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The prevalence of dynamic pharyngeal collapse is high in brachycephalic dogs undergoing videofluoroscopy

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Abstract

The aim of this retrospective study was to determine the frequency of pharyngeal collapse in a large group of brachycephalic dogs undergoing videofluoroscopic assessment of swallowing or airway diameter. We hypothesized that brachycephalic dogs would have pharyngeal collapse more frequently than dolichocephalic or mesocephalic dogs with or without airway collapse. The medical records database was searched for brachycephalic dogs undergoing videofluoroscopy of swallowing or airway diameter between January 1, 2006 and December 31, 2015. A cohort of dolichocephalic/mesocephalic dogs with videofluoroscopically confirmed airway collapse was age and time matched for comparison. A control group of dolichocephalic/mesocephalic dogs that did not have documented airway collapse was also evaluated. All fluoroscopic studies were assessed by a board certified veterinary radiologist for the presence and degree of pharyngeal collapse. Results demonstrate that pharyngeal collapse was significantly more common in brachycephalic dogs (58/82; 72%) than in nonbrachycephalic dogs with (7/25; 28%) and without (2/30; 7%) airway collapse. Pharyngeal collapse is more prevalent in brachycephalic dogs undergoing videofluoroscopy than in dolichocephalic/mesocephalic dogs with or without airway collapse.

KEYWORDS
airway collapse, brachycephalic, fluoroscopy, pharyngeal collapse

1 | INTRODUCTION

Pharyngeal collapse is defined as partial or complete collapse of the pharynx due to dorsal displacement of the soft palate, ventral deviation of the dorsal pharyngeal wall, or a combination of both.[1] In people, pharyngeal collapse is considered a major component of obstructive sleep apnea syndrome, which is likely the result of a combination of anatomic abnormalities and pharyngeal dilator myopathies.[2–4] It is unclear whether pharyngeal collapse is a part of the cause or a result of abnormal pharyngeal pressures in people with obstructive sleep apnea. Diagnosis of pharyngeal collapse is made using gated computed tomography, magnetic resonance imaging, or videofluoroscopy.[4,5]

Pharyngeal collapse is sparsely documented in veterinary patients,[6–13] but at least one study has suggested that most dogs with videofluoroscopic evidence of pharyngeal collapse also had airway collapse in other parts of the respiratory tract.[14] Rubin et al. determined that 27 of 28 dogs with pharyngeal collapse suffered from concurrent diseases, including mainstem bronchial collapse, tracheal collapse, or brachycephalic obstructive airway syndrome. Chronic upper airway obstruction from brachycephalic obstructive airway syndrome (stenotic nares, soft palate elongation, and laryngeal saccule eversion) results in increased inspiratory effort, which is speculated to reduce pharyngeal dilator muscle function and predispose to pharyngeal collapse in affected dogs.[6–8] In the previously described study, authors reported that 28.6% of brachycephalic dogs undergoing fluoroscopic imaging of the airways had pharyngeal collapse in comparison to 13.3% of mesocephalic or dolichocephalic dogs. As with people, it is unclear whether pharyngeal collapse is a result of abnormal pharyngeal pressure generated by airway collapse of any origin or if it is a part of the problem to begin with.

Anecdotally, we have perceived that pharyngeal collapse occurs in a high percentage of brachycephalic breeds. The purpose of this retrospective study was to evaluate airway and swallowing videofluoroscopic studies for the presence of pharyngeal collapse in a large cohort of dogs representing breeds prone to brachycephalic obstructive airway syndrome and to compare the frequency to that found in dogs representing breeds not prone to brachycephalic obstructive airway syndrome with and without airway collapse. We hypothesized that the frequency of pharyngeal collapse would exceed 50% in brachycephalic dogs prone to brachycephalic obstructive airway syndrome.

This study was presented in part at the annual meeting of the European College of Veterinary Diagnostic Imaging, Verona, Italy 2017.

2 | MATERIALS AND METHODS

2.1 | Criteria for selection of cases

Medical records of dogs prone to brachycephalic obstructive airway syndrome (brachycephalic airway syndrome)[14] (English Bulldogs, French Bulldogs, Pugs, Boston Terriers, and Pekingese) that underwent videofluoroscopic assessment of airway diameter or swallowing at the University of California, Davis, Veterinary Medical Teaching Hospital over a 10-year period between January 2006 and January 2016 were retrospectively reviewed (L.R.J. and S.L.M.). An animal care and use protocol was not required due to this being a retrospective study. A control cohort of nonbrachycephalic dogs with airway collapse was date matched for comparison, all of which were undergoing airway fluoroscopy to confirm the presence of tracheobronchomalacia and airway collapse. A control group of nonbrachycephalic dogs that did not have documented airway collapse and which were undergoing videofluoroscopic assessment of swallowing for dysphagia or regurgitation was also included. The final diagnosis was variable in this group and included dogs with diseases such as gastroesophageal reflux, sliding hiatal hernia, esophageal dysmotility, esophageal stricture, and cricopharyngeal asynchrony. Both control group sizes were arbitrarily set at 25–30 dogs to allow for adequate patient number without evaluating all imaging studies done during the study timeframe. For inclusion in this study, the videofluoroscopic evaluation had to be available for review, follow standardized image acquisition techniques (see below), and include adequate assessment of the pharynx without motion or active swallowing based upon evaluation by a board certified veterinary radiologist (R.E.P.). Information gathered from the medical records included age, breed, weight, body condition score, gender, neutering status, presenting complaint, duration and type of clinical signs, and presence or absence of airway collapse.

Group assignments included brachycephalic dogs (Group 1) and nonbrachycephalic dogs with (Group 2A) and without (Group 2B) airway collapse. Brachycephalic dogs were further evaluated based on breed assignment. Dogs in all groups were further segregated based on the presence and absence of pharyngeal collapse.

2.2 | Imaging assessment

Dogs underwent videofluoroscopic imaging while fully awake regardless of study type. Contrast videofluoroscopic assessment of swallowing was performed using a standardized institutional protocol. Sixty percent w/v liquid barium sulfate (Novopaque, LPI Diagnostics, Yorba Linda, CA) was the contrast medium used for all studies. Dogs were manually restrained in right lateral recumbency by trained imaging personnel and were imaged using a standard fluoroscopy unit (EasyDiagnost Eleva, Philips Medical Systems, N.A., Bothell, WA). Protective gear including leaded gloves, aprons, thyroid shields, and glasses were worn by all personnel present in the imaging suite as per institutional guidelines. Radiation detection devices were worn and no excessive exposure was reported at any time when monthly radiation dosage levels were examined. For the liquid barium swallows, boluses of 3–5 ml were injected into the dogs' mouth using a catheter tipped syringe while the fluoroscopic image was engaged. Collimation was used to minimize exposure to personnel. Attempts at standardizing bolus size were not made. For the barium coated kibble swallows, dogs were encouraged to voluntarily ingest a solid bolus of any size while in lateral recumbency. However, if the animal failed to swallow voluntarily while in lateral recumbency, a bolus consisting of five or six kibbles was placed into the dog's mouth and the mouth was held closed until a swallow was observed. Again, attempts at standardizing bolus size were not made. At least three swallows and often up to eight swallows of both liquid and kibble were observed, with at least one bolus of each consistency followed into the stomach.

Airway fluoroscopy (EasyDiagnost Eleva, Philips Medical Systems, N.A., Bothell, WA) was performed with the dog positioned in right lateral recumbency during tidal respiration and following tracheal manipulation to induce a cough. The entire airway was included so that the cervical and intrathoracic trachea and mainstem bronchi could be evaluated for evidence of collapse.

All videofluoroscopic imaging studies were reviewed by a board certified veterinary radiologist (R.E.P.) who was masked to the patient background and the initial interpretation of the study. Studies were viewed in a commercially available viewing system (Quicktime, Apple, Inc. Cupertino, CA) at a frame rate of 30 frames per second. The presence or absence of pharyngeal collapse was recorded during a portion of the study, where dogs were breathing normally and not actively swallowing. When present, pharyngeal collapse was defined as complete (total loss of the pharyngeal air column) or partial (luminal collapse of >50% but less than 100%) based upon visual estimation of pharyngeal area as previously reported.[15]

2.3 | Statistical analysis

Statistical analysis was performed by one of the authors (L.R.J.). Clinical data including age, weight, body condition score, and duration of clinical signs were assessed for normality using D'Agostino & Pearson omnibus testing (GraphPad Prism 5.0f, San Diego, CA). Data that were normally distributed are presented as mean ± standard deviation and differences among groups were evaluated using analysis of variance with post-hoc testing by Tukey's Multiple Comparison testing or with Student's *t*-test. Nonparametric data are presented as median with range and were compared using the Kruskal–Wallis test with Dunn's multiple comparison test for post-hoc analysis or with the Mann–Whitney *U* test.

Age, weight, and body condition score were compared between Groups 1, 2A, and 2B and between dogs with and without pharyngeal collapse. Duration of clinical signs was also compared between dogs with and without pharyngeal collapse. Number of brachycephalic dogs with pharyngeal collapse was compared to nonbrachycephalic dogs with pharyngeal collapse using Fisher's exact test. Presentation for gastrointestinal vs. respiratory imaging was compared for groups with and without pharyngeal collapse using Fisher's exact test. For all analysis, significance was set at $P < 0.05$.

3 | RESULTS

A total of 137 dogs were included in the study. In 89 of 137 dogs (65%), an esophageal videofluoroscopic swallow study was performed for investigation of vomiting, regurgitation, recurrent aspiration, or a combination of signs. In 48 of 137 dogs (35%), airway videofluoroscopy had been completed for evaluation of cough. Dynamic pharyngeal collapse was identified via videofluoroscopy in 66 of 137 dogs (48%), while 71 of 137 dogs (52%) had no evidence of collapse. Of the dogs with pharyngeal collapse, 21 of 66 (32%) had partial (Figure 1) and 45 of 66 (68%) had complete (Figure 2) collapse. Clinical data for all dogs are presented in Table 1.

Group 1 included 82 brachycephalic dogs, 59 (72%) of which underwent videofluoroscopic assessment of swallowing and 23 (28%) of which underwent videofluoroscopy of the airways. There were nine intact female, 20 spayed female, 24 intact male, and 29 neutered male dogs. Pharyngeal collapse was documented in two of eight (25%) Boston Terriers, 19 of 22 (86%) English Bulldogs, 18 of 21 (86%) French Bulldogs, 0 of four Pekingese, and 18 of 27 (67%) Pugs. Group 2A included 25 nonbrachycephalic dogs that underwent videofluoroscopy of the airways and were confirmed to have airway collapse. There were two intact female, 10 spayed female, one intact male, and 12 neutered male dogs. Pharyngeal collapse was documented in one of five (20%) Yorkshire Terriers, two of five (40%) Pomeranians, one of three (33%) Chihuahuas, 0 of two Maltese, 0 of two Jack Russell Terriers, two of two Poodles, and 0 of one each Rat Terrier, Dachshund, Fox Terrier, Papillon, Beagle, and mixed breed dog. Group 2B included 30 dogs that underwent videofluroscopic assessment of swallowing but had no evidence of or clinical suspicion for airway collapse. This group had five more dogs than the other control group because all 30 studies that were evaluated met the inclusion criteria. There were two intact female, 12 spayed female, one intact male, and 15 neutered male dogs. Pharyngeal collapse was documented in 0 of three Labrador Retrievers, 0 of three Poodles, 0 of three mixed breed dogs, two of two Chow Chows, 0 of two Dachshunds, 0 of two Border Collies, 0 of two Cavalier King Charles Spaniels, and 0 of one each Yorkshire Terrier, Beagle, Airedale, Manchester Terrier, Australian Shepherd, Pit bull, Corgi, Sheltie, Malinois, Coton de Tulear, Cairn Terrier, and Rottweiler. Clinical data comparisons between the three groups are presented in Table 2.

4 | DISCUSSION

Results of this study validate our hypothesis and indicate that 72% of dogs prone to brachycephalic obstructive airway syndrome that undergo swallowing or airway videofluoroscopy have evidence of

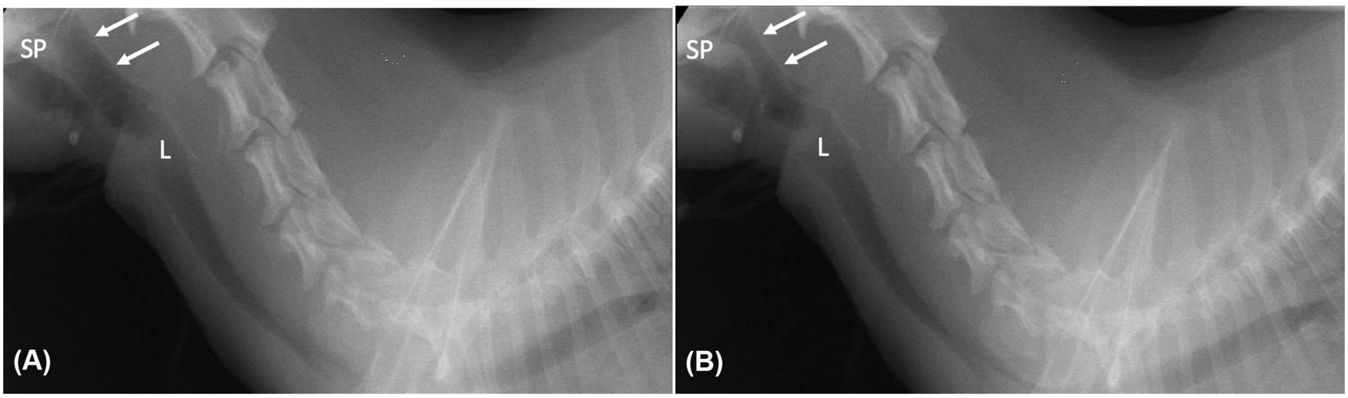

FIGURE 1 A, A lateral radiograph of the cervical region of a Yorkshire Terrier is shown during expiration, where an open air column can be seen in the nasopharynx (arrows) and the oropharynx ventral to the soft palate. B, An inspiratory radiograph of the same dog as in (A) shows partial (>50% but <100% reduction in air column height) collapse of the nasopharynx (arrows) but an open oropharynx. SP, soft palate; L, larynx

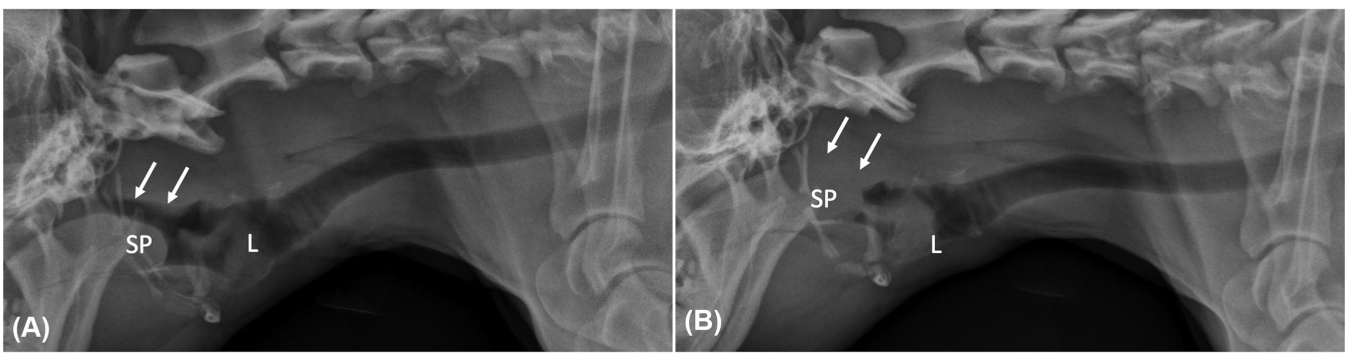

FIGURE 2 A, A lateral radiograph of the cervical region of a French Bulldog is shown during expiration, where an open air column can be seen in the nasopharynx (arrows). Note that the oropharynx is attenuated, likely as a result of the severely thickened soft palate. B, An inspiratory radiograph of the same dog as in (A) shows complete collapse of the nasopharynx (arrows) and continued attenuation of the oropharynx. SP, soft palate; L, larynx

TABLE 1 Clinical data (median and range) for dogs with (*n* = 66) and without (*n* = 71) pharyngeal collapse

	PC	No PC	*P*-value
Age (years)	4.0 (0.5–16.0)	3.0 (0.25–17.0)	0.64
Weight (kg)	10.3 (3–26.6)	8.5 (1.3–47.7)	0.012
BCS/9	5.6 ± 1.5	4.8 ± 1.4	0.002
Number brachycephalic (%)	58/66 (88)	24/71 (34)	<0.0001
Presentation for swallowing study	43/89	46/89	0.86
Presentation for respiratory imaging	22/48	26/48	0.86
Gender (F/FS/M/MC)	3/16/23/23	13/21/5/32	0.33
Duration of signs (days)	180 (3–1825)	150 (1–3000)	0.82

Notes. BCS, body condition score; FS, female spayed; MC, male castrated; PC, pharyngeal collapse.

TABLE 2 Clinical data (median and range) for Group 1 (brachycephalic dogs), Group 2A (meso or dolichocephalic dogs with airway collapse), and Group 2B (meso or dolichocephalic dogs without airway collapse)

	Group 1 (*n* = 82)	Group 2A (*n* = 25)	Group 2B (*n* = 30)	*P*-value
Age (years)	3.0 (0.25–16.0)[a]	9.0 (1.0–17.0)[b]	1.5 (0.5–9.0)[a, b]	< 0.0001
Weight (kg)	9.7 (2.0–26.6)[a]	4.6 (1.3–15.0)[b]	15.2 (1.6–47.7)[c]	<0.0001
BCS/9	5.3 ± 1.6[a]	6.0 ± 1.1[b]	4.5 ± 1.0[c]	0.009
PC present	58/82 (71%)[a]	7/25 (28%)[b]	2/30 (7%)[b]	<0.0001

Notes. Letters in superscript that vary within a row represent significant differences among groups.
BCS, body condition score; PC, pharyngeal collapse.

pharyngeal collapse. In people, facial shape and brachycephaly in particular are associated with obstructive sleep apnea syndrome and pharyngeal collapse.[16] Several publications have suggested a link between brachycephaly and pharyngeal collapse in dogs but the exact incidence has never been defined.[6–9,15] While our population does not directly reflect the population at large, these results would suggest that pharyngeal collapse is truly common in brachycephalic dogs.

Moreover, our data indicate that certain brachycephalic breeds, including the English Bulldog, French Bulldog, and Pug, appear more predisposed to pharyngeal collapse while others, such as the Pekingese and Boston Terriers, are not. One possible explanation for this is related to the classification of the English Bulldog, French Bulldog, and Pug as “extremely” brachycephalic based upon ratios of skull width to length[17,18] and the relatively higher frequency with which these breeds have brachycephalic obstructive airway syndrome.[19,20] Regardless, it remains unclear whether pharyngeal collapse is a part of brachycephalic obstructive airway syndrome or the result of abnormal pharyngeal pressures generated as a result of brachycephalic obstructive airway syndrome.

When looking at all dogs in this study, 88% of those with pharyngeal collapse were brachycephalic. In addition, the incidence of pharyngeal collapse was significantly higher in brachycephalic dogs compared to nonbrachycephalic dogs with and without airway collapse. While the incidence of pharyngeal collapse was higher in nonbrachycephalic dogs with airway collapse relative to those without airway collapse, this was not statistically significant. These findings are different from a previous study where pharyngeal collapse was found to be most prevalent in dogs with tracheobronchial collapse and other forms of respiratory disease.[15] This may reflect a difference in the study population and inclusion criteria.

Clinical data differed among groups in this study. Body weight was significantly different with nonbrachycephalic dogs with airway collapse weighing the least and nonbrachycephalic dogs without airway collapse weighing the most (Table 2). This is most likely a reflection of the fact that airway collapse is most commonly detected in small breed dogs. Body condition score was significantly lower in nonbrachycephalic dogs without airway collapse. This correlates with the previously defined link among higher body condition score, airway collapse, and pharyngeal collapse.[15,21] Moreover, considering all dogs, body weight and body condition score were significantly higher in dogs with pharyngeal collapse than in those without (Table 1). Age was significantly lower in nonbrachycephalic dogs without airway collapse, which is likely a reflection of the selection of this group from dogs undergoing videofluoroscopic assessment of swallowing. At our institution, swallowing disorders are more frequently identified in younger dogs (unpublished data), while airway and pharyngeal collapse are more typical in older dogs.[15,21]

Interestingly, the duration of signs did not impact the presence or absence of pharyngeal collapse in dogs examined here. This could reflect inaccurate history taking or might indicate that pharyngeal collapse does not develop over time but instead can be a static phenomenon. Further study is required to determine if it might also be reversible with control of the primary disease process.

There are several limitations to this study. First, this is a retrospective study where clinical data were not available or standardized for every factor being assessed. More specifically, it was impossible to determine from the records exactly which dogs had brachycephalic obstructive airway syndrome and which did not. In addition, only a handful of nonbrachycephalic dogs with and without airway collapse were available as control groups. Had all dogs undergoing videofluoroscopy for airway or swallowing assessment been reviewed, a more comprehensive evaluation of the overall incidence of pharyngeal collapse could have been determined; however, this was not the goal of the study. Another limitation of this study is that it is unclear whether body position has an impact on the presence of pharyngeal collapse. As with other cases of pharyngeal collapse that have been described in the veterinary literature, dogs in the current study were imaged in lateral recumbency. Body position (lateral versus sternal) has been shown to effect esophageal transit time derived from videofluoroscopic swallowing assessment, although body position did not influence pharyngeal contraction or bolus transit time from the pharynx through the upper esophageal sphincter in healthy dogs.[22] Further studies are warranted to assess the effects of body position on the presence of pharyngeal collapse. Finally, the population studied included dogs that presented to a tertiary care veterinary hospital and might not directly represent the population as a whole. Therefore, the data presented may not reflect the incidence of pharyngeal collapse in brachycephalic and nonbrachycephalic dogs at large.

In conclusion, results of this study support that pharyngeal collapse is frequently seen in brachycephalic breeds with the English Bulldog, French Bulldog, and Pug being most commonly affected. The incidence of pharyngeal collapse appears to be higher in brachycephalic dogs relative to nonbrachycephalic dogs with and without airway collapse. We postulate that pharyngeal collapse is linked to brachycephalic obstructive airway syndrome but whether it is a component or sequela of the syndrome is unclear. As a result, caution should be used in assigning significance to this finding in brachycephalic dogs until further data can determine the role of pharyngeal collapse in airway obstruction. Prospective studies evaluating brachycephalic breeds with and without documented brachycephalic obstructive airway syndrome would be necessary to make this distinction.

LIST OF AUTHOR CONTRIBUTIONS

Category 1

- **(a)** Conception and Design: Pollard RE, Johnson LR, Marks SL
- **(b)** Acquisition of Data: Pollard RE, Johnson LR, Marks SL
- **(c)** Analysis and Interpretation of Data: Pollard RE, Johnson LR

Category 2

- **(a)** Drafting the Article: Pollard RE
- **(b)** Revising Article for Intellectual Content: Pollard RE, Johnson LR, Marks SL

Category 3

- **(a)** Final Approval of the Completed Article: Pollard RE, Johnson LR, Marks SL

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