

# OCT ANGIOGRAPHY AND DOPPLER ULTRASOUND IN HYPERTENSION GLAUCOMA

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## SUMMARY

**Aims:** The main aim of this work was to find out if there is a correlation between vessel density (VD) and results of measured perfusion values in ophthalmic artery and in central retinal artery of the same eye in a group with hypertension glaucoma (HTG).

**Materials and methods:** The file included 20 patients with HTG, thereof 13 women of average age 68.7 years (49–80 years) and 7 men of average age 58.4 years (27–81 years). Criteria for inclusion in the study: visual acuity 1.0 with possible correction less than  $\pm 3$  diopters, approximately the same changes in visual fields in every patient, intraocular pressure (IOP) less than 18 mmHg, no other ocular or neurological diseases. VD was measured by Avanti RTVue XR by Optovue firm, perfusion parameters were measured using Doppler ultrasound with Affinity 70G machine by Philips firm. The peak systolic velocity (PSV) and end diastolic velocity (EDV) and resistance index (RI) were measured both in ophthalmic artery (AO) and in central retinal artery (CRA). Visual field (VF) was examined by quick threshold glaucoma program by Medmont M 700 machine. The sum of sensitivities in apostilbs (abs) was evaluated in the range 0–22 degrees of visual field. The results of sensitivities in visual field were compared to VD and perfusion parameters in CRA and AO of the same eye.

**Results:** Pearson's correlation coefficient ( $p = 0.05$ ) was used to assess the dependency between chosen parameters. By comparing VF and VD from measured areas, strong correlation ( $r = 0.64$ , resp.  $0.65$ ) was revealed. It was then proved that VD (WI-VDs) correlates with RICRA weakly ( $r = -0.35$ ) and moderately strongly (WI-VDa  $r = -0.4$ , PP-VDs  $r = -0.43$  and PP-VDa  $r = -0.45$ ). This means that with increasing resistance index in CRA the density in VD decreases. The other correlations between VD and perfusion parameters (PSV and EDV) in CRA and AO were not significant.

**Conclusion:** Measured values showed that the vascular component of VD has a huge impact on the changes in visual fields in HTG. Weak to moderate influence exists between VD and RI in CRA. OCTA has proven to be more suitable than Doppler ultrasound for determining the condition of blood circulation in the eye.

Key words: OCTA, vessel density, color Doppler imaging (CDI), visual field, hypertension glaucoma

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## INTRODUCTION

In hypertension glaucoma (HTG), where the main role is played by high intraocular pressure (IOP), the ganglion cells of the retina are damaged and later the whole visual tract is damaged [1,2,3,4].

About 50 years ago, local ophthalmologists considered that blood flow in the eye can play a role in morphological changes in HTG [5,6,7].

It is widely known from the recent literature that the ophthalmic artery (AO) and central retinal artery (CRA) are altered in glaucoma [8,9].

Therefore, the aim of this study was also to determine whether there is a dependency between vessel density (VD) and perfusion parameters in the CRA and AO in hypertension glaucoma.

## MATERIALS AND METHODS

The cohort included 20 patients with HTG, specifically 13 women with an average age of 68.7 years (49–80 years) and 7 men with an average age of 58.4 years (27–81 years). Criteria for inclusion in the study: visual acuity 1.0 with possible correction less than  $\pm 3$  dioptres, approximately the same changes in the visual fields in each patient, intraocular pressure (IOP) less than 18 mmHg, no other ocular or neurological diseases. VD was measured using Avanti RTVue XR from the Optovue firm. We assessed the values of VD in the whole image (WI) and also peripapillary (PP). Then in both cases all vessels (VDa) and small vessels (VDs).

The perfusion parameters were measured using Doppler ultrasound (CDI) with an Affinity 70G machine from

the Philips firm with 5–12 MHz sound. Peak systolic velocity (PSV), end diastolic velocity (EDV) and resistance index (RI) were measured both in the ophthalmic artery (AO) and in the central retinal artery (CRA). The visual field was examined using a fast threshold glaucoma program by a Medmont M 700 machine. The sum of sensitivities in apostilbs (abs) was evaluated within the range 0–22 degrees of the visual field (the values ranged within an interval of 1900 and 2212 abs). The results of sensitivities in the visual field were compared to the VD and perfusion parameters of the CRA and AO of the same eye. A Pearson's correlation coefficient ( $p = 0.05$ ) was used to assess the dependency between the chosen parameters.

## RESULTS

The measured values showed that the vascular component of VD has the main impact on changes in the visual field.

We further demonstrated that VD correlates with RICRA weakly WI-VDs ( $r = -0.35$ ) and moderately strongly WI-VDa ( $r = -0.4$ ), PP-VDs ( $r = -0.43$ ) and PP-VDa ( $r = -0.45$ ). This means that with an increasing resistance index in the CRA, VD decreases. The other correlations between VD and perfusion parameters (PSV and EDV) in the CRA and AO were not significant.

There was also a weak negative relationship between the visual field and resistance index in the CRA and AO.

This table shows the average values of the measured parameters and correlation coefficient.

## DISCUSSION

In our previous work, in which we conducted a similar measurement in normal tension glaucoma (NTG), we discovered an indirect moderate correlation between VD and PSVOA. Other correlations between VD and perfusion parameters were not significant [10].

We pointed out the differences between NTG and HTG in other works [11,12]. We were interested in whether certain changes between HTG and NTG would be detectable even in evaluation of blood circulation in the eye.

The most frequently used method for determining the condition of blood circulation in clinical conditions is colour Doppler imaging (CDI). It is used for evaluating the velocity of blood flow in the eye vessels and also for determination of their resistance index. A higher value of resistance the index means higher vascular resistance, which indicates a circulatory disorder.

Compared to OCTA, CDI is an older method and has been used in ophthalmology since the end of the last century. Vascular dysregulation leads to unstable blood

**Table 1.** Pearson's correlation coefficient at level of significance  $p < 0.05$ . The last line shows the average values of the measured parameters

PEARSON'S CORRELATION COEFFICIENT											
	VF asb	PP-VDa	PP-VDs	WI-VDa	WI-VDs	PSV-AO	PSV-CRA	EDV-AO	EDV-CRA	RI-AO	RI-CRA
<b>VF asb</b>	1,00	0,65	0,64	0,65	0,64	-0,24	-0,08	0,09	0,15	-0,31	-0,39
<b>PP-VDa</b>	0,65	1,00	0,99	0,97	0,97	0,01	0,18	0,23	0,14	-0,24	-0,45
<b>PP-VDs</b>	0,64	0,99	1,00	0,95	0,97	0,00	0,18	0,21	0,11	-0,23	-0,43
<b>WI-VDa</b>	0,65	0,97	0,95	1,00	0,99	0,07	0,21	0,24	0,09	-0,19	-0,40
<b>WI-VDs</b>	0,64	0,97	0,97	0,99	1,00	0,05	0,23	0,20	0,06	-0,15	-0,35
<b>PSV-AO</b>	-0,24	0,01	0,00	0,07	0,05	1,00	0,42	0,73	0,24	-0,09	0,08
<b>PSV-CRA</b>	-0,08	0,18	0,18	0,21	0,23	0,42	1,00	0,17	0,30	0,12	0,14
<b>EDV-AO</b>	0,09	0,23	0,21	0,24	0,20	0,73	0,17	1,00	0,48	-0,71	-0,41
<b>EDV-CRA</b>	0,15	0,14	0,11	0,09	0,06	0,24	0,30	0,48	1,00	-0,46	-0,41
<b>RI-AO</b>	-0,31	-0,24	-0,23	-0,19	-0,15	-0,09	0,12	-0,71	-0,46	1,00	0,67
<b>RI-CRA</b>	-0,39	-0,45	-0,43	-0,40	-0,35	0,08	0,14	-0,41	-0,41	0,67	1,00
<b>AVE</b>	2022,48	55,08	48,96	52,81	46,49	40,11	14,27	9,82	4,17	0,76	0,73
<b>SD +/-</b>	154,30	5,08	5,15	4,35	4,31	12,83	4,17	4,30	2,31	0,07	0,09

AVE – average, PP-VDa – vessel density of all vessels peripapillary, PP-VDs – vessel density of small vessels peripapillary, WI-VDa – vessel density of all vessels in whole image, WI-VDs – vessel density of small vessels in whole image, PSV – peak systolic velocity, EDV – end diastolic velocity, RI – resistance index, CRA – central retinal artery, AO – ophthalmic artery ( $R = 0.00–0.19$  very weak,  $0.20–0.39$  weak,  $0.40–0.59$  moderate,  $0.60–0.79$  strong,  $0.80–1.00$  very strong)

flow in the eye, resulting in ischemia and damage to the optic nerve [13,14].

OCT angiography can be considered a relatively new, non-invasive and reproducible diagnostic method. The results of studies point to its high potential to become an integral component in the diagnosis of glaucoma [15]. The method offers the possibility of examining the parameters PPVDA (vessel density of all vessels peripapillary), PPVDs (vessel density of small vessels peripapillary), WIVDA (vessel density of all vessels in the whole image), WIVDs (vessel density of small vessels in the whole image) and RNFL in the area of the optic nerve papilla.

In glaucoma research, the examination of the perfusion parameters of retinal microcirculation in the peripapillary area has a larger validity than in the macular area [16].

Several authors have dealt with the relationships of VD in various studies of HTG. They have all determined that the more advanced glaucoma is, the more VD decreases [17,18,19,20,21,22]. In addition, the value of IOP plays a significant role in the value of VD. Holló registered that VD increases when there is reduction of IOP in young patients with high IOP [23]. Conversely, after an increase to over 20 mmHg, the density of macular and peripapillary vessels is significantly decreased [24].

There is a small number of works comparing OCTA with CDI in HTG.

In our cohort we have demonstrated that VD correlates with RICRA weakly WI-VDs ( $r = -0.39$ ) and moderately strongly WI-VDs ( $r = -0.4$ ), PP-VDs ( $r = -0.43$ ) and PP-VDA ( $r = -0.45$ ). This means that with an increasing resistance

index in the CRA, VD decreases.

Deokule et al. investigated the correlation between changes in visual fields and perfusion parameters with the help of CDI. They demonstrated that peripapillary perfusion parameters do not correlate with changes in the perimeter [25].

In this study also, we demonstrated a strong relationship between VD and changes in visual fields, but no relationship between changes in visual fields and perfusion parameters was identified by CDI.

In our previous study, in which we compared VD with RNFL in altitudinal halves of retina in HTG, we found a moderate correlation (in upper halves of the retina  $r = 0.5$ , in lower halves of the retina  $r = 0.51$ ). This is a significant discovery, because alteration of VD subsequently leads to damage in the RNFL, and thereby to changes in visual fields [26]. Yarmohammadi et al. also reached a similar conclusion about damage to the RNFL and VD in unilateral glaucoma [27].

## CONCLUSION

Our results demonstrated that blood circulation in the eye in HTG has a huge impact on changes in visual fields. A weak negative relationship was demonstrated between the visual field and resistance index in the CRA and AO. Perfusion parameters in the CRA and AO do not have this impact. The resistance index in the CRA had a weak to moderate relationship with VD. OCTA is better than Doppler ultrasound in examining the condition of blood circulation in the eye.

## LITERATURE

1. Morgan JE, Uchida H, Caprioli J. Retinal ganglion cell death in experimental glaucoma. *Br J Ophthalmol.* 2000;84:303-310.
2. Naskar R, Wissing M, Thanos S. Detection of Early Neuron Degeneration and Accompanying Microglial Responses in the Retina of a Rat Model of Glaucoma. *Invest Ophthalmol Vis Sci.* 2002;43:2962-2968.
3. Shou T, Liu J, Wang W, Zhou Y, Zhao K. Differential dendritic shrinkage of alpha and beta retinal ganglion cells in cats with chronic glaucoma. *Invest Ophthalmol Vis Sci.* 2003;44:3005-3010.
4. Lesták J, Fůs M. Neuroprotection in glaucoma – a review of electrophysiologist. *Exp Ther Med.* 2020;19:2401-2405.
5. Řehák S. Etiologie a patogeneze primárních glaukomů [Etiology and Pathogenesis of the Primary Glaucoma]. *Cesk Oftalmol.* 1975;31:1-14. Czech.
6. Karel I, Kraus H, Peleška M. Příspěvek k fluoroangiografickým nálezům u glaukomu s otevřeným úhlem [Contribution to the Fluoroangiographic Findings on Open-angle Glaucoma]. *Cesk Oftalmol.* 1975;31:40-46.
7. Dienstbier E. Glaukom v pojetí neurovaskulární teorie. [Glaucoma in the concept of neurovascular theory]. *Cesk Oftalmol.* 1975;31:81-92.
8. Deokule S, Vizzeri G, Boehm AG, Bowd C, Medeiros FA, Weinreb RN. Correlation among choroidal, peripapillary, and retrobulbar vascular parameters in glaucoma. *Am J Ophthalmol.* 2009;147:736-743.
9. Meng N, Zhang P, Huang H, et al. Color Doppler imaging analysis of retrobulbar blood flow velocities in primary open-angle glaucomatous eyes: a meta-analysis. *PLoS One.* 2013 May 13;8(5):e62723. doi: 10.1371/journal.pone.0062723
10. Lešták J, Fůs M, Benda A, Marešová K. OCT angiography and Doppler sonography in Normal-tension glaucoma. *Cesk Slov Oftalmol.* 2020;76:120-123. doi: 10.31348/2020/20
11. Lešták J, Pitrová Š, Nutterová E, Bartošová L. Normal tension vs high tension glaucoma: an - overview. *Cesk Slov Oftalmol.* 2019;75(2):55-60. doi: 10.31348/2019/2/1
12. Lešták J, Pitrová Š, Marešová K. Highlights of hypertensive and normotensive glaucoma. *Cesk Slov Oftalmol.* 2020;76:222-225. doi:10.31348/2020/31
13. Flammer J, Mozaffarieh M. What is the present pathogenetic concept of glaucomatous optic neuropathy? *Surv Ophthalmol.* 2007;52:162-173.
14. Ehrlich R, Harris A, Siesky BA, et al. Repeatability of retrobulbar blood flow velocity measured using color Doppler imaging in the Indianapolis Glaucoma Progression Study. *J Glaucoma.* 2011;20:540-547.
15. Alnawaiseh M, Lahme L, Eter N, Mardin C. Optical coherence tomography angiography: Value for glaucoma diagnostics. *Ophthalmologe.* 2019;116:602-609. doi: 10.1007/s00347-018-0815-9
16. Richter GM, Chang R, Situ B, et al. Diagnostic Performance of Macular Versus Peripapillary Vessel Parameters by Optical Coherence Tomography Angiography for Glaucoma. *Transl Vis Sci Technol.* 2018 Dec 6;7(6):21. doi: 10.1167/tvst.7.6.21. eCollection 2018 Nov
17. Mammo Z, Heisler M, Balaratnasingam C, et al. Quantitative Optical Coherence Tomography Angiography of Radial Peripapillary Capillaries in Glaucoma, Glaucoma Suspect, and Normal Eyes. *Am J Ophthalmol.* 2016;170:41-49.
18. Yarmohammadi A, Zangwill LM, Diniz-Filho A, et al. Relationship between Optical Coherence Tomography Angiography Vessel Density and Severity of Visual Field Loss in Glaucoma. *Ophthalmology.* 2016 Dec;123(12):2498-2508.
19. Hou H, Moghimi S, Zangwill LM, et al. Inter-eye Asymmetry of Optical Coherence Tomography Angiography Vessel Density in Bilateral Glaucoma, Glaucoma Suspect, and Healthy Eyes. *Am J Ophthalmol.* 2018;190:69-77.
20. Hollo G. Comparison of Peripapillary OCT Angiography Vessel Density and Retinal Nerve Fiber Layer Thickness Measurements for Their Ability to Detect Progression in Glaucoma. *J Glaucoma.*

2018;27:302-305.

21. Penteado RC, Zangwill LM, Daga FB, et al. Optical Coherence Tomography Angiography Macular Vascular Density Measurements and the Central 10-2 Visual Field in Glaucoma. *J Glaucoma*. 2018;27:481-489.
22. Mangouritsas G, Koutropoulou N, Ragkousis A, Boutouri E, Diagouras A. Peripapillary Vessel Density In Unilateral Preperimetric Glaucoma. *Clin Ophthalmol*. 2019;13:2511-2519. doi: 10.2147/OPTH.S224757
23. Holló G. Influence of Large Intraocular Pressure Reduction on Peripapillary OCT Vessel Density in Ocular Hypertensive and Glaucoma Eyes. *J Glaucoma*. 2017 Jan;26(1):e7-e10. doi: 10.1097/IJG.0000000000000527
24. Ma ZW, Qiu WH, Zhou DN, Yang WH, Pan XF, Chen H. Changes in vessel density of the patients with narrow anterior chamber after an acute intraocular pressure elevation observed by OCT angiography. *BMC Ophthalmol*. 2019 Jun 21;19(1):132. doi: 10.1186/s12886-019-1146-6
25. Deokule S, Vizzeri G, Boehm A, Bowd Ch, Weinreb RN. Association of visual field severity and parapapillary retinal blood flow in open-angle glaucoma. *J Glaucoma*. 2010;19:293-298.
26. Zakova M, Lestak J, Fus M, Maresova K. OCT angiography and visual field in hypertensive and normotensive glaucomas. *Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub*. 2020, 164, doi: 10.5507/bp.2020.044
27. Yarmohammadi A, Zangwill LM, Manalastas PIC, et al. Peripapillary and Macular Vessel Density in Patients with Primary Open-Angle Glaucoma and Unilateral Visual Field Loss. *Ophthalmology*. 2018;125:578-587.