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CASE STUDY

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MORPHOMETRIC DESCRIPTION OF THE LARYNX IN THE DOG (*CANIS FAMILIARIS*)

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ABSTRACT

The anatomy of the canine larynx has been described in numerous text books. However there is still a lack of information regarding the most individually variable linear parameters of this organ. Due to a limited number of publications devoted to the morphological structure of the canine larynx in the context of individual variation among dogs, the authors decided to explore this subject. The study material comprised 13 canine larynges obtained from adult male and female dogs. Following dissection, linear measurements and weight were performed. It was demonstrated that the weight and size of the larynx are correlated with the dog's body weight. The percentage share of the larynx weight in the dog's body weight ranged between 0.101 and 0.203 %. It was found that parameters presenting the highest variability were: the maximum height of the thyroid cartilage and the maximum width of the epiglottis, whereas the lowest variability was observed with regard to the maximum width of the laryngeal inlet.

Key words: morphology, canine, linear parameters, laryngeal cartilages

INTRODUCTION

The long history of selective breeding of the dog (*Canis familiaris*), which mainly aims to maintain the desired hereditary traits, has resulted in a great number of significantly diversified dog breeds. These differences pertain to morphological characteristics, personality traits, and some of the physiological parameters. The morphological differences within this species are most profoundly visible in the head region. Thus, dogs can be classified into three main morphological skull types: short-headed (brachycephalic), medium-headed (mesaticephalic) and long-headed (dolichocephalic). Even though the anatomy of the larynx in the domestic dog has been well documented in numerous anatomy text books, there is still a lack of information regarding specific differences in its structure and proportions of its particular elements, determined by individual or morphotypic variation. Due to a limited number of publications devoted to this subject, the authors of the present paper decided to explore this issue. Laryngeal conditions, e.g. BAS (Brachycephalic Airway Syndrome), LTS (Laryngo-Tracheal Stenosis), and oedema glottidis due to variable causes, constitute a common and serious problem among the numerous dog diseases [Avelino et al. 2005, Pink et al. 2006, Koch et al. 2013, Meola 2013, Mullins et al. 2014, Skerrett et al. 2015, Dupré and Heidenreich 2016, Tokunaga et al. 2020]. Studies on the pathology and dysfunction of this organ revealed that laryngeal disorders were exceptionally often observed in dogs representing given morphological types. For instance brachycephalic dogs often developed the brachycephalic airway syndrome (BAS), which was associated with degenerative changes in the arytenoid cartilage [White 2011, Tokunaga et al. 2020]. Dogs affected by this pathology displayed degenerative features and changed stiffness in this cartilage, which led to the weakening or fracture of the arytenoid cartilage in some individuals [Flanders and Thompson 2009]. The dogs represented such breeds as Boxer, Pekingese, French Bulldog, and English Bulldog. It was also shown that BAS may lead to tracheal collapse and another disease called laryngo-tracheal stenosis (LTS) [Eliashar

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et al. 2000]. Furthermore, these authors demonstrated yet another pathology in brachycephalic dogs, namely epiglottal retroversion, whose most common symptoms were stridor and dyspnea. Concomitant or past upper respiratory tract diseases were reported in 79.1% of brachycephalic dogs [Tokunaga et al. 2020]. A study conducted among 23 Norwich terriers showed that the dogs had excessively widened nostrils, an elongated soft palate, enlarged tonsils, everted laryngeal pouches, and a collapsing laryngeal entrance. Moreover, most of the dogs exhibited pathological breathing sounds from the upper airways and coughing [Koch et al. 2013]. Dogs representing brachycephalic breeds were reported to have a chronically increased airway resistance, also in the larynx, and increased pressure in the larynx, which resulted in the softening of laryngeal cartilages, deflection of their laminae, and laryngeal collapse [Lindsay et al. 2020]. According to Torrez and Hunt [2006], laryngeal collapse in brachycephalic dogs was present in 53% of the individuals studied. The few studies on the anatomy of the arytenoid cartilage in dogs demonstrated that the morphological traits of this cartilage significantly differ among various breeds. This pertained mainly to the structure of the arytenoid cartilage in brachycephalic and non-brachycephalic dogs [Tokunaga et al. 2020].

At the beginning, it is worth mentioning that the larynx is a component of the airways, situated in the rostral neck, between the pharynx and the trachea. The organ is positioned between the upper and lower airways. Its portion located rostrally from the vocal folds is considered to be a part of the upper airways. It is a partially-mobile cartilaginous-membranous tube lined with laryngeal mucosa [Dyce et al. 2011]. The laryngeal cartilages (*cartilagines laryngi*) are: thyroid cartilage, cricoid cartilage, arytenoid cartilages, and epiglottic cartilage [Charuta et al. 2009].

The thyroid cartilage (*cartilago thyroidea*) is the largest among the laryngeal cartilages. Rostrally it is connected with the epiglottal cartilage, and caudally with the cricoid cartilage. The thyroid cartilage is composed of thyroid laminae (*laminae thyroideae*) pointing laterally and dorsally. The oblique line (*linea obliqua*) on the external surface of the lamina is a point of attachment for muscles. On the dorsal side of the thyroid cartilage there are the rostral horns (*cornua rostralia*), while the caudal horns (*cornua caudalia*) are situated ventrally. The rostral horns articulate with the laryngeal horns of the hyoid bone, and the caudal horns articulate with the cricoid cartilage. Situated in the dorsal aspect of the rostral horns is the thyroid fissure (*fissura thyroidea*) covered with ligaments, except for an opening called the thyroid foramen (*foramen thyroideum*). Sensory fibres of the cranial laryngeal nerve pass through that fissure. Where the symmetrical thyroid laminae fuse, on the caudal border, there is the caudal thyroid notch (*incisura thyroidea caudalis*). Dorsally, the cricoid cartilage (*cartilago cricoidea*) consists of a lamina (*lamina cartilaginis cricoideae*), with a median crest on its dorsal surface (*crista mediana*). On both sides of the rostral border of the lamina there are arytenoid articular surfaces (*facies articulares arytenoideae*) for articulation with the arytenoid cartilages. Below the articular surfaces there are symmetrical thyroid articular surfaces (*facies articulares thyroideae*) for articulation with the thyroid cartilage. The cricoid lamina extends laterally and ventrally, forming the arch of the cricoid cartilage (*arcus cartilaginis cricoideae*), which narrows ventrally. The two arytenoid cartilages (cartilagines arytaenoideaei) are highly mobile, which is important for breathing and vocalisation. The proper position of the cartilages is determined by the muscles. The structure of the arytenoid cartilages resembles a three-sided pyramid, whose base is situated on the side of the cricoid cartilage. At the back of the base, dorsally, there is a medial articular surface for articulation with the cricoid cartilage, and a vocal process (*processus vocalis*) ventrically. The apex of the arytenoid cartilage pyramid is directed rostrodorsally and bears a horn-shaped process consisting of elastic cartilage. In the dog, there is additionally the interarytenoid cartilage (*cartilago interarytenoidea*) between the arytenoid cartilages [Done et al. 2005, Dyce et al. 2011]. The epiglottic cartilage (*cartilago epiglottica*), also called the epiglottis, consists of elastic cartilage and is covered with a mucous membrane. It keeps the larynx open during breathing and closes it during swallowing. The base of the epiglottis (*basis epiglottidis*) connects to the thyroid cartilage and narrows into the epiglottic stalk (*petiolus epiglottidis*). The epiglottis has an anterior, lingual surface (*facies lingualis*) and a posterior, laryngeal surface (*facies laryngea*). Opposite the base, dorsally, the epiglottic cartilage forms the apex of the epiglottis (*apex epiglottidis*). A fragment of the arytenoid cartilage forms the cuneiform process facing anteriorly [Evans and Lahunta 2013].

The aim of the present study was to describe the morphology and morphometry of the larynx in the domestic dog (*Canis familiaris*), with particular focus on the linear and weight proportions of the organ, and to identify any differences indicating individual variability. The existing research papers concern mainly the descriptive anatomy, histology and topography of the canine larynx, without addressing the subject of its proportions. Thus, to bridge this gap in knowledge, the authors decided to explore this aspect in more detail.

MATERIAL AND METHODS

The study material comprised 13 larynges collected from adult dogs, with 9 larynges from females and 4 from males. The dogs, whose larynges were dissected, had been obtained from veterinary clinics in Warsaw upon the consent of their owners. As the animals were euthanized with their owners' consent or died, it was not necessary to obtain an approval from the Ethics Committee because in accordance with the Polish law (Act of 21 August, 1997 on the protection of animals, Journal of Laws 1997 no. 111, item 724), the use of tissues collected post-mortem does not require an approval from the Ethics Committee.

The dogs were weighed post-mortem and their weight was recorded. Next, initial dissection was performed to obtain the study material, i.e. the larynx. The larynges were then examined in the laboratory of the Department of Morphological Science at the Institute of Veterinary Medicine, Warsaw University of Life Sciences, in Warsaw. Initially, the larynges were fixed in a 10% formalin solution for 6 weeks. Then, a thorough dissection was performed using a standard set of microsurgical instruments. This was followed by linear, angular, and surface measurements. The larynges were also weighed using an analytic scales with an accuracy of 0.01 g. Based on the results obtained, relative weight of the organ was calculated with an accuracy of 0.0001%, using the following formula:

$$\text{organ relative weight, \%} = \frac{\text{organ absolute weight}}{\text{body weight}} \times 100$$

The dissection revealed a detailed structure of the larynx (Fig. 1–5). Linear measurements of the larynx were performed using a calliper with an accuracy of 0.01 mm. The following measurements were carried out:

a – width between the cuneiform processes of the arytenoid cartilage,

b – distance between the cuneiform process of the arytenoid cartilage and the apex of the epiglottis,

c – distance between the cuneiform process of the arytenoid cartilage and the base of the epiglottis,

d – maximum width of the epiglottis,

Fig. 1. Cross-section of the larynx along the median plane, measuring instrument (cm) visible at the bottom. Description: 1, 3 – cricoid cartilage *cartilago cricoidea*, 2 – vocal fold *plica vocalis*, 4 – thyroid cartilage *cartilago thyroidea*, 5 – arytenoid cartilage *cartilago arytenoidea*, 6 – epiglottic cartilage *cartilago epiglottica*, 7 – vestibular fold *plica vestibularis*, 8 – laryngeal ventricle *ventriculus laryngis*, 9 – infraglottic cavity *cavum infraglotticum* (phot. M. Dzierzęcka)

e – maximum length of the epiglottis,

f – length of the cricoid cartilage at midline,

g – maximum height of the thyroid cartilage,

h – maximum width of the thyroid cartilage,

i – maximum width of the laryngeal inlet,

j – maximum width of the inner contour (lumen) of the cricoid cartilage.

Based on the values obtained, the following statistical calculations were performed: median, arithmetic mean and standard deviation. The Pearson correlation coefficient was also calculated.

RESULTS AND DISCUSSION

Table 1 presents the measurements of the dogs' body weight, weight of the dissected larynx and its percentage share in the dog's body weight, including information of the sex of the dogs studied.

Fig. 2. Measurement of the width between the cuneiform processes of the arytenoid cartilage (phot. M. Dzierzęcka)

The percentage share of the larynx weight in the body weight was similar among the individuals examined and ranged between 0.101 and 0.203 %. The smallest share of the larynx weight in the body weight was observed in dog no. 4, 0.101%, and the largest in dog no. 5, 0.203% (Fig. 2). The lowest larynx weight was recorded in dog no. 2, 4.32, and the highest in dog no. 11, 22.56 (Table 1).

Fig. 3. Measurement of the maximum width of the epiglottis (phot. M. Dzierzęcka)

The lowest value of the width between the cuneiform processes of the arytenoid cartilage (a) was about 4 times smaller relative to the highest value. The distance between the cuneiform process of the arytenoid cartilage and the apex of the epiglottis (b) presented the smallest variation among the dogs studied. The lowest value of the distance between the cuneiform process of the arytenoid cartilage and the base of the epiglottis (c) was about 2 times smaller relative to the highest value. The lowest value of the maximum width of the epiglottis (d) was over 2 times smaller relative to the highest value. The lowest value of the maximum length of the epiglottis (e) was about 2 times smaller relative to the highest value (Table 2).

The lowest value of the length of the cricoid lamina at midline (f) was about 2 times smaller relative to the highest value. The lowest value of the maximum height of the thyroid cartilage (g) was over 2 times smaller relative to the highest value. The lowest value of the maximum width of the thyroid cartilage (h) was over 2 times smaller relative to the highest value. The lowest value of

Table 1. Measurements of the dogs' body weight, weight of the dissected larynx and its percentage share in the dog's body weight, and sex

No.	Sex	Body weight, kg	Larynx weight, g	Share of the larynx weight in the body weight, %
1	female	6.60	11.99	0.181
2	male	3.95	4.32	0.109
3	female	8.25	6.88	0.083
4	male	5.80	5.86	0.101
5	female	5.35	10.87	0.203
6	female	13.35	18.10	0.136
7	female	9.45	12.24	0.129
8	male	9.00	13.87	0.154
9	male	10.75	11.66	0.108
10	female	9.30	13.13	0.141
11	female	16.80	22.56	0.134
12	female	7.00	12.52	0.179
13	female	21.60	22.42	0.104

Table 2. Morphometric measurements of the larynx in the dog population studied, mm*

Dog no.	a	c	b	d	e
1	3.65	14.99	13.62	18.00	23.12
2	9.39	14.76	13.50	13.68	17.35
3	9.58	11.94	10.65	19.56	19.71
4	4.46	15.71	12.96	16.08	19.25
5	13.15	15.63	18.43	22.98	20.91
6	13.88	15.41	20.33	25.71	22.99
7	11.89	18.38	19.42	16.50	21.49
8	10.97	20.47	20.81	19.79	30.42
9	5.63	15.82	15.82	17.89	25.11
10	5.22	7.78	15.40	21.84	19.65
11	9.34	19.77	22.09	31.18	26.32
12	11.55	18.55	14.33	22.99	23.64
13	7.03	18.52	19.57	32.76	25.44

*Letters a–e – see Material and Methods

Table 3. Morphometric measurements of the larynx in the dog population studied, mm*

Dog no.	f	g	h	i	j
1	17.42	35.43	24.55	11.33	18.70
2	14.60	20.41	16.44	9.43	15.20
3	13.74	21.90	18.64	10.00	14.80
4	15.52	23.61	17.80	9.87	16.20
5	20.16	30.57	27.14	14.12	21.09
6	20.93	33.14	29.98	14.33	21.13
7	20.98	33.93	28.98	14.37	21.24
8	21.48	36.34	25.76	13.48	19.56
9	17.01	27.55	24.36	11.72	18.33
10	15.48	24.31	23.98	12.64	16.11
11	22.34	44.22	32.36	16.18	27.40
12	16.99	30.3	24.05	10.42	19.12
13	21.63	34.65	33.34	15.06	23.64

*Letters f–j – see Material and Methods

Table 4. Mean, median and standard deviation (SD) of the parameters studied

Parameter	Mean	Median	SD
Body weight, kg	9.78	9.00	4.94
Larynx weight, g	12.80	12.24	5.62
Share of the larynx weight in the body weight, %	0.14	0.134	0.04
a, mm	8.90	9.39	3.40
b, mm	15.98	15.71	3.41
c, mm	16.69	15.82	3.61
d, mm	21.46	19.79	5.70
e, mm	22.72	22.99	3.54
f, mm	18.33	17.42	3.02
g, mm	30.49	30.57	6.79
h, mm	25.18	24.55	5.30
i, mm	12.53	12.64	2.23
j, mm	19.42	19.12	3.57

the maximum width of the laryngeal inlet (i) was about 2 times smaller relative to the highest value. The lowest value of the maximum width of the inner contour (lumen) of the cricoid cartilage (j) was about 2 times smaller relative to the highest value (Table 3). Table 4 presents the mean, median and standard deviation values of all the morphological parameters of the larynx in the dog population studied.

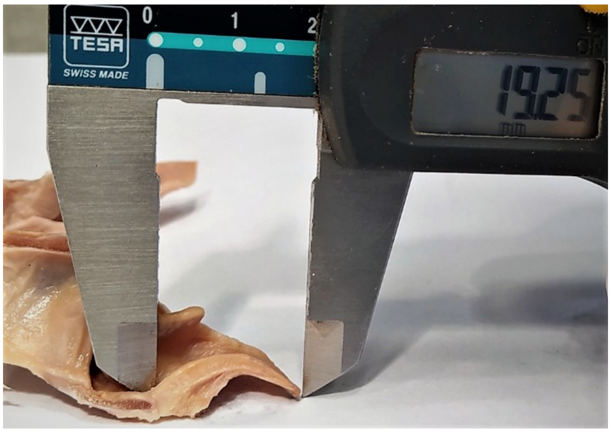

Fig. 4. Measurement of the maximum length of the epiglottis (phot. M. Dzierzęcka)

High SD values of a given morphological parameter indicate that the values of the variable are very spread out from the mean, which denotes high variation of this variable. In contrast, low SD values point to a narrow dispersion of the parameter values, indicating small variation of the variable in the dog population studied.

Based on the Pearson correlation coefficient values obtained, it was observed that the most constant larynx parameters are those which fall in the range of 0.7–1, whereas the most variable parameters are those in the range of 0.3–0.3. Thus, the analyses conducted allowed for determining the relative linear and weight proportions of the larynx in the dog population studied. There was a low correlation between the dog's body weight and the width between the cuneiform processes of the arytenoid cartilage, and a low correlation between the dog's body weight and the distance between the cuneiform process of the arytenoid cartilage and the apex of the epiglottis. At the same time, a high correlation was observed between the body weight and the larynx weight, and between the body weight and the following parameters: distance between the cuneiform process of the arytenoid cartilage and the base of the epiglottis; maximum width of the epiglottis; maximum length of the epiglottis; length of the cricoid lamina at midline; maximum height of the thyroid cartilage; maximum width of the thyroid cartilage; maximum width of the laryngeal inlet; and maximum width of the inner contour (lumen) of the cricoid cartilage. A high positive correlation indicates that a body weight increase is accompanied by an increase in all the larynx parameters referred to in the key as c-j.

On the other hand, the width between the cuneiform processes of the arytenoid cartilage presented a low correlation with all the other parameters. Furthermore, it was found that the distance between the cuneiform process of the arytenoid cartilage and the apex of the epiglottis showed a low correlation with the maximum width of the thyroid cartilage and the maximum width of the laryngeal inlet. In contrast, the distance between the cuneiform process of the arytenoid cartilage and the apex of the epiglottis was highly correlated with the distance between the cuneiform process of the arytenoid cartilage and the base of the epiglottis, maximum length of the epiglottis, maximum height of the thyroid cartilage, length of the cricoid lamina at midline, and maximum height of the thyroid cartilage. The distance between the cuneiform process of the arytenoid cartilage and the base of the epiglottis was highly correlated with the maximum width of the epiglottis, maximum length of the epiglottis, maximum height of the thyroid cartilage, length of the cricoid lamina at midline, maximum width of the thyroid cartilage, maximum width of the laryngeal inlet, and maximum width of the inner contour (lumen) of the cricoid cartilage. There was a low correlation between the maximum width and the maximum length of the epiglottis, and a high correlation between the maximum width of the epiglottis and the maximum height of the thyroid cartilage, length of the cricoid lamina at midline, maximum width of the thyroid cartilage, maximum width of the laryngeal inlet, and maximum width of the inner contour (lumen) of the cricoid cartilage.

Fig. 5. Measurement of the length of the cricoid lamina at midline (phot. M. Dzierzęcka)

In the dog population studied, a high correlation was also observed between the maximum length of the epiglottis and the following parameters: maximum height of the thyroid cartilage, length of the cricoid lamina at midline, maximum width of the thyroid cartilage, maximum width of the laryngeal inlet, and maximum width of the inner contour (lumen) of the cricoid cartilage. At the same time, the length of the cricoid lamina at midline was highly correlated with the maximum height of the thyroid cartilage, maximum width of the thyroid cartilage, maximum width of the laryngeal inlet, and maximum width of the inner contour (lumen) of the cricoid cartilage.

A high correlation was found between the maximum height of the thyroid cartilage and the maximum width of the thyroid cartilage, maximum width of the laryngeal inlet, and maximum width of the inner contour (lumen) of the cricoid cartilage. The maximum width of the laryngeal inlet and maximum width of the inner contour (lumen) of the cricoid cartilage were also highly correlated.

CONCLUSIONS

The results obtained yielded the following conclusions: the anatomical structure of the canine larynx is significantly associated with the body weight of a given individual. Both the larynx weight and the linear parameters of this organ are significantly associated with the body weight of a given individual. The highest individual variability in this species was observed with regard to the maximum height of the thyroid cartilage and the maximum width of the epiglottis, and the lowest with regard to the maximum width of the laryngeal inlet.

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MORFOMETRYCZNY OPIS KRTANI PSA (*CANIS FAMILIARIS*)

STRESZCZENIE

Anatomia krtani psa domowego została opisana w podręcznikach, wciąż jednak brakuje informacji na temat najbardziej zmiennych osobniczo parametrów liniowych tego narządu. Z uwagi ograniczoną liczbę prac dotyczących budowy morfologicznej krtani psa, w odniesieniu do zmienności osobniczej, ze względów poznawczych zdecydowano się je szerzej zbadać. Materiał do pracy stanowiło 13 psich krtani, pochodzących od osobników dorosłych obu płci. Po wypreparowaniu, wykonano pomiary liniowe oraz zmierzono masę krtani. Wykazano, że masa krtani oraz jej wielkość są silnie skorelowane z masą ciała psa. Udział procentowy masy krtani w stosunku do masy ciała znajdował się w zakresie 0,101–0,203 %. Wykazano że największą zmiennością charakteryzował się parametr oznaczony jako maksymalna wysokość chrząstki tarczowatej oraz maksymalna szerokość nagłośni, a najmniejsza zmienność dotyczyła maksymalnej szerokości wejścia do kieszonki krtani.

Słowa kluczowe: morfologia, pies, parametry liniowe, chrząstki krtani

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