

1 **Digestive Diseases in Brachycephalic Dogs**

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26 Department for providing illustrations.

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28

29 **Synopsis**

30 In addition to presenting with respiratory signs, many dogs with brachycephalic airway obstructive
31 syndrome also show digestive tract signs that are related to the same conformational abnormalities.

32 A detailed diagnostic investigation is usually required, including clinicopathological analyses,
33 thoracic radiographs, fluoroscopic studies, abdominal ultrasound exams and both upper airway and
34 gastrointestinal tract endoscopy. In most cases, medical therapies are successful in managing
35 clinical signs, but surgery can occasionally be required to resolve hiatal hernia or pyloric stenosis.

36 In determining prognosis, the features of each individual case should be considered, with the
37 overall prognosis depending upon both severity and extent of all the identified lesions.

38

39 **Key words (5-8)**

- 40 • Brachycephalic airway obstructive syndrome
- 41 • Endoscopy
- 42 • Vomiting
- 43 • Stomach
- 44 • Duodenum
- 45 • Esophagus
- 46 • Lymphofollicular GastritisHiatal hernia

47 **Key Points**

- 48 • Primary conformation anomalies in brachycephalic dogs have arisen as a result of
49 inbreeding, resulting in a high prevalence of chronic respiratory and digestive clinical signs.
- 50 • As a result, many dogs that present for evaluation of brachycephalic airway obstruction
51 syndrome also have concomitant gastrointestinal signs.
- 52 • Digestive diseases should be carefully characterized in brachycephalic dogs because
53 several abnormalities may coexist. Many diagnostic procedures are required for a full
54 assessment of the extent of the syndrome. These may include clinicopathological analyses,
55 thoracic radiography, fluoroscopy, abdominal ultrasonography and both upper airway and
56 gastrointestinal tract endoscopy.
- 57 • Most brachycephalic dogs with digestive diseases are managed medically, although surgery
58 may be necessary if hiatal hernia or pyloric stenosis are confirmed. In addition to improving
59 respiratory function, upper airway surgery can often significantly improve digestive clinical
60 signs in brachycephalic dogs.

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62 **Video content accompanies this article at: xxx**

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70 **Introduction**

71 The number of dogs affected by brachycephalic airway obstructive syndrome (BAOS) has
72 increased dramatically over the two past decades, likely as a result of the increasing popularity of
73 brachycephalic breeds including bulldogs and pugs¹. Over the years, these dogs have been bred to
74 accentuate features desirable to the owner (e.g. brachycephalic features), but this has likely had a
75 detrimental repercussion on their health. Most previous publications describe the respiratory
76 consequences of BAOS, but many of the dogs also present with alimentary tract signs including
77 ptyalism, excessive swallowing attempts, regurgitation, eructation, vomiting, and changes in
78 appetite. A systematic approach is needed in order to both characterize the nature of the problem
79 and determine the most appropriate treatment and follow-up.

80

81 **BACKGROUND: Brachycephalic dogs: anatomic and pathophysiologic characteristics**

82 There are many brachycephalic dog breeds, all of which display particular anatomic and
83 pathophysiologic changes due to their wide and short skull (Box 1). However, problems are most
84 commonly reported in French bulldogs, English bulldogs and pugs²⁻⁴. In addition to alterations in
85 the shape of their skull, these dogs have abnormalities in soft tissue structures including
86 elongated soft palate, macroglossia, stenotic nares, undersized nasal chambers, malformed and
87 aberrantly growing nasal conchae, tracheal hypoplasia and acquired laryngeal complications^{5,6}.
88 The most common clinical manifestations relate to the respiratory tract, with signs including
89 exercise and heat intolerance, frequent sleep disruption and syncope which can sometimes be
90 life-threatening (Figure 1). However, digestive signs are also commonly reported⁷, and their
91 severity correlates strongly with that of the respiratory signs⁸. In one study, alimentary tract signs
92 occurred more frequently in French bulldogs compared with pugs and English bulldogs⁵,
93 although this was not confirmed in another study³. The association between digestive and

94 respiratory signs in brachycephalic dogs is further supported by clinical improvement and
95 decrease in post-surgical complications when digestive signs are treated, even in dogs initially
96 presenting with respiratory tract signs⁸. Lesions of the upper digestive tract are often detected
97 (e.g., using endoscopy), even in dogs without any alimentary tract signs. It has been suggested
98 that increased negative pressure within the upper airways in brachycephalic dogs might promote
99 both secondary respiratory abnormalities (e.g. everted tonsils, laryngeal and tracheal collapse,
100 and everted laryngeal sacculles) and digestive tract lesions, such as hiatal hernia (HH) or gastro-
101 esophageal reflux⁹. More recently, studies have examined swallowing, sliding HH and post-
102 operative regurgitation in brachycephalic dogs, emphasizing the fact that gastroesophageal
103 junction abnormalities and HH have been underestimated in brachycephalic dogs¹⁰⁻¹³.
104 Videofluoroscopic swallowing studies have documented the presence of esophageal dysmotility
105 with prolonged esophageal transit time and gastro-esophageal reflux in brachycephalic dogs¹³.

106

107 **DIGESTIVE SIGNS IN BRACHYCEPHALIC DOGS**

108 Alimentary tract signs reported in brachycephalic dogs are listed in Box 2, the most common of
109 which are regurgitation and vomiting. Different grading schemes have been published for
110 assessing the dogs “pre” and “post” surgery, including both respiratory (snoring, inspiratory
111 efforts, exercise intolerance, syncope) and digestive signs (ptyalism, regurgitations, vomiting)
112 frequency and scaling from 1(mild) to 3 (marked)⁷ Brachycephalic dogs can also suffer from
113 chronic enteropathy, and pugs are affected by a particularly severe form of protein-losing
114 enteropathy¹⁴. French bulldogs and English bulldogs might also be predisposed to food
115 responsive diarrhea and chronic flatulence (Freiche, unpublished observations). However, none
116 of these conditions appear to be related to BAOS.

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DIAGNOSIS OF DIGESTIVE DISEASES IN BRACHYCEPHALIC DOGS

Brachycephalic airway obstructive syndrome is known to be a progressive disease⁶. Age at presentation ranges from a few months to a few years, although BAOS is unlikely to develop for the first time in dogs older than 5 years⁹. Definitive diagnosis requires a systematic approach including history, physical examination, detailed clinicopathological investigations, diagnostic imaging and finally endoscopy to examine both the upper airways and digestive tract. The main diseases affecting the digestive system in brachycephalic dogs are listed in Box 3.

History and physical examination

Brachycephalic dogs can present with different combinations of clinical signs and, as a result, a detailed history is essential in order to accurately characterize the problem. Note that owner perception of the clinical signs in brachycephalic dogs is often unreliable^{2,15}, not least because owners often consider stertor, loud breathing and regurgitation to be normal for their dog. Clinical signs can be predominantly respiratory or consist of a mix of respiratory and digestive signs. Respiratory signs include dyspnea, stertor, stridor, increased respiratory effort, exercise intolerance, heat or stress intolerance and even cyanosis and collapse^{2,4,7,9}. Digestive signs are listed in Box 2. Acute vomiting and regurgitation episodes can occasionally be suggestive of pseudo-obstruction, where the clinical picture suggests mechanical obstruction of the digestive tract, but there is no demonstrable evidence of any such obstruction in the intestine. (REF)

It is important to specifically question owners about the presence of digestive signs, even if they do not volunteer this information, since they are usually present in most of the cases^{5,7,9,10}.

141 Physical examination should include an initial observation to determine the dog's phenotype (e.g.
142 examining the overall morphology of the dog, including skull dimensions and nares such as the
143 degree of stenosis), to evaluate of the respiratory cycle (especially the inspiratory effort) and to
144 listen for spontaneous respiratory noises. Tachypnea can often be noted at this stage⁹. Next, the
145 head and neck should be examined carefully. Given the particular anatomic conformation of
146 brachycephalic dogs, it can be difficult to examine their oral cavity because they often struggle to
147 breathe with their mouth wide open. Thoracic auscultation should then be performed, although
148 this can be challenging due to by the presence of loud referred upper respiratory tract noises.
149 Finally, the rest of the body should be examined although specific abnormalities are rarely
150 identified on physical exam in brachycephalic dogs with alimentary tract disease.

151

152 **Diagnostic approach**

153 Detailed diagnostic investigations are usually required in order to accurately diagnose alimentary
154 tract disease in brachycephalic dogs. They include clinical pathology, thoracic radiographs,
155 fluoroscopic assessment of swallowing function, and upper airway and gastrointestinal
156 endoscopy.

157

158 Clinical pathology

159 Hematological and biochemical assessments are recommended routinely. Arterial blood analysis
160 may be important when severe concurrent upper airway disease is present, however in most cases
161 partial pressure of carbon dioxide, blood pH and bicarbonate concentration obtained by venous
162 sample are sufficient⁹. In a recent prospective study, the systemic inflammatory response and
163 metabolic profile were evaluated in 30 brachycephalic dogs presenting with BAOS. Digestive
164 signs were present in many (77%) of these dogs; however, although there were variable

165 alterations both in their inflammatory and metabolic profiles (e.g. CRP, beta lipoproteins,
166 chylomicrons, fructosamine, and cholesterol), these were not associated with either clinical signs
167 or the anatomic abnormalities present⁷. In conclusion, no specific laboratory changes could be
168 identified in brachycephalic dogs with digestive disease.

169

170 Diagnostic imaging

171 *Radiographs*

172 Thoracic radiographs are indicated to assess for possible lower airway changes which, in
173 brachycephalic dogs, can include hypoplastic trachea and also pulmonary lesions (e.g. non-
174 cardiogenic pulmonary edema, and concurrent aspiration pneumonia). Alimentary tract
175 abnormalities such as esophageal deviation or dilation and HH can also be identified. A contrast
176 study may be useful although fluoroscopy is far more valuable than standard radiography, not
177 least if esophageal dilation is subtle or when sliding HH is suspected (Figure 2)¹⁰. Finally,
178 although unrelated to respiratory or alimentary tract signs, vertebral malformations are also
179 commonly observed.

180

181 *Fluoroscopy*

182 Video fluoroscopic swallow studies (VFSS) are the gold-standard test to investigate esophageal
183 motility disorders, and HH (Video 1)^{10,11,13,16,17}. In one study, esophageal dysmotility (ED) was
184 found to be more common in young brachycephalic dogs when compared to non-brachycephalic
185 dogs¹³. The most common abnormalities identified by VFSS include prolonged esophageal transit
186 time, morphological esophageal variations, decreased propagation of secondary peristaltic waves,
187 gastroesophageal reflux and HH¹³. Another study found that esophageal abnormalities and HH
188 were more common in French bulldogs than in brachycephalic dogs of other breeds¹⁰.

189

190 Abdominal ultrasound

191 Abdominal ultrasound is usually recommended in brachycephalic dogs to assess gastric wall
192 characteristics, particularly mucosal folds and the pyloric muscular layer (Figure 3), whilst
193 gastric motility can be assessed at the same time. Delayed vomiting of food might suggest gastric
194 retention and / or pyloric stenosis (Figure 4). Gastric stasis was present in 32% of the cases in a
195 prospective study recruiting 73 brachycephalic dogs with upper respiratory syndrome ⁷ .

196

197 Endoscopy

198 Endoscopy of both the upper respiratory and digestive tracts is required to obtain a complete
199 overview of abnormalities and to help guide management. As previously discussed, concurrent
200 digestive abnormalities can be found, even in dogs that do not present with any alimentary tract
201 signs^{7,9}. Delayed gastric emptying is often present even in the absence of pyloric stenosis⁷ . As a
202 result, it is advisable to withhold food for at least 14h prior to esophago-gastroduodenoscopy.
203 For the procedure, it is important to place the dog in left lateral recumbency since this will aid
204 intubation of the antrum and pylorus. Endoscopic examination enables direct examination of the
205 digestive mucosa and collection of standardized gastric and duodenal biopsy samples. At least 6
206 biopsies per site are needed for histopathologic analysis. Esophageal biopsies are usually not
207 feasible in dogs with a normal or only mildly abnormal mucosa. It is advisable to formally
208 record any findings and use of the WSAVA endoscopic scoring system is recommended¹⁸ . Table
209 1 summarizes the alimentary tract endoscopic findings in brachycephalic dogs.

210

211

212 *Esophageal lesions:* esophageal inflammatory lesions are most frequently localized and display a
213 “star pattern” as illustrated by **Figure 5**. They reflect both chronic gastroesophageal reflux and
214 atony of the lower esophageal sphincter (**Video 2**). Esophageal luminal contents are often present,
215 including food, gastric juice and saliva (**Video 3**). Esophageal redundancy is quite common in
216 brachycephalic dogs and, in some cases, deviation is so pronounced that existence of a persistent
217 fourth aortic arch may be suspected.

218 In a recent pilot study of 20 BAOS dogs, the presence of both sliding HH and gastro-esophageal
219 junction abnormalities were under-estimated during endoscopy, whilst performing manipulations
220 to increase the transdiaphragmatic pressure gradient (e.g. manual pressure on the cranial
221 abdomen, moving into the Trendelenburg position [30° angle], or temporary complete
222 endotracheal tube obstruction) during endoscopy improved the chances of identifying them^{11, 10}.
223 Of the manipulations evaluated, temporary complete endotracheal tube obstruction was the most
224 likely to enable identification of gastro-esophageal junction abnormalities including sliding HH.
225 Although no complications were identified in the study, some anesthetists have been concerned
226 about the safety of such a manipulation (German, unpublished observations).

227
228 *Gastric lesions:* Diffuse, non-specific inflammatory lesions are often reported. Various degrees
229 of discoloration, erythema or edema of the gastric mucosa can be observed. In one recent study,
230 a strong positive association was established between inspiratory dyspnea and chronic gastritis
231 with lymphofollicular hyperplasia in dogs^{19,20}. Lymphofollicular hyperplasia was also recently
232 reported in another study⁷. Characteristic gastric lesions are illustrated in **Figures 6 and 7**. It is
233 also common to identify differences in pyloric conformation in brachycephalic dogs, compared
234 with other breeds, most notably prominent mucosal folds surrounding the pyloric canal, even
235 without any confirmed pyloric stenosis (**Figure 8**). This finding is reported to occur in

236 brachycephalic dogs presented with frequent vomiting of food, retarded growth and chronic
237 gastric dilation²¹. In such cases, retrograde peristaltic waves can be identified during the
238 endoscopic procedure (Video 4).

239
240 *Duodenal lesions:* Although duodenal lesions can be observed, the duodenal mucosa is usually
241 unremarkable in brachycephalic dogs (Figure 9). In the authors' experience, a 'rice-grain'
242 appearance to the mucosa attributed to dilated lacteals is often seen, even though the dogs do not
243 show any clinical sign of protein-losing enteropathy such as diarrhea or hypoalbuminemia. The
244 significance of this finding is unclear.

245

246 **TREATMENT OF DIGESTIVE DISEASES IN BRACHYCEPHALIC DOGS**

247 Management of brachycephalic dogs with digestive signs typically involves medical management
248 (including dietary modifications and pharmaceutical agents) and surgical management in cases of
249 HH that remains unresponsive to medical management.

250

251 **Medical treatment**

252 Dietary modifications that can be helpful include altering the type of food (e.g. wet food rather
253 than dry food; feeding food with less fiber and fat), its consistency (e.g. adding water), and meal
254 pattern (e.g. feeding the daily requirement over a number of small meals). These adjustments are
255 designed to promote passage of food through the digestive tract, thereby reducing the tendency
256 for regurgitation, vomiting or gastro-esophageal reflux.

257 The drugs most often used in brachycephalic dogs with alimentary tract disease include anti-
258 emetics, acid-blocking drugs, mucosal 'protectants' and prokinetic agents. Since robust clinical
259 trials on the efficacy of these drugs have not yet been performed, therapies are usually a matter of

260 personal preference of the attending clinician. Where there is evidence of esophagitis (e.g.
261 secondary to gastro-esophageal reflux or HH), acid blocking drugs and mucosal protectants (e.g.
262 sucralfate) are indicated. The authors favor proton pump inhibitors (e.g. omeprazole at 1 mg/kg
263 q12h PO) over H₂ antagonists for gastric acid suppression. Occasionally, ranitidine is
264 recommended based on its putative gastric prokinetic activity on account of the fact that they
265 inhibit acetylcholinesterase activity.²² However, it is unlikely to have any effect in the esophagus
266 given the predominance of skeletal muscle in this site²³. Anti-emetics, usually either maropitant
267 or metoclopramide, can be used in dogs with confirmed vomiting. The use of metoclopramide is
268 controversial given the reported effects on lower esophageal sphincter tone,²⁴ although this effect
269 has not been confirmed in other work.²⁵ It is unclear as to whether such effects will be of benefits
270 or be detrimental. Table 2 summarizes the options available to medically manage digestive
271 diseases in brachycephalic dogs

272 Whatever treatments are selected, care should be taken with owners administering pills orally,
273 since many brachycephalic dogs do not like having their mouth opened. Forcible drug
274 administration might also cause nausea, salivation or vomiting. One further problem with
275 administering medications via the oral route is the fact that transit might be impaired in the
276 presence of esophageal dysmotility and HH, so that orally administered drugs might be retained
277 within the esophagus for prolonged periods.

278

279 **Surgical treatment**

280 Surgical treatment of digestive diseases is rarely needed. As previously mentioned, BAOS
281 corrective surgery is followed by improvement of digestive clinical signs in many cases^{3,8,9,15}.
282 The two main indications for surgery include pyloric stenosis and permanent HH . In the first
283 case, clinical signs include gastric dilation or distention and frequent vomiting of food long after

284 a meal that do not respond to medical treatment. *Hiatal hernia*: as previously mentioned, HH can
285 be an acquired condition due to BAOS. The main clinical signs include chronic vomiting,
286 regurgitation, weakness, odynophagia, and other complications such as aspiration pneumonia.

287

288 *Pyloric stenosis surgical treatment.*

289 Pyloric stenosis in brachycephalic dogs results from a benign outlet gastric obstruction. As
290 previously illustrated, brachycephalic dogs generally show a typical pylorus, surrounded with
291 hyperplastic mucosal folds. During endoscopic procedure, passing through the pylorus is often
292 challenging in those breeds, even in the absence of stenosis. In a small percentage of cases,
293 clinical signs and ultrasonography confirm the stenosis. Different surgical procedures are
294 performed, depending on the severity of the disease but all the procedure focused on removing
295 outflow obstruction, normalizing gastric outflow and decreasing gastric emptying time^{13,26}.

296 Corrective surgical techniques include Y-U pyloroplasty and modified Finney Jabouley
297 pyloroplasty.¹⁶ Y-U pyloroplasty is generally indicated in cases of mucosal or combined mucosal
298 and muscular hypertrophy (Figure 10). Modified Finney Jabouley pyloroplasty can be performed
299 after exclusion of pyloric neoplastic lesions²⁶. It provides a direct communication between the
300 antrum and the duodenum (antroduodenostomy, without pylorotomy) and is indicated in case of
301 severe thickening and inflammation of the pylorus (Video 5).

302

303 *Hiatal hernia surgical treatment.*

304 Several surgical techniques are described for hiatal hernias surgical treatment. The most
305 commonly used technique in combinaison or alone are left-sided gastropexy, esophagopexy, and
306 phrenoplasty (diaphragmatic hiatal reduction).²⁶

307

308 Post-operative medical therapy include proton-pump inhibitors sucralfate, and maropitant or
309 metoclopramide to prevent vomiting and/or nausea (see Table 2). In one prospective study, some
310 dogs still displayed digestive clinical signs postoperatively¹⁶.

311

312 **FOLLOW-UP AND PROGNOSIS**

313 The prognosis of brachycephalic dogs with alimentary tract disease is difficult to determine
314 precisely due to the variability in their presentation and the concurrent respiratory
315 pathology^{2,3,12,15}. All features of each individual case should be considered. The overall
316 prognosis depends on both severity and extent of all identified lesions. The digestive signs of
317 dogs with BAOS usually respond well to medical treatment. Further, studies have reported
318 improvement of respiratory and digestive signs following airway corrective surgery in about 90%
319 of dogs^{2,3,8}. However, postoperative vomiting, dyspnea and regurgitation have also been
320 reported following BAOS-corrective surgery^{3,7,12,20}, therefore the owners need to be advised of
321 the possible complications prior to providing their consent.

322

323 **CONCLUSION**

324 Brachycephalic dogs are predisposed not only to upper respiratory tract disease, but also to
325 diseases affecting the alimentary tract. Association of respiratory and digestive signs is due to
326 breed-related anatomical characteristics (e.g. esophageal redundancy) and to increased negative
327 intra-thoracic pressure that occurs during the breathing cycle. It is important for the veterinarian
328 to perform a detailed diagnostic investigation in brachycephalic dogs presenting with either
329 respiratory signs, digestive signs or both, in order to design a plan to optimally manage each
330 individual patient. Although medical management to treat esophagitis is often the mainstay for
331 digestive signs, a surgical approach may be required for treatment of HH in dogs that do not

332 respond well to medical therapy. In addition, BAOS corrective surgery often has beneficial
333 effects on digestive signs as well in brachycephalic dogs.

334

335

336 References

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340

341 **Figure legends**

342

343 **Figure 1.** Signs of brachycephalic airway obstructive syndrome in a young English bulldog; soft
344 palate hyperplasia (red arrow) and everted tonsils are present (green arrows). Note also
345 hyperplasia of mucosal folds and aberrant tooth implantation (orange arrows). The dog also had
346 macroglossia and everted laryngeal sacculae but these are not clearly evident in the photograph.

347

348 **Figure 2.** Severe redundant esophagus in an English Bulldog (red arrow). Despite the tortuous
349 nature of the esophagus in the cranial mediastinum, no persistent right aortic arch was detected in
350 this dog (Courtesy Dr. Juan Hernandez).

351

352 **Figure 3.** Abdominal ultrasonography in a 3 y.o. spayed female Boston Terrier presented with
353 chronic vomiting. The gastric wall is thickened, and mucosal folds (red arrows) are prominent
354 (Courtesy ENVA Diagnostic Imaging Department).

355

356 **Figure 4.** Ultrasonographic appearance of the pylorus (red arrow) in a young brachycephalic dog
357 that presented with chronic vomiting containing partially digested food. Pyloric stenosis was
358 confirmed at exploratory celiotomy.

359

360 **Figure 5.** Upper digestive endoscopy in an English bulldog dog with chronic vomiting and
361 regurgitation. There is evidence of a “star pattern” in the distal esophagus, where stripes of
362 hyperemia can be seen radiating outwards from the lower esophageal sphincter (blue arrows).

363

364 **Figure 6.** Gastroscopy image from a French bulldog presented for BAOS upper airway surgery.
365 Despite the fact that no alimentary tract signs were reported, severe edema is evident in the
366 mucosa of the lesser curvature (red arrow).

367

368 **Figure 7.** Gastroscopy performed in a 3 y.o. male French bulldog. Multiple small gray-to-red
369 punctiform areas are present (red arrows) scattered over the gastric mucosal surface. This pattern
370 is consistent with lymphofollicular hyperplasia.

371

372 **Figure 8.** Typical endoscopic appearance of the pylorus in brachycephalic dogs. The pylorus is
373 protuberant and thickened (red arrow), but no stenosis is evident. Despite this, it can often be
374 difficult to pass an endoscope through to the duodenum.

375

376 **Figure 9.** Duodenoscopy in a brachycephalic dog with BAOS and presented for investigation of
377 the alimentary tract. There is marked thickening and granularity of the gastric mucosa.

378

379 ~~Figure 11: Y-U pyloroplasty in a brachycephalic dog presented for frequent vomiting and~~
380 ~~gastric retention. Photo: courtesy of Dr Mathieu Manassero.~~

381
382 - Figure 10: Pyloric stenosis in a 2-year-old female French bulldog that was vomiting on a daily
383 basis. A: During the endoscopic procedure, the pylorus appeared hyperplastic and abnormal (red
384 arrow) and neoplasia was excluded on the basis of histopathological examination

385

386 **Video legend**

387

388 - Video 1: Esophageal fluoroscopic study in a 2 y.o female Boston terrier presented for chronic
389 intermittent dysphagia and regurgitation. A sliding hiatal hernia is evident.

390

391 - Video 2: The association between respiratory tract and alimentary tract signs in brachycephalic
392 dogs is illustrated in this case. The tip of the endoscope is located between the heart base and the
393 lower esophageal sphincter (LES). Atony of the LES is visible and the gastroesophageal opening
394 gets wider during inspiration.

395

396 - Video 3: Esophagoscopy in a young French bulldog presented with regurgitation. The tip of the
397 endoscope is shown advancing towards the lower esophageal sphincter (LES). The esophagus is
398 filled with gastric fluid containing partially digested food and atony of the LES is observed.

399 Presence of gastric content was attributed to chronic LES atony.

400

401 - Video 4: Gastroscopy in a French Bulldog. The pylorus is surrounded by thickened mucosal
402 folds, whilst the antrum is discolored and mucosal edema is present. Anti-peristaltic waves can
403 also be observed during the procedure.

404

405 - Video 5: Endoscopy of the pylorus in a young French bulldog presented with vomiting on a
406 daily basis. The tip of the endoscope is located in the gastric antrum. The pylorus appears
407 hyperplastic and abnormal and neoplasia was excluded with histopathological examination.

408

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410

411 **Boxes and tables.**

412

413 Box 1: Most commonly encountered brachycephalic dog breeds.

414

<ul style="list-style-type: none">▪ English bulldog▪ French bulldog▪ Pug▪ Boston terrier▪ Mixed breeds	<ul style="list-style-type: none">▪ Shih tzu▪ Cavalier King Charles▪ Pekingese▪ Boxer▪ Dogue de Bordeaux▪ Bullmastiff▪ Chinese Shar Pei
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416

417 Box 2: Digestive signs observed in brachycephalic dogs.

<ul style="list-style-type: none">▪ Ptyalism▪ Regurgitation*▪ Retching▪ Vomiting▪ Dysphagia	<ul style="list-style-type: none">▪ Aerophagia▪ Gastroesophageal reflux▪ Pica▪ Pain-relieving positioning (including “prayer” posture)
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418 *may be exacerbated by exercise

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420

421 Box 3: Main alimentary tract diseases affecting brachycephalic dogs

<ul style="list-style-type: none"> ▪ Redundant esophagus (deviation) ▪ Esophagitis ▪ Gastroesophageal reflux ▪ Sliding hiatal hernia (type 1) ▪ Delayed gastric emptying 	<ul style="list-style-type: none"> ▪ Gastritis (potentially lymphofollicular) ▪ Pyloric mucosal folds hypertrophy ▪ Pyloric stenosis ▪ Duodenitis
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423

424 Table 1: Endoscopic lesions identified in brachycephalic dogs (adapted from Poncet et al)⁷

	Esophagus	Stomach	Duodenum
Inflammatory lesions	-Esophagitis (mainly distal)	- Non-specific gastritis (localized or diffuse) - Lymphofollicular gastritis	- Non-specific duodenitis
Anatomic or functional disorder	- Redundant esophagus - Gastroesophageal reflux (frequent) - Hiatal hernia	- Cardiac atony (rare) - Delayed gastric emptying - Pyloric mucosal hyperplasia - Pyloric stenosis - Pyloric atony (very rare)	- None

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427

428 Table 2. Medical treatments usually recommended for digestive diseases in brachycephalic dogs.

Molecule	Pharmacological class	Dosage	Potential side effects
Metoclopramide	Dopamine (D2) receptor antagonist Anti-emetic	0.25-0.50 mg/kg PO q8h	Extrapyramidal neurological signs (rare)
Maropitant citrate	NK-1 receptor antagonist Anti-emetic	2 mg/kg PO q24h 1 mg/kg SC, IV q24h	Transient pain at injection site
Aluminium hydroxide Sodium alginate Sucralfate	Mucosal protectants	0.5 -1.0 ml/kg PO q8h 1 ml/kg PO q8h 0.5-2.0 g/dog PO q8h	Constipation Ptyalism
Cimetidine ¹ Ranitidine Famotidine	H2 Antagonists	5-10 mg/kg TID PO 2 mg/kg PO q8-12h 0.5-1.0 mg/kg PO q12- 24h	Drug interactions ²
- Omeprazole - Pantoprazole - Esomeprazole	Proton pump inhibitors	1mg/kg PO q12h	Intestinal dysbiosis

430

431 ¹ Although cimetidine is not commonly used in most countries, it is licensed for use in dogs in
432 Europe. As such, veterinarians in the UK are obliged to use it as a first line agent according to
433 the prescribing cascade for veterinary medicines.

434 ² H2 antagonists can decrease hepatic microsomal enzyme systems to varying degrees and ,
435 theoretically at least might decrease hepatic metabolism of drugs including: benzodiazepines,
436 barbiturates, propranolol, calcium channel blockers, metronidazole, phenytoin, theophylline and
437 warfarin. However, the clinical significance of this effect has not been established.

438

- 440 1. Packer, R. M. & Tivers, M. S. Strategies for the management and prevention of conformation-
441 related respiratory disorders in brachycephalic dogs. *Vet Medicine Auckl N Z* **6**, 219–232 (2015).
- 442 2. Dupré, G. & Heidenreich, D. Brachycephalic Syndrome. *Vet Clin North Am Small Animal*
443 *Pract* **46**, 691–707 (2016).
- 444 3. Haimel, G. & Dupré, G. Brachycephalic airway syndrome: a comparative study between pugs
445 and French bulldogs. *J Small Anim Pract* **56**, 714–719 (2015).
- 446 4. Fasanella, F. J., Shivley, J. M., Wardlaw, J. L. & Givaruangsawat, S. Brachycephalic airway
447 obstructive syndrome in dogs: 90 cases (1991-2008). *J Am Vet Med Assoc* **237**, 1048–51 (2010).
- 448 5. Kaye, B. M., Rutherford, L., Perridge, D. J. & Haar, G. T. Relationship between
449 brachycephalic airway syndrome and gastrointestinal signs in three breeds of dog. *J Small Animal*
450 *Pract* **59**, 670–673 (2018).
- 451 6. Roedler, F. S., Pohl, S. & Oechtering, G. U. How does severe brachycephaly affect dog's
452 lives? Results of a structured preoperative owner questionnaire. *Vet J Lond Engl 1997* **198**, 606–
453 10 (2013).
- 454 7. Poncet, C. M. *et al.* Prevalence of gastrointestinal tract lesions in 73 brachycephalic dogs with
455 upper respiratory syndrome. *J Small Anim Pract* **46**, 273–279 (2005).
- 456 8. Poncet, C. M., Dupre, G. P., Freiche, V. G. & Bouvy, B. M. Long-term results of upper
457 respiratory syndrome surgery and gastrointestinal tract medical treatment in 51 brachycephalic
458 dogs. *J Small Anim Pract* **47**, 137–142 (2006).
- 459 9. Lodato, D. L. & Hedlund, C. S. Brachycephalic airway syndrome: pathophysiology and
460 diagnosis. *Compend Yardley Pa* **34**, E3 (2012).
- 461 10. Reeve, E. J., Sutton, D., Friend, E. J. & Warren-Smith, C. M. R. Documenting the prevalence
462 of hiatal hernia and oesophageal abnormalities in brachycephalic dogs using fluoroscopy. *J Small*
463 *Anim Pract* **58**, 703–708 (2017).
- 464 11. Broux, O. *et al.* Effects of manipulations to detect sliding hiatal hernia in dogs with
465 brachycephalic airway obstructive syndrome. *Vet Surg* **47**, 243–251 (2017).
- 466 12. Fenner, J. V. H., Quinn, R. J. & Demetriou, J. L. Postoperative regurgitation in dogs after
467 upper airway surgery to treat brachycephalic obstructive airway syndrome: 258 cases (2013-
468 2017). *Vet Surg Vs* **49**, 53–60 (2019).
- 469 13. Eivers, C., Rueda, R. C., Liuti, T. & Schmitz, S. S. Retrospective analysis of esophageal
470 imaging features in brachycephalic versus non-brachycephalic dogs based on videofluoroscopic
471 swallowing studies. *J Vet Intern Med* **33**, 1740–1746 (2019).

- 472 14. S, S., DJ, B., S, C. & al., et. The pug breed demonstrates a worse response to treatment of
473 protein-losing enteropathy than other breeds of dog. *JVIM* (2020).
- 474 15. Freiche, C. P. & V. Kirk's Current Veterinary Therapy XV. in vol. 1 649–658 (n.d.).
- 475 16. Mayhew, P. D., Marks, S. L., Pollard, R., Culp, W. T. N. & Kass, P. H. Prospective
476 evaluation of surgical management of sliding hiatal hernia and gastroesophageal reflux in dogs.
477 *Vet Surg Vs* **46**, 1098–1109 (2017).
- 478 17. Pollard, R. E., Johnson, L. R. & Marks, S. L. The prevalence of dynamic pharyngeal collapse
479 is high in brachycephalic dogs undergoing videofluoroscopy. *Vet Radiol Ultrasoun* **59**, 529–534
480 (2018).
- 481 18. Washabau, R. J. *et al.* Endoscopic, Biopsy, and Histopathologic Guidelines for the Evaluation
482 of Gastrointestinal Inflammation in Companion Animals. *J Vet Intern Med* **24**, 10 26 (2010).
- 483 19. Faucher, M. R., Biourge, V., German, A. J. & Freiche, V. Comparison of clinical,
484 endoscopic, and histologic features between dogs with chronic gastritis with and without
485 lymphofollicular hyperplasia. *J Am Vet Med Assoc* **256**, 906–913 (2020).
- 486 20. M.R., F., V., B., A.J., G. & V., F. Comparison of clinical, endoscopic, and histologic features
487 between dogs with chronic gastritis with and without lymphofollicular hyperplasia. *JAVMA*
488 (2020).
- 489 21. Aslanian, M. E., Sharp, C. R. & Garneau, M. S. Gastric dilatation and volvulus in a
490 brachycephalic dog with hiatal hernia. *J Small Animal Pract* **55**, 535–7 (2014).
- 491 22. Washabau RJ. Gastrointestinal motility disorders and gastrointestinal prokinetic therapy. *Vet*
492 *Clin Small Anim* **33**, 1007-1028 (2003).
- 493 23. Mann, C. V. & Shorter, R. G. Structure of the canine esophagus and its sphincters. *J Surg Res*
494 **4**, 160–163 (1964).
- 495 24. Dowling, P. M. Prokinetic drugs: metoclopramide and cisapride. *Can Vet J La Revue*
496 *Vétérinaire Can* **36**, 115–6 (1995).
- 497 25. Kempf J, Lewis F, Reusch CE, Kook PH. High-resolution manometric evaluation of the
498 effects of cisapride and metoclopramide hydrochloride administered orally on lower esophageal
499 sphincter pressure in awake dogs. *Am J Vet Res* **75**, 361-366 (2014)
- 500 26. Cornell K. Stomach. In: Veterinary Surgery Small Animal. KM Tobias, SA Johnston Eds).
501 Elsevier Saunders, St Louis, USA, pp. 1484-1512.