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CT measurements of tracheal diameter and length in normocephalic cats

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Abstract

Objectives The aim of this study was to measure the tracheal dimensions of normocephalic cats using CT.

Methods CT images of 15 client-owned normocephalic cats were retrospectively evaluated to measure the length of the feline trachea. Transverse and vertical inner diameters were measured in five different tracheal regions, and the cross-sectional area of the tracheal lumen was calculated for each point of measurement. Descriptive statistics were applied using a two-tailed *t*-test.

Results The mean ± SD length of the trachea was 125.13 ± 14.41 mm. Male cats had significantly larger tracheas than female cats. The transverse diameter first increased by 0.94 mm between the most cranial point of measurement and the middle of the trachea. It then decreased by 1.38 mm between the middle of the trachea and the most caudal point of measurement. The vertical diameter decreased by 1.16 mm between the first point of measurement and the penultimate point, and then increased by 0.06 mm between the penultimate point of measurement and the end of the trachea. The two different diameters resulted in an elliptical trachea shape.

Conclusions and relevance The feline trachea was circular only at its cranial and caudal ends, and elliptical with a dorsoventral flattening along the rest of its length. Vertical and transverse diameters varied along the entire length. Tracheal shape differences should be considered when performing permanent tracheostomy, tracheal anastomosis or stenting in cats.

Keywords: Tracheal anatomy; trachea; tracheal length; CT; respiratory tract surgery

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Introduction

Tracheal surgeries such as tracheostomy, tracheal anastomosis and stenting are rarely performed, challenging procedures in cats. The main reasons for surgical intervention in the feline trachea are tracheal or laryngeal obstruction, stenosis and tracheal collapse.[1–3] Some of these surgeries, particularly in the case of tracheostomy, are associated with a high rate of complications.[4–11]

Tracheal surgery techniques have been developed primarily for dogs. These techniques were then translated and adapted to cats under the assumption that the tracheal anatomy is comparable between the two species.[1–3,12–15] The detailed tracheal measurements available for dogs are unparalleled in the feline species.[16–19] If these measurements are applied to all feline patients, some operative or postoperative complications may occur due to the lack of information about the feline anatomy.[1,12,13]

Moreover, the interpretation of tracheal hypoplasia, which is defined as an underdeveloped trachea, is possible only with precise anatomical knowledge.

Reported tracheal measurements in cats are limited to diameter measurements at the thoracic inlet and at the level of the third rib, taken from lateral radiographs.[20] According to a recent review paper, a particular permanent tracheostomy technique used in children (Björk

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flap) might find a possible application in cats.[21] As some anatomical similarities between the tracheas of children and cats were found, especially in size, this alternative surgical technique could represent an interesting option potentially associated with a better prognosis.[21] However, before applying such a technique to a feline patient, detailed and specific anatomical knowledge of the feline trachea is paramount. In particular, in order to identify the best area for a permanent tracheostomy, precise assessment of the average size of the trachea at different levels is necessary.

The aim of this study was therefore to investigate the height and width variations, and the exact length, of the feline trachea using CT.

Materials and methods

CT images of 15 client-owned cats were used to measure the length, transverse diameter and vertical diameter of the trachea (Figures 1 and 2). Only cats with a normocephalic conformation, a full medical record and standardised neck and thoracic CT scans without an inflated cuff crossing the planned measurement points were included in the study. Exclusion criteria were any history or clinical signs of airway disease and a body weight <3kg. CT images were retrospectively taken from already existing in-house data of a 16-slice CT unit at the Small Animal Hospital of the Vetsuisse Faculty, University of Bern. For optimal results and the avoidance of artefacts, all CT scans were taken under general anaesthesia in dorsal recumbency and in apnoea (inspiration phase). American Society of Anesthesiologists (ASA) class I patients were anaesthetised using butorphanol (0.2–0.3mg/kg IV) + medetomidine (0.01–0.08mg/kg IV) + propofol IV to effect. ASA class II–III patients received methadone (0.2mg/kg IV) + ketamine (1–2mg/kg IV) + midazolam (0.1–0.2 mg/kg IV) + propofol IV to effect. Mechanical hyperventilation was applied before scanning to suppress respiratory drive, and a mild positive pressure of 10 cmH_2O was maintained throughout image acquisition. Scanning direction was cranial to caudal. Scanning parameters were 120kV, 150mAs, a collimator pitch of 0.938 and a rotation time of 1s.

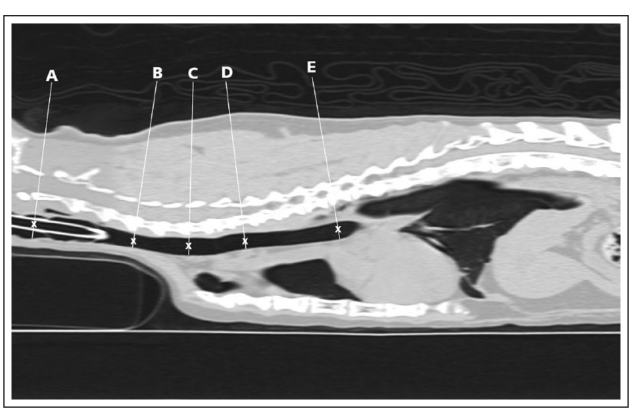

Figure 1 Lateral feline thoracic CT image showing the five different points of measurement along the trachea. A = 1cm caudal to the cricoid cartilage; B = at the level of the C4–C5 intervertebral disc space; C = at the cranial end of the manubrium sterni; D = at the level of the second rib; E = 1cm cranial to the carina

Figure 2 Measurements of the transverse (solid line) and vertical (dotted line) internal diameters

Image reconstructions were made with a 1.5mm slice thickness and an overlap of one-third using soft tissue and bone algorithms. The images were exported to a workstation for review in pulmonary (–600 level/1600 width) and soft tissue (160 level/600 width) windows.

Tracheal length (L) was measured from the caudal aspect of the thyroid cartilage to the cranial aspect of the carina. Transverse (T) and vertical (V) inner diameter measurements (internal diameter without the wall) were taken at five different points along the trachea: site A, 1cm caudal to the cricoid cartilage; site B, at the level of the C4–C5 intervertebral disc space; site C, at the cranial end of the manubrium sterni; site D, at the level of the second rib; site E, 1cm cranial to the carina.

The ratio of the transverse and vertical diameters (T:V) and the cross-sectional area (CSA; equation for ellipse = $(r_1 \times r_2) \times \pi$) of the tracheal lumen were calculated for each point of measurement (CSA = $((T/2) \times (V/2)) \times 3.14$). The results are provided in Table 1.

Statistical analysis

The power of this study was calculated using a post-hoc power calculation, based on the existing data on dogs.[16] Assuming a two-tailed type I error of 5% and a power of 100%, a sample size of 15 was required.

Descriptive statistics were performed using MedCalc. To assess the differences between the two groups in their mean ± SD transverse and vertical diameters, a two-tailed *t*-test was applied.

Table 1 Measurements of the transverse and vertical diameters of the trachea in 15 cats

	Transverse diameter (mm)	Vertical diameter (mm)	*P* value	T:V ratio	CSA (mm²)
A	8.53 ± 1.54	8.58 ± 1.70	0.93	0.99	57.45
B	9.47 ± 1.38	8.35 ± 1.80	0.067	1.13	62.07
C	9.47 ± 1.67	8.32 ± 1.79	0.082	1.14	61.85
D	8.69 ± 1.36	7.42 ± 1.27	0.013	1.17	50.61
E	8.09 ± 1.07	7.48 ± 0.95	0.112	1.08	47.50

Data are presented as mean ± SD unless otherwise stated
T:V = transverse to vertical ratio; CSA = cross-sectional area; A = 1 cm caudal to the cricoid cartilage; B = at the level of the C4–C5 intervertebral disc space; C = at the cranial end of the manubrium sterni; D = at the level of the second rib; E = 1 cm cranial to the carina

Results

Eight male and five female domestic shorthair cats, one female Bengal and one female Norwegian Forest Cat met the inclusion criteria. Indications for CT were suspected mediastinal lymphoma, which was unconfirmed (n = 1), skull fracture (n = 1), mandible fracture (n = 1), abscess in the spinal cord (n = 1), foreign body (grass) in the nasopharynx (n = 1) and staging of neoplastic diseases (n = 10). Staging was indicated for soft tissue sarcoma of the scapular region (n = 1), Hodgkin lymphoma of the deep cervical lymph nodes (n = 1), fibrosarcoma of the shoulder region (n = 2), parotid gland lymphoma (n = 1), mandibular squamous cell carcinoma (n = 2), intestinal adenocarcinoma (n = 2) and preputial epidermoid carcinoma (n = 1). Mean ± SD age was 8.9 ± 5.29 years and weight was 4.9 ± 1.8 kg. Mean weight differed between male (5.16 ± 1.67 kg) and female (4.56 ± 2.04 kg) cats. Tracheal length ranged from 106.3 mm to 147.6 mm (mean 125.19 ± 14.41 mm). Female cats had a slightly shorter trachea (116.9 ± 9.07 mm) than males (132.4 ± 14.73 mm).

CSA increased by 8.5% between site A (mean 57.45 mm²) and site B (mean 62.07 mm²), where the mean value was highest overall. From this point, it decreased by 0.3% (B to C) to 61.85 mm² at site C and then decreased significantly by 18.5% (B to D) to 50.61 mm² at site D and by 23.5% (B to E) to 47.50 mm² at site E (Table 1).

The CSA differed between male and female cats. Male cats had a significantly bigger CSA at each point of measurement (site A: 68.55 mm²; site B: 72.95 mm²; site C: 75.47 mm²; site D: 60.45 mm²; site E: 54.55 mm²) than female cats (site A: 46.11 mm²; site B: 50.72 mm²; site C: 47.91 mm²; site D: 40.46 mm²; site E: 40.01 mm²).

The mean transverse diameter of the trachea was smallest at site A (mean 8.53 ± 1.54 mm). In all cats, the largest transverse diameter was observed at site Bs (mean 9.47 ± 1.38 mm) and C (mean 9.47 ± 1.67 mm) followed by a gradual decrease in transverse diameter to site D (mean 8.69 ± 1.36 mm) and site E (mean 8.08 ± 1.07 mm). Mean ± SD vertical diameters ranged from 8.58 ± 1.71 mm at the widest point (site A) to 7.42 ± 1.27 mm at the narrowest point (site D), giving rise to an overall elliptical tracheal shape between sites B and D (Figure 3). At site E, the trachea was circular with a smaller transverse and vertical diameter than at site A.

The transverse diameter differed significantly from the vertical diameter at site D ($P = 0.013$). No significant difference between the two diameters was found at site A ($P = 0.93$), B ($P = 0.067$), C ($P = 0.086$) or E ($P = 0.112$).

The results showed that at sites A and E, the trachea was almost circular, while it was elliptical in shape between sites B and D, with the biggest difference between transverse and vertical diameters observed at site D (Figure 3).

Discussion

Our CT measurements showed that the feline trachea was partly elliptical. It showed a dorsoventral flattening along its middle part and was circular at its cranial and caudal poles. The dorsoventral flattening was most prominent at the location where tracheal surgeries such as tracheostomies are typically performed. This differs from the canine trachea, which is almost circular along its entire length.[16,18,19] Moreover, while the narrowest portion of the canine trachea is at level of the thoracic inlet,

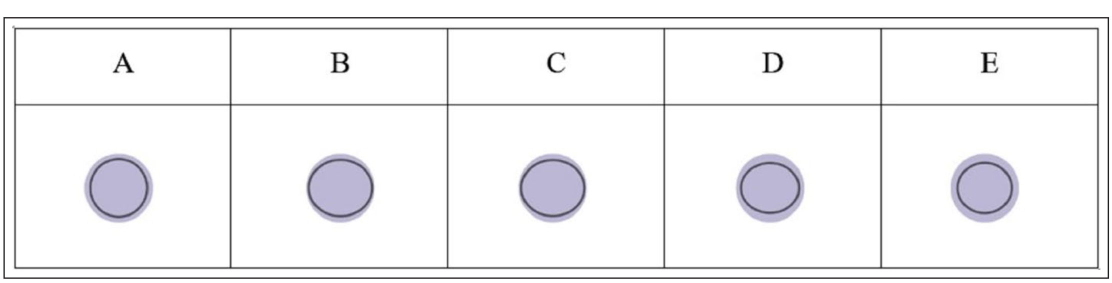

Figure 3 Tracheal shape according to the mean transverse and vertical diameters. The black circle shows the shape of the trachea and the grey background shows a perfect circle for comparison. A = 1 cm caudal to the cricoid cartilage; B = at the level of the C4–C5 intervertebral disc space; C = at the cranial end of the manubrium sterni; D = at the level of the second rib; E = 1 cm cranial to the carina

our data showed that the cross-sectional area of the feline trachea was smallest at 1 cm cranial to the carina (site E). A significant narrowing of the trachea (by 23.2%) was seen between sites C and E, with the CSA decreasing by 18.2% between sites C and D and by 5.0% between sites D and E. Based on our findings, these data can be useful in the interpretation of the grade of tracheal hypoplasia or pathological narrowing and flattening of the feline trachea in cases of tracheal disease.

The average length and CSA of the trachea differed between male and female cats. The trachea was significantly longer and bigger in male cats than in female cats, presumably because male cats tend to be larger and heavier than female cats. Interestingly, the CSA and tracheal length were not correlated to weight in either group.

Techniques for tracheal surgeries such as permanent tracheostomy, tracheal end-to-end anastomosis and stenting are well described in dogs. As specific recommendations are scarcely available for cats, surgeons typically follow the same protocol as recommended in dogs. Given the lack of availability of tracheal measurements in cats, it is unsurprising that these surgical techniques are not tailored to the feline tracheal anatomy. As a result, complications, especially in the case of tracheostomies, are common in cats undergoing tracheal surgeries.

The results from our study could pave the way to improvement of feline tracheal surgeries and subsequent reduction of complications.

This study has some limitations. Although CTs of cats with a cuff near sites A or B were excluded from the study, it is possible that the presence of an endotracheal tube slightly affected the measurements overall. Therefore, further studies evaluating the tracheal diameter with and without an endotracheal tube should be performed. Moreover, the impact of different methods of oxygen delivery on tracheal diameter was not evaluated in this study and warrants further investigation.

In addition, the scarcity of complete, standardised neck and thoracic CT scans without malformations of the trachea gave rise to an admittedly small number of cases. Finally, brachycephalic cats were excluded from this study; data from only normocephalic and average sized cats were collected.

Conclusions

Given the different shape of the trachea of cats compared with dogs, we believe that recommendations for tracheal surgeries in this species should be reconsidered. The development of surgical techniques tailored to the feline anatomy may give rise to improved outcomes. Further clinical studies are necessary to investigate additional factors responsible for complications associated with tracheal surgery.

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Ethical approval The work described in this manuscript involved the use of non-experimental (owned or unowned) animals. Established internationally recognised high standards ('best practice') of veterinary clinical care for the individual patient were always followed and/or this work involved the use of cadavers. Ethical approval from a committee was therefore not specifically required for publication in *JFMS*. Although not required, where ethical approval was still obtained, it is stated in the manuscript.

Informed consent Informed consent (verbal or written) was obtained from the owner or legal custodian of all animal(s) described in this work (experimental or non-experimental animals, including cadavers) for all procedure(s) undertaken (prospective or retrospective studies). No animals or people are identifiable within this publication, and therefore additional informed consent for publication was not required.

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