VIA MEDICA

ORIGINAL ARTICLE

Morphology of the temporal canal and postglenoid foramen with reference to the size of the jugular foramen in man and selected species of animals

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The jugular foramen and postglenoid foramen are the main venous foramina of the skull of placental mammals. Their mutual relations are closely related to the development of the internal and external jugular vein, depending on the given kind. On the basis of measuring studies, it was decided to investigate the relations of the size of these foramina and to quantitatively determine which of them prevails. The studies were performed with macerated human and animal skulls. Altogether 100 skulls of human adults of both sexes, 100 of macaccas, 67 of bisons, 25 of mongrel dogs, 37 of foxes and 25 of rats were examined. The jugular foramen was the outlet of the sigmoid sinus or its equivalents and the postglenoid foramen — the petrosquamous or temporal canal. The jugular foramen was always singular and characterised by a small variability in the morphology, consisting only in the occurrence of the internal division or its lack. The postglenoid foramen, on the other hand, in the majority of the studied kinds was variable and numerous. The number of foramina ranged from 1 in man to 7–10 in bisons. In the course of measurements, it was found that the area of the postglenoid foramen in relation to the area of the jugular foramen is 0.87% in man, 24% in macaccas, 30.7% in dogs, 34.4% in foxes, 53.9% in rats and 248.5% in bisons. The results obtained indicate that in bisons the system of venous sinuses, connected with the postglenoid foramina, has a decisive significance for the drainage of the cranial cavity. In contrast, the postglenoid foramen in man has a marginal significance. The remaining kinds, whose skulls have been investigated, occupy on that score an intermediate position.

key words: postglenoid foramen, jogular foramen, skull, human, animals

INTRODUCTION

The postglenoid and jugular foramina are the main venous foramina in the mammalian skull, draining off nearly all the blood from the cranial cavity [1, 2, 5, 9, 16, 24, 25, 28]. The jugular foramen or the posterior lacerated foramen is situated between the occipital bone and the temporal one [1, 2, 9, 16, 21, 24]. It is almost a permanent component of the skull of all mammals. The postglenoid foramen is also called the "false" jugular foramen (foramen jugulare spurium). It is situated on the inferior part of the skull surface, backwards from the glenoid of the

temporo-mandibular joint [23]. It occurs in rodents, armadillos and in almost all hoofed mammals except for suids, hippopotamuses and rhinoceroses [8, 17]. Among the hoofed mammals this foramen is the largest in the deer family, in which it is one of the series of foramina ending the temporal canal [3, 4, 28]. The postglenoid foramen does not occur in elephantines and Pinnipedia. In general, it does not occur in leporines, but is present in the rabbit [5, 8]. Among the carnivora, it is absent in the cat family, but occurs in the family Canidae and in bears [3–5]. Also among the Primates the occurrence and size of this foramen are highly variable. In the lemurs this foramen lies superior to the jugular foramen [3, 4], on the other hand, in the family Hominidae and in man it is observed as a rare case of modification in the development stage [25, 26, 29, 30]. The occurrence of the postglenoid foramen in man is connected with the variations of transverse and sigmoid sinuses [25, 26, 29]. This variability is in keeping with the variability of the configuration of outflow of sinuses, development of mastoid emissary and also degree of pneumatisation of the temporal bone and the asymmetry of jugular foramina [3, 4, 31]. The jugular foramen is a direct extension of the sigmoid sinus while the postglenoid is the outlet of the petrosquamous sinus or the temporal canal [7, 15, 16, 19, 20]. The temporal canal starts in the groove of the transverse sinus and then the petrosquamous sinus and proceeds between the squama and the pyramid of the temporal bone, leaving the skull through one or several foramina on the inferior and lateral skull surface [3–5, 15, 16, 25, 28]. This canal occurs in horses, ruminants, some carnivora (Canidae and bears) and Insectivora [5, 8, 16, 28]. The temporal canal in man, if it occurs, is called the Vergi canal [3].

The mutual relations between the postglenoid and jugular foramina are very variable and closely connected with the development of both main veins of the head: the external and internal jugular veins. Here, one can observe a whole possible collection of forms, from entire domination of the external jugular vein and lack of the internal one (horses) up to the domination of the internal jugular vein, as we can see in the family Hominidae, suids and Hyracoidea [5, 8, 10, 11, 16, 17, 19, 21, 24, 28]. The external jugular vein, as a small additional vein gathering blood from the cranial cavity, functions in many remaining groups of placental mammals, e.g. in Insectivora (mole), the family Canidae and many Primates, including macacca [5, 10, 16, 18, 24, 28]. The internal jugular vein as the main draining vein of the skull cavity occurs in many placental mammals, such as ruminants or carnivora [16].

The present authors desired to review and to systematise the knowledge on both most important venous foramina of the skull, which are the jugular and postglenoid foramina. Investigation of the mutual relations of both these foramina in selected, distant from each other in the systematics of mammalian kinds, would allow to show to what an extent the venous drainage from the skull cavity depends on each of the two foramina. The data available in the literature dealing with this subject are of qualitative, but not of quantitative, character.

MATERIAL AND METHODS

Studies were performed with macerated skulls. This material included: 100 skulls of human adults of both sexes (50 M and 50 F), 100 of macaccas (Macaccus rhesus, rhesus A and cynomologus, 40 M and 60 F), 67 of bisons (35 M and 32 F), 25 of mongrel dogs (sex unknown), 37 of foxes (17 M and 20 F) and 14 skulls of rats (sex unknown). While examining the human skulls, the sex was determined on the basis of features of sexual dimorphism. Once the sex of a species had been determined, identification of venous sinuses of the skull and analysis of asymmetric features of these sinuses were performed. The area of the venous foramina was determined using a computerised system of image analysis. The data obtained on both the skull capacity and the measured area were evaluated statistically. The results of studying the nonnumeric data allowed us to follow the occurrence and variability of the morphology of venous foramina of the skull. Metric examination made it possible to calculate the surface of both sinuses and the relation between their sizes. In the course of analysis of non-metric data, the difference test χ^2 was applied. During testing of the significance of differences of the metric features of monomial (left or right) foramina, a test was used for the dependent pairs, whereas in the remaining cases the Student test and the analysis of variance (F-Suedecor distribution) were applied to calculate the coefficient of linear correlation between two measurable features.

RESULTS

The morphology of the jugular foramen is presented in Table 1 and in Figures 1–5. The jugular foramen had two basic morphological modifications: divided and undivided. In man, in the majority of cases the undivided modification prevailed (Fig. 1A).

Table 1. Occurrence and morphology of the jugular foramen in particular kinds with reference to the sex and body sides

Kind	Feature of jugular foramen			
	Divided		Undivided	
Man	M		M	
	L	R	L	R
	6	4	44	46
	F		F	
	L	R	L	R
	5	6	43	44
Macacca	M		M	
	L	R	L	R
	4	5	37	36
	F		F	
	L	R	L	R
	6	4	53	55
Bison	0		70	
Fox	0		37	
Dog	2		48	
Rat	27		1	

The occurrence of the wholly divided jugular foramen has been observed in 10% of male skulls and in 11% of female skulls. For both sexes together it amounted to 10.5% with reference to 200 sides (Fig. 1B).

No case has been found in which the jugular foramen would be divided on both sides simultaneously. The divided jugular foramen in a similar percentage has been observed in macaccas (Fig. 2C). In the skulls of bisons jugular foramina were extremity irregular in shape, however not divided into two parts (Fig. 3A). In the skulls of foxes, the morphology of the jugular foramen did not show variability (Fig. 4B). In dogs, in both cases on the left side a small foramen has been twice observed, separated from the main jugular foramen. This small foramen was situated in the posterior part of the appropriate jugular foramen and had an insignificant size (Fig. 4A). It was decided to describe this state as the divided jugular foramen because no data were available either in the literature or in our studies and the content of this foramen was unknown to us. The jugular foramen in rat was, in the majority of cases, entirely divided into two separate components: anterior and posterior (Fig. 5A). Only in one case was an undivided foramen observed.

The occurrence of temporal canal was observed in bison, macacca, dog and fox. In macacca, dog and fox it has the form of a single canal or a vein of diploe, proceeding on the border of the squama and pyramid of the temporal bone joining the groove of
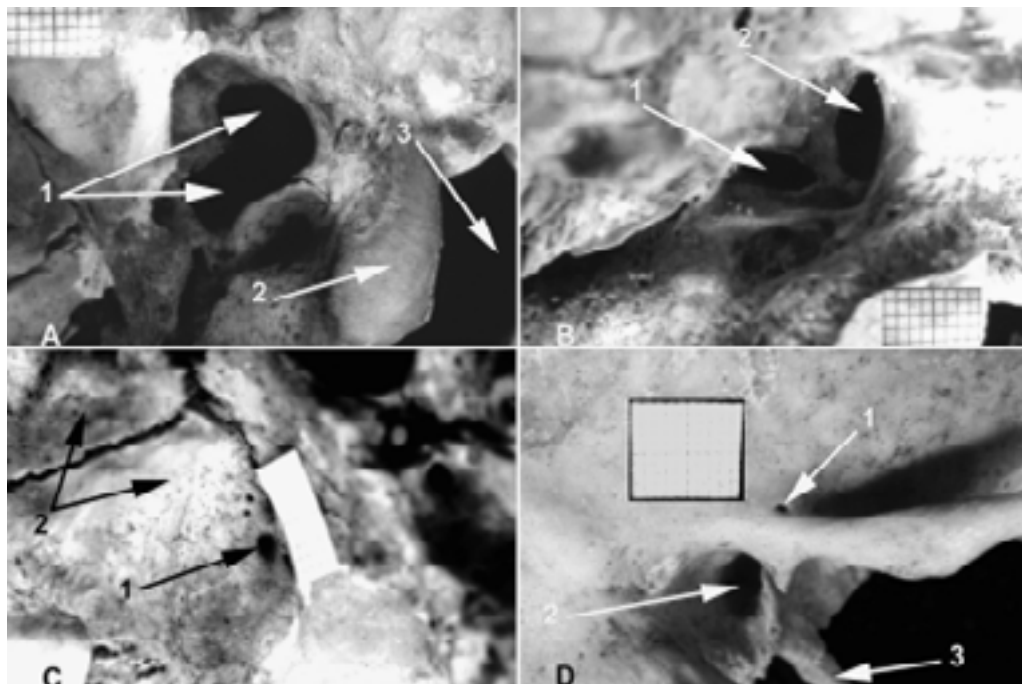

Figure 1. Jugular and postglenoid foramina of human. **A.** Inferior aspect of human skull; left side; an undivided jugular foramen; 1 — anterior and posterior parts of jugular foramen, 2 — occipital condyle, 3— foramen magnum; **B.** Inferior aspect of human skull; left side; a divided jugular foramen; 1 — anterior part of jugular foramen, 2— posterior part of jugular foramen; **C.** Inferior aspect of human skull; right side; vicinity of glenoid cavity; 1 — inferior postglenoid foramen, 2 — glenoid cavity; **D.** Lateral aspect of human skull; right side; 1 — superior postglenoid foramen, 2 — external auditory opening, 3 — styloid process.
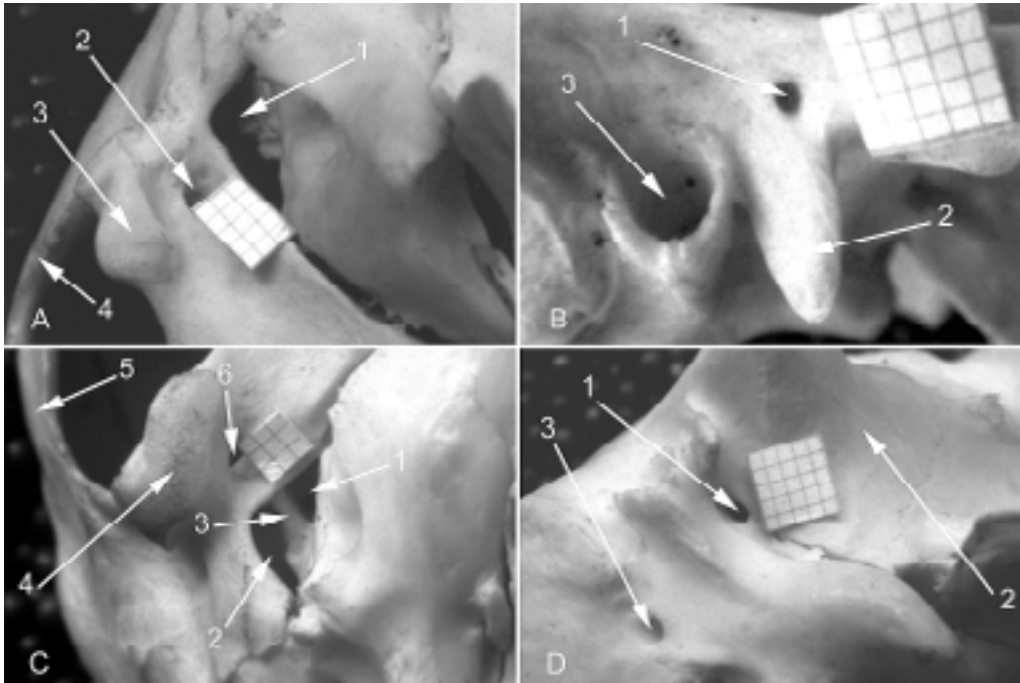
Figure 2. Jugular and postglenoid foramina of macacca. **A.** Inferior aspect of macacca's skull; right side; 1 — both parts of jugular foramen, 2 — external opening of hypoglosseal canal, 3 — occipital condyle, 4 — ridge of foramen magnum; **B.** Lateral aspect of macacca's skull; right side; 1 — superior postglenoid foramen, 2 — postglenoid process, 3 — external auditory foramen; **C.** Inferior aspect of macacca's skull; left side; 1 — anterior part of jugular foramen, 2 — posterior part of jugular foramen, 3 — intrajugular process, 4 — occipital condyle, 5 — ridge of foramen magnum, 6 — external opening of hypoglosseal canal; **D.** Inferior aspect of macacca's skull; right side; 1 — inferior postglenoid foramen, 2 — glenoid cavity, 3 — styloid foramen.
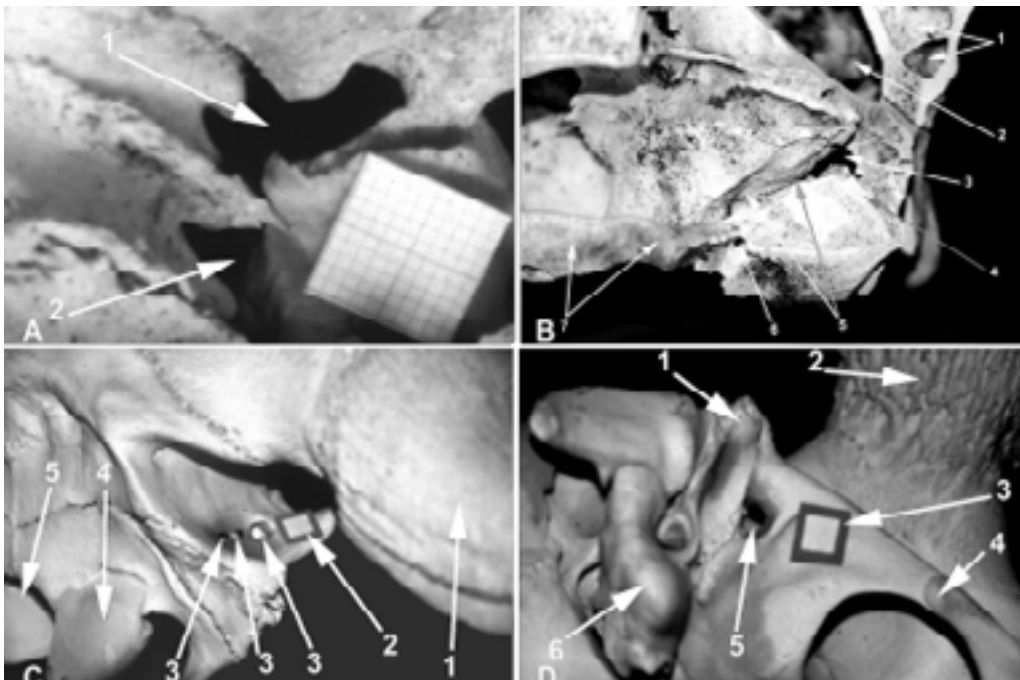

Figure 3. Jugular and postglenoid foramina of bison. **A.** Inferior aspect of bison's skull; left side; 1 — jugular foramen, 2 — middle lacerated foramen; **B.** Lateral aspect of bison's skull; left side; cranial cavity opened, temporal canal dissected to reveal its course and terminal foramina; 1 — occipital bone, pneumatic, 2 — cranial cavity, 3 — internal opening of temporal canal, 4 — 2 cm measure, 5 — course of temporal canal, 6 — one of external inferior openings of temporal canal, 7 — zygomatic arch; **C.** Lateral aspect of bison's skull; right side; 1 — bony corn, 2 — 1 cm measure, 3 — external superior openings of temporal canal, 4 — right occipital condyle, 5 — foramen magnum; **D.** Inferior aspect of bison's skull; right side; localisation of single inferior opening of temporal canal (inferior postglenoid foramen); 1 — external auditory meatus, 2 — bony corn, 3 — 1 cm measure, 4 — zygomatic arch, 5 — single inferior opening of temporal canal, 6 — tympanic bulla.
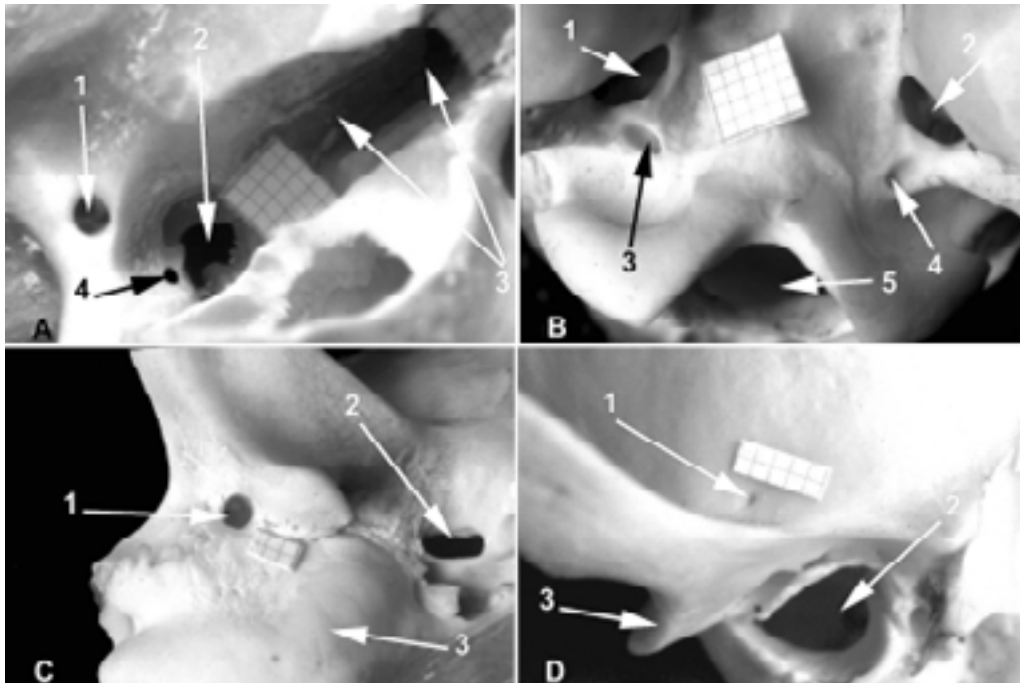
Figure 4. Jugular and postglenoid foramina of fox and dog. **A.** Inferior aspect of dog's skull; right side; jugular foramen and accessory jugular foramen (second part of the jugular foramen); 1 — external opening of hypoglosseal canal, 2 — jugular foramen, 3 — groove of petrooccipital sinus, 4 — accessory jugular foramen; **B.** Inferior aspect of fox's skull; 1 — right jugular foramen, 2 — left jugular foramen, 3 — external opening of the right hypoglosseal canal, 4 — external opening of the left hypoglosseal canal, 5 — view into skull cavity through foramen magnum; **C.** Inferior aspect of fox's skull; right side, 1 — inferior postglenoid foramen, 2 — oval foramen, 3 — tympanic bulla; **D.** Lateral aspect of fox's skull; left sight, 1 — superior postglenoid foramen, 2 — external auditory foramen, 3 — postglenoid process.
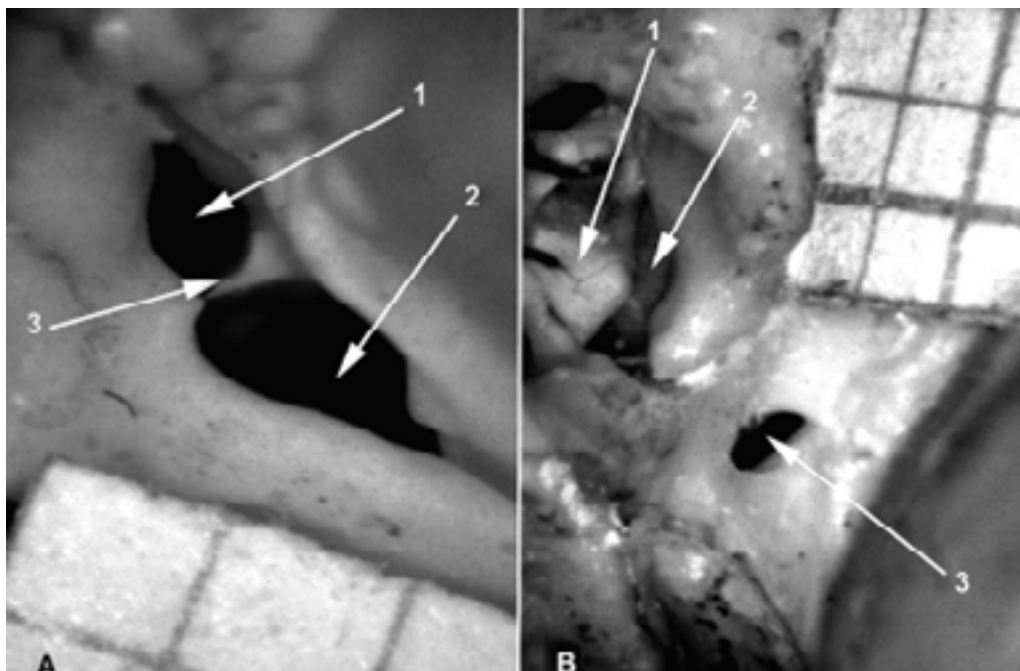

Figure 5. Jugular and postglenoid foramina of rat. **A.** Inferior aspect of rat's skull; right side; 1 — anterior part of jugular foramen, 2 — posterior part of jugular foramen, 3 — intrajugular process; **B.** Lateral aspect of rat's skull; left side; view opened into tympanic cavity; 1 — malleus and incus complex, 2 — interior of tympanic cavity, 3 — postglenoid foramen.

the transverse sinus with the postglenoid foramen. In this substance, the temporal canal was in these kinds a sort of petrosquamous sinus, but running along the whole length in the bony canal. In bison, the temporal canal was of a considerable diameter (Fig. 3B), started similarly; however, in its further course it divided into a number of branches, opening itself finally into several or a dozen or so foramina of different sizes, situated below or higher than the zygomatic arch (Fig. 3C, D). Therefore, a division has been proposed into main foramina, usually larger and less numerous, which were situated on the lower surface of the skull, and the additional ones, numerous and small, situated on its lateral and posterior wall. The main foramina, in number 1–4, were located in the vicinity of the external acoustic meatus, backwards with regard to the glenoid of the mandibular joint. The additional foramina were situated in the surroundings of the squama of temporal bone or at the epiphysis of the zygomatic process of this bone, thus already on the lateral surface of the skull, or higher than the zygomatic arch, in the vicinity of the bony cores (bony core foramina) or on the occiput, often already within the occipital bone (occipital foramina). The occurrence and morphology of the postglenoid foramen in the studied species are presented in Table 2. The postglenoid foramen was found in all the studied species in two

localisations: superior and inferior (Fig. 1–5). The superior foramen was situated at the epiphysis of zygomatic emissary. The inferior foramen, in some cases numerous, was situated in the vicinity of the skull base, backwards to the mandibular cavity of the temporal bone, and forwards from the ear-drum part of that bone. The postglenoid foramen in man was found in 2 out of 50 male skulls examined, and in 5 out of 50 female skulls examined, always one-sidedly. This is 2% and 5% respectively and together 3.5%. It was situated in superior or/and inferior location (Fig. 1C, D). The postglenoid foramen occurred in the majority of macaccas. No significant differences were observed between the variants of the kind macacca. The main foramina, in number 1–4, were situated in the vicinity of the external eardrum (Fig. 2C, D). The additional foramina (superior) were situated in the neighbourhood of the squama of the temporal bone, or at the base of zygomatic emissary of this bone, either somewhat upper up in the vicinity of bony horns or on the occiput, often already in the vicinity of the occipital bone (Fig. 2B). The superior foramen in macaccas was found occasionally. The inferior foramen of the temporal canal was found in 84 cases on the left and right sides. This is 84% with regard to the number of left and right sides, respectively. As far as the sex of the species is concerned, the inferior foramen was observed

Table 2. Occurrence and morphology of the postglenoid foramina in particular kinds with reference to the sex and side

Kind	Name and feature of foramen		M		F	
			L	R	L	R
Man	Superior		0	1	2	1
	Inferior		1	0	2	0
Macacca	Superior		39	36	45	48
	Inferior		6	4	3	5
Bison	Main foramen	Single	10	11	15	13
	of temporal canal	Multiple	25	24	20	22
	Additional	Temporal	28	29	28	29
	foramina of temporal canal	Cerebral	19	18	23	20
		Occipital	15	10	9	17
Fox	Inferior	Single	16	17	18	18
		Multiple	1	0	2	2
	Superior	Single	8	8	9	10
		Multiple	2	2	1	0
Dog	Inferior		25			
Rat	Superior		14			

in 93 cases in females and 75 in males, which is 93% and 75% with regard to the number of sides, the difference being characteristic. The postglenoid foramen was numerous in all bisons. The main foramina ending the temporal canal were the inferior foramina. In foxes, the main external foramen of the temporal canal was the inferior postglenoid foramen, which occurred constantly and in the majority of cases was single (Fig. 3). In one male species (in 34 skull sides) and in 4 female ones (in 40 skull sides), near the main foramen, a second one, considerably smaller, was observed; its communications with the cranial cavity in the majority of cases could not be evidenced. The superior postglenoid foramen, situated at the base of zygomatic emissary of the skull, was unstable and considerably smaller. It was single or, more rarely, numerous (Fig. 3C). The postglenoid foramen was a constant element of the dog and fox skull (Fig. 4A, C, D). In fox it was single or multiple, in dog almost always single (only in one case in dog was a second postglenoid foramen found. In dog all the postglenoid foramina were situated inferiorly, directly behind the glenoid cavity. From among the studied foramina of the rat skulls, the postglenoid always occurred as single, located only inferiorly and did not show variability in morphology (Fig. 5B).

The results of measurements of the jugular and postglenoid foramina are presented in Tables 3 and 4. They contain data concerning the area of venous foramina of the human skull, separately for sexes and sides. The size of areas in Tables 4 and 5 are given in mm². In the brackets, standard deviation is given and below the variability range (minimal and maximal values of area of a foramen in the studied

material). In the case of postglenoid foramen in man, the calculation results were limited to give only the arithmetic mean, not calculating standard deviation because of the small number of observations. After the statistical evaluation had been performed, it was found that the differences appearing between the sex and body side, except for human skulls, and concerning the area of the studied foramina were not statistically significant. In man the difference between the area of jugular foramen left and right, for male skulls and for both sexes jointly, were statistically significant, with right-side predominance. Separately, the significance of that difference in female skulls was not demonstrated. In Table 5 and in the corresponding diagram (Fig. 6) a comparison is presented of the size of both studied foramina, jugular and postglenoid, expressed in per cent of the area of the jugular foramen occupied by the postglenoid foramen. The results were jointly given for both sides (data added up).

DISCUSSION

According to the literature data, full division of the jugular foramen in man occurs in the range 2––8.33%, which is in agreement with our results [12, 13, 18, 22, 27]. The jugular foramen in macacca was irregularly divided into two elements in 9.5%, the figure being close to that for man. In the available literature, there are no extensive elaborations on the morphology of jugular foramina in the skulls of bison, fox and dog. Thus, there is no basis to realise a broad discussion. Based on our results, it should be underlined that, generally, the system of these foramina on the surface of skull and their morphol-

Table 3. Area of the jugular foramen in particular kinds with reference to the sex and body sides. All dimensions in square millimetres

| Kind | L | | R | | Skull sides |
	M	F	M	F	jointly
Man	51.11 (23.77) 21–126.2	57.53 (17.86) 12.5–94.9	53.83 (21.33) 15.8–112.7	59.84 (21.03) 25.6–121.7	111.35 (31.3) 40.5–221.1
Macacca	7.12 (2.45) 3–13.1	7.69 (3.30) 2.68–18.6	7.54 (2.69) 2.29–13.8	7.75 (2.59) 2.6–13.9	15.1 (5.12) 5.39–31.7
Bison	51.3 (18.2) 24–117	51.2 (16.9) 22.4–95	47.2 (12.9) 24.8–76.6	45.6 (13.9) 21.5–100.5	97.6 (28.5) 51.7–209.8
Fox	9.91 (1.45) 7.42–12.3	10.54 (1.49) 8.04–13.1	9.41 (1.39) 7.24–12.2	9.88 (1.55) 6.8–12.6	19.7 (2.72) 14.04–25.0
Dog	15.9 (6.87) 6.04–28.2		15.4 (6.37) 6.26–29.3		31.3 (13.1) 13.54–57.2
Rat	0.74 (0.15) 0.51–1.16		0.78 (0.18) 0.51–1.09		1.52 (0.2) 1.18–1.81

Table 4. Area of the postglenoid foramina in particular kinds with reference to the sex and body sides. All dimensions in square millimetres

Kind		L		R		Skull sides
		M	F	M	F	jointly
Man		0.9 (n = 1)	1.08 (n = 4)	0.43 (n = 1)	1.17 (n = 1)	0.97 (0.61) 0.25–2.14
Macacca	Superior foramen	0.34 (0.25) 0.16–0.51	1.2 (1.56) 0.1–2.3	0.64 (0.34) 0.4–0.88	1.16 (1.47) 0.12–2.2	1.67 (1.95) 0.22–4.5
	Inferior foramen	1.25 (0.65) 0.18–2.78	1.15 (0.76) 0.07–3.04	1.17 (0.82) 0.12–4.25	1.2 (1.56) 0.1–2.3	1.95 (1.27) 0.15–5.15
Bison	Inferior foramen	89.4 (30.4) 31.4–162.9	72.6 (21.5) 34.4–126.6	85.3 (27.1) 43.5–172	75.5 (25.7) 20.2–116.3	161.2 (44.5) 77.7–284
	Superior foramen	12.8 (5.79) 6.6–22.8	23.4–(29.3) 4.1–75.1	10.76 (6.1) 3.6–19.9	13.0 (7.6) 3.8–24.3	22.6 (17.8) 3.6–75.1
Fox		3.6 (1.05) 1.62–5.5	3.34 (0.81) 2–5.37	3.5 (1.24) 0.31–5.66	3.14 (0.68) 2.1–4.47	6.77 (1.67) 3.21–10.66
Dog		4.55 (1.75) 2.44–7.65		5.1 (2.56) 0.61–14.2		9.62 (3.87) 5.2–20.86
Rat		0.43 (0.14) 0.12–0.65		0.39 (0.12) 0.2–0.69		0.82 (0.22) 0.49–1.34

Table 5. Comparison of the ratio of the areas of the postglenoid to jugular foramina (Pg/J) in the studied species

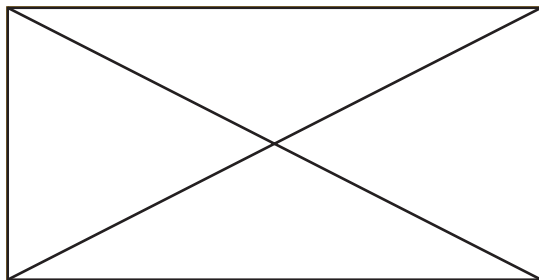| Kind	Man	Macacca	Dog	Fox	Rat	Bison
Pg/J	0.87%	24%	30.7%	34.4%	53.9%	248.5%

Figure 6. Comparison of the ratio of the areas of the postglenoid to jugular foramina in the studied species, in per cent.

ogy were almost identical in dogs and foxes. The jugular foramen in dog, similarly as in fox, is deeply situated in the bony niche. To this niche also the petro-basilar sinus exits, which a number of authors mention [16, 24, 28]. This sinus runs backwards through the paracentral edge of the pyramid of the temporal bone and the base of occipital bone. It is difficult to treat these results, because the size of sinus was not measured, avoiding eventual damage of the material at disposal. In rat the occurrence of divided jugular foramen was a rule, only in one case

on one of the side was the presence of undivided jugular foramen observed.

In the case of the area of the jugular foramen, the obtained values are, in general, comparable with the results of other authors. No essential differences were found concerning the sex, which is in accordance with the findings of other workers [1, 18, 27]. The ascertainment of the significance of the differences between the left and right sides in humans, in favour of the right side for male skulls and the whole material (jointly of both sexes), shows that the difference, though not large, favouring the right side, is characteristic for human skulls. The lack of significance of that feature in women probably resulted from their weak right-sided dominance, which with this number of species it is impossible to observe by the Student test.

Occurrence, morphology and size of the postglenoid and temporal foramina.

The postglenoid foramen was found relatively rarely in human skulls, jointly in 3.5%. Schelling [27] found the postglenoid foramen on the left side (3%) and on the right side (2%), which is in agreement

with our results. Boyd [3] gives a value of 0.6%. The size of the foramen ranges from 1 to 5 mm, which corresponds with our results [3, 6, 14, 27]. Also the counting of the linear data given by Schelling [27] and Boyd [3, 4] on the area, gives the value ranging from 0.79 to 7.1 mm^2, which approximately coincides with the results obtained in the present study (the mean value amounts to 0.97 mm^2; fluctuations from 0.25 to 2.14 mm^2). The postglenoid foramen occurring in macaccas was present in the decided majority of species, i.e. 84% in the case of inferior foramen and 9% in superior foramen. According to Boyd [4], in the Prosimiae the postglenoid foramen occurred in 43%, on the other hand, in monkeys it occurred only in 12%. The results obtained for monkeys in this study are considerably greater than the findings of Boyd. This difference may lie in the selection of the material, because Boyd [4] had no macacca skulls at disposal. In bisons, the postglenoid foramina were always numerous and always as the endings of the branched temporal canal. The number of the temporal canal foramina was changeable but always considerable. According to other authors, the main foramen of the canal is usually numerous and numbers from 1 to 5 [28]. In fox the main external temporal canal was the inferior postglenoid foramen, which occurred constantly and in the majority of cases was single. Similarly as in the bison or macacca the presence was observed of the superior foramina of temporal canal.

The area of the studied venous foramina in both the jugular and postglenoid animals did not show significant differences depending on the body side, whereas in the human skulls a distinct difference in the area of jugular foramen was observed in favour of the right side. This confirms the results of our earlier studies, according to which the dominance of the right jugular foramen can be stated [31].

Analysis of the size of the postglenoid foamen compared with the jugular foramen has shown that in the bulk of the studied species the postglenoid foramen (the sum of postglenoid foramina) did not exceed the size of the jugular foramen. Only in the bison was a reversed situation observed since the sum of the area of the postglenoid foramina of both sides surpassed the sum of the area of both the jugular foramina by a factor of almost 2.5 (Table 5 and Fig. 5). The differences observed between the kinds of animal were significant, except for the dog and fox because such a difference between them was not demonstrated. This is under-

standable, considering the great proximity of both kinds. This confirms, in part, a hypothesis formulated by van Gelderen [16], who considered that comparison of evolutional proximity of kinds basing on the model of venous sinuses is, to a certain extent, possible. Based on the literature and our own results, it can be said that the temporal canal in the macaccas, fox and dog refers to the primitive system, in which the foramen canal is situated exactly beyond the temporal-mandibular joint, whereas in ruminants and horses it has a branched shape [4, 5]. The temporal canal occurs in man in a rudimentary form. This canal was best developed in bisons and ended with the greatest number of foramina. Originally, the postglenoid foramen was situated between the ear-drum ring and the temporal-mandibular joint, however, it can change location in various mammals; the original location is preserved in dog.

In the present study it turned out that in the structure of the studied skull foramina asymmetry is marked, but in man it is significantly greater than in all the animals studied. The size of this asymmetry oscillates from 1 to 3.47, and exceeds, in about 8% of human population, the ratio 2.0, which may be a contraindication to the ligature operation of internal jugular vein in such patients. In the light of the results of the present study, it is obvious that the morphology of skull foramina in mammals shows the same pattern and the encountered variabilities are solely the result of development of the particular elements of this pattern.

REFERENCES

1. Adams LA, Eddy S (1949) Comparative anatomy. An introduction to the vertebrates. Wiley & Sons, New York, Chapman & Hall Ltd., London, pp. 168–179.
2. Barone R (1976) Anatomie comparée des mammiféres domestiques. T. I Osteologie, fasc. 1 et 2, Vigot Freres, Paris, pp. 55–121.
3. Boyd GI (1930) The emissary foramina in the cranium of man and anthropoids. J Anat (Lond), 65: 108–121.
4. Boyd G (1934) The emissary foramina of the cranium in primates. J Anat (Lond), 69: 113–117.
5. Butler H (1967) The development of mammalian dural venous sinuses with special reference to the post-glenoid vein. J Anat, 102: 33–56.
6. Cheatle AH (1899) On the anatomy and pathological importance of the petrosquamosal sinus. Lancet, II: 611–612.
7. Cooper ERA (1962) Cranial and spinal ciné angiography in animals. Acta Anat, 50: 112–134.
8. Cuvier G (1837) Leçons d'anatomie comparée. 2nd ed., Vol. II, Crochard et Cie, Paris, pp. 454–500.

9. Davison A (1903) Mammalian anatomy with special reference to the cat. Rebman Ltd, London, pp. 40–51, 156–158.
10. De La Torre E, Netsky MG, Meschan I (1959) Intracranial and extracranial circulations in the dog - anatomic and angiographic studies. Am J Anat, 105: 343–362.
11. Dennstedt A (1904) Die Sinus durae matris der Haussaugetiere. Anat Hefte, 75: 1–92.
12. Dodo Y (1986) Observations on the bony bridging of the jugular foramen in man. J Anat, 144: 153–165.
13. Dyce KM, Sack WO, Wensing CJG (1996) Veterinary anatomy. 2nd ed., WB Saunders Co, Philadelphia, London, Toronto, Montreal, Sydney, Tokyo, pp. 241–242, 246–248, 305–306.
14. Fischer MH (1926) Le sinus pétrosquameux chez l'homme - un cas de communication de la jugulaire externe avec le sinus lateral. L' Assoc des Anastomistes (Paris), 1: 210–211.
15. Frąckowiak H (1984) The sinuses of the dura mater in bovine fetuses. Folia Morphol (Warsz.), 43: 303–310.
16. Gelderen van Chr (1925) Die Morphologie der Sinus durae matris. Z f Ges Anat Z Anat Entw-Gesch, 75: 525–596.
17. Greene ECh (1963) The anatomy of the rat. Hafner, New York, London, 1963, pp. 215–223.
18. Hatiboglu MT, Antil A (1992) Structural variations in the jugular foramen of the human skull. J Anat, 180 (Pt. 1): 191–196.
19. Hegedus SA, Shackleford RT (1965) A comparative-anatomical study of the cranio-cervical venous system in mammals with special reference to the dog. Am J Anat, 116: 375–386.
20. Hofer H, Schultz AH, Starck D (1960) Primatologia. Bd. 3, teil 2, Karger, Basel, New York, pp. 377–379.
21. Ihle JEV, Van Kampen PN, Nierstrasz HF, Versluys J, Hirsch GCh (1927) Vergleichende anatomie der Wirbeltiere. Springer Verlag, Berlin, pp. 285–301.
22. Katsuta T, Rhoton AL, Matsushima T (1997) The jugular foramen - microsurgical anatomy and operative approaches. Neurosurgery, 41: 149–202.
23. Luschka H (1859) Das Foramen jugulare spurium und des Sulcus petrosquamosus des Menschen. Zeitschr Rat Med, 3: 72–81.
24. Miller ME (1964) Anatomy of the dog. WB Saunders, Philadelphia, London, pp. 19–25, 419–429.
25. Padget DH (1956) The cranial venous system in man in reference to development, adult configuration, and relation to the arteries. Am J Anat, 307–342.
26. Padget DH (1957) The development of the cranial venous system in man, from the viewpoint of comparative anatomy. Carnegie Inst Wash Publ, 611, Contrib Embryol 36: 81–151.
27. Schelling F (1978) Die Emissarien des menschlischen Schädels. Anat Anz, 143: 340–382.
28. Sisson S, Grossman JD (1945) The anatomy of the domestic animals. 3rd ed., WB Saunders Co, Philadelphia, pp. 49–177, 696–702.
29. Streeter GL (1915) The development of the venous sinuses of the dura mater in the human embryo. J Anat, 18: 145–178.
30. Waltner JG (1944) Anatomic variations of the lateral and sigmoid sinuses. Arch Otolaryngol, 39: 307–312.
31. Wysocki J, Sikorska-Piwowska Z, Przespolewska H, Kupczyńska M, Kobryń H, Kobryńczuk F (1988) Lateralization of the jugular foramen of the skull in human and particular mammals. Clinical and anatomical study. Med Sci Monit, 4 (Suppl 2): 49–51.