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Original Article

Anatomical study of the Foramen Venosum and its clinical implications

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ABSTRACT

Introducción: The foramen venosum (FV) is located in the sphenoid bone anterior and medial of the foramen ovale and is crossed by a vein connecting the pterygoid plexus with the cavernous sinus. Anatomical knowledge of the FV is important because its variants may lead to surgical complications in procedures in the region of the middle cranial fossa. To assess the incidence of the FV, its unilateral or bilateral frequency and the distances from the FV to the foramen ovale (FO) (FV-FO) and from the FV to the foramen spinosum (FS) (FV-FS), including analysis by sex and race.
Method: We examined 178 macerated skulls belonging to individuals of both sexes, black and white. Bilateral or unilateral presence of FV was analysed. The FV-FO and FV-FS distances were measured with a digital caliper. Statistical analysis was done using chi-squared and Student's t tests.
Results: FV was found in 32.02% of the sample. In 23.6% the FV presented bilaterally and in 8.42% unilaterally. FV was more prevalent in white males than in white females. The FV-FO distance was greater in white males than in white females and significantly greater in black females than in white females. There were racial and sexual differences in the FV-FS distance, which was significantly greater in white males than in white females.
Discussion: FV is a very frequent anatomical variation, located antero-medially of the FO; it may present either bilaterally or unilaterally, and there is no preference for either side. Specific differences exist in FV distribution by sex and race.

1. Introduction

The foramen venosum (FV) or venous foramen, also known as the sphenoid emissary foramen or foramen of Vesalius, is an inconstant foramen generally present in 40% of individuals.[1,2] It may present unilaterally or bilaterally, and in addition may be double in 1.75% of individuals.[3]

When present, the FV is located in the sphenoid bone anterior and medial of the foramen ovale[4–6] and is crossed by a vein connecting the pterygoid plexus with the cavernous sinus.[2,7] Lang[2] says that a small nerve, the nervulus sphenoidalis lateralis, may also pass through the FV; furthermore, in 20% of cases the FV contains an accessory meningeal artery.[8]

Anatomical knowledge of the FV is important because its variants may lead to surgical complications in procedures in the region of the middle cranial fossa, as well as in radiofrequency rhizotomy, the technique used to treat neuralgia of the trigeminal nerve.[3] Furthermore, because the FV is a communication pathway between the cavernous sinus and the outside of the skull, it may facilite the dissemination of extracranial infections resuting from acute sinusitis, otitis or a dental abcess into the intracranial region.[9,10]

The object of the present study was to assess the incidence of FV, the number of FV in each half of the skull, its unilateral or bilateral frequency and the distances from the FV to the FO and from the FV to the FS, including analysis by sex and race.

2. Materials and Methods

We examined 178 macerated skulls of Brazilian individuals, both sexes, black and white, aged between 20 and 100 years (mean 40.38 years), belonging to the Museum of skulls – Department of Morphology and Genetics, UNIFESP, Brazil. Skulls in poor condition

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Fig. 1. Inferior view of the skull showing the foramen venosum (FV), foramen ovale (FO) and foramen spinosum (FS).

or for which the sex and/or skin colour were not identified were excluded from the study. The presence of FV (bilateral or unilateral) was observed (Fig. 1), with the side and the number of FV in each half of the skull. The distances from the FV to the foramen ovale (FO) (FV-FO distance) and from the FV to the foramen spinosum (FS) (FV-FS distance) were measured using a digital caliper. Statistical analysis was done using Pearson's Correlation, chi-squared and the Student's *t* tests as appropriate. Results were considered statistically significant at $p \leq 0.05$.

3. Results

FV was found in 114 half skulls (32.02%) generally antero-medial of the FO. In 23.60% the FV presented bilaterally and in 8.42% unilaterally, of which there were 4.21% on each side (half-skull). Presence of the FV only on the left side was more common in white males (53.1%) and black females (52.4%), presence of the FV only on the right side was more common in white females (52.3%); for black males 50% of the unilateral FV presented on the right side and 50% on the left. There was no statistically significant difference between sides.

In our study FV was more prevalent in white males than white females ($p = 0.02$); black males and black females each presented FV in 30.2% of cases (Table 1). The presence of double FV was not observed in the sample studied.

Black females, white males and black males presented approximate mean values for the FV-FO distance; white females presented lower mean values (Table 2). A statistically significant difference was observed between white males and white females ($p = 0.01$) and between white females and black females ($p = 0.03$).

The highest mean values for the FV-FS distance were found in white male, while white females presented the lowest values found (Table 3). A statistically significant difference was observed between black males and white males ($p = 0.05$), between black females and white females ($p = 0.05$) and between white males and white females ($p = 0.001$).

Pearson's test was used to calculate the correlation between the FV-FO x FV-FS distances. A statistically significant positive correlation was found only on the left side in black females (Table 4).

4. Discussion

FV is a fairly common anatomical variant. In the present study in Brazilian individuals we observed that FV was present in 32.02%, a similar percentage to that found by Shinohara et al.[3] (33.75%), Gupta et al.[15] (34%), Martínez et al.[18] (34%) and Ozer and Govsa[19]

Table 1
Results of studies reporting the frequency of the foramen venosum and its unilateral or bilateral presence on left and right sides in males and females.

Authors	Sample size	Specimen examined	Total frequency (%)	Unilateral (%)	Bilateral (%)	Right (%)	Left (%)	Males (%)	Females (%)
Kale et al.[1]	347	skulls	45	19.9	25.1	9.5	10.4	–	–
Lang et al.[2]	–	–	40	–	–	49	36	–	–
Shinohara et al.[3]	400	macerated skulls	33.75	18.25	15.5	7.75	10.5	–	–
Berlis et al.[11]	60	dry skulls	36	21	15	25	35	–	–
Boyd[12]	1500	skulls	36.5	21.8	14.7	10.6	11.2	–	–
Gingsberg et al.[13]	123	temporal bone CT	80	30.8	48.8	–	–	–	–
Gupta et al.[14]	35	dry skulls	32.85	20	22.85	20	12.85	22.7	50
Gupta et al.[15]	200	dry skulls	34	20	14	15	19	–	–
Kim and Kim[16]	305	temporal bone CT	47.5	21.3	26.2	10.2	11.1	–	–
Kodama et al.[17]	400	skulls	adults: 21.75	male: 24.64[b] female: 27.78[b]	male: 75.36[b] female: 72.22[b]	–	–	21.5	22.78
Martínez et al.[18]	53	dry skulls	34	22.7	11.3	7.5	3.8	–	–
Ozer and Govsa[19]	172	dry skulls	34.8	25.5	9.3	10.4	15.1		
Reymond et al.[20]	100	macerated skulls	17	6	5	6	5	–	–
Rossi et al.[21]	80	dry skulls	40	26.25	13.75	15.62	11.25	25	52.25
Sharma and Garud[22]	50	dry skulls	62	18	44	8	10	–	–
Wohua et al.[23]	100[a]	skulls	42.5	14.5	28	45	40	–	–
Presenty study	178	dry skulls	32.02	8.42	23.6	4.21	4.21	40^{WM} 30.2^{BM}	25^{WF} 30.2^{BF}

-Not informed, CT computed tomography.[WM] white males, [WF] white females, [BM] black males, [BF] black females.
[a] Only males.
[b] Different method of calculating percentage.

Table 2
Mean, minimum and maximum values (in millimetres) and standard deviation (SD) found for the distance from the Foramen Venosum to the Foramen Ovale (FV-FO distance).

	Black males		White males		Black Females		White females	
	right	left	right	left	right	left	right	left
Average (sides)	1.99	2.16	2.52	1.94	2.27	2.31	1.56	1.68
p-value (sides)	0.96		0.63		0.70		0.77	
Minimum	0.78		0.71		1.01		0.8	
Maximum	4.04		3.42		3.88		2.7	
Average	2.08		2.20*		2.29§		1.61*§	
SD	±0.75		±0.71		±0.91		±0.62	

*Statistically differences between sexes, §statistically differences between sexes.

(34.8%). The highest frequencies of FV were reported by Sharma and Garud[22] with 62% and Gingsberg et al[13] with 80%. Reymond et al.[20] reported the lowest frequency with 17% presence of FV (Table 1).

In our study FV was more frequent in white males than in white females, while for the black individuals the FV frequency percentages between sexes were similar. Kodama et al.[17] reported a statistically significant difference between sexes in their study. Gupta et al.[14] and Rossi et al.[21] report that FV was significantly more frequent in females (Table 1). We have not found other studies in the literature which analyzed differences related to skin color, being our study the only one that provides this information.

Double FV has been reported in several studies, varying between 0.5% and 3.1%;[1,3,19,24] only Gingsberg et al.[13] report higher values (17.3%); in our research we found no double FV.

The literature shows that FV may present a higher percentage either bilaterally[1,13,14,16,17,22,23] or unilaterally.[11,12,15,18–21] In our study bilateral FV was more frequent, however the difference was not statistically significant (Table 1).

We observed that FV presents no prevalence of one side over the other and can appear on either side, as reported by other authors[1,3,11,16,20,22] who corroborate the statement of Andreas Vesalius.[25] Lang,[2] Gupta et al.[14] and Rossi et al.[21] found a difference, with the presence of FV on the right side significantly more frequent than on the left; Gupta et al.,[15] Ozer and Govsa,[19] and Berlis et al.[11] found a higher percentage of FV on the left side (Table 1).

In our study the mean value for the FV-FO distance was between 2.08 mm and 2.29 mm for black males, black females and white males. These values are similar to those reported by Chaisuksunt et al[26] (2.05 mm for both sides) and by Ozer and Govsa[19] (2.30 mm, right side). More expressive values were found by Dogan et al,[27] with 4.42 mm on the right side and 2.80 mm on the left side (Table 5). Kaplan et al.[28] and Ramalho et al.[29] report much larger values for this distance (of 3–5 mm and 6–7 mm respectively), probably because they used a different method from

Table 3
Mean, minimum and maximum values (in millimetres) and standard deviation (SD) found for the distance from the Foramen Venosum to the Foramen Spinosum (FV-FS distance).

	Black males		White males		Black Females		White females	
	right	left	right	left	right	left	right	left
Average (sides)	11.02	10.65	11.68	11.70	11.03	11.32	9.47	9.77
p-value (sides)	0.35		0.22		0.75		0.79	
Minimum	6.86		8.44		8.09		6.86	
Maximum	15.12		17.48		14.52		11.91	
Average	10.84§		11.69§*		11.06†		9.61*†	
SD	±1.87		±1.82		±2.11		±1.69	

*Statistically differences between sexes, §statistically differences between races, for males, †statistically differences between races, for females.

Table 4
Pearson's correlation coefficient was used to calculate correlation between the FV-FO x FV-FS distances.

Population	Right side		Left side	
	r	*p*	*r*	*p*
Black males	0.28	0.23	0.26	0.27
White males	0.03	0.90	0.32	0.16
Black females	0.10	0.69	0.73	0.004*
White females	0.45	0.36	0.26	0.67

*Statistically significant correlation, *r*: correlation coefficient, *p*: *p*-value, FV: foramen venosum, FO: foramen ovale; FS: foramen spinosum.

other authors. White females presented the smallest values found in our study, close to those reported by Gupta et al.[15] (1.36 mm right side; 1.48 mm left side). Other mean values found in the literature are described in Table 5. In our study we found marked sexual differences between white individuals and significant differences between races when white and black females were compared. This is important information for surgeons planning surgery in this region.

In our research the distance between FV and FS was more expressive in white males (11.69 mm); this was similar to the value reported by Shinohara et al.[3] (11.52 mm right side). For black males and black females we found mean values of 10.84 mm and 11.06 mm respectively, close to the values found by Ozer and Govsa[19] (10.76 mm right side) and Shinohara et al.[3] (10.95 mm left side) (Table 5). White females presented the lowest mean value found in our study and in the literature reviewed, of only 9.61 mm. We found an important difference between races and an important difference between sexes for this measurement for white individuals, since it was smaller in white females than in white males.

When the correlation between the FV-FO x FV-FS distances was analysed, only black females on the left side presented a statistically significant positive correlation, which is very poor scientific evidence for stating that a correlation exists. However, Shinohara et al.[3] and Ozer and Govsa[19] state that they did find a correlation between these distances.

In our research we analysed the FV in detail, comparing the results obtained between sexes and races. There are few studies in the literature which analyse for sex and we found none that analyse for race.

The clinical importance of knowledge of anatomical variants in the region of the sphenoid bone arises from the fact that during an operation a needle may be introduced by accident into the inferior orbital fissure, the foramen lacerum or the jugular foramen;[30] a needle may also penetrate the FV and might perforate the cavernous sinus, resulting in a haematoma in the temporal lobe[31]. Another accident which may occur is a direct lesion of anastomosed venous structures between the cavernous sinus and the

Table 5
Mean values (in millimetres) for the FV-FO and FV-FS distances reported in other studies.

Author	Distance FV-FO		Distance FV-FS	
	right	left	right	left
Shinohara et al.[3]	2.55	2.59	11.52	10.95
Gupta et al.[15]	1.36	1.48	–	–
Ozer and Govsa.[19]	2.30	2.46	10.76	10.42
Rossi et al.[21]	1.85	2.46	–	–
Chaisuksunt et al.[26]	2.05	2.05	–	–
Dogan et al.[27]	4.42	2.80	–	–
Aviles-Solis et al.[32]	2.51	2.46	–	–
Lazarus et al.[33]	2.83	2.42	–	–

- Not reported, FV: foramen venosum, FO: foramen ovale; FS: foramen spinosum.

pterygoid plexus.[28] Furthermore the FV transmits a small emissary vein which serves as a venous connection between the cavernous sinus and the pterygoid plexus, and this connection may be responsible for transmitting an infected thrombus from the extracranial region to the cavernous sinus.[9,14] As this foramen is inconstant, it may be a complicating factor in a surgical procedure in the region when the professional does not possess well-founded anatomical knowledge.

5. Conclusions

In conclusion, the FV is a very frequent anatomical variation, located antero-medially of the FO; it may present either bilaterally or unilaterally, and there is no preference for either side. Specific differences exist in FV distribution by sex and race. This study provides important information not previously reported in the literature, thus contributing not only to detailed knowledge of the anatomy of the FV but also to the planning of surgical procedures.

Ethical Standards

The authors declare that all procedures adopted for this research are in agreement with the Brazilian laws.

Conflict of Interest

The authors declare that they have no conflict of interest.

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