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The morphology of the hypoglossal canal and its size in relation to skull capacity in man and other mammal species

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The hypoglossal canal is a permanent element of the human skull. As well as the hypoglossal nerve, the canal also contains the venous plexus and an arterial branch leading to the dura mater. It emerged from our earlier studies that the venous plexus is a dominant component in this canal. In the present work the morphology and dimensions of the canal were studied on macerated skulls of humans and animals (rhesus monkey, European bison, fox, dog, cat, hare and rat). The hypoglossal canal was found in all the human and animal skulls examined. In both humans and animals the hypoglossal canal was frequently duplicated. The double canal was found in 43% specimens of human skulls. However, no triple division of the hypoglossal canal was found in the material under investigation. It was found that the hypoglossal canal in man, rhesus monkey and European bison had significant dimensions and in fact correlated with the size of skull capacity. This suggests that the hypoglossal canal is an essential venous emissary in man, rhesus monkey and European bison, but that in the remaining species it is of secondary importance in this respect.

Key words: hypoglossal canal, skull, human, animals, anatomy

INTRODUCTION

The hypoglossal canal is a permanent component of the skull in both man and animals [1, 11, 17, 21]. Beside the hypoglossal nerve, the canal also contains an ample venous plexus, a small variable emissary vein and a branch of the ascending pharyngeal artery [12, 13, 18, 20, 23, 26]. Taking into account such pathological symptoms as fracture of the occipital bone, intra-cranial and extracranial neoplasm and also congenital defects, the hypoglossal canal is of essential, clinical importance [5, 12, 13, 20, 24]. The venous plexus of the hypoglossal canal creates a link between the marginal sinuses and the superior jugular bulb and, indirectly, with the vertebral veins [9, 13]. The venous plexus is a predominant constituent of the canal in man and rhesus monkey, implying that it has a vital function in venous drainage in these species [26]. The veins of the hypoglossal canal should also be well developed in the Artiodactylae and Lagomorpha orders [3, 7]. In dogs this

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canal does admittedly communicate with the sigmoid sinus and the condyloid canal [10, 15, 16], but its role as a venous emissary seems to be of little importance [26]. In rodents anastomoses of the venous system of the cranial cavity with the vertebral canal are essential, as is the role of the hypoglossal canal, whose vein is well developed, particularly in the guinea-pig [3]. These may play a similar important role in the rabbit [3].

There are few papers in the literature describing the dimensions of the hypoglossal canal. The most detailed work, that by Schelling, which describes the dimensions of the venous foramina of the human skull as obtained by traditional methods of measurement, was published almost 30 years ago and is, in some respects, outdated [19]. There is also a lack of papers in the literature on comparative anatomy which enable the location and formation of this structure to be investigated in different mammals. In particular, there is an absence of papers setting out any comparison between the canal and skull capacity. This would make it possible for the scalar relation between these to be understood and, consequently, conclusions to be drawn as to the role of the canal in the drainage of the cranial cavity. The principal aim of this work is to measure the dimensions of the hypoglossal canal in man and animals in relation to skull capacity. By determining the relationship between the size of the canal and skull capacity, a new contribution will be made to existing knowledge of the interrelationships between the size parameters of the skull. The gathering of data concerning the comparative anatomy of cranial foramina will be an additional cognitive aspect of the present study.

The mammalian species selected for the present study are obviously very distant in taxonomy, and were therefore particularly useful in bringing out some of the important differences in the morphology and dimensions of skull structures.

MATERIALS AND METHODS

The material examined included 100 macerated adult human skulls of both sexes. The material originated from the collection of the Department of Historical Anthropology, Faculty of Archaeology, Warsaw University, and represented the population of the Kielce region from the 12th to the 14th centuries. The animal material examined comprised the following: 100 skulls of rhesus monkeys (*Macacus Rhesus*, *Rhesus A* and *Cynomolgus*) from the collection of the Department of Normal Anatomy, Medical University in Warsaw, 67 skulls of European bison (Caucasian breed, Białowieża breed and Pszczyna breed), 25 skulls of mongrel dogs, 37 skulls of foxes, 22 of cats, 80 of hares and 14 skulls of rats, all from the collection of the Chair of Animal Anatomy of Veterinary Medicine, Main School of Agriculture, Warsaw. The capacity of the cranial cavity was measured by filling the skull with lead shot, ≤ 1 mm in diameter, with the aid of a calibrated cylinder. A cross-sectional area of the external foramen of the hypoglossal canal was measured by means of a computer system using Multiscan image analysis software coupled with a microscope and a camera. Each measurement was repeated 3 times, and the mean calculated to minimise systematic error.

The numerical data involving both non-metric features and measured capacities and areas were analysed statistically. In studying the distribution of numerical data the Kołmogarov goodness-of-fit D test was applied. A significance level of 0.05 was taken as proven difference. Where assumptions on the normality of distribution of variables were not fulfilled, transformation of data was used. In testing the significance of differences in the metric features of the left and right foramina, a test for dependent pairs was performed. In the analysis of non-metric data, the chi-square test χ^2 was used. The Pearson test was applied in calculating the linear correlation between the skull capacity and the cross-sectional area of hypoglossal canal.

RESULTS

The results of the morphological and measurement studies are presented in Tables 1–3. In man the external foramen of the hypoglossal canal was single or double (Fig. 1). The bilateral single canal was found in 11 male skulls (22%) and 16 female skulls (32%), amounting to 27% of the total. The unilateral single canal was found in 29 female and 30 male skulls, amounting to 58% and 60%, respectively, and to 59% of the total number of skulls. The divided internal foramen of the canal occurred bilaterally in 5 female and 9 male skulls, amounting to 10% and 18%, respectively, and 14% when taken together. These differences, like those in the cross-sectional area of the external foramen of the canal, were not statistically significant. In cases of a double canal, either the two internal orifices were of equal size or one of them, usually the posterior, dominated (Fig. 1B). In one case, this division persisted as far as the external foramen of the canal.

Table 1. Non-metric features of the hypoglossal canal in man and animals

Species and feature of hypoglossal canal in skulls of known sex		Male specimens		Female specimens	
		L	R	L	R
Man (N = 49 M, 47 F)	Single	37	36	36	36
	Double	13	13	11	11
Macacus (N = 100)	Single	24	26	35	39
	Double	16	14	23	19
	Triple	1	1	0	0
European bison (N = 70)	Single	35	35	35	35
Fox (N = 17 M, 20 F)	Single	17	17	20	20

Species and feature of hypoglossal canal in skulls of unknown sex		L	R
Dog	Single	22	22
	Double	3	3
Cat	Single	20	21
	Double	2	1
Hare	Single	2	3
	Double	55	50
	Triple	13	19
	Fourfold	10	8
Rat	Single	13	14
	Double	1	0

The hypoglossal canal in the rhesus monkey was single or divided into two constituents (Fig. 2A, B). In one case (*Macacus Rhesus A*), a triple internal foramen of the canal was found (Fig. 2C). Substantial differences were manifested in the size of the hypoglossal canal depending on the variant within a species, but were manifested exclusively between *Macacus Cynomolgus* (MC) and *Rhesus* and *Rhesus A* (examined jointly). Differences between the variants R and RA, however, turned out to be insignificant. Taking this into account, the numerical data on the size of the foramina are given jointly in Table 2, with the magnitude of the cross-sectional area of the hypoglossal canal in the MC variant indicated in bold.

In European bison the hypoglossal canal was always single. The size of the external foramen of this canal differed significantly between males and females.

In the fox skulls the morphology of the hypoglossal canal did not vary and differences in their size were insignificant.

The hypoglossal canal was a permanent component of the dog skull. In 22 skulls a single canal was found, on both the right and left sides (Fig. 3A). The canal was found to be divided into two sections 3 times and on either side. The divided hypoglossal canal occurred on both sides of one

Table 2. Values of the cross-sectional areas of the hypoglossal canal in man and in animals. All values are given in square millimetres. The variability range is give beneath the mean value and standard deviation (in parentheses). Values for *Macacus cynomolgus* are in bold

Cross section areas of hypoglossal canal skulls of known sex	Male specimens		Female specimens		Sum of cross section areas
	L	R	L	R	
Man	19.16 (7.92) 6.2–41.1	18.70 (7.0) 3.9–39.7	17.96 (8.75) 6.5–46.1	18.65 (6.70) 8.5–37.3	36.9 (14.5) 9.1–77.3
Rhesus monkey	3.23 (1.14) 1.39–6.24 **2.21 (0.44) 1.94–2.82**	3.23 (1.07) 1.11–5.57 **2.29 (0.48) 1.78–2.74**	3.11 (1.21) 0.97–6.8 **2.21 (0.79) 0.97–3.07**	3.1 (1.19) 0.77–6.21 **2.48 (0.97) 0.77–3.67**	6.32 (2.24) 1.74–12.16 **4.68 (1.43) 1.74–6.74**
European bison	48.6 (9.34) 26.7–67.2	49.7 (16.7) 23–84.8	42.9 (9.94) 26.7–63.5	42.1 (9.51) 25–61,4	90.8 (21.9) 39.4–133,5
Fox	1.7 (0.29) 0.98–2.13	1.73 (0.43) 0.77–2.54	1.7 (0.49) 0.52–2.65	1,66 (0,63) 0,51–3,32	3,42 (0,83) 1,48–5,97

Cross-sectional areas of hypoglossal canal in skulls with unknown sex	L	R	Sum
Dog	1.83 (1.33) 0.62–6.37	1.85 (1.25) 0.5–5.24	3.67 (2.35) 1.21–9.63
Cat	1.44 (0.56) 0.6–2.68	1.35 (0.63) 0.52–2.8	2.79 (1.03) 1.13–5.27
Hare	2.99 (1.07) 0.98–5.78	2.98 (0.89) 0.94–6.1	5.97 (1.8) 2.27–11.03
Rat	0.25 (0.13) 0.096–0.53	0.24 (0.11) 0.12–0.45	0.5 (0.23) 0.25–0.9

Table 3. Capacity of the cranial cavity in particular variants of rhesus monkey. The values are given in cm^3. The variability range is displayed beneath the mean value and standard deviation (in parentheses)

Variant in Macacus species	Males	Females	Males and females altogether
C	87.3 (7.69) 72–96	73 (6.3) 52–96	77.8 (15.6) 52–96
MR	91.9 (12.6) 74–114	88.6 (10.7) 70–112	90.4 (11.5) 70–114
MRa	99. 1 (9.71) 76–112	90.2 (10.5) 68–116	93.8 (11.0) 68–116

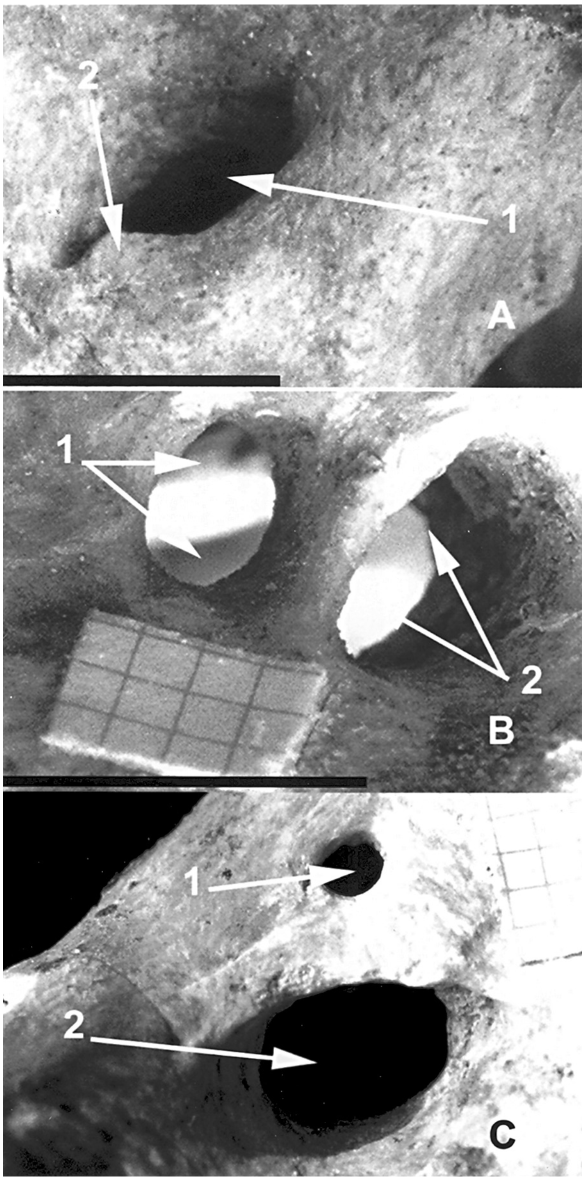

Figure 1. The various forms of the internal orifice of the hypoglossal canal in human specimens. A millimetre gauge is seen on some figures. Additionally a 5 mm bar is displayed in the bottom left-hand corner of each figure. **A.** Single internal orifice of the hypoglossal canal: 1 — internal orifice of the hypoglossal canal, 2 — bony process overhanging internal orifice of the hypoglossal canal; **B.** Divided internal foramen with two internal orifices of equal size: 1 — anterior orifice of the divided hypoglossal canal, 2 — posterior orifice of the divided hypoglossal canal; **C.** Divided internal foramen with inequality of size between the two internal orifices: 1 — anterior orifice of the divided hypoglossal canal, 2 — posterior orifice of the divided hypoglossal canal.

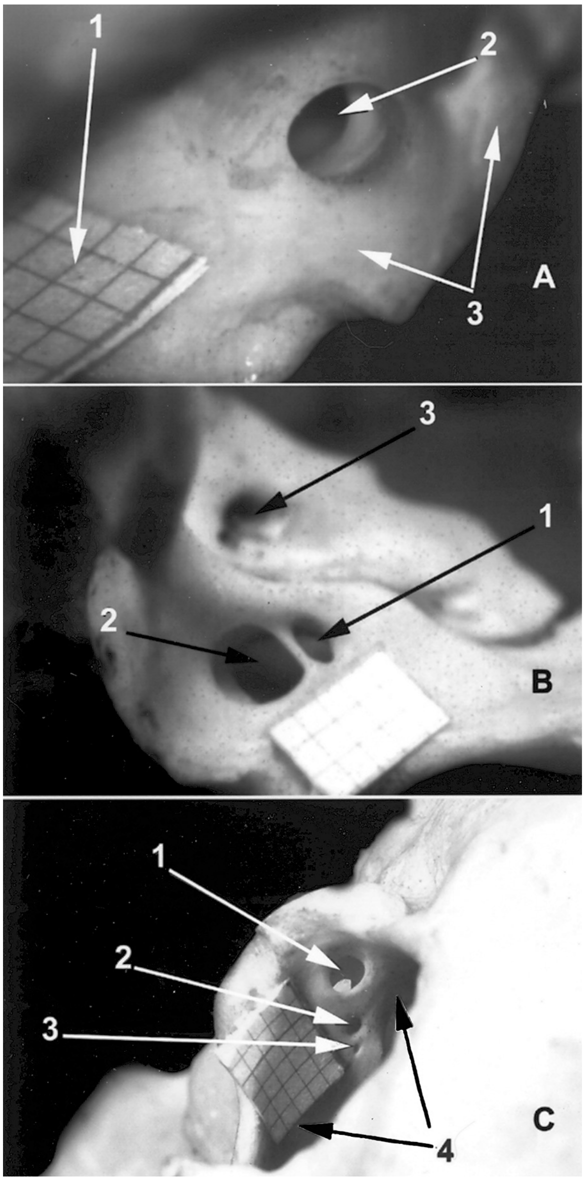

Figure 2. Various forms of the internal orifice of the hypoglossal canal in Macacus specimens. A millimetre gauge is seen on each figure. **A.** Single internal orifice of the hypoglossal canal: 1 — millimetre gauge, 2 — internal orifice of the hypoglossal canal, 3 — left occipital condyle; **B.** Divided internal foramen of the hypoglossal canal: 1 — anterior orifice of the divided hypoglossal canal, 2 — posterior orifice of the divided hypoglossal canal, 3 — left temporal bone; **C.** Triple internal foramen of the hypoglossal canal: 1 — anterior orifice of the hypoglossal canal, 2 — middle orifice of the hypoglossal canal, 3 — posterior orifice of the hypoglossal canal, 4 — left occipital condyle.

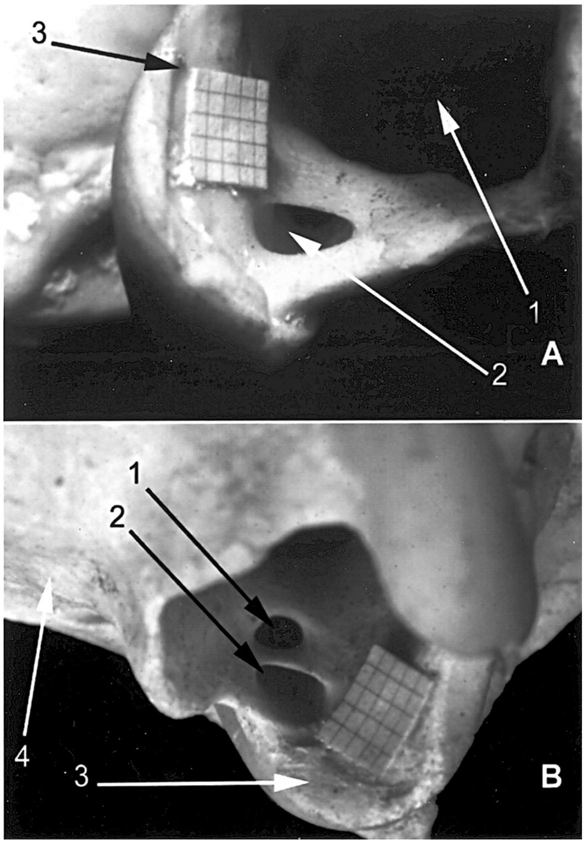

Figure 3. Various forms of internal orifice of the hypoglossal canal in dog specimens. A millimetre gauge is seen in each figure. **A.** Single internal orifice of the hypoglossal canal: 1 — cranial cavity, 2 — internal orifice of the hypoglossal canal, 3 — left occipital condyle with a groove for a branch of sigmoid sinus; **B.** Divided internal foramen with two internal orifices of equal size: 1 — anterior orifice of the divided hypoglossal canal, 2 — posterior orifice of the divided hypoglossal canal, 3 — left occipital condyle, 4 — occipital squama.

skull, while on the remaining 4 skulls it appeared as single (Fig. 3B). In all these cases the canal was divided along its whole length, i.e. the division also appeared within the external foramen of the canal, in contrast to the routine observation in man or rhesus monkeys. In one skull, on which the division occurred on both sides, the external foramen of the canal was composed of two separate small openings several millimetres apart, but lying in the common bony niche. Differences in the size of foramen of the external canal were statistically insignificant.

The internal orifice of the hypoglossal canal in the cat was almost always single, except for 3 cases where its division into two components was observed. The differences between the cross-sectional areas of left-sided and right-sided foramina were statistically insignificant.

The hypoglossal canal in the hare was characterised by the greatest variability. Its internal orifice was always single. These features did not differ significantly in relation to its location on one side or the other. Differences concerning the cross-sectional area of the canal between the cranial sides were statistically insignificant.

The hypoglossal canal in the rat was always present and there was little variation. Only in one case was a double hypoglossal canal observed on one side. The differences between cross-sectional areas were statistically insignificant.

The average capacity of the total number of human skulls amounted to 1350 cm^3 (SD 151.39). In female skulls it was 1279.17 cm^3 (SD 126.15), ranging from 1100 to 1600 cm^3, while in male skulls the average capacity was 1421.67 cm^3 (SD 143.28), with a variability range of 1060–1720 cm^3. The differences were statistically significant. On the basis of analysis of the data obtained it was proved that a significant correlation exists between the cranial fossa and the sum of the cross-sectional area of the hypoglossal canals in both male and female skulls separately, and also when taken together for the total material under investigation.

In case of the rhesus monkey considerable differences were observed in skull capacity between the 3 variants of the species. These data are therefore presented in a separate table (Table 3). Essential differences were found in the volume of the skull between the variants MC and MR and MRa. No differences were observed between the R and Ra variants. Sex differences appeared to be substantial only within the Ra variant, where the capacity of the skull in males significantly exceeded that in females. This difference turned out to be so important that it influenced the result calculated for the whole material, while in the MR and MC variants, which were examined separately, these differences were not in evidence. On the basis of the above measurement data the correlation was calculated between the size of the particular venous foramina of the skull of the rhesus monkey and its significance was evaluated. A correlation between the cross-sectional area of the hypoglossal canal and the skull capacity was found to be significant only for the female rhesus monkey.

The capacity of European bison skulls amounted, on average, to 669.4 cm^3 in the female of the species (SD 61.1), ranging from 470 to 750 cm^3. In male specimens these figures were equal to 726.7 cm^3 (SD 53.8) and 600–840 cm^3 respectively. Differences in the capacity of cranial fossa between male and female specimens were statistically significant. Taken together, the average skull capacity in European bison amounted to 697.7 cm^3 (SD 64.1). Of importance was the relationship between the capacity of cranial cavity and the cross-sectional area of both hypoglossal canals for males and females separately and for the whole material.

Skull capacity in foxes was, on average, 53.07 cm^3 (SD 4.56) for female specimens, the variability range being 46–61 cm. In the male specimens these figures were 55.25 cm^3 (SD 3.77), and 50.0–60.0 cm^3, respectively. These differences were statistically significant at $p < 0.01$. The average skull capacity in foxes was 54 cm^3 (SD 4.11). No correlation between the skull capacity and the cross-sectional area of the hypoglossal canal was found.

Skull capacity in dogs was, on an average, 84.96 cm^3 (SD 26.4), ranging from 48 to 170 cm^3. In dogs, as with foxes, no correlation between the skull capacity and the cross-sectional area of the hypoglossal canal was evidenced.

Skull capacity in cats was, on average, 25.68 cm^3 (SD 2.68), ranging from 21 to 31 cm^3. The correlation between the cross-sectional area of the left and right hypoglossal canals was found to be substantial. However, their cross-sectional area did not show a correlation with skull capacity.

Skull capacity in hares was, on average, 15.23 cm^3 (SD 1.14), ranging from 12.6 to 18.2 cm^3. The correlation between the cross-sectional area of the left and right hypoglossal canals turned out to be significant, although that between their cross-sectional areas and skull capacity was not.

Skull capacity in rats was, on average, 1.98 cm^3 (SD 0.25), ranging from 1.55 to 2.45 cm^3. The correlation between the cross-sectional area of the left and right hypoglossal canals appeared to be significant, although again this was not true of the correlation between cross-sectional area and skull capacity.

DISCUSSION

The hypoglossal canal was invariably a component of the human skull. The percentage of cases of one-sided or bilateral division of the canal in the material as a whole amounted to 43.5%. According to other authors this division occurs in 12.2–22.5%, depending on the side of the skull [2, 6, 8, 14]. Our results are somewhat higher than those presented by other authors. However, if we total our results for one-sided or bilateral occurrences of the divided canal, then we obtain 22.5% for the left side and 21% for the right side, which falls within the range given by other researchers. Poirier and Charpy (cited by Lillie) and also Solter and Paljan [22] reported in their study rare cases of the canal being divided into 3 or 4 compartments. This, however, was not observed in our material. Division of the hypoglossal canal is connected with the fact that the nerve originates from 2–3 stems which initially run separately and join only near its exit from the canal, the external foramen of which is almost always single [12, 14, 26]. The cross-sectional area of the hypoglossal canal is, as measured in this study, fairly closely consistent with the data of Braun, according to whom the external foramen of the canal is evaluated as being approximately 20 mm^2 [4]. According to Schelling, on the other hand, the venous part of the canal measures, on average, 6.6 mm^2 and has no essential haemodynamic significance [19]. Our results seem to be closer to the data of Braun than those of Schelling, as the cross-sectional area of the canal ranged from 17.96 to 19.16 mm^2, depending on sex and side of the body involved. Moreover, we found in our material that the cross-sectional area of the hypoglossal canal is a parameter strongly correlated with the capacity of the cranial cavity. The size of this canal is considerable, if we compare its cross-sectional area with that of the jugular foramen [27].

The hypoglossal canal is a constant element of the occipital bone in the rhesus monkey. From the literature data it appears that it is double in 38% of cases [25]. In the course of this study, it was found that the divided canal occurred on both sides in 36%, the result being similar to that of Wilgoszyński and Metera [25]. It worth noting the fact that a threefold canal was twice evidenced in the male skulls. No information on this has been found in the available literature. The hypoglossal canal has a significant cross-sectional area compared with, for example, the jugular foramen [27]. This fact and its close relationship with the capacity of the cranial cavity indicate its importance for venous drainage.

In contrast to the fox, whose hypoglossal canal did not display any variants, the dog sample contained 3 skulls in which it was divided into two canals. This has not been mentioned in the available literature.

The hypoglossal canal in the hare manifested the greatest variability. Its foramina were numerous and their number ranged from 1 to 4. The external foramen was always single. Information on this subject was not found in the available literature either.

The hypoglossal canal in the rat was always present, although its variability was insignificant. Only in one case on one side was the presence of the double hypoglossal canal observed.

CONCLUSION

The hypoglossal canal has significant dimensions in man, rhesus monkey and European bison and demonstrates a correlation with skull capacity.

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