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The *Foramen Magnum* in the Chinchilla (*Chinchilla lanigera*) - Computed Tomography and Anatomical Study

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ABSTRACT

***Background*:** The *foramen magnum* (FM) is a crucial anatomical aperture situated in the occipital bone, forming the primary communication between the cranial cavity and the vertebral canal. It transmits critical neurovascular structures, including the medulla spinalis, vertebral arteries, spinal accessory nerves, and associated meninges. Morphological and morphometric analysis of the FM is essential for various disciplines including clinical neurology, veterinary neuroanatomy, forensic anthropology, and surgical planning. In contrast to well-documented FM data in humans and domestic species, available literature on exotic species, particularly *Chinchilla lanigera*, is remarkably limited. The current study aims to fill this knowledge gap by offering detailed CT-based morphometric data on the FM in chinchillas, thereby contributing a novel anatomical reference for this species.

***Materials and Methods & Results*:** The study was conducted on 12 clinically healthy, 18-month-old adult *C. lanigera* specimens (6 males, 6 females), each weighing approximately 0.6 kg. Animals were housed under controlled conditions with a 12:12 h light-dark cycle and received a standard pellet diet and water ad libitum. CT imaging was performed under anesthesia induced by intramuscular administration of Zoletil® 50 (15 mg/kg). Imaging was carried out using a Toshiba Alexion 16-slice CT scanner with standardized parameters. The following parameters were measured from axial, sagittal, and coronal slices: transverse diameter (TD), anteroposterior diameter (AP), foramen magnum area (FMA), and foramen magnum index (FMI). The mean AP in males was 6.15 ± 0.62 mm, TD was 6.35 ± 0.59 mm, and FMA was 0.3176 ± 0.028 cm². In females, AP was 6.12 ± 0.66 mm, TD was 6.37 ± 0.61 mm, and FMA was 0.311 ± 0.0257 cm². FMI values were 103.25 ± 0.93 (males) and 104.08 ± 0.89 (females). No statistically significant sex-based differences were observed ($P > 0.05$).

***Discussion*:** This is the 1st study to provide CT-based morphometric data of the FM in *Chinchilla lanigera*. The results show no significant sexual dimorphism in FM dimensions, which contrasts with findings in humans, cats, and some non-human primates where male-female differences are marked. The observed anatomical uniformity in chinchillas may be reflective of limited intraspecific cranial variation. Similar findings have been noted in camels and certain canine breeds where sex-based osteometric differences are also minimal. While in human studies the FMI often aids in sex estimation, in this study, FMI showed no discriminatory value between male and female chinchillas. These findings suggest that FM metrics are not reliable indicators of sex in this species. Nonetheless, the data provide a critical baseline for clinical applications involving neurological diagnostics, radiologic assessments, and surgical procedures in exotic rodents. Furthermore, FM morphology may be relevant for interpreting evolutionary trends in skull base organization among hystricomorph rodents. This study establishes reference values for FM morphometry in *C. lanigera*, contributing essential data for veterinary anatomical databases and clinical practice. Future studies incorporating different age groups, pathological samples, and 3D volumetric reconstruction methods may offer further insight into the developmental, functional, and evolutionary aspects of the *foramen magnum* in exotic and laboratory rodents.

Keywords: *Chinchilla lanigera*, computed tomography, *foramen magnum*, morphometry.

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INTRODUCTION

The *foramen magnum* is a large opening in the basal cranium bounded by the os occipitale [4]. Lateral to it are the condylus occipitalis [7], which articulate with the fovea articularis cranialis of the atlas to form the ellipsoid joint, articulatio atlanto-occipitalis [5]. Critical structures such as a. vertebralis, a. spinalis, v. spinalis, medulla spinalis, n. hypoglossus, and ramus meningeus nervus hypoglossus pass through the *foramen magnum* [14, 21, 22]. Its morphological and morphometric analysis is vital in both clinical and anatomical contexts [11,14,17], providing insight into interspecies variation, evolutionary development, and some neurological disorders [1,18,19]. It also supports surgical planning and imaging procedures [21]. Studies on various populations help identify ethnic and sex-based anatomical differences, supporting forensic and anthropometric research [6,9,18]. Beyond normative evaluation, these analyses are useful in diagnosing cranial anomalies [20]. Computed tomography (CT), a high-resolution, noninvasive imaging method, is ideal for assessing complex structures like the *foramen magnum* [3,23,24]. *Chinchilla lanigera* is significant in research and as an exotic pet [9,13,25]. This study evaluated the transversal diameter, anteroposterior diameter, and area of the *foramen magnum* in chinchillas using CT. Existing literature lacks sufficient data on exotic species, and this study aims to provide a reference for future research.

MATERIALS AND METHODS

Animals

The sample size of the study group was calculated with the G*Power (v3.1.9.2) program. For analyses to be conducted between independent groups; Type 1 error probability (α) is accepted as 0.05 (95% confidence level), Type 2 error probability (β) is accepted as 0.20 (80% power level). The results of a similar study [8] were used to determine the effect size (δ = 1.8) to be considered. It was calculated as a total of 12, 6 in each group. The present study was conducted on 12 clinically healthy chinchillas (6 males and 6 females), each 18 months of age with an average body weight of 0.6 kg. Subjects were kept in separate enclosures under carefully regulated thermal conditions at 20-25°C with a 12:12 h light:dark cycle. Their diet consisted of a standardized pellet formulation and they were given *ad libitum* access to potable water.

CT imaging procedure

For the acquisition of computed tomography (CT) images, all chinchillas were placed in the ventrodorsal position and anesthetized by intramuscular administration of Tiletamine hydrochloride[1] 125 mg and Zolazepam hydrochloride 125 mg at a dose of 15 mg/kg. CT imaging was performed using a Toshiba Alexion scanner 16 CT[2]. Scan parameters were configured as follows: 100 kV x-ray tube voltage; 100 mA electric current power; 500 window width; 200 window levels; 750 ms exposure time; and 75 exposure values. CT images were obtained with a slice thickness of 1 mm and an inter-slice distance of 1 mm [8].

Measurements

The following parameters were used for morphometric evaluations of the *foramen magnum* on the obtained CT images

Transverse Diameter (TD): This parameter indicates the maximum horizontal distance of the *foramen magnum*. It measures the width of the opening in the mediolateral axis and thus serves as a critical criterion for assessing symmetry and anatomical variations (Figure 1).

Anteroposterior Diameter (AP): It serves as a metric that evaluates the distance between the basion point located anterior to the *foramen magnum* and the opisthion point located posteriorly. This particular measurement aims to elucidate the vertical dimension of the *foramen magnum* along its axial alignment (Figure 1).

Foramen magnum Area: This term refers to the cumulative surface area of the *foramen magnum*. Such a measurement serves to assess the dimensions of the opening (Figure 2).

Foramen magnum Index (FMI): This metric is calculated using the formula "FMI: TD/AP*100", which represents a quantitative ratio related to the *foramen magnum*.

Statistical analysis

Measurements were performed using axial, coronal and sagittal sections. Each parameter was measured bilaterally and the results averaged. The mean and standard deviation of the data were calculated using SPSS software, version 19.0, for Windows[3]. The suitability of variables for normal distribution was assessed using Shapiro-Wilk tests. The Mann-Whitney U test was used to compare data that were not normally distributed.

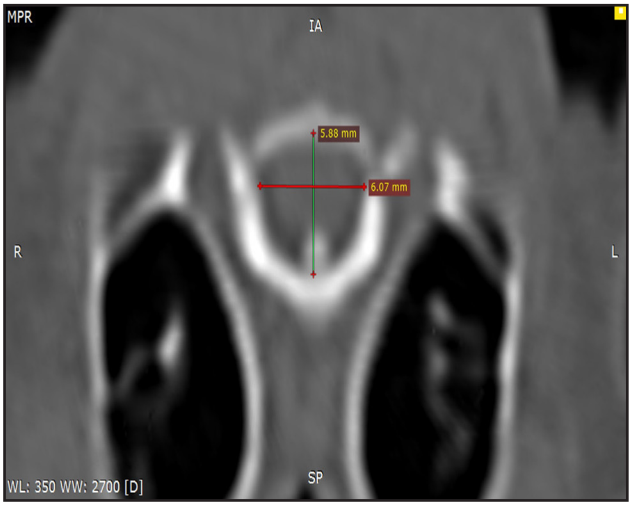

Figure 1. Measurements of the transversal and anteroposterior diameters of the *foramen magnum* in *Chinchilla lanigera*. The red line represents the transverse diameter, while the green line indicates the anteroposterior diameter.

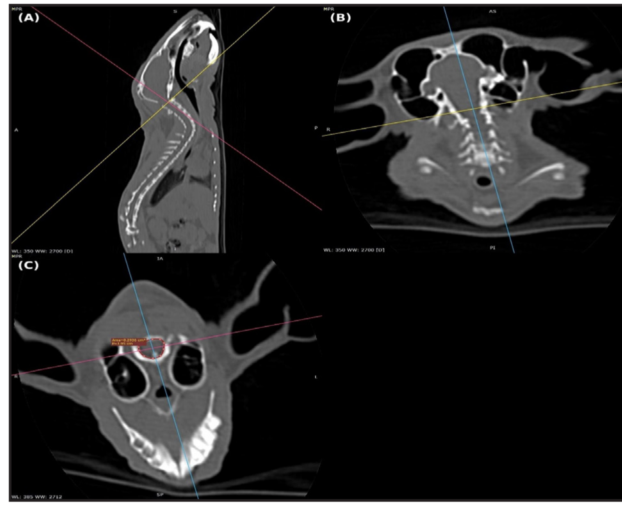

Figure 2. In bone-window CT MPR sections, sagittal oblique (A), coronal oblique (B), and axial oblique (C) images show the manual measurement of the spinal canal area at the level of the *foreman magnum* in *Chinchilla lanigera*.

RESULTS

The area, anteroposterior and transversal diameters of the *foramen magnum* were measured and the *foramen magnum* index was calculated in male and female chinchillas (Table 1). In male chinchillas, mean AP measurement was 6.15 ± 0.62 mm, mean TD measurement was 6.35 ± 0.59 mm and mean area was 0.3176 ± 0.028 cm^2. In female chinchillas, mean AP measurement was 6.12 ± 0.66 mm, mean TD measurement was 6.37 ± 0.61 mm and mean area was 0.311 ± 0.0257 cm^2. *Foramen magnum* index (FMI) was calculated as 103.25 ± 0.93 for males and 104.08 ± 0.89 for females. As a result of the general average analysis on 12 specimens, AP diameter was 6.135 mm, TD diameter was 6.36 mm, area was 0.3143 cm^2 and FMI value was 103.67. There was no significant difference of between the 2 sexes (Table 1).

Table 1. *Foramen magnum* measurement data in *Chinchilla lanigera*.

Measurement Parameter	Male (Mean ± SD)	Female (Mean ± SD)	U	*P*
AP Diameter (mm)	6.15 ± 0.62	6.12 ± 0.66	20.500	0.699
TD Diameter (mm)	6.35 ± 0.59	6.37 ± 0.61	16.500	0.818
Area (cm^2)	0.3176 ± 0.028	0.311 ± 0.0257	21.000	0.699
FMI	103.25 ± 0.93	104.08 ± 0.89	16.000	0.818

U: Mann-Whitney U test; SD: Standard deviation; $P < 0.05$.

DISCUSSION

In this study, the morphometric characteristics of the *foramen magnum* in *Chinchilla lanigera* were examined and the findings were evaluated in comparison with the literature. Measurements of the *foramen magnum* have significant value as a prospective metric to distinguish sexual dimorphism [9,19,24,25]. However, the lack of research on exotic species such as chinchilla is particularly evident in existing studies. In this study, we attempted to fill this gap and conducted a comprehensive investigation of the morphometric characteristics of the *foramen magnum* in chichillas.

Results showed that there were no significant differences in the anteroposterior (AP) and transversal diameter (TD) measurements, as well as the area measurements of the *foramen magnum* in male and female specimens. The AP measurement was calculated as 6.15 ± 0.62 mm in male specimens and 6.12 ± 0.66 mm in female specimens; TD measurements were recorded as 6.35 ± 0.59 mm in males and 6.37 ± 0.61 mm in females.

In one study with mixed-breed cats, it was found that *foramen magnum* measurements showed a significant difference between sexes [2]. In this study all chinchillas had the same breed. Additionally the absence of a sexually dimorphic feature in chinchillas can be explained by the physiological and anatomical uniformity inherent in the species.

Significant morphological disparities in the dorsal margin of the *foramen magnum* have been documented in camels; however, sexual dimorphism is negligible in osteometric assessments [26]. This study is consistent with the results of the present study, where sexual differences in chinchillas were also minimal.

In humans, anteroposterior (AP) measurements in male individuals have been reported to range between 35-39.75 mm, while female individuals exhibit a range between 29.5-34.75 mm [7,11]. This indicates that the marked sexual dimorphism observed in humans is relatively reduced in chinchilla populations. The lack of a statistically significant difference in AP and TD measurements between male and female chinchilla suggests that morphological variation within this species is minimal.

The area of the *foramen magnum* was measured as 0.3176 ± 0.028 cm² for male specimens and 0.311 ± 0.0257 cm² for female specimens. In addition, the results calculated for the *foramen magnum* index (FMI) were 96.85 for males, 96.08 for females and the overall mean was 96.46. In the context of human research, FMI has been recognized as an important metric for sex differentiation. Devadas *et al*. [7] reported higher FMI levels in males compared to females. Onar *et al*. [16] reported that *foramen magnum* index (FMI) did not show a statistically significant difference in a study on dolichocephalic and mesocephalic dog populations. In chinchillas, no statistically significant difference was observed between the sexes regarding FMI, suggesting that *foramen magnum* dimensions may be a limited criterion for sex differentiation. Furthermore, these similarities in measurements explain the limited influence of typological variations in cranial morphology on the dimensions and index of the *foramen magnum*.

Variations in the size of the *foramen magnum* have both clinical and evolutionary significance. In humans, narrowing of the *foramen magnum* may indicate the presence of pathologic conditions such as Chiari malformation [12], but there is a paucity of data on such pathologic conditions in the chinchilla. Nevertheless, the measurements obtained from this study could serve as a valuable reference for surgical procedures or radiologic evaluations in the chinchilla.

CONCLUSION

Morphometric analysis of the *foramen magnum* in chinchillas may provide a resource for new research in evolutionary biology, basic sciences and clinical applications. Future research could be expanded to include various age demographics, pathological conditions and comparative assessments with alternative taxa. Furthermore, augmenting such morphometric investigations with biomechanical assessments and imaging methods may facilitate a better understanding of the functional and evolutionary significance of the *foramen magnum*.

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***Ethical approval*.** This study was approved by the Burdur Mehmet Akif Ersoy University Animal Experiments Local Ethics Committee (Approval Date: 18.12.2024, Approval Number: 1400).

***Declaration of interest*.** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of paper.

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