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The venous plexus of Rektorzik — anatomo-clinical issues retrieved from the literature data

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Abstract: The venous plexus of Rektorzik is a network of small veins, which enlace outside the wall of the internal carotid artery while it traverses the petrous part of the temporal bone. The anatomical and clinical issues related to the communication between the plexus of Rektorzik and other cranial venous structures were discussed in this paper.

Keywords: venous plexus of Rektorzik, pericarotid venous plexus, internal carotid venous plexus, plexus venosus caroticus internus.

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Introduction

The internal carotid artery is surrounded by a network of interconnected veins of small caliber, which communicate with other veins of the intracranial venous system. The venous plexus together with the internal carotid artery, and accompanying sympathetic nerve fibers are embraced by the bony canal which traverses the petrous part of the temporal bone (Fig. 1). The average length of the carotid canal measures about 30 mm, and its diameter is usually 4–8 mm [1]. Likewise, the average length of the petrous segment of the internal carotid artery approximates 30 mm [2].

Due to the fact that the interconnected veins adhere to the wall of the internal carotid artery, they are termed as the internal carotid venous plexus, the venous pericarotid plexus or the petro-occipital venous plexus as it runs along the petro-occipital suture [3, 4].

In spite of the fact that the internal carotid venous plexus was recognized in the 19th century by Ernst Rektorzik, contemporary knowledge of its clinical significance is still scanty [5]. To date, few anatomical studies have been performed to clarify the contribution of this plexus to the blood flow through the basicranial drainage system [6–11].

Usually, in human anatomy textbooks the veins accompanying the petrous portion of the internal carotid artery are presented as a continuous plexus which merely entwines around the arterial wall. In order to verify the common way of depicting the venous plexus of Rektorzik we overviewed the current knowledge about the anatomy, physiological function and clinical role of this structure.

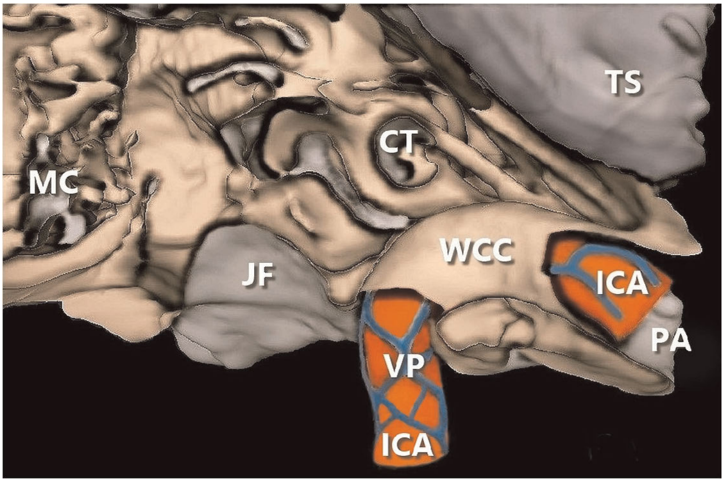

Fig. 1. Schematic demonstration of the internal carotid artery (ICA) enveloped by the venous plexus (VP) passing through the carotid canal, exposed partially in the vicinity of the petrous apex (PA). WCC — wall of the carotid canal; MC — mastoid cells; JF — jugular fossa; CT — cochlear turn; TS — temporal squama.

Materials and Methods

Review of the literature regarding the description of the venous plexus of Rektorzik was based on the articles found through web search engines like: PubMed, Google Scholar, and Google.

For illustrative purpose we used a 3D model of the petrous bone seen in cross-section to display location of the internal carotid artery surrounded by the venous plexus of Rektorzik in the carotid canal. The 3D model was created from CT scans of the dry temporal bone sample devoid of its original neurovascular structures, being the natural content of the carotid canal. Thus, the internal carotid artery was added to the virtual scene as a 3D model obtained from a geometric primitive (bended tube) whose course follows the shape of the carotid canal. Similarly, the position and appearance of the venous plexus is a graphical representation of the native structure, which is usually demonstrated in anatomical atlases as a mesh of thin veins that envelops around the petrous portion of the internal carotid artery. The final 3D model demonstrating the topographic relationship between the internal carotid artery, its venous plexus and the osseous structures of the temporal bone was created according to the rules described widely in the literature [12–16].

Anatomy and topography of the venous plexus of Rektorzik

The venous plexus of Rektorzik is formed by interconnected thin veins, arranged in an irregular mesh, which adhere to wall of the internal carotid artery, and incorporate into its outer layer — the tunica adventitia. Recent anatomical studies performed by Cironi *et al.* [7] with the aid of corrosion casts revealed a much more complicated arrangement of this plexus than previously thought. These authors recognized two distinct parts of the venous plexus surrounding the internal carotid artery and defined them as: epimembranous and submembranous, the latter being less robust and less extensive compared to the epimembranous part. Each part of the venous plexus was differently distributed along the internal carotid artery and the veins were most concentrated near the cavernous plexus [7].

Mizutani *et al.* [8] defined the venous plexus of Rektorzik as the extension of the cavernous sinus that diverges into small channels, which enter the carotid canal on the distance ranging from 1 to 22 mm, as reported Paullus *et al.* [1].

Early studies of Haike [17] performed at the beginning of the 20th century, indicate that the venous blood-spaces are mainly distributed around the horizontal and descending part of the internal carotid artery. Thereby, the venous plexus does not always completely surround the internal carotid artery. Predominantly, the venous plexus is located on the anterior or inferior side of the artery [1]. Moreover, the medial or lateral aspect of the internal carotid artery may be devoid of such a plexus, or the venous plexus is poorly developed on these sides of the artery [18].

In the first half of the 20th century, D'Avino [19] examined anatomical and histological features of the intrapetrous portion of the internal carotid artery and its relationship to its bony canal. He found that the lumen of the carotid canal is greater than that of the artery in the proportion of 5 to 3. Thus, the internal carotid artery is separated from the wall of the carotid canal by a narrow space, except the points of its entry and exit from the canal, where it firmly adheres to the bony walls. Later, Piffer and Zorzetto [20] described the organization of the connective tissue surrounding the internal carotid artery and its relationship to the wall of the carotid canal and the perivascular venous plexus. They found that the sheath of connective tissue separated the internal carotid artery from the bony wall of the carotid canal, and enclosed the artery and the vascular space containing the venous plexus, as well.

Dalgiç *et al.* [21] reported that the venous plexus often surrounds the internal carotid artery inside the periosteal sheath, whereas other authors maintain that the internal carotid artery is separated from the bony wall of the carotid canal by a prolongation of dura mater [22].

Thus, the space between the wall of the carotid canal and the wall of the internal carotid artery may facilitate the venous plexus of Rektorzik to act as a buffer during dilation and contraction of the artery [11].

Simultaneously, the venous plexus of Rektorzik may dampen arterial pulsations, and this is a probable mechanism reducing the bony transmission of sound to the cochlea. It was found that the venous plexus of Rektorzik is the most extensive in the part of the carotid canal whose wall is adjacent to the cochlea. This may support the presumption about its role in reducing the sound effect caused by the blood flow through the petrous part of the internal carotid artery [23].

Similar vascular mechanism involved in the attenuation of blood pulsation can be found in the cochlea, where tortuous arterioles of the stria vascularis dampen blood flow, thereby diminishing the impact of the arterial pulse on the hearing receptors [24]. In turn, De Ridder [25] reported that vascular loops in the internal auditory canal may generate pulsatile tinnitus, however this is not audible due to a dampening effect of the venous plexus. In contrast, arteriosclerotic changes in the internal carotid artery, or pathological processes affecting the pericarotid sheath, can cause pulsatory ringing in the ears due to sound transmission across the bony wall separating the carotid canal from the cochlea [26].

Communications between the internal carotid venous plexus and other veins

One of the main routes of blood flow is the connection of the venous plexus of Rektorzik with the cavernous sinus in the antero-superior direction, and postero-inferior connection with the internal jugular vein. However, this pathway of blood flow appeared more prominent in the fetus than in adults [27]. Occasionally, the branches from the venous plexus of Rektorzik can be tributaries of the anterior condylar confluence which is commonly formed by the confluence of the anterior, lateral and posterior condylar veins. Such an antero-posterior venous route may coexist with the other venous connections provided by the inferior petro-occipital vein (petroclival vein) which communicates the cavernous sinus with the internal jugular vein. Additionally, the venous plexus of Rektorzik may have connections to the inferior petro-occipital vein [8, 28]. The inferior petro-occipital vein may regularly exist as a tributary of the anterior condylar confluence collecting the blood from the venous plexus of Rektorzik [6].

Another venous route is provided by the diploic vein located within the clivus, which occasionally can be split into two veins that terminate in the venous plexus of Rektorzik [9]. Additionally, connections between the internal carotid venous plexus and small intraosseous veins traversing the petrous part of the temporal bone have been found in humans [10].

Aforementioned variants of the blood flow from the venous plexus of Rektorzik to other venous structures of the cranial base have been demonstrated in Fig. 2.

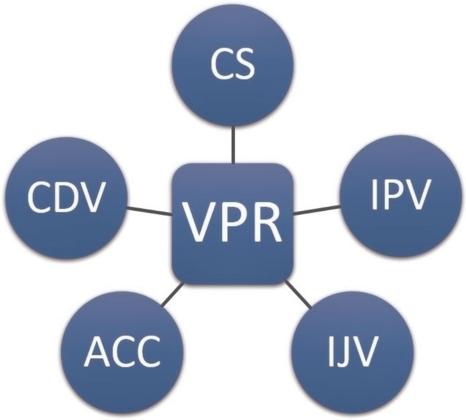

Fig. 2. Diagram showing communications between the venous plexus of Rektorzik (VPR) and other venous structures: cavernous sinus (CS), internal jugular vein (IJV), anterior condylar confluence (ACC), clival diploic vein (CDV), inferior petroclival vein (IPV).

Clinical issues

The internal carotid venous plexus may serve as a pathway that favors propagation of infections originating from the ear, or the temporal bone afflicted with an inflammatory process. Nager [29] found that the proximity of an empyema in the peritubal air cells, to the pericarotid venous plexus, can facilitate transmission of infection to the venous system. Both Kuczkowski *et al.* and Miura *et al.* [30, 31] reported that internal carotid venous plexus can promote the expansion of the inflammatory processes inside the skull (e.g.: intracranial complications of acute or chronic otitis media). Thereby, otitic suppuration may reach the cavernous sinus through the venous plexus surrounding the internal carotid artery. Furthermore, the venous plexus of Rektorzik was found to be the path of infection in thrombophlebitis of the cavernous sinus of otitic origin, as reported by Eagleton [32].

Radiographically altered venous plexus (asymmetric enhancement) and narrowing of the internal carotid artery was recognized at a 12-year-old girl who was afflicted with ophthalmoplegia after COVID-19 infection. MRI examination of the brain revealed an inflammatory process suggesting occurrence of the Tolosa-Hunt syndrome [33].

Furthermore, preexisting non-functioning communication between minor branches of the internal carotid artery and veins that form the pericarotid venous plexus may spontaneously initiate formation of a carotid-cavernous fistula [34]. According to Osawa *et al.* [35] a fistula formed between the petrous part of the internal carotid artery and its venous plexus can be similar to a carotid-cavernous fistula. It should be also noted that the venous plexus of Rektorzik can be the source of an extra bleeding if the surgical procedures are performed in the carotid canal, e.g.: surgical exposure of the petrous portion of the internal carotid artery [35]. In such cases, application of the bipolar coagulation can be necessary to control bleeding from the venous plexus [36, 37]. Otherwise, unstopped bleeding around the internal carotid artery hinders the performance of endoscopic surgery in the petrous portion of the temporal bone [8].

Another important issue is the capability of imaging the venous plexus in clinical examination by means of the computed tomography angiography (CTA) and magnetic resonance imaging (MRI). Bonnevile *et al.* [18] reported that visualization of the venous plexus surrounding the internal carotid artery was rare in the early venous phase of angiographic imaging, and its enhancement is delayed in relation to other laterosellar veins. In turn, Imai *et al.* [11] found that the venous plexus of Rektorzik was visible on images as a contrast-enhanced structure around the internal carotid artery, demonstrated by the computed tomography digital subtraction venography in venous phases, but absent in arterial phases. However, absence of the normal contrast enhancement of the internal carotid venous plexus on MRI may be one of the angiographic evidences indicating the wall of the internal carotid artery was invaded by a tumor [38]. On the other hand, enhancement of the venous plexus surrounding the internal carotid artery can mimic vasculitis or atherosclerotic plaque [39]. It should be also noted that the venous plexus of Rektorzik can be encountered during petrosectomy or transnasal endoscopic approach to the arteriovenous fistulas involving the anterior condylar confluence [8]. Thereby, preoperative high resolution imaging and thorough observation of the anatomical relations between the venous plexus and the petrous part of the internal carotid artery should be taken with precaution to avoid misinterpretation of the radiographic images.

Conclusions

The venous plexus of Rektorzik is a clinically important vascular structure, which may be involved in various lesions of the cranial base, hence it is a potential route for disseminating pathogens. Close contact between venous plexus and the internal carotid artery seems to be intriguing both from anatomical and physiological point of view. Therefore experimental and retrospective studies can help to gain complete knowledge on its function and clinical significance.

Future studies should be aimed on examination hemodynamic interactions between the internal carotid artery and the venous plexus of Rektorzik to verify its capabilities for effective damping of blood pulsation while it flows through the artery, to diminish its effect on the organ of hearing.

Also, application of modern imaging techniques should shed new light on its appearance, and the attitude towards the walls of the carotid canal and the petrous portion of the internal carotid artery.

Conflict of interest

The authors declare no conflict of interest nor any financial interest associated with the current study.

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