COMPUTED TOMOGRAPHY OF NONANESTHETIZED CATS WITH UPPER AIRWAY OBSTRUCTION

KRYSTINA STADLER, ROBERT O'BRIEN

Upper airway obstruction is a potentially life-threatening problem in cats and for which a noninvasive, sensitive method rapid diagnosis is needed. The purposes of this prospective study were to describe a computed tomography (CT) technique for nonanesthetized cats with upper airway obstruction, CT characteristics of obstructive diseases, and comparisons between CT findings and findings from other diagnostic tests. Ten cats with clinical signs of upper airway obstruction were recruited for the study. Four cats with no clinical signs of upper airway obstruction were recruited as controls. All cats underwent computed tomography imaging without sedation or anesthesia, using a 16-slice helical CT scanner and a previously described transparent positional device. Three-dimensional (3D) internal volume rendering was performed on all CT image sets and 3D external volume rendering was also performed on cats with evidence of mass lesions. Confirmation of upper airway obstruction was based on visual laryngeal examination, endoscopy, fine-needle aspirate, biopsy, or necropsy. Seven cats were diagnosed with intramural upper airway masses, two with laryngotracheitis, and one with laryngeal paralysis. The CT and 3D volume-rendered images identified lesions consistent with upper airway disease in all cats. In cats with mass lesions, CT accurately identified the mass and location. Findings from this study supported the use of CT imaging as an effective technique for diagnosing upper airway obstruction in nonanesthetized cats.

Key words: cat, dyspnea, larynx, mass, upper airway, trachea.

Introduction

UPPER AIRWAY OBSTRUCTION is uncommon in cats, but may be life threatening when it occurs. Reported causes include laryngeal paralysis, trauma, foreign bodies, and benign and neoplastic masses.[1–3] Radiography is the standard screening test for most veterinary patients with suspected upper airway obstruction,[1,4,5] however superimposition may limit accurate evaluation of the degree and extent of disease. Definitive diagnosis for upper airway obstruction is most often based on visual laryngoscopy and endoscopy. In cases with intra or extramural masses, fine-needle aspirate and/or biopsy are also commonly used.[1,3] However, these tests require heavy sedation or general anesthesia and may not be suitable for patients in which corrective surgery or tracheostomy is not an option.

Computed tomography (CT) has been previously described as an effective diagnostic test for nonanesthetized dogs with functional upper airway disease,[6] cats with lower airway disease,[7] and a cat with tracheal rupture.[8] We hypothesized that it would be feasible to also perform CT in cats with upper airway obstruction without the need for intubation and general anesthesia. The aims of this prospective study were to describe a CT technique and characteristics observed for a cohort of nonanesthetized cats with upper airway obstruction vs. control cats and to subjectively compare CT findings with findings from other diagnostic tests.

Materials and Methods

With informed client consent, 10 cats that were presented for clinical signs of upper airway obstruction were prospectively recruited during the period between May 2009 and February 2012. Clinical signs used for study inclusion were: dyspnea, dysphagia, dysphonia, increased upper airway sounds, stridor, cyanosis, or a palpable mass in the upper airway region. Four cats that were presented for reasons unrelated to the upper airway were also included as controls. All affected cats underwent head, neck, and thoracic CT examination using a 16-slice helical scanner (GE Healthcare, Buckinghamshire, UK). Control cats underwent head and neck CT examinations using the same scanner. Cats were imaged in sternal recumbency using a transparent

From the Department of Veterinary Clinical Medicine, University of Illinois at Urbana-Champaign, 1008 W. Hazelwood Dr, Urbana, IL 61802 (Stadler, O'Brien)

Address correspondence and reprint requests to Robert O'Brien, Department of Veterinary Clinical Medicine, University of Illinois at Urbana-Champaign, 1008 W. Hazelwood Dr., Urbana, IL 61802. E-mail: bobrien@illinois.edu

Received April 20, 2012; accepted for publication January 16, 2013.
doi: 10.1111/vru.12019

Vet Radiol Ultrasound, Vol. 54, No. 3, 2013, pp 231–236.

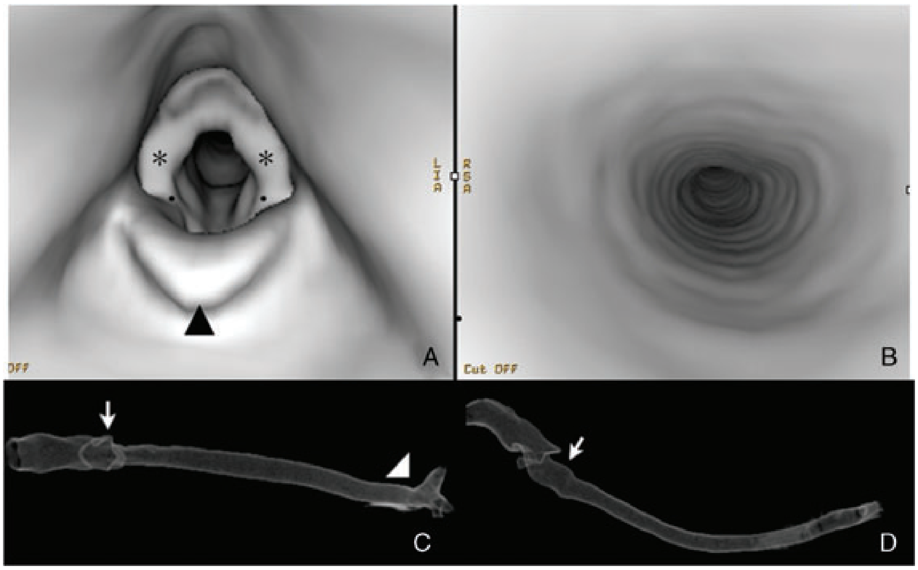

FIG. 1. Computed tomography images of the upper airway from a cat with no clinical signs of upper airway disease. (A) Three-dimensional internal volume-rendered images of the cranial larynx and (B) caudal cervical trachea at presumed inspiration. (C) Dorsal and (D) sagittal three-dimensional external volume-rendered images extending from the nasopharynx to the tracheal bifurcation. (A) The epiglottis (black arrow head), cuneiform (black dot), and corniculate processes (black asterisk) are in a normal anatomic position. (C and D) Note the appearance of the normal larynx (white arrow) and tracheal bifurcation (white arrow head).

positioning device (VetMouseTrap, University of Illinois, Urbana, IL), and no sedation or anesthesia. The cats were monitored visually throughout the procedure and all received supplemental oxygen. All CT scans were performed with a gantry rotation time of 0.5 s and a small field of view (25 mm). The kVP was 80 ($n = 1$), 100 (7), or 120 (3) and the mA ranged from 45 to 200 (median = 120). The pitch was 0.562 ($n = 2$), 0.938(5), 1.375(2) with a respective table speed of 5.62, 9.38, and 13.75 mm/s. Multiplanar reformatting was performed to obtain dorsal and sagittal image sets in all cats using detail algorithm, 0.625-mm slice thickness, and 0.312-mm slice reconstruction interval. Intravenous iodinated contrast medium at 2 mg/kg (Iohexol, Omnipaque, GE Healthcare, Waukesha, WI) was administered for all cases with suspected mass lesions. Examinations with severe motion artifacts or head turning were repeated. The phase of respiration was unknown for all cats. Cats without obvious mass lesions were scanned multiple times to increase the likelihood of imaging the lesion at its greatest severity. The scan with the most severe airway obstruction was used for MPR and 3D volume rendering.

In all cats, three-dimensional (3D) internal and external volume rendering of the upper airway was performed with CT image analysis software (Navigator Smooth and Volume Rendering: Lung Transparency Preset, GE Healthcare). Three-dimensional internal volume-rendered images were generated from the level of the nasopharynx to the principal bronchi. In cats with complete obstruction of the airway lumen, 3D images were created proximal and distal to the obstruction. To further evaluate degree of luminal obstruction, normograde and retrograde 3D internal volume-rendered image sets were created. For cats with mass lesions, 3D external volume-rendered images were generated at the area of interest. For normal reference, 3D volume-rendered images of the larynx and trachea were generated from CT images of four cats that underwent nonanesthetized neck and head CT for conditions other than upper airway disease (Fig. 1).

Six of the ten affected cats also had radiographs performed as part of their initial diagnostic workup. Radiographs were not required for study participation. Radiographed cats had a left and right lateral, dorsoventral, or ventrodorsal and an expiratory lateral thoracic view and a lateral cervical view. Oxygen was administered as needed. Radiographs and CT images were independently interpreted by a board-certified radiologist (R.T.0). Characteristics recorded were lesion location, extent and degree of the airway obstruction, and other clinically relevant lesions. Airway obstruction was defined as a subjective decrease of 50 percent or more of the total airway luminal diameter. Radiographic findings and CT findings were subjectively compared.

The diagnosis of upper airway obstruction was confirmed in all affected cats by one or more of the following methods: biopsy, endoscopy, laryngoscopy, cytology, and necropsy. Computed tomography findings were subjectively compared with findings from these additional diagnostic tests.

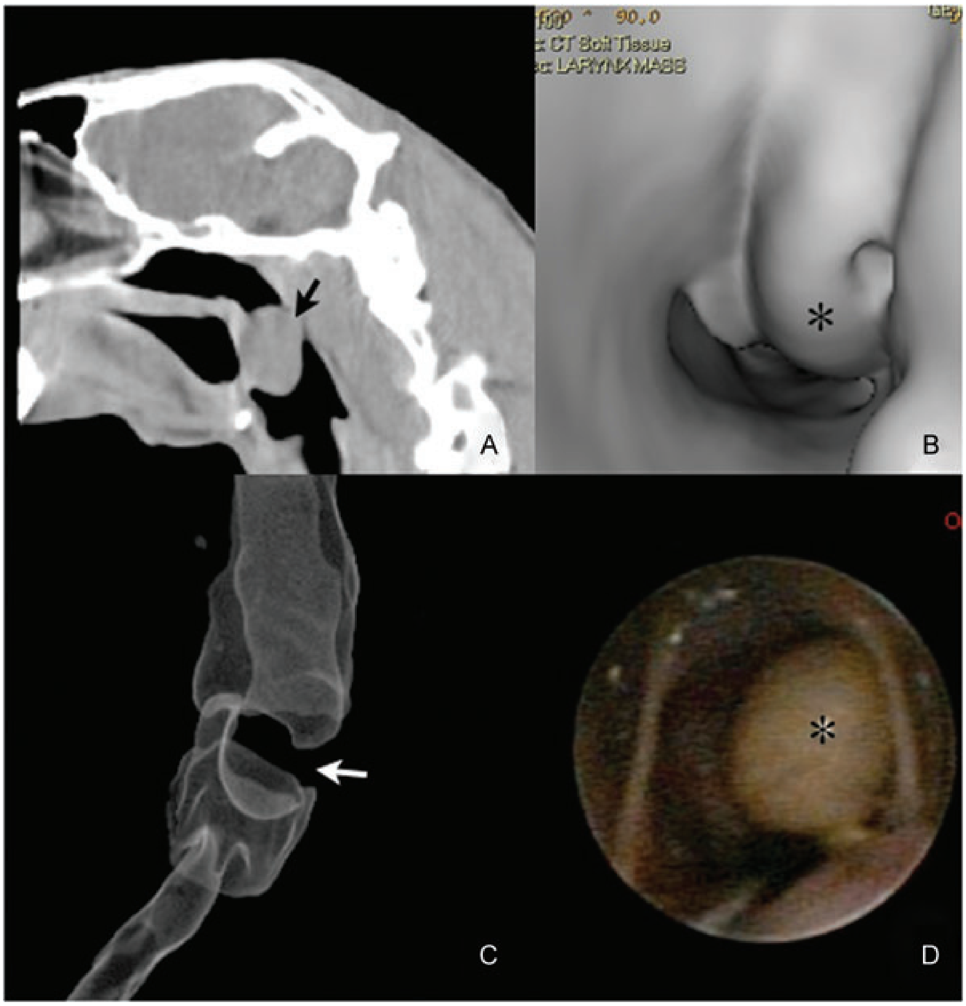

FIG. 2. Computed tomography images of the upper airway from a cat with a nasopharyngeal abscess. (A) Sagittal computed tomography image. Note the large soft tissue attenuated mass present at the level of the caudal soft palate extending into the cranial larynx and caudal nasopharynx (black arrow). (B) Three-dimentional internal volume-rendered image at the level of the caudal nasopharynx. Note the large predominately right sided mass (black asterisk). (C) Three-dimensional external volume-rendered image at the area of interest. Note the large defect in intraluminal air (white arrow) at the lesion location. (D) Endoscopy image of the nasopharynx of the same cat, showing a right-sided nasopharyngeal mass, diagnosed by cytology as an abscess.

Results

For the 10 affected cats, breeds included domestic shorthair (n = 6), domestic longhair (2), Himalayan (1), and Maine coon (1). The cats ranged in age from 6 years to 17 years (mean = 9.5 years) and weights ranged from 3.6 kg to 9.4 kg (mean = 5.75 kg). Eight of the affected cats were male castrated and two were female spayed. Control cats (n = 4) ranged in age from 3 years to 12 years (mean = 5.3 years) and weights ranged from 3.3 kg to 10.4 kg (mean = 5.68 kg). Three of the control cats were male castrated and one was female spayed. Three control cats were domestic shorthair and one was a domestic mediumhair.

Computed tomography protocols varied due to patient movement during the scan and patent size. Multiple scans were performed as necessary on patients in which functional airway obstruction was suspected. In these patients scans were repeated on an average of five times. The total scanning time per patient was approximately 15 min. Post-processing required approximately 15 min for generation of multiplanar reformatted sets and 30 min for 3D volume-rendered images. Patient positioning and degree of obstruction affected the level of difficulty for generating volume-rendered images and duration of reconstruction times. In seven cases, additional foam material was required inside the restraint device to further limit movement of the patient during imaging. Subjectively, the more dyspneic the patient, the less movement was encountered during the image session and fewer repeat scans were required for a diagnostic set.

Original transverse CT images were adequate for identification of the lesion in all cases. Multiplanar reformatted and 3D volume-rendered images were complimentary. Three-dimensional internal volume-rendering images

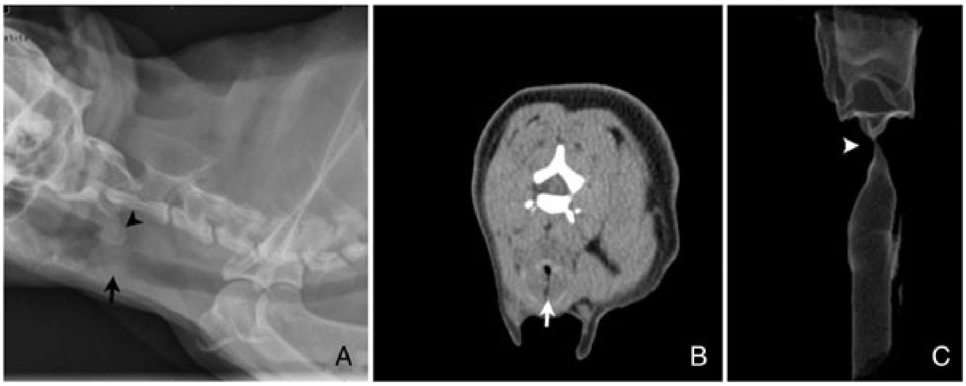

FIG. 3. Computed tomography images of the upper airway from a cat with laryngeal lymphoma. (A) Lateral cervical radiograph of a cat with a laryngeal mass. Note the laryngeal soft tissue opacity (black arrow) and dorsal margination of a mass (black arrow head). (B) Transverse computed tomography image at the cranial larynx. Note the severe decrease in luminal diameter and surrounding soft tissue attenuating mass (white arrow). (C) Three-dimensional external volume-rendered image at the level of the larynx, confirming almost complete luminal obstruction (white arrow head). The mass was confirmed laryngeal lymphoma by histopathology.

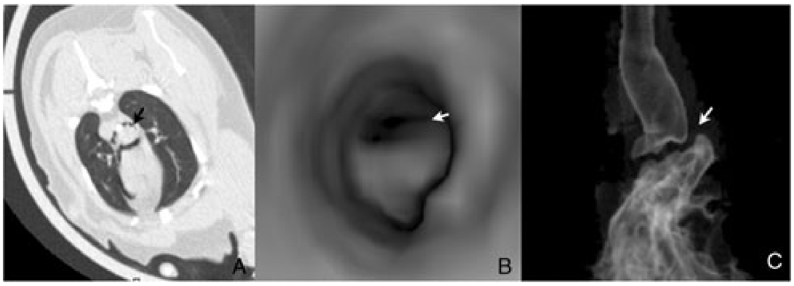

FIG. 4. Computed tomography images of the upper airway from a cat with tracheal adenocarcinoma. (A) Transverse computed tomography image just cranial to the tracheal bifurcation. Note the soft tissue attenuated mass present within the trachea (black arrow). Three-dimensional (B) internal and (C) external volume-rendered images of the area of interest. Note severe obstruction of the tracheal lumen (white arrow). Tracheal adenocarcinoma was diagnosed by histopathology.

appeared similar to endoscopic images. Three-dimensional external volume-rendering images allowed assessment of the airspace within the airway.

Intramural masses were present in seven cats. Breeds with intramural masses included domestic shorthair ($n = 5$), Maine coon (1), and Himalayan (1). Computed tomographic findings included soft tissue attenuating masses originating from the larynx ($n = 5$), trachea (1), and soft palate (1). Diagnosis was achieved by laryngoscopy with fine-needle aspirate ($n = 2$), laryngoscopy with fine-needle aspirate and biopsy (3), percutaneous aspirate (1), and necropsy (1). Six of the seven cats with intramural masses had pre and postcontrast scans. In five cats, homogenous contrast enhancement was observed. These masses were further diagnosed as carcinoma (2), lymphoma (2), and inflammatory (1). In the sixth cat, the mass had heterogeneous contrast enhancement and mineralization with rim enhancement. This mass was diagnosed as carcinoma by fine-needle aspirate. The decrease in luminal airspace was best appreciated subjectively with 3D volume-rendered images (Figs. 2, 3 and 4).

Three cats had airway obstruction not attributable to mass lesions. Diagnosis was achieved by necropsy ($n = 2$) and bronchoscopy with biopsy (1). Two cats had CT findings of everted laryngeal saccules and diffuse tracheal narrowing (Fig. 5). Computed tomographic findings consistent with everted laryngeal saccules included the following: bilateral soft tissue attenuating structures present on the ventral aspect of the larynx, just caudal to the cuneiform process of the arytenoid cartilage and cranial the vocal folds. Both cats were diagnosed with laryngotracheitis, one by necropsy and the other by endoscopic biopsy. Endoscopic findings in the second cat included a diffusely narrowed upper airway with thickened mucosa. Computed tomographic findings for the third cat included symmetric narrowing of the rima glottis with medially displaced cuneiform processes. This finding was considered suggestive of laryngeal paralysis, however the upper airway was not mentioned in the necropsy report. This cat also had a peritoneal pericardial diaphragmatic hernia and right cranial lung lobe atelectasis with a pulmonary bulla present on CT and necropsy. This cat presented with respiratory stridor and dyspnea.

For cats that were also examined using lateral neck radiographs, findings included the following: suspect intramural laryngeal mass ($n = 2$), increased laryngeal soft tissue opacity of the larynx (2), diffuse tracheal narrowing (2), soft

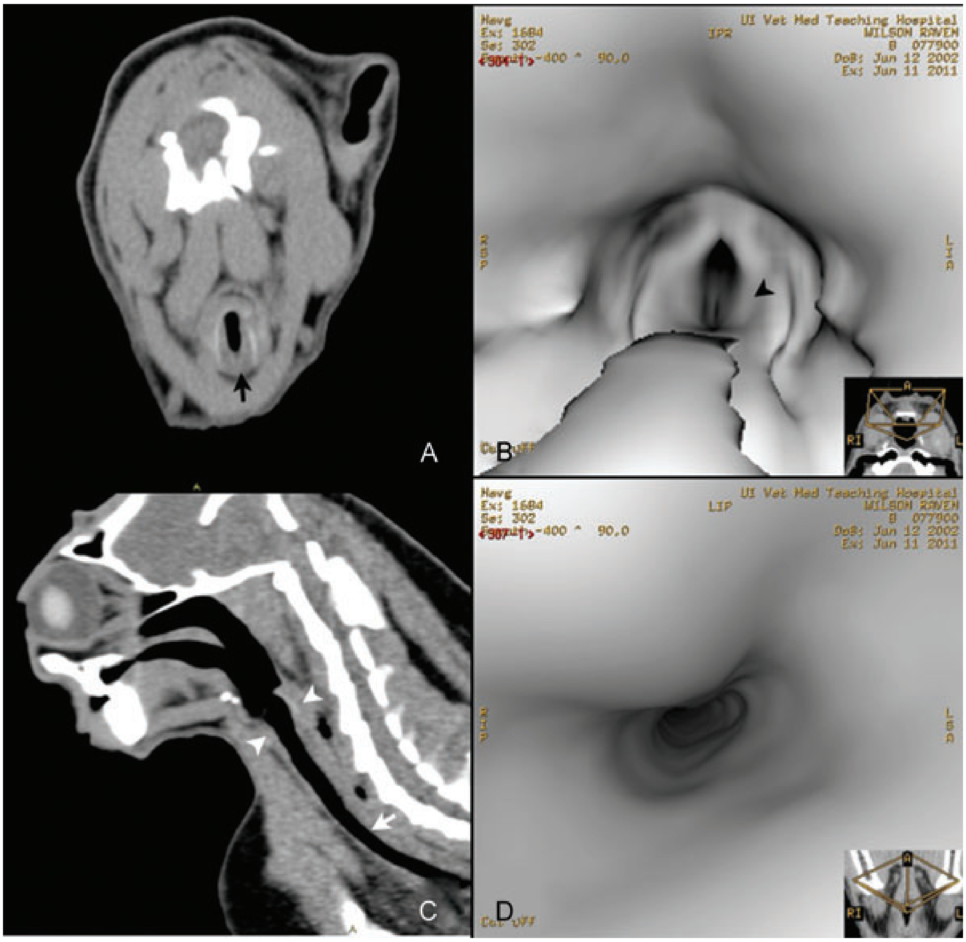

FIG. 5. Computed tomography images of the upper airway from a cat with laryngotracheitis. (A) Transverse computed tomography image at the level of the larynx. Note the diffuse soft tissue thickening, most prominent in the ventral larynx (black arrow). (B) Three-dimensional internal volume-rendered image of the larynx. Note the increase in soft tissue (black arrow head) present and decreased diameter of the rima glottis. (C) Sagittal computed tomography image. Increased laryngeal soft tissue (white arrow head) and diffuse tracheal narrowing (white arrow) are present. (D) Three-dimensional internal rendered image of the cervical trachea. Note the decrease in diameter. Laryngotracheitis was diagnosed on necropsy.

palatal mass (1), and an extramural mass with secondary tracheal compression (1). The extramural mass observed with radiography was later diagnosed by CT as being intramural. Increased laryngeal soft tissue opacity and diffuse tracheal narrowing was present in two cats diagnosed with laryngotracheitis. Four cats were also examined using thoracic radiographs and findings included one or more of the following: pulmonary alveolar pattern ($n = 3$), pleural effusion (2), bronchiolar pattern, (1) and bronchiectasis (1). Of these cats, two were diagnosed with laryngotracheitis, one with a soft palatal abscess, and one with intramural lymphoma.

Discussion

All cats with intramural airway masses were correctly diagnosed using CT when compared to reference standard diagnostic modalities. In all cats, original transverse CT images were sufficient for detection of lesions. Multiplanar reformatted and 3D volume-rendered CT images provided complimentary information that improved assessment of mass extent and severity of airway compromise. Etiologic causes for intramural airway masses described in this study have been previously described.[5] Three of the four cats with intramural airway masses and radiographs had radiographic findings of well-defined increased intramural soft tissue opacity. This finding has been previously described as being suggestive of neoplastic etiologies,[5] however one of the three cats in our study was diagnosed with a pyogranulomatous inflammatory mass. An extramural mass was suspected on radiographs in the fourth cat, but was interpreted to be intramural with extensive expansion dorsal to and lateral to the larynx based on CT. The diagnostic confirmation for this cat was percutaneous cytology and cytological diagnosis was interpreted to be consistent with laryngeal lymphoma. Endoscopy was not performed.

Two cats with upper airway obstruction not attributable to mass lesions in our study were found to have severe laryngotracheitis. Both cats had increased laryngeal soft tissue opacity on radiographs. This finding has been associated with laryngeal collapse in the dog.[6] Computed tomographic findings in these cats included everted laryngeal saccules and diffuse tracheal narrowing. Everted laryngeal saccules have been described in brachycephalic cat breeds as a component of brachycephalic airway syndrome.[1] Both cats of our study were domestic breeds (DSH, DLH). The CT finding of everted saccules may have been due to severe laryngeal inflammation and swelling of the ventral larynx. Severe upper airway inflammation also may have led to increased inspiratory pressure, creating the potential for laryngeal saccule eversion.

Laryngeal paralysis was diagnosed in one cat based on CT findings. Laryngeal paralysis is common in middle-aged to older dogs but relatively rare in cats.[3,9,10] Congenital and acquired forms of laryngeal paralysis have been reported to exist in cats. Based on the signalment and presence of additional concurrent disease, the cat in this study most likely had the acquired form. The underlying etiology of laryngeal paralysis in cats remains unknown. Reported causes of acquired laryngeal paralysis have included intrathoracic masses, thyroidectomy complication, neoplastic infiltration, neuromuscular disorders, and lead toxicosis.[3,9] The cat in this study had a peritoneal–pericardial diaphragmatic hernia. To the author's knowledge, peritoneal–pericardial diaphragmatic hernia has not been described as a cause of laryngeal paralysis. A necropsy was performed on this cat, however no laryngeal pathology was noted and a laryngeal exam was not performed. The presumptive diagnosis of laryngeal paralysis was made based on clinical signs (stridor) and CT imaging findings.

In cats with a severe decrease in luminal diameter due to mass lesions, 3D internal volume-rendered images were challenging to construct due to partial or complete obliteration of the luminal airspace by mass lesions or compression. The 3D internal volume-rendering software uses a predefined attenuation coefficient to generate a threshold for the air-lumen interface.[11] If the lumen diameter is decreased or obstructed, the air-lumen interface is obscured and generation of 3D internal images can be difficult or impossible. In our study, 3D external imaging was used to demonstrate the loss of luminal air, especially in cases where 3D internal rendering was insufficient for assessing extent of the lesion. Additional challenges for 3D volume rendering in our cats included neck turning and head motion, both of which have been previously described in dogs.[6] In these cases, repeated scans were necessary.

Limitations of this study included small numbers of cats in all disease categories. Additionally, the inability to obtain images in a specific respiration phase may have decreased detection of dynamic airway diseases in some cats. However, all cats with suspected functional obstruction in our study were scanned multiple times to maximize the chances of imaging the most severely affected phase of respiration. Also, in comparison to more invasive diagnostic modalities performed under general anesthesia, CT imaging of nonanesthetized cats did not allow fine-needle aspirate cytology or biopsies at the time of the study. However, the CT images did assist clinicians in planning approaches for biopsy, fine-needle aspirate cytology or surgery.

In conclusion, CT imaging of nonanesthetized cats is a feasible noninvasive method for rapidly diagnosing upper airway lesions and characterizing extent of involvement. For upper airway inflammation and laryngeal paralysis, CT may be helpful for preliminary investigation but definitive diagnosis requires a visual laryngeal exam and/or endoscopy. Future CT studies using a large number of cats with confirmed neoplastic and non-neoplastic upper airway disease are needed to determine the diagnostic sensitivity of CT for differentiating these etiologic categories.

REFERENCES

1. Aron DN, Crowe DT. Upper airway obstruction. General principles and selected conditions in the dog and cat. Vet Clin North Am Small Anim Pract 1985;15:891–917.

2. Tasker S, Foster DJ, Corcoran BM, et al. Obstructive inflammatory laryngeal disease in three cats. J Feline Med Surg 1999;1:53–59.

3. Taylor SS, Harvey AM, Barr FJ, et al. Laryngeal disease in cats: a retrospective study of 35 cases. J Feline Med Surg 2009;11:954–962.

4. Carlisle CH, Biery DN, Thrall DE. Tracheal and laryngeal tumors in the dog and cat – literature-review and 13 additional patients. Veterinary Radiology 1991;32:229–235.

5. Jakubiak MJ, Siedlecki CT, Zenger E, et al. Laryngeal, laryngotracheal, and tracheal masses in cats: 27 cases (1998–2003). J Am Anim Hosp Assoc 2005;41:310–316.

6. Stadler K, Hartman S, Matheson J, et al. Computed tomographic imaging of dogs with primary laryngeal or tracheal airway obstruction. Vet Radiol Ultrasound 2011;52:377–384.

7. Oliveira CR, Mitchell MA, O'Brien RT. Thoracic computed tomography in feline patients without use of chemical restraint. Vet Radiol Ultrasound 2011;52:368–376.

8. Bhandal J, Kuzma A. Tracheal rupture in a cat: diagnosis by computed tomography. Can Vet J 2008;49:595–597.

9. Schachter S, Norris CR. Laryngeal paralysis in cats: 16 cases (1990–1999). J Am Vet Med Assoc 2000;216:1100–1103.

10. Thunberg B, Lantz GC. Evaluation of unilateral arytenoid lateralization for the treatment of laryngeal paralysis in 14 cats. J Am Anim Hosp Assoc 2010;46:418–424.

11. Naidich DP, Webb WR, Grenier PA. Imaging of the airways: functional and radiologic correlations. Philadelphia: Lippincott Williams & Wilkins, 2005.