eISSN 1303-1775 • pISSN 1303-1783

Neuroanatomy (2005) 4: 2–7

Original Article

The parasellar dura mater and adjacent dura: a microsurgical and light microscopic study in fetal materials

Published online 15 April, 2005 © http://www.neuroanatomy.org

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Received 3 January 2005; accepted 29 March 2005

ABSTRACT

The parasellar dura mater should be distinguished from the adjacent dura because the cavernous sinus, the internal carotid artery, and certain cranial nerves passes through it. The purpose of this study is to demonstrate the difference between the structure of the parasellar and the adjacent dura mater. The study was held with 80 fetuses at a gestational age of 20-40 weeks. Microdissection and histological investigation was performed without decalcification.

The results are as follows: The meningeal layer of the parasellar dura mater was thicker from that of the adjacent dura, but their periosteal layers had similar thickness. The meningeal layer of the cranial dura mater had a multilayered structure, and also two types of lamellas have been found, the compact and the loose lamellas. Four compact and four loose lamellas of the meningeal layer of the parasellar dura mater have been shown by dissection and histological method. Through these lamellas are passing the cranial nerves III, IV, V_1, V_2, V_3, VI and their vessels. Through the fourth loose lamellae pass the parasellar portion of the internal carotid artery. In the third and fourth loose lamellas there are venous spaces arranged around the internal carotid artery, which form the cavernous sinus. The compact lamellas are thinner but firmer in comparison to loose lamellas.

On the other hand, three compact and three loose lamellas have been found in the meningeal layer of the adjacent dura mater. Neither evident vessels nor nerves have been noticed between these lamellas. ***Neuroanatomy; 2005; 4: 2–7.***

Key words [parasellar region] [dura mater] [cavernous sinus] [venous space]

Introduction

The external membrane which invests the brain is called the cranial dura mater. It consists of a periosteal layer, which is rich in blood and lymphatic vessels and nerves, and an inner layer named the meningeal layer. At certain places the periosteal and meningeal layers are separated to form the dural venous sinuses. This is the typical description of the cranial dura mater [1–15].

As for localization, cranial dura mater may be roughly divided as the dura of the calvaria and the dura of the skull base, but concerning the adjacent structures it may be divided to the dura of the small wing, the dura of the clivus, the dura of the parasellar region etc.

In literature, further attention was given to the parasellar dura mater than the other parts, and special interest was given to the cavernous sinus, as a part of the parasellar dura mater. In fact, many pathological processes are located in the parasellar region [14, 16–20].

In accordance with other authors [1, 7–14, 18–19, 21–22], we define the parasellar dura mater as the part which extends along to the lateral side of the body of the sphenoid bone. Also, it extends anteriorly to the superior orbital fissure, and to the level of the apex of the petrous bone posteriorly. The frontier between the parasellar dura mater and the adjacent dura mater is forms a line starting from the lateral end of the superior orbital fissure and passes through the lateral edge of the foramen rotundum, foramen ovale and foramen lacerum.

The internal carotid artery and its sympathetic plexus use the parasellar dura mater as a milieu through which travel from the extradural space to the intradural space. On the other hand, some cranial nerves and some special venous canals use the parasellar dura mater as a milieu through which travel from the intradural space to the extradural space.

In literature, we didn't find any comparison between the description of the structure of the dura mater of the parasellar region and the dura mater of the middle cranial fossa, which is just near to the parasellar region. Is there any difference between the parasellar dura mater and the dura mater of the other cranial regions, or are they completely the same? The aim of this study is firstly to point out the difference between these two.

Also, we would like to list and demonstrate our findings on the disposition of the components passing through the parasellar dura mater as the cranial nerves and their vessels, the internal carotid artery and its parasellar branches, which is very important in surgery. Especially, we would like to report our histological and dissection findings on the venous spaces which form the famous cavernous sinus.

Material and Methods

The parasellar dura mater and the dura of the middle cranial fossa which is just near to the parasellar dura were examined in 80 fetuses at 20–40 weeks of gestational age, in accordance with the ethical standards. The fetuses were obtained from the Gynaecology and Obstetrics Clinic of the Medical Faculty of Nis. The arterial system of the fetuses were injected with Micropaque contrast medium. The fetuses were kept in 10% formaldehyde for 10 days and then the brains were removed from the skulls, and fetuses were returned to 10% formaldehyde for a period of five years to tan the connective tissue that forms the dura mater. After using the above described method, we studied the parasellar dura mater with micro dissection technique using an operating microscope. We started the micro dissection at the level of the apex of the petrous bone. We prepared the lamellar connective tissue of the parasellar dura mater and the middle cranial fossa dura, and the components passing through this region.

In this study, in contrast to the other authors, the histological investigation was held without decalcification and staining. 10–15 microns thick frontal sections were prepared from the parasellar dura mater and the dura mater of the middle cranial fossa.

Results

We found that the parasellar dura mater and the dura mater near to the parasellar region were built up of two layers, a periosteal layer and an inner layer named the meningeal layer. The thickness of the periosteal layer of the parasellar dura mater, and the periosteal layer of the

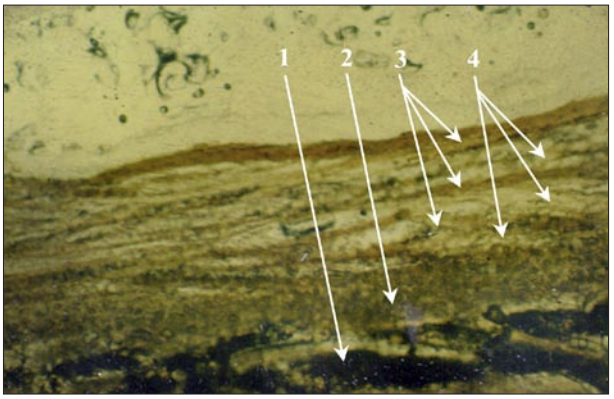

Figure 1. Microphotography of the frontal section of the fetal dura mater of the floor of the middle cranial fossa, just near to the parasellar region [Unstained X40]. *(**1:** great wing of the sphenoid bone, **2:** periosteal layer of the dura mater, **3:** compact lamellas of the meningeal layer of the dura mater, **4:** loose lamellas of the meningeal layer of the dura mater)*

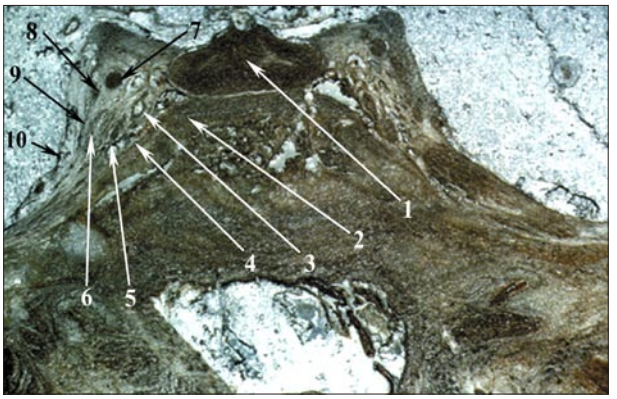

Figure 2. Microphotography of the frontal section of the fetal parasellar dura mater [Unstained X20]. *(**1:** hypophysis, **2:** endosteal layer of the parasellar dura mater, **3:** internal carotid artery, **4:** venous space of the inferior group of the cavernous sinus, **5:** abducent nerve, **6:** ophthalmic division of the trigeminal nerve, **7:** oculomotor nerve, **8:** trochlear nerve, **9:** second compact lamella, **10:** first compact lamella)*

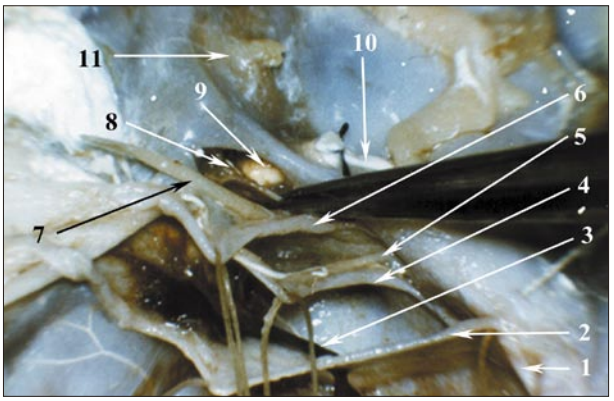

Figure 3. The compact lamellas on the way to the fetal parasellar portion of the internal carotid artery [microdissection, superior-lateral view]. *(**1:** posterior margin of the right small wing of the sphenoid bone, **2:** first compact lamella, **3:** superficial middle cerebral vein, **4:** second compact lamella, **5:** trochlear nerve, **6:** third compact lamella, **7:** oculomotor nerve, **8:** fourth compact lamella, **9:** parasellar portion of the internal carotid artery, **10:** ophthalmic artery, **11:** hypophysis)*

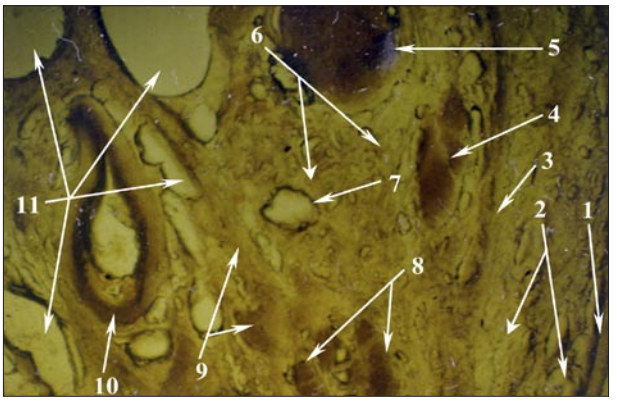

Figure 4. Microphotography of the frontal section of the fetal meningeal layer of the parasellar dura mater [Unstained X40]. *(**1:** first compact lamella, **2:** first loose lamella, **3:** second compact lamella, **4:** trochlear nerve, **5:** oculomotor nerve, **6:** third compact lamella, **7:** small venous space of the cavernous sinus, **8:** ophthalmic division of the trigeminal nerve, **9:** fourth compact lamella and the abducent nerve, **10:** internal carotid artery, **11:** large venous spaces of the cavernous sinus around the internal carotid artery)*

dura mater near to the parasellar region are same (about 0.4 mm). The thickness of the meningeal layer of the parasellar dura was about 4 mm and that of the meningeal layer of the dura mater adjacent to the parasellar region was about 1 mm (Figures 1–2, 4–5). Our examination demonstrated that the connective tissue of the meningeal layers of the parasellar dura mater and the adjacent dura were in a multilamellar structure.

Essentially, we found two types of lamellae of the connective tissue of the meningeal layer as the compact and the loose lamellae. The compact lamellae were thinner than the loose lamellae (Figures 1–2, 4–5).

We also found three compact and three loose lamellae in the meningeal layer of the middle cranial fossa dura adjacent to the parasellar region (Figure 1). Inside of these lamellae and between the compact lamellae we did not detect any large components, but a few branches of the accessory or middle meningeal artery may be found (Figure 1).

On the other hand, we found four compact and four loose lamellae in the meningeal layer of the parasellar dura mater by dissection and histological examination (Figures 2–5, 7). The outer or superficial compact lamella of the connective tissue of the parasellar dura mater was

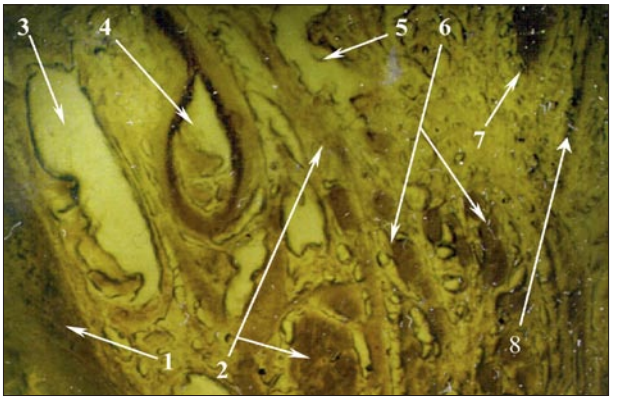

Figure 5. Microphotography of the frontal section of the fetal parasellar dura mater. The fourth loose lamella of the meningeal layer of the parasellar dura mater, which is between the endosteal layer and the fourth compact lamella of the parasellar dura mater [Unstained X40]. *(**1:** periosteal layer of the parasellar dura mater, **2:** fourth compact lamella and the abducent nerve, **3:** venous space of the medial group of the cavernous sinus, **4:** internal carotid artery, **5:** venous space of the lateral group of the cavernous sinus, **6:** ophthalmic division of the trigeminal nerve, **7:** trochlear nerve, **8:** second compact lamella)*

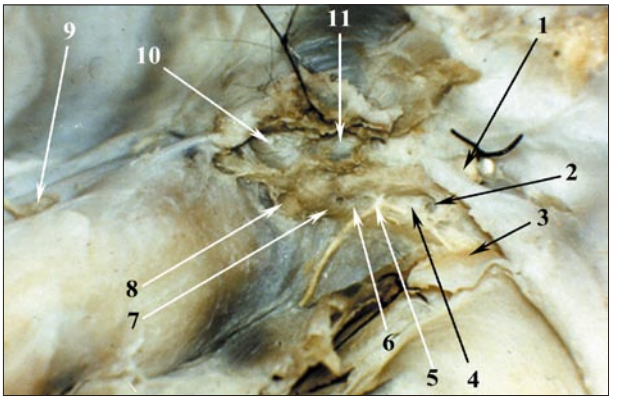

Figure 6. The lateral group of the venous spaces of the fetal cavernous sinus [microdissection, lateral view]. *(**1:** supraclinoid portion of the internal carotid artery, **2:** communicating opening of the venous space of the lateral group, **3:** third compact lamella, **4:** venous space of the lateral group, **5:** infero-lateral trunk of the internal carotid artery, **6:** venous space of the lateral group and its communicating openings, **7:** parasellar portion of the abducent nerve, **8:** venous space of the lateral group, **9:** subarachnoid portion of the abducent nerve, **10:** venous space of the lateral group, **11:** venous space of the lateral group)*

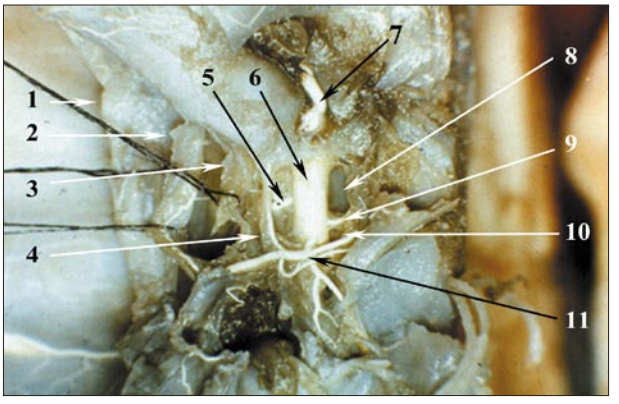

Figure 7. The medial group of the venous spaces of the cavernous sinus [microdissection, superior view]. *(**1:** first compact lamella, **2:** second compact lamella, **3:** third compact lamella, **4:** fourth compact lamella, **5:** infero-lateral trunk, **6:** parasellar portion of the internal carotid artery, **7:** ophthalmic artery, **8:** medial-anterior venous space, **9:** inferior hypophyseal artery as a direct branch of the parasellar portion of the internal carotid artery, **10:** medial-posterior venous space, **11:** dominant type of the meningohypophyseal trunk)*

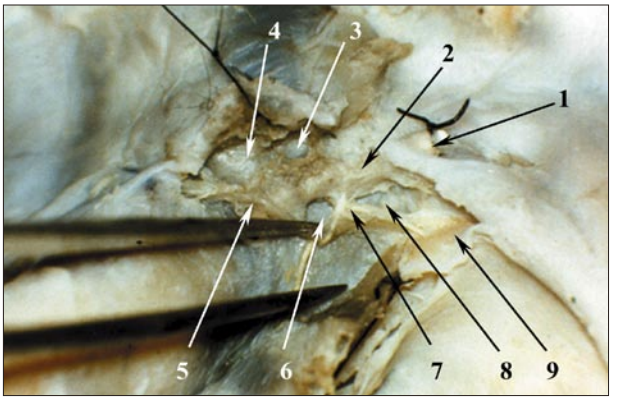

Figure 8. The inferior group of the venous spaces of the cavernous sinus [microdissection, lateral view]. *(**1:** supraclinoid portion of the internal carotid artery, **2:** parasellar portion of the internal carotid artery, **3:** anterior venous space of the superior group, **4:** posterior venous space of the superior group, **5:** parasellar portion of the abducent nerve, **6:** posterior venous space of the inferior group, **7:** infero-lateral trunk of the parasellar portion of the internal carotid artery, **8:** anterior venous space of the inferior group, **9:** third compact lamella)*

more compact and firm than the other lamellae of this region (Figures 2–4, 7). This lamella was spreading from the parasellar region along all over the middle cranial fossa. In the parasellar region, the middle cerebral superficial vein was piercing the anterior part of the lateral side of this lamella in about 30% of the cases, and going backwards along the inner side of this lamella to the venous spaces of the cavernous sinus (Figure 3). The second compact lamella was less compact and less firm than the outer or superficial compact lamella, and lying below the first one. At the level of the parasellar region, along the inner side of this lamella, the trochlear nerve and its arterial vessels were passing (Figures 3–4, 7). The third compact lamella was very close to the oculomotor, ophthalmic, maxillary, mandibular nerves, anterior parts of the trigeminal ganglion and to their arteries (Figures 3–4). In contrast to the first three compact lamellae, the fourth compact lamella was spreading only at the parasellar region (Figures 3–5). It was lying adjacent to the lateral side of the parasellar segment of the internal carotid artery. The abducent nerve and its arterial vessels were passing along the inferior margin of this lamella (Figures 4–6, 8).

The loose connective tissue of the meningeal layer of the parasellar dura mater was lying between the compact lamellae, connecting them and forming the respective loose lamellae (Figures 2, 4–5). We found four loose lamellae in the meningeal layer of the parasellar dura mater.

In about 30% of the cases, the middle superficial cerebral vein was piercing the anterior part of the lateral side of the first compact lamella and going backward through the first loose lamella (Figures 3–4). Through the second loose lamella were passing the trochlear nerve with its arterial vessels. This nerve was penetrating to the first two compact lamellae at the level of the posterior part of the oculomotor triangle and going ahead toward the superior orbital fissure, through the second loose lamella (Figures 3–5). In the third loose lamella we found the venous spaces of the lateral group of the cavernous sinus. Only one or two large venous spaces and several smaller venous spaces were presented in this loose lamella. The first three loose lamellae had the similar thickness (Figures 4–5). In contrast with the first three loose lamellae, the fourth loose lamella was slightly thicker than the first three loose lamellae (Figure 5). This lamella was lying between the fourth compact lamella and the periosteal layer of the parasellar dura mater. Through the fourth loose lamella was passing the parasellar segment of the internal carotid artery and within this lamella were the largest number of the venous spaces of the cavernous sinus (Figures 4–8).

After piercing the periosteal layer of the parasellar dura mater at the level of the apex of the petrous bone, the internal carotid artery was immediately entering the fourth loose lamella and climbing to its first parasellar curve. Then it was turning abruptly forward to its horizontal portion, and was terminating by passing upward on the medial aspect of the anterior clinoid process, where it perforated all lamellae of the meningeal layer of the parasellar dura mater, and reached subarachnoid space. Also, we encountered its parasellar branches the meningohypophyseal trunk, the infero–lateral trunk, the McConnell's capsular arteries and some of its variations (Figures 6–8).

Our histological and dissection findings demonstrated that the venous spaces of the cavernous sinus were located mainly in the fourth and partly in the third loose lamella of the parasellar dura mater (Figures 2, 4–8). There were two types of venous spaces around the parasellar portion of the internal carotid artery as large and small ones. We did not find any small venous space on dissection but large ones were present (Figures 6–8). Histologicaly, the walls of the venous spaces were consisted of an endothelial layer and connective tissue layers of different thickness (Figures 4–5). 10 to 14 large venous spaces were found during dissection. In younger fetuses the venous spaces had smaller dimensions than the older fetuses. The venous spaces had an oval, triangular or a short canal form (Figures 4–8).

Among the mentioned 10–14 large venous spaces we did not find wide communications. Small openings were present on the walls of the venous spaces, and we believe that these small openings regulate the anterograde and the retrograde circulation of the venous blood through the venous spaces of the cavernous sinus (Figure 6). Our findings suggest that the dissected large venous spaces were organized in five groups: around the internal carotid artery, lateral, medial, superior, inferior and posterior group (Table 1).

The lateral group of the venous spaces was lateral to the parasellar portion of the internal carotid artery. We observed 3–6 venous spaces in this group (Figures 4–7). One or two of this venous spaces were located in the third loose lamella, but the others were located in the fourth. The medial group of the venous spaces were medially located to the parasellar portion of the internal carotid artery, in the fourth loose lamella (Figures 5, 7). We detected two venous spaces in this group, the anterior and the posterior ones. The superior group of the venous spaces was above the horizontal part of the internal carotid artery within the fourth loose lamella, and two venous spaces were present in this group, the anterior and the posterior ones (Figure 4). The inferior group of the venous spaces was below the horizontal part of the parasellar portion of the internal carotid artery, and medial to the parasellar portion of the abducent nerve, again in the fourth loose lamella. In this group 1–2 venous spaces were found, the anterior and posterior ones, or solitary one (Figures 4, 8). The posterior group of the venous spaces was in the form of canals; lying in the fourth loose lamella of the petro–clinoido–clival dura mater, behind the first curve and the first, or ascending part of the parasellar portion of the internal carotid artery (Figure 8). In this group two venous spaces were found as superior and inferior. The superior venous space or canal of this group was above the petro–clinoido–clival part of the abducent nerve and the corresponding part of the dorsal meningeal artery. Anteriorly, it was extending to the level of the meningohypophyseal trunk and posteriorly,

Table 1. Large venous spaces of the cavernous sinus.

Group	Number of large venous space
Lateral	3–6
Medial	2
Superior	2
Inferior	1–2
Posterior	2

it was draining into the superior part of the basilar sinus, just below the posterior clinoid process. The inferior venous space or canal of this group was below the petro–clinoido–clival part of the abducent nerve. Anteriorly, it was narrow and extending to the posterior side of the first or ascending part of the parasellar portion of the internal carotid artery. Posteriorly, it was wider and draining to the inferior petrosal sinus, just below the apex of the petrous bone (Figure 8).

Discussion

Numerous pathological processes may appear in the parasellar and adjacent dura mater, such as various kinds of tumors, aneurysms, carotid–cavernous fistulas etc. A comprehensive understanding of the structure of the parasellar and adjacent dura mater is a prerequisite for successful surgical outcomes.

In the available literature we did not find the parallel description of the structure of the parasellar dura mater and the middle cranial fossa dura, which is just adjacent to the parasellar region. All authors underline the fact that the cavernous sinus is a component which is inside of the parasellar dura mater. Some authors [4, 14, 23] underline the fact that Ridly and Winslow were the first authors who studied the parasellar dura mater, and Winslow's finding (1732) were still convincing for a large number of authors of anatomical books in the second last half of the XXth century [1, 7, 9–11, 14].

It is commonly accepted that the cranial venous sinuses are located between the periosteal and meningeal layer of the dura mater, but Inoue et al. [20] believe that these sinuses are within the dural folds. It seems that the inferior sagittal sinus and the straight sinus are within the dural folds, because these sinuses do not have any periosteal layer. On the other hand, it seems that the superior sagittal sinus, the cavernous sinus and other sinuses are located between the periosteal and the meningeal layer of the dura mater.

Many authors [1, 7–12, 14, 22–24] were able to show only schematic, phlebographic and one type of histological findings of the structure of the venous sinuses, but none of them had photographed of dissected cavities of these venous sinuses.

Our findings are the same as many others, regarding the fact that the parasellar dura mater and adjacent dura were formed from the periosteal and the meningeal layers. We found that the thickness of the periosteal layer of the parasellar dura mater and of the adjacent dura were similar, but they were thinner than the meningeal layer of the both mentioned regions. Also, our results demonstrated that the meningeal layer of the parasellar dura mater and of the adjacent dura were in a multilamellar structure and consisting of two type of lamellae, the compact and the loose lamellae. Four compact and four loose lamellae were found in the meningeal layer of the parasellar dura mater and three compact and three loose lamellae in the adjacent dura. From the surgical point of view the compact lamellae of the parasellar dura mater were lying on the way to the parasellar portion of the internal carotid artery. Umansky and Nathan [14] described only two layers on the way to the parasellar portion of the internal carotid artery.

Several cranial nerves and some vessels use the loose lamellae of the meningeal layer of the parasellar dura mater as a milieu through which travel from the intradural space to the extradural space and reversally, but in the loose lamellae of the meningeal layer of the adjacent dura we did not find any evident vessels nor nerves.

Our findings specified that in about 30% of cases, the middle superficial cerebral vein was traveling through the first loose lamella of the meningeal layer of the parasellar dura mater on the way to the cavernous sinus or into the middle meningeal vein. Also, we specified that the trochlear nerve and its vessels travel through the second loose lamella, and in the third loose lamella we found the venous spaces of the lateral group of the cavernous sinus. We specified that the thickness of the first three loose lamellae of the meningeal layer of the parasellar dura mater were similar, but the thickness of the fourth loose lamella was slightly thicker than the first three loose lamellae. We found that through the fourth loose lamella was passing the parasellar portion of the internal carotid artery. We specified that within the fourth loose lamella were the largest number of the venous spaces of the cavernous sinus, around the internal carotid artery, but not between the meningeal and periosteal layer as affirmed by many authors, and not into interperiosto–dural space of Taptas [12, 13]. The walls of the mentioned venous spaces were consisted of an endothelial layer and connective tissue layers of different thickness. We believe that these layers of the connective tissue of different thickness lying between the adjacent venous spaces represent famous trabeculae or 'the cords of Willis'.

Our findings suggest that the way of the venous blood through the meningeal layer of the parasellar dura mater is arranged in a few paths around the parasellar portion of the internal carotid artery, in the medial, lateral, superior et inferior path. In addition, the blood flow through the mentioned paths was not continuous, but segmented. The presence of large and small venous spaces around the parasellar portion of the internal carotid artery confirm that opinion. These results are the similar to that of Rhoton et al. [18, 19] and Kehrli et al. [4], but differs from the findings of Parkinson [17] who stated that the

cavernous sinus is a plexus formed by several various–sized veins.

The posterior group of the venous spaces were in form of canals, and lying in the fourth loose lamella of the petro–clinoido–clival dura mater, behind the ascending part of the parasellar portion of the internal carotid artery at the posterior end of the cavernous sinus. We see the superior and inferior venous canal of the posterior group as parts of the notion which is named as Dorello's canal [25, 26].

We found small openings on the walls of the venous spaces serving for communication, but other authors did not have the similar findings.

Conclusion

Our findings demonstrated that the meningeal layer of the cranial dura mater is in a multilamellar structure, containing compact and loose lamellae in it.

We confirmed that there are differences between the structures of the meningeal layers of the parasellar dura mater and of the adjacent dura.

We specified that some cranial nerves and their vessels use the respective loose lamellae on their way through the meningeal layer of the parasellar dura mater.

We confirmed that the venous spaces of the cavernous sinus are located in the third and mainly in the fourth loose lamella of the meningeal layer of the parasellar dura mater, but not between the meningeal and periosteal layer as affirmed by many authors.

Our findings contribute to a better understanding of the dura mater and to successful microsurgical interventions in this area.

Acknowledgements

This study was supported by Gynaecology and Obstetrics Clinic of Nis. The collaboration of Prof.Dr. Dragomir Vucetic is gratefully acknowledged.

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