VARIANTS OF MASTOID AND OCCIPITAL EMISSARY FORAMENS AND THEIR CLINICAL CORRELATION

Ivan Maslarski¹, Lyudmila Belenska-Todorova²

1) Department of Anatomy, Histology, Pathology and Forensic medicine, Faculty of Medicine, University of Sofia, Bulgaria.

2) Department of Biology, Medical Genetics and Microbiology, Faculty of Medicine, University of Sofia, Bulgaria.

ABSTRACT

Purpose: Emissary foramina in the skull and emissary veins (EV), respectively, have been known for a long time, but their importance is often disregarded. In the present study, we introduce variants of occipital emissary foramina (OEF) unilaterally located on the left, close to the occipital condyle in a formation of three apertures that open together in a sinus near clivus.

Material/Methods: Corpses of 30 dead people were dissected in the Department of Anatomy, and standard techniques for soft tissue separation or maceration of the skull were used. After the removal of the calvaria, fixed bones of the skull were disarticulated. Foramina were cleaned using a double-ended probe, and depth and diameter measurements were performed using an anatomical caliper.

Results: We found variants of mastoid emissary foramina (MEF) situated into two groups, each of a couple of foramina. Their clinical significance is discussed, compared with existing experience and analysis of their phylogeny and embryogenesis.

Conclusion: We introduce OEF and MEF to be important markers for detection of dural venous sinuses (DVS). The latter, together with EV, provide an important mechanism for decreasing intracranial pressure. This happens due to the absence of a valve apparatus in the veins of the brain, and the lack, or small amount, of muscle tissue. There is a possibility of existing varicose veins, such as those caused by arterio-venous fistulas and the pathology associated with it. We suggest the application of EV in imaging as an important study before surgery by lateral and transcondylar approach to the anterior foramen magnum.

Keywords: emissary veins, arteriovenous fistula, dural venous sinuses, intracranial pressure,

INTRODUCTION

Morphological differences between the skulls of humans have long been a subject of investigation. There is more data from anthropological studies, as the variations are related to the phenotypic manifestation of skull scars, such as pronounced superciliary arch, zygomatic arch, ex-

ternal protuberance of occipital bone or superciliary arch. Additional openings or foramina of the skull are of interest according to an anatomical and neuro-surgical point of view (fig.1). The existing additional emissary foramina are of the little studied variations in the human skull. These are the apertures that are located near the normally existing openings in the skull for the penetration of small veins, which later merge into sinuses and drain to larger vessels, finally connecting to the system of the superior vena cava. Analysis of the literature shows that emissary foramina (EF) are relatively rarely mentioned, especially in the field of the mastoid process of the temporal bone and occipital bones [1, 2, 3, 4]. It is noteworthy that the presence of emissary openings is often overlooked by neurosurgeons and is described as accidental or rare. The same is their description in a number of atlas books in anatomy and neurology. Keskil et al. suggest that any variation in the skull needs to be described and studied to ensure safe head and neck surgery [5]. Knowledge of the openings in the base of the skull and the vital vessels and nerves passing through them in combination with the options is a good basis for distinguishing between normal and possible pathology in the cranial cavity [6, 7]. There are many cases of misinterpretation of variations in the cranial foramina and subsequent complications during clinical interventions. We can summarize that the emissary's veins are related to the regulation of intracranial pressure, and if necessary, they can export blood to the venous sinuses of the skull and from there to the extracranial veins. It should be noted that the veins in the brain do not have muscles and valve apparatus. This implies a slow movement of blood in these areas and the ability to return in the opposite direction.

Emissary veins and foramina, as well as intracranial sinuses or dural venous sinuses, are important for the lateral and transcondylar approach to anterior foramen magnum surgery. The localization of this type of vessels and openings could prevent complications such as sinus thrombosis, bleeding, and air embolism [8]. Another clinical application of variations of the emissary openings is in fractures or injuries of the temporal, occipital or parietal bones. Tomography and imaging are generally helpful in these cases and will contribute to the classification and topo-

graphic location of the vessels described. Emissary openings and vessels are important not only for preparing surgical techniques used for stopping bleeding or for lowering intracranial pressure, but also they are a route of transmission of infections in the cranial cavity [9, 10]

Fig. 1. Representative image of dural sinuses in skull and blood circulation; SPHS – sphenoparietal sinus; TS – transverse sinus; SS – sigmoid sinus; SPS – superior petrosal sinus; CS – cavernous sinus.

MATERIALS AND METHODS

Corpses of 30 dead people were dissected in the Department of Anatomy, and the available skulls were analyzed for variations of emissary openings in terms of their description, location and clinical correlation. Twenty of the corpses were female and ten were male. In cases where the openings were at the border of the sutures between the bones, it was necessary to carefully disarticulate them while preserving the suture structure and examining the passability of the emissary canals. The small diameters and curved course of the canal vascular structures were examined using a soft microprobes tip.

RESULTS

Of the 30 skulls examined, only three of them revealed emissary variations with clinical significance. This makes up about 10 percent of the skulls studied.

In skull number 1, there was a single emissary hole located near the occipitomastoid suture and at the base of the mastoid process (Fig.2).

Fig. 2. Mastoid emissary foramen in skull 1; OMS – occipitomastoid; MEF – mastoid emissary foramen.

The opening on the outgrowth was relatively wide, then the channel narrowed considerably, curved in the direction of the suture and flowed through a very small opening into the sigmoid sinus.

In skull number 2, a group of five emissary holes of different caliber was observed, which formed the shape of the letter V on the mastoid process of the temporal bone (Fig. 3). The largest emissary foramen was relatively separate from the others and was close to the occipitomastoid suture. The diameter decreases sharply towards the cranial cavity and opens into the transverse sinus. The other holes were combined in pairs. In the center of the mastoid process, 2 emissary openings with well-defined grooves were located above each other. The two openings merged just before flowing into the boundary between the transverse sinus and the sigmoid sinus (Fig. 3). The last pair of openings were located on the parietomastoid suture itself, their position being oblique relative to each other, following the natural course of the described suture. The two holes transversely pierced the suture and fell into the superior petrosal sinus (Fig. 3).

Fig. 3. V shaped formation of mastoid emissary foramens; PMS – parietomastoid suture; MP- mastoid process; UMEF – upper mastoid emissary foramens; TS – transverse sinus; LMEF – lower mastoid emissary foramens; SS – sagittal sinus; OMS – occipitomastoid suture; SPS – superior petrosal sinus.

Careful disarticulation of the suture located between the temporal bone and the parietal bone showed well-developed two vascular openings of dense bone.

In skull number 3, there was a remarkable variation in the area of the foramen magnum (Fig. 4, Fig. 5). On the left side of the condylar fossa were symmetrically arranged three holes forming a triangle (Fig. 5). One of the described emissary openings had a well-defined groove.

The three openings united and fell into the area of the clivus and the connection between the occipital sinus and the basilar plexus. The union of the three openings can be seen in (Fig. 5). Two openings were observed on the opposite side or near the inner right condylar fossa (Fig. 4). The proximal opening was smaller in diameter than the distal one, with both openings merging into the clivus and flowing into the occipital sinus.

Fig. 4. Occipital emissary foramens near the right condylar process; FM- foramen magnum; OEF – occipital emissary foramen; MOEF – medial occipital emissary foramen; LOEF – lateral occipital emissary foramen; CP – condylar process

Fig. 5. Occipital emissary foramens near the left condylar process; CC- condylar canal; FM – foramen magnum; CF – condylar fossa; OEF – occipital emissary foramen

DISCUSSION

Emissary veins and their function, origin, classification and clinical correlation have not been well studied. In this article, we discuss their origin, their relationship with intracranial blood circulation, pathologies, related variations of emissary veins and their corresponding openings. The phylogeny of their appearance and subsequent embryonic development in the human species should be considered concerning the origin of these vessels and the presence of variants. Anthropological studies show that from prehistoric

man to Homo sapiens, the skull undergoes changes not only in terms of brain volume, smoothing of the supraciliary arcus and a number of protrusions, but also with respect to the openings (foramens). The mastoid foramen is used as a hallmark to distinguish the skulls of contemporary humans from those of prehistoric ones. This hole is also one of the common EFs [4]. Adaptation associated with standing and walking with two limbs leads to physiological changes in the venous system of the base of the skull, as well as their organization with deeper sinuses. This leads to the reorgani-

zation of the entire drainage apparatus intracranially. A comparison of the presumed venous circulation of Australopithecus and Contemporary man shows that the occipital sinus is highly developed in both of them due to upright standing, and the volume of circulating blood in the described vessel decreases, leading to the formation of new veins [3, 10]. Among these new veins are the emissary ones. Evolution also shows changes in the contact of the emissary veins and the located intracranial sinuses. An example is an extensive use of the sigmoid sinus, which drains into the vertebral venous plexus when the body is upright and the internal jugular vein when lying down [4]. Regarding the embryonic development of EV, the literature is relatively scarce. The emissary veins of the hypoglossal canal are the first to appear in embryogenesis, occurring during 2 weeks after fertilization. EVs of the parietal bone are the last to appear in embryonic development and are remnants whose vascular system is thought to be associated with epiphyseal structures characteristic of some vertebrates [11]. The appearance of more EV can be observed during embryonic period 7, in which the notochordal process occurs immediately rostral to the primitive node and streak [12]. Approximately in the third fetal month appear the mastoid, anterior, and posterior condylar emissary vessels. A significant increase in their size occurs in the 5th month, and their connection with the intracranial sinuses occurs in the seventh and eighth months of pregnancy. The formation of the transversal sinus is considered to be a hallmark for the completion of embryonic development of EV.

EVs are often underestimated, and their presence has been considered as variants of little relevance to the clinic and physiology of venous circulation. In the literature, the main variants of emissary's veins are mastoid emissary foramen, parietal emissary foramen, sphenoidal emissary foramen, occipital emissary foramen, emissary veins of foramen ovale, caecum and clivus. Unlike the described vessels, the venous sinuses are permanent structures, without variations in their position, but with a different degree of organization of the volume of blood flowing through them and from the vessels that are included in their system. The combination of emissary's veins, including their variations, and the sinuses in which they drain is of clinical and physiological significance.

Mastoid emissary veins (MEV) that we describe are closely located and open between the transverse sinus and sigmoid sinus, as well as two other MEVs located along the parietomastoid suture itself which transversely pierce the skull and fall into the superior petrosal sinus (fig. 3). This position of EV is important as a surgical landmark for the described venous sinuses, as well as to be a cause of hemorrhage during surgery in the head, middle ear, especially in the so-called retrosigmoid approach. Postoperative complications in the presence of MEV and their involvement is the occurrence of epidural hematoma or air embolism. We observed in the skull 2 a midline of the MEV deep grooves and dilated canals, caused probably by a vascular malformation. There is a typical symptom characterized by tinnitus in the presence of dilated veins on the MEV [4]. MEV may act as an alternative route for the

spread of infections and tumors arising in the facial area and infratemporal fossa [3, 13].

The mastoid emissary vein may also be a route of the distribution of infections or tumors occurring in the face and infratemporal fossa [5]. We mentioned that MEV is the most common variation of EV, and this can be explained evolutionarily by the upright posture of the human body and the movement of the hands. Moreover, the MEV cranial openings are an important anatomical feature for distinguishing hominid species in anthropology.

We observed two MEV openings of skull 2 located on the suture, separating the temporal and parietal bones and flowing into the superior petrosal sinus. Here we can suspect the presence of cavernous and petrous thrombosis. This often occurs in patients with a neck infection, inner ear malformations or an underdeveloped jugular vein. Another dangerous site for the penetration of infectious agents into the venous sinuses is the area of skin above the apex nasi and the orbit. This area of the face is also the most dangerous in terms of the transition of abscesses to the sagittal sinus superior and from there to the other dural sinuses.

The MEV can serve as a bypass drainage route for venous sinus obstruction. This occurs in direct anastomoses or shunts between small arterioles and venules and the appearance of dural arteriovenous fistulas. It is similar to the dilations of the mastoid emissary veins described by us. MEVs are an important navigational method for detecting fistulas in vascular malformation and removal of this type of aneurysm in surgery.

We observed in the skull 3 triangular-shaped small occipital sinuses symmetrically located near the foramen magnum and to the left of the condylar fossa. In the literature, occipital emissary veins (OEV) are also named clivus emissary veins (emissary veins of the clivus), and these variations are among the rarest. Apart from the presence of these openings and venous vessels, respectively, we suggest that it is important to pay attention to their exact position and location relative to the foramen magnum and condylar fossa. Usually, these types of openings are located on the inside near the occipital basis. Formation of openings near the clivus that drain between the clivus, occipital sinus and basilar plexus have not been reported yet. The three openings that we observed unite and fall into the area of the clivus and the connection between the occipital sinus and the basilar plexus. The presence of several OEVs also shows a peculiar course of connection between the dural and deep sinuses of the skull and the corresponding large venous vessels, such as the brachiocephalic veins and jugular ones. We observed two emissary openings in the right part of the skull, on the inside of the condylar process. This was a double variation, which was asymmetric, and the occipital sinus was used for draining. The occipital sinus was located in the clivus and had a direct connection with the vertebral extradural sinuses. These findings point to the probability of spreading infections from the dural sinuses to the described large venous vessels and vice versa. Vessel ligation in craniocerebral interventions can be essential for future microcirculation bypass pathways and regulation of intracranial pressure. OEVs are especially important for suboccipital exposure in surgery

or anatomical dissection. This approach is applied to access the posterior cranial fossa in pathology and is always accompanied by injuries in the area of the posterior edge of the foramen magnum. One of the OEV foramen has an enlarged opening and a clearly visible leading groove. Together with the small accessory foramina in the skull 3, it forms complex microcirculatory anastomoses targeting dural sinuses. Miyachi et al. proposed a mechanism for the formation of dural arteriovenous fistulas [13]. According to these authors, dilatation of the vessel occurs in the presence of local inflammation of the EV. In our case, we can assume that the groove and dilated opening of the OEV are a result of inflammation and subsequent neovascularization and the formation of aberrant connections to nearby vessels. It should be considered that we observed unilateral expression of OEVs. As a result, micro fistulas are formed, and a change in normal vascular circulation appears. On the other hand, OEVs are important structures for the effective cooling of the head. Any deviation in their structure could disturb the proper cooling and the effective regulation of the pressure in the skull.

CONCLUSION

Variations, amount and location of EV are essential for surgical practice and anatomical dissection of the head and neck. The classification and detailed description of their location are indispensable for the emergence of many pathologies as an option for the spread of tumors and the formation of fistulas. Purulent infections can pass bilaterally between the dural sinuses and the intracranial and facial-cranial structures. The described rare variants of EV also suggest a more detailed study in terms of creating “bypass” vascular routes, reducing intracranial pressure and effective venous drainage in an upright position and cooling of venous blood circulation through the head. This type of variable emissary findings, in combination with Doppler ultrasonography, is an important way to avoid side effects from surgery, such as dural hematomas and air embolism. The classification and description of the EV position will also determine the approach to surgery and the possible spread of tumors and abscesses.

REFERENCES:

1. Murlimanju BV, Prabhu LV, Pai MV, Jaffar M, Saralaya VV, Tonse M, et al. Occipital emissary foramina in human skulls: an anatomical investigation with reference to surgical anatomy of emissary veins. *Turk Neurosurg.* 2011 Jan;21(1):36-8. [PubMed]
2. Jeleu L, Malinova L. Occipital emissary foramina in human skulls: review of literature and proposal of a classification scheme of the occipital venous anastomoses in the posterior cranial fossa. *Anatomy.* 2020 Apr;14(1): 11-15. [Crossref]
3. Halagatti M, Sagar S. An Anatomical study of parietal emissary foramina in dry adult human skulls. *Int J Anat Radiol Surg.* 2018 Apr;7(2):A020-A022.
4. Freire AR, Rossi AC, de Oliveira VCS, Prado FB, Caria PHF, Botacin PR. Emissary foramina of the human skull: Anatomical characteristics and its relations with clinical neurosurgery. *Int J Morphol.* 2013; 31(1):287-292.
5. Keskil S, Gözil R, Calgüner E. Common surgical pitfalls in the skull. *Surg Neurol.* 2003 Mar;59(3):228-31. [PubMed]
6. Mortazavi MM, Tubbs RS, Riech S, Verma K, Shoja MM, Zurada A, et al. Anatomy and pathology of the cranial emissary veins: a review with surgical implications. *Neurosurgery.* 2012 May;70:1312-8. [PubMed]
7. Okudera T, Huang YP, Ohta T, Yokota A, Nakamura Y, Maehara F, et al. Development of posterior fossa dural sinuses, emissary veins, and jugular bulb: morphological and radiologic study. *AJNR Am J Neuroradiol.* 1994 Nov;15(10):1871-83. [PubMed]
8. Jadhav SD, Ambali MP, Zambare BR. Sphenoidal emissary foramen and its clinical consideration. *Int J Res Med Sci.* 2016 Jul;4(7):2926-2929. [Crossref]
9. Zdilla MJ, Cyrus LM, Laslo JM, Lambert HW. Bilateral duplication of the sphenoidal emissary foramen: A case report with implications for surgeries using transovale cannulation. *Anat Physiol.* 2014; 4:4. [Crossref]
10. Leonel LCPC, Peris-Celda M, de Sousa SDG, Haetinger RG, Liberti EA. The sphenoidal emissary foramen and the emissary vein: Anatomy and clinical relevance. *Clin Anat.* 2020 Jul;33(5):767-781. [PubMed]
11. Cakmak PG, Ufuk F, Yagci AB, Sagtas E, Arslan M. Emissary veins prevalence and evaluation of the relationship between dural venous sinus anatomic variations with posterior fossa emissary veins: MR study. *Radiol Med.* 2019 Jul;124(7):620-7. [PubMed]
12. Cakmak PG, Herek D, Ufuk F, Sagtas E, Arslan M. Posterior fossa emissary venous canal prevalence and visibility on standard computed tomography. *Med-Science.* 2019 Sep;8(3):569-72. [Crossref]
13. Miyachi S, Izumi T, Matsubara N, Naito T, Haraguchi K, Wakabayashi T. Mechanism of the formation of dural arteriovenous fistula - the role of the emissary vein. *Interv Neuroradiol.* 2011 Jun;17(2): 195-202. [PubMed]

Please cite this article as: Maslarski I, Belenska-Todorova L. Variants of mastoid and occipital emissary foramina and their clinical correlation. *J of IMAB.* 2021 Oct-Dec;27(4):4004-4009. DOI: <https://doi.org/10.5272/jimab.2021274.4004>

Received: 04/03/2021; Published online: 05/10/2021

Address for correspondence:

Lyudmila Filipova Belenska-Todorova;
Department of Biology, Medical Genetics and Microbiology, Faculty of Medicine, University of Sofia.
1, Kozyak Str., 1407 Sofia, Bulgaria;
E-mail: lyudmila_bt@yahoo.com