



## Topographic and microscopic anatomical description of the emissary sinus of foramen ovale in adult humans

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### ABSTRACT

**Objective:** Although the Emissary Sinus of Foramen Ovale (ESFO) was first described by Trolard in 1868, its definition remains confused and neglected in the medical literature. This structure represents a vein, two veins, a venous plexus, or a dural sinus? Does it really exist? To understand this topic, this work aimed to describe the anatomy, topography, and microscopic features of the ESFO, precisely characterizing its structure, routes and anatomical correlations.

**Patients and methods:** ESFO from the skull's base of adults were dissected into fifty anatomical blocks and evaluated using Hematoxylin and Eosin, Picro-sirius red and Weigert staining, and by Scanning Electron Microscopy (SEM).

**Results:** ESFO was always present between cavernous sinus and pterygoid plexus on both antimeres, its inferior route passing through the foramen ovale and/or sphenoidal emissary foramen (foramen of Vesalius), anterior to the mandibular branch of trigeminal nerve. Its microscopic arrangement resembled what was found on transverse sinus, that is composed by layers of collagen fibers oriented on transversal and longitudinal planes. It wasn't possible to identify the media and adventitial tunica, features seen in veins, and the elastic layer was very thin near its lumen. SEM analysis showed that, like the transverse sinus, the ESFO was composed by parallel cells that presented a rhombus shape containing central rounded nuclei.

**Conclusion:** In summary, the venous channel passing through the foramen ovale and/or sphenoidal emissary foramen (foramen of Vesalius) is a dural venous sinus constituted by dura mater layers and should be considered during surgical approaches near the foramen ovale in the middle cranial fossa.

### 1. Introduction

The description of the main vessels responsible for the vascularization and blood drainage of the intracranial space was previously reported by the great anatomist Andreas Vesalius (1514–1564) [1,2]. In the 19th century, Cruveilhier [3] showed the communication between the vessels of the middle cranial fossa, and the vascular network outside the skull, and Trolard [4] described the blood drainage from the cavernous sinus to the pterygoid venous plexus.

Due to the complexity of the vascular network access and the intracranial blood drainage system, as the diagnostic techniques advance, more studies are dedicated to its description, which contributes not only to the diagnosis of different diseases but mainly to assist surgical intervention approaches [5–7].

Regarding the vascular system near the trigeminal nerve and its

main branches, even today the detailed description of the anatomy and topographic aspects of these vessels remain controversial [8–13].

The aim of this work was to describe the anatomy, topography and microscopic features of the Emissary Sinus of Foramen Ovale (ESFO) since, as previously described [8,14,15], this structure might be responsible for the failure of different surgical interventions in the trigeminal branches and ganglion when the access route is the foramen ovale, a route that is still used [16–20].

### 2. Material and methods

The study was approved by the Ethics Committee of research with human beings of the Institute of Biomedical Sciences, and the Committee of Ethics on Use of Animals of the School of Veterinary Medicine and Animal Science of the University of São Paulo.

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### 2.1. Sampling selection and criteria

According to age, ethnicity and gender, 50 anatomical blocks containing the peri-trigeminal region (middle cranial fossa) were dissected from adults. (Supplementary file)

### 2.2. Method of collection of anatomical block

Skull opening and removal of the brain to expose the skull base were performed like a regular necropsy procedure of the cephalic region [21], and in order to preserve the peri-trigeminal structure, the dura mater of the skull base was maintained intact.

The right and left peri-trigeminal regions were delimited according to the following anatomical landmarks: 1) *anterior*: a frontal plane passing posteriorly to the ethmoid bone and the sphenofrontal suture; 2) *posterior*: a frontal plane, parallel to the anterior, passing posteriorly through the internal acoustic meatus; 3) *lateral*: two planes parallel to each other, passing approximately 15 mm lateral to the foramen spinosum. The anatomical blocks were fixed in formalin (10%) for a period of 20 days and dissected second to the following step.

### 2.3. Dissection of anatomical blocks under binocular magnifying glass (Mesoscopy)

With the aid of appropriate surgical instruments to bilaterally expose the peri-trigeminal region under a mesoscopic magnifying glass, a continuous incision was made initially along the dura mater that covers the roof of the superior petrosal, cavernous and sphenoparietal sinus. After the lateral displacement of the trigeminal complex dura mater (motor root, ganglion, ophthalmic, maxillary and mandibular branches), the visualization of ESFO was accomplished, which in many specimens was facilitated by the presence of blood clots along the entire sinus path.

### 2.4. Histology

Histology technique was performed on ten fragments of ESFO (five of the superior and five of the inferior path), obtained from different individuals, and on five fragments of the internal jugular vein and transverse sinus (control group).

All specimens were submitted to a routine histological procedure, with 5 µm cross sections stained by Hematoxylin-Eosin, Weigert [22] and Picro-sirius red under polarized light [23].

### 2.5. Scanning electron microscopy (SEM)

This assay was performed on fragments of seven ESFOs, three of the internal jugular vein, one of the great saphenous vein and three of the transverse sinus as described in the previous step. Samples were sectioned and ultrasonically washed during ten minutes in distilled water (five washes of two minutes) and then immersed in a 70% alcohol solution for a period of 12 h. After dehydration using alcohol solutions with increasing concentrations, samples were submitted to critical point, sputtered with gold ions and then analyzed.

## 3. Results

### 3.1. Shape (Fig. 1)

A venous channel of reasonable size located under the trigeminal ganglion and near the proximal segment of the maxillary and mandibular branches was always present and observed.

The venous channel (that has a craniocaudal tapering aspect, and a curvilinear sense with an anterior concavity) had two openings at its end: the superior opening located on the cavernous sinus' floor at the level of the sphenoidal lingula, and the inferior opening that is smaller

and directed towards the foramen ovale, and establishes a communication with the pterygoid plexus. As reported by Simões [24], two shapes were observed: the pyramidal and the tubular.

#### 3.1.1. Pyramidal shape

Like a triangular pyramid with an inverted base, three walls, a base and an apex. The medial wall, which is attached to the sphenoidal bone and formed by the continuous dura mater of the cavernous sinus' floor, it crosses the external face of the sphenoid's body vertical to the lateral wall towards the foramen ovale. The anterolateral wall relates to the medial surface of the maxillary and mandibular nerves, near to its origin in the trigeminal ganglion. Regarding the medial aspect of the trigeminal ganglion and the mandibular's nerve intracranial segment, the posterolateral wall maintains a close relationship with the motor root of the trigeminal nerve. The anteroposterior and posterolateral walls represent the extension of the cavernous sinus' superior covering.

At their upper edges, these walls delimit the superior opening, or the pyramid base. Virtually truncated, the apex is related to the medial border of the foramen ovale, inferiorly communicating with the pterygoid plexus.

#### 3.1.2. Tubular shape

Concerning this form, the ESFO exhibited a cylindrical outline along its length, slightly flattened on the transverse plane and inferiorly tapered. Thus, only two walls were identified: a medial wall, which was identical in composition and in anatomical location of the described to the pyramidal shape; and a lateral wall that is contralateral to the medial wall, and results from the junction of the anteroposterior and the posterolateral walls. In these cases, both superior and inferior openings showed an elliptical outline.

#### 3.1.3. Superior opening

On both shapes (pyramidal and tubular), the medial margin was superior of the sphenoidal lingula where it was attached, and the lateral portion was at the level of the maxillary nerve' superior margin near its origin in trigeminal ganglion.

#### 3.1.4. Inferior opening

The inferior opening represented the communication between ESFO and the pterygoid plexus, regardless the shape presented. In forty-three bilateral cases, it corresponded to a transverse plane in contact with the medial margin of the foramen ovale. In seven cases, of which three was bilateral and four was unilateral, it was observed that the opening passed internally through the foramen of Vesalius (Fig. 2). Even in those cases, ESFO always communicated with the pterygoid plexus. In three cases, a case of bilateral occurrence, and cases on each side of the body, the opening was anatomically located on both foramen ovale and Vesalius, due to the ESFO emissary branch, thus creating two blood drainage pathways.

### 3.2. Topography of ESFO (Fig. 2)

Due to its topographic localization in the middle cranial fossa, the ESFO maintains a contiguity relationship with another anatomical structure located in the peri-trigeminal region. In all individuals, the lateral walls of the ESFO were adjacent to the convex margin of the trigeminal ganglion, very close to the intersection between ophthalmic and maxillary nerves, and in between the maxillary and mandibular nerves.

The ESFO was attached anteromedial to the mandibular nerve on its superior route, and to the motor root of the trigeminal nerve on its inferior route. Exceptions were found in those individuals who presented the inferior opening passing through the foramen of Vesalius. The relation between the lateral walls sinuses with the mandibular nerve and with the motor root was interrupted by the foramen ovale's medial margin.

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