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An Osteometric Evaluation of the Foramen Spinosum and Venosum

Una Evaluación Osteométrica de los Forámenes Espinoso y Venoso

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SUMMARY: The foramen spinosum (FS) and foramen venosum (of Vesalius) (FV) are alisphenoid apertures situated within the hub of the middle cranial fossa in close proximity to foramen ovale (FO). The FS and FV provide a passage to important neurovascular structures. An accurate knowledge of the morphometric details of the FS and FV including their shape, incidence, relation to other foramina and/or presence of any anomalies may represent a reliable anatomical landmark during surgical explorative maneuvers. Therefore, the aim of this study was to investigate the morphologic and morphometric features of the FS and FV. The study was conducted on 100 dry human skulls (n= 200) obtained from the osteological bank at the University of KwaZulu-Natal, to produce a database which may serve as a useful guideline to surgeons and anesthetists. Although single (95%), duplicate (2.5%) and triplicate (0.5%) FS were identified; only single (5%) and duplicate (0.5%) FV were found. Oval (FS: 43.5%; FV: 4.5%) and round (FS: 58%; FV: 0.5%) foramina were observed. In addition, the relationship of the FS and FV to FO was recorded: postero-lateral (FS: 93%; FV: 0%); posterior (FS: 1.9%; FV: 0%); postero-medial (FS: 0.5%; FV: 0%); anterior (FS: 0%; FV: 0.5%); antero-medial (FS: 0%; FV: 4.5%). The mean morphometric parameters of the FS and FV included the internal diameter (FS: 2.53±0.76 mm; FV: 1.93±0.46 mm), external diameter (FS: 2.50±0.74 mm; FV: 2.81±1.53 mm) and distance to the FO (FS: 3.45±1.29 mm; FV: 2.63±1.24 mm). In light of the morphometric and morphological variations of skull-based foramina, the evaluation of the FS and FV in our study may provide a reliable osteometric reference in clinical practice which may be beneficial during interpretation of imaging and surgical intervention.

KEY WORDS: Foramen spinosum; Foramen venosum; Foramen of Vesalius; Middle cranial fossa; Greater wing of sphenoid bone.

INTRODUCTION

The greater wing of the sphenoid bone is marked by numerous foramina which transmit vital neural and vascular structures (Dogan *et al*., 2014). These foramina are characteristically situated along the medial aspect of the floor of the middle cranial fossa. Many variants have been described in the anatomic and radiologic literature which is not only important to understand the complex regional neurovascular anatomy but also to distinguish the normal from the potentially abnormal structures (Curtin *et al*., 1984; Pandolfa *et al*., 1987).

One such foramen is the Foramen Spinosum (FS) which is located in close proximity postero-lateral to Foramen ovale (FO) and transmits the middle meningeal vessels, the meningeal branch of mandibular nerve and the nervous spinosus (Dogan *et al*.; Srimani *et al*., 2014). The transmission of these neurovascular structures allows for communication between the middle cranial and the infratemporal fossae (Kwathai *et al*., 2012; Srimani *et al*.).

In addition, the foramen venosum (Foramen of Vesalius) (FV) is occasionally present within the greater wing of the sphenoid bone (Wood-Jones, 1931; Chaisuksunt *et al*., 2011). The FV is also known as the sphenoid emissary foramen, foramen venosum and canaliculus sphenoidalis and usually opens into the scaphoid fossa infero-laterally (Bergman *et al*., 2006; Shaik *et al*., 2012). Although the relatively small FV is unique to humans due to its inconsistency, it is generally situated antero-medial to the FO (Wood-Jones; Chaisuksunt *et al*.; Shaik *et al*.). The name of FV is derived from the structure it transmits intracranially, the small emissary vein or "*Vein of Vesalius*", through which the pterygoid plexus and cavernous sinus communicate in

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the parapharyngeal space (Henderson, 1966; Gupta *et al*., 2005; Chaisuksunt *et al*.; Shaik *et al*.). Henderson stated that occasionally this emissary vein may be a venous sinus which exits through the anterior aspect of FO when FV is absent; thus non-visualization is a known anatomic variation. Additionally, Fisher (1913) reported entry of the meningeal branch of ascending pharyngeal artery into FV; while Lang (1983) and Gupta *et al*. described a small nerve, the "nervoulus sphenoidalis lateralis", passing through this foramen to the cavernous sinus.

As the FO is regarded as an easily accessible portal to the mandibular division of the trigeminal nerve during percutaneous trigeminal rhizotomy and neural blockade anesthesia, the proximity of the FS to the FO may render the middle meningeal vessels vulnerable to iatrogenic injury, thereby increasing the risk of extradural hematomas (Shaik *et al*.; Srimani *et al*.). Since the emissary vein connects the intracranial venous sinuses with the extracranial veins, the FV presents a passage along which a diseased thrombus may pass from the exterior into the interior of the cranium (Gupta *et al*.; Chaisuksunt *et al*.; Shaik *et al*.). The FV is also considered to be one of the most pathologically affected foramina as tumors of nasopharyngeal origin often tend to invade the middle portion of the skull base (Lanzieri *et al*., 1988).

In view of the surgical and anesthetic explorative maneuvers involving the skull-base, an accurate osteometric evaluation of the FS and FV including their relative incidences, shapes, morphometric details, respective relations to the FO and/or presence of any anomalies bears much significance. Therefore, this study aimed to document the morphology and morphometry of the FS and FV.

MATERIAL AND METHOD

Osteometric investigations were performed on 100 randomly selected dry human skulls which were obtained from the existing osteological bank at the Department of Clinical Anatomy, University of KwaZulu-Natal. Metric as well as non-metric parameters were analyzed and a database was created (n= 200). A total of 213 foramina were identified (106 right, 107 left). Measurements were recorded with a digital caliper (Wilson Wolpert 110-15DAB, Netherlands). The shape, mean width, distance of FV and its relation to FO were calculated as a percentage of the total number of foramina on each side. Statistical analysis was conducted using a paired T-Test and significant parameters were values whose reality level was ≤0.05. These results were compared with those available in the literature.

RESULTS

All foramina were described as separate entities. There was no confluence of FS with FV or FO or vice versa. No statistically significant differences between sides were observed.

Morphological features of the FS and FV were recorded as follows:

i) Incidence (n= 200): single (FS: 95%; FV: 5%); duplicate (FS: 2.5%; FV: 0%); triplicate (FS: 0.5%; FV: 0%); absent (FS: 2%; FV: 0%) (Figs. 1–4, Table I);

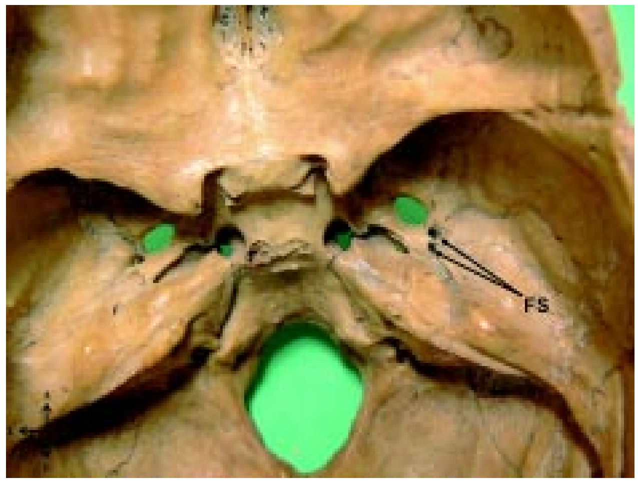

Fig. 1. Superior view of middle cranial fossa demonstrating duplicate FS. Key: A= Anterior; FS= Foramen spinosum; L= Lateral; M= Medial; P= Posterior.

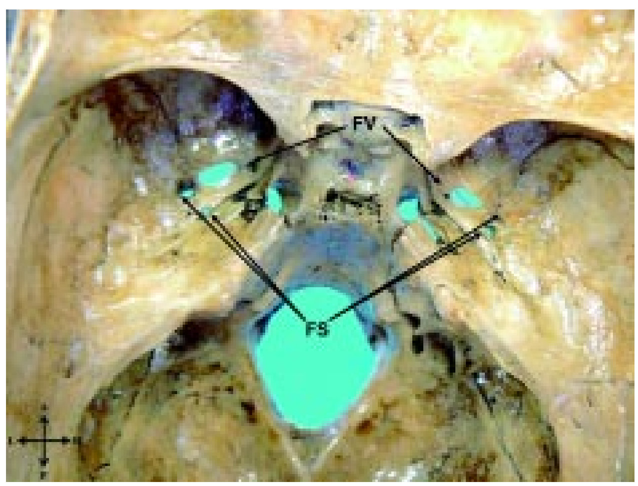

Fig. 2. Superior view of middle cranial fossa demonstrating duplicate FS and single FV bilaterally. Key: A= Anterior; FS= Foramen spinosum; FV= Foramen Venosum; L= Lateral; M= Medial; P= Posterior.

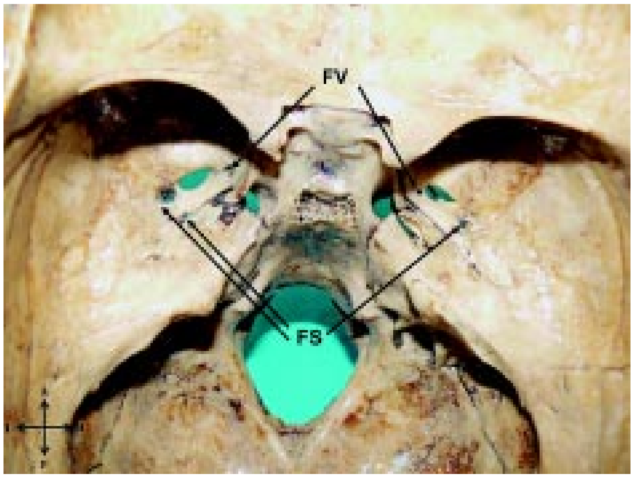

Fig. 3. Superior view of middle cranial fossa demonstrating duplicate FS and single FV on the left side and single FS and FV on the right side. Key: A= Anterior; FS= Foramen spinosum; FV= Foramen Venosum; L= Lateral; M= Medial; P= Posterior.

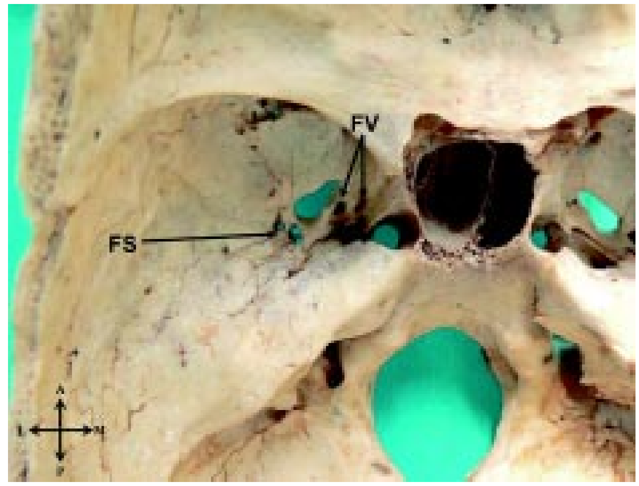

Fig. 4. Superior view of the middle cranial fossa demonstrating triplicate FS and duplicate FV on the left side. Key: A= Anterior; FS= Foramen spinosum; FV= Foramen Venosum; L= Lateral; M= Medial; P= Posterior.

Table I. Morphology and morphometry of FS and FV.

Parameter	**Foramen Spinosum**			**Foramen Venosum**		
Incidence	**R (n= 100)**	**L (n= 100)**	**Total (n= 200)**	**R (n= 100)**	**L (n= 100)**	**Total (n= 200)**
Single	95 (95%)	95 (95%)	190 (95%)	5 (5%)	5 (5%)	10 (5%)
Duplicate	3 (3%)	2 (2%)	5 (2.5%)	---	1 (1%)	1 (0.5%)
Triplicate	---	1 (1%)	1 (0.5%)	---	---	---
Absent	2 (2%)	2 (2%)	4 (2%)	---	---	---
***Shape**	**R (n= 106)**	**L (n= 107)**	**Total (n= 213)**	**R (n= 106)**	**L (n= 107)**	**Total (n= 213)**
Oval	39 (36.8%)	48 (44.9%)	87 (43.5%)	4 (3.8%)	5 (4.7%)	9 (4.5%)
Round	62 (58.5%)	54 (50.5%)	116 (58%)	1 (0.9%)	---	1 (0.5%)
***Mean diameter (mm)**						
Internal	2.47 ± 0.73	2.59 ± 0.78	2.53 ± 0.76	2.06 ± 0.19	1.79 ± 0.73	1.93 ± 0.46
External	2.46 ± 0.72	2.54 ± 0.76	2.50 ± 0.74	2.83 ± 1.65	2.79 ± 1.40	2.81 ± 1.53
***Distance to FO (mm)**	3.44 ± 1.32	3.46 ± 1.26	3.45 ± 1.29	2.83 ± 1.59	2.42 ± 0.88	2.63 ± 1.24
***Relation to FO**						
Postero-lateral	99 (93.4%)	99 (92.5%)	198 (93%)	---	---	---
Posterior	2 (1.9%)	2 (1.9%)	4 (1.9%)	---	---	---
Postero-medial	---	1 (0.9%)	1 (0.5%)	---	---	---
Anterior	---	---	---	1 (0.9%)	---	1 (0.5%)
Antero-medial	---	---	---	4 (3.8%)	5 (4.7%)	9 (4.5%)

* Shape, Mean length, distance and relation to FO were calculated as a percentage of the total number of foramina on each side

ii) Shape (n= 213): oval (FS: 43.5%; FV: 4.5%); round (FS: 58%; FV: 0.5%) (Table I);

iii) Relation to FO: postero-lateral (FS: 93%; FV: 0%); posterior (FS: 1.9%; FV: 0%); postero-medial (FS: 0.5%; FV: 0%); anterior (FS: 0%; FV: 0.5%); antero-medial (FS: 0%; FV: 4.5%) (Table I).

Mean morphometric parameters pertaining to the FS and FV and their relation to FO were documented:

i) Internal diameter (FS: 2.53±0.76 mm; FV: 1.93±0.46 mm) (Table I);

ii) External diameter (FS: 2.50±0.74 mm; FV: 2.81±1.53 mm) (Table I);

iii) Distance to FO (FS: 3.45±1.29 mm; FV: 2.63±1.24 mm) (Table I).

DISCUSSION

The FS is typically located postero-lateral to FO (93% in this study), along the postero-medial aspect of the greater wing of the sphenoid bone and is usually round or oval in shape (Ginsberg *et al*., 1994). This study also describes posterior and postero-medial locations of the FS in relation to the FO (Table I).

The FS was absent in 2% of cases in our study (Tables I and II). It is postulated that in the absence of a FS, the middle meningeal artery enters the cranial cavity through the FO (Reymond *et al*., 2005). Ginsberg *et al*. provide an additional explanation of the absence of a FS in the case of an aberrant middle meningeal artery which arises from the stapedial branch of the internal carotid artery or the ophthalmic artery (Lindblom, 1936; Paullus, 1977). Fisher (1914) and Greig (1929) have explained the embryologic development of the middle meningeal artery. The stapedial artery originates as a dorsal branch of the second aortic arch and is part of the carotid arterial system (Fisher; Greig). In the 15mm embryo, the infraorbital and mandibular branches of the stapedial artery fuse with the external carotid artery and are destined to become the internal maxillary artery (Fisher; Greig). The main trunk of the stapedial artery atrophies and its origin from the internal carotid disappears (Fisher; Greig). The usual distribution of the stapedial artery is then replaced by branches from the external carotid artery (Fisher; Greig). If the connection with the external carotid artery fails to occur, the superior or supraorbital branch of the ophthalmic artery becomes the middle meningeal artery (Fisher; Greig). In this case the middle meningeal artery enters the skull through the superior orbital fissure. Lindblom reported this variation in 0.4% of cases. However, the stapedial artery may also persist. This vessel has also been associated with an aberrant internal carotid artery. The persistent stapedial artery courses through the tympanic cavity, between the crura of the stapes and enters the facial canal distal to the geniculate ganglion. It enters the middle cranial fossa by the facial hiatus and becomes the middle meningeal artery. In both of these cases of a variant middle meningeal artery, the FS will be tiny or absent (Ginsberg *et al*.).

Table II. Incidence and shape of foramina spinosum and venosum in a review of literature.

Author (year)	Sample size	Incidence (%) Spinosum	Incidence (%) Venosum
Incidence: Absent			
Lindblom (1936)	Not recorded	0.4	---
Berlis *et al.* (1992)	60	0.8	64.0
Ginsberg *et al.* (1994)	123	3.2	20.3
Kim *et al.* (1997)	163	2.5	45.4
Sharma & Garud (2011)	50	---	38.0
Chaisuksunt *et al.* (2012)	754	---	89.1
Present study	***200***	***2.0***	---
Incidence: Single			
Sondheimer (1971)	50	---	15%
Lang (1983)	Not recorded	---	40.0
Lanzieri *et al.* (1988)	54	---	72.2
Ginsberg *et al.* (1994)	123	48	80.0
Kim & Kim (1995)	305	---	47.5
Kim *et al.* (1997)	163	---	51.5
Kodama *et al.* (1997)	400	---	21.8
Teul *et al.* (2002)	187	100	---
Gupta *et al.* (2005)[a]	35	---	42.9
Reymond *et al.* (2005)	100	100	17.0
Sharma & Garud (2011)	50	100.0	62.0
Chaisuksunt *et al.* (2012)	754	---	10.9
Kwathai *et al*. (2012)	206	52.4	---
Shaik *et al.* (2012)	250	---	36.0
Dogan *et al.* (2014)	62	---	32.3
Ozer & Govsa (2014)	344	---	34.8
Srimani *et al*. (2014)	80	---	5.0
Present study	***200***	***95.0***	***5***
Incidence: Duplicate			
Ginsberg *et al.* (1994)	123	0.8	13.8
Kim *et al.* (1997)	163	---	3.1
Ozer & Govsa (2014)	344	---	0.6
Present study	***200***	***2.5***	***0.5***
Incidence: Triplicate			
Present study	***200***	***0.5***	---
Shape: Oval			
Kwathai *et al*. (2012)	206	39.3	---
Srimani *et al.* (2014)	80	30	---
Lazarus et al. (2014)	***213***	***43.5***	***4.5***
Shape: Round			
Kwathai *et al.* (2012)	26	43.2	---
Srimani *et al.* (2014)	80	51.3	---
Present study	***213***	***58***	***0.5***

In this study single FS appeared in 95% of cases which corroborated the findings of previous studies (Table II). Duplicate FS were observed in 2.5% of cases vs. 0.8% recorded by Ginsberg *et al*. (Table II). Duplication can be explained by early division of the middle meningeal artery into a posterior and anterior division resulting in a duplicate FS (Lindblom; Sondheimer, 1971; Reymond *et al*.). The literature reviewed remains silent on the course of the meningeal branch of the mandibular nerve in the absence or duplication of a FS.

FS was observed at a distance of 3.45±1.29 mm to FO which compared favorably to that reported by Paullus *et al*. and Aslan *et al*. (1998) (Table III).

Table III. Distance of foramen spinosum to foramen ovale in a review of literature.

Author (year)	Distance (mm)	Range (mm)
Paullus *et al*. (1977)	3.2	1.0–6.0
Aslan *et al*. (1998)	3.7	2.0–11.0
Present study	**3.5**	**0.9–8.6**

The internal and external diameters of FS varied from side to side but did not usually exceed 3 mm (Table I). Table IV describes diameters of FS culled from the literature. According to Sondheimer, in the instance of the diameter exceeding 5 mm, the patient should be immediately evaluated for middle meningeal artery abnormality.

The FV is regarded as a small opening in the medial aspect of the greater wing of the sphenoid bone antero-medial to FO. In this study FV was located anterior (0.5%) or antero-medial (4.5%) to FO (Table I). Single (5%) and duplicate (0.5%) FV were observed which correlated with the wide range in incidence of this foramen reported in the literature reviewed (0.6–80%) (Table II). In the absence of the FV, the respective emissary vein leaves the skull through the FO (Henderson). It is also postulated that the emissary vein is a dural venous sinus rather than a vein (Henderson). In addition, Lang and Gupta *et al*. described a small nerve, the nervoulus sphenoidalis lateralis, which may also pass through the FV into the cavernous sinus.

The FV was identified to be situated 2.63±1.24 mm from the FO, a finding which may be regarded as a unique reference measurement as it has not been reported in previous literature. The internal and external diameters were found to be 1.93±0.46 mm and 2.81±1.53 mm, respectively, which were markedly increased in comparison with the values recorded in earlier studies (Table IV). Ozer & Govsa (2014) explained that the FV presenting with a diameter of less than 0.5 mm are most reliable and safe during percutaneous practice as apertures of greater than 0.5 mm pose a major risk on the adjacent FO.

Table IV. Diameter of foramina spinosum and venosum in a review of literature.

Author (year)	F. Spinosum (mm)	F. Venosum (mm)
Sondheimer (1971)	1.50–3.0	---
Lang *et al*. (1984)	2.1	1.1
Yanagi (1987)	2.7	---
Berlis *et al*. (1992)	1.9	1.0
Aslan *et al*. (1998)	---	---
Sharma & Garud (2011)	2.6	---
Chaisuksunt *et al*. (2012)	---	1.5±0.7
Kwathai *et al*. (2012)	2.2	---
Dogan *et al*. (2014)	1.9±0.4	1.3±0.5
Ozer & Govsa (2014)	---	0.9±0.3
Srimani *et al*. (2014)	---	---
Present study	**2.5**	**2.4**

Many authors have claimed that the variations observed in skull-based foramina may be a result of the evolutionary process such that the incidence of a specific previously-observed variant may later be considered to be the variant-normal or constant of a particular geographical population and/or ethnic group (Sharma & Garud, 2011).

CONCLUSION

In this study the evaluation of the FS and FV and their respective relationships to FO may provide a reliable osteometric standardization of the alisphenoid structures in the middle cranial fossa. The recognition and knowledge of the normal and abnormal foramen anatomy may assist in misinterpretation during various imaging procedures. As a connecting passage, the significance of the FV lies in thorough surgical intervention to prevent puncture of the trigeminal cave and cavernous sinus as well as subsequent hemorrhage of the temporal lobe. Therefore, the above information may serve as a guideline to surgeons, radiologists and anesthetists.

LAZARUS, L.; NAIDOO, N. & SATYAPAL, K. S. Una evaluación osteométrica de los forámenes espinoso y venoso. ***Int. J. Morphol., 33(2)***:452-458, 2015.

RESUMEN: El foramen espinoso (FE) y foramen venoso (FV) son aberturas situadas en el centro de la fosa craneal media en las proximidades de un foramen oval permeable (FO). El FE y FV proporcionan el acceso a importantes estructuras neurovasculares. Un conocimiento preciso de los datos morfométricos del FE y FV, incluyendo su forma, incidencia, relación con otros forámenes o presencia de cualquier anomalía puede representar un punto de referencia anatómica fiable durante las maniobras exploratorias quirúrgicas. El objetivo de este estudio fue investigar las características morfológicas y morfométricas del FE y FV. El estudio se realizó sobre 100 cráneos humanos secos (n= 200) obtenidos del banco osteológico de la Universidad de KwaZulu-Natal, para producir una base de datos que pueda servir como guía útil para los cirujanos y anestesistas. Se identificaron FE únicos (95%), dobles (2,5%) y triples (0,5%); junto a FV únicos (5%) y dobles (0,5%). Según forma, se encontraron forámenes de tipo oval (FE: 43,5%; FV: 4,5%) y circular (FE: 58%; FV: 0,5%). Además, se registró la relación entre FE, FV y FO: postero-lateral

(FE: 93%; FV: 0%); posterior (FE: 1,9%; FV: 0%); postero-medial (FE: 0,5%; FV: 0%); anterior (FE: 0%; FV: 0,5%) y antero-medial (FE: 0%; FV: 4,5%). Los parámetros morfométricos medios de los FE y FV incluyeron el diámetro interno (FE: 2, 53±0,76 mm; FV: 1,93±0,46 mm), diámetro externo (FS: 2,50±0,74 mm; FV: 2,81±1,53 mm) y distancia al FO (FS: 3,45±1,29 mm; FV: 2,63±1,24 mm). Considerando la morfometría y las variaciones morfológicas de los forámenes en la base del cráneo, la evaluación del FE y FV puede proporcionar una referencia osteométrica fiable en la práctica clínica, que puede ser beneficiosa durante la interpretación imagenológica y la intervención quirúrgica.

PALABRAS CLAVE: Foramen espinoso; Foramen venoso; Foramen de Vesalio; Fosa craneal media; Ala mayor del esfenoides.

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