BIOMEDICINSKA ISTRAŽIVANJA
2019;10(1):1–7

UDK: 617.73:611.13
DOI: 10.7251/BII1901001B

Original article

Characteristics of perioptic and intraoptic arterial vascularization of extracranial segment of optic nerve

Radmila Balaban-Djurević[1], Samra Hajrović[2], Siniša Šolaja[3], Vanja Pljevaljčić[1], Valvita Reçi[4], Stefan Kulić[5], Milan Milisavljević[6]

[1]University of East Sarajevo, Faculty of Medicine Foča, Department of Anatomy, Foča, The Republic of Srpska, Bosnia and Herzegovina

[2]General Hospital, Ophthalmology Division, Novi Pazar, Serbia

[3]University Hospital Foča, The Republic of Srpska, Bosnia and Herzegovina

[4]State University of Tetovo, Faculty of Medicine, Department of Anatomy, Tetovo, The Republic of North Macedonia

[5]Health Care Center, Nikšić, Montenegro

[6]University of Belgrade, Faculty of Medicine, Institute of Anatomy, Belgrade, Serbia

Received – Primljen: 29/12/2018
Accepted – Prihvaćen : 31/01/2019

Corresponding author:
Prof. Milan Milisavljević, MD, DSc.
Dr Subotića 4/2, 11000 Belgrade, Serbia
milmili@eunet.rs

Summary

Introduction. The optic nerve is supplied by the arterial branches of the superficial pial plexus and direct intraneural branches. The aim of the study was to study the morphological characteristics (origin, number of arteries, calibers, and branching pattern) of perioptic arterial vascularization and intraoptic vascular network of the extracranial sections of the optic nerve: canalicular and intraorbital.

Methods. The study included 18 pairs of the optic nerves of both sexes (11 males and 7 females), aged 51 to 78 years, with no signs of changes in the structures of the nervous system. The vasculature of the optic nerves was microdissected and examined under the stereoscopic microscope, after injecting their arteries with 10% mixture of India ink and gelatin, and 5% formaline fixation.

Results. The intracanalicular part of the optic nerve received fine blood vessels from the ophthalmic artery, usually in two branches in 29 (82.9%) cases, while in 6 (17.1%) specimens there was only one branch for the nerve. The intraorbital segment of the optic nerve was supplied by two interconnected systems of blood vessels, peripheral and axial, both coming from the central retinal artery.

Conclusion. On the basis of the obtained results, it has been confirmed that both segments of the optic nerve have a rich and very delicate vascular network. The superficial pial arterial plexus of the intracanalicular segment of the optic nerve has been identified as the only source of its vascular supply. The intraorbital part of the optic nerve has two interconnected systems of blood vessels: peripheral and axial.

Keywords: optic nerve, arteries, perioptic vascularization, intraoptic vascularization

Introduction

Opticus (Latin) is an ancient Greek word (optikós), and it means seeing, sight or vision. The first description of the optic nerve dates from the period around 500 BC, and it comes from Alcmaeon of Croton (Croton was a Greek colony in the south of Italy). For a long period of time, it was considered that the optic nerve was hollow and that contained spiritual fluid. The more modern description of the optic nerve came from an Italian anatomist Costanzo Varolio. Constantius Varolius (latinized) (1543-1575) was a professor of anatomy and surgery in Bologna, and later in Rome, and the subject of his anatomical interest was the brain. The pons as part of the brainstem were described in his book „De nervis opticis“, published in Padua in 1573 [1]. Optic chiasm, as the place of decus-

sation and partial crossing of the optic nerves, was first described by Rufus of Ephesus, around 50 AD. Hundreds of years later, it was showed that chiasm was responsible for the coordination of the eye bulb movements. Hermann Ludwig Ferdinand von Helmholtz (1821-1894), was a German physicist, a professor of philosophy, pathology, and anatomy. With his discovery and introduction of ophthalmoscope in 1851, he showed the inner part of eyeball with the area around the optic disc. In 1856, he published the first volume of his „Handbook of physiological optics", being one of the most important works on this subject [2, 3, 4].

We have accepted the division of the optic nerve (ON) into two parts: 1) cranial part and 2) extracranial part, whereby the extracranial part can be subdivided into two segments: a) intracanalicular part (in the optic canal) and b) intraorbital part (in the orbit) [5].

The earliest descriptions have pointed out that pial arterial plexus vascularize optic nerve over its entire length [6]. This vascular scheme was completed with the findings of other researchers, who described more branches, 1-3, coming from the ophtalmic artery (OA), as it passed through the optic canal [7-9]. The intracanalicular part is vascularized from recurrent ophthalmic artery (lateral and ventral), while intraorbital part is supplied from the posterior ciliary arteries and the central retinal artery [9]. The already-mentioned perioptical arterial network gives even smaller branches, which enter the optic nerve and supply all deep structures [10]. Therefore, we clearly differentiate between two mutually connected vascular systems of blood vessels: peripheral and axial [11].

Traumatic optic neuropathy is a condition in which acute injury of the optic nerve, caused by direct or indirect trauma, results in vision loss. Orbital hemorrhage, hematoma of the optic nerve coverings, or direct injury of the optic canal walls by bony fragments can lead to this condition. Vision loss is usually the result of the compression or injury of fine vascular network of the optic nerve, which is of utmost importance for our research [12].

The aim of the study was to investigate the micromorphological characteristics (origin, the numbers of arteries, calibers and the way of branching) of perioptic arterial vascularization and intraoptic vascular network of the extracranial section of the optic nerve, composed of intracanalicular and intraorbital parts.

Methods

The study included 18 pairs of the optic nerves, obtained from persons of both sexes (11 males and 7 females), aged from 51 to 78 years, without any signs of change concerning the optic system structure, using the collection of the Laboratory for Vascular Anatomy of the Brain of the Institute of Anatomy at the Faculty of Medicine in Belgrade. The material was obtained during the regular autopsies at the Institute of Pathology of the Faculty of Medicine in Belgrade. The study was approved by the Ethics Committee of the Faculty of Medicine, University of Belgrade.

The optic nerve, regardless of its size, is fragile and positioned deep in the optic canal and in the orbit. Therefore, a special method of approaching and cutting the nerve was used. Intraorbital and intracanalicular sections of the optic nerve were taken in a block with surrounding bones of the skull base and dural covering, to the level of the eyeball, including carvenous segment of the internal carotid artery and ophthalmic artery. A plastic tube was fixed in the isolated segment of the internal carotid artery, and the arterial system of the optic nerve was injected, first with saline solution, then with 5% formaldehyde, and finally with 10% mixture of melted gelatin and India ink.

Microdissection of injected blood vessels was performed with the help of micro-instruments, and all measurements were obtained under Leica MZ6 stereo microscope using 35 well-injected nerves. All specimens were photographed with Canon Power Shot A710 digital camera, and all details recorded by using Leica DFC 295 digital camera under stereo microscope. Vascular network of the optic nerves and topographic relations were sketched in the already prepared schemes. An original software Leica Interactive Measurements was used for morphometric analysis.

Results

The intracanicular and intraorbital segments of the optic nerve had prominent and delicate vascular network.

A) An intracanalicular part of the optic nerve received the gracile blood vessels from the ophthalmic artery on which it lay. With respect to the point of entrance of the ophtalmic artery in a fibrous tissue of the dural sheath of the optic nerve, we described two groups of intracanicular optic branches: extradural and intradural. a) Optic branches, which were separated from the ophthalmic artery before its entrance into the dural layer of the optic nerve covering, were present in 14 (40%) cases, always one artery (Figure 1); b) Optic branches, which were coming from the ophthalmic artery after its entrance into the dural sheath of the optic nerve covering, were present in all cases (100%), one artery in 20 (57.1%) cases, and two arteries in 15 (42.9%) cases (Figure 2).

Overall, the intracanalicular part of the optic nerve most commonly received two small arteries, branches of the ophthalmic artery, in 29 (82.9%) cases, while on 6 (17.1%) specimens there was only one branch for the nerve supply, from 104.3 to 162.9 μm, an average of 148.3 μm. Having been separated from the ophthalmic artery, these branches continued to branch upwards and backwards through intracanalicular segment of the optic nerve, oriented towards the orbital opening of the optic canal. They anastomosed with branches coming from the cranial cavity, as well as with branches from the orbit, forming the pial arterial network or plexus of this part of

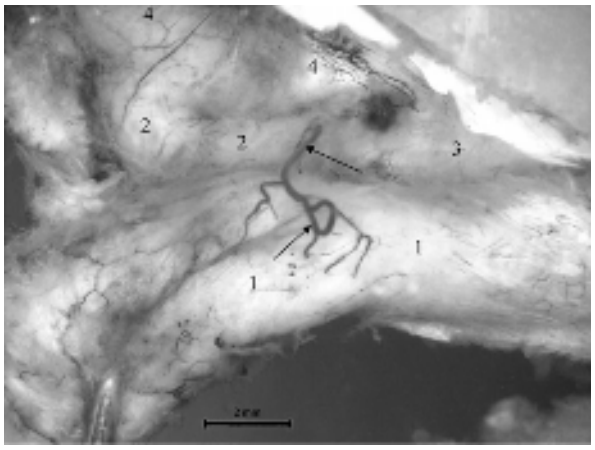

Figure 1. Optic branch (arrows) for the supply of intracanalicular segment of the optic nerve (1) (elevated) coming from the ophthalmic artery (2) before its entrance into the dural sheath of the optic nerve (3); (4) internal carotid artery (dissection, India ink and gelatin).

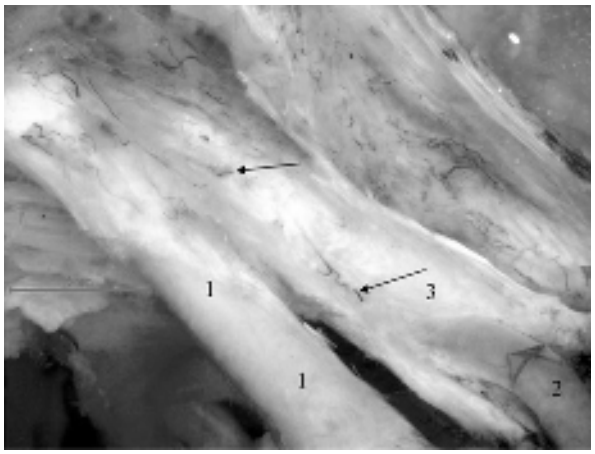

Figure 2. Intracanalicular segment of the optic nerve (1), elevated to show two optic branches (arrows) coming from the ophthalmic artery (2) after its entrance into the dural sheath of the optic nerve (3) (dissection, India ink and gelatin).

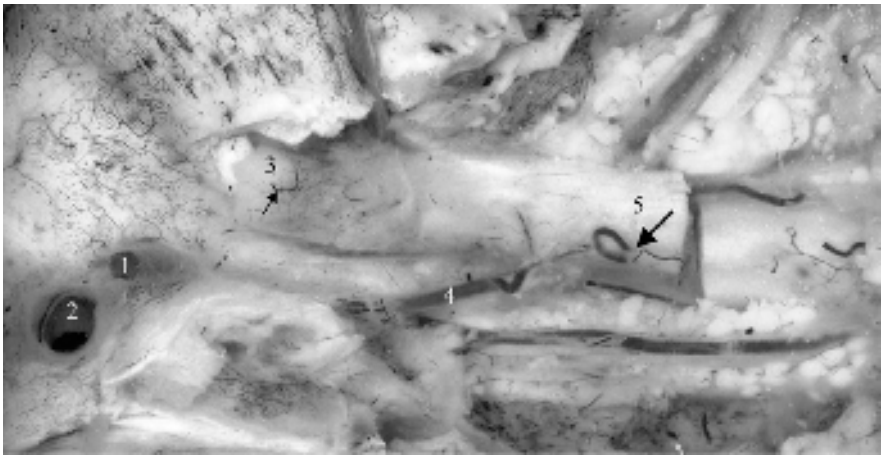

Figure 3. Ophthalmic artery (1), branch of the internal carotid artery, cut (2), besides little branch (small arrow) for the intracanalicular segment of the optic nerve (3) gives off central retinal artery (4), which enters (large arrow) in the intraorbital segment of the optic nerve (5) (dissection, India ink and gelatin).

the optic nerve. At this level, we did not notice the existence of any kind of axial arterial blood vessel of the segment.

B) The intraorbital part of the optic nerve was the only one vascularized by two, interconnected, separated systems of blood vessels: peripheral and axial. a) The peripheral vascular system consisted of the pial arterial network, formed by two or three branches of the central retinal artery (CRA). They branched from the CRA before it entered into the lower surface of the optic nerve (Figures 3, 4). Each of these branches, most frequently in 3 in 27 (77.1%) cases, ramified over the lower part of the nerve, proceeding to its upper part. b) The axial vascular system was composed of many branches, separated radially from the central retinal artery and located in the central part of the optic nerve. These small intraneural branches are the main source of vascularization of the central part of the nerve, and are connected with the superficial pial arterial plexus via capillary anastomoses (Figures 5, 6).

Discussion

Anatomical variations of the origin of branches forming pial arterial plexus of the optic nerve, as well as the morphometric results of our study,

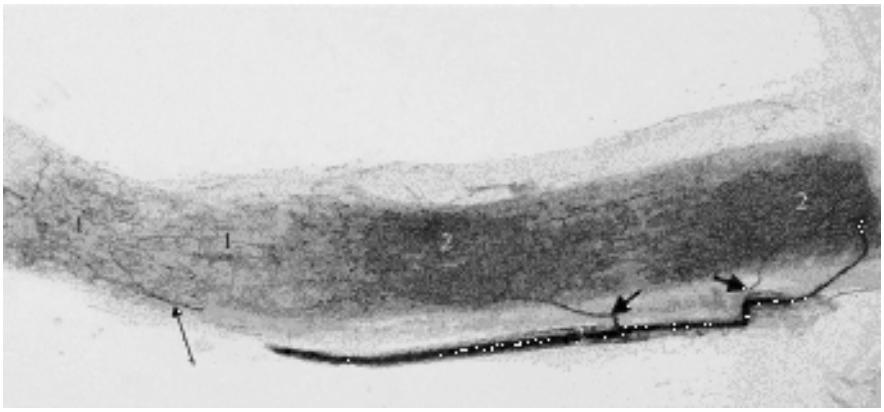

Figure 4. Vascular system of the intracanalicular (1) and intraorbital (2) parts of the optic nerve. Optic branch (arrow) coming from the ophthalmic artery, and optic branches (red arrows) from the central retinal artery (3) (dissection of the isolated optic nerve, India ink and gelatin).

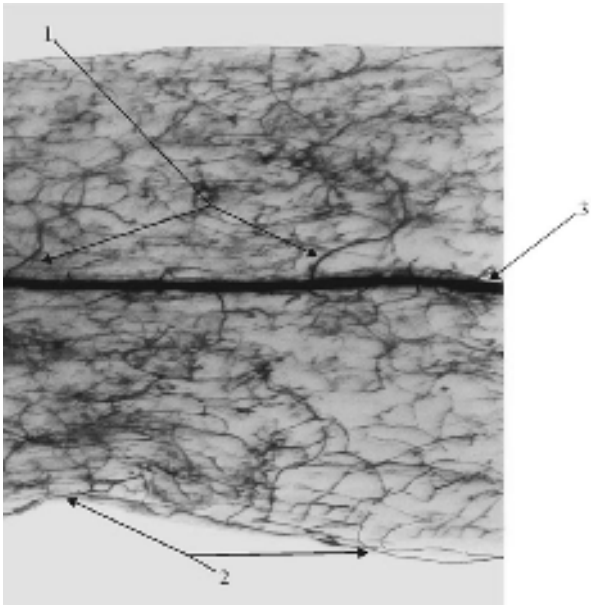

Figure 5. Axial (1) and peripheral (2) vascular systems of the intraorbital part of the optic nerve; (3) central retinal artery (longitudinal section of the isolated optic nerve, India ink and gelatin).

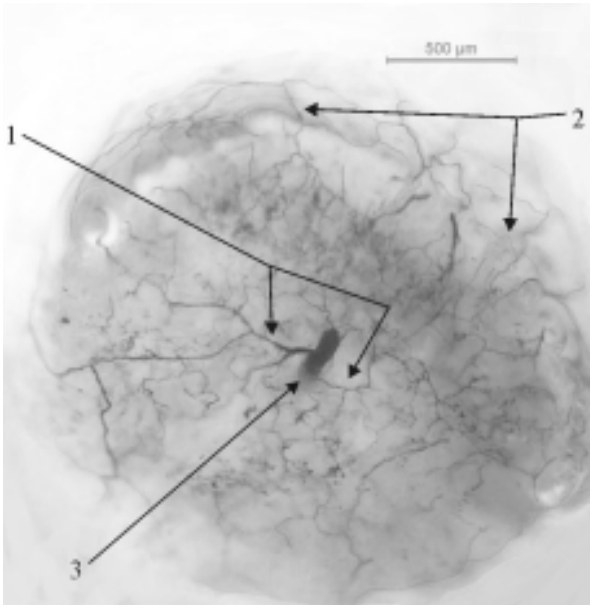

Figure 6. Axial (1) and peripheral (2) vascular systems of the intraorbital part of the optic nerve; (3) central retinal artery (transverse section of the isolated optic nerve, India ink and gelatin).

are important not only for understanding variability of arterial vascularization of the intracanalicular and intraorbital segments, but also for developing practical strategies for the surgical interventions in this region[11].

The intracanalicular part of the optic nerve normally gave off two small arteries, ophthalmic artery branches, in 29 (82.9%) cases, while on 6 (17.1%) specimens there was only one branch for the nerve. On the surface of the optic nerve, the small arteries were interconnected with branches coming from the cranial cavity, as well as with branches from the orbit, forming the pial arterial network or plexus covering this part of the nerve. The fragility of the intracanalicular arterial system of the optic nerve was noticeable only on the specimens injected with India ink and gelatin. Mainly due to this, there are not so many descriptions of the blood vessels of this part of the optic nerve, except from one author. He stated that more small branches (one to three), coming from the ophthalmic artery during its passage through the optic canal, pierced dural sheath and ended up in the optic nerve [7]. The mentioned author did not document his results by means of photographs.

The intraorbital segment of the optic nerve was the only one who had two, mutually connected, segregated systems of the blood vessels: peripheral (made of the pial arterial network) and axial. The results of the authors who gave detailed descriptions of the existence of the central artery of the optic nerve showed that it proceeded to the retina. Nevertheless, they estimated that it did not participate in vascularization of the optic nerve [6]. The other groups of authors had doubts about the existence of this kind of vascular division. Our study has also showed that axial vascular system is made of numerous branches, which are radially directed from the central retinal artery, situated centrally in the optic nerve, and originated from the ophthalmic artery [13]. Those small intraneural branches are the main source of vascularization of the central part of the nerve and are interconnected with the superficial pial arterial network via capillary anastomoses.

The optic nerve can be damaged by the compression of different origin. The disruption in vascularization of intracanalicular and intraorbital parts of the optic nerve is commonly accepted as the cause of visual loss in traumatic optic neuropathy, an irreversible process resulting in neuronal loss. In this case, the damage to the endothelial cells of the nutritive arteries of the optic nerve can lead to thrombocytes aggregation, as well as to thrombus formation. This trauma can also cause reflex vasospasm, as the reaction to the injury of the smooth musculature of the arterial wall, which leads to ischemic optic neuropathy. Hemorrhages in the optic nerve, dural sheath and the spaces between the optic coverings, soft tissue edema, tearing of nerves, as well as the contusion necrosis of the nerve, are primary lesions in indirect trauma of the optic nerve. All these data show special sensibility of the perineural and intraneural capillary networks of the optic nerve to traumatic damage, emphasize their recognition, and acknowledge the importance of our research [12-16].

Conclusion

The intracanalicular part of the optic nerve most commonly received two small arteries, branches of the ophthalmic artery, in 29 (82.9%) cases, while on 6 (17.1%) specimens there was only one branch for each nerve. The intraorbital segment of the optic nerve was the only one that had two, interconnected with anastomoses, separated systems of blood vessels: peripheral and axial. The peripheral vascular system of the optic nerve was made of superficial pial arterial plexus, made from three branches of the central retinal artery, in 27 (77.1%) cases. The axial vascular system was formed from numerous branches that were radially separated from central retinal artery, located centrally in the optic nerve. The results showed that both segments of the optic nerve had a rich and very delicate vascular network.

Funding source. This work was supported by grant No. 175030 from the Ministry of Education, Science and Technological Development of the Republic of Serbia.

Ethical approval. The Ethics Committee of the Faculty of Medicine, University of Belgrade approved the study.

Conflicts of interest. The authors declare no conflict of interest.

References

1. Sakai T, Ikeda R, Tsukisawa M. Galen „On the anatomy of nerves": translation from the Greek text and discussion. Nippon Ishigaku Zasshi 2003;49(3):403–54.
2. Singer Ch. A short history of anatomy from the Greeks to Harvey. New York: Dover Publications, Inc; 1957.
3. Skinner HA. The origin of medical terms. New York: Hafner Publishing Company; 1970.
4. Persaud TVN. A history of anatomy. Springfield: Charles Thomas Publisher Ltd; 1997.
5. FitzGerald MJT. Neuroanatomy, basic and clinical. London-Tokyo: WB Saunders Compmany; 1996. p. 164–70.
6. Francois J, Neetens A, Collete JM. Vascularization of the primary optic pathways. Br J Ophthalmol 1958;42:65–80.
7. Hayreh SS, Dass R. The ophthalmic artery. I. Origin and intra-cranial and intra-canalicular course. Br J Ophthalmol 1962;46:65–98.
8. Hayreh SS. The ophthalmic artery. III. Branches. Br J Ophthal 1962;46:212–47.
9. Chou PI, Sadun AA, Lee H. Vasculature and Morphometryof the optic canal and intracanalicular optic nerve. J Neurol ophthalmol 1995;15:186–90.
10. Haines DE, Harkey HL, Al-Mefty O. The "subdural" space: a new look at an outdated concept. J Neurosurg 1993;32:111–20.
11. Nagulić M, Ćetković M, Manojlović R, Nikolić I, Alempijević Đ, Vitošević Z. Vaskularizacija distalnog dela vidnog živca. Vojnosanit pregl 2010;67(4):297–302.
12. Marinković S, Milisavljević M, Kostić V. Funkcionalna i topografska neuroanatomija. Beograd: Nauka; 1998.
13. Yu-Wai-Man P. Traumatic optic neuropathy - Clinical features and management issues. Taiwan J Ophthalmol 2015;5(1):3–8.
14. Kuppersmith RB, Alford EL, Patrinely JR, et al. Combined transconjunctival/ intranasal endoscopic approach to the optic canal in traumatic optic neuropathy. Laryngoscope 1997;107:311–5.
15. Warner J, Lessell S. Traumatic optic neuropathy. Int Ophthalmol Clin 1995;35:57–62.
16. Lohmror I, Hada M, Agarwal V, Khilnani K. Optic nerve avulsion associated with central retinal artery occlusion following rotational globe injury. Indian J Ophthalmol 2018;66:1040–1.

Karakteristike perioptičke i intraoptičke arterijske vaskularizacije vanlobanjskog dijela vidnog živca

Radmila Balaban-Đurević[1], Samra Hajrović[2], Siniša Šolaja[3], Vanja Pljevaljčić[1], Valvita Reçi[4], Stefan Kulić[5], Milan Milisavljević[6]

[1]Univerzitet u Istočnom Sarajevu, Medicinski fakultet Foča, Katedra za normalnu anatomiju čovjeka, Foča, Republika Srpska, Bosna i Hercegovina

[2]Opšta bolnica, Očno odeljenje, Novi Pazar, Srbija

[3]Univerzitetska bolnica Foča, Republika Srpska, Bosna i Hercegovina

[4]Državni univerzitet u Tetovu, Medicinski fakultet, Institut za anatomiju, Tetovo, Republika Severna Makedonija

[5]Dom zdravlja Nikšić, Crna Gora

[6]Univerzitet u Beogradu, Medicinski fakultet, Institut za anatomiju, Beograd, Srbija

Uvod. Optički nerv je vaskularizovan arterijskim granama površinskog pijalnog pleksusa i direktnim intraneuralnim granama. Cilj našeg istraživanja bio je ispitivanje morfoloških karakteristika (porijeklo, broj arterija, kalibri i način grananja) perioptičke arterijske vaskularizacije i intraoptičke vaskularne mreže vanlobanjskih segmenata vidnog živca: intrakanalikularnog i intraorbitalnog.

Metode. Istraživanje je obavljeno na 18 parova vidnih živaca, osoba oba pola (11 muških i 7 ženskih), starosti od 51 do 78 godina, bez znakova promjena na strukturama nervnog sistema. Arterije namijenjene vaskularizaciji vidnih živaca su mikrodisekovane i proučavane korišćenjem stereo mikroskopa i mikroinstrumenata a po injiciranju 10% mješavinom tuša i želatina i fiksiranju u 5% rastvoru formaldehida.

Rezultati. Intrakanalikularni segment vidnog živca je dobijao gracilne krvne sudove iz oftalmičke arterije, najčešće po dvije, u 29 (82,9 %) slučajeva, dok je na 6 (17,1 %) preparata postojala samo po jedna grana za nerv. Vaskularizovan je isključivo penetrantnim granama koje polaze od pijalne arterijske mreže. Intraorbitalni segment vidnog živca dobija arterijsku vaskularizaciju iz dva međusobno povezana sistema krvnih sudova, perifernog i aksijalnog, oba porijeklom iz središnje arterije mrežnjače.

Zaključak. Poštujući postavljeni cilj, analizom dobijenih rezultata zaključili smo da intrakanalikularni i intraorbitalni segment vidnog živca posjeduju bogatu i vrlo osjetljivu vaskularnu mrežu. U našem istraživanju vaskularizacija intrakanalikularnog segmenta vidnog živca potiče iz površinske pijalne arterijske mreže ovog dijela nerva. Intaorbitalni dio vidnog živca imao je dva povezana sistema krvnih sudova, periferni i aksijalni.

Ključne riječi: vidni živac, arterije, perioptička vaskularizacija, intraoptička vaskularizacija