Computed tomographic imaging of the nose in brachycephalic dog breeds*

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Key words

Brachycephalic airway syndrome, computed tomography, nasal anatomy, intranasal obstruction, septum deviation, aberrant turbinates, laser-assisted turbinectomy, LATE

Summary

Introduction and objective: Inappropriate selection for extreme brachycephaly has led to almost complete loss of the nose in brachycephalic dog breeds. This structural deformity causes severe malfunction of the airways and is referred to as brachycephalic airway syndrome (BAS). The aim of this study was to examine and compare the anatomical features of the brachycephalic and normocephalic nose of dogs using computed tomography (CT). **Methods:** A total of 23 brachycephalic dogs (11 pugs, seven French bulldogs, five English bulldogs) and one normocephalic German shepherd dog were examined. Multislice CT images of all animals were evaluated. For comparison of structural differences between normocephalic and brachycephalic breeds, anatomical parameters were determined. **Results:** Extreme shortening of the craniofacial skull and thus of the nasal cavity lead to abnormal configuration of the conchae. Two main types of aberrant conchal growth were recorded: Rostral aberrant turbinates (RAT) obstructing the nasal passage and caudal aberrant turbinates (CAT) obstructing the nasopharyngeal meatus. Furthermore, all nasal conchae were characterised by a low degree of branching and crude lamellae. Measurements of the skull revealed characteristic differences among the brachycephalic dog breeds. The pug had a shorter facial skull than the French and English bulldogs. **Conclusion:** The finding that severe intranasal deformities occur in brachycephalic dogs provides new data for the understanding of the pathophysiology of BAS. **Clinical relevance:** Detailed structural analysis of rostral and caudal aberrant turbinates (RAT, CAT) is an indispensable prerequisite for planning and implementing intranasal treatment of BAS using laser-assisted turbinectomy (LATE therapy).

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Introduction

The popularity of brachycephalic dog breeds such as the pug and bulldog has increased in recent years and has led to an increase in the frequency of severe respiratory insufficiency among patients, many of which require veterinary intervention. In our experience, the severity of clinical signs in brachycephalic dogs has markedly increased in the last ten years, and many dogs are affected in the first two years of life. Brachycephalic airway syndrome (BAS) is a complex of respiratory problems mainly attributable to abnormalities of the nose and larynx caused by extreme shortening of the facial bones. The syndrome is characterised by upper airway obstruction and stenosis of the nose and pharynx, an elongated fleshy soft palate, stenotic nares, soft tissue thickening in the nasopharynx, enlargement of the root of the tongue, everted pharyngeal tonsils and laryngeal ventricles, instability of the laryngeal cartilages and in advanced cases, laryngeal or tracheal collapse (1, 12–14, 21). These abnormalities may occur individually or in combination and always result in impaired respiratory function.

In BAS, airway obstruction may be primary or secondary, whereby primary obstruction leads to secondary obstruction. The structures considered to be involved in primary obstruction are subject to debate. For many years, stenotic nares and elongation of the soft palate were thought to be the cause of primary obstruction (1, 3, 12, 13, 18, 31). However, we hypothesise that abnormal intranasal structures are a fundamental cause of increased respiratory resistance as well (17, 24, 26).

Current treatment for BAS is aimed at correcting three of the most obvious abnormalities. Stenotic nares are widened via wedge excision, the soft palate is shortened, and everted laryngeal saccules are removed (1, 19). However, the outcome is not always satisfactory (21) because this type of treatment only addresses the problems proximal and distal to the nasal cavity but not the abnormalities within the nasal cavity itself.

A preliminary investigation found marked morphological changes within the nasal cavity of brachycephalic dogs (26). This prompted the development of laser-assisted turbinectomy

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Table 1
Signalment and results of computed tomography of the nose of a normocephalic dog and 23 brachycephalic dogs.

Nr.	Breed	Age (years)	Sex	Septum deviation	RAT	CAT
1	German shepherd dog	4	female	–	–	–
2	Pug	2	female	to the left	right	right and left
3	Pug	2	male	to the left	right	–
4	Pug	1	male	to the left	right	–
5	Pug	2	female	to the left	right	right and left
6	Pug	6	female	to the left	right	–
7	Pug	5	female	to the right and left	right and left	right
8	Pug	10	female	to the right	left	left
9	Pug	1	male	to the right	left	–
10	Pug	6	male	to the right	left	–
11	Pug	7	female	to the left	right	–
12	Pug	2	male	to the left	right	right
13	French bulldog	1	male	–	–	–
14	French bulldog	4	male	–	–	right and left
15	French bulldog	2	female	–	–	–
16	French bulldog	1	male	to the left	right	right
17	French bulldog	2.5	male	–	–	–
18	French bulldog	3	female	–	–	right
19	French bulldog	0.5	male	–	–	–
20	English bulldog	2	female	–	–	–
21	English bulldog	1	male	–	–	–
22	English bulldog	5	male	–	right and left	right and left
23	English bulldog	0.5	male	–	–	–
24	English bulldog	1	male	–	–	right and left

RAT = rostral aberrant turbinates
CAT = caudal aberrant turbinates

(LATE), which has led to noticeable long-term improvement in dogs with BAS (25, 26, 29). Patients first undergo computed tomography (CT), followed by removal of obstructive portions of the nasal chonchae with a diode-laser.

The structure of the nose of brachycephalic dogs is complicated and can only be imaged using high-resolution techniques such as CT. A thorough understanding of the anatomy of the canine nose is mandatory when interpreting CT images for diagnostic purposes and for tailoring intranasal surgery to the patient. Computed tomographic studies of the canine nose have been done in normocephalic breeds (2, 9, 32), but not, to our knowledge, in brachycephalic breeds.

The goal of the present study was to compare the anatomy of the nose of brachycephalic and normocephalic dogs using CT. Proportional differences in the skull measurements of brachycephalic dogs and a normocephalic dog were compared.

Materials and Methods

A total of 23 brachycephalic dogs, which included 11 pugs, seven French bulldogs and five English bulldogs, underwent CT imaging of the skull (▶Table 1). All the dogs had been referred to the Small Animal Clinic, University of Leipzig, for surgical treatment of BAS. The CT images were compared with those of a healthy German shepherd dog to determine abnormalities in the nasal structure of the brachycephalic dogs.

Table 2 Anatomical landmarks for skull measurements (Fig. 1).

Length	Starting point	End point
(1) Nasal cavity	Alveolar point of incisive bone (prosthion)	Caudal border of sphenoidal sinus
(2) Hard palate	Alveolar point of incisive bone (prosthion)	Caudal point of hard palate
(3) Skull I	Alveolar point of incisive bone (prosthion)	Most ventral point of foramen magnum
(4) Skull II	Alveolar point of incisive bone (prosthion)	External occipital protuberans
(5) Brain cavity	Junction of frontal bone and ethmoid bone	Dorsal margin of foramen magnum

Computed tomographic imaging was done using a multislice spiral CT scanner (Philips Mx8000 Brilliance, 6-slice, Philips Medical Systems GMBH, Germany). The dogs were placed under general anaesthesia and positioned in sternal recumbency on the CT table. The upper jaw was secured so that the hard palate was parallel to the table. The topograms were done in laterolateral and dorsoventral views to plan the slice series. Two series of slices were carried out at settings of 200 mAs and 120 KV. In the first series, the head and neck region from the tip of the nose to the larynx was imaged with a slice thickness of 1 mm. The emphasis of the second series was on visualisation of the delicate structures of the nasal cavity. A slice thickness of 0.6 mm was used to obtain images from the tip of the nose to the caudal parts of the sinuses. The CT images were taken using a modified lung window (–300 WL and 2500 WW) for optimal visualisation of the structure of the conchae in the air-filled nasal cavity.

Anatomical landmarks were defined and measured for comparison of the length of the nasal cavity with the length of the entire skull, the length of the hard palate and the length of the cranial cavity (▶Table 2, 3; Fig. 1). All measurements were determined in relation to the length of the nasal cavity, and the measurements of the brachycephalic skulls were compared with those of the normocephalic skull (▶Fig. 5). The osteometric data were evaluated for normal distribution using the Kolmogorov-Smirnov test, and differences among brachycephalic breeds were analysed using a *t*-test. A *P*-value of 0.05 was considered significant. The type and severity of the deviation of the nasal septum and abnormal growth of the turbinate structures rostrally into the nasal cavity (rostral aberrant turbinates = RAT) and caudally into the nasopharynx (caudal aberrant turbinates = CAT) were also determined (▶Table 1).

Results

Comparison of the CT slice series of a pug and the German shepherd dog (Figs. 2, 3) clearly showed the structural differences within the nasal cavity. Compared with normocephalic **nares**, those of the pugs were much narrower and slit-like (▶Figs. 2A and B) and the lateral wings of the nose were closer together. In addition, the lateral wings appeared more prominent, and the plica alaris, which emerges further caudally from the wings, was enlarged considerably (Fig. 2C, D: 2a). Because of shortening of the nose, the skin folds and maxillary canine tooth (Fig. 2D: 9a) were seen at this level; the latter became visible much further caudally in the German shepherd dog.

In the German shepherd dog, the **nasal folds** were clearly demarcated, whereas in the brachycephalic dog, they were compact and telescoped (Fig. 2E, F: 2a-e). In 13 of 23 cases (57%), the middle nasal conchae were displaced further rostrally than normal and extended close to the vestibulum (Fig. 2F: 4a; Table 1).

The four **nasal passages** (Fig. 2E: 5a-d) were clearly demarcated in the German shepherd dog, but were narrowed, asymmetric and distorted in the brachycephalic breeds. In the rostral nasal cavity, this was caused by asymmetric mucosal folds and the rostrally-located aberrant turbinates (RAT; Fig. 2F: 4a). Further caudally and immediately rostral to the meatus nasopharyngeus, the ventral nasal meatus (Fig. 3: 5c) was frequently obstructed by tissue of the ventral or middle nasal conchae. In contrast to the German shepherd dog, in which the folds of the conchae clearly ended rostral to the wing of the vomer (Fig. 2I: 7a), the ventral nasal conchae occupied this part of the nasal passageway in the pug (Fig. 2J: 3, Fig. 3: 3). An important finding were aberrant growing turbinates within the meatus nasopharyngeus (Fig. 2N, P: 4a, Fig. 3: 4a). In

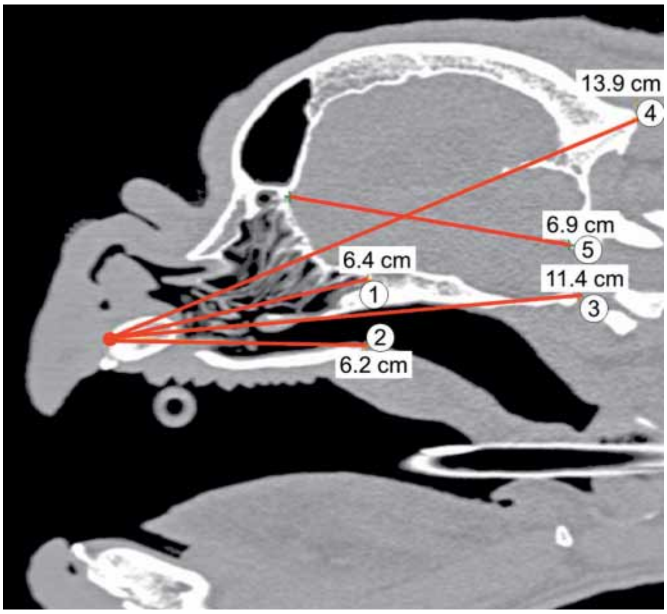

Fig. 1 The skull measurements in all the dogs included the length of the nasal cavity (1), hard palate (2), skull I (3), skull II (4) and brain cavity (5) (Table 2).

10 of 23 dogs (43%), parts of the ventral or middle conchae extended into the meatus nasopharyngeus causing stenosis of this transition from the nasal cavity to the nasopharynx. In extreme cases (4 of 23), the lamellae of the middle nasal concha extended even further caudally, beyond the choanae, into the **nasopharynx** (Fig. 3: 4a, 5f). When viewed from the side, the entire course of the nasal passage was in a more upright position in all the brachycephalic dogs (Fig. 3: 5c).

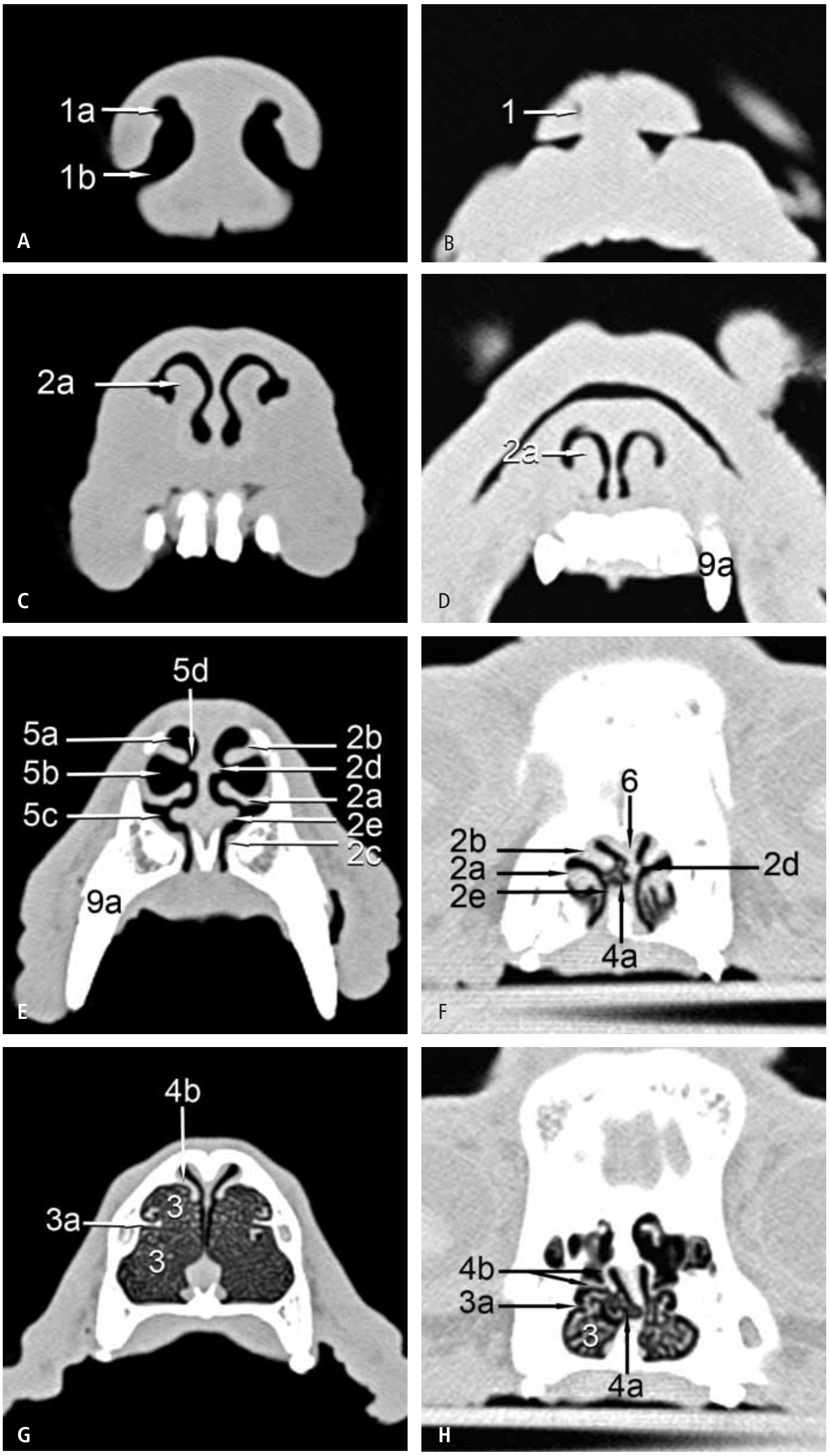

Fig. 2
Comparison of transverse CT images of the nose of a German shepherd dog (left row) and that of a pug (right row). 1 = nares, 1a = comma head-shaped nasal opening, 1b = comma tail-shaped nasal opening, 2 = entrance to nasal cavity (mobile part of the nose) and septal swell bodies, 2a = plica alaris, 2b = plica recta, 2c = plica basalis, 2d = dorsal septal swell body, 2e = ventral septal swell body, 3 = ventral nasal concha, 3a = basal lamellae, 3b = caudal extension (with the sphenopalatine artery and vein), 4 = ethmoid bone, 4a = middle nasal concha (endoturbinate II), 4b = dorsal nasal concha (endoturbinate I), 4c = basal lamina, 4d = endoturbinate IV, 5 = air passage, 5a = dorsal nasal meatus, 5b = middle nasal meatus, 5c = ventral nasal meatus, 5d = common nasal meatus, 5e = choanae, 5f = nasopharyngeal meatus, 6 = nasal septum, 7 = vomer, 7a = wing of vomer, 8 = palatine bone, 8a = perpendicular plate of palatine bone, 9 = maxilla, 9a = canine tooth.

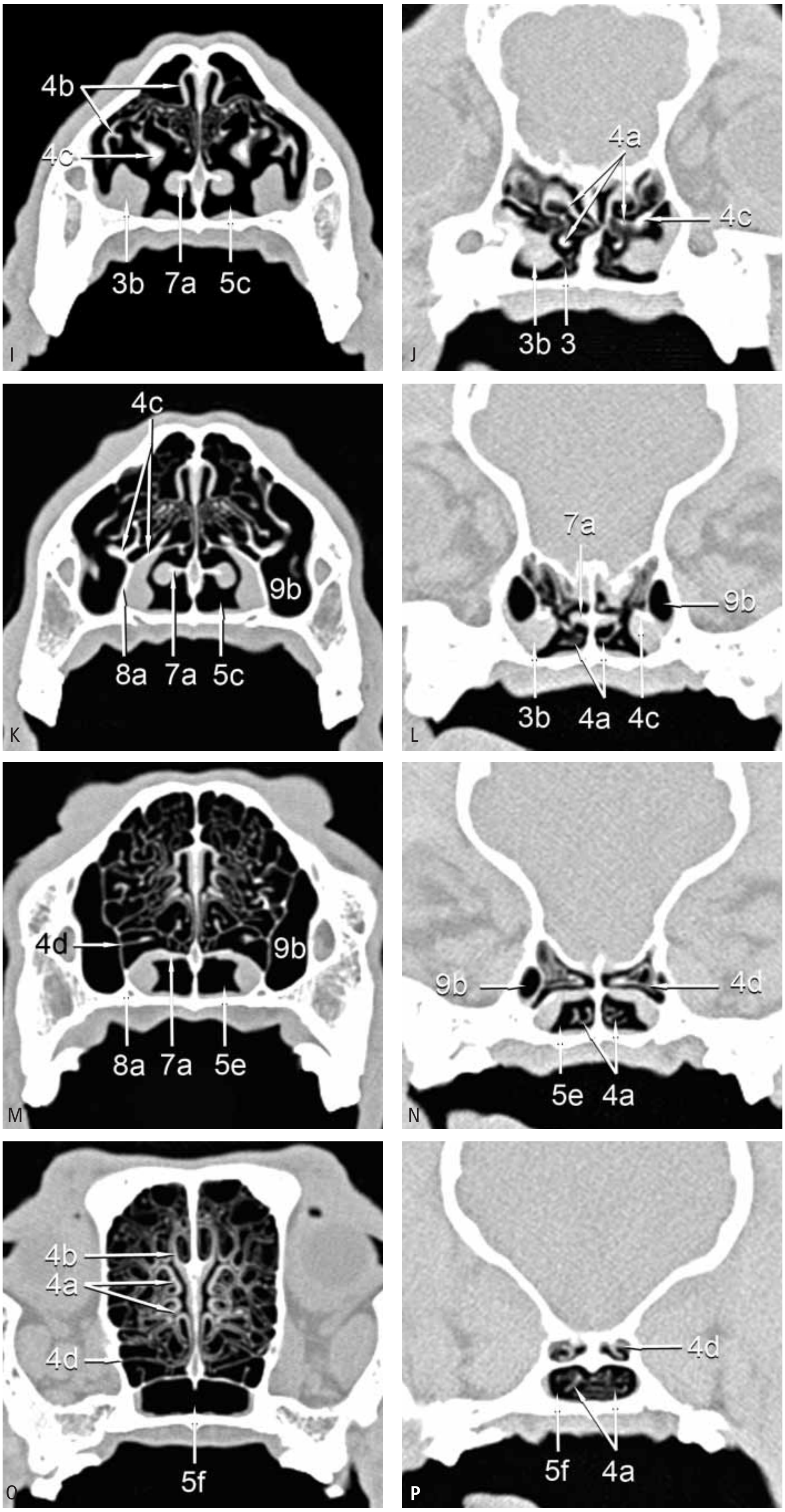

Fig. 2
continued
1 = nares, 1a = comma head-shaped nasal opening, 1b = comma tail-shaped nasal opening, 2 = entrance to nasal cavity (mobile part of the nose) and septal swell bodies, 2a = plica alaris, 2b = plica recta, 2c = plica basalis, 2d = dorsal septal swell body, 2e = ventral septal swell body, 3 = ventral nasal concha, 3a = basal lamellae, 3b = caudal extension (with the sphenopalatine artery and vein), 4 = ethmoid bone, 4a = middle nasal concha (endoturbinate II), 4b = dorsal nasal concha (endoturbinate I), 4c = basal lamina, 4d = endoturbinate IV, 5 = air passage, 5a = dorsal nasal meatus, 5b = middle nasal meatus, 5c = ventral nasal meatus, 5d = common nasal meatus, 5e = choanae, 5f = nasopharyngeal meatus, 6 = nasal septum, 7 = vomer, 7a = wing of vomer, 8 = palatine bone, 8a = perpendicular plate of palatine bone, 9 = maxilla, 9a = canine tooth.

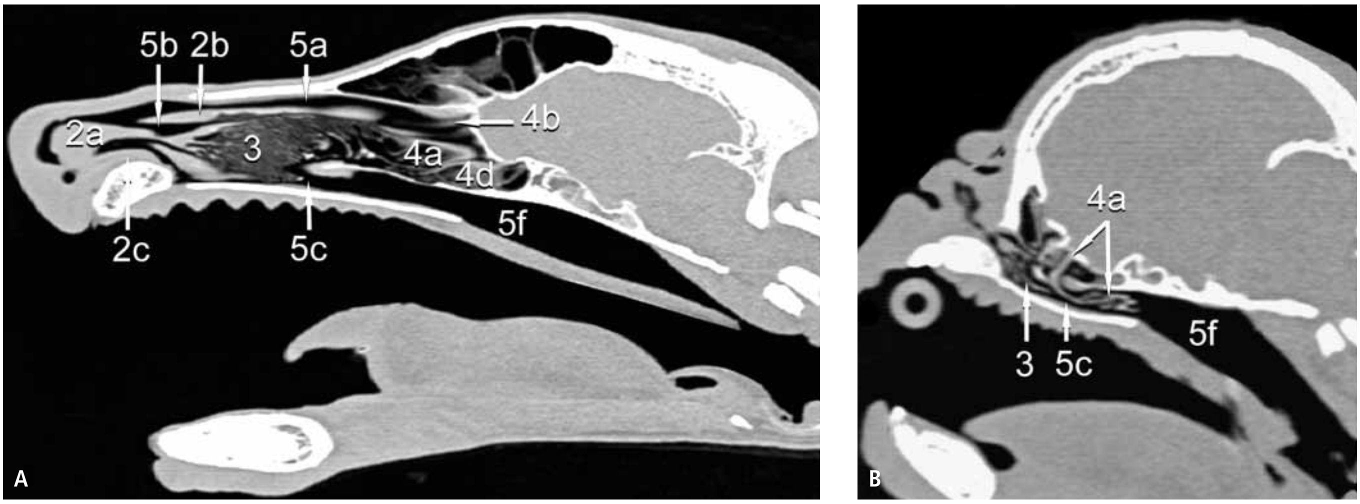

Fig. 3 Comparison of sagittal CT images of the head of a German shepherd dog (A) and that of a pug (B). In the pug, caudal aberrant turbinates (CAT) originating from the middle nasal concha (4a) extend caudally and obstruct the air passage (5c) as well as the nasopharyngeal meatus (5f).

There was severe deviation of the **nasal septum** in 11 pugs and mild deviation in one French bulldog (Fig. 2F: 6, Table 1). In these 11 pugs, there was marked rostral displacement of the middle nasal conchae (RAT) on the concave side of the nasal septum (Fig. 2F: 4a). In only one English bulldog did both middle nasal conchae extend far rostrally, even though there was no deviation of the nasal septum (Table 1).

There were moderate to severe changes in the configuration of all **nasal conchae** in brachycephalic dogs. In the German shepherd dog, the ventral nasal conchae appeared very delicate, whereas in the pugs, they appeared coarse (Fig. 2G, H: 3). This resulted in fewer ramifications and thickened conchal lamellae.

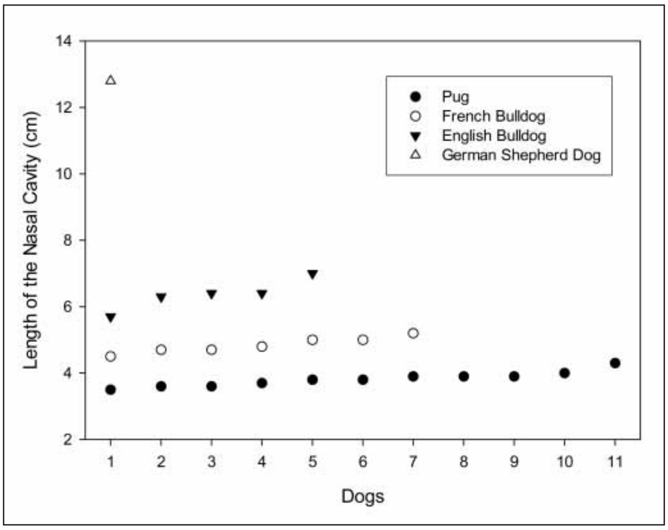

Fig. 4 The length (cm) of the nasal cavity using the anatomical landmarks listed in Table 2 in 11 pugs, seven French bulldogs, five English bulldogs and one German shepherd dog.

The skull of brachycephalic dogs had marked **proportional abnormalities**. In normocephalic dogs, the floor of the nasal cavity, which separates the nasal cavity from the nasopharynx caudally, is formed by the wing of the vomer (Fig. 2K, M: 7a) and the perpendicular lamellae of the hard palate (Fig. 2K, M: 8a). The basal lamina of the ethmoid bone (Fig. 2I-L: 4c) forms the transition between the nasal cavity and nasopharynx further rostrally and dorsal to the wing of the vomer and serves as a point of attachment for the middle nasal concha (Fig. 2J: 4a). In contrast, the basal lamina of the ethmoid bone (Fig. 2J: 4c) in brachycephalic dogs were seen further rostrally, which was why the point of attachment of the middle nasal concha was also located further rostrally than in normocephalic dogs. Ventral to this point of attachment, there was no closure of the floor of the nasal cavity because this occurred further caudally. Instead, this area was occupied by conchal tissue, which extended unhindered into the nasal cavity and even as far as the choanae and nasopharynx.

The proportional abnormalities became most obvious when the skull measurements of the brachycephalic dogs and the German shepherd dog were compared (▶Table 3). The pug had the shortest head and thus the shortest nasal cavity (▶Fig. 4), hard palate, skull length I and II and brain cavity, followed by the French and English bulldog. Compared with the pug, the skull of the German shepherd dog was twice as long and the nasal cavity more than three times as long. The brain cavity, on the other hand, was only 1.4 times larger than that of the pug and 1.2 times larger than that of the English bulldog (▶Table 3). Because these absolute values do not accurately reflect the characteristic proportional differences, the individual measurements were expressed in relation to the corresponding length of the nasal cavity, to determine differences among the brachycephalic breeds (▶Fig. 5, Table 4, 5).

Compared with the length of the nasal cavity, the hard palate was relatively longer in the pug and French bulldog and relatively

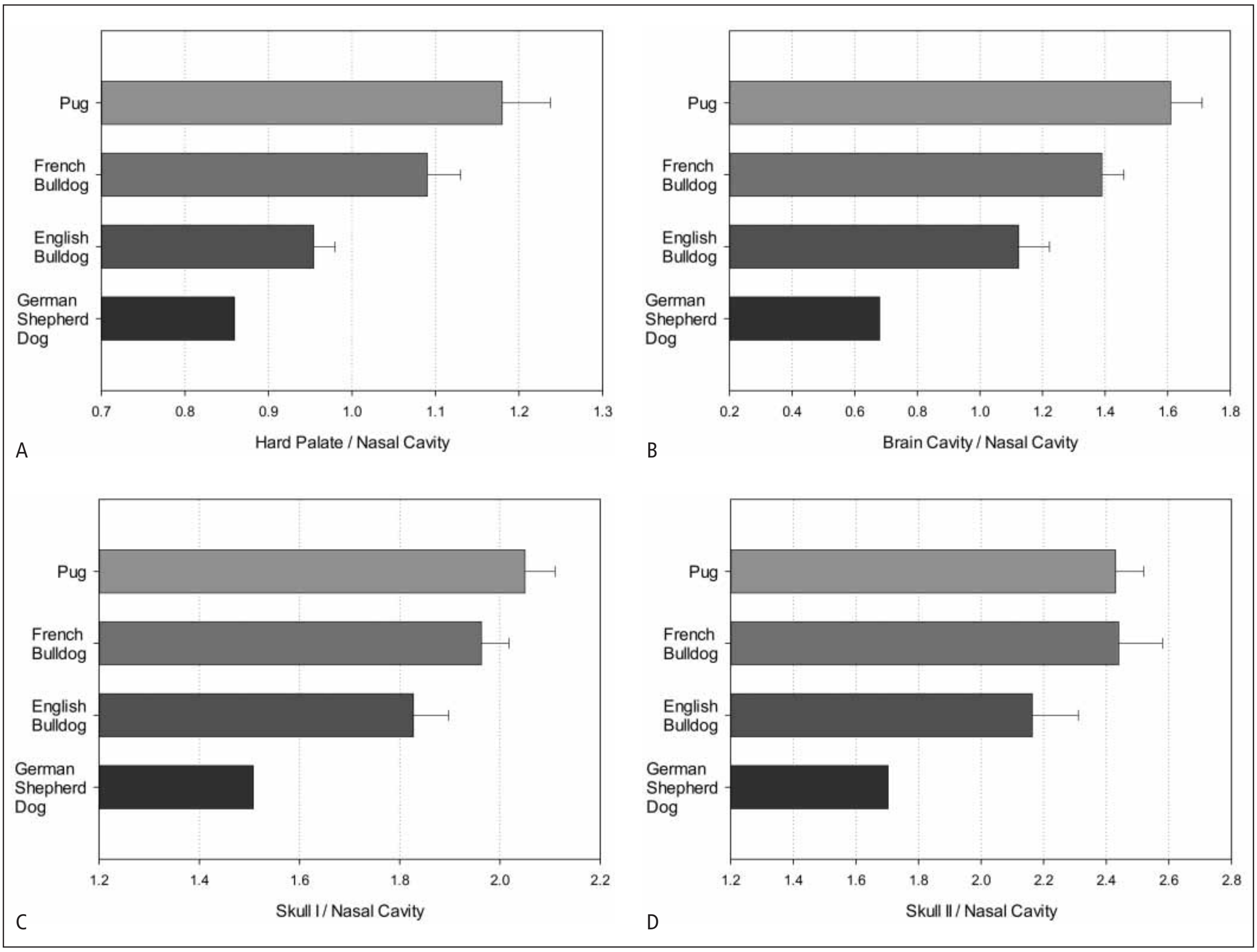

Fig. 5 Relationships (mean + SD) of the length of the hard palate (A), brain cavity (B), skull I (C) and skull II (D) to the length of the nasal cavity using the landmark measurements shown in Table 2 in 11 pugs, seven French bulldogs, five English bulldogs and one German shepherd dog.

shorter in the English bulldog and particularly in the German shepherd dog. The nasal cavity was 39% of the length of the skull in the pug and 66% in the German shepherd dog. The relative length of the brain cavity was markedly greater than that of the nasal cavity in the brachycephalic breeds, but markedly shorter in the German shepherd dog (▶Fig. 5).

In the pug, the relationship between the length of the skull and the length of the nasal cavity differed the most from the corresponding relationship in the German shepherd dog. The relationships calculated for the pugs and French bulldogs were generally similar, and in the English bulldog, the relationships were between those of the French bulldogs and the German shepherd (▶Table 4). With the exception of the skull II/nasal cavity relationship in the pug and French bulldog, all differences between the relative lengths differed significantly among the breeds (▶Table 5).

Discussion

To the authors' knowledge, this is the first study to investigate the structure of the nose of brachycephalic dogs via CT. It was shown that airway occlusion is, at least in part, the result of rostral aberrant turbinates (RAT), which extend into the nasal cavity, or caudal aberrant turbinates (CAT), which extend into the nasopharynx. To date, most comparative studies of the skull structure of normocephalic and brachycephalic dogs have used conventional radiography (33). However, superimposition of many of the skull structures is a major problem in the interpretation of radiographs. A number of studies have used multi-slice CT to investigate the structures of the nose of normocephalic dogs (2, 9, 32). This imaging modality is the method of choice for evaluating the delicate nasal structures. Our study used established protocols for CT of the canine skull (15, 16).

Severe stenosis of the nares and nasal vestibule was seen in all the brachycephalic dogs in the present study. Stenotic nares occur

Table 3 Absolute anatomical landmark measurements of the skull in a normocephalic dog and 23 brachycephalic dogs.

Breed		Length of nasal cavity (cm)	Length of hard palate (cm)	Length of skull I (cm)	Length of skull II (cm)	Brain cavity
Pug	$\bar{x}$	3.90	4.55	7.95	9.44	6.23
	SD	0.35	0.30	0.56	0.76	0.34
French bulldog	$\bar{x}$	4.85	5.28	9.52	11.85	6.63
	SD	0.26	0.25	0.48	0.70	0.19
English bulldog	$\bar{x}$	6.36	6.06	11.60	13.72	7.12
	SD	0.46	0.30	0.51	0.66	0.41
German shepherd dog		12.80	11.00	19.30	21.80	8.70

$\bar{x}$ = mean
SD = standard deviation

Table 4 Anatomical landmark measurements of the skull in relation to the length of the nasal cavity in a normocephalic dog and 23 brachycephalic dogs.

Breed		Relationship of hard palate to nasal cavity	Relationship of skull I to nasal cavity	Relationship of skull II to nasal cavity	Relationship of brain cavity to nasal cavity
Pug	$\bar{x}$	1.18	2.05	2.42	1.61
	SD	0.06	0.06	0.09	0.10
French bulldog	$\bar{x}$	1.09	1.96	2.44	1.39
	SD	0.04	0.05	0.14	0.07
English bulldog	$\bar{x}$	0.95	1.83	2.16	1.12
	SD	0.03	0.07	0.15	0.10
German shepherd dog		0.86	1.51	1.70	0.68

Relationships are based on the length of the nasal cavity. $\bar{x}$ = mean; SD = standard deviation

Table 5 Comparison of the relative anatomical landmark measurements among groups of brachycephalic dogs.

Relationship	Pug versus French bulldog	Pug versus English bulldog	French bulldog versus English bulldog
Hard palate/nasal cavity	$p = 0.011$	$p < 0.001$	$p < 0.001$
Skull I/nasal cavity	$p = 0.021$	$p = 0.005$	$p < 0.001$
Skull II/nasal cavity	$p = 0.710$ (n. s.)	$p = 0.003$	$p = 0.012$
Brain cavity/nasal cavity	$p < 0.001$	$p < 0.001$	$p < 0.001$

P-values of t-test, $\alpha = 0.05$, n. s.= not significant

commonly in brachycephalic dogs and are likely a contributing factor in BAS (8, 21, 34). In our experience, there is telescoping and compression of the structures within the mobile part of the nose. The mobile part of the nose is the rostral aspect of the nasal cavity, which is supported by the nasal cartilages, and has a membranous to cartilaginous septum. The dorsolateral nasal cartilages form the lateral wings of the nares (7, 23), in brachycephalic dogs they are very prominent and positioned adjacent to the nasal septum. Because of this, there is no discernable nasal opening, which leads to obstruction. Brachycephalic cats also suffer from this problem (24). Another contributing factor to respiratory obstruction is the perpendicular mucosal fold referred to as the closing fold at the transition between the wing of the nostril and the alar fold (plica alaris) (28). Depending on the patient, this fold should also be removed during surgical enlargement of the nostrils in brachycephalic dogs. Comparative anatomical studies indicate that the closing fold may act as a protective barrier to the entrance of material, such as water, into the nasal cavity, and is important in aquatic mammals (22).

The entire course of the nasal passage in brachycephalic dogs is pushed into a more upright position compared with normocephalic dogs. This abnormality has also been described in brachycephalic cats (20, 24). Bending of the nasal passage is a result of severe shortening of the facial skull, which possibly leads to displacement of the nasal structures via dorsorotation of dental crowns (24).

Extreme shortening of the facial skull, particularly the bony part of the nasal cavity, does not necessarily lead to a reduction in intranasal structures. Rather, it results in abnormal configuration of the nasal conchae, especially the ventral and middle conchae, which can almost entirely obstruct the nasal passage. In 43% of our cases, there was conchal tissue that extended into the choanae, which form the transition between the nasal cavity and nasopharynx (▶Table 1: CAT). In extreme cases (17% of brachycephalic dogs), conchal tissue extended beyond the choanae into the nasopharynx (▶Fig. 2O, P: 4a, 5f, Fig. 3: 4a, 5f). The presence of conchal tissue in the choanae has been reported in a limited number of rhinoscopic studies, although the origin of the tissue was not identified (4, 10). Normally the caudal part of the ventral nasal meatus, the choanae and nasopharynx are completely devoid of conchal tissue and function to conduct air through the respiratory passages (5, 23). Thus, it is not only excessive soft tissue that causes airway obstruction (13), but more importantly conchal tissue occupying the normally open air passages of the choanae and nasopharynx.

All the pugs in the present study had severe deviation of the nasal septum. This abnormality is seen in only 6% of normocephalic dogs. It therefore appears that deviation of the nasal septum is common in brachycephalic dogs, especially pugs. It is known that nasal septal deviation results in nasal obstruction caused by increased air resistance on the convex side of the deviated septum in humans, and hypertrophy of the nasal concha occurs on the concave side (11). Our study also found RAT on the concave side of the deviated nasal septum in all the pugs. Hypertrophy of the middle nasal concha resulted in rostral extension of these structures causing marked stenosis of the nasal opening. We feel that there is an association between the length of the nasal cavity, which is the shortest in the pug, and the observation that the pug consistently had nasal septal deviation and RAT.

Various landmarks and parameters were measured for the osteometric evaluation of the skull (▶Fig. 1, Table 2). With the exception of the length of the nasal cavity, all parameters were adopted from previous studies (20, 30). Determination of the length of the nasal cavity and definition of a useful landmark to achieve this was difficult in brachycephalic dogs because of marked shortening of the nasal bone and the overall limited space. Our study showed that the nasal bone of severe brachycephalic dogs was almost absent. Compared with normocephalic dogs, the nose was deformed and reduced to almost nothing but the rostral mobile part. Thus, it was necessary to establish a new parameter for characterising the length of the nasal cavity. This parameter was the distance from the alveolar point of the incisive bone (prosthion) to the caudal border of the sphenoidal sinus (▶Fig. 1: 1, Table 2: 1).

Absolute measurements of the skull did not allow meaningful direct comparisons among the various breeds. Therefore, relative measurements were defined, which clearly showed that the nose of the normocephalic dog occupied a considerably larger space within the skull and was longer than the brain cavity and hard palate. In contrast, the nose of brachycephalic dogs, especially pugs and French bulldogs, was considerably shorter. This was not surprising because similar findings were reported in a conventional radiographic study of brachycephalic dog breeds (19). However, it was surprising to find that there were distinct differences among brachycephalic breeds, but almost no differences within a given breed (▶Table 4, 5).

The proportional measurements allowed an estimate of the relationship between the lengths of the nose and skull and thus, potential characterisation of the degree of brachycephaly. However, the osteometric data alone did not allow a definitive conclusion as to the severity of respiratory problems because only dogs with BAS were included in this study. However, the data did provide convincing evidence that respiratory problems are a direct result of shortening of the facial skull, which affects the nasal cavity to a greater degree than the hard palate. From a developmental standpoint, further shortening of the hard palate appears problematic because of space requirements for the teeth. Shortening of the facial skull may also affect the function of the eustachian tube and subsequently the middle ear. In the majority of brachycephalic dogs examined, the tympanic bullae contained fluid or solid material, which could have been caused by impaired ventilatory function of the auditory tubes (6).

The results of the present study support the hypothesis that rostral and caudal aberrant nasal turbinates (RAT, CAT) cause intranasal stenosis and are a major contributing factor in BAS (24, 26).

Clinical relevance

It is well known that surgical correction of stenotic nares and elongation of the soft palate are often required in brachycephalic dogs with BAS. However, the findings of the present study strongly suggest that airway stenoses within the nasal cavity must also be addressed in the treatment of BAS. Laser-assisted turbinectomy (LATE) was developed to remove the parts of the nasal conchae that cause stenosis as determined by CT. The result is an improved and patent respiratory passage (27).

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Conflict of interest

The authors confirm that they do not have any conflict of interest.

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