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Computed tomographic bronchioarterial ratio for brachycephalic dogs without pulmonary disease

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The bronchoarterial (BA) ratio measured with computed tomography is widely used in human medicine to diagnose bronchial dilation or collapse. Although use of the BA ratio in veterinary medicine has been recently studied, this has not been evaluated in brachycephalic dogs predisposed to bronchial diseases including bronchial collapse. The purpose of this study was to establish BA ratios for brachycephalic dogs and compare the values with those of non-brachycephalic dogs. Twenty-three brachycephalic dogs and 15 non-brachycephalic dogs without clinical pulmonary disease were evaluated. The BA ratio of the lobar bronchi in the left and right cranial as well as the right middle, left, and right caudal lung lobes was measured. No significant difference in mean BA ratio was observed between lung lobes or the individual animals ($p = 0.148$). The mean BA ratio was 1.08 ± 0.10 (99% CI = 0.98 ~ 1.18) for brachycephalic dogs and 1.51 ± 0.05 (99% CI = 1.46 ~ 1.56) for the non-brachycephalic group. There was a significant difference between the mean BA ratios of the brachycephalic and non-brachycephalic groups ($p = 0.00$). Defining the normal limit of the BA ratio for brachycephalic breeds may be helpful for diagnosing bronchial disease in brachycephalic dogs.

Keywords: brachycephalic, bronchoarterial ratio, computed tomography, dog

Introduction

Bronchial diseases, such as bronchitis, bronchiectasia, and bronchomalacia, are frequently encountered in small animal medicine. Among these conditions, bronchiectasia and bronchial collapse caused by bronchomalacia are disorders during which the bronchial diameter is altered. Bronchomalacia in dogs is defined as weakening of the walls of principal bronchi and other smaller airways so that they become less rigid and functionally incompetent [1]. Bronchiectasia is a chronic and irreversible disease of the pulmonary system. Severe bonchiectasia can be readily diagnosed using conventional radiography, but focal or mild cases are not easily detected. Additionally, bronchomalacia is only diagnosed by bronchoscopy in veterinary medicine at the present. All of these diseases are associated with changes of the bronchial diameter. Therefore, more accurate diagnostic methods for identifying changes in the bronchial diameter are important for diagnosing theses bronchial diseases.

Conventional radiography is the most non-invasive modality for diagnosing pulmonary disease, but there is limitation of identifying each bronchus due to its superimposing characteristics of conventional radiography. Bronchoscopy is one of the most accurate modalities for diagnosing bronchial disease. However, this technique is not easily performed in small dogs due to their smaller bronchial lumen. Computed tomography (CT) is an accurate method for diagnosing bronchiectasia as well as other pulmonary diseases. This technique is more accurate than conventional radiography and less invasive than bronchoscopy. In human medicine, CT features of bronchiectasia have been characterized. The bronchoarterial (BA) ratio is one of the most widely used criteria for identifying cases of bronchiectasia [5,6]. Evaluation of the BA ratio in small animal medicine has been recently performed in dogs and cats [2,7]. However, the study populations were small and BA ratios in specific breeds have not been established.

Shih tzu, Pekingese, and pugs are usually considered brachycephalic and have brachycephalic syndrome including stenotic nares, elongation of the soft palate, and tracheal problems. Due

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to dynamic upper airway obstruction, brachycephalic dogs must generate large pressure changes during inhalation and exhalation throughout their lifetime. During both respiratory phases, pressure gradients change the diameter of the bronchus, thereby altering airway resistance [3,4]. We hypothesized that the BA ratio of brachycephalic dogs may be different from that in other non-brachycephalic dogs because of pressure gradient changes in bronchus. The purpose of this study was to determine the BA ratio of clinically normal brachycephalic dogs.

Materials and Methods

Thoracic CT results for brachycephalic dogs were obtained from three institutions (Seoul National University, Royal Animal Medical Center, and Irion Animal Hospital) in Korea. Dogs with a history of pulmonary diseases as well as those with any abnormal thoracic radiography or CT findings of the cardiopulmonary system were excluded. Twenty-three thoracic CT scans and 112 lung lobes were evaluated. The age of the dogs ranged from 3 to 13 years with a mean age of 8.1 years. Nine males and 14 female dogs were included. Twenty Shih tzu and these Pekingese were assessed. As a control, 10 thoracic CT scans without any abnormal findings were also evaluated. Four poodles, three English cocker spaniels, two miniature Schnauzers, and one Coton de Toluea dogs were included in the non-brachycephalic group.

Pulmonary CT images were acquired with three different helical CT scanners. The examination was performed with the animals in a sternal recumbent position under general anesthesia induced with isoflurane (Ifran; Hana Pharm, Korea) and propofol (Provive 1%; Claris Lifesciences, India). A breath hold technique was performed by inducing apnea using manual hyperventilation. A single breath hold technique with positive pressure was not performed. For all examinations, transvers images with at least 3-mm slice thickness were acquired using a moderately edge enhancing reconstruction algorithm at the lung window level (WW: 2000; WL: −100). A dedicated imaging viewing station with commercially available viewing and analysis software (Spectra; INFINITT Healthcare, Korea) was used for CT image analysis. All measurements were performed by a single observer (S Won). Five lung lobes including the right cranial, left cranial, right middle, right caudal, and left caudal were assessed. The accessory lobe was excluded due to poor reproducibility.

The right and left cranial lobar bronchi were evaluated by reviewing axial images acquired at the level of the fourth rib. The internal diameter of the bronchial lumens and accompanying arteries were measured in the same image with electronic calipers. If a bronchus or pulmonary artery was not prominent enough to be measured at the level of the fourth rib, the delineated bronchus and arteries were measured in the neighboring image up to the level of the rib immediately cranial or caudal. The same approach was used to determine the bronchus lumen and arterial diameter of the right and left caudal lung lobes at the level of the ninth rib (Fig. 1). Measurement of the right middle bronchus and artery was performed at the greatest width of this airway usually visible parallel in the axial image (Fig. 2).

The mean and standard deviation of each lung lobe and each dog were calculated individually. A one-way repeated measures analysis of variance was performed for the BA ratios of each lung lobe. A mean of the mean BA ratios of each dog and the corresponding 99% confidence intervals was also calculated. A linear regression analysis of the BA ratio along with a Welch

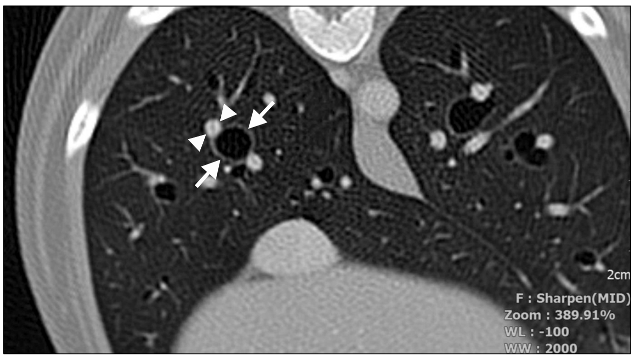

Fig. 1. Computed tomography (CT) image of the thorax of a brachycephalic dog at the level of the middle section of the ninth rib. The internal diameter of the right caudal bronchial lumen and diameter of the corresponding pulmonary artery in the cross-section were measured to determine the BA ratio. An arrow indicates the measured bronchus in the right caudal lung lobe while an arrowhead indicates the corresponding pulmonary artery.

Fig. 2. CT image of the thorax of a dog at the level of the middle section of the seventh rib showing the right middle bronchus in the long-axis orientation. The internal diameter of the bronchial lumen and pulmonary artery diameter were measured to determine the BA ratio. An arrow indicates the measured diameter of the right middle lobar bronchus and an arrowhead indicates the corresponding pulmonary artery.

two sample *t*-test for the Shih tzu and Pekingese dogs were performed. To evaluate differences relative to the non-brachycephalic dogs, an independent T-test was also carried out.

Results

A total 23 dogs and 112 BA ratios were obtained for the five measurement locations. Three measurements for two dogs could not be obtained due to poor visualization of the bronchus. The mean of mean BA ratios for the dogs was 1.08 ± 0.10 (99% CI = 0.98 ~ 1.18, Table 1). There was no significant difference in mean BA ratio between the lung lobes or the individual canines (p = 0.148, Fig. 3). Furthermore, no relationship according to breed (p = 0.59) or age (r = 0.06, Figs. 4 and 5) was observed.

A total 10 dogs and 49 BA ratios for non-brachycephalic dogs were obtained to assess differences between brachycephalic dogs and normal animals. The mean of mean BA ratios for non-brachycephalic dogs was 1.50 ± 0.06 (99% CI = 1.46 ~ 1.56, Table 1). There was significant difference between the two groups identified by the independent sample *t*-test (p = 0.00).

Table 1. Mean bronchoarterial (BA) ratio and standard deviation (SD) for each lung lobe in 23 brachycephalic dogs and 15 non-brachycephalic dogs without clinical pulmonary disease

Location	Mean BA ratio ± SD (brachycephalic, n = 23)	Mean BA ratio ± SD (non-brachycephalic, n = 15)
Rt cranial	0.95 ± 0.19	1.44 ± 0.10
Lt cranial	1.05 ± 0.34	1.50 ± 0.17
Rt middle	1.15 ± 0.29	1.53 ± 0.21
Rt caudal	1.10 ± 0.28	1.56 ± 0.19
Lt caudal	1.12 ± 0.30	1.51 ± 0.23
Mean of means	1.07 ± 0.10	1.51 ± 0.05

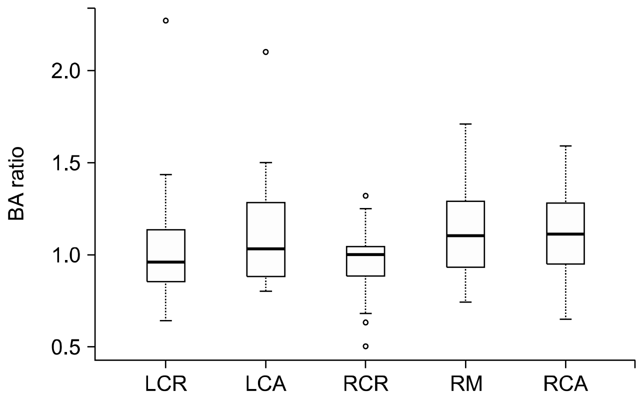

Fig. 3. Analysis of variation among the five lobes. No significant differences were detected among the BA ratios for the lobes (p = 0.148). LCR: left cranial lobe, LCA: left caudal lobe, RCR: right cranial lobe, RM: right middle lobe, RCA: right caudal lobe.

Discussion

The BA ratio for the brachycephalic animals (1.08 ± 0.10) was lower than that of the non-brachycephalic healthy dogs (1.50 ± 0.06). In a previous study, a mean BA ratio of healthy dogs similar to the one calculated for our study was identified [2]. A lower mean BA ratio for brachycephalic dogs could represent a higher prevalence of upper airway obstruction and chronic airway obstruction that may change the bronchus. Additionally, the BA ratio for brachycephalic dogs varied more widely in this study compared to the ratio for non-brachycephalic animals.

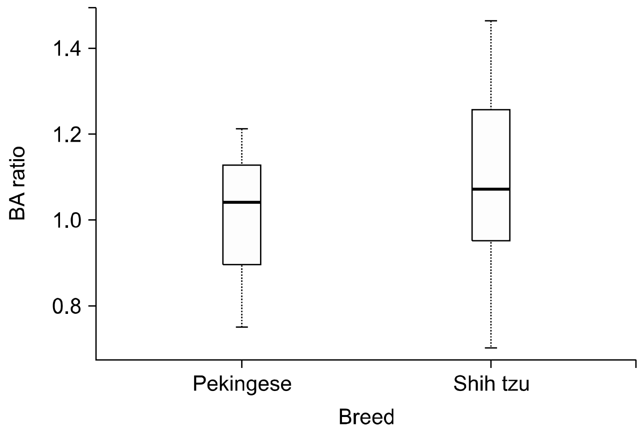

Fig. 4. Welch sample *t*-test results for the Shih-tzu and Pekingese dogs. There was no difference between the two breeds (p = 0.59).

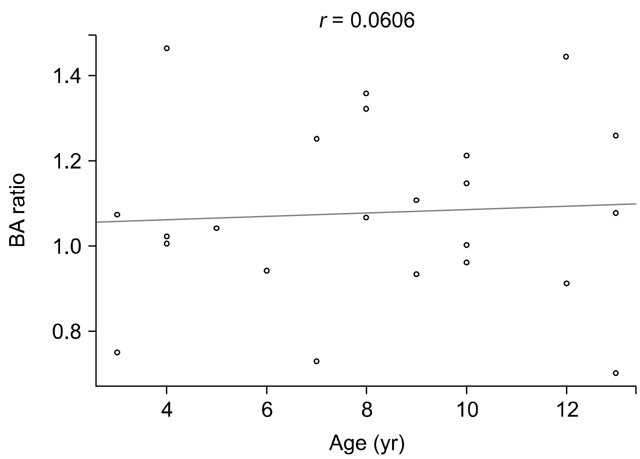

Fig. 5. Linear regression analysis of age and BA ratios. There is no correlation between BA ratio and age.

Irregularity of the bronchus lumen and diameter in brachycephalic dogs due to the nature of the upper airway obstruction may account for this variation. Overall, results of this study demonstrated that evaluation of local bronchial disease in brachycephalic animals by CT can be performed precisely and used to avoid misinterpretation caused by normal variation.

The mean BA ratios of the five lobes were not significantly different. Additionally, no specific difference was found between Shih tzu and Pekingese dogs. These results indicated that anatomical variation of each lung lobe did not influence the BA ratios. No significant difference associated with age was found, showing that conditions related to advanced age such as bronchial wall calcification or decreased elasticity did not affect the BA ratios.

In other studies of BA ratios obtained for normal dogs and cats, the single breath hold technique was used to facilitate adequate inhalation [2,7]. In the current investigation, apnea was induced for almost every animal by hyperventilation due to the retrospective nature of the study. Therefore, exact comparison with previous studies is difficult. All the participating animals in both the brachycephalic and non-brachycephalic groups were subjected to the same breath hold technique. Thus, comparison between the two groups was reliable. In the present study, CT was performed for almost all patients to screen for non-pulmonary conditions such as intervertebral disc disease or orthopedic problems. Accordingly, contrast medium injection was not performed for every animal.

Dogs included in the present investigation were small breed animals (Shih tzu and Pekingese) and chest conformation varied. Conventionally, the bronchus and vessels of both caudal lung lobes are evaluated at the level of the eleventh rib. However, in our population most lungs were not present at this level. Our brachycephalic group was limited to small and toy breeds. The BA ratio of larger brachycephalic breeds (*e.g.*, boxer or English bulldog) requires further study. In conclusion, the BA ratio of brachycephalic breeds was evaluated in the present investigation. Data from this study will be useful for diagnosing early bronchial disease in specific breeds.

Conflict of Interest

There is no conflict of interest.

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