GENDER, WEIGHT, AND AGE EFFECTS ON PREVALENCE OF CAUDAL ABERRANT NASAL TURBINATES IN CLINICALLY HEALTHY ENGLISH BULLDOGS: A COMPUTED TOMOGRAPHIC STUDY AND CLASSIFICATION

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English Bulldogs have been reported to demonstrate abnormal growth and development of the nasal turbinates, which contribute to an increase in airway resistance and hence clinical signs of brachycephalic airway syndrome. The purpose of this prospective, cross-sectional study was to assess the prevalence and severity of caudal aberrant turbinate protrusion via CT studies of English Bulldogs with, according to the owners, none or minimal clinical signs of brachycephalic airway syndrome. An additional objective was to propose a classification scheme for describing the degree of caudal aberrant turbinate protrusion in English Bulldogs and to apply this scheme in assessing the effect of gender, weight, and age on prevalence and severity of turbinate protrusion. The nasal cavities of 40 clinically healthy English Bulldogs were examined. The prevalence of caudal aberrant turbinates in this group was 100%. Using our proposed classification scheme, Grade 1 (minimal) was detected in 7 of 40 (17.5%), Grade 2 (mild) in 28 of 40 (70%), and Grade 3 (moderate) in 5 of 40 (12.5%) English Bulldogs. No significant effect of gender, weight, and age on degree of protrusion was found. In conclusion, this study identified minimal to moderate protrusion of caudal aberrant turbinates toward the nasopharynx in all the sampled English Bulldogs, despite the absence of clinical signs of brachycephalic airway syndrome.

Key words: brachycephalic airway syndrome, computed tomography, caudal aberrant turbinates, English Bulldog, nasopharyngeal turbinates.

Introduction

English Bulldogs, as other brachycephalic breeds, have typical anatomical abnormalities of the upper respiratory tract that may lead to increased negative pressure on inspiration and upper airway obstruction, known as brachycephalic airway syndrome. Clinical signs in affected animals include stridorous breathing, inspiratory dyspnoea, exercise intolerance, cyanosis, and, in the most severe cases, episodes of syncope.[1] These respiratory problems are thought to be initiated by primary components of the syndrome such as stenotic nares, elongated soft palate, and possibly tracheal hypoplasia.[2,3] These primary changes may lead to secondary abnormalities like oedematous swelling of the airway mucosa, tonsillar eversion, and laryngeal collapse. Recent studies using computed tomography (CT) and/or endoscopy have demonstrated that the nasal turbinates and soft tissue thickening in the nasopharynx may be part of the primary anatomic components of brachycephalic airway syndrome.[4–7] Selective breeding of brachycephalic dogs has led to extreme shortening of the facial bones, especially the bony part of the nasal cavity. The reduction in size of the nasal cavity results in dislocation of the nasal structures and dorso-rotation of the teeth. Postnatal development and growth of the nasal conchae is a normal process in healthy animals, and the nasal conchae will grow until the whole nasal cavity is occupied.[8] The development of the conchae normally stops before the mucosae of adjacent turbinate lamellae touch each other.[8] In brachycephalic breeds this mechanism appears to fail, favouring an aberrant extension of the conchae. In a histological comparison of the aberrant nasal conchae in brachycephalic and dolichocephalic breeds, nasal mucous membrane, and bone tissue of the brachycephalic conchae

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were found to be increased compared with the conchae of dolichocephalic dogs.[9] The combination of these factors may provide an explanation for the origin of aberrant nasal conchae in brachycephalic breeds. Structural deformities of the nasal turbinates leading to extension beyond their normal anatomic limits have been described as aberrant turbinates. Rostral aberrant turbinates are defined as parts of the middle or ventral conchae (maxilloturbinates) that extend rostrally beyond the level where the plica alaris branches into the ventral nasal concha.[5,10] Caudal aberrant turbinates are parts of the maxillo- and/or ethmoturbinates that extend caudally into the nasopharyngeal meatus.[5,10] In more severe cases, the caudal aberrant turbinates pass through the choanae and extend into the nasopharynx, and have been referred to as nasopharyngeal turbinates.[6] The nasal vestibule, the ventral nasal meatus, the nasopharyngeal meatuses, the choanae, and nasopharynx should be completely devoid of conchal structures and function to conduct air through the respiratory passages. The presence of aberrant nasal turbinates has been previously demonstrated to be related to intranasal obstruction in brachycephalic breeds by functional testing.[11–15] Both rostral and caudal aberrant turbinates can be unilateral or bilateral and can occur simultaneously.[5] In English Bulldogs with brachycephalic airway syndrome caudal aberrant turbinates have been reported to have a much higher prevalence (up to 63%) as compared to rostral aberrant turbinates (up to 26%).[5,16,17] No differences between gender, age, or weight were mentioned in these reports, but these parameters were not examined specifically.

Computed tomography of the head enables detailed evaluation of the nasal structures, including the presence and severity of these aberrant turbinates.[13,16,18] Especially caudal aberrant turbinates are easily recognized on CT, however a classification as to the severity and degree of protrusion has not been reported. In addition, the authors are not aware of any publication reporting the prevalence of aberrant turbinates in a large and clinically healthy group of brachycephalic animals and hence the clinical importance of these findings in animals with asymptomatic brachycephalic airway syndrome is currently unknown. To the authors' knowledge, aberrant nasal turbinates have not been previously reported in English Bulldogs with absent or low historical and clinical signs of brachycephalic airway syndrome. In addition, the effects of gender, weight, and age on the prevalence and severity of protrusion have not been reported in a larger study.

The purpose of the present study was (1) to assess the prevalence and severity of caudal aberrant turbinate protrusion using CT in clinically healthy English Bulldogs, (2) to determine correlations between the severity of protrusion and gender, weight, and age, and (3) to propose a classification scheme for the degree of protrusion of caudal aberrant turbinates in English Bulldogs. We hypothesized that (1) clinically healthy English Bulldogs would exhibit a lower prevalence of caudal aberrant turbinates on CT imaging of the nose compared to reported clinical cases and (2) that a more severe degree of protrusion of caudal aberrant turbinates will be found in male, heavier and older English Bulldogs as compared to female, lighter, and younger English Bulldogs.

Material and Methods

English Bulldogs

Between November and December 2011, 40 healthy client-owned English Bulldogs were recruited prospectively and at random from breeders invited by the Dutch English Bulldog Club (Engelse Bulldog Club Nederland E.B.C.N.). The invitation process was performed under the supervision of the Dutch Kennel Club (Raad van Beheer) the principal cynological organization in the Netherlands to assure selected animals were older than one year of age, had no previous history of respiratory disease or airway surgery and were nonrelated (no littermates or same parent combination offspring was included). Informed consent was obtained from all owners to conduct this study and all examinations took place at the Department of Clinical Sciences of Companion Animals and the Division of Diagnostic Imaging, Faculty of Veterinary Medicine, Utrecht University. A clinical history was taken via a standard questionnaire and a physical examination was performed by one of the authors (G. H.). With the questionnaire owners were asked about the subjective frequency of snoring, open mouth breathing, inspiratory efforts, stress or exercise intolerance, and syncope experienced by their pets. The respiratory clinical signs were graded in a 1–3 score by one of the authors (G.H.), according to a scale previously established.[19] On the basis of the frequency and nature of the respiratory signs, only English Bulldogs clinically scored as grade 1 were included in this study. Breed, gender, age, body weight, and history were recorded for all English Bulldogs.

Anesthesia and Physical Status Classification System (ASA)

A complete clinical examination was performed as part of the preanesthetic evaluation by clinicians and/or members of the anesthesia department of the Faculty of Veterinary Medicine, Utrecht University in all dogs included in this study. Food was withheld from all dogs for 12 h prior to anesthetic procedures. All English Bulldogs were classified as ASA 2 after a standard clinical examination preceding premedication and general anesthesia.

A standardized anesthetic protocol was used in all English Bulldogs. The dogs were preoxygenated and

TABLE 1. Definition of the Classification System for Caudal Aberrant Turbinates and Caudal Aberrant Turbinate Scoring in English Bulldogs by Dogs and Nasal Cavities

Grade	Definition	English Bulldogs ($n = 40$)		Nasal cavities ($n = 80$)	
0 (normal)	No turbinates visible in the ventral nasal meatus	0/40	(0%)	0/80	(0%)
1 (minimal)	Turbinates visible in the ventral nasal meatus, but not extending into the nasopharyngeal meatus Fig. 1A	7/40	(17.5%)	18/80	(22.5%)
2 (mild)	Turbinates visible in nasopharyngeal meatus, but not extending through the choanae Fig. 1B	28/40	(70%)	57/80	(71.25%)
3 (moderate)	Turbinates visible in the choanae but not extending caudal to the caudal border of the nasal septum (vomer) that is the rostral opening of the nasopharynx Fig. 1C	5/40	(12.5%)	5/80	(6.25%)
4 (severe)	Turbinates visible in the nasopharynx	0/40	(0%)	0/80	(0%)

premedicated with an intravenous injection of dexmedetomidine at 5 μg/kg (Dexdomitor, Orion Corporation, Espoo, Finland, 0.5 mg/mL) and butorphanol at 0.1 mg/kg (Dolorex, Intervet Nederland BV, Boxmeer, the Netherlands, 10 mg/mL). Anesthesia was induced with intravenous injection of propofol administered to effect (1–3 mg/kg) (Propofol, Frisenius Kabi,'s Hertogenbosch, the Netherlands, 10 mg/mL). An upper airway examination (pharyngolaryngoscopy) was performed in all the English Bulldogs by the same author (G.H.), with the dog in sternal recumbency. After endotracheal intubation, anesthesia was maintained with isoflurane (Isoflo, Abbott Laboratories Ltd., Queenborough, Kent, UK) vaporized in oxygen. All dogs were breathing spontaneously. During the recovery an intravenous injection of atipamezole was administered at an initial dose of 12.5 μg/kg (Antisedan, Orion Corporation, Espoo, Finland, 5 mg/mL).

Computed Tomography

All the dogs were placed under general anesthesia and positioned in sternal recumbency on the CT table using a single-slice helical CT scanner (Philips Secura, Philips NV, Eindhoven, the Netherlands). The dogs were scanned with open mouth and the scanogram was made in laterolateral and dorso-ventral views from the tip of the nose to the larynx. Scan plane was planned perpendicularly to the hard palate. Technical settings were 120 kV, 200 mA, 1 s tube rotation time, 250 mm field of view, 512 × 512 matrix and with a high spatial frequency algorithm. The scans were made in helical acquisition mode with a slice thickness of 3 mm.

Computed Tomography Image Analysis

All the images were reviewed using modified window settings (–300 WL and 2500 WW) for optimal visualization of the conchal structures in the air-filled nasal cavity. The CT examinations were reviewed by a second year resident in veterinary diagnostic imaging (F.V.G.) under direct supervision of a board-certified veterinary radiologist (S.B.) and the decisions were based on consensus. Presence, relative location (uni- or bilateral) and degree of extension of caudal aberrant turbinates were investigated. The degree of extension of caudal aberrant turbinates was described according to the classification system described below. Transverse images were used primarily for evaluation and classification in all the patients. Both sides of the nasal cavity were evaluated and classified independently.

Classification System for Caudal Aberrant Turbinates

Caudal aberrant turbinates were classified in a five-point ordinal grading scheme depending on the degree of caudal extension of turbinates (Table 1). Dogs without turbinates visible in the ventral nasal meatus were classified as Grade 0 (normal dogs). When turbinates were visible in the ventral nasal meatus before the point where the basal lamina of the ethmoid bone branches with the perpendicular lamina of the palatine bone and the nasopharyngeal meatus starts (Fig. 1A), caudal aberrant turbinates were classified as Grade 1. The nasopharyngeal meatus is the air passage extending from the caudal ends of the ventral and common nasal meatuses to the choanae. When turbinates were visible in the nasopharyngeal meatus but not extending through the choanae (Fig. 1B), caudal aberrant turbinates were classified as Grade 2. The choanae were defined as the openings from the nasopharyngeal meatus into the nasopharynx. They were located at the caudal border of the vomer where it extended rostrally from the floor of the cranial cavity to the hard palate. Grade 3 was assigned when the turbinates were visible in the choanae, but not passed the point caudal to the nasal septum where the nasopharynx starts (Fig. 1C); and Grade 4 when turbinates were visible in the nasopharynx. The nasopharynx was defined as the respiratory portion of the pharynx dorsal to the hard and soft palate and that extended from the choanae of the nasal cavity to the intrapharyngeal opening of the pharynx.

Animals were graded for both sides of the nasal cavity independently, but given one final grade based on the highest grade of extension of turbinates into the ventral nasal

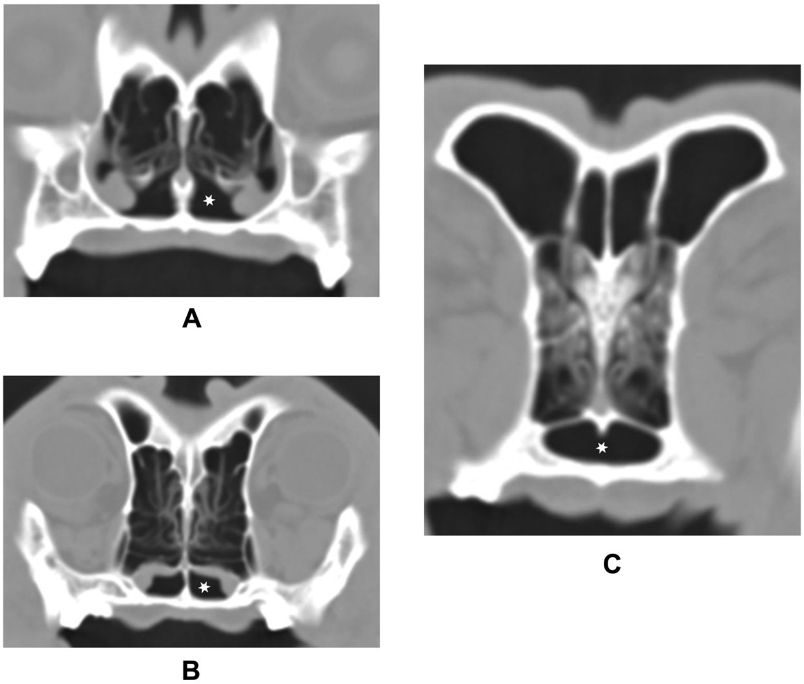

FIG. 1. (A) Transverse CT image of an English Bulldog without caudal aberrant turbinates at the level of the nasopharyngeal meatuses (star in the left nasopharyngeal meatus). (B) Transverse CT image of an English Bulldog without caudal aberrant turbinates at the most caudal aspect of the vomer bone, which is the level of the choanae (star in the left choana). (C) Transverse CT image of an English Bulldog without caudal aberrant turbinates at the rostral part of the nasopharynx (star).

meatus, nasopharyngeal meatus, or choanae if the grades were different for either side.

Data Analysis

Associations between the total caudal aberrant turbinates grade and the caudal aberrant turbinates grade for each side of the nose with respect to age, weight, and gender were tested. Spearman's correlation was used to determine whether there was an association with respect to age, weight, and caudal aberrant turbinate grade in English Bulldogs. Mann–Whitney *U* test was used to determine if there was a difference between male and female English Bulldog populations with dependent variable being the grade. Statistical tests were done using commercially available software (SPSS Statistics 21, IBM Corporation, Hampshire, UK). Differences of $P < 0.05$ were considered statistically significant. Statistical analyses were selected and performed by a statistical consultant (Ben Kaye).

Results

The sample was composed of 26 females (22 intact and four neutered) and 14 males (11 intact and three neutered). Age ranged from fourteen to 31 months (mean 20 months, median 28 months) and weight ranged from 18.1 to 30.8 kg (mean 23.5 kg, median 23 kg). Male dogs were heavier than female dogs ($P = 0.001$), but no significant difference between genders and age ($P = 0.877$) was found (Table 2). There was no correlation between population age and weight ($P = 0.113$). Using the proposed classification scheme, the overall prevalence of caudal aberrant turbinates was 100% in this sample of English Bulldogs. Grade 1 caudal aberrant turbinate protrusion (Fig. 2A) was detected in 7 of 40 (17.5%) English Bulldogs and in 18 of 80 (22.5%) nasal cavities. Grade 2 protrusion (Fig. 2B) was observed in 28 of 40 (70%) English Bulldogs and in 57 of 80 (71.25%) nasal cavities. Grade 3 protrusion (Fig. 2C) was detected in 5 of 40 (12.5%) English Bulldogs and in 5 of 80 (6.25%) nasal cavities. Grades 0 and 4 were not detected in any of the English Bulldogs (Table 2). In all cases caudal aberrant turbinates were bilateral, having the same grade for both sides in 31 of 40 (77.5%) and a different grade between both sides in 9 of 40 (22.5%) English Bulldogs. In the cases where

TABLE 2. Population Characteristics of the 40 English Bulldogs, Subdivided by Gender

	Male ($n = 14$)	Female ($n = 26$)	*P*-value
Age (months)	16 (14 – 30)	16.5 (14 – 31)	0.878
Weight (kg)	26.0 (±3.0)	22.3 (±3.1)	0.001

Normally distributed data are represented as mean (±SD), and nonnormally distributed data are represented as median (range).

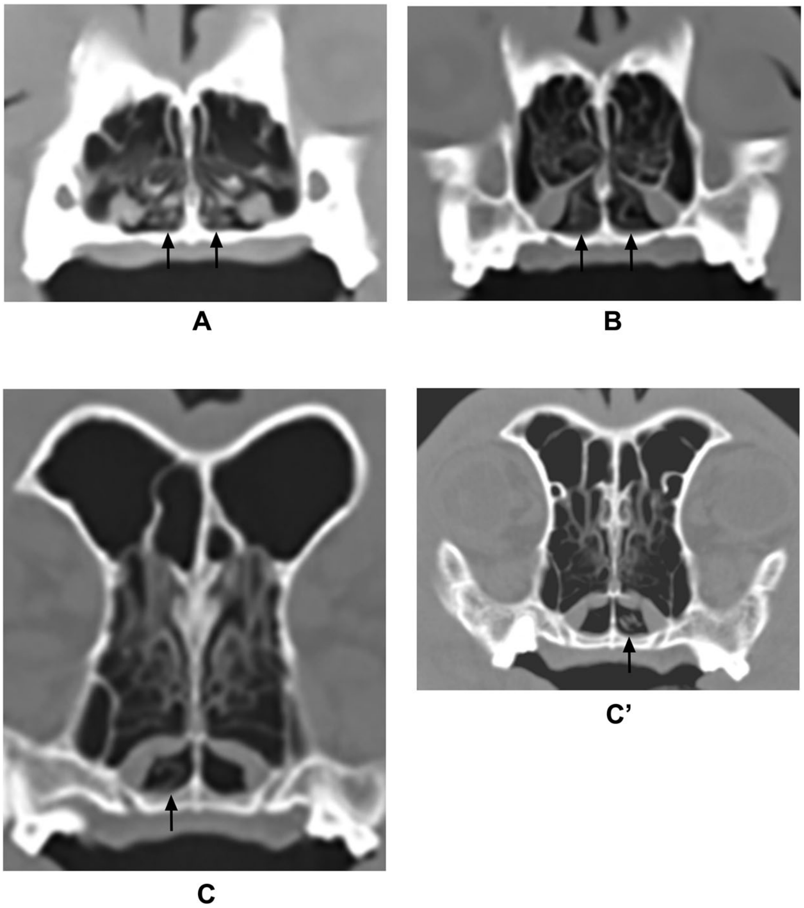

FIG. 2. (A) Transverse CT image of an English Bulldog with bilateral grade 1 caudal aberrant turbinates visible within the ventral nasal meatuses (black arrows), but not extending into the nasopharyngeal meatus. (B) Transverse CT image of an English Bulldogs with bilateral grade 2 caudal aberrant turbinates visible at the level of the nasopharyngeal meatuses (black arrows). **(C)** Transverse CT image of an English Bulldogs with unilateral grade 3 caudal aberrant turbinates within the right choana (Black arrow).This image is made at the most caudal aspect of the vomer bone. (C') Transverse CT image of an English Bulldogs with unilateral grade 3 caudal aberrant turbinates within the left choana (black arrow). This image is made at the most caudal aspect of the vomer bone.

caudal aberrant turbinates had the same grade bilaterally, 7 of 40 (17.5%) dogs had grade 1 and 24 of 40 (60%) dogs grade 2. In the cases where caudal aberrant turbinates had a different grade on each side, concurrent grades 1 and 2 were noted in 4 of 40 (10 %) dogs and concurrent grades 2 and 3 in the other 5 of 40 (12.5%) dogs.

There was no association between the final caudal aberrant turbinates grade and age ($P = 0.139$), weight ($P = 0.203$), or gender ($P = 0.104$). There was no association between the caudal aberrant turbinates grade of each side and age [left side ($P = 0.250$) and right side ($P = 0.508$)], weight [left side ($P = 0.182$), and right side ($P = 0.386$)] or gender [left side ($P = 0.171$) and right side ($P = 0.146$)].

The frequency of genders observed for each grade, as well as a description of age and body weight for each grade (minimum, first quartile, median, third quartile, and maximum), is shown in Table 3 and Figures 3 and 4.

TABLE 3. Frequency of Genders and Description of Age and Body Weight for Each Grade of Caudal Aberrant Turbinate Protrusion

		Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
Gender	Males	0	0	11 (2 MN)	3 (1 MN)	0
	Females	0	7 (3 FN)	17 (1 FN)	2	0
Age (months)	Minimun	N/A	15	14	27	N/A
	1st quartile	N/A	15	15	27	N/A
	Median	N/A	15.5	16	28	N/A
	3rd quartile	N/A	16.7	24.5	30	N/A
	Maximum	N/A	28	30	30	N/A
Weight (Kg)	Minimun	N/A	18.1	18.5	21.3	N/A
	1st quartile	N/A	18.8	20.8	23.6	N/A
	Median	N/A	21.4	22.9	25.6	N/A
	3rd quartile	N/A	25.3	25.7	26.9	N/A
	Maximum	N/A	28	30.8	27.7	N/A

N/A, not applicable; MN, male neutered; FN, female neutered.

Discussion

Contrary to what was hypothesized in our first hypothesis, CT demonstrated the presence of caudal aberrant

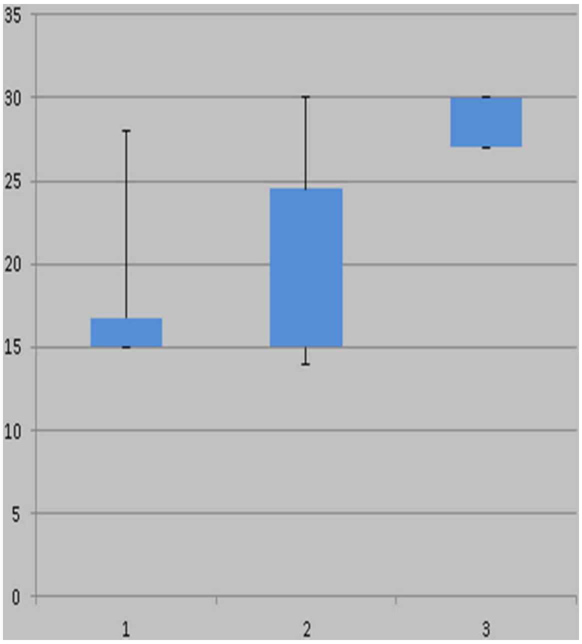

FIG. 3. Box and whisker plot showing the relation of age for each each grade of caudal aberrant turbinate protrusion.

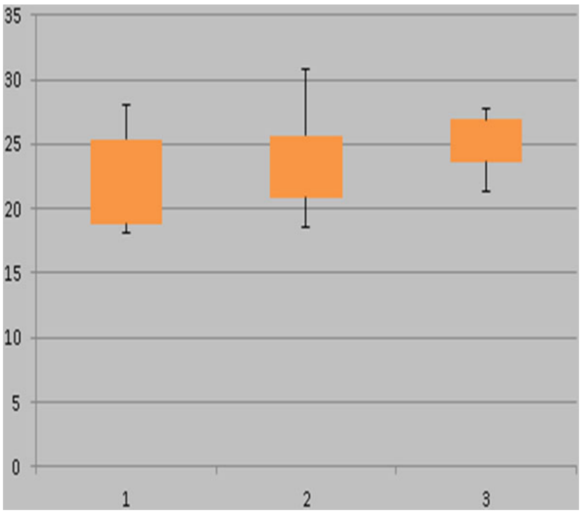

FIG. 4. Box and whisker plot showing the relation of weight for each each grade of caudal aberrant turbinate protrusion.

turbinates in all included clinically healthy English Bulldogs. This high prevalence (100%) of caudal aberrant turbinates in our group is greater than expected, especially considering the fact that this group of English Bulldogs had no clinical signs of respiratory disease. It is possible that grade 1 caudal aberrant turbinate protrusion was not recognized or included in the statistical analysis of previous studies because the condition was diagnosed by endoscopy rather than with CT. No caudal aberrant turbinates were observed in the nasopharynx (Grade 4) in any of our cohort of English Bulldogs. This again is mostly likely because these dogs had no significant clinical signs of brachycephalic airway syndrome. Nasopharyngeal turbinates, equivalent to our grade 4 protrusion, have been described by other authors in brachycephalic dogs with more severe signs of brachycephalic airway syndrome.[5,6,17] The high prevalence of caudal aberrant turbinates in this group of healthy English Bulldogs is surprising, but could indicate that mild to moderate caudal aberrant turbinates may be sub-clinical in English bulldogs. In affected animals with signs of upper airway obstruction clinicians are advised to thoroughly evaluate the entire airway to rule out another cause of the obstruction. Several studies have focused on the abnormal configuration of the nasal conchae of brachycephalic breeds by CT and endoscopy in dogs with respiratory complaints related to brachycephalic airway syndrome.[5,12,13,16,17] In these studies the prevalence of caudal aberrant turbinates ranged between 43% and 67% in breeds such as the Pug, French Bulldog, and English Bulldog. The prevalence of caudal aberrant turbinates in English Bulldogs has been described up to 63%,[16] but because no classification scheme was used a comparison with the much higher prevalence of caudal aberrant turbinates in our study is difficult. Brachycephalic breeds in which aberrant conchae have been reported in clinically affected animals are the Pug, French Bulldog, English Bulldog, and Pekingese.[4–7,13,16] A relation between the presence of caudal aberrant turbinates with gender, weight, or age was not investigated or reported in most of these studies. Ginn et al.[6] reported no statistically significant difference in age between dogs with and without nasopharyngeal turbinates.

Most English Bulldogs included in our study demonstrated concurrent brachycephalic abnormalities such as pharyngeal hypoplasia with mildly elongated soft palate and laryngeal hypoplasia with Grade I collapse (eversion of the saccules was present in all Bulldogs). Studies on clinically healthy brachycephalic dogs were not found in the literature, so it is unknown which degree of hypoplasia of the airways is clinically tolerated or what the importance of the individual anatomical parameters on breathing is. In addition, Packer et al.[20] demonstrated that owners cannot be relied upon for noticing clinical signs of brachycephalic airway syndrome and generally underestimate the severity of the respiratory complaints. Furthermore, the population in this study was relatively young, and therefore it is possible that in the future clinical signs of respiratory compromise may still develop. In addition, at this stage it is unknown whether or not dogs with turbinate protrusion are more severely affected by mucosal swelling or are at a greater risk for airway obstruction than dogs without protrusion. English Bulldogs have been previously reported to demonstrate rostral aberrant turbinates nevertheless we did not investigate these structures because of their relatively low prevalence in English bulldogs and because of their equivocal detection only by CT. Combined rhinoscopy and computed tomographic examination of the nostrils and nasal vestibule provides a better evaluation of the presence and severity of rostral aberrant turbinates.[18] We failed to prove our second hypothesis because no significant correlation was found between the degree of protrusion of the caudal aberrant turbinates with the age, gender, and weight of the animal. Our second hypothesis was based on the fact that heavier, male, brachycephalic dogs are clinically more affected by brachycephalic airway syndrome than lighter females.[19,21] It is possible that the small sample size prohibited finding such a relationship. Also, all the dogs included in our study were relatively young (maximum 2.5 years) and a prospective longitudinal study design would be more appropriate to establish the effect of age on degree of protrusion and to evaluate associations between gender and weight in clinically affected animals.

We propose a new classification system for a more objective assessment of the severity of protrusion of caudal aberrant turbinates in English Bulldogs and for statistical analysis. This new classification scheme will allow better comparison in clinical studies and in assessing the clinical relevance of these findings. In this study, the achieved data were used to define this new classification scheme, but the association between the grade of extension of turbinates and the severity of the clinical signs of brachycephalic airway syndrome could not be evaluated, since all Bulldogs were sub-clinical. Whether or not our classification scheme is suitable for use in other brachycephalic dog breeds and in clinically affected dogs will be the topic of future studies. Prospective studies are needed in all brachycephalic dog breeds, clinically normal, and affected by brachycephalic airway syndrome, to determine the prevalence and clinical relevance of turbinate protrusion. Surgical treatment for severe turbinate protrusion in patients suffering from brachycephalic airway syndrome by laser assisted turbinectomy has been reported with a good outcome in some patients, but peri-operative morbidity and mortality rates are high.[5,12,13,16,17] An objective assessment scheme needs to be developed to evaluate the results of surgical treatment of the several components of brachycephalic airway syndrome before routine surgery on the individual components can be recommended in daily practice. In conclusion, findings from this study indicated that (1) no significant associations were present between the severity of the protrusion of the caudal aberrant turbinates with gender, age, and body weight in clinically healthy English Bulldogs and (2) that minimal to moderate, Grade 1–3, caudal aberrant turbinate protrusion is common in English Bulldogs even with minimal or absent signs of upper respiratory disease. Future studies need to develop proper clinical tools to evaluate the severity of the brachycephalic airway syndrome and the effects of current surgical treatment options.

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