PAPER

Diagnosis and treatment of gastro-oesophageal junction abnormalities in dogs with brachycephalic syndrome

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Objectives: To determine whether there is a benefit of using pre- and postoperative antacid treatment in dogs undergoing surgery for brachycephalic syndrome. To assess the use of an obstruction manoeuvre during endoscopy for the detection of dynamic gastro-oesophageal junction abnormalities.

Materials and Methods: Thirty-six client-owned brachycephalic dogs were prospectively included in a randomised trial. Antacid treatment was randomly prescribed in 18 dogs before and after surgery while the other 18 dogs did not receive any gastrointestinal medical treatment. At presentation, at the time of surgery and at recheck, digestive clinical signs and gastro-oesophageal junction abnormalities were assessed using specific scores. Gastro-oesophageal junction abnormalities were assessed during endoscopy in standard conditions as well as during endotracheal tube obstruction. This manoeuvre was also applied in an unrelated control group.

Results: The results suggest a beneficial effect of antacid treatment on the improvement of digestive clinical signs and lesions in dogs with brachycephalic syndrome undergoing surgery. At postsurgical control 83% of dogs had a digestive clinical score ≤1 in the treated group in contrast to 44% in the non-treated group and 39% of dogs had a gastro-oesophageal abnormalities score (during obstruction manoeuvre) ≤1 in the treated group in contrast to 16.7% in the non-treated group. The use of the obstruction manoeuvre during endoscopic assessment in a control group revealed that gastro-oesophageal junction movements are negligible in healthy animals.

Clinical Significance: The addition of antacid treatment during the pre- and postoperative period for brachycephalic dogs undergoing surgery may result in a faster and greater improvement in treated dogs. The obstruction manoeuvre is an interesting technique to improve detection of gastro-oesophageal junction abnormalities.

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INTRODUCTION

Brachycephalic syndrome (BS) is an established cause of respiratory distress in brachycephalic breeds (Poncet & Freiche 2014, Dupré & Heidenreich 2016, Oechtering 2017). Anatomical changes associated with congenital shortening of the skull lead to obstruction of the upper airways and respiratory symptoms such as snoring, stridor, exercise intolerance, dyspnea, cyanosis and syncope. Digestive clinical signs, such as regurgitation and vomiting, secondary to oesophagitis, gastro-oesophageal reflux, cardial atony, sliding hiatal hernia and/or gastritis are also often reported (Lecoindre & Richard 2004, Poncet *et al.* 2005,

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2006, Roedler *et al.* 2013, Poncet & Freiche 2014, Haimel & Dupré 2015, Broux *et al.* 2018). Persistent regurgitation and/or vomiting might aggravate the respiratory signs by inducing inflammation and encumbering the pharyngeal region (Poncet & Freiche 2014). Consequently, antacid drugs are frequently advised in brachycephalic dogs after surgery to decrease complication rate and improve postoperative prognosis (Poncet *et al.* 2006), although efficacy of this adjunctive medical treatment has not been specifically investigated yet. Moreover, the benefit of starting antacid treatment before surgery has not been explored.

Because of the dynamic nature of gastro-oesophageal junction abnormalities (GJA) in dogs with BS their prevalence based on standard endoscopic evaluation is suspected to be underestimated (Reeve *et al.* 2017, Broux *et al.* 2018). Recent studies demonstrated that their prevalence is indeed higher than previously estimated. Using fluoroscopy as diagnostic tool, Reeve *et al.* (2017) showed a prevalence of 44% of sliding hiatal hernia in French bulldogs with BS. By increasing the trans-diaphragmatic pressure gradient during endoscopy using temporary endotracheal tube obstruction, Broux *et al.* (2018) also showed increased detection of GJA, including sliding hiatal hernia in dogs with BS. However, whether this latter technique potentially overestimates GJA detection during endoscopy has not been specifically addressed.

The main objective of the present study was to assess the effect of antacid treatment before and after surgery on digestive clinical signs and lesions, including GJA using endotracheal tube obstruction manoeuvre during endoscopy. We also applied this latter technique to detect GJA during endoscopy in dogs not suspected to be at risk for GJA.

MATERIALS AND METHODS

Brachycephalic dogs presented at the small animal hospital for upper respiratory clinical signs with or without digestive clinical signs were prospectively included. Breeds other than French bulldogs, pugs and English bulldogs were excluded. For ethical reasons, dogs with severe digestive clinical signs and oesophagitis were excluded as they could not participate to the randomised treatment protocol. Breed, age, sex, body condition score and complete history were recorded. Complete physical examination and thoracic radiographs were performed in all dogs. Endoscopic examination of the upper respiratory airways and upper digestive tract was performed by a board-certified specialist (FB or CC) using a video-gastroscope (Fujinon gastroscope, 5.2 mm, 100 cm; EG-470N5, Fujinon, Saitama City, Japan) after a fasting period of 24-48 hours. Preoxygenation was systematically provided using an oxygen mask. Sedation was induced with 5-20 µg/kg of medetomidine (Sedator; Eurovet) and 0.1-0.2 mg/kg butorphanol (Butomidor; Ecuphar) intravenously (iv). Following induction with propofol (Diprivan; Zeneca), injected iv to effect (maximum of 10 mg/kg), endoscopy of the upper airways was performed in sternal recumbency. The dogs were then intubated, maintained with isoflurane in 100 per cent oxygen and positioned in left lateral recumbency for oesophagoscopy. If needed, buprenorphine (Vetergesic; Ecuphar; 10-20 µg/kg q6-8 hours) was used for rescue analgesia per- and postoperatively.

Each dog underwent three physical and endoscopic examinations: at diagnosis (T_0), at time of surgery (T_1; which was scheduled 2-3 weeks after T_0) and at recheck 1 month after surgery (T_2). Diagnosis was based on clinical history, physical examination and assessment of respiratory and digestive lesions associated with BS including nasopharynx examination, laryngoscopy, tracheobronchoscopy and oesophagoscopy (rhinoscopy was not routinely performed). A respiratory clinical score (RCS) ranging from 0 to 4 was attributed based on the frequency of snoring, inspiratory efforts, exercise intolerance and cyanosis/syncope (Table 1). Based on the frequency of regurgitation and vomiting, a digestive clinical score (DCS) was assigned ranging from 0 to 4 (Table 1). A GJA score, ranging from 0 to 9, was determined based on the presence and severity of cardial opening, gastro-oesophageal reflux, distal oesophagitis and sliding of the gastro-oesophageal junction (Table 2; Fig 1; video 1). The GJA score was determined in two consecutive situations: in standard conditions (GJA-standard score) and during endotracheal tube obstruction (GJA-obstruction score). The latter was performed by manual obstruction of the endotracheal tube during up to three spontaneous breathings within a period of maximum 30 seconds to reproduce deep inspiratory efforts as occurring during episodes of upper respiratory obstruction. The stomach was not insufflated before assessment of the GJA. At T_1 and T_2, a clinical history and physical examination was performed to re-evaluate the digestive clinical score and the GJA score (standard and during obstruction) was also re-assigned during control oesophagoscopy). All endoscopic procedures were recorded and reviewed

Table 1. Digestive and respiratory clinical score grading system (Broux *et al.* 2018)

	Absent	Occasionally (≤1/month)	Regularly (≤1/week)	Daily (≤1/day)	Often (>1/day)
Respiratory clinical signs					
Snoring	0	0	0	1	2
Inspiratory efforts	0	1	2	3	4
Exercise intolerance	0	1	2	3	4
Cyanosis/syncope	0	3	4	4	4
Digestive clinical signs					
Regurgitation or vomiting	0	1	2	3	4

The highest grade determines the final score (ranging from 0 to 4) for the respiratory clinical score
Inspiratory efforts were defined as episodes during which the dog presented difficulties during inspiration, *i.e.* with deeper inspiration than normal
Exercise intolerance was defined as any decreased ability to perform exercise or difficulties to recover after an effort

Table 2. Gastro-oesophageal junction abnormalities score grading system (adapted from Broux *et al.* 2018)

Gastro-oesophageal junction abnormalities grades	0	1	2	3
Cardia	Closed	Intermittently open	Gaping	/
GOR	Absent	Intermittent	Permanent	/
Oesophagitis	Absent	Mild	Severe	/
GJ sliding	Absent	Bulging and partial circumferential gastric mucosal eversion	Bulging and complete circumferential gastric mucosal eversion <2 cm	Sliding hiatal hernia

The sum of the grades determines the final score (ranging from 0 to 9)
Sliding hiatal hernia = bulging and complete circumferential gastric mucosa eversion >2 cm based on assessment in human medicine (Kahrilas *et al*. 2008)
GOR Gastro-oesophageal reflux, GJ Gastro-oesophageal junction

blindly during a single session and by a single person to assign the GJA scores (EV). The scoring system was similar to the one used by Broux *et al.* (2018) which was considered reliable, repeatable and independent of the reader's expertise.

After clinical and endoscopic examination at diagnosis, all dogs were treated with prednisolone (0.5 mg/kg per os (PO) twice daily for 5 days and then once daily until surgery). Antacid treatment consisting of omeprazole (1 mg/kg PO q24 hours) and magaldrate (5-10 mL/dog PO q8-12 hours) was randomly prescribed (drawing lots with sealed envelopes at T_0) until recheck (T_2). If dogs were not randomly selected to receive antacid treatment, they only received the anti-inflammatory (prednisolone) medication. Two to 3 weeks later, a conventional surgical procedure was performed including nasoplasty (vertical wedge resection), ventriculectomy and staphylectomy (semicircular resection of caudal soft palate with scissors, the caudal border of the soft palate was shortened to the caudal level of the tonsils) depending on the abnormalities observed at diagnosis. Postoperative medical treatment consisted in prednisolone (0.5 mg/kg PO twice daily for 5 days followed by tapering doses until control) in all dogs and antacid treatment was pursued until postsurgical control (T_2) if already prescribed at diagnosis.

In order to assess whether endotracheal tube obstruction manoeuvre does not overestimate the detection rate of GJA, this procedure was performed during endoscopic examination of the gastro-oesophageal junction in a group of control dogs. Control dogs were healthy or had diseases that were not expected to interfere with gastro-oesophageal junction dynamics; they were anesthetised for independent purposes. GJA-standard score and GJA-obstruction score were calculated as explained above. Owner's consent was obtained for each dog. Study was approved by the institutional ethical committee (n = 1425).

Statistical analysis

Normality of data distribution was assessed using the Shapiro-Wilk normality test. No data showed a normal distribution ($P \leq 0.001$). A mixed multinomial regression model was performed to assess the effect of antacid treatment on digestive clinical score and GJA-obstruction score (following variables were entered in the model: breed, sex, body condition score, age, endoscopy, antacid treatment, GJA-obstruction score at diagnosis, antacid treatment:endoscopy interaction and random factor). The influence of the study group (dogs with BS versus control group) on the GJA-obstruction score at diagnosis was measured with a similar model. The criteria for statistical significance was set to $\alpha = 0.05$. Analyses were performed using the R program (Version 3.1.3).

RESULTS

BS population

Thirty-six brachycephalic dogs were prospectively enrolled over 17 months (September 2014 to February 2016). Breed distribution in our main study population was 58% French bulldogs (n = 21), 25% pugs (n = 9), 17% English bulldogs (n = 6). There were 23 males (10 neutered) and 13 females (11 spayed). Median age was 21 months (9-97 months) and median body condition score was 5 out of 9 (range 2-7).

Median respiratory clinical score at diagnosis was 4 (range 2-4). Four dogs (11%) were presented with grade 2, 11 dogs (31%) with grade 3 and 21 (58%) with grade 4 respiratory clinical score. Multivariate analysis did not show influence of age, sex, breed or body condition score on respiratory clinical score.

All but one dog had stenotic nares (externally visible reduction of the nasal entrance into a vertical slit). All dogs had an elongation of the soft palate, which was moderate (a soft palate extending past the epiglottis) in 19% (n = 7) and severe (entering the laryngo-tracheal opening) in 81% (n = 29). Aberrant caudal nasal turbinates were noted in 70% (n = 16/23) of dogs in which retrograde rhinoscopy was performed and nasopharyngeal collapse in 17% (n = 4/23) of dogs. Laryngeal saccule eversion was observed in 86% (n = 31) of cases, 25% (n = 9) had moderate laryngeal collapse (partial reduction of the laryngeal opening by medial displacement of arytenoid cartilages) and 22% (n = 8) had severe laryngeal collapse (complete obstruction of the laryngeal opening). There was a significant correlation between pugs and severity of laryngeal collapse ($P < 0.001$). Laryngeal granulomas were present in five dogs (14%). Bronchoscopy revealed various degrees of bronchial collapse in 10 dogs (left cranial bronchial narrowing in most cases). Thoracic radiographs were performed in 34 dogs. Tracheal hypoplasia (Harvey & Fink 1982) was observed in four cases (12%; one French bulldog, one English bulldog and two pugs). Three dogs were diagnosed with pneumonia or bronchitis at T_0 (mild aspiration pneumonia n = 1, severe aspiration pneumonia n = 1 and bronchitis due to *Bordetella Bronchiseptica* n = 1). They were treated accordingly until complete resolution of bronchopulmonary disease before entering the study.

At diagnosis 32 dogs (89%; 15 and 17 dogs in the antacid treated and non-treated groups, respectively) were presented with

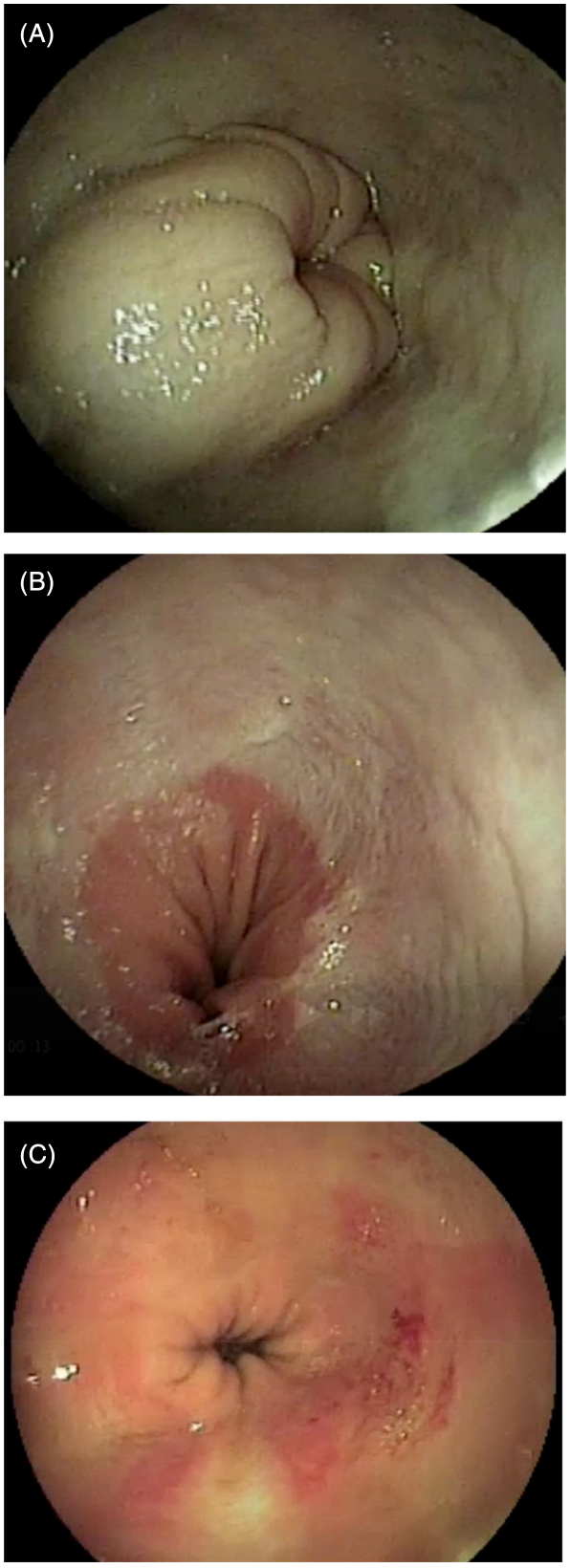

FIG 1. Endoscopic images of gastro-oesophageal junction abnormalities. (A) Bulging or protrusion of the gastro-oesophageal junction within the oesophagus. (B) Circumferential mucosal eversion. Note the intersection between the oesophageal (pale) and gastric (pink-reddish) mucosa. (C) Severe oesophagitis with erosive lesions of the distal oesophageal mucosa. Open cardia which was gaping (never closing completely) during the oesophagoscopy

digestive clinical signs, with a median digestive clinical score of 3 (range 0-4). Digestive clinical signs were classified as grade 0 in 4 dogs (11%), grade 1 in 7 dogs (19%), grade 2 in 4 dogs (11%), grade 3 in 13 dogs (36%) and grade 4 in 8 dogs (22%). There was a significant association between French bulldogs and severity of digestive clinical score (P = 0.03).

In standard conditions the median GJA-standard score was 1 (range 0-4), no sliding hiatal hernia was observed in these conditions. During the obstruction manoeuvre, the median GJA-obstruction score at diagnosis was 4 (range 1-6). The following abnormalities were found during oesophagoscopy: mild to moderate oesophagitis in 14 cases (39%), severe oesophagitis in 2 cases (5%), gastro-oesophageal reflux in 9 cases (25%), intermittent opening of the cardia in 23 (64%) and gaping cardia in 8 (22%) cases. All dogs had some degree of gastro-oesophageal sliding at presentation with a grade 1 gastro-oesophageal junction sliding in 11 dogs (30%), grade 2 in 16 dogs (44%) and grade 3 (sliding hiatal hernia) diagnosed in 9 dogs (25%; all French bulldogs). Overall, French bulldogs had a significantly more severe GJA-obstruction score (P = 0.01).

Treatment and follow-up in the population

Antacid treatment was randomly prescribed in 18 dogs before and after surgery while the other 18 dogs did not receive any gastrointestinal medical treatment.

Palatoplasty was performed in all dogs, rhinoplasty in 34 cases and ventriculectomy in 31 cases. Excision of a laryngeal granuloma with diode laser was performed in one dog during the same surgery (French bulldog in group treated with antacids). All 36 dogs were followed until 1 month after surgery. The second endoscopy before surgery (T_1) was realized in 33 dogs (16 and 17 in the treated and non-treated group respectively) and the control endoscopy (T_2) in 34 dogs (17 in each group of treated and non-treated dogs).

Altogether, median respiratory and digestive clinical score and GJA-obstruction score significantly improved pre- and postoperatively in contrast to the GJA-standard score.

Effect of antacid treatment in the population

Age, body condition score and severity of respiratory and digestive clinical signs at diagnosis did not differ between groups (receiving antacid treatment or not). Females and pugs were more represented in the non-treated group and GJA-obstruction score at diagnosis was higher in the treated group despite randomization (Table 3). However, multivariate analysis did not show any influence of these variables on the different scores. The only variable showing a significant association with the digestive clinical signs and lesions was the French bulldog breed which was well balanced between the treated and non-treated groups (Table 3).

Although results of multivariate analysis failed to demonstrate a direct effect of antacid treatment, a significant interaction between antacid treatment status and improvement of digestive clinical score throughout the endoscopies was present meaning that treated animals seem to improve faster and have lower clinical scores after surgery than untreated ones (Fig 2). A significant pre- and postoperative improvement was present only in the

Table 3. Comparison of groups with and without antacid treatment

	Antacid treatment (n = 18)	No antacid treatment (n = 18)
Age (months), median (range)	23 (9-97)	24 (12-61)
Females, n (%)	4 (22%)	9 (50%)
Breed	French bulldog (n = 11) Pug (n = 3) English bulldog (n = 4)	French bulldog (n = 10) Pug (n = 6) English bulldog (n = 2)
Body condition score, median (range)	5 (3-7)	5 (2-7)
DCS at diagnosis, median (range)	3 (0-4)	3 (0-4)
RCS at diagnosis, median (range)	4 (2-4)	4 (2-4)
GJA-obstruction score at diagnosis, median (range)	4 (1-6)	3 (2-5)

DCS Digestive clinical score; RCS Respiratory clinical score; GJA-obstruction score, gastro-oesophageal junction abnormalities score during manual obstruction of the endotracheal tube

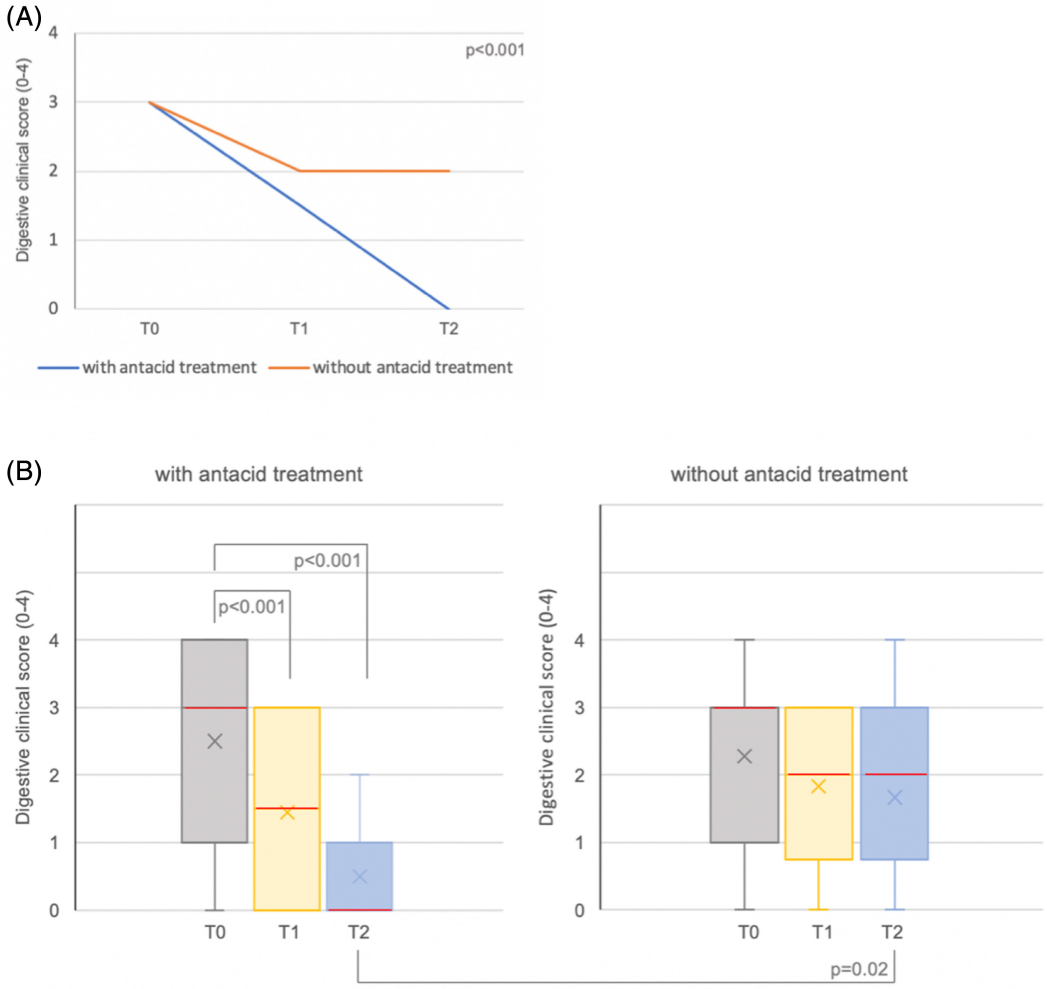

FIG 2. Effect of antacid treatment on the digestive clinical score at different time points. (A) Interaction plot for digestive clinical score *versus* treatment status and endoscopy. (B) Results presented as boxplots. In the boxplots, median (red line), mean (cross), minimum, maximum, first quartile and third quartile are represented. T_0 = endoscopy at diagnosis, T_1 = endoscopy at the time of surgery, T_2 = control endoscopy one month after surgery

treated group (Fig 2). At T_2 83% (15/18) of dogs had a digestive clinical score ≤1 in the treated group in contrast to 44% (8/18) in the non-treated group.

A significant interaction was also present for the GJA-obstruction score. A pre- and postoperative significant improvement could only be observed in the treated group (Fig 3). At T_2 39% (n = 7) of dogs had a GJA-obstruction score ≤1 in the treated group in contrast to 17% (n = 3) in the non-treated group. A GJA-obstruction score = 1 among these 10 dogs was only represented by a grade 1 gastro-oesophageal junction sliding. Sliding hiatal hernia (detected with the obstruction manoeuvre) was still present in two dogs after surgery (one French bulldog of the treated group and one French bulldog of the non-treated group), associated clinical signs were mild and surgical intervention was not necessary.

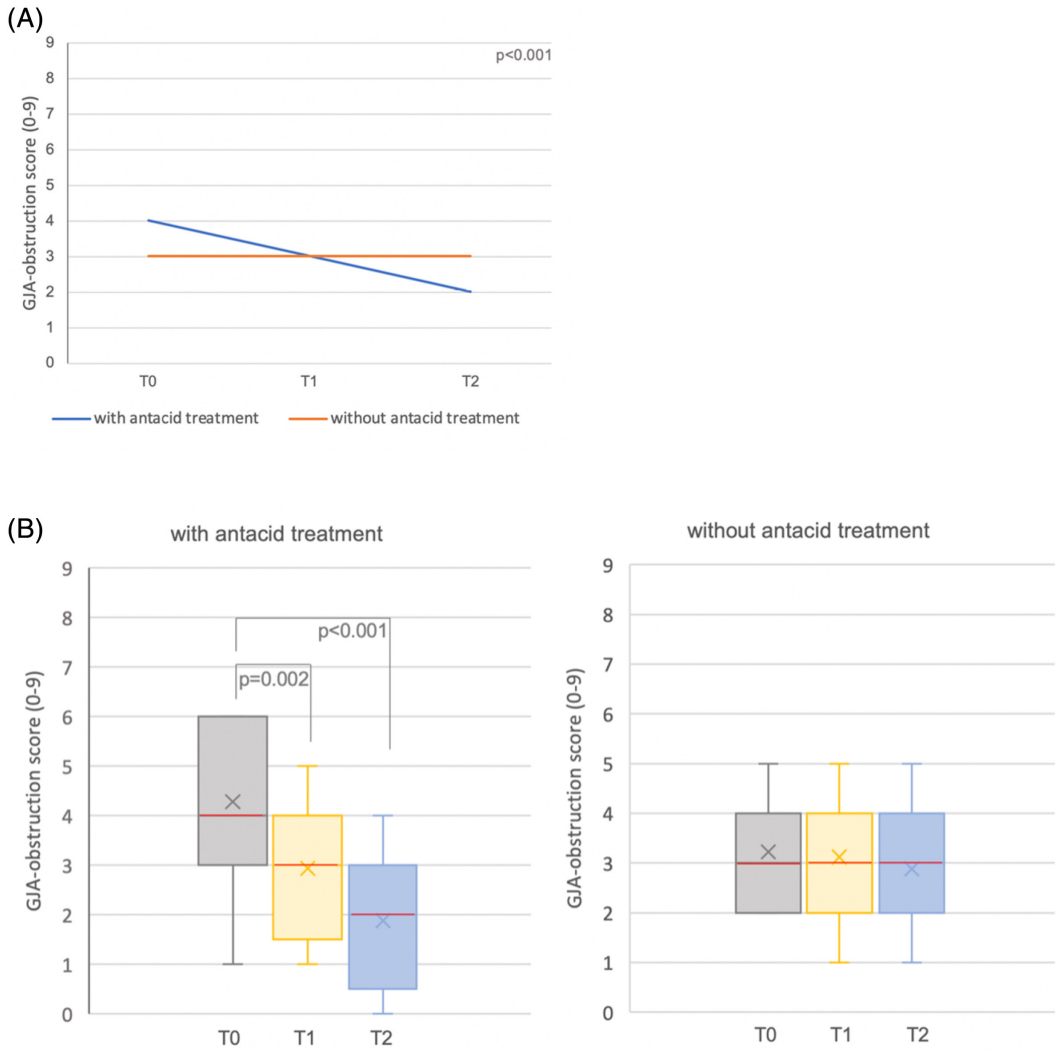

FIG 3. Effect of antacid treatment on the gastro-oesophageal abnormalities score at different time points. (A) Interaction plot for GJA-obstruction score *versus* treatment status and endoscopy. (B) Results presented as boxplots. In the boxplots, median (red line), mean (cross), minimum, maximum, first quartile and third quartile are represented. GJA-obstruction score = gastro-oesophageal junction abnormalities score during manual obstruction of the endotracheal tube. T_0 = endoscopy at diagnosis, T_1 = endoscopy at the time of surgery, T_2 = control endoscopy 1 month after surgery

Obstruction manoeuvre in dogs free of BS

The control group consisted of 10 dogs: 5 experimental beagle dogs and 5 adult client-owned dogs (2 Dachshund, 2 Maltese, 1 American Staffordshire terrier), with 6 females (2 spayed) and 4 males (3 neutered). Median age was 24 months (12-120 months). In standard conditions, the GJA score was 0 in all but one dog. A GJA-obstruction score of 1 was present in 3 of 10 dogs (grade 1 gastro-oesophageal junction sliding in the 3 dogs). There was a significant difference between GJA-obstruction score in dogs from the BS group (median 3; range 0-7) and control dogs (median 0; range 0-1).

DISCUSSION

Results of this study suggest a beneficial effect of antacid treatment on improvement of digestive clinical signs and lesions in dogs with BS undergoing surgery. In contrast to standard endoscopy, the obstruction manoeuvre during endoscopy was able to detect more GJA in dogs with BS.

In accordance with what has previously been reported, the prevalence of digestive clinical signs in brachycephalic dogs presented with upper respiratory tract symptoms was high (89%) (Lecoindre & Richard 2004, Poncet *et al.* 2005, 2006, Reeve *et al.* 2017, Broux *et al.* 2018, Kaye *et al.* 2018). The relationship between French bulldogs and severity of digestive disorders in dogs presented with BS as observed in this study has also already been documented (Poncet *et al.* 2005, Haimel & Dupré 2015, Kaye *et al.* 2018). In this breed, we found a high prevalence of sliding hiatal hernia (9/21; 43%), which was also pointed out in the study by Reeve *et al.* (2017) with 16 of 36 with a diagnosis of sliding hiatal hernia, all of them being French bulldogs. In human and veterinary medicine, a primary disturbance of the intrinsic lower oesophageal sphincter has not been demonstrated to play a role in the aetiology of sliding hiatal hernia (Sivacolundhu *et al.* 2002). Because of the high prevalence of sliding

hiatal hernia among French bulldogs, compared to other breeds, we suspect that intrinsic gastro-oesophageal junction laxity might exist in this breed. The association between pug and severity of laryngeal collapse also confirms previous findings in the literature (Haimel & Dupré 2015).

We decided to include dogs of different brachycephalic breeds (French bulldog, English bulldog and pug) because the goal was to assess the effect of antacid treatment in dogs undergoing surgery for BS. However, improvement of digestive clinical signs in dogs with BS following corrective surgery can vary between breeds with French bulldogs showing the most important reduction of digestive clinical signs in the study of Kaye *et al*. (2018). As there was a balance between the French bulldog breed (n = 11 in treated group and n = 10 in non-treated group) and other breeds in which digestive clinical signs could improve less after corrective surgery (n = 7 in treated group and n=8 in non-treated group), we believe it is unlikely that breed distribution could have influenced the results.

In humans, during sliding hiatal hernia, the gastro-oesophageal junction is displaced cranially causing an axial separation of the extrinsic factors from the lower oesophageal sphincter often resulting in reflux oesophagitis (Patti *et al*. 1996, Kahrilas *et al*. 1999, 2000). The same pathophysiologic mechanism is suspected in dogs (Bright *et al*. 1990, Sivacolundhu *et al*. 2002). The presence of gastro-oesophageal reflux and subsequent oesophagitis have been pointed out as being responsible for shortening of lower oesophageal sphincter and further decreasing his pressure (Sivacolundhu *et al*. 2002) which may cause a self-perpetuating problem. As a result, medical treatment of gastro-oesophageal reflux and oesophagitis seems important to manage GJA in dogs with BS. Currently, medical treatment of gastro-oesophageal disorders is advised depending on the presence of digestive clinical signs, endoscopic appearance of gastro-oesophageal lesions and severity of histopathologic lesions (Poncet & Freiche 2014). Treatment commonly includes antacid drugs such as proton pump inhibitors (omeprazole) and gastrointestinal protectants (sucralfate, aluminium phosphate) (Lecoindre & Richard 2004, Poncet *et al*. 2006, Mercurio 2011). Use of prokinetics (metoclopramide, cisapride) has also been described (Lecoindre & Richard 2004, Poncet *et al*. 2006, Poncet & Freiche 2014). In humans, proton pump inhibitors are very potent to neutralize gastric acidity, thereby increasing lower oesophageal sphincter pressure (Sivacolundhu *et al*. 2002). In canine medicine, omeprazole has been shown to provide superior gastric acid suppression compared to famotidine (Tolbert *et al*. 2011). In a study by Kempf *et al*. (2014), cisapride was susceptible to increase lower oesophageal sphincter pressure while an effect could not be demonstrated with metoclopramide. As cisapride is no longer readily available, we chose to combine a proton pump inhibitor (omeprazole) and magnesium hydroxide (magaldrate) as adjunctive antacid treatment.

It has been suggested that medical treatment of gastro-oesophageal clinical signs improves the outcome of dogs treated surgically for BS both in terms of gastrointestinal and respiratory symptoms (Poncet *et al*. 2006, Poncet & Freiche 2014). Mechanisms by which medical treatment of upper digestive tract diseases could improve outcome include reduction of vomiting, regurgitation and gastro-oesophageal reflux further reducing the risk of inflammation of the oropharyngeal region and prevention of postoperative aspiration pneumonia (Poncet *et al*. 2006). One study investigated the influence of postoperative medical treatment of digestive disorders in association with surgery for BS (Poncet *et al*. 2006) and showed a resolution of digestive clinical signs in more than 80% of cases on a short- and long-term basis. To the author's knowledge, this is the first prospective randomized study evaluating the benefit of pre- and postoperative antacid treatment on a short-term basis in dogs undergoing surgery for BS.

The results of this study suggest a beneficial influence of pre- and postoperative antacid treatment. At postsurgical control, 83% of cases had a digestive clinical score ≤1 in the treated group, which was considered as a good clinical control of digestive clinical signs on a short-term basis, while in the non-treated group, this was achieved in less than 50% of dogs. A marked difference in digestive clinical score was also observed after surgery (T_2) between the two groups. At the time of surgery (T_1), the score distribution is still quite similar (Fig 2), either because antacid treatment needs more time to induce a more efficient clinical response or because there could be a permissive influence of surgery on the effect of antacid treatment. Indeed, upper respiratory tract obstruction in dogs with BS is responsible for upper airway narrowing, causing increased airway resistance. Consequently, greater inspiratory effort is strived by the diaphragm, intercostal and extrinsic chest wall muscles leading to a more important negative airway pressure (Hardie *et al*. 1998). A transient increase in negative intra-thoracic pressure is reported to be sufficient to worsen or even induce gastro-oesophageal reflux and/or hiatal hernia (Burnie *et al*. 1989, Hardie *et al*. 1998, Pratschke *et al*. 1998, Lecoindre & Richard 2004, Jergens 2010, Broux *et al*. 2018). As a result of surgery, a decrease in the trans-diaphragmatic pressure gradient could interrupt this vicious circle and permit antacid therapy to exert its full effects. Only two dogs were diagnosed with sliding hiatal hernia after surgery in contrast to nine dogs at presentation. These results are in favour of an important role of trans-diaphragmatic pressure in the pathophysiology of sliding hiatal hernia in dogs with BS. A slight decrease of the digestive clinical score was observed in dogs without antacid treatment at the time of surgery (T_1). The administration of prednisolone in all dogs before surgery already led to an improvement of respiratory clinical score secondary to a decrease of upper airway inflammation and oedema. If respiratory clinical score improves, it is not surprising that digestive clinical score also improves to a certain degree.

At recheck, endoscopy after surgery, 39% of treated dogs had a GJA-obstruction score ≤1. A GJA-obstruction score ≤1 was also observed in the control group, emphasizing that such result may be observed in healthy dogs, possibly associated with anaesthesia. Indeed, variations in lower oesophageal sphincter pressure associated with anaesthesia and preanaesthetic treatments has been reported in dogs (Hashim *et al*. 1995). In retrospect, a longer follow-up period might have yielded more information about the further evolution of GJA in the two groups, as it is possible that GJA do not achieve maximal resolution so quickly.

The obstruction manoeuvre allowed detection of GJA in dogs, even in the absence of digestive clinical signs reported by the owner. Such digestive clinical signs might have been undetected by the owners, alternatively GJA might not be severe enough to induce overt clinical signs. One way or another, it can be expected that these occult GJA would also benefit from medical treatment, as suggested by the overall improvement of the GJA-obstruction score in treated dogs.

There is currently little uniformity concerning the assessment of sliding hiatal hernia during endoscopic evaluation. In this study, the prevalence of sliding hiatal hernia in dogs with BS, measured during evaluation of GJA through obstruction manoeuvre, was 25%, in contrast to 0% under standard conditions, with sliding hiatal hernia defined as the presence of bulging and eversion of the gastric mucosa for more than 2 cm cranial to the oesophageal hiatus. The most recent previous reports showed a prevalence of 20%, using the same definition and obstruction technique (Broux *et al*. 2018); and 44%, where sliding hiatal hernia was defined as any portion of the stomach protruding cranial to the diaphragm accompanied by cranial movement of the remainder of the stomach towards the diaphragm (Reeve *et al*. 2017). Other studies evaluating the presence of sliding hiatal hernia (defined as a protrusion of the stomach towards the thorax in the oesophageal lumen during oesophagogastroscopy) reported a prevalence of <5% under standard conditions (Poncet *et al*. 2005, 2006). This discrepancy between studies has been reported to be due to underestimation of GJA during standard conditions secondary to alleviation of upper respiratory obstruction during anaesthesia (Broux *et al*. 2018). Our results were in accordance with this hypothesis as sliding hiatal hernia could not be diagnosed under standard conditions.

Since we were concerned about the obstruction manoeuvre inducing false positive results for the diagnosis of dynamic GJA, we performed the technique during endoscopic evaluation in control non-brachycephalic dogs free of respiratory and digestive clinical signs in which GJA are not expected to be present. In this control group, GJA during obstruction manoeuvre were found to be negligible suggesting that this technique does not overestimate significantly the presence of GJA. Only three control dogs showed a gastro-oesophageal junction sliding score of 1 during obstruction. This mild bulging of the GJ might be associated with anaesthesia (Hashim *et al*. 1995) but could also just be normal during complete upper airway obstruction, as it has never been investigated before. In all cases, such low degree of GJA-obstruction score would not lead to misdiagnosis of hiatal hernia based on our criteria.

This study has some limitations. A direct influence of antacid treatment on digestive clinical and lesion scores could not be significantly demonstrated, only the interaction between the time of endoscopy and the use of antacids reached significance. The small sample size, the use of scores and the large range of the values around the median (Figs 2 and 3) might have contributed.

The endoscopic diagnosis of sliding hiatal hernia and gastro-oesophageal reflux is a rather subjective method, this was partly compensated by the retrospective blinded evaluation of endoscopic images by one single person. Other methods exist, such as high-resolution manometry, to more accurately investigate the presence and degree of sliding hiatal hernia (Khajanchee *et al*. 2013). However, this technique is not readily available in veterinary medicine and reference values are still lacking (Kempf *et al*. 2013). Underestimation of gastro-oesophageal reflux can also occur during acquisition of endoscopic images due to the short period of time during which the gastro-oesophageal junction was observed. This might partly explain the discrepancy between the prevalence of gastro-oesophageal reflux in this study (25%) and the study by Reeve *et al*. (2017) (75%) using fluoroscopy, although it has been shown in people that the presence or absence of reflux during barium oesophagography has poor value for the diagnosis of gastro-oesophageal reflux (Saleh *et al*. 2015). Impedance pH-metry has been used to detect acid and non-acid reflux in veterinary patients (Zacuto *et al*. 2012) and would have been more accurate to diagnose and follow evolution of gastro-oesophageal reflux. Nonerosive reflux disease could also have been missed due to the lack of histopathological examination in absence of overt macroscopic oesophageal lesions. Indeed, histopathologic evaluation of oesophageal epithelium was reported to improve diagnosis of reflux disease in dogs (Muenster *et al*. 2017).

The obstruction manoeuvre, safe and easy to perform, has still some shortcomings. The dog needs to breathe spontaneously slowly with inspirations of normal amplitude. Indeed, if the dog shows rapid and superficial breathing the desired effect of inducing intra-thoracic depression does not occur and GJA might be underestimated.

In conclusion, adding pre-and postoperative antacid treatment seem to influence positively the improvement of digestive clinical signs and lesions in dogs undergoing surgery for BS. We recommend administering antacid treatment even if the owners do not report significant digestive clinical signs, as early as at the time of the diagnosis as well as after surgery. Transient manual obstruction of the endotracheal tube did not induce significant GJA in healthy dogs and seems to be a valuable tool to diagnose GJA in dogs with BS and follow the evolution of these lesions after surgery.

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Conflict of interest

No conflicts of interest.

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Supporting Information

The following supporting information is available for this article:

Video S1: Supplementary Video