Laryngeal structure and function in dogs with cough

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OBJECTIVE
To investigate the prevalence and type of laryngeal abnormalities in dogs examined because of cough that did not have signs of upper airway disease and to compare the prevalence of those abnormalities among dogs with various respiratory tract diseases.

DESIGN
Prospective study.

ANIMALS
138 dogs with cough that did not have signs of upper airway disease.

PROCEDURES
The study was conducted between July 2001 and October 2014 and included dogs examined for cough that had laryngoscopic and bronchoscopic examinations performed by 1 examiner. Laryngeal hyperemia and swelling were recorded, and laryngeal function was assessed before and after doxapram stimulation when indicated. Results were compared among dogs on the basis of cough duration (acute [< 2 weeks], subacute [2 weeks to 2 months], and chronic (> 2 months)) and disease diagnosed (inflammatory airway disease, airway collapse, lower respiratory tract infection, and eosinophilic bronchopneumopathy).

RESULTS
Laryngeal hyperemia was detected in 73 of 134 (54%) dogs with cough of subacute or chronic duration, and its prevalence did not vary significantly among dogs with various diseases. Thirteen dogs had laryngeal paresis, and 13 dogs had laryngeal paralysis; dysphonia (n = 2) and stridor (1) were uncommon findings in those dogs. The prevalence of laryngeal dysfunction (paresis or paralysis) did not differ significantly among diseases.

CONCLUSIONS AND CLINICAL RELEVANCE
Results indicated that 26 of 138 (19%) dogs examined because of cough alone had laryngeal dysfunction, which suggested that a complete laryngoscopic examination should be included in the diagnostic evaluation of dogs with cough. (J Am Vet Med Assoc 2016;249:195–201)

ABBREVIATIONS
AWC Airway collapse
BAL Bronchoalveolar lavage
EBP Eosinophilic bronchopneumopathy
IAD Inflammatory airway disease
LRTI Lower respiratory tract infection
that did not have clinical signs of upper airway disease. The primary hypothesis for the study was that laryngeal dysfunction would exist in dogs without clinical signs and physical examination findings such as voice change, abnormal inspiratory effort, and stridor. A secondary hypothesis was that dogs with neutrophilic or lymphoplasmacytic airway disease would have evidence of laryngeal dysfunction more frequently than dogs with LRTI or EBP.

Materials and Methods

Animals

Dogs that were examined because of cough and that did not have clinical signs of upper airway disease at the University of California–Davis William R. Pritchard Veterinary Medical Teaching Hospital from July 2001 through October 2014 were eligible for inclusion in the study. Dogs with nasal discharge in conjunction with cough, that had stridor during auscultation of the larynx with a stethoscope, or for which information elicited from the owner suggested possible dysphonia were not excluded from the study. Dogs were also not excluded from the study if the owner reported any of the following clinical signs: gagging, retching, vomiting, or regurgitation. To be included in the study, a dog had to undergo laryngoscopic examination in conjunction with bronchoscopic examination by the author. Dogs with thoracic neoplasia or for which cough was not the primary reason for examination were excluded from the study.

Data collection

For each dog, data abstracted from the medical record included age, breed, sex, weight, duration of cough, and physical, laryngoscopic, and bronchoscopic examination findings. For the purpose of this study, dogs were assigned into 3 groups on the basis of the duration of cough (acute [<2 weeks], subacute [2 weeks to 2 months], and chronic [>2 months]). Those categories were devised to allow specific assessment of dogs with chronic bronchitis or IAD (cough with or without a recognizable cause for >2 months) and dogs with cough due to other causes. Physical examination findings were reviewed for evidence of laryngeal disease such as stridor auscultated over the upper airway during inspiration and inspiratory difficulty or effort in addition to cough.

Laryngoscopic examination

Each dog was preoxygenated and premedicated and then anesthetized as deemed most appropriate by the anesthesia service at the teaching hospital. Dogs were maintained at a light plane of anesthesia so that normal respiration was preserved. For most dogs, use of a laryngoscope with a blade attached was sufficient for evaluation of the larynx, although use of a rigid arthroscope was necessary in some dogs. The jaw was manually stabilized in an open position, and the tongue was manually extended, taking care not to place excessive tension on the tongue or to displace the epiglottis with the instrument used for the laryngeal examination. When normal laryngeal function could not be confirmed and when patient status allowed, 1 to 3 boluses of doxapram hydrochloride (0.5 to 1.0 mg/kg [0.23 to 0.45 mg/lb], IV) were administered to stimulate respiration.

Laryngeal collapse was graded on a scale of 1 to 3. Dogs with grade 1 (eversion of laryngeal saccules) laryngeal collapse were not considered further; however, dogs with grade 2 (medial displacement or overlap of the corniculate processes) and grade 3 (medial displacement or overlap of the corniculate processes) were described further. Laryngeal paralysis (unilateral or bilateral) was defined as a total lack of abduction of the corniculate processes of the arytenoids during inspiration. Laryngeal paresis or weakness was defined as inappropriate abduction of laryngeal cartilages given the level of inspiratory effort following doxapram administration.

Bronchoscopy and BAL

The clinical diagnosis for each dog was obtained on the basis of results of a bronchoscopic examination and bacterial culture and cytologic evaluation of a BAL fluid sample. All bronchoscopic examinations were performed by the same investigator who performed the laryngoscopic examination. The presence and location of tracheal or bronchial collapse were recorded. The severity of tracheal collapse was graded on a 4-point scale (grade 1 [25% reduction in lumen diameter], grade 2 [50% reduction in lumen diameter], grade 3 [75% reduction in lumen diameter], and grade 4 [90% to 100% reduction in lumen diameter]). Bronchial collapse was defined as static or dynamic circumferential narrowing of a bronchial airway. When present, the specific locations of foreign bodies and airway dilatation (bronchectasis) were recorded.

Bronchoalveolar lavage was performed at 1 or more sites by instillation and aspiration of warm, sterile saline (0.9% NaCl) solution through the biopsy channel of the endoscope. Each BAL fluid sample was submitted for cytologic evaluation that included both total and differential inflammatory cell counts (based on evaluation of 200 cells) and assessment for the presence of fungal or neoplastic elements, oropharyngeal contaminants, intracellular bacteria, and foreign material. All cytologic evaluations were performed by board-certified veterinary clinical pathologists. Reference limits used for canine BAL fluid samples were a total inflammatory cell count of 300 to 500 cells/μl and a differential inflammatory cell count comprising <8% each of eosinophils, neutrophils, and lymphocytes and 65% to 85% macrophages. An aliquot of each BAL fluid sample was cultured for the presence of aerobic bacteria and Mycoplasma spp. Select samples were also cultured for the presence of anaerobic bacteria.

Bronchoalveolar lavage fluid samples with >8% neutrophils without intracellular bacteria, >8% lymphocytes, or a mixed inflammatory cell pattern and from which clinically relevant pathogens were not
cultured were characterized as inflammatory, and the patient was classified as having IAD. Eosinophilic bronchopneumopathy was diagnosed for dogs with BAL fluid samples that contained predominately eosinophils. Fluid samples that contained neutrophils with intracellular bacteria or from which pathogenic bacteria were cultured were categorized as septic, and the patient was classified as having an LRTI. Thus, dogs were classified into 4 disease categories (AWC, IAD, EBP, and LRTI [which included foreign body pneumonia]).

**Statistical analysis**

Each dog was represented only once in all analyses. The data distributions for age and body weight were assessed for normality by use of the D’Agostino and Pearson omnibus normality test. Fisher exact tests were used to compare the respective prevalences of laryngeal hyperemia or edema (laryngeal inflammation) and abnormal laryngeal function (laryngeal paresis or paralysis) between dogs with subacute and chronic cough and between dogs with IAD and dogs with LRTI. Diagnoses were further subdivided into 5 categories (IAD alone, IAD with AWC, AWC alone, LRTI, and EBP), and $\chi^2$ analysis was used to compare the respective prevalence rates of laryngeal abnormalities among those categories. All analyses were performed with commercially available software, and values of $P < 0.05$ were considered significant.

**Results**

**Dogs**

One hundred thirty-eight dogs met the inclusion criteria for the study. The age of the dogs ranged from 4 months to 15.5 years (median, 8 years). The body weight of those dogs ranged from 1.5 to 63.4 kg (3.3 to 139.5 lb; median, 13 kg [28.6 lb]). The weight was $< 5$ kg (11 lb) for 31 dogs, $> 5$ to 9.9 kg ($> 11$ to 21.8 lb) for 28 dogs, $> 9.9$ to 20 kg ($> 21.8$ to 44 lb) for 24 dogs, $> 20$ to 40 kg ($> 44$ to 88 lb) for 45 dogs, and $> 40$ kg for 9 dogs (body weight was unavailable for 1 dog). Nine dogs belonged to brachycephalic breeds. Breeds with $> 2$ dogs in the study population included Yorkshire Terrier (n = 11 dogs), Labrador Retriever (8), Miniature Poodle (6), Cocker Spaniel (6), and Standard Poodle, Alaskan Malamute, Chihuahua, and Pomeranian (4 each). The duration of cough was acute ($<$ 2 weeks) for 4 dogs, subacute (2 weeks to 2 months) for 30 dogs, and chronic ($> 2$ months) for 104 dogs. Of the 138 study dogs, 15 (11%) had nasal discharge and sneezing in addition to cough.

**Laryngoscopic examination**

Moderate to severe hyperemia (Figure 1) or edema (ie, laryngeal inflammation) as determined by the subjective appearance of the larynx and clinical judgement of the clinician performing the examination was identified in 73 of 138 (53%) dogs. Mild changes in the epithelial color and surface were not reported to avoid overinterpretation of findings. Laryngeal inflammation was not observed in any of the dogs with cough of acute duration but was commonly observed in dogs with cough of subacute (16/30 [53%]) and chronic (57/104 [55%]) duration. The prevalence of laryngeal inflammation did not differ significantly ($P = 0.30$) between dogs with cough of subacute and chronic duration. Two brachycephalic dogs had laryngeal collapse (Figure 2).

Normal laryngeal function was apparent in 79 of 138 (57%) dogs; however, appropriate laryngeal abduction on inspiration could not be determined during initial examination for 59 (43%) dogs. Doxapram was administered as 1, 2, or 3 boluses to 48, 9, and 2 dogs, respectively. Laryngeal function was normalized following doxapram administration in 25 of 48 dogs that received 1 bolus and 5 of 9...
dogs that received 2 boluses. Laryngeal function remained inconclusive for 2 and 1 dogs following administration of 1 and 3 boluses of doxapram, respectively. Of the remaining 26 dogs, laryngeal paralysis (total lack of abduction of the corniculate processes of the arytenoids during inspiration following doxapram administration) was diagnosed in 13 dogs (9, 3, and 1 dogs after 1, 2, and 3 boluses of doxapram, respectively). Paralysis was bilateral in 6 dogs and unilateral in 7 dogs (left-side paralysis, n = 5; right-side paralysis, 2). Laryngeal paresis (inappropriate abduction of laryngeal cartilages given the level of inspiratory effort displayed following doxapram administration) was diagnosed in 13 dogs (12 and 1 dogs after 1 and 2 boluses of doxapram, respectively) and was bilateral in 5 dogs and confined to the left side in 8 dogs. The median age and body weight for dogs with laryngeal paralysis or paresis (laryngeal dysfunction) were 10 years (range, 0.5 to 15.5 years) and 16 kg (35.2 lb; range, 2.3 to 50 kg [5.1 to 110 lb]), respectively. Among the dogs with laryngeal dysfunction, breed groups or breeds represented more than once included retrievers (Labrador Retriever [n = 4] and Golden Retriever [1]), terriers (Australian Terrier [1], Irish Terrier [1], and Soft-Coated Wheaten Terrier [1]), Alaskan Malamute (2), Standard Poodle (2), and Cocker Spaniel (2).

Laryngeal function appeared normal in all dogs with cough of acute duration. Of the 30 dogs with cough of subacute duration, 3 had laryngeal paralysis (1 each with left-side, right-side, and bilateral paralysis) and 1 had laryngeal paresis (right-side paresis). Of the 104 dogs with cough of chronic duration, 10 had laryngeal paralysis (paralysis was bilateral in 5, affected the left side in 4, and affected the right side in 1) and 12 had laryngeal paresis (paresis was bilateral in 5 and affected the left side in 7). The prevalence of laryngeal dysfunction did not differ significantly (P = 0.80) between dogs with cough of subacute and chronic duration.

Voice change was not reported in any of the dogs with cough of acute duration but was reported in 3 of the 30 (10%) dogs with cough of subacute duration, and 1 of those 3 dogs had laryngeal paralysis. Voice change was reported in 2 of the 104 (2%) dogs with cough of chronic duration, and 1 of those 2 dogs had bilateral laryngeal paralysis. Results of laryngeal auscultation were available for 93 dogs, of which stridor was detected in 10 (11%; 1/3 dogs with cough of acute duration, 1/20 dogs with cough of subacute duration, and 8/70 dogs with cough of chronic duration). In the dogs with cough of acute and subacute duration and 2 of 8 dogs with cough of chronic duration, the larynx appeared clinically normal and stridor was attributed to collapse of the cervical portion of the trachea. Four of the 8 dogs with cough of chronic duration and stridor belonged to brachycephalic breeds; however, all had

![Figure 2](image)

**Figure 2**—Endoscopic image of the larynx of a dog with grade 2 laryngeal collapse. Notice that the left (L) and right (R) cu-

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>No. of dogs</th>
<th>Laryngeal hyperemia</th>
<th>Laryngeal paresis</th>
<th>Laryngeal paralysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAD only</td>
<td>33</td>
<td>19 (55)</td>
<td>6 (18)</td>
<td>5 (15)</td>
</tr>
<tr>
<td>IAD and AWC</td>
<td>50</td>
<td>25 (50)</td>
<td>0 (0)</td>
<td>5 (10)*</td>
</tr>
<tr>
<td>AWC only</td>
<td>6</td>
<td>3 (50)</td>
<td>0 (0)†</td>
<td>0 (0)†</td>
</tr>
<tr>
<td>LRTI</td>
<td>34</td>
<td>19 (55)</td>
<td>5 (15)</td>
<td>3 (9)</td>
</tr>
<tr>
<td>EBP</td>
<td>15</td>
<td>7 (47)</td>
<td>2 (13)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Total</td>
<td>138</td>
<td>73 (53)</td>
<td>13 (9)</td>
<td>13 (9)</td>
</tr>
</tbody>
</table>

*Denominator used to calculate the percentage was 48. †Denominator used to calculate the percentage was 5.
apparently normal laryngeal function without evidence of laryngeal collapse. Of the 2 remaining dogs with cough of chronic duration and stridor, one had inconclusive laryngeal function despite administration of doxapram and the other had left-side laryngeal paralysis.

Gagging or retching was described in 29 dogs. Occasional or possible vomiting during the month prior to examination was reported in 9 dogs, and regurgitation within the 6 months prior to examination was reported in 2 dogs. Of those 11 dogs with gastrointestinal tract signs, 3 had laryngeal paresis or paralysis, 1 had laryngeal paresis or paralysis and a concurrent LRTI, 1 had laryngeal collapse and a concurrent LRTI, 1 had indeterminate laryngeal function, 4 had clinically normal laryngeal function and laryngeal inflammation, and 1 had clinically normal laryngeal function with LRTI.

Of the 138 dogs, 85 (60%) had a final diagnosis of IAD (of which 50 [60%] had concurrent AWC), 6 (4%) had AWC alone, 34 (25%) had LRTI (of which 6 [18%] also had a foreign body), and 15 (11%) had EBP. The prevalence of laryngeal inflammation ($P = 0.30$) and laryngeal dysfunction ($P = 0.47$) did not differ significantly among dogs in those 4 disease categories (Table 1). Additionally, 24 of the 104 (23%) dogs with cough of chronic duration had bronchiectasis, which was associated with either an airway infection ($n = 14$) or IAD ($n = 10$), and 5 of those 24 (21%) had laryngeal paresis or paralysis.

**Discussion**

Results of the present study indicated that dogs with cough of subacute (> 2 weeks) and chronic (> 2 months) duration commonly had laryngeal hyperemia and swelling regardless of the underlying etiology or disease process or the presence of laryngeal dysfunction. Changes to the laryngeal mucosa might develop secondary to mechanical injury, turbulent airflow, or extension of an inflammatory process from the lower portion of the respiratory tract in an oral direction. The role of upper airway changes in the generation or perpetuation of cough in dogs is unknown. In dogs in which laryngeal injury was induced by an experimental model of gastroesophageal reflux, grossly visible laryngeal abnormalities correlated with histologic evidence of inflammation. Those abnormalities might subsequently result in altered sensory or motor responses within the larynx. In human medicine, cough hypersensitivity is ascribed to laryngeal sensory abnormalities that persist after recovery from a primary disease, although the mechanism remains unclear. Upper airway cough syndromes are common in human patients, but it is unknown whether similar syndromes develop in dogs or could affect the resolution of clinical signs associated with disease of the lower respiratory tract. Further research is warranted to determine whether laryngeal changes such as those identified in the present study resolve with the successful treatment of lower airway disease.

Various methods have been used to assess laryngeal function, and direct visual examination via laryngoscopy is deemed the most clinically relevant. However, laryngoscopy requires anesthesia. The depth of anesthesia affects laryngeal function, and the laryngoscopic examination can become time-consuming when the initial laryngeal response observed is equivocal. In another study, healthy dogs that were anesthetized with a protocol that involved acepromazine, butorphanol, and isoflurane by mask had appropriate laryngeal function. Multiple anesthetic protocols were used for the dogs of the present study. The anesthetic doses for each dog were titrated to achieve a light plane of anesthesia; however, clinically normal laryngeal function was initially observed in only 79 of 138 (57%) dogs with cough. The present study was not designed to assess anesthetic protocols, and it is unlikely that the anesthetic protocols used affected the results given that a respiratory stimulant (doxapram) was used when necessary to assess laryngeal function.

Stimulation of respiration facilitates assessment of laryngeal abduction. In the present study, administration of doxapram normalized laryngeal function in 30 of 59 (51%) dogs in which laryngeal function was initially uncertain. However, doxapram was administered IV in boluses that were equivalent to a dose of 0.5 to 1.0 mg/kg, which is lower than the dose of doxapram (1.1 to 2.2 mg/kg [0.5 to 1.0 mg/lb], IV) previously established to facilitate opening of the rima glottidis. It is possible that the low dose of doxapram used in the present study might have impaired normalization of laryngeal function in some dogs. Administration of additional boluses of doxapram may have helped normalize laryngeal function in some dogs, although laryngeal function remained indeterminate for 1 of the 2 dogs that received 3 boluses of doxapram and persistent laryngeal paralysis was diagnosed in the other. For the dogs of the present study in which laryngeal paresis or paralysis was diagnosed, administration of additional boluses of doxapram was deemed unnecessary because those dogs had inappropriate laryngeal motion despite adequate inspiratory effort, and there was concern that administration of multiple doses of doxapram might induce excessive excitability.

In the present study, laryngeal paresis or paralysis was fairly common (26/134 [19%]) for dogs with cough of subacute and chronic duration caused by diverse disease processes. In a previous study, laryngeal paresis or paralysis was detected during induction of anesthesia in 65 of 250 (26%) dogs, although laryngeal dysfunction was fairly common (26/134 [19%]) of those dogs. The prevalence of laryngeal paresis or paralysis in that study might have been overestimated because doxapram was not used to stimulate respiration and confirm laryngeal dysfunction. Furthermore, the authors of that study reported that clinical suspicion of laryngeal disease was an important factor in the high diagnostic sensitivity and specificity of laryngoscopic evaluation for dogs with bilateral laryngeal paresis, and this might have affected the estimated prevalence of the condition. Laryngeal disease was not suspected prior to the laryngoscopic examination for any of the dogs of the present study, yet laryngeal dysfunction was identified in a substantial proportion (26/138 [19%]) of those dogs.
The 7 dogs with unilateral laryngeal paralysis in the present study were more frequently affected on the left side (n = 5) than on the right (2), a finding that was similar to the results of another study. Laryngeal paralysis is generally considered a permanent condition; however, less is known about laryngeal paresis. Laryngeal paresis might be a consequence of laryngeal inflammation and chronic laryngospasm, which could resolve when the inciting stimulus is withdrawn. Thus, administration of additional boluses of doxapram might have normalized laryngeal function in the 13 dogs with laryngeal paresis in the present study, but the author’s clinical experience suggested that laryngeal dysfunction that fails to resolve following administration of multiple doses of doxapram is generally persistent, which provided confidence in the final diagnosis. Finally, it is possible that paresis precedes complete paralysis. Of the 8 dogs with unilateral laryngeal paralysis in the present study, all were affected on the left side, which could support the supposition that laryngeal paresis is a premonitory sign for laryngeal paralysis, but further investigation is necessary to confirm that theory. None of the dogs in this study had clinical signs severe enough to require surgical intervention for laryngeal dysfunction or to warrant follow-up evaluation, although adjunct measures to minimize the risk of aspiration such as raising the height of the food dish were initiated in all dogs with laryngeal dysfunction. Owners of dogs with laryngeal dysfunction were also encouraged to limit exercise during hot weather and to maintain their pets in a lean body condition.

Stridor is often reported as a characteristic finding in dogs with laryngeal disease, but none of the dogs with bilateral laryngeal paralysis in the study had detectable stridor despite specific auscultation of the larynx. To the author’s knowledge, the prevalence of stridor or voice change in dogs with confirmed laryngeal paralysis has not been reported. In another study, clinical signs of laryngeal disease were reported only in dogs that had paradoxical laryngeal motion observed during induction of anesthesia, which represented 5% (12/250) of the dogs evaluated. Given that only 6 of 138 (4%) dogs of the present study had bilateral laryngeal paralysis, perhaps the low prevalence of stridor is not unusual. Assuming that clinical suspicion of laryngeal disease is an important factor in determining which dogs undergo laryngoscopic examination, the lack of clinical signs reported for dogs in the present study suggested that laryngeal dysfunction might be overlooked as a contributing factor to the disease process in dogs with cough.

A clear association has been established between laryngeal dysfunction and aspiration pneumonia. Because the purpose of the present study was to investigate the prevalence and type of laryngeal abnormalities in dogs with cough that did not have clinical signs of upper airway disease, dogs with suspected upper airway dysfunction were specifically excluded from the study, and aspiration pneumonia was not diagnosed in any of the study dogs. In this study, the prevalence of laryngeal dysfunction did not differ significantly between dogs with LRTI or EBP and dogs with IAD, which disproved the hypothesis that dogs with IAD would have laryngeal dysfunction more frequently than dogs with LRTI or EBP. Perhaps this finding should have been anticipated because aspirated material can contain pathogenic bacteria resulting in LRTI, gastric acid and enzymes leading to IAD, or both. Thus, microaspiration associated with laryngeal dysfunction that resulted in infection or inflammation cannot be ruled out for some dogs evaluated in the present study. Vomiting or regurgitation was reported for only 11 of 138 (8%) dogs of this study, which suggested that active or observable gastrointestinal disease was an unlikely cause of cough or laryngeal inflammation.

Findings of the present study indicated that a comprehensive endoscopic examination of the respiratory tract should be performed in all dogs examined because of cough. Although laryngeal hyperemia and swelling might be attributed to the mechanical effects of subacute or chronic cough, these abnormalities might also contribute to clinical signs and perpetuation of disease. In this study, stridor was more frequently detected in dogs with collapse of the cervical portion of the trachea than in dogs with laryngeal disease. Importantly, the fact that laryngeal paresis or paralysis was diagnosed in 26 of 138 (19%) dogs with cough that did not have any other clinical signs of upper airway disease indicated that laryngeal dysfunction in those dogs would have remained undiagnosed had a laryngoscopic examination not been performed. This suggested that a complete laryngoscopic examination should be included in the diagnostic evaluation of all dogs with cough. Further studies are necessary to elucidate the role of laryngeal dysfunction and structural laryngeal changes in the generation and perpetuation of cough in dogs.

Acknowledgments
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Presented in part as a poster at the 25th Annual Congress of the European College of Veterinary Internal Medicine—Companion Animal, Lisbon, Portugal, September 2015.

Footnotes
a. Karl Storz 0 degree rigid telescope. Karl Storz, Goleta, Calif.
b. Prism, version 5, GraphPad Software Inc, La Jolla, Calif.

References
5. Adhami T, Goldblum JR, Richter JE, et al. The role of gastric and
Assessment of novel digital and smartphone goniometers for measurement of canine stifle joint angles

Kristin A. Freund et al

OBJECTIVE
To evaluate accuracy and reliability of 3 novel goniometers for measurement of canine stifle joint angles and compare the results with those obtained with a universal goniometer (UG).

SAMPLE
8 pelvic limbs from 4 canine cadavers.

PROCEDURES
Each limb was secured to a wooden platform at 3 arbitrarily selected fixed stifle joint angles. Goniometry was performed with 2 smartphone-based applications (novel goniometers A and B), a digital goniometer (novel goniometer C), and a UG; 3 evaluators performed measurements in triplicate for each angle with each device. Results were compared with stifle joint angle measurements on radiographs (used as a gold standard). Accuracy was determined by calculation of bias and total error; coefficients of variation were calculated to estimate reliability, and strength of linear association between radiographic and goniometer measurements was assessed by calculation of correlation coefficients.

RESULTS
Mean coefficient of variation was lowest for the UG (4.88%), followed by novel goniometers B (7.37%), A (7.57%), and C (12.71%). Correlation with radiographic measurements was highest for the UG (r = 0.97), followed by novel goniometers B (0.93), A (0.90), and C (0.78). Constant bias was present for all devices except novel goniometer B. The UG and novel goniometer A had positive constant bias; novel goniometer C had negative constant bias. Total error at 50° and 100° angles was > 5% for all devices.

CONCLUSIONS AND CLINICAL RELEVANCE
None of the devices accurately represented radiographically measured stifle joint angles. Additional veterinary studies are indicated prior to the use of novel goniometers in dogs. (Am J Vet Res 2016;77:749–755)