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# RELATIONS OF THE INITIAL SEGMENT OF THE OCULOMOTOR NERVE AND ADJACENT ARTERIES IN FETAL AND ADULT PERIOD

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**Abstract**. *The relationship between the initial part of the oculomotor nerve and the posterior cerebral and superior cerebellar arteries is well understood, but there is still insufficient data about details of these relationships. The aim of this work was to examine the relationships of the initial segment of the oculomotor nerve with adjacent arteries in fetal and adult period. The examination was performed on 259 human brains (191 adults and 68 fetuses). Arteries in fetal brain were perfused with Micropaque and examined by photo film. Adult cases were examined during the forensic autopsy and then basis of the brain was photographed. The close relationship of the initial segment of the oculomotor nerve with basilar artery in 8.3%, with superior cerebellar artery in 17.3%, with posterior cerebral artery in 68.6% of cases was noted. The root of the nerve appeared above postcommunicating part of the posterior cerebral artery in 1.3% of cases and under the level of superior cerebellar artery in 1.6% of cases. The oculomotor nerve with two roots was noted in 2.6% of cases. Neurovascular relationship between oculomotor nerve and adjacent arteries, as morphological characteristic on the ventral side of the brain trunk, has pathoanatomical meaning by the nerve disfunction caused by compression.*

**Key words**: *Human cadavers, brain base, oculomotor nerve, cerebral arterial circle, vertebrobasilar system*

## Introduction

The oculomotor nerve (III) controls the most of the sceletal and two smooth eye muscles. The third nerve is divided into four segments: initial (cisternal), supracavernous, intracavernous and orbital [1].

The root of the oculomotor nerve converges and leaves the midbrain in the posterior part of the interpeduncular fossa, proximately anteriorly and laterally to the posterior perforated substance. The roots of the oculomotor nerve continue their course transversally through the interpeduncular fossa, change their course ventrolaterally around medial surface of the cerebral peduncle and pass between the superior cerebellar artery (SCA) and the posterior cerebral artery (PCA) [2]. The oculomotor nerve passes further ventrally, laterally and rostrally, reaching the lateral wall of the cavernous sinus and, finally goes into the orbit [1].

The posterior cerebral artery, terminal branch of the basilar artery, Zeal and Rhoton [3] divided into four segments. These segments are named by Terminologia Anatomica [4] as the precommunicating part (P1 segment), the postcommunicating part (P2 segment), the lateral occipital artery (P3 segment) and the medial occipital artery (P4 segment). The superior cerebellar artery is the branch of the basilar artery that supplies the numerous structures of the cerebellum. The posterior communicating artery (PCoA) is the branch of the cerebral segment of the internal carotid artery and posteriorly, it communicates with the posterior cerebral artery separating P1 and P2 segments [5,6].

Boeri and Passerini [7] examined clinical manifestations caused by trunk extension and elongation of the basilar artery (BA). Guy and Day [8] analysed intracranial aneurysms that caused the oculomotor nerve palsy. Marinković and Gibo [1] investigated neurovascular relations and blood supply to the initial segment of the oculomotor nerve. Schumacher-Feero et al. [9] analysed the causes of the oculomotor nerve palsy in children. Birchall et al. [10] described recovery after the endovascular treatment of the posterior communicating artery aneurysm that caused the oculomotor nerve palsy.

Zhang et al. [11] emphasized variations among the neurovascular relations of the oculomotor nerve and adjacent arteries. Uz and Tekdemir [12] paid attention to relation between the oculomotor nerve and the PCA. Mulderink et al. [13] described the oculomotor nerve palsy caused by the PCoA compression, but Lee et al. [14] and Chen et al. [15] analysed the third nerve palsy caused by the PCoA aneurysm. Takahashi et al. [16] reported the case of the incomplete oculomotor palsy caused by the PCoA aneurysm.

The previous facts define the presence of the close relationships between the oculomotor nerve, the PCA and the SCA, but there is still insufficient data about peculiarities of those neurovascular relations [12]. Importance of the relations of the oculomotor nerve and

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adjacent arteries can be discussed in the light of the compressive lesions, vascular penetrations, arteriovenous malformations, and the arterial aneurysms [1].

The aim of this study was to examine neurovascular relationships of the initial segment of the oculomotor nerve with the adjacent arteries in fetal and adult period.

## Material and Methods

We performed a retrospective analysis of digital images of 68 fetal and 191 adult cases respectively, dissected at the Department of Anatomy and Institute for Forensic Medicine in Niš. The study included cases with 9 vascular components in the circle of Willis in which the oculomotor nerve was detected bilaterally. For that reason, 36 fetal cases and 120 adult cases were statistically observed and reported.

Fetuses of both genders, from 17 to 24 weeks of gestation were a part of the collection of our Department of Anatomy, and they were used in the preparation of doctoral thesis [16]. All fetuses were obtained legally from the Clinic of Gynecology and Obstetrics in Niš. The Council for Postgraduate Study of the Faculty of Medicine in Niš at this time gave permission to investigate the fetal material. The arteries of fetuses were injected with Micropaque or latex through the left cardiac ventricle or through the common carotid artery. All fetuses were fixed in 10% formalin for 2 weeks. Fetal brains were removed and kept in individual calvarias.

The dissected brains originated from cadavers of both genders and different ages (from the neonate to 95 years) and different causes of death in the period between 2006 and 2013. Investigation of these cases was in accordance with the rules of the internal Ethics Committee (no. 01-9068-4) of our Faculty of Medicine. Morphological features of structures at the base of brain and their relationships were observed through a magnifying glass and recorded on a film and in workbook. Measurement of distances between the oculomotor nerve and adjacent arteries was performed with ImageJ (http://rsb.info.nih.gov/ij/index.html).

## Results

Results were presented in four phases.

I. *Typical symmetry in neurovascular relationships*
In 3 adult cases, the oculomotor nerve left the midbrain in the level of the basilar bifurcation bilaterally (Fig. 1, a). In 17 adult and 3 fetal cases, the third nerve appeared bilaterally at the ventral side of the midbrain in the level of the P1 segment (Fig. 1, b), but in 18 adult and 6 fetal cases in the level of the P1–P2 junction (Fig. 1, c). The oculomotor nerve bilaterally left the midbrain in the level of P2 segment in 15 adult and 11 fetal cases (Fig. 1, d).

In summary, bilateral symmetry in relationships between the oculomotor nerve and the BA or segments of the PCA was noted in 55.6% of fetal and 44.2% of adult cases. Among adult cases, the most frequent pattern of the neurovascular relations was bilateral relation with the P1 segment (16.7%). In fetal period, that was bilateral relation of the oculomotor nerve and P2 segment, with the presence in 30.6% of cases (Table 1).

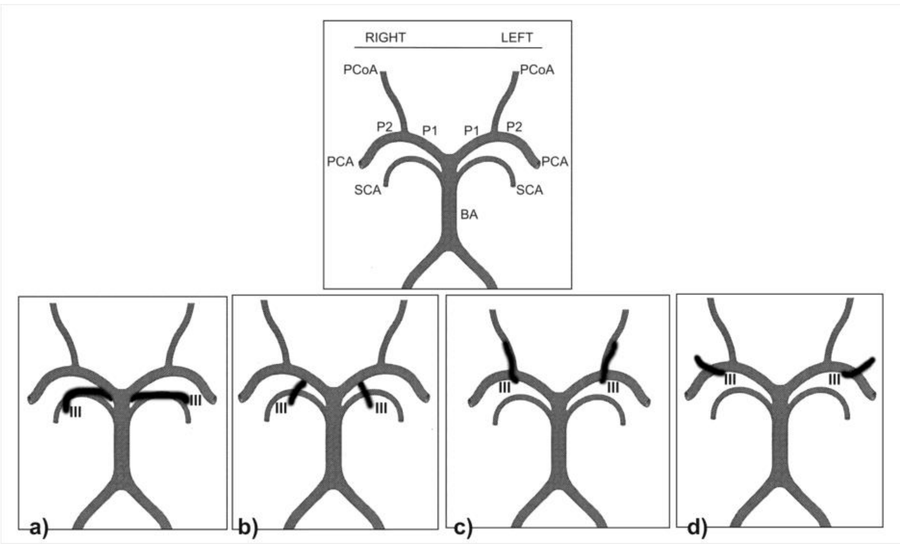


**Fig. 1.** Different examples of symmetrical neurovascular relationships between the oculomotor nerve and adjacent arteries. a) Bilateral relationship of the oculomotor nerve and the basilar bifurcation; b) bilateral relationship of the oculomotor nerve and the precommunicating segment of the posterior cerebral artery; c) bilateral relationship of the oculomotor nerve and the junction of the precommunicating and postcommunicating segment of the posterior cerebral artery; d) bilateral relationship of the oculomotor nerve and the postcommunicating segment of the posterior cerebral artery.

PCA, posterior cerebral artery; P1, precommunicating part of the PCA; P1–P2, junction of the pre- and postcommunicating parts of the PCA; P2, postcommunicating part of the PCA; SCA, superior cerebellar artery; BA, basilar artery; PCoA, posterior communicating artery; III, oculomotor nerve.

**Table 1**. Rewiev of the neurovascular relation of the initial part of the oculomotor nerve and the posterior cerebral artery (PCA) related to the side orientation

| The PCA segments | | Number of cases | | | | | |
|---|---|---|---|---|---|---|---|
| | | Adult cases | | Fetal cases | | Summa | |
| Right | Left | 120 | (100%) | 36 | (100%) | 156 | (100%) |
| P1 | P1 | 20 | (16.7%) | 3 | (8.3%) | 23 | (14.7%) |
| P1 | P1–P2 | 8 | (6.7%) | 1 | (2.8%) | 9 | (5.8%) |
| P1 | P2 | 12 | (10%) | 2 | (5.6%) | 14 | (9%) |
| P1–P2 | P1 | 15 | (12.5%) | 2 | (5.6%) | 17 | (10.9%) |
| P1–P2 | P1–P2 | 18 | (15%) | 6 | (16.7%) | 24 | (15.4%) |
| P1–P2 | P2 | 8 | (6.7%) | 4 | (11.1%) | 12 | (7.7%) |
| P2 | P1 | 14 | (11.7%) | 2 | (5.6%) | 16 | (10.3%) |
| P2 | P1–P2 | 10 | (8.3%) | 4 | (11.1%) | 14 | (9%) |
| P2 | P2 | 15 | (15%) | 11 | (30.6%) | 26 | (16.7%) |

P1, precommunicating part of the posterior cerebral artery; P1–P2, junction of the pre- and postcommunicating parts of the PCA; P2, postcommunicating part of the PCA.

II. *Typical asymmetry in neurovascular relationships*
The third nerve was related to the level of the P1–P2 junction at the right, but at the level of P1 segment at the left side, in 15 adult and 2 fetal cases (Fig. 2, a). The oculomotor nerve had a relation with the P1 segment at right side and with the P1–P2 junction at left side in 8 adult and in 1 fetal case (Fig. 2, b). The third nerve left the midbrain in the level of the right P1 and the left P2 segment of PCA in 12 adult and 2 fetal cases (Fig. 2, c). Relation of the oculomotor nerve with the left P1 segment and right P2 segment was noted in 14 adult and 2 fetal cases (Fig. 2, d). Relation of the third nerve with the P2 segment at right and the P1–P2 junction at left was noted in 10 adult and 4 fetal cases (Fig. 2, e). The opposite neurovascular relation, the third nerve in the level of the P1–P2 junction at the right and in the level of the P2 segment at the left side, was noted in 8 adult and 4 fetal cases (Fig. 2, f).

Asymmetry of the typical neurovascular relationships of the initial segment of the oculomotor nerve was noted in 55.8% of adult and 41.7% of fetal cases (Table 1).

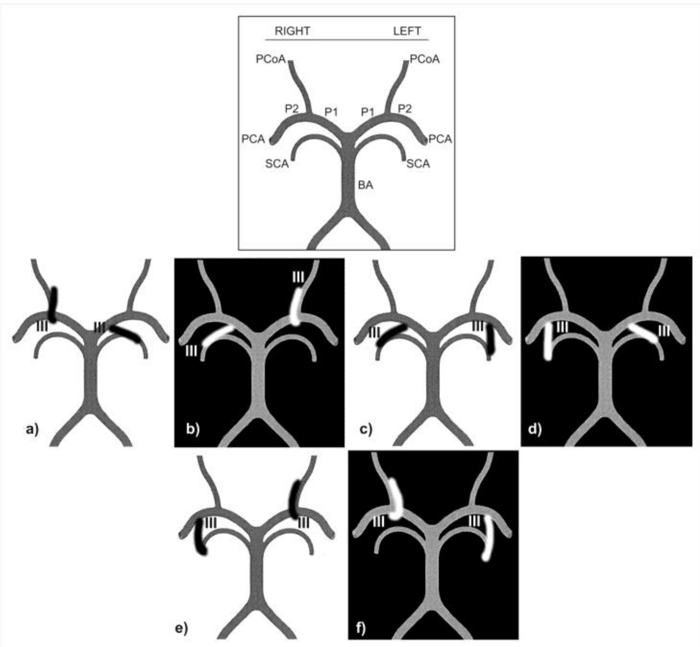


**Fig. 2**. Review of examples of asymmetrical neurovascular relationships between the oculomotor nerve and adjacent arteries. a) Relationship of the oculomotor nerve and the precommunicating–postcommunicating (P1–P2) junction at the right side and the P1 segment at the left; b) relationship of the oculomotor nerve and the P1 segment at the right side and the P1–P2 junction at the left side; c) relationship of the oculomotor nerve with the P1 segment at the right and the P2 segment at the left side; d) relationship of the oculomotor nerve and the P2 segment at the right and the P1 segment at the left side; e) relationship of the oculomotor nerve and the P2 segment at the right and the P1–P2 junction at the left side; f) relationship of the oculomotor nerve and the P1–P2 junction at the right side and the P2 segment at the left side.

PCA, posterior cerebral artery; SCA, superior cerebellar artery; BA, basilar artery; PCoA, posterior communicating artery; III, oculomotor nerve.

III. *Specific neurovascular relationships*

These cases were found in 14 cases (Fig. 3). In one adult case, the oculomotor nerve left the midbrain rostral in relation to the P2 segment bilaterally (Fig. 3, a) and in two more adult cases this phenomenon was noted unilaterally. The frequence of this phenomenon was 1.3% of all cadaveric cases. In one adult case (0.3% of all examined cases), the third nerve appeared ventrally in relation to the left P2 segment and passed parallel and compressed with the PCA to the point of nerve cutting (Fig. 3, b). In 3 adult cases, the initial segment of the third nerve went caudally crossing the dorsal, caudal and ventral surface of the SCA, and after the curve around the SCA, run rostrally. In adult cases, this pattern was noted unilaterally. In one fetal case, the oculomotor nerve appeared at the ventral side of the midbrain caudally of the SCA at the both sides (Fig. 3, c). In summary, this pattern of the neurovascular relationship was noted in 1.6% of cases. The oculomotor nerve had two big roots unilaterally at the ventral surface of the midbrain in 7 adult cases and one fetal case that is 2.6% of cases (Fig. 3, d).

IV. *Rewiev of the neurovascular relationships distribution*

Irrespective of the side orientation, the oculomotor nerve mostly had the relationship with the P1 segment at one and some part of the PCA at the other side in adult period (57.5%).

In fetal period, the oculomotor nerve had the most frequent relation (63.9%) with the P2 segment at one, and some part of the PCA at the other side (Fig. 4 and Table 2).

The oculomotor nerve was in close proximity with the PCA in 77.9% of adult cases. In distribution of the PCA segments, the P1–P2 junction and the P2 segment had an equal presence (28.9%) and were more frequent

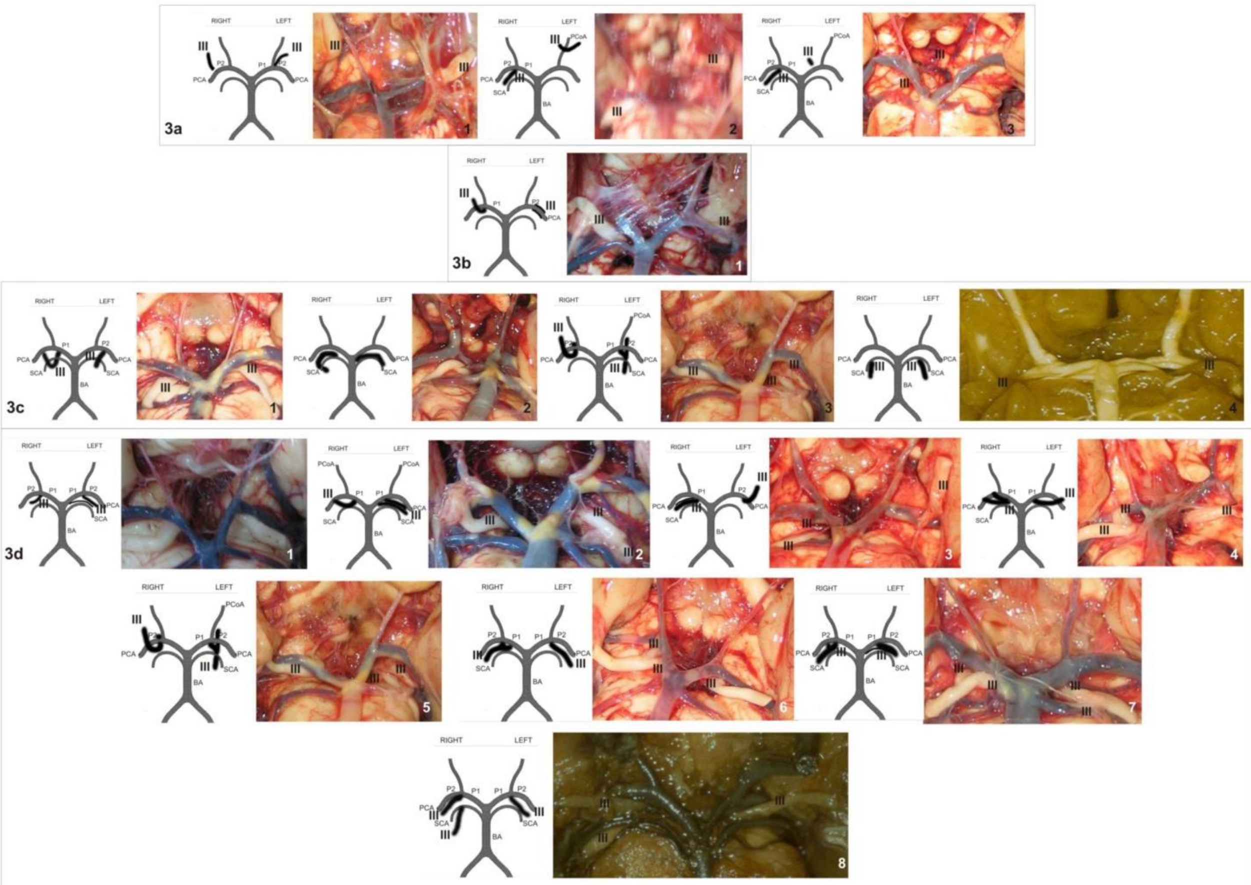


**Fig. 3**. Review of specific neurovascular relations of the oculomotor nerve and adjacent arteries in 14 cases: a) the oculomotor nerve left the midbrain rostral in relation to the postcommunicating (P2) part of the posterior cerebral artery (PCA) bilaterally in three cases; b) third nerve appeared dorsal in relation to the left P2 segment and passed parallel and compressed with the PCA in one case; c) the initial segment of the third nerve went caudally crossing the superior cerebellar artery (SCA), and after the curve around the SCA, ran rostrally in three adult cases, and the oculomotor nerve appeared at the ventral side of the cerebral trunk caudally of the SCA bilaterally in a fetal case; d) the oculomotor nerve had two big roots unilaterally in seven cases and bilaterally in one case.

PCA, posterior cerebral artery; P1, precommunicating part of the PCA; P1–P2, junction of the pre- and postcommunicating parts of the PCA; P2, postcommunicating part of the PCA; SCA, superior cerebellar artery; BA, basilar artery; PCoA, posterior communicating artery; III, oculomotor nerve.

**Table 2**. Review of the neurovascular relation of the initial part of the oculomotor nerve and segments of the posterior cerebral artery (PCA) irrespective of the side orientation

| PCA segments | | Number of cases | | | | | |
|---|---|---|---|---|---|---|---|
| | | Adult cases | | Fetal cases | | Total | |
| | | 120 | (100%) | 36 | (100%) | 156 | (100%) |
| P1 | P1 | 20 | (16,7%) | 3 | (8.3%) | 23 | (14.7%) |
| P1 | P1–P2 | 23 | (19,2%) | 3 | (8.3%) | 26 | (16.7%) |
| P1 | P2 | 26 | (21,7%) | 4 | (11.1%) | 30 | (19.2%) |
| P1–P2 | P1–P2 | 18 | (15%) | 6 | (16.7%) | 24 | (15.4%) |
| P1–P2 | P2 | 18 | (15%) | 8 | (22.2%) | 26 | (16.7%) |
| P2 | P2 | 15 | (12,5%) | 11 | (30.6%) | 26 | (16.7%) |

P1, precommunicating part of the PCA; P1–P2, junction of the pre- and postcommunicating parts of the PCA; P2, postcommunicating part of the PCA.

than the P1 segment (20.1%). The third nerve was in close relationship with the SCA in 18.6%, and with the basilar bifurcation in 9.3% of adult cases (Table 3).

Average relations between the oculomotor nerve and adjacent arteries in adult cases were presented in Table 4. The biggest average distance (2.75 mm) was noted between the third nerve and the basilar bifurcation at the right side. At the left side, this distance was 2.62 mm. Average neurovascular distance with the SCA was 1.48 mm at the right, and 1.52 mm at the left side. The closest artery to the oculomotor nerve was the PCA with all its segments, and measured distances varied from 0.01 mm related to the P2 segment at the right side to 0.19 mm related to the P1 segment at the right side.

## Discussion

The initial segment of the oculomotor nerve is in close relationship with the basilar artery distal segment branches. These arteries are two PCAs (as the terminal branches), two SCAs and many lateral branches of the previous arteries [1]. Also, the oculomotor nerve can form close neurovascular relationship with the PCoA, but it depends on the size and location of the PCA [11].

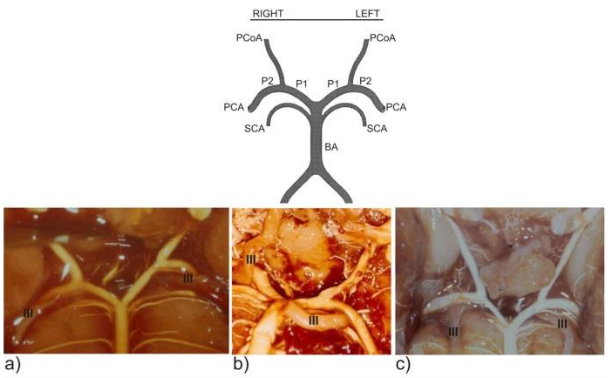


**Fig. 4**. Relationship of the oculomotor nerve and postcommunicating part of the posterior cerebral artery — bilaterally (a), on the left (b) and right (c) sides.
PCA, posterior cerebral artery; P1, precommunicating part of the PCA; P2, postcommunicating part of the PCA; SCA, superior cerebellar artery; BA, basilar artery; PCoA, posterior communicating artery; III, oculomotor nerve.

Location of nerves and blood vessels is mostly unchanged in adult period in comparison with prenatal state [18]. For that reason, it was possible to summarize the results, irrespective of life period.

Zhang et al. [11] analysed MRI images of 140 individuals and 3 adult cadavers, and found that the oculomotor nerve had a close relationship with the BA in almost 50% of cases. The third nerve had a close relationship with P1 segment in 98.6% of cases (56.8% with the posterior third, and 41.8% with the medial third of the P1). In most of cases, the oculomotor nerve was located in the proximity of the SCA, too. The most frequent type of relationship made by the PCA, the SCA and the oculomotor nerve, is so-called a “sandwich-like” structure. This study described that the oculomotor nerve runs dorsally and ventrally around the SCA, making the curve, in one case. Only in 3.6% of cases, the third nerve had the close relationship with the PCoA, and in 0.7% of cases compression by this artery was noted. Authors emphasized that the state of PCoA was significantly associated with the state of the PCA and its relationship to the oculomotor nerve.

Esmer et al. [19] analysed neurovascular relationships of the oculomotor nerve and adjacent arteries in 140 adult hemispheres, and found the close relationship between the oculomotor nerve and the PCA in 97.9%. In our study, this type of the neurovascular relationship was noted in 68.6% of cases (77.9% in adults and 76.4% in fetal cases).

The close relationship between the oculomotor nerve and the BA was described in cases of the nerve root appearance in the level of the basilar bifurcation. This neurovascular pattern has 8.3% of cases (9.3% of adults and 9.7% of fetal cases) in our study. The third nerve has close proximity with the SCA in cases of the close relations with the basilar bifurcation or in cases of the nerve course and/or appearance under the SCA. This neurovascular relationship was found in 17.3% of cases. The neurovascular relationship with the P1 segment was noted in cases of the nerve appearance in the level of P1 segment, but in the cases of close relationsip with the basilar bifurcation, too; it was noted in 17.3% of cases.

Pai et al. [9] emphasized that position of the oculomotor nerve between the SCA and PCA is almost constant. Liang et al. [20] analysed 392 oculomotor nerves via MRI and found that the SCA was situated superior and compressed only one nerve. Hardy et al. [21] and Uchino et al. [22] also reported that the SCA or some of its branches can run superior to the oculomotor nerve.

The route of the oculomotor nerve below the SCA and crossing its trunk in the further course of the nerve were noted in one fetus bilaterally and in three adults unilaterally, and that is more frequently in comparison to the data from the available literature.

In some of our cases, the neurovascular pattern was different in relation to literature description. In one adult case, the oculomotor nerve left the midbrain rostral in relation to the P2 segment bilaterally, and in two adult cases more, this phenomenon was noted unilaterally. In these cases, the oculomotor nerve runs parallel with the PCoA. We did not find the similar description of the oculomotor relation with the P2 segment in the available literature.

Importance of the close relations of the oculomotor nerve and adjacent arteries can be discussed by the clinical importance of the compressive lesions, vascular penetrations, arteriovenous malformations, and the arterial anurysms [1].

In general, it is possible to discuss about two types of the compressive lesions. The first is associated with the third cranial nerve disfunctions, manifested by diffrerent clinical signs. This phenomenon is caused by a crossing compression of the nerve at the level of its root exit. Mostly, the oculomotor nerve root has a close relationship only with small arteries, as the collicular artery, the accessory collicular artery, the medial posterior choroidal artery and the perforating diencephalic arteries. Some of these arteries can compress the nerve root and cause hyperactive disfunction and, further, the spasm of bulbomotors. The second type of compressive lesions is the simple vascular compression of the distal part of the initial segment of the oculomotor nerve, which results in the conductional block and the intraneural circulatory disturbance. This part of the nerve is often in contact with the SCA and the P2 segment, and not so often with the BA, the P1 segment, the PCoA, and their variants or embrional arterial forms (duplicated arteries, fenestrations of the arterial trunk and the persistent trigeminal artery) [5]. According to Liang et al. [20], it is postulated that detection of neurovascular compression would have high sensitivity and low specificity for nerve paralysis. Also, the compression of the oculomotor nerve can be asymptomatic when it is compressed sufficiently and form a curve by the PCA, SCA, PCoA or BA.

Vascular penetration of the oculomotor nerve is described only in some papers [1,5]. As shown in the reports of the previous authors, the roots of the oculomotor nerve, which range in number between 20 and 25, can leave the midbrain in various parts. In 8% of cases, the oculomotor nerve has two roots – the main root, which leaves the midbrain through the medial sulcus of the crus cerebri, and accessory root, which leaves the midbrain through the middle part of the crus cerebri. The rarity of the oculomotor nerve penetration is not clear in the close relationship of the nerve and adjacent small arteries, and having in mind the possibility of appearance of the numerous nerve roots in the interpeduncular fossa, but this neurovascular relation is the possible reason for the frequent cross-compression of the nerve roots. In our study, 2.6% of cases (7 adult and 1 fetal) have the oculomotor nerve with two roots at one side.

Aneurysms of the terminal part of the basilar artery are located between the beginning of the SCA and the PCA. They are almost always in contact with the initial segment of the oculomotor nerve and this state can cause the partial or complete oculomotor neve palsy. Aneurysms of the basilar bifurcation make 5% of intracranial aneurysms and almost 50% of all vertebrobasilar saccular aneurysms. Saccular aneurysms are mostly situated in the interpeduncular fossa where they can compress the initial segment of the oculomotor nerve, the crus cerebri and the most of the interpeduncular blood vessels. Aneurysms of the PCA make up 2.2% of all saccular aneurysms, and 7-15% of all vertebrobasilar aneurysms. In Yasargil's [5] cases, aneurysms of the P1 and P2 segments were usually in close proximity with the initial segment of the third nerve. In the presence of the clinical manifestation of the superior oculomoror division paresis, aneurysm was sited at the SCA-PCA junction [8]. Vascular compression of the oculomotor nerve by the PCoA without pathological changes of the arterial wall is possible only in case of parallel course of the nerve and artery. It is more frequent in young persons. In older persons, compression of the oculomotor nerve is more possible besause of the atherosclerotic changes that cause elongation and dislocation of the arteries. This possibility has to be considered in cases of the oculomotor nerve palsy with unknown etiology [13]. Absence of the oculomotor nerve palsy in the cases of arterial aneurysms that are in close relationships with the third nerve, indicate small aneurysms or specific location of aneurysms without the nerve compression [14]. Boeri and Passerini [7] presented the cases with the oculomotor nerve palsy caused by the megadolichobasilar artery, anomaly that implies the extreme length and width of the BA. They emphasized atherosclerotic changes as the cause of that anomaly, and further, the palsy. Our study included cases with atheromatous changes. Among adults, 40% of cases had atheromatous plaques in the cerebral arteries which were related to the age of cases.

## Conclusion

Bilaterally symmetrical neurovascular relationship of the initial segment of the oculomotor nerve and surrounding arteries was noted in 46.8% of cases. Asymmetrical relationship between the initial segment of the oculomotor nerve and surrounding arteries in the majority of cases is characterized by a direct relationship to the P1–P2 junction on one side, and the P1 segment, on the other. The case of the oculomotor nerve with two roots was noted in 2.6% of cases and this pattern was unilateral. The route of oculomotor nerve below the superior cerebellar artery and crossing its trunk in the further course of the nerve was noted in one fetus bilaterally and in three adults unilaterally.

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