

## MORPHOMETRIC INVESTIGATION OF NEUROCRANIUM IN DOMESTIC CAT (*Felis catus*)

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### ABSTRACT

This study was intended to investigate some aspects of the morphometric characteristics of the neurocranium in domestic cat (*Felis catus*) of Bangladesh. Twenty adult domestic cat including 10 males and 10 female were euthanized using diazepam (@ 20 mg/kg) and their skulls were macerated to give morphometric parameters. Student t-test with level of significance set at 5% ( $p < 0.05$ ) was used to analyze the obtained values. The mean (mean  $\pm$  SE) neurocranial volume was  $28 \pm 0.97$  ml, neurocranial length was  $6.63 \pm 0.77$  cm, and the neurocranial height and index were  $3.32 \pm 0.38$  cm and 49.83%, respectively. The mean height and width of the foramen magnum were  $1.32 \pm 0.09$  cm and  $1.35 \pm 0.08$  cm, respectively, while the foramen index was below 100 at  $90.72 \pm 4.93$ . Parameters for the foramen magnum index showed significant difference between both sexes at  $p < 0.05$ . The foramen magnum showed shape variations and there were multiple hypoglossal foramina in over 80% of the cats. Foramen magnum index was positively correlated with neurocranial volume. The results were discussed in terms of the usage of morphologic and morphometric characteristics of cranium and skulls in several basic and clinical applications in cat such as estimation of the brain density and the use of the cat for cranial pressure experiments.

**Key words:** domestic cat, cranial pressure, foramen magnum, morphometry

### INTRODUCTION

The morphological and morphometrical studies of the skull are not only reflect contributions of genetic and environmental components to individual development and describe genetic variation and ecophenotypic variation, but also are foundations of the clinical, surgical stereotaxic practices (Wehausen and Ramey, 2000). It enables the surgeon visualize details of structures relevant to the case at hand (Dyce *et al.*, 1996). Neurocranium is an important part of the head that protects the brain (McClure *et al.*, 1973). It consist of os occipitale, os sphenoidale, os pterygoieum, os ethmoidale, os vomer, os temporale, os parietale and os frontale (Getty, 1975). The cranium serves as a means of protection for the encephalon and the organs of the special senses (Getty, 1986). It consists of a mosaic of many bones that are perfectly fitted together to form a single rigid structure. The cranium is divided into two portions, the caudal part (neurocranium) housing the encephalon, while the rostral part sustains the face. In most domestic animals, the face has been observed to be larger than the neural part (Dyce *et al.*, 2000). The interior of the neurocranium presents contours that correspond to the gyri and sulci of the brain; it also corresponds to the space filled by the brain, the meninges and the cerebrospinal fluid in the cranial cavity (Dyce *et al.*, 2000). There are many reported macroanatomical investigations on the skeletal system of mammals, including the dog (Onar *et al.*, 2001; ), rabbit, the guinea pig, the rat (Özkan *et al.*, 1997), the badger (Dlinc, 2001) the porcupine (Yilmaz *et al.*, 1998), the hedgehog (Özkan, 2005), and the mole rat (Özkan, 2007), but the skeletal systems of domestic cats, particularly the neurocranial osteometry, have rarely been investigated in detail, although measurements of selected parameters of the brain of the Persian cat (Monfared, 2013) have been documented. The aim of the present study was to investigate some aspects of the osteometry and morphology of the neurocranium of the domestic cat to make contribution in scarce basic research data on the neurocranium of cat.

### MATERIALS AND METHODS

All animal handling and experimental procedures were carried out in accordance with the Guide for the Care and Use of Laboratory Animals at Chittagong Veterinary and Animal Sciences University. A total of 20 adult native domestic cat (*Felis catus*) of both sexes, equal in number (3–3.5 kg body weight) were collected from local fish markets of Chittagong. The live animals were first selected during ante mortem examination based on parameters of apparent good health and no skeletal deformation. The animals were weighed with a standard bath-room scale and euthanized by injecting diazepam (20 mg/kg) in jugular vein. The heads were severed at the atlanto-occipital junction and processed in the Anatomy Laboratory of Chittagong Veterinary and Animal Sciences University using the hot water maceration techniques as described by Simoens *et al.*, (1994) which briefly were: on the working day, frozen cat head were allowed to thaw.

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Skin and most of the muscles were separated and eyes were enucleated. Heads were heated to over 80°C for at least 1 hour in solution of polycarboxylate and anionic surfactant (detergent) and soap chips. Muscle of boiled heads was separated with the aid of forceps and scalpel in running water. Further separation of muscles and ligaments from the skulls was done after left in detergent water at least 20-30 minutes. Separation of remaining muscles and ligaments from the skull was done after left in 1% sodium hypochlorite solution for at least 24 hours. After that, the skulls were left in the above solution, for 48-72 hours with solution, being changed at least twice and clean in running tap water. The skulls were then left to dry. Different visualize details of structures relevant to the case at craniometrical parameters were recorded with the help of measuring scale, thread and digital Vernier calipers. The following measurements were made as defined by Olude *et al.*(2009), Simoens *et al.*(1994) and Onar *et al.* (1997) (Figure 1-2). Neurocranial volume (NCV): The volume of the neurocranium was measured by first using Plasticine to block all the foramina of the intact skull. The neurocranium was then filled with grains from the foramen magnum. When full, the grains were emptied into a measuring cylinder and the volume determined. Neurocranial length (NCL): From the deepest indentation of the fronto-ethmoidal junction to the middle of the distal surface of the cranium at the level of the cerebral surface of the external occipital protuberance (Figure 1). Neurocranial height (NCH): From the deepest indentation of the sella turcica directly dorsal to the inner layer of the root of the cranium (Figure 1).

Neurocranial index (NCI) = NCH/NCL (%).

Foramen magnum width (FMW): Largest width of the foramen magnum (Figure 2).

Foramen magnum height (FMH): Mid vertical height of the foramen magnum (Figure 2).

Foramen magnum index (FMI) = FMH/FMW × 100

For terminology, Nomina Anatomica Veterinaria (International Committee on Veterinary Gross Anatomical Nomenclature, 1994) was used.

## RESULTS

In the present work, the mean neurocranial volume, length and height were  $28 \pm 0.97$  ml,  $6.63 \pm 0.77$  cm and  $3.32 \pm 0.38$  cm, respectively (Figure1 and Table1). Also, the neurocranial index was 49.83%. The crista galli was slanted caudoventrally to accommodate the large olfactory bulb of the cat. The height and width of the foramen magnum were  $1.23 \pm 0.09$  cm,  $1.35 \pm 0.08$  cm respectively, while the foramen index was below 100 at  $90.72 \pm 4.93$  (Fig.2). The foramen magnum index was significant between both sexes at  $p < 0.05$  and positively correlated with neurocranial volume. The occurrence of multiple hypoglossal foramina was observed in 80% of the cats in this study ( $n = 16$ ). Side to side variation with respect to this feature was observed in this study with two hypoglossal foramina on the right side and a single one on the left in 55% ( $n = 11$ ), while 50% ( $n = 10$ ) were actually divided by a bony specule. The morphometrical observations of neurocranium in cats are given away in Table 1.

Table 1. Morphometric analysis of the neurocranium of the domestic cat skulls.

Parameter	Overall mean	Male	Female
NCV (ml)	$28 \pm 0.97$	$27.5 \pm 1.11$	$28.5 \pm 0.5$
NCL (cm)	$6.63 \pm 0.77$	$6.4 \pm 0.96$	$6.86 \pm 0.54$
NCH (cm)	$3.32 \pm 0.38$	$3.36 \pm 0.49$	$3.48 \pm 0.16$
NCI (%)	49.83%	49.45%	50.23%
FMW (cm)	$1.35 \pm 0.08$	$1.37 \pm 0.09$	$1.33 \pm 0.06$
FMH (cm)	$1.23 \pm 0.09$	$1.19 \pm 0.08$	$1.27 \pm 0.09$
FMI*(%)	$90.72 \pm 4.93$	$86.98 \pm 2.78$	$94.42^* \pm 3.52$

NCV—neurocranial volume; NCL—neurocranial length; NCH—neurocranial height; NCI—neurocranial index; FMW—foramen magnum width; FMH— foramen magnum height; FMI— foramen magnum index; NS- non significant. Values presented as mean ± SE for 20 cats (10 male and 10 female cats); \*the values FMI differed significantly between the two sexes at  $p < 0.001$ .

## DISCUSSION

Comparatively, the values of neurocranial length and cranial width of the domestic cats were almost similar to the results from previous investigation on the cats with round-shaped skulls (Künzel *et al.*, 2003; Monfared, 2013) but were relatively different from the findings on the cats with triangular or cuneiform skulls (Künzel *et al.*, 2003). It may be due to the existence of significant differences in the skull's shape and size between various breeds and individuals (Sisson, 1975).

The mean neurocranial volume in this study was  $28 \pm 0.97$  ml, and the neurocranial index was 49.83%. Since a direct correlation exists between cranial volume and brain volume (Hidaka *et al.*, 1998), the values obtained in this study could give a more accurate estimation of brain volume/density in the domestic cat.

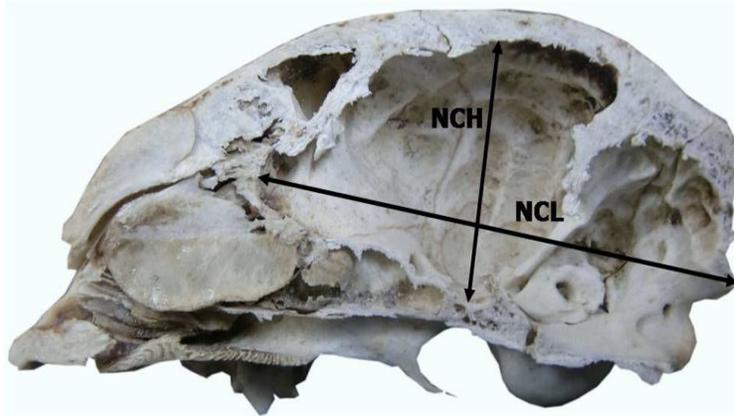


Figure 1. Outline of the mid-neurocranial region of the cat skull showing dimensions for neurocranial height (NCH) and neurocranial length (NCL).

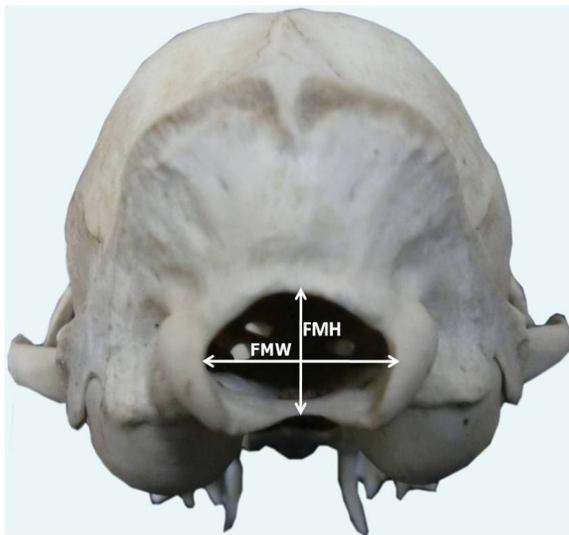


Figure 2. Outlines of the caudal view of the skull showing foramen magnum height (FMH), foramen magnum width (FMW).

Preliminary work has been done on the brain weight of the cat (Eric, 2006) and since the brain weight is known to be 85–90% of the weight of the cranial content (Olopade and Onwuka, 2003), the brain density of the domestic cat can then be assessed from this data. Thus, in addition to being used for landmine detection of tuberculosis (Lindow, 2008) the cat could also be a good experimental candidate for studies of intracranial pressure. The female animals had larger neurocranial dimensions, most likely due to size differences between the sexes.

The mean foramen magnum width and height were 1.35 cm and 1.23 cm, respectively. Comparatively, these values in domestic cats were higher than rabbit (Kahvecioglu *et al.*, 2000), mole rat (Özkan, 2007) and African giant rat (Olude *et al.*, 2009) but lower than dog (Janeczek *et al.*, 2008). The foramen magnum index of the domestic cat was 90.72 which was almost similar to that of the mole rat (88.41; (Özkan, 2007) and perkingese dog (93.4; Janeczek *et al.*, 2011) and higher than the rabbit (74.78; Kahvecioglu *et al.*, 2000) and African giant rat (81.42; Olude *et al.*, 2009), where the foramen magna were relatively wide. However, the foramen magnum index was relatively higher in the West African Dwarf goat (102.5; Olopade and Onwuka, 2005) and American Staffordshire terrier newborns (106.82; Chroszcz *et al.*, 2006).

These above analysis proved that the foramen magnum had a large size variability and was related to animal age and species. The foramen magnum width was significantly greater in the male than in the female in our study, although it is speculative whether this translates to the morphometry of the contained spinal cord and meninges.

Various authors have stated that irregularities in the shape of the foramen magnum constitute a crucial problem in Veterinary Medicine and can cause a variety of clinical symptoms, for example, convulsions, ataxias, prolapse of the brain to the medullary canal, and occipital dysplasia (Jensen and Kreiborg, 1993; Herpen and Voorhout, 1993). However, Janeczek *et al.*, (2008) considered it an ancient characteristic which is compatible with longevity and the absence of major pathology. However, this occurrence needs to be verified to ascertain its effect in the domestic cat.

A study on humans and other mammalian species (Wysocki *et al.*, 2004) revealed double hypoglossal canals in 43% of cases. In the same study, 28.12% of cases had the hypoglossal canal divided in two by a small bony spicule. The doubling of the hypoglossal canal by a bony spicule is not a rare phenomenon (Bhuller *et al.*, 1998). Fifty percent of the cats in this study had the canal divided by a bony spicule. The clinical significance of this has been attached to the variations in the hypoglossal foramen in humans, and knowledge of this anatomical variation could be important for various fields of medicine (Bergman *et al.*, 1988; Nayak, 2008). The slanting crista galli evidently accommodates the extensive olfactory bulb of the brain.

In conclusion, the morphometric values of the neurocranium and clinical anatomy of the head region of the domestic cats provide an important baseline for further research in this field. Furthermore, these results can also be useful tool that will aid the regional surgery around the head especially during treating head injury, brain diseases as well as experimental study for intracranial pressure.

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