COMPUTED TOMOGRAPHY BRONCHIAL LUMEN TO PULMONARY ARTERY DIAMETER RATIO IN DOGS WITHOUT CLINICAL PULMONARY DISEASE

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Bronchiectasis is diagnosed in humans using multiple computed tomography (CT) criteria, the most important being dilatation of the bronchi. The most widely used criterion for detection of bronchial dilatation is a bronchial lumen to pulmonary artery diameter (bronchoarterial [BA]) ratio >1.0. No studies have been performed to determine the BA ratio in normal dogs. Thoracic CT images of 24 dogs without clinical pulmonary disease were reviewed. The BA ratio of the lobar bronchi of the left cranial (cranial and caudal parts), right cranial, right middle, left caudal, and right caudal lung lobes was measured. The mean of the mean BA ratio for all dogs was 1.45 ± 0.21 (99% confidence interval [CI] = 1.34–1.56). The mean of the mean BA ratio as determined by lung lobe was 1.45 ± 0.04 (99% CI = 1.41–1.49). The range of individual BA ratios was 0.8–2.0. There was no significant difference in mean BA ratios as a function of lung lobe ($P = 0.60$). The BA ratio in these clinically normal dogs was consistent and may be a useful tool in evaluating for bronchiectasis on CT images. BA ratios >2.0 were not identified in this population, suggesting a threshold to differentiate normal from abnormal bronchi. *Veterinary Radiology & Ultrasound, Vol. 50, No. 6, 2009, pp 622–624.*

Key words: bronchiectasis, bronchoarterial ratio, bronchus, computed tomography.

Introduction

BRONCHIECTASIS IS A pathologic, irreversible dilatation of the bronchi that is usually secondary to chronic airway inflammation and subsequent loss of bronchial wall integrity.[1–5] It is associated with multiple disorders including chronic bronchitis, foreign body pneumonia, smoke inhalation, and other chronic, smoldering pulmonary disorders.[2–4,6] In many instances, the primary disease responsible for bronchiectasis is not discovered because of the delay between initial injury and the development of bronchial dilatation.

Computed tomography (CT) features of bronchiectasis have been characterized extensively in humans and abnormal bronchial dilatation is a fundamental finding. The range of absolute measurements of normal bronchial diameters have not been established in humans. However, the diameter of a normal bronchus is approximately equal to the diameter of the associated pulmonary artery, which is often expressed as a bronchoarterial (BA) ratio. A bronchial diameter greater than that of the accompanying pulmonary artery (BA > 1) is the most widely used criterion in determining bronchial dilatation and is supportive of a diagnosis of bronchiectasis.[2,3,7]

We are not aware of any quantification of the BA ratio in dogs. Based on our clinical observations, it is possible that dogs without clinical pulmonary disease can have a BA > 1, indicating that extrapolation of data regarding this ratio from humans may be misleading. Our purpose was to quantify the bronchoarterial ratio of dogs without clinical pulmonary disease.

Materials and Methods

Our database was searched for dogs without a clinical history of pulmonary disease for which thoracic CT images were available for review. Dogs with CT evidence of pulmonary disease were not included. Twenty-four thoracic CT scans were identified. The scans had been performed as a screening test for metastatic disease and no abnormalities were found. The dogs ranged in age from 4 to 13 years with a mean age of 9.2 years. Body weight ranged from 8.1 to 52.5 kg, with a mean weight of 28.3 kg. Breeds included Golden Retriever (three), Bernese Mountain Dog (three), Labrador Retriever (two), Samoyed, Miniature Schnauzer, Scottish Terrier, Doberman Pincher, Shetland Sheepdog, English Springer Spaniel, Beagle, Basset Hound, Rottweiler, Viszla, Irish Wolfhound, and six mixed breed dogs.

Pulmonary CT images were acquired with a helical CT scanner.* Examinations were performed with dogs in

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*fx/I helical CT scanner, General Electric Co., Milwaukee, WI.

sternal recumbency under general inhalational anesthesia using a single breath-hold technique with airway pressure maintained at 15 cm of water and scan times limited to 60 s or less. All examinations consisted of contiguous, 5–7 mm collimated transverse images using a moderately edge-enhancing (lung) reconstruction algorithm.

Analysis of DICOM CT images was performed on a dedicated image viewing station using commercially available viewing and analysis software.† All measurements were performed by a single investigator (M.S.C.). The right and left cranial lobar bronchi were identified in cross-section on images acquired at the level of the 4th rib. The internal diameter of the bronchial lumen was measured with electronic calipers. The oval representing the bronchial lumen was always measured in its smallest diameter to eliminate any effect of obliquity in determining the true luminal diameter. The diameter of the companion pulmonary artery viewed in the same image was measured in a similar manner. If a representative bronchus was not well delineated at the proper level, one was selected from an adjacent image immediately cranial or caudal to the 4th rib.

The same approach was used at the level of the 11th rib to obtain a representative BA ratio for the right and left caudal lobes (Fig. 1). A similar approach was used to measure the luminal diameter of the lobar bronchi to the right middle lung lobe and to the caudal part of the left cranial lung lobe. These two airways are typically seen in a long-axis orientation on CT images, and luminal diameters were measured at the largest width (Fig. 2). The accessory lobe was not evaluated in this study due to inconsistency in identifying a measurable bronchus and pulmonary artery.

The mean BA ratio, and the standard deviation, were calculated for each dog and for each lung lobe. A one-way repeated measures analysis of variance was performed on BA ratios calculated by lung lobe. A mean of the mean BA ratios by dog and corresponding 99% confidence intervals (CI) were calculated. Linear regression analysis of BA ratio and subject weight was also performed.

Results

A total of 139 BA ratios were obtained from the six measurement locations. Five measurements, one each in three different dogs and two from a single dog, could not be acquired due to the lack of a well-delineated and measurable bronchus and pulmonary artery at the described location. The mean of the mean BA ratios by dog was 1.45 ± 0.21 (99% CI = 1.34–1.56). Individual BA ratios ranged from 0.8 to 2.0. The mean of the mean BA ratios by lung lobe was 1.45 ± 0.04 (99% CI = 1.41–1.49). There was no significant difference in mean BA ratio between lung lobes or between dogs ($P = 0.60$, Table 1). There was a weak association between BA ratio and body weight ($r = 0.33$) and the slope of the regression line was not significantly different from 0 ($P = 0.11$).

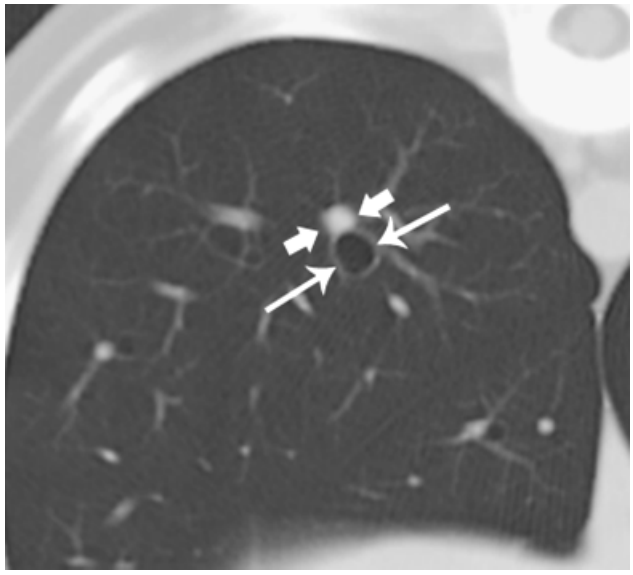

FIG. 1. Computed tomography image of the thorax at the level of the 11th rib. The internal diameter of a representative bronchial lumen and the diameter of the corresponding pulmonary artery in cross-section were measured with electronic calipers. In this image, the measured bronchus in the right caudal lung lobe is designated by large, thin arrows while the corresponding pulmonary artery is designated by short, thick arrows. The bronchoarterial ratio is 1.29. For the images in this paper, the patient's left is to the right of the image.

Discussion

CT is considered the best non-invasive means of diagnosing bronchiectasis in humans, with high-resolution CT having similar accuracy as histopathology and broncho-

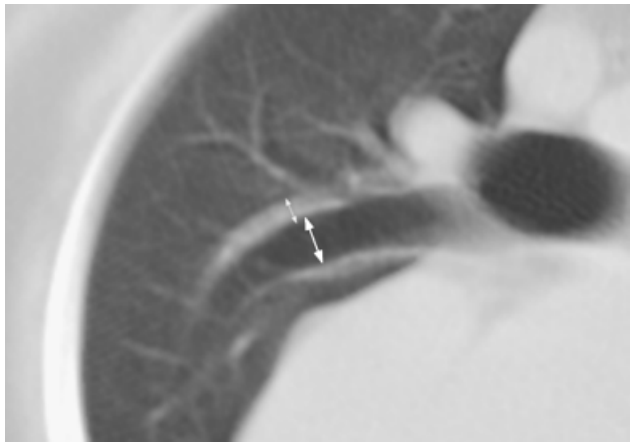

FIG. 2. Computed tomography image of the thorax in which the bronchus to the caudal part of the left cranial lung lobe is seen. Measurements of the bronchial lumen and pulmonary artery diameter were made with electronic calipers. Arrows designate the measurement locations. The bronchoarterial ratio is 1.67.

†efilm 2.0, Merge Healthcare, Milwaukee, WI.

TABLE 1. Mean Bronchoarterial (BA) Ratio and Standard Deviation (SD) for each Lung Lobe in 24 Dogs without Clinical Pulmonary Disease

Location	Mean BA Ratio ± SD
R cranial lobe 4th rib (cranial part)	1.47 ± 0.29
L cranial lobe 4th rib	1.44 ± 0.29
R caudal lobe 11th rib	1.46 ± 0.30
L caudal lobe 11th rib	1.41 ± 0.32
R middle lobe	1.52 ± 0.28
L cranial (caudal part)	1.42 ± 0.25
Mean of means	1.45 ± 0.04

graphy.[8–10] Bronchiectasis is diagnosed in humans using a combination of multiple CT criteria, which in addition to bronchial dilatation include lack of bronchial tapering, identification of distinct airways within 1 cm of the pleural surface, as well as indirect findings including bronchial wall thickening, mucus plugging, and peripheral air trapping.[2,3,11] Little is known about the CT features of canine airways, either normal or abnormal.[12] To evaluate CT images from patients with clinical pulmonary disease, and especially bronchiectasis, quantitative measurements of bronchi in normal dogs must be obtained first.

Based on our work, a BA ratio of approximately 1.45 is consistent between lung lobes and between dogs, and the BA ratio should not be >2.0 in normal dogs. Further, there is no statistically significant association between weight and BA ratio, indicating that our findings can be applied in different-sized dogs. The BA ratio threshold for dogs is greater than the accepted value of 1.0 in normal humans. Although relative diameters of bronchi and corresponding arteries may be inherently different in dogs and humans, another factor contributing to the difference in the normal BA ratio may be the standard use of forced breath-holding during image acquisition in anesthetized dogs causing bronchi to be more dilated compared with spontaneous breath-holding in humans during thoracic CT. Our study was not designed to address the effect of inspiratory pressure on airway diameter, but this would need to be considered when extrapolating these data to CT studies produced under different conditions.

There are several limitations of this study. In these patients, 5–7 mm collimated axial images were obtained. In humans, thin-section high-resolution CT is the preferred method of evaluating airways to avoid volume averaging due to slice thickness.[3] This was not possible in this study due to its retrospective nature and reason for the scans, but would be indicated in future prospective studies. Also, although most measurements were obtained in cross-section, those for the right middle lobe and caudal part of the left cranial lobe were obtained in longitudinal orientation due to the lobar orientation in dogs. This has the potential to introduce measurement error due to slice thickness artifact. However, the BA ratio did not differ between these lobes and other lobes with measurements obtained in cross-section, suggesting minimal error in measurement. Another potential limitation of a quantitative measure such as the BA ratio is interobserver variability. However, we felt that since the margins of the bronchus and airway are well delineated that there is little chance for measurement error.

Our study population was relatively small and lacked small and chondrodystrophic dogs. Certain toy breeds of dogs in particular are predisposed to developing histologically abnormal airway cartilage, which could contribute to altered bronchial size.[13,14] Also no juvenile dogs were evaluated. The effect of our population makeup on the normal BA ratio presented herein is not known and will require further work.

In conclusion, the BA ratio in clinically normal dogs is consistent between dogs and between lung lobes and may be a useful tool in evaluating for bronchiectasis on CT images. BA ratios >2.0 were not identified in this population, suggesting a cut-off value between normal and abnormal dogs. Further studies are indicated to evaluate and compare BA ratios in dogs with chronic airway disease and bronchiectasis.

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