharynx, although this patient only had findings of delayed transit on the fluoroscopy study. For the dogs that had been presented for a fluoroscopy study primarily for gastro-oesophageal disease (Cases 1, 5, 7, 9, 10 and 36), five were due to the primary clinical complaint of regurgitation and vomiting, and one (Case 5, boxer) was investigated because of concurrent myositis and concern for oesophageal dysmotility.

Of the 36 dogs, 16 had hiatal hernias, all of which were French bulldogs; one of these (Case 6) had abdominal compression used, and the others demonstrated a hernia without the need to apply compression. Of the dogs, 31 had delayed oesophageal transit time, 27 had gastro-oesophageal reflux, and 4 had redundant oesophagus (which, when present, was seen at the thoracic inlet in all cases). Nearly all of the dogs demonstrated more than one abnormality (see Table 1). In addition, 14 of 16 dogs with hiatal hernias had concurrent evidence of gastro-oesophageal reflux seen on fluoroscopy (Figs 1 and 2).

Table 1. Summary table of results displaying the breed, age, gender and fluoroscopic barium swallow findings

Patient	Age (months)	Gender	Breed	Findings			
				Hiatal hernia	Delayed transit	Gastro-oesophageal reflux	Oesophageal redundancy
1*	<12	Unknown	Bulldog		◆	◆	
10*	<12	M	Bulldog		◆	◆	
25	<12	M	Bulldog			◆	
24	12 to 24	M	Bulldog		◆	◆	
13	24 to 36	MN	Bulldog		◆	◆	
4	Unknown	F	Bulldog		◆		◆
16	<12	M	French bulldog	◆	◆	◆	
26	<12	M	French bulldog			◆	◆
31	<12	M	French bulldog	◆	◆		
6	12 to 24	MN	French bulldog	◆†	◆	◆	
8	12 to 24	MN	French bulldog	◆	◆	◆	
36*	12 to 24	M	French bulldog	◆	◆	◆	
15	12 to 24	MN	French bulldog	◆	◆	◆	
17	12 to 24	F	French bulldog		◆	◆	
18	12 to 24	M	French bulldog	◆	◆	◆	
21	12 to 24	F	French bulldog	◆		◆	
29	12 to 24	MN	French bulldog	◆	◆	◆	
30	12 to 24	M	French bulldog	◆	◆		
33	12 to 24	M	French bulldog	◆	◆	◆	
34	12 to 24	M	French bulldog	◆	◆	◆	
20	24 to 36	M	French bulldog		◆	◆	
22	24 to 36	MN	French bulldog		◆		◆
35	24 to 36	MN	French bulldog	◆	◆	◆	
14	>36	MN	French bulldog	◆	◆	◆	
23	>36	MN	French bulldog	◆	◆	◆	
27	>36	FN	French bulldog		◆	◆	
28	>36	MN	French bulldog	◆	◆	◆	
2	Unknown	FN	Boston terrier		◆		
32	12 to 24	MN	Boston terrier		◆		
19	12 to 24	M	Boston terrier		◆	◆	
11	24 to 36	MN	Boston terrier		◆		◆
9*	12 to 24	Unknown	Shih-tzu		◆		
3	>36	FN	Pug		◆	◆	
12	>36	M	Pug		◆	◆	
7*	>36	FN	Boxer			◆	
5*	>36	FN	Boxer				
			Totals	16	31	27	4

*These six patients presented for GI signs of regurgitation, recurrent or intermittent vomiting. All the other 30 patients presented primarily for BOAS

†This was the only patient in which the hernia was demonstrated with the use of paddles. All other hiatal hernia were noted without the use of increased abdominal pressure

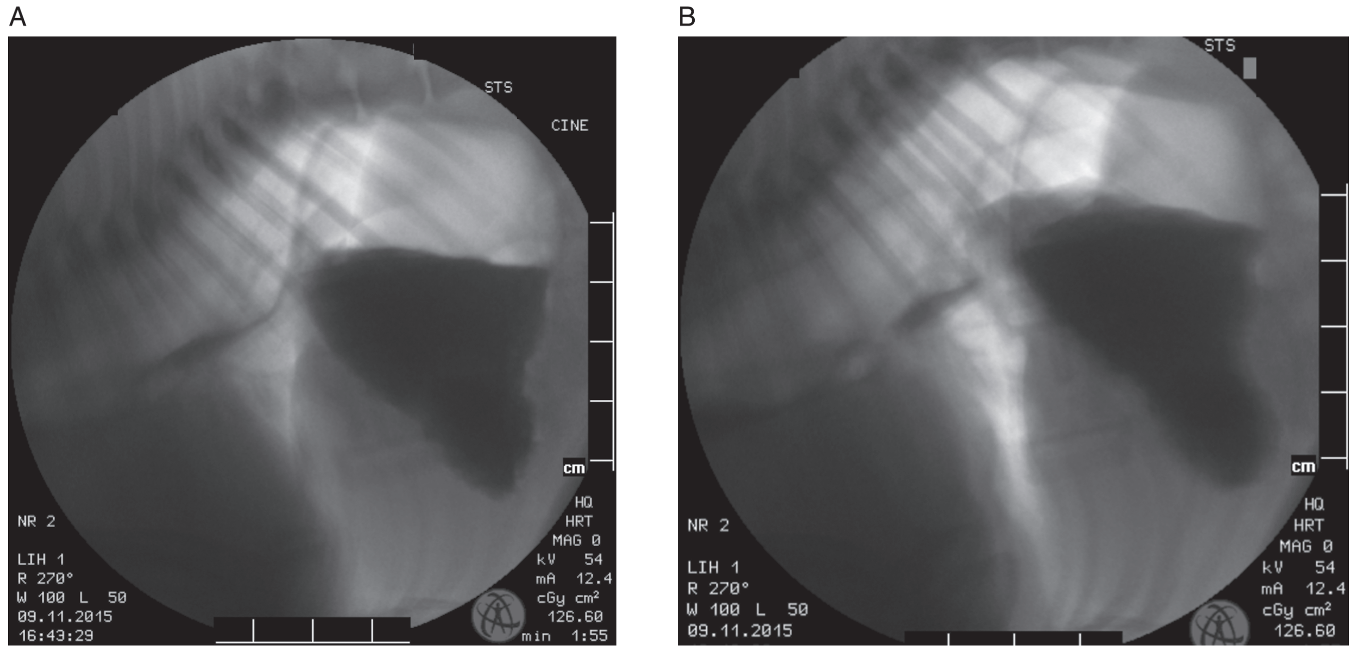

FIG 1. Fluoroscopic still frame images of the liquid contrast phase in a dog that had a moderate-sized hiatal hernia, oesophageal reflux and poor motility. (A) The stomach is in a normal position, caudal to the diaphragm, and contains liquid positive contrast medium. (B) Cranial displacement of the gastro-oesophageal junction into the thorax

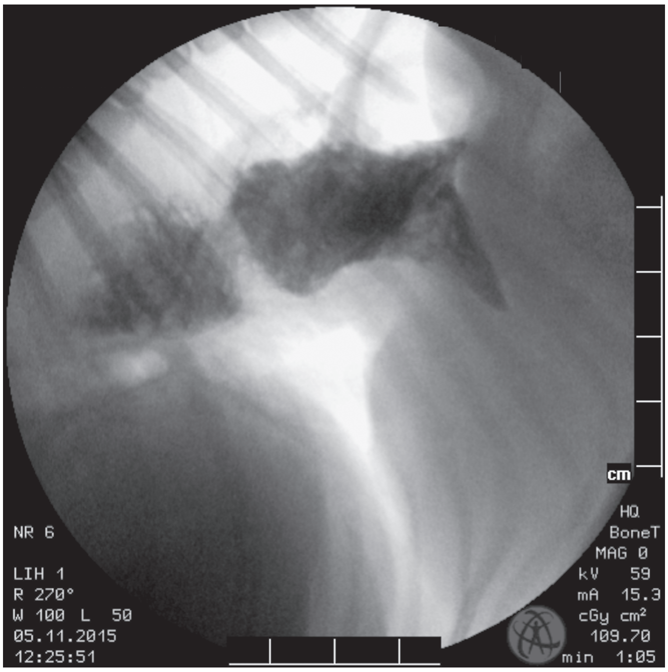

FIG 2. A moderate-sized hiatal hernia, demonstrating displacement of the gastro-oesophageal junction into the thorax, with the cardia of the stomach containing gas, and positive contrast-soaked kibble clearly visible cranial to the diaphragm

DISCUSSION

The results of this study suggest that hiatal hernia is common in brachycephalic dogs that are presented primarily with clinical signs of brachycephalic obstructive airway disease and that its prevalence is higher than has previously been reported in French Bulldogs. Congenital hernias have previously been reported in the Chinese shar pei, bulldog, French bulldog and chow chow breeds (Callan *et al.* 1993), Washabau 2005, 2012, Cornell 2011, Poncet *et al.* 2005). However, many of the previous studies suggesting possible breed predisposition were based on very small numbers of dogs (n=7) or are individual case reports (n=2) A case study in 2005 documented only 20 previous reports of sliding hiatal hernias in the veterinary literature (Kirkby *et al.* 2005).

It is known that many BOAS-affected dogs have gastrointestinal signs, and the majority (30/36) of the brachycephalic dogs in this study were primarily presented for surgical treatment of obstructive airway disease because of typical clinical signs, such as upper respiratory obstruction, collapse, exercise intolerance or inability to cope with heat or stressful events. They were not referred for a gastrointestinal disorder but, during history taking, there was evidence of gastrointestinal disease in each case. This was most commonly regurgitation, often during or after exercise and, therefore, a fluoroscopy swallowing study was indicated. A previous study of brachycephalic dogs that were presented for respiratory signs demonstrated a 97.3% prevalence of gastrointestinal tract clinical disease, including oesophageal deviation, distal oesophagitis, gastro-oesophageal reflux, hiatal hernia, gastritis and duodenitis based on clinical evaluation, endoscopic and histological examination (Poncet *et al.* 2005). It also documented a significant relationship between the severity of the respiratory and digestive signs for three of their independent variables: French bulldogs, males and heavy brachycephalic dogs. A second study revealed improvement in gastrointestinal disorders following upper respiratory tract surgery and gastrointestinal medical management in 91.4% of 51 dogs (Poncet *et al.* 2006).

Poncet *et al.* (2005) described 73 dogs, of which 49 were French bulldogs, of which only 3 were found to have a hiatal hernia (6%). Poncet *et al.* (2006) included 61 dogs, of which only 2 of 42 French bulldogs were diagnosed with hiatal hernia (5%). Neither of these studies used fluoroscopy as a diagnostic test for hiatal hernia. It appears possible that these two studies may have underestimated the prevalence of the condition in this brachycephalic breed based on a comparison with the results we report here [16/21 (76%) French bulldogs diagnosed with hiatal hernia].

The most common findings in the current group of dogs were delayed oesophageal transit time (31 of 36 dogs) and gastro-oesophageal reflux (27 of 36 dogs). Normal swallowing is a combined voluntary and reflex action, which, once initiated, should propel food to the stomach *via* three phases. The initial oral voluntary phase is bolus formation and presentation to the pharynx. The second pharyngeal phase is the initiation of the reflex swallow. The soft palate is pulled dorsally, and the palatophalangeal folds medially; the epiglottis moves forward to cover the larynx, and the cranial oesophageal sphincter relaxes. The food is propelled to the oesophagus due to forcible constriction of the dorsal pharyngeal muscles. This second phase should occur in less than 1 second. The third phase, also involuntary and under partial control of the swallowing centre, is constriction of the cranial oesophageal sphincter after the bolus has passed, followed by initiation of a primary peristaltic wave, which should traverse the oesophagus in 10 seconds. If this is insufficient to propel the bolus to the stomach, a secondary peristaltic wave is initiated. During the primary peristaltic wave, the caudal oesophageal sphincter will relax allowing food to enter the stomach, and should constrict after passage of the food (Gengler 2010).

Delayed oesophageal transit time is a result of reduced coordination or a poor bolus passage. Delayed maturation of the oesophagus has been proposed as a mechanism for delayed oesophageal transit time in dogs under one year of age (Bexfield *et al.* 2006). In the current study, six dogs were under one year of age, but only four of these displayed delayed transit. The remaining 27 dogs with delayed transit were over one year old; therefore, delayed maturation must be considered an unlikely cause of reduced motility. In addition, in the current study, two of the four dogs under one year of age with delayed transit also had a hiatal hernia, which is always an abnormal finding.

The two boxers were older (72 and 116 months) than the majority of the other dogs and also had additional presenting signs: one had generalised weakness, and the other had diarrhoea in addition to regurgitation. Therefore, although they were included within our retrospective search criteria, they would be unlikely to have the same pathophysiology of hiatal hernia development compared with the other individuals.

The identification of reflux and regurgitation is important because it increases the risk of postoperative aspiration, which is already an increased risk in dogs undergoing upper airway surgery (Ovbey *et al.* 2014, Davies *et al.* 2015). Therefore, prior knowledge regarding the severity of oesophageal disease could allow for the improved assessment of anaesthetic risk.

There are no reports in the veterinary literature regarding the relative sensitivities and specificities of each diagnostic modality for hiatal hernia. This may be in part due to the fact that a gold-standard diagnosis at surgery or *post mortem* examination is infrequently achieved. Given the intermittent nature of sliding hiatal hernia, we would support previous statements that fluoroscopy during feeding of a barium meal is more sensitive than radiography. However, small hiatal hernias are still likely to be overlooked due to the superimposition of other structures (Kahrilas *et al.* 2008). The sensitivity of fluoroscopy in humans for the diagnosis of hiatal hernia is improved when abdominal pressure is increased during the examination (normally in the form of the Valsalva manoeuvre), and we have found that increasing intra-abdominal pressure using paddles or hands on either side of the abdomen immediately before fluoroscopic image acquisition can aid recognition of herniation in dogs. The application of abdominal pressure is not a technique that has been validated in the veterinary literature and is performed at our institution only if a hiatal hernia has not been seen already. Due to the retrospective nature of this study in the cases where abdominal pressure was used, it was not possible to determine which dogs demonstrated a hiatal hernia after increased abdominal pressure, but not before. However, the use of paddles was recorded, and only one dog found to have a hiatal hernia was diagnosed subsequent to their use. Given that only one of the dogs with a hiatal hernia required the use of paddles, the technique, although historically used if a hernia has not been seen at the authors' institution, may be less rewarding than we had previously perceived. Similar comments regarding the variability of the usefulness of increasing the abdominal pressure to diagnose a hernia is mentioned in previous literature (Suter & Lord 1984).

It is also notable that, often being intermittent in nature, hiatal hernia may occur but not be detected during a study, especially in non-cooperative subjects. It can therefore be assumed that our estimation of the prevalence may also likely be an underestimate. We find that a short duration of starvation, such as 12 hours before the procedure, improves the likelihood of patient cooperation and eating for the fluoroscopy study as does the use of a food type familiar to the patient. The radiation dose to personnel must be considered and the correct personal radiation protection and safety measures taken. A disadvantage of fluoroscopy as a diagnostic test is the availability and cost of equipment, which is often only available in referral centres.

Endoscopy has the advantage of not involving ionising radiation, but it requires anaesthesia and, in human medicine, there are documented difficulties in diagnosing hiatal hernia due to the difficulty in precisely locating the diaphragmatic crura. In addition, insufflation of the stomach may artificially increase the size of a hernia (Kahrilas *et al.* 2008). It is possible that in comparison with the 2005 and 2006 reports by Poncet *et al.*, the higher prevalence of hiatal hernias noted in the current study may be related in part to the use of fluoroscopy rather than endoscopy for diagnosis.

In humans, manometry has also been used to assess the spatial and topographic pressure profiles of the diaphragm and the gastro-oesophageal junction. In comparison with endoscopy, manometry had a significantly higher specificity, but both modalities had a high proportion of false negatives for the diagnosis of sliding hiatal hernia (Khajanchee *et al*. 2013). Manometry has been performed in dogs and is possible without sedation, but the procedure was reported in mesaticephalic dogs, and there are currently no known reference values (Kempf *et al*. 2013). Recent work has also shown that the prevalence of hiatal hernias diagnosed during endoscopy is likely artefactually low due to the effects of anaesthesia and intubation, mainly because ET intubation negates the pressure changes associated with brachycephalic airway disease (Vangrinsven *et al*. 2015).

In conclusion, we propose that the prevalence of oesophageal disease and, particularly, the prevalence of hiatal hernia, is higher than previously documented in brachycephalic dogs that are presented with BOAS, especially in French bulldogs. This is clinically relevant because recognition of the hiatal hernia and oesophageal disease, with appropriate management of secondary oesophagitis, is beneficial to reduce the anaesthesia risk. Further studies are warranted to determine if the prevalence or severity of hiatal hernia is reduced following correction of the obstructive airway syndrome.

Conflict of interest

No conflicts of interest have been declared.

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