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Tracheal Collapse and Bronchomalacia in Dogs: 58 Cases (7/2001–1/2008)

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Background: Tracheobronchomalacia is diagnosed in people by documentation of a reduction in airway diameter during bronchoscopy. While tracheal collapse in the dog has been well described in the literature, little information is available on bronchomalacia in the dog.

Hypotheses: Bronchomalacia is common in dogs with tracheal collapse, is associated with inflammatory airway disease, and is poorly documented radiographically.

Animals: One hundred and fifteen dogs admitted for evaluation for respiratory disease and examined by bronchoscopy.

Methods: Case-controlled, observational study. Dogs examined and having a bronchoscopic procedure performed by a single operator were separated into groups with and without visually identified airway collapse. Clinical parameters and bronchoalveolar lavage findings were compared between groups. Radiographs were reviewed in masked fashion to assess the sensitivity and specificity for detection of bronchomalacia.

Results: Tracheobronchomalacia was documented in 50% of dogs examined, with tracheal collapse in 21% and bronchomalacia in 47%. In dogs with bronchomalacia, collapse of the right middle (59%) and left cranial (52%) lung lobes was identified most commonly. Dogs with bronchomalacia were significantly more likely to display normal airway cytology and to have mitral regurgitation and cardiomegaly than dogs without airway collapse ($P < .05$). Radiographs were insensitive for detection of airway collapse.

Conclusions and Clinical Importance: Bronchomalacia was identified more commonly than tracheal collapse in this population of dogs, and documentation required bronchoscopy. This study could not confirm a role for airway inflammation in bronchomalacia, and further studies are required to determine the role of cardiomegaly in the disorder.

Key words: Bronchi; Canine; Respiratory tract endoscopy; Thoracic radiography.

Tracheal collapse is a common cause of cough in dogs and can affect the cervical region, intrathoracic segment, or most commonly both areas.[1,2] The correlate of this condition in people is tracheomalacia, a softening of tracheal cartilages, which can also affect the cervical or intrathoracic trachea, with most cases affecting the intrathoracic trachea.[3,4] In people, if the principal bronchi are also involved, the condition is known as tracheobronchomalacia, and if only the principal bronchi are involved, the syndrome is termed bronchomalacia. Malacic airway disease is a visual diagnosis characterized by >50% collapse of the airway segment during bronchoscopic assessment, and occurs as a primary or secondary condition in children or in adults.[3,5–7] As in dogs, the precise cause of weakness in the airway is not fully understood and may be related to softening of the cartilage associated with congenital disease, extrinsic compression, or chronic inflammation, or to alterations in elastic fibers.[5,8]

Bronchoscopy is the gold standard for documenting all types of airway collapse in people.[9] Various methods of diagnosis have been evaluated to confirm tracheal collapse in dogs. While radiography is a reasonable screening test for dogs with tracheal collapse, a recent study reported that static radiography underdiagnosed the frequency and underestimated the degree of tracheal collapse in comparison with fluoroscopy.[2] Although bronchoscopy requires anesthesia in animals, it is the most reliable method for documenting tracheal collapse and is currently the only technique available to visualize collapse of principal, lobar or sublobar bronchi accurately.

Bronchomalacia has not been characterized in the dog. We hypothesized that bronchomalacia would be a frequent finding in dogs with tracheal collapse and that bronchomalacia would be associated with concurrent inflammatory airway disease, as either a cause or effect of the collapse. We also anticipated that radiography would be useful in detecting tracheal collapse but would not be helpful in identifying bronchial or sublobar collapse.

Abbreviations:

BAL	bronchoalveolar lavage
BCS	body condition score
LB1	left cranial lobe
LB2	left caudal lobe
LPB	left principal bronchus
RB1	right cranial lobe
RB2	right middle lobe
RB3	accessory lung lobe
RB4	right caudal lobe
RPB	right principal bronchus

Materials and Methods

All dogs that were examined and had bronchoscopy performed by 1 of the authors (L.R.J.) from 7/2001 to 1/2008 were included in

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this study. Clinical features abstracted from the medical record included breed, sex, age, body weight, and body condition score (BCS). Cardiopulmonary auscultation findings were collated. Bronchoalveolar lavage (BAL) retrieval, total and differential cell counts, and microbiology reports were retrieved along with fluoroscopic and echocardiographic data where available. Dogs were divided into 2 groups based on the presence or absence of bronchoscopically detectable airway collapse. Dogs with airway collapse were further divided into those with and without tracheal collapse.

Bronchoscopic examination was performed under general anesthesia in all dogs. Dogs with tracheal size appropriate for a #7 endotracheal tube were intubated with a truncated endotracheal tube and maintained on gas anesthesia. Endoscopes used in these dogs included a 5.0 mm×55 cm fiberoptic endoscope[a] or a 5.3 mm×85 cm fiberoptic endoscope.[b] Dogs too small for a #7 endotracheal tube were maintained at a stable plane of anesthesia with a constant rate infusion of propofol at 6 μg/kg/min, and oxygenation was maintained by use of jet ventilation at a rate of 180 breaths/minute. A 3.8 mm×55 cm videoendoscope[c] was used in these dogs.

All bronchoscopic procedures were performed in standardized fashion. Grade of tracheal collapse was recorded according to a previously defined scheme based on the percent reduction in luminal size.[10] (Fig 1) The canine endobronchial map was used for examination and identification of lower airways.[11] Normal airway openings were recognized as round to ovoid in appearance and demonstrating minimal (subjectively <20%) variation in luminal size during phases of respiration. Airway collapse was visualized as >25% static flattening of lobar airways, circumferential narrowing or distortion of the normal round appearance of airway openings, or as dynamic changes in luminal diameter with respiration in sublobar and smaller airways. Collapse was reported at the left principal bronchus (LPB), left cranial lobe (LB1), or left caudal lobe (LB2) and the right principal bronchus (RPB), right cranial lobe (RB1), right middle lobe (RB2), accessory lung lobe (RB3), or right caudal lobe (RB4). Sublobar airway collapse was reported as focal or diffuse. Additional bronchoscopic findings were recorded to assist in documentation of disease including the presence of airway secretions, nodularity, hyperemia, or irregularity in the epithelial surface, dilatation of airways, and the presence of foreign bodies.

BAL for culture and cytology was completed by wedging the bronchoscope into the smallest airway visible followed by instillation and aspiration of warmed, sterile saline through the 2 mm biopsy channel of the endoscope. One to 4 lavages were performed as clinically indicated and the volume recovered was recorded for each separate lavage. Cytology results were reported as total and differential cell count from a cytofuge sample based on assessment of 200 cells. Normal cytologic parameters were interpreted as 400–600 cells/μL with 70–75% macrophages and 5–8% lymphocytes, neutrophils, and/or eosinophils.[12] Samples with increased number or percentage of inflammatory cells were categorized by the predominant cell type comprising the inflammation. Qualitative bacterial cultures were reported as 1+, 2+, 3+, or 4+ growth based on the number of quadrants with positive growth.

Right lateral and dorsoventral thoracic and, when available, left lateral thoracic and cervical radiographs were reviewed for evidence of tracheal or bronchial collapse by a board certified radiologist (R.E.P.) who was masked to group assignment. Cervical projections were evaluated for collapse of the trachea. Right lateral thoracic views were assessed for collapse of the trachea, LPB or left lobar bronchi. Dorsoventral projections were examined for collapse of the right and left caudal and accessory lobar bronchi. Left lateral thoracic views were inspected for collapse of the trachea, RPB or right lobar bronchi. Collapse of an airway was identified as either positive or negative. A positive result was recorded if the airway appeared to be narrowed to any extent or completely attenuated and only had to be visualized on one view. When cervical radiographs were not available, the portion of the trachea seen on the thoracic views was assessed. When a left lateral thoracic radiograph was not available, results for the RPB and right cranial and middle lobar bronchi were not recorded. In addition, cardiomegaly was subjectively reported as mild, moderate, or severe for all cases.

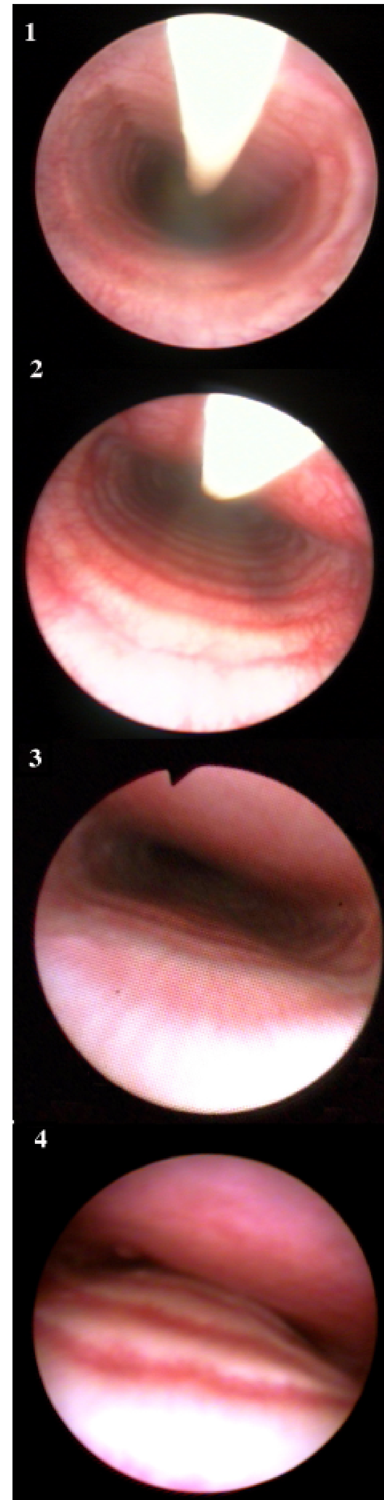

Fig 1. Grades of tracheal collapse based on reduction in luminal diameter. 1, 25%; 2, 30–50%; 3, 60–75%; 4, 90–100%.

Clinical diagnoses made by the primary clinician (L.R.J.) were based on combined assessment of physical examination, radiographic findings, bronchoscopy, and BAL analysis. A diagnosis of respiratory infection was made in dogs that had septic, suppurative inflammation (>8% neutrophils) on cytology with intracellular bacteria and growth of >2+ bacteria (including *Mycoplasma* spp.) on culture. Inflammatory airway disease was characterized as neutrophilic, lymphocytic, and/or eosinophilic depending on the presence of >8% of the respective inflammatory cell on airway cytology or if total cell numbers exceeded 600/µL, and there was no growth or 1+ growth of bacteria on culture. Bronchiectasis was documented as endoscopic visualization of persistent airway dilatation independent of the phase of respiration. Foreign bodies were identified as discovered.

Statistical Analysis

Data were examined for normality by the Kolmogorov-Smirnov test. Data with normal distribution are reported as mean ± standard deviation and were analyzed by Student's *t*-test. Variables that were non-Gaussian in distribution are reported as median values with range. Age, weight, BCS, and percent BAL retrieval were compared between dogs with and without airway collapse by use of the Mann-Whitney test for nonparametric data. In dogs with airway collapse, all parameters were compared between dogs that had concurrent tracheal collapse and those that did not. Select parameters were compared among dogs with tracheal and airway collapse, dogs with airway collapse that lacked tracheal involvement and dogs without airway collapse by use of Kruskal-Wallis analysis of variance for nonparametric data with post hoc analysis by Dunn's multiple comparison test. Fisher's exact test was used to detect differences between groups on the basis of the frequency of findings for clinical complaints, thoracic auscultation abnormalities, airway cytology or infection, and radiographic evidence of cardiomegaly. Sensitivity and specificity were calculated with confidence intervals to assess the ability of radiographs to confirm or deny bronchoscopically visible collapse within the population examined. Positive likelihood ratio (PLR) and negative likelihood ratio (NLR) were calculated to determine the probability of a positive or negative radiographic finding in the presence or absence of bronchoscopically identified collapse. The PLR ranges from 1 to infinity, with higher values indicating that radiographs can rule in airway collapse in the region. The NLR ranges from 1 to 0, with lower values indicating that radiographs can rule out airway collapse. Commercial software was used to perform all statistical analyses[d] with significance set at $P < .05$.

Results

Between 7/2001 and 1/2008, a bronchoscopic procedure was performed by one of the authors (L.R.J.) on 115 dogs. Of these, 58 dogs (50%) had some form of airway collapse and the remaining 57 dogs (50%) had no airway collapse. Of dogs with airway collapse, 24/58 (41%) had tracheal collapse with or without bronchial collapse and 34/58 (59%) had bronchial collapse in the absence of tracheal involvement. Breed distribution varied between groups with all Pugs (n = 6), Chihuahuas (n = 4), Shih Tzus (n = 3), and Miniature/Toy Poodles (n = 3) in the group of dogs with airway collapse, while all Standard Poodles (n = 4) were in the group of dogs without airway collapse. All Yorkshire Terriers (n = 10) and 2 of 6 Pugs were in Group 1A.

Dogs with airway collapse were significantly older, were of significantly lower body weight, and had a significantly higher BCS than dogs without airway collapse.

Table 1. Dogs with airway collapse were significantly older, had lower body weight, and had higher body condition score (BCS) compared with dogs without airway collapse.

	Age (years)	Weight (kg)	BCS
Dogs with airway collapse	8.5 (0.5–15.5)*	8.6 (1.5–52.7)*	6 (4–8)*
Dogs with tracheal collapse	7.0 (0.5–15.5)	3.7 (1.5–15.2)†	6 (4–8)
Dogs with airway collapse alone	9.0 (1.5–15.0)†	12.8 (4.1–52.7)†	6 (4–8)
Dogs without airway collapse	6.0 (0.5–13)*†	24.8 (2.9–63.4)*	5 (3–9)*
P value	.02* .02†	< .0001* ≤.0001†	.002*

Symbols identify groups with significant differences.

(Table 1). In dogs with airway collapse, body weight of dogs with tracheal collapse was significantly lower (mean 3.7 kg, range 1.5–15.2 kg) than dogs without tracheal collapse (mean 12.8 kg, range 4.1–52.7 kg; $P < .0001$); however, BCS did not differ between groups.

Respiratory complaints were similar between dogs with and without airway collapse with 86% of dogs in each group presenting for cough. Heart rate, respiratory rate, presence of adventitious lung sounds, and detection of tracheal sensitivity did not differ between groups; however, auscultation of a heart murmur associated with mitral regurgitation was found significantly more often in dogs with airway collapse (10/58; 17%) than in dogs without airway collapse 2 (1/57; 1.8%), $P = .008$. One dog with airway collapse had a continuous murmur of a patent ductus arteriosus.

Tracheal collapse was identified bronchoscopically as Grade 1 (5/24 dogs; 21%), Grade 2 (11/24 dogs; 46%), Grade 3 (4/24 dogs; 17%), and Grade 4 (4/24 dogs; 17%). Coincident collapse of 1–5 lobar bronchi (median 2) was documented in 20/24 dogs (83%), and collapse of sublobar airways was documented in 9/24 (38%) dogs. (Table 2) Sublobar collapse was diffuse in 4 dogs and focal in 5. In dogs with airway collapse in the absence of tracheal collapse, 1–6 lobar bronchi (median 2.5) were collapsed in 12/34 dogs (35%) and sublobar collapse alone was documented in 6/34 dogs (18%) (3 focal, 3 diffuse). The remaining 16/34 dogs (47%) had lobar and sublobar airway collapse.

In dogs with airway collapse, static collapse of the LPB (Fig 2) was found in 17/58 dogs (29%) and of the RPB in

Table 2. Grade of tracheal collapse and identification of concurrent lobar and sublobar collapse in dogs with cervical tracheal collapse (Group 1A).

Tracheal Collapse (n = 24)	Lobar Bronchial Collapse (n = 20)	Sublobar Airway Collapse (n = 9)
Grade 1 (n = 5)	4	2
Grade 2 (n = 11)	10	5
Grade 3 (n = 4)	2	1
Grade 4 (n = 4)	4	1

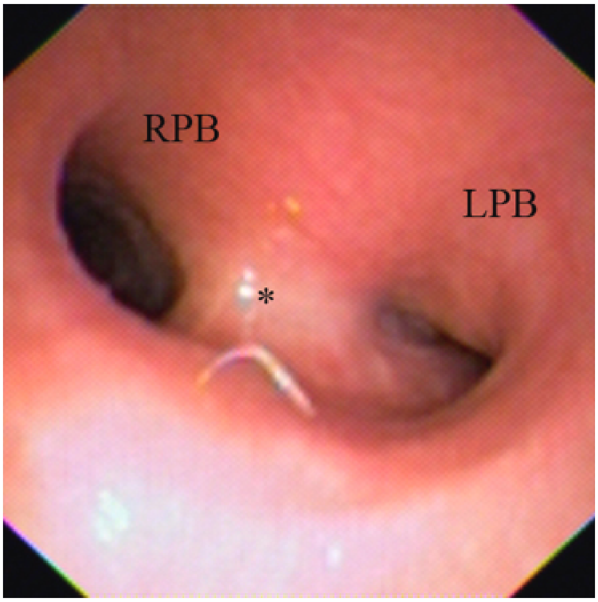

Fig 2. Bronchoscopic image demonstrating static collapse of the left principal bronchus (LPB). The carina is indicated by the asterisk (*). RPB, right principal bronchus.

Fig 4. Diffuse airway collapse in sublobar bronchi of the left caudal lung lobe.

5/58 dogs (9%). Collapse of the right middle lobar bronchus (Fig 3) was identified most commonly (34/58 dogs, 59%) followed by collapse of the left cranial (30/58 dogs, 52%), accessory (22/58 dogs, 38%), and left caudal lung lobe bronchus (17/58 dogs, 29%). The right cranial (9/58 dogs, 16%) and right caudal (3/58 dogs, 5%) lung lobe bronchi were least frequently involved in lobar bronchial collapse. In dogs with collapse of sublobar airways, focal airway collapse was identified in 14/29 dogs (48%) and diffuse airway collapse was present in 15/29 (52%) dogs (Fig 4).

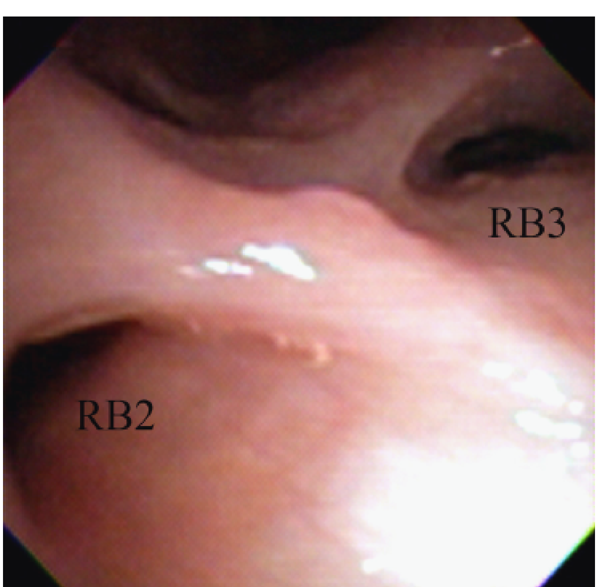

Fig 3. Collapse of the right middle lobar bronchus (RB2) and accessory lung lobe bronchus (RB3).

Radiographic studies were available for 49 dogs with airway collapse (15 with tracheal collapse and 34 with airway collapse alone) and for 50 dogs without airway collapse. Tracheal collapse was correctly identified in 11/15 dogs (73%) but was incorrectly reported in 2/34 dogs (6%) with airway collapse alone and 2/50 dogs (4%) that lacked airway collapse. Radiographic identification of airway collapse at individual bronchi was variably accurate (Table 3). Specificity for ruling out airway collapse was high for all lobar bronchi but was low in sublobar bronchi (Table 4). The highest sensitivity (50–55%) of radiographs for detection of airway collapse was recorded for the cervical trachea, left cranial and right caudal lobar bronchi (Fig 5).

Radiographic evidence of mild or moderate cardiomegaly was reported significantly more often in dogs with airway collapse (11/49; 22%) than in dogs without (1/50; 2%), $P = .0018$. Echocardiography was performed in 8 dogs with airway collapse and 3 dogs lacking airway collapse. Only 2 dogs with airway collapse that had cardiomegaly (moderate) described radiographically had echocardiograms performed. Both echocardiograms were abnormal with eccentric left ventricular hypertrophy from mitral regurgitation in 1 dog and a patent ductus arteriosus with left ventricular dilation in a 2nd dog. Left atrial to aortic ratios in these 2 dogs were 1.8 and 1.9, and bronchial collapse of the left cranial and right middle lung lobes was found in both dogs, while 1 dog also had collapse of the left caudal lobar bronchus. In the remaining 9 dogs to undergo echocardiography because of a murmur ($n = 2$), arrhythmia ($n = 2$), or to rule out pulmonary hypertension ($n = 5$), radiographs did not indicate cardiomegaly and left atrial to aortic ratio ranged from 1.1 to 1.6 (mean 1.4).

Fluoroscopy was performed in 12 dogs with airway collapse and correctly identified cervical tracheal collapse

Table 3. Accuracy of thoracic radiographs in identifying airway collapse in Group 1 dogs.

	Trachea (n = 49)	Left Cranial (n = 49)	Left Caudal (n = 49)	Right Cranial (n = 22)	Right Middle (n = 22)	Accessory (n = 27)	Right Caudal (n = 27)	Small Airway (n = 49)
Radiographs + Bronchoscopy +	11	16	2	0	4	27	2	0
Radiographs − Bronchoscopy −	25	15	27	15	6	1	19	32
Radiographs − Bronchoscopy +	9	16	17	4	8	12	2	17
Radiographs + Bronchoscopy −	4	2	3	3	4	1	4	0

Number in parentheses indicates the number of dogs with radiographs that could be adequately evaluated at the site of interest.

in 4/6 dogs. Fluoroscopy indicated principal bronchial collapse in 8/12 dogs, 2 of which had collapse of the principal bronchi on bronchoscopy while lobar bronchial collapse was documented in the remaining dogs. Fluoroscopy was performed in 3 dogs without airway collapse and incorrectly reported principal bronchial collapse in 1 dog.

Percent BAL fluid retrieved was similar in dogs with airway collapse (mean 50%, range 10–120%) compared with dogs without (mean 48%, range 12–100%), $P = .051$; however, retrieval in dogs with tracheal and airway collapse (63%, range 23–120%) was significantly greater than in dogs with airway collapse alone (47%, range 10–100%) and dogs without airway collapse (48%, range 12–100%), $P < .0001$. Median number of lavages performed in each group was 2.

Normal airway cytology was reported significantly more often in dogs with airway collapse (8/58; 16%) than in dogs without collapse (0/57 dogs), $P = .006$ (Table 5). Airway infection was found significantly more often in dogs lacking airway collapse (16/57; 28%) compared with dogs with collapse (6/58; 10%), $P = .018$. *Bordetella*, *Mycoplasma*, and enteric organisms were isolated in both groups. Various types of inflammation were recorded in 42/58 (72%) dogs with airway collapse and in 41/57 (72%) dogs without collapse but no trends were identified (Table 5). Bronchiectasis was evident bronchoscopically in equivalent numbers of dogs with (6/58) and without (5/57) airway collapse. In 5/6 dogs with airway collapse and bronchiectasis, lobar bronchial collapse was detected and bronchiectasis was noted in distal lung segments.

Discussion

Airway collapse was documented in approximately half of all dogs that had bronchoscopy performed for evaluation of respiratory illness in this study, indicating that tracheomalacia and bronchomalacia are common in dogs with respiratory complaints. Although only cases evaluated by a single clinician were included here, the incidence is higher than that of acquired tracheobronchomalacia in adults (<5%)[5] and congenital tracheobronchomalacia in children (34%).[13] Bronchomalacia is suspected before bronchoscopy in only half of people examined, and this likely reflects the similarity in presentation and physical examination findings between bronchomalacia and other respiratory conditions,[3,7,14] a finding reflected in the current study. While tracheal collapse in the dog is readily recognized clinically and several studies have investigated the etiopathogenesis of the disorder,[15,16] bronchomalacia has not previously been described. This study suggests that the condition is common because 83% of dogs with cervical tracheal collapse had concurrent lobar collapse.

Clinical features were not predictive of of airway collapse, although dogs affected by tracheal collapse and/or bronchomalacia in this study were typically older, small breed dogs that were overweight, similar to clinical

Table 4. Sensitivity and specificity with confidence intervals of thoracic radiographs in documentation of the presence of airway collapse at specific sites within the airways in all dogs evaluated here.

	Sensitivity	CI	Specificity	CI	PLR	NLR
Trachea (n = 99)	0.55	0.32–0.77	0.92	0.84–0.97	6.88	0.49
Left cranial lobe (n = 99)	0.50	0.32–0.68	0.90	0.80–0.96	5.00	0.56
Left caudal lobe (n = 99)	0.11	0.01–0.33	0.94	0.86–0.98	1.83	0.95
Right cranial lobe (n = 52)	0	0–0.60	0.92	0.80–0.98	0	1
Right middle lobe (n = 52)	0.33	0.10–0.65	0.70	0.53–0.83	1.10	0.96
Accessory lobe (n = 59)	0.08	0–0.36	0.93	0.78–0.99	1.14	0.99
Right caudal lobe (n = 59)	0.50	0.07–0.93	0.91	0.80–0.97	5.56	0.55

Positive likelihood ratio (PLR) and negative likelihood ratio (NLR) were calculated to determine the probability of a positive or negative radiographic finding in the presence or absence of bronchoscopically identified collapse irrespective of the prevalence of disease. Number in parentheses indicates the number of dogs with radiographs that could be adequately evaluated at the site of interest.

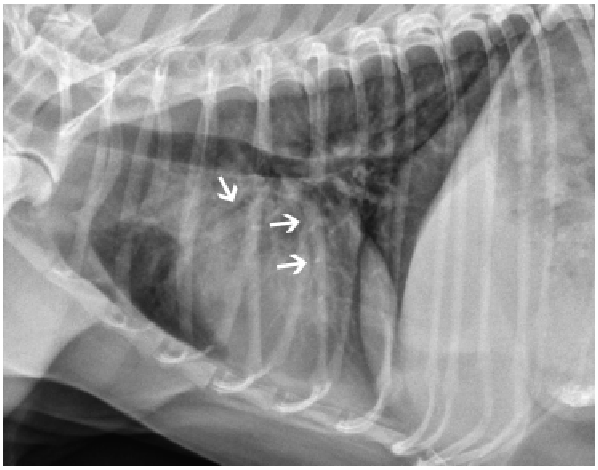

Fig 5. Right lateral radiographic image demonstrating collapse of the lobar bronchi to the left cranial lung lobe, cranial and caudal segments.

reports of cervical tracheal collapse.[1,17–19] However, bronchomalacia and sublobar airway collapse in the absence of cervical tracheal collapse were common in medium and large breed dogs examined here, providing further evidence for the utility of bronchoscopy in the diagnostic evaluation of dogs with cough. As anticipated, most dogs in this study had a primary complaint of cough with lesser numbers presented for evaluation of respiratory difficulty. As an obstructive disease of intrathoracic airways, bronchomalacia would be expected to increase expiratory effort and lead to crackles or an end-expiratory snap as airways close and quickly open with respiration. However, physical examination features and thoracic auscultation uncommonly suggested airway obstruction as few dogs examined here were reported to have adventitious lung sounds or abnormalities in respiratory effort. The lack of detectable auscultatory abnormalities could be a reflection of the retrospective nature of this study, although it does suggest that bronchomalacia has few discerning physical examination features.

Table 5. Cytologic findings in bronchoalveolar lavage fluid from dogs with (Group 1) and without (Group 2) airway collapse.

	Group 1A	Group 1B	Group 2
*Septic neutrophilic inflammation	2	4[a]	16[b]
Neutrophilic inflammation	6[b]	10	12[c]
Lymphocytic inflammation	6[c]	6	8
Eosinophilic inflammation	1	1	4
Neutrophilic and lymphocytic inflammation	0	7	7
Neutrophilic and eosinophilic inflammation	1	0	4[c]
Eosinophilic and lymphocytic inflammation	0	0	3
Mixed inflammation	3	1	3
*Normal cytology	5	3	0

Dogs in Group 1A had tracheal collapse while dogs in Group 1B had only bronchial collapse.

*Significantly different results between dogs in Group 1 and Group 2, $P < .05$.

[a]Bronchiectasis in 3 dogs.

[b]Bronchiectasis in 1 dog.

[c]Bronchiectasis in 2 dogs.

Mitral regurgitation was found concurrently with airway collapse in 17% of dogs, although congestive heart failure was not present in any dog. In people, the combination of left heart enlargement and compression from the left pulmonary artery can lead to collapse of the LPB.[6,8] Also, cardiomegaly was more common in dogs with airway collapse than in dogs lacking airway collapse. It is possible that the increased incidence of obesity in Group 1 dogs or reduced thoracic volume from airway collapse could have contributed to the radiographic documentation of an enlarged cardiac silhouette in these dogs. It is also possible that space-occupying effects of an enlarged heart might play a role in airway collapse. The 2 dogs documented to have left atrial enlargement on echocardiography had collapse in the region where the heart could press on the left cranial and right middle lobar bronchi, although 1 dog also had collapse of the left caudal lobar bronchus. This study does not adequately address the role of cardiomegaly in airway collapse because echocardiograms were performed in a minority of dogs, although left atrial dimensions appeared normal in most animals examined and cardiomegaly was reported radiographically in a minority of dogs with airway collapse.

In people, tracheobronchomalacia is thought to increase the likelihood of infection because of trapping of secretions and reduced mucociliary clearance.[3] However, this study found that dogs with airway collapse were less likely to have bacterial infection than other dogs that had bronchoscopy performed for evaluation of cough. This may reflect a bias in the use of bronchoscopy in veterinary medicine to confirm infectious lung disease in comparison with its use in people. This study also supports results of a previous study[1] that failed to establish a role for bacterial infection in tracheal collapse.

Inflammation in the absence of infection was found in equal numbers of dogs with and without airway collapse (Table 5), suggesting that inflammation was not a risk factor for development of bronchomalacia in dogs examined here. In contrast, bronchomalacia was reported in 40–70% of people with bronchitis or bronchiectasis.[20] In addition, this study did not confirm an association between tracheal collapse and bronchiectasis as was reported previously in a retrospective study.[21] This difference could be explained by the fact that the current study utilized bronchoscopy to diagnose both airway collapse and bronchiectasis, while the previous study used radiographs alone, which are variably able to detect collapse or bronchiectasis.[2,22]

Radiographs were relatively useful in ruling out tracheal collapse although collapse of 1 or more large airway segments was incorrectly reported in almost 25% of dogs lacking airway collapse. In addition, radiographs performed poorly in documenting sublobar collapse.

This likely reflects the limits of the resolution of radiography. In addition, many cases in this retrospective study only had 1 lateral projection, which limited the ability to assess large airway structures. A final confounding feature regarding the inability to detect dynamic changes in airway diameter may be related to the fact that only inspiratory projections were acquired. Further studies are indicated to determine the full utility of radiographs for the detection of bronchial and sublobar collapse.

In this study, isolated tracheal collapse was rarely encountered and most dogs had concurrent lobar bronchial collapse as well as small airway collapse. This finding might suggest that the cartilage abnormalities reported in tracheal rings of dogs with tracheal collapse[15,17] also affect the cartilage plates supporting lobar bronchi and larger airways. Bronchomalacia in dogs examined here was found more commonly at the LPB than the RPB, similar to what is reported in children.[13] Bronchomalacia most commonly affected multiple lobar bronchi (median of 2.5 lobes affected), with the right middle and left cranial lobar bronchus affected most commonly. In addition, collapse of smaller airway in the absence of lobar bronchial collapse occurred in 10% of dogs in this study. Collapse of smaller airways might indicate deficient smooth muscle control of airway diameter or an alteration in the transpulmonary pressure gradient to enhance collapse of intrathoracic airways. Reduction in thoracic volume because of obesity or hepatomegaly might contribute to the latter phenomenon.

The finding of lobar and small airway collapse in the majority of dogs with tracheal collapse examined here underscores the importance of thorough bronchoscopic assessment of airways in dogs suspected of tracheal collapse, particularly in light of the increasing use of stents for treatment of tracheal collapse.[18,19] Continued collapse of bronchial and sublobar airways after stent placement could lead to persistent clinical signs and complications such as stent migration or fracture. In dogs, surgical intervention or placement of intraluminal stents is most often performed in dogs with Grade 3 and 4 collapse.[17–19] In this study, dogs with Grade 3 and 4 tracheal collapse had lobar airway collapse less frequently than dogs with less severe forms of tracheal collapse, and this might suggest that most dogs with severe clinical signs related to tracheal collapse could still be good candidates for stent procedures.

Bronchomalacia was common in this study of dogs undergoing bronchoscopy for evaluation of respiratory disease with an overall incidence of 50%. In dogs with tracheal collapse, concurrent bronchomalacia was present in 83%, although it was not possible to assess the relative role that differing regions of collapse had on clinical presentation in this retrospective study. As anticipated, radiographs greatly underestimated the incidence of bronchomalacia. Contrary to our hypothesis, airway inflammation was found in dogs with and without bronchomalacia, and a role for chronic inflammation in malacic airway changes could not be confirmed. Bronchoscopy with culture and cytology of BAL fluid is recommended to identify infectious or inflammatory disease and to determine the extent and grade of tracheal collapse and bronchomalacia in dogs with cough. Bronchoscopy can also provide information that might impact prognosis after stent placement.

Footnotes

[a] Olympus P20D, Olympus Corporation, Melville, NY
[b] Pentax FG16-X or 16-V, Pentax Medical Corp., Montvale, NJ
[c] Olympus BF3C160, Olympus Corporation
[d] GraphPad Prism 5.0, San Diego, CA

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