Abstract

Objectives. To estimate the prevalence of subclinical abnormalities reported in thoracic CT scans of cats and to test associations between respiratory signs and CT signs.

Methods. Retrospective review of signalment, indications, respiratory signs and reported CT findings in a series of cats having thoracic CT scans. Associations between patient variables, respiratory signs and CT signs were tested using multivariable regression methods.

Results. Records of 352 consecutive cats were reviewed. Abnormalities affecting thoracic structures were reported in CT scans of 138/179 (77%) cats without respiratory signs. The most prevalent CT findings in cats without respiratory signs were pulmonary collapse (41%), signs of bronchial disease (24%) and space-occupying lesions (21%). Dyspnoea, cough and tachypnoea were associated with space-occupying lesions. Dyspnoea was also associated with pulmonary consolidation and atelectasis. Increasing body weight was associated with pulmonary atelectasis and increasing age was associated with signs of bronchial disease.

Clinical significance. Abnormalities are reported frequently in thoracic CT scans of cats without respiratory signs. The most prevalent abnormality, pulmonary atelectasis, is probably a temporary effect of sedation or anaesthesia for CT. A high prevalence of subclinical abnormalities and limited correlations between clinical signs and CT findings will complicate diagnosis.

Introduction

Computed x-ray tomography (CT) is used increasingly to investigate cats with thoracic conditions (Henninger 2003; Cohn et al. 2004; Oliveira et al. 2011; Aarsvold et al. 2015). Being a cross-sectional imaging modality, CT eliminates the problem of superimposition that affects radiography and therefore enables clearer depiction of internal anatomy and morphological abnormalities that alter anatomy. As a result CT has a higher sensitivity for pulmonary disease than radiography (Nemanic et al. 2006). In general, higher sensitivity is advantageous, but one of the drawbacks of using more sensitive diagnostic tests is that more of the abnormalities detected may represent clinically silent conditions and, potentially, incidental findings (Aspinall et al. 2013). For example, previous CT studies have documented the tendency for lung collapse in anaesthetised cats (Henao-Guerrero et al. 2012). It is the authors' impression that other abnormalities, such as signs of bronchial disease, are observed frequently in cats having thoracic CT for reasons unrelated to respiratory signs.

Clinicians interpreting diagnostic images must always consider the possible relationship between imaging signs and clinical signs in order to assess the likely meaning of the images (Wood, 1999). For example, it is generally accepted that coughing in cats is more associated with bronchial lesions whereas dyspnoea is more associated with cardiac disease or space-occupying lesions, such as a pulmonary mass or pleural fluid (Moise et al. 1989; Corcoran et al. 1995; Dye et al. 1996; Sauve et al. 2005; Swift et al. 2009; Foster & Martin 2011; Johnson & Vernau 2011; Sigrist et al. 2011); however, such associations are not pathognomonic, so it can be difficult to judge if the imaging signs in an individual patient fully explain their clinical signs. Particularly in patients with non-specific or vague clinical signs, it can be difficult to decide if an imaging finding represents a clinical or subclinical condition, and whether to treat it or employ further diagnostic tests.

The aims of the present study were to estimate the prevalence of subclinical abnormalities reported in thoracic CT scans of cats and to test the associations between clinical signs and CT signs.

Methods

For this retrospective cross-sectional study, electronic medical records of cats referred to the Queen Mother Hospital for Animals (QMHA) between September 2013 and September 2015 were reviewed. The only inclusion criterion was CT imaging of the thorax. The signalment, body weight, body condition score, indication for CT and respiratory signs (if any) were extracted from contemporaneous clinical notes by one investigator (IDJ). Indications for CT were categorised as follows: suspected respiratory condition, metastasis check, trauma, comprehensive medical work-up, other. Respiratory signs were categorised as follows: none, cough, upper respiratory signs (stertor, change of voice, nasal discharge, nasal obstruction, dyspnoea), dyspnoea not associated with upper airway signs, tachypnoea, hyperpnoea, other.

CT scans were acquired using a multi-detector row CT scanner (MX 8000 IDT, Philips Medical Systems, Cleveland, USA). CT images were obtained using helical acquisition, 120kVp, 200mAs, 16 x 1.5mm collimation, 0.688 pitch, 2mm slice thickness, 150-300mm field of view, 512x512 matrix (pixel size 0.3-0.6mm). All cats had separate CT series to examine the lung and the thoracic soft tissues, respectively. Images of the lung were reconstructed using a high frequency (lung enhanced) algorithm whereas images of the thoracic soft tissues were reconstructed using a sharp reconstruction algorithm. When indicated, post-contrast CT images of the thoracic soft tissues were obtained 60s after the start of rapid intravenous injection of 2ml/kg bolus of iohexol (Omnipaque 300, GE Healthcare, Oslo, Norway). Use of sedation or anaesthesia for CT was recorded.

Abnormalities in CT scans, as reported individually at the time of clinical work-up by the six Board-certified radiologists employed at the QMHA in this period, were extracted from imaging reports by another investigator (CRL) without reference to the clinical information. Experience of small animal CT in this group of radiologists ranged from 5 to 26 years. CT signs were categorised as follows: space-occupying lesions (pulmonary mass, other intrathoracic mass, pleural fluid, pneumothorax, pneumomediastinum), pulmonary nodules (solid, subsolid, cavitary, bulla/cyst), consolidation (sublobar, lobar, bronchocentric, multifocal), atelectasis/collapse (sublobar, lobar, bronchocentric, multifocal), ground-glass opacities (focal, multifocal, diffuse), air-trapping (focal/lobar, multifocal, diffuse, interstitial emphysema), bronchial lesions (wall thickening, bronchiectasis, mucus plugging, "tree-in-bud," foreign body, broncholith), other (honeycombing, septal lines, parenchymal bands, adenopathy, vascular congestion) and thoracic wall lesions (rib fractures, barrel-chested conformation, pectus excavatum, peritoneopericardial diaphragmatic hernia, other). The "tree-in-bud" pattern applies to centrilobular branching structures that resemble a budding tree. Terminology followed recommendations for thoracic imaging by the Fleischner Society (Hansell et al. 2008).

Calculation based on the need to estimate a prevalence of 30% to within +/-5% indicated a sample size equal to 322 cats (Eng 2003). Associations between respiratory signs and reported CT signs were tested using multinomial logistic regression with respiratory signs as the dependent variable. Associations between age, body weight, body condition score, use of sedation or anaesthesia and atelectasis were tested using binary logistic regression. The association between age and bronchial lesions was also tested using binary logistic regression. Statistical testing was done using SPSS Statistics, version 22 (IBM Corporation, Chicago, IL). Results with $p<0.05$ were considered significant.

Results

Records of 352 consecutive cats were reviewed. No cats were excluded. There were 195 (55%) male cats (186 neutered) and 157 (45%) females (150 neutered). The most prevalent breeds were Domestic Short Hair (n=213, 61%), Domestic Long Hair (34, 10%), British Short Hair (14, 4%), Siamese (14, 4%) and Maine Coon (12, 3%). There were 21 other feline breeds with less than 10 individuals. Age was known in 350 cats. Median (range) age of cats was 9.5y (4m – 18y). Body weight was recorded in 311 cats and body condition score was recorded in 202 cats. Median body weight was 4.4kg (range 1.2 – 13.1kg) and median body condition score was 4 (range 1 – 9).

The principal indications for thoracic CT were respiratory signs (n= 144, 41%), comprehensive medical work-up (107, 30%), search for metastasis (64, 18%) and trauma (37, 11%). Respiratory signs were present in 173 (49%) cats, including upper respiratory signs in 78 (22%) cats, dyspnoea not associated with upper airway signs in 42 (12%) cats, combinations of two or more other categories of respiratory signs in 20 (6%) cats, tachypnoea in 17 (5%) cats and cough in 16 (4%) cats. There were no cats in which hyperpnoea was recorded as the sole respiratory sign.

Two hundred and thirty-seven (67%) cats were anaesthetised for CT and the remainder were sedated. Cats were positioned in sternal recumbency for CT, except for four cats with suspected vertebral fractures, which were placed in lateral recumbency. Abnormalities affecting thoracic structures were reported in CT scans of 138 (77%) cats without respiratory signs, 65 (83%) cats with upper respiratory signs and 91 (96%) cats with other respiratory signs ($p=0.0004$). CT scans were interpreted as normal in 58 (16%) cats.

Abnormalities reported in CT scans of the 179 cats without respiratory signs are summarised in table 1. The most prevalent abnormalities in these cats were pulmonary atelectasis (reported in 41%) and signs of bronchial disease (24%). No abnormalities were reported in 23% cats without respiratory signs. Of the 57 cats without respiratory signs in which the indication for CT was to search for metastasis, 50 (88%) had a cellular diagnosis of neoplasia and, of these, 15 (30%) had pulmonary nodules and 9 (18%) had pleural fluid reported on CT. Of the 28 cats without respiratory signs in which the indication for CT was trauma, 9 (32%) had space-occupying lesions, including pneumomediastinum in 5 (18%) and pneumothorax in 4 (14%). The 92 cats without respiratory signs in which the indication for CT was the need for a comprehensive medical work-up included a wide range of conditions. The most prevalent of these were 21 cats subsequently shown to have neoplasia. Of these, 5/21 (24%) had space-occupying lesions (3 pulmonary mass, 1 mediastinal cyst, 1 pleural effusion) and 4/21 (19%) had pulmonary nodules on CT. The second most prevalent group were 15 cats with uncontrolled diabetes mellitus (including 11 with hypersomatotropism). Of these, only one diabetic cat had a CT abnormality related to its condition, which was pleural effusion secondary to metastatic adrenal carcinoma.

The frequencies of reported CT abnormalities CT in cats with different respiratory signs are summarised in table 2 and the results of statistical testing are summarised in table 3. Air-trapping and thoracic wall lesions were excluded from the statistical analysis because of the small number of affected individuals. The strongest association found between respiratory signs and CT abnormalities was between dyspnoea and space-occupying lesion (odds ratio 8.7, 95% confidence interval 3.6-21.1) (p=0.00002). Cough and tachypnoea were also significantly associated with a CT report of a space-occupying lesion. Space-occupying lesions reported in 99 cats in this series were pulmonary mass in 25%, other thoracic mass in 27%, pleural fluid in 53%, pneumothorax in 18% and pneumomediastinum in 11% cats. Masses and pleural fluid occurred together in 17% cats with space-occupying lesions. Dyspnoea was also significantly associated with a CT report of pulmonary consolidation or atelectasis. Upper respiratory tract signs were significantly associated with a CT report of bronchial lesions and inversely associated with space-occupying lesions or ground-glass opacities.

Overall, pulmonary atelectasis/collapse was the most frequent reported CT abnormality, affecting 159 (45%) cats in this series. The most frequently collapsed lobes, in descending order were the right middle (collapsed in 53% affected cats), left cranial (45%), right cranial (39%), left caudal (16%), accessory (11%) and right caudal (9%). All lobes had some degree of atelectasis in 8% affected cats. The predominant distribution of atelectasis was sub-lobar, which was reported in 71% lobes affected by atelectasis. Other reported distributions of pulmonary atelectasis were lobar (19%), bronchocentric (5%) and multifocal (5%) (Figure 1). There was an association between body weight and CT signs of pulmonary atelectasis (odds ratio 1.2, 95% confidence interval 1.0-1.5) (p=0.02). Neither body condition score (p=0.8) nor use of anaesthesia (p=0.08) were significantly associated with pulmonary atelectasis.

Bronchial abnormalities were reported in CT scans of 103 (29%) cats in this series. Reported bronchial abnormalities were thickened bronchial walls in 91%, mucus plugging in 14%, tree in bud in 5%, bronchiectasis in 3% and broncholithiasis in 1% instances (Figure 2). Signs of thickened bronchial walls and mucus plugging occurred together in 12% cats with bronchial lesions. There was an association between age and CT signs of bronchial disease (odds ratio 1.12, 95% confidence interval 1.07-1.19) (p=0.0003).

Discussion

These results support the conclusion that the prevalence of abnormalities reported in thoracic CT scans is high (77%) in cats having CT for reasons other than to investigate respiratory signs. A high prevalence of potentially subclinical abnormalities is problematical because it will complicate diagnosis and tend to undermine the correlations between clinical signs and CT findings that are normally used as a basis for interpretation of findings.

Although the high prevalence of lung atelectasis observed in the present study is probably a temporary effect of the routine use of sedation or anaesthesia for CT, signs of bronchial disease and space-occupying lesions were also reported frequently in cats without respiratory signs. Previous studies have found that cats with infectious pneumonia may lack respiratory signs (Macdonald et al. 2003) and that histological lesions affecting the lung of cats with diabetes mellitus may be unassociated with respiratory signs (Mexas et al. 2006). These findings may correspond with the widely-held belief that the cat – like the sheep – is a species able to hide signs of disease, with the result that by the time an owner recognises their pet is unwell, its condition may be advanced; however, the present study provides no information about the possibility that certain subclinical lesions may eventually become serious. Only a cohort study with long term follow-up of patients could determine the extent to which that occurs. Alternatively, many of the abnormalities reported in the thoracic CT scans in this series may represent static conditions that will never cause clinical signs. If so, labelling affected cats carries the potential for overdiagnosis (Moynihan et al. 2012).

In this study, respiratory signs were significantly associated with abnormal findings on CT but there were few significant associations between specific respiratory signs and CT-detected abnormalities. Dyspnoea, cough and tachypnoea were associated with space-occupying lesions. Dyspnoea was also associated with pulmonary consolidation and atelectasis. A previous study found that cardiac disease is the most frequent cause of dyspnoea in cats (Swift et al. 2009). This finding is applicable to a referral population of cats, but the present study underrepresented this group of patients because relatively few cats with cardiac disease are considered candidates for CT. Cough was a relatively infrequent clinical sign in this study and was not significantly associated with bronchial abnormalities on CT. An association between expiratory dyspnoea and lower airway disease in cats has been reported (Sigrist et al. 2011), but a similar association was not evident in the present study. Bronchial abnormalities, mainly thickened bronchial walls and signs of mucus plugging, were observed in many cats with no respiratory signs or signs referable to the upper respiratory tract, hence the clinical significance of these findings is uncertain. One of the limitations of the present study is that the severity of radiographic signs cannot be assessed on the basis of CT reports, hence it is unclear if – for example –signs of bronchial disease were more marked in cats with cough than cats without respiratory signs.

The tendency for lung atelectasis in anaesthetised cats has been reported previously (Henao-Guerrero et al. 2012). In dogs, use of high inspired pO2 during anaesthesia has been associated with a higher prevalence of lung atelectasis than moderate inspired pO2 (Staffieri et al. 2007). The same effect may apply to cats, although this was not evident in the present study because cats having CT under general anaesthesia were no more likely to have lung atelectasis than those having CT under sedation. Avoiding lung atelectasis may be expected to aid interpretation of CT images and to increase sensitivity for lesions that could be obscured by lung atelectasis. A reduced tendency for lung atelectasis may be an advantage of conscious CT for cats (Oliveira et al. 2011). Hence, CT scanning of conscious cats or cats under anaesthesia with positive pressure ventilation may be preferred; however, a recent study of anaesthetised dogs and cats that had brief hyperventilation and CT scan during the subsequent expiratory pause (which is the technique usually employed in the authors' hospital), found that ability to detect pulmonary nodules or bulla was not significantly different than when images were acquired with the lungs inflated by positive pressure ventilation (Simone et al. 2016). Cats in ventral or dorsal recumbency are probably affected less by lung atelectasis than those in lateral recumbency, although this cannot be tested in the present study because at the authors' hospital only cats presented after trauma that are considered at risk of being repositioned have CT scans in lateral recumbency (Figure 1D).

In this study, lung atelectasis was associated with increasing body weight, likely reflecting the tendency for reduced lung volume in cats with accumulation of intrathoracic fat. Body condition score is used widely as a method of estimating obesity (Laflamme 1997), and would be expected to be correlated with likelihood of lung atelectasis under anaesthesia, possibly better than body weight, but that was not observed. The lack of recorded body condition score in a large proportion of cats will have reduced statistical power and may at least partly explain this negative result.

The most frequently collapsed lung lobes in cats in the present study were the right middle and the left and right cranial lobes. The right middle lobe is most prone to collapse in the cat (and dog) (Robinson 1982) and is frequently found to be collapsed in cats with bronchial disease because of mucus or exudate obstructing the airways (Moise et al. 1989). The association found between CT signs of bronchial disease and patient age may reflect progressive disease that is initially feline asthma. Asthma is thought to the result of an allergic response triggered by inhaled allergens that leads to bronchial smooth muscle constriction and airway narrowing (Trzil & Reinero 2014). Many cats with asthma have minimal radiographic signs other than pulmonary overinflation (Gadbois et al. 2009); however, chronic antigenic stimulation in affected cats leads to permanent bronchial luminal narrowing and wall thickening because of smooth muscle hyperplasia, goblet cell and submucosal gland hypertrophy and hyperplasia, epithelial erosion and eosinophilic infiltration (Padrid et al. 1995;

Reinero et al. 2004) and these pathological changes are more likely to become visible radiographically.

It should be emphasised that this study was not designed to estimate the accuracy of CT for thoracic lesions in cats or to estimate the reliability of observers. Our principal aim was to estimate the prevalence of subclinical abnormalities reported in thoracic CT scans of cats and this is probably best achieved by extracting data from imaging reports produced in a consecutive series of patients by radiologists working according to their normal routine in a clinical environment. As a result, the authors' data include variability occurring as a result of patients (all were included regardless of indication or diagnosis) and radiologists (including hawks and doves, working with clinical histories of varying quality). Other methods, such as limiting the study to cats in which there is a certain final diagnosis, or employing a panel of observers to reach a consensus about the CT findings without knowledge of the clinical history, would produce results less representative of clinical practice.

Table 1. Abnormalities reported in CT scans of 179 cats without respiratory signs

	CT abnormalities									
Indication for CT	None	Space-occupying lesion	Pulmonary nodules	Consolidation	Atelectasis	Ground glass opacity	Air-trapping	Bronchial lesions	Other	Thoracic wall lesion
Suspected respiratory condition[a] n=1	0	1 (100%)	0	0	1 (100%)	0	0	0	1 (100%)	0
Metastasis check n=57	11 (19%)	10 (18%)	17 (30%)	4 (7%)	21 (37%)	7 (12%)	0	12 (21%)	7 (12%)	2 (4%)
Trauma n=28	6 (21%)	9 (32%)	1 (4%)	0	16 (57%)	0	0	3 (11%)	3 (11%)	2 (7%)
Comprehensive medical work-up n=92	24 (26%)	18 (20%)	11 (12%)	9 (10%)	35 (38%)	8 (9%)	0	27 (29%)	10 (11%)	1 (1%)
Other[b] n=1	0	0	0	0	1 (100%)	0	0	1 (100%)	0	0
Totals	41 (23%)	38 (21%)	29 (16%)	13 (7%)	74 (41%)	15 (8%)	0	43 (24%)	21 (12%)	5 (3%)

[a] Reduced lung sounds on auscultation, subsequently shown to be secondary to pleural effusion

[b] Pre-operative assessment of suspected vascular ring anomaly

Table 2. Associations between respiratory signs and abnormalities reported in CT scans of 352 cats

	CT abnormalities									
Respiratory signs	None	Space-occupying lesion	Pulmonary nodules	Consolidation	Atelectasis	Ground glass opacity	Air-trapping	Bronchial lesions	Other	Thoracic wall lesion
None n=179	41 (23%)	38 (21%)	29 (16%)	13 (7%)	74 (41%)	15 (8%)	0	43 (24%)	21 (12%)	5 (3%)
Cough n=16	0	8 (5%)	2 (13%)	1 6(%)	10 (62%)	2 (13%)	1 (6%)	7 (44%)	0	0
Upper respiratory n=78	13 (17%)	8 (10%)	12 (15%)	5 (6%)	34 (44%)	2 (3%)	0	33 (42%)	4 (5%)	1 (1%)
Dyspnoea n=42	1 (2%)	30 (71%)	3 (7%)	8 (19%)	28 (67%)	3 (7%)	2 (5%)	9 (21%)	9 (21%)	6 (14%)
Tachypnoea n=17	3 (18%)	7 (53%)	4 (24%)	3 (18%)	4 (24%)	0	0	3 (18%)	4 (24%)	0
Combination of respiratory signs n=20	0	6 (30%)	4 (20%)	4 (20%)	9 (45%)	2 (10%)	0	8 (40%)	2 (10%)	0
Totals	58 (17%)	99 (28%)	54 (15%)	34 (10%)	159 (45%)	24 (7%)	3 (1%)	103 (29%)	40 (11%)	12 (3%)

Table 3. Significant associations between respiratory signs and abnormalities reported in CT scans of 352 cats

Respiratory signs	CT abnormalities Space-occupying lesion	Pulmonary nodules	Consolidation	Atelectasis	Ground glass opacity	Bronchial lesions	Other
Cough	4.1 (1.3-13.3) p=0.017	NS	NS	NS	NS	NS	NS
Upper respiratory	0.4 (0.17-0.98) p=0.04	NS	NS	NS	0.2 (0.04-0.8) p=0.03	2.0 (1.1-3.8) p=0.04	NS
Dyspnoea	8.7 (3.6-21.1) p=0.00002	NS	5.0 (1.5-17.0) p=0.009	3.5 (1.4-8.9) p=0.009	NS	NS	NS
Tachypnoea	3.8 (1.1-13.3) p=0.03	NS	NS	NS	NS	NS	NS
Combination of respiratory signs	NS	NS	NS	NS	NS	NS	NS

Values are odds ratio (95% confidence interval)

NS, non-significant, p>0.05

References

Aarsvold, S., Reetz, J. A., Reichle, J. K., Jones, I. D., Lamb, C. R., Evola, M. G., Keyerleber, M. A. & Marolf, A. J. (2015) Computed tomographic findings in 57 cats with primary pulmonary neoplasia. *Veterinary Radiology & Ultrasound* **56**, 272-277

Aspinall, S.R., Ong, S.G.S., Wilson, M.S.J., Lennard, T.W.J., 2013. How shall we manage the incidentally found thyroid nodule? Surgeon-Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland 11, 96-104.

Cohn, L. A., Norris, C. R., Hawkins, E. C., Dye, J. A., Johnson, C. A. & Williams, K. J. (2004) Identification and characterization of an idiopathic pulmonary fibrosis-like condition in cats. *Journal of Veterinary Internal Medicine* **18**, 632-641

Corcoran, B. M., Foster, D. J. & Fuentes, V. L. (1995) Feline asthma syndrome - a retrospective study of the clinical presentation in 29 cats. *Journal of Small Animal Practice* **36**, 481-488

Dye, J. A., McKiernan, B. C., Rozanski, E. A., Hoffmann, W. E., Losonsky, J. M., Homco, L. D., Weisiger, R. M. & Kakoma, I. (1996) Bronchopulmonary disease in the cat: Historical, physical, radiographic, clinicopathologic, and pulmonary functional evaluation of 24 affected and 15 healthy cats. *Journal of Veterinary Internal Medicine* **10**, 385-400

Eng, J. (2003) Sample size estimation: how many individuals should be studied? Radiology 227, 309-313

Foster, S. F. & Martin, P. (2011) Lower respiratory tract infections in cats. Reaching beyond empirical therapy. *Journal of Feline Medicine and Surgery* **13**, 313-332

Gadbois, J., d'Anjou, M-A., Dunn, M., Alexander, K., Beauregard, G., D'Astous, J. et al. (2009) Radiographic abnormalities in cats with feline bronchial disease and intra- and interobserver variability in radiographic interpretation: 40 cases (1999-2006). *Journal of the American Veterinary Medical Association* **234**, 367-375

Hansell, D. M., Bankier, A. A., MacMahon, H., McLoud, T. C., Muller, N. L. & Remy, J. (2008) Fleischner Society: Glossary of terms tor thoracic imaging. *Radiology* **246**, 697-722

Henao-Guerrero, N., Ricco, C., Jones, J. C., Buechner-Maxwell, V. & Daniel, G. B. (2012) Comparison of four ventilatory protocols for computed tomography of the thorax in healthy cats. *American Journal of Veterinary Research* **73**, 646-653

Henninger, W. (2003) Use of computed tomography in the diseased feline thorax. *Journal of Small Animal Practice* **44**, 56-64

Johnson, L. R. & Vernau, W. (2011) Bronchoscopic findings in 48 cats with spontaneous lower respiratory tract disease (2002-2009). *Journal of Veterinary Internal Medicine* **25**, 236-243

Laflamme, D. (1997) Development and validation of a body condition score system for dogs. *Canine Practice* **22**, 10-15

Macdonald, E. S., Norris, C. R., Berghaus, R. B. & Griffey, S. M. (2003) Clinicopathologic and radiographic features and etiologic agents in cats with histologically confirmed infectious pneumonia: 39 cases (1991-2000). *Journal of the American Veterinary Medical Association* **223**, 1142-1150

Mexas, A. M., Hess, R. S., Hawkins, E. C. & Martin, L. D. (2006) Pulmonary lesions in cats with diabetes mellitus. *Journal of Veterinary Internal Medicine* **20**, 47-51

Moise, N. S., Wiedenkeller, D., Yeager, A. E., Blue, J. T. & Scarlett, J. (1989) Clinical, radiographic, and bronchial cytologic features of cats with bronchial disease - 65 cases (1980-1986). *Journal of the American Veterinary Medical Association* **194**, 1467-1473

Moynihan, R., Doust, J., Henry, D. (2012) Preventing overdiagnosis: how to stop harming the healthy. BMJ 344. doi: 10.1136/bmj.e3502

Nemanic, S., London, C. A. & Wisner, E. R. (2006) Comparison of thoracic radiographs and single breath-hold helical CT for detection of pulmonary nodules in dogs with metastatic neoplasia. *Journal of Veterinary Internal Medicine* **20**, 508-515

Oliveira, C. R., Mitchell, M. A. & O'Brien, R. T. (2011) Thoracic computed tomography in feline patients without use of chemical restraint. *Veterinary Radiology & Ultrasound* **52**, 368-376

Padrid, P., Snook, S., Finucane, T., Shiue, P., Cozzi, P., Solway, J. & Leff, A.R. (1995) Persistent airway hyperresponsiveness and histologic alterations after chronic antigen challenge in cats. *American Journal of Respiratory and Critical Care Medicine* **151**, 184-193

Reinero, C.R.N., Decile, K.C., Berghaus, R.D., Williams, K.J., Leutenegger, C.M., Walby, W.F., Schelegle, E.S., Hyde, D.M. & Gershwin, L.J. (2004) An experimental model of allergic asthma in cats sensitized to house dust mite or Bermuda grass allergen. *International Archives of Allergy and Immunology* **135**, 117-131

Robinson, N. E. (1982) Some functional consequences of species-differences in lung anatomy. *Advances in Veterinary Science and Comparative Medicine* **26**, 1-33

Sauve, V., Drobatz, K. J., Shokek, A. B., McKnight, A. L. & King, L. G. (2005) Clinical course, diagnostic findings and necropsy diagnosis in dyspneic cats with primary pulmonary parenchymal disease: 15 cats (1996-2002). *Journal of Veterinary Emergency and Critical Care* **15**, 38-47

Sigrist, N. E., Adamik, K. N., Doherr, M. G. & Spreng, D. E. (2011) Evaluation of respiratory parameters at presentation as clinical indicators of the respiratory localization in dogs and cats with respiratory distress. *Journal of Veterinary Emergency and Critical Care* **21**, 13-23

Simone, K. M., Robertson, I. D. & Seiler G. S. (2016) Impact of inspiratory vs. expiratory lung computed tomography for detection of pulmonary nodules and bullae (abstract). Annual Scientific Conference of the ACVR, Minneapolis, Minnesota, October 7–10, 2015. *Veterinary Radiology & Ultrasound* **57**, 84–98

Staffieri, F., Franchini, D., Carella, G. L., Montanaro, M. G., Valentini, V., Driessen, B., Grasso, S. & Crovace, A. (2007) Computed tomographic analysis of the effects of two inspired oxygen concentrations on pulmonary aeration in anesthetized and mechanically ventilated dogs. *American Journal of Veterinary Research* **68**, 925-931

Swift, S., Dukes-McEwan, J., Fonfara, S., Loureiro, J. F. & Burrow, R. (2009) Aetiology and outcome in 90 cats presenting with dyspnoea in a referral population. *Journal of Small Animal Practice* **50**, 466-473

Trzil, J.E. & Reinero, C.R. (2014) Update on Feline Asthma. *Veterinary Clinics of North America-Small Animal Practice* **44**, 91-105

Wood, B. P. (1999) Decision making in radiology. *Radiology* **211**, 601-603

Legends

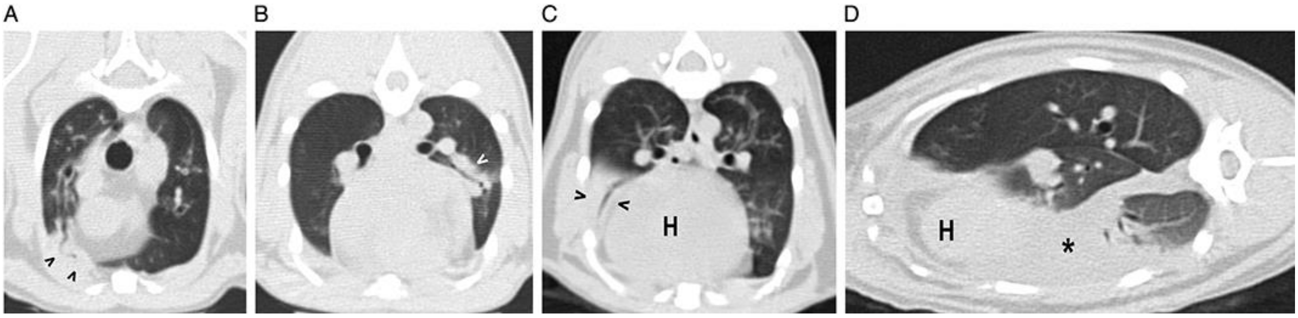

Figure 1. Examples of CT images reported as showing signs of pulmonary atelectasis. All are transverse images displayed with window 1500HU and centre -500HU. A) Sub-lobar atelectasis affecting the tip of the right cranial lobe (arrowheads) in a cat with chronic cough. There is mediastinal shift to the right. Other images showed signs of bronchial disease. B) Bronchocentric atelectasis affecting the left cranial lobe (arrowhead) in a cat with metastatic adenocarcinoma and no history of respiratory signs. C) Lobar atelectasis affecting the right middle lobe (between arrowheads) in a cat with chronic cough. The heart (H) is displaced to the right. Other images showed signs of bronchial disease. D) Unilateral left lung atelectasis (*) in an anaesthetised cat that had CT scan in left lateral recumbency because of trauma and suspected spinal fracture. The heart (H) is displaced to the left.

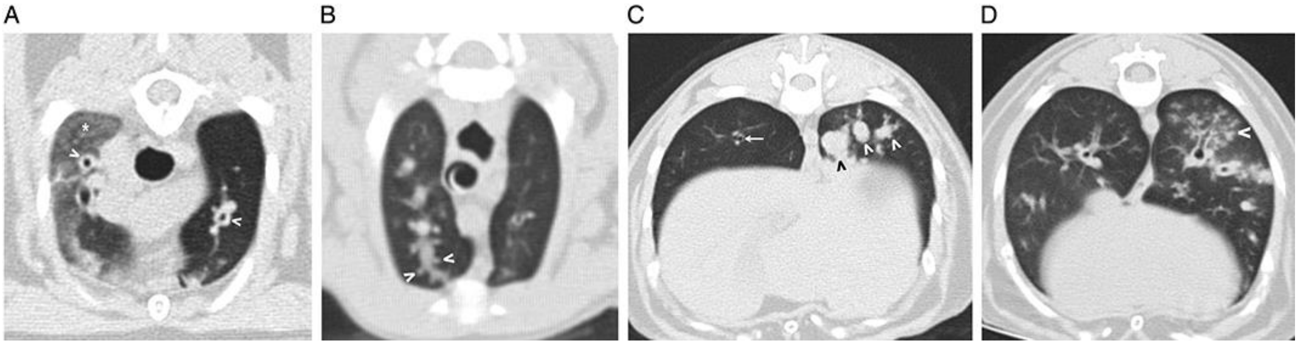

Figure 2. Examples of CT images reported as showing signs of bronchial disease. All are transverse images displayed with window 1500HU and centre -500HU. A) Thickened bronchial walls (arrowheads) in a cat with a suspected vertebral neoplasm and no history of respiratory signs. There is also ground-glass opacity (*) affecting the right cranial lobe. B) Mucus plugging of the right cranial lobar bronchus (between arrowheads) in a cat with chronic cough and tachypnoea. C) Mucus plugging of dilated bronchi (arrowheads) at the periphery of the left caudal lobe in a cat with multiple cutaneous mast cell tumours and no history of respiratory signs. The diameters of each of these bronchi grossly exceed the diameter of the bronchus in the right caudal lobe (arrow) compatible with bronchiectasis. D) Tree-in-bud sign (arrowhead) in the left caudal lobe of a cat with chronic cough.