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Foramen Magnum in Dogs of Small and Toy Breeds - Morphometric Study

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ABSTRACT

***Introduction*:** The foramen magnum is located in the occipital bone and communicates the cranial cavity with the spinal canal of the vertebral column. Variations in the shape and size of this foramen, such as the presence of a notch in its dorsal contour, characterize occipital dysplasia and may occur due to a defect in the supraoccipital bone ossification process during the gestational period. Occipital dysplasia has been reported primarily in small, toy, and brachycephalic breeds, and its clinical relevance remains controversial. The aim of the present study was to evaluate the size of the foramen magnum in asymptomatic dogs of small and toy breeds.

***Materials, Methods & Results*:** The study was conducted at the Veterinary Hospital of the Center for Rural Health and Technology of the Federal University of Campina Grande (UFCG), Patos Campus, located in Paraíba state, Brazil. Twelve (n = 12) asymptomatic, small and toy breed dogs, with variable sex and over 10 months of age, were referred to the Veterinary Hospital for elective surgical procedures and were used in this study. All dogs underwent complete neurological examination to confirm the asymptomatic status and were radiographed in rostrocaudal position, with their mouths closed and the hard palate at an angle of approximately 70º to 80º with the table of the X-ray apparatus. The foramen magnum of each specimen was evaluated in the radiographs using a precision caliper. The analyzed parameters included height (H), the height of the dorsal notch (N), total height (H+N), and width (W), and the obtained data were used to establish the degree of occipital dysplasia and determine the shape of the foramen magnum. Of the 12 animals studied, 75% (n = 9) exhibited a dorsal notch in the foramen magnum, which varied between 3.00 and 10.00 millimeters (mm) in height, characterizing occipital dysplasia. Among the affected animals, 77.77% (n = 7) were classified as grade 1 for the alteration, 11.11% (n = 1) as grade 2 and one animal (11.11%) as grade 3. The prevalent shape observed for the foramen magnum was oval (83.3%).

***Discussion*:** Although occipital dysplasia has been associated with the occurrence of nonspecific neurological clinical signs, such as tremors, ataxia, and epileptic seizures, the presence of this alteration in asymptomatic dogs indicates that the formation alone is just an anatomical variation, as demonstrated herein and in previous studies conducted over the past few years. This hypothesis has been increasingly supported by scientific evidence through publications that portray occipital dysplasia in dogs of various breeds and sizes without clinical manifestations. The clinical signs attributed to occipital dysplasia may originate in situations where there is a coexistence of other conditions. Occipital dysplasia has been reported several times in conjunction with other pathologies, such as occipital hypoplasia and syringomyelia, in symptomatic dogs. The dorsal notch-shaped occipital defect is covered by a fibrous tissue membrane in dogs affected by occipital dysplasia. The presence of this soft tissue membrane has been related to the late onset of syringomyelia due to the decompressive effect that it provides to the flow of cerebrospinal fluid. When occipital dysplasia is identified in symptomatic dogs, it is suggested that the lesion be correctly located within the nervous system and that, according to its neurolocalization, a thorough investigation of other underlying causes for the occurrence of the neurological clinical manifestation be carried out. To date, there is no evidence characterizing occipital dysplasia as a single entity causing neurological deficits.

Keywords: anatomy, morphology, occipital bone, skull, occipital dysplasia, neurology.

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INTRODUCTION

The bones that delimit the cranial cavity constitute the neurocranium. The occipital bone is responsible for delimiting the cranial cavity at its caudoventral aspect, forming the nuchal wall of the neurocranium [16]. This bone is anatomically divided into 4 portions: 1 basilar (basioccipital), 2 lateral (exoccipital), and 1 squamous (supraoccipital) [17]. The basilar portion and the right and left lateral portions delimit the foramen magnum, a structure that communicates the cranial cavity with the spinal canal of the vertebral column. In dogs, the occipital bone develops from 4 centers of ossification: a supraoccipital (dorsal) center, a basioccipital (ventral) center, and 2 exoccipital (lateral) centers [3].

It is believed that the incomplete ossification of the ventromedial portion of the supraoccipital bone during pregnancy originates a continuous notch located dorsally to the foramen magnum, characterizing a condition known as occipital dysplasia [18]. This alteration has been frequently associated with small-sized and brachycephalic breeds [1,2,4,12,17,18], and, more recently, with a wide variety of medium-sized dogs and, for the first time, in some large-sized breeds [6]. Much has been discussed regarding the clinical relevance of the morphological variations of the foramen magnum. Some authors accept the condition as a pathological entity responsible for neurological signs [7,8,14], while others consider it an anatomical variation, without any clinical correlation when found in isolation [4,6,9,10,13,18].

The aim of the present study was to evaluate the dimensions of the foramen magnum in small and toy breed dogs without neurological manifestations.

MATERIALS AND METHODS

Animals

Twelve (n = 12) asymptomatic, small and toy breed dogs, with variable sex and ages above 10-months-old, were used in this study. All of them were admitted to the Veterinary Hospital of the Center for Rural Health and Technology of the Federal University of Campina Grande, Patos Campus, in Paraíba state, Brazil, for routine surgical procedures and were used to carry out the experiment. During admission, the patients were submitted to complete neurological examination to confirm the health of the nervous system. After the elective surgical procedure, which was unrelated to the experiment, each animal was sent to the diagnostic imaging sector, where they underwent a rostrocaudal radiography of the foramen magnum.

Radiography and morphometric procedures

The animals were placed in dorsal decubitus for the radiography, with the atlantooccipital joint flexed so as to form an angle of approximately 70º to 80º between the hard palate and the table of the X-ray machine [5]. After obtaining the full-size radiographs, the morphometric analysis of the foramen magnum was initiated, in which the following variables were evaluated: height (H), the height of the dorsal notch (N), total height (H+N), and width (W) (Figure 1). The shape of each foramen magnum was also established, according to the ratio of the height (H) and width (W) variables, *i.e.*, disregarding the dorsal notch, when present.

The variables were evaluated with the aid of a precision caliper (2 decimal digits). Once the measurements were taken, the degree of dysplasia was determined through the N/h ratio. Results < 0.5 suggests grade 1 dysplasia, values between 0.6 and 1.0 indicates grade 2 and results > 1.0 characterizes grade 3 [11].

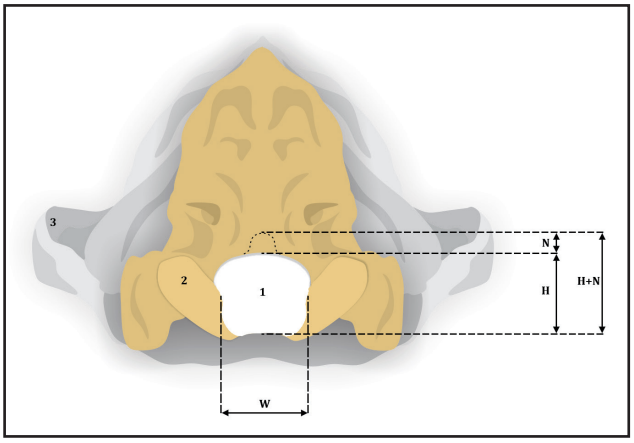

Figure 1. Canine skull, caudal view. 1- Foramen magnum. 2- Left occipital condyle. 3- Left zygomatic arch. W: Width of the foramen magnum; H: Height of the foramen magnum; N: Height of the dorsal notch; H+N: Total height of the foramen magnum.

RESULTS

The neurological exams carried out on the studied animals did not reveal alterations, confirming the asymptomatic status of the patients. According to the radiographs, 25% (n = 3) of the analyzed animals did not show alterations of the foramen magnum in the form of a dorsal notch (patients No. 2, 8, and

11). Among the remaining 75% (n = 9) comprised of animals that presented a dorsal notch, 77.77% (n = 7) were characterized as grade 1 occipital dysplasia, 1 dog (11.11%) had suggestive grade 2 occipital dysplasia and another dog (11.11%) were characterized as grade 3. The dorsal notch, when present, had variable height (between 3.00 and 10.00 mm). Disregarding the dorsal defect, 2 shapes of foramen magnum were recognized: oval and quadrangular; the predominant shape was oval (83.3%). The morphometric evaluation of each foramen magnum is shown in Table 1.

Table 1. Morphometric parameters of the foramen magnum in asymptomatic dogs of small and toy breeds in milimeters.

Patient	Breed	Age	H (mm)	N (mm)	H+N (mm)	W (mm)	Shape
1	Pinscher	1y 3m	6.00	10.00	16.00	12.00	Oval
2	Dachshund	10y	12.00	0.00	12.00	17.00	Oval
3	Pinscher	6y	10.00	4.00	14.00	16.00	Oval
4	Pinscher	8m	10.00	4.00	14.00	14.00	Oval
5	Pinscher	2y	11.00	4.00	15.00	13.00	Oval
6	Pinscher	1y 6m	11.00	5.00	16.00	13.00	Oval
7	Yorkshire	5y	10.00	4.00	14.00	15.00	Oval
8	Dachshund	2y	12.00	0.00	12.00	13.00	Quadrangular
9	Poodle	1y 6m	11.00	4.00	15.00	16.00	Oval
10	Shih Tzu	2y	10.00	6.00	16.00	14.00	Oval
11	Dachshund	6y	15.00	0.00	15.00	13.00	Quadrangular
12	Poodle	10m	10.00	3.00	13.00	14.00	Oval

H: height; N: height of the dorsal notch; H+N: total height; W: width.

DISCUSSION

Occipital dysplasia in dogs has been associated with neurological signs in several studies. A 6-month-old Poodle was radiographically diagnosed with occipital dysplasia, and the authors related the radiographic alteration with the clinical signs exhibited by the patient, such as paraplegia and epileptic seizures [7]. Similarly, a 3-month-old Maltese was diagnosed with occipital dysplasia, presenting with epileptic seizures and drooling, attributed to the abnormality seen on the radiograph [14]. Likewise, a 5-month-old Pinscher had clinical manifestations of ataxia and tremors attributed to the diagnosis of occipital dysplasia [8].

However, considering that all the dogs analyzed in this study were asymptomatic and that 75% had some degree of occipital dysplasia, it is believed that this alteration is an individual anatomical variation and not a pathological entity *per se*, corroborating several publications over the past decades. In a cadaveric study, grade 2 occipital dysplasia was found in a Papillon dog that was asymptomatic during life and who died for reasons unrelated to the nervous system [4]. Meanwhile, in another study involving 30 dogs that were equally divided in Yorkshires and Poodles and that lacked any clinical manifestations, 26 presented a continuous notch dorsal to the foramen magnum in the radiographic study [1]. Recently, occipital dysplasia was visualized by computed tomography or direct observation in 33.3% of 138 asymptomatic dogs, including a wide variety of breeds, not only small-sized ones. In that study, the authors visualized the alteration for the 1st time in breeds such as Boxer and Rottweiler [6]. In a *post mortem* archaeological study with 472 skulls of mesaticephalic and dolichocephalic dogs from the Byzantine era, approximately 1 in every 5 skulls analyzed exhibited occipital dysplasia, all of which were of the mesaticephalic type. The analyzed skulls belonged to relatively old dogs, which allowed the authors to interpret the presence of the dorsal notch as a morphological variation, not directly related to the dogs' death [10]. In a *post mortem* study with 80 Pekingese skulls, 78 exhibited

a defect in the form of a dorsal notch in the foramen magnum [15]. In addition to small and brachycephalic breeds, which are associated with a high incidence of occipital dysplasia, recent studies highlight the occurrence of the alteration also in mesaticephalic breeds, regardless of their size [6,10].

In dogs, there is no standard nomenclature for the shapes of the foramen magnum, which include oval, quadrangular, round, pentagonal, and rhomboid [1,6]. In a study involving 30 small-sized dogs, the predominant shape found by the authors was oval (70%) [1], a relatively similar rate to that found in the present study. Similarly, the oval shape was the most frequent (45.1%) among the shapes found in 138 morphologically evaluated foramina [6]. This corroborates the concept that there is no morphological standard for the foramen magnum in dogs and that its shape can vary even between specimens of the same breed [10].

It can be suggested that the occurrence of clinical signs in animals with occipital dysplasia is related to the presence of other concomitant alterations, such as occipital hypoplasia (or caudal occipital malformation) and consequent syringomyelia, which contribute to the genesis of clinical signs [2,6,12] that are often precipitously attributed to the occipital dysplasia alone. In these cases, the clinical manifestation occurs due to the reduction of the caudal cranial fossa, seen in occipital hypoplasia, which promotes an accumulation of nervous structures and compromises the dynamics of cerebrospinal fluid flow at the level of the cerebellum, even predisposing, in severe cases, to its caudal projection through the foramen magnum. In contrast, in isolated occipital dysplasia, the dimensions of the caudal fossa are apparently not affected, and the defect is limited to the contour of the foramen magnum [12]. Also, in these cases, the dorsal notch is covered by fibrous tissue [13], enabling the functional maintenance of the shape of the foramen magnum, which prevents the caudal displacement of nervous structures [2,6]. In addition to not directly contributing to the genesis of neurological clinical manifestations, the soft tissue membrane of the dorsal notch has been associated with the attenuation of early clinical signs of syringomyelia in cases of simultaneous occipital dysplasia and hypoplasia since it provides greater flexibility to the flow of cerebrospinal fluid in the reduced space due to occipital hypoplasia [9,12].

Putting it differently, there is no evidence that occipital dysplasia alone is the underlying cause of neurological deficits. When there is loss of nervous system function in dysplastic patients, it is prudent to further investigate the underlying cause of the deficit, taking as a starting point the correct location of the lesion through neurological examination. The authors recognize the limitations of this study regarding the small number of the analyzed sample and the absence of other morphometric variables, such as the total area of the foramen magnum. However, it is believed that the obtained results may assist in understanding the clinical relevance of occipital dysplasia in dogs and contribute to the development of future studies on the subject.

CONCLUSIONS

Small and toy breed dogs may present different degrees of morphological variations in the foramen magnum (occipital dysplasia) without neurological deficits.

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***Ethical approval*.** The entire experimental protocol described here was carried out according to guidelines proposed by the Research Ethics Committee of the Federal University of Campina Grande, Patos Campus, Paraíba-Brazil, and was approved under protocol No. 298/2015.

***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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