

Retinal nerve fiber layer versus peripapillary capillary density assessment – A powerful tool for detecting optic nerve head diseases especially glaucoma

Sefić Kasumović Sanja, Kasumović Aida, Halimić Tarik and Sefić Mustafa

EYE Polyclinic „Dr. Sefić“, Sarajevo, Bosnia & Herzegovina

Keywords

optical coherence tomography angiography, peripapillary capillary density, glaucoma, optic nerve diseases, pathophysiology of glaucomatous damage

Abstract

Optical coherence tomography angiography (OCTA) is a new and non-invasive diagnostic tool in detecting changes in eye microvascular circulation. It is based on two innovative technologies such as Split Spectrum Amplitude Decorrelation Angiography (SSADA) algorithm and Motion Correction Technology (MCT) protocol.

According to the present findings, the vascular capillary network inside and outside of the optic disc has a significant, in fact, the leading role in nerve nutrition that is essential in glaucoma. OCTA can give us important information that has not been visible by other testing techniques. AngioVue imaging protocol allows visualization of microvasculature within specific retinal layers without the blurring effects of staining. It is useful in the detection of optic nerve vascular diseases and offers us the opportunity to expand our knowledge of the physiology of the optic disc.

2018 brings us radial peripapillary capillaries analysis (RPC). It's about a unique vascular plexus from the inner limiting membrane (ILM) to the posterior boundary of the retinal nerve fiber layer (RNFL). We can do quantitative analysis of RPC. The new OptoVue software offers Radial Peripapillary Capillary Maps (PCD maps). They give us a custom image analysis that provides qualitative and quantitative analysis of the perfused peripapillary capillaries

We presented the images of the healthy, incipient, moderate and advanced glaucoma, the ischemic optic neuropathy and papillitis presenting the angiography, colour maps of vessel density, the percentage of the vessel density and RNFL thickness. We emphasize the importance of the evaluation of ganglion cell body/inner plexiform layer enclosed to the evaluation of the above mention findings.

OCTA is not capable of direct blood flow measuring, but it offers insight into the perfusion status of the peripapillary region by identifying perfused vessels and quantifying the overall density of perfused vessels. Visualization of perfused peripapillary capillaries by the OCTA becomes an attractive imaging modality. PCD maps and new angiography technologies may provide an earlier functional sign of progressive optic nerve disease and new insights into the pathophysiology of glaucomatous damage.

Corresponding author:

Assist. professor Sanja Sefić Kasumović, MD, PhD, email: sefic1@bih.net.ba

Introduction

Optical coherence tomography angiography (OCTA) is a new and non-invasive diagnostic tool in detecting changes in eye microvascular circulation. It is based on two innovative technologies such as Split Spectrum Amplitude Decorrelation Angiography (SSADA) algorithm and Motion Correction Technology (MCT) protocol. The SSADA algorithm uses multiple spectra from single B-scan to improve image quality. It offers the best quality OCT angiography images. This technology achieves higher signal-to-noise ratio and better and more detailed visualization of the vasculature. This new approach recognizes early retinal, macular and optic disc disorders, and is becoming a part of the standard care in everyday practice in ophthalmology. (1)

The AngioVue Imaging System acquires different scan sizes with each volume scan acquired in less than 3 seconds. Two imaging volumes are obtained consecutively to perform motion correction later in order to remove the saccadic artefacts.

According to the present findings, the vascular capillary network inside and outside of the optic disc has a significant, in fact, the leading role in nerve nutrition

that is essential in glaucoma. OCTA can give us unique information that has not been visible by other testing techniques. AngioVue imaging protocol allows visualization of microvasculature within specific retinal layers without the blurring effects of staining. It is useful for detection the optic nerve vascular diseases and offers us the opportunity to expand our knowledge of the physiology of the optic disc. (2)

What we did to monitor and diagnose glaucoma until 2017?

So, we did the funduscopy where the size, shape, colour, cupping, margins, rim of the disc were seen. We checked intraocular pressure. Pachymetry checked the corneal thinning or thickening. According to the corneal thickness we corrected the measured intraocular pressure.

Also, we did the gonioscopy and saw anterior chamber angle, we did the visual field tests and recognized an increase of the blind spot, found out the arcuate scotoma or discovered the altitudinal defect.

OCT detected the thickness of the retinal nerve fiber layer and found out the organisation of them.

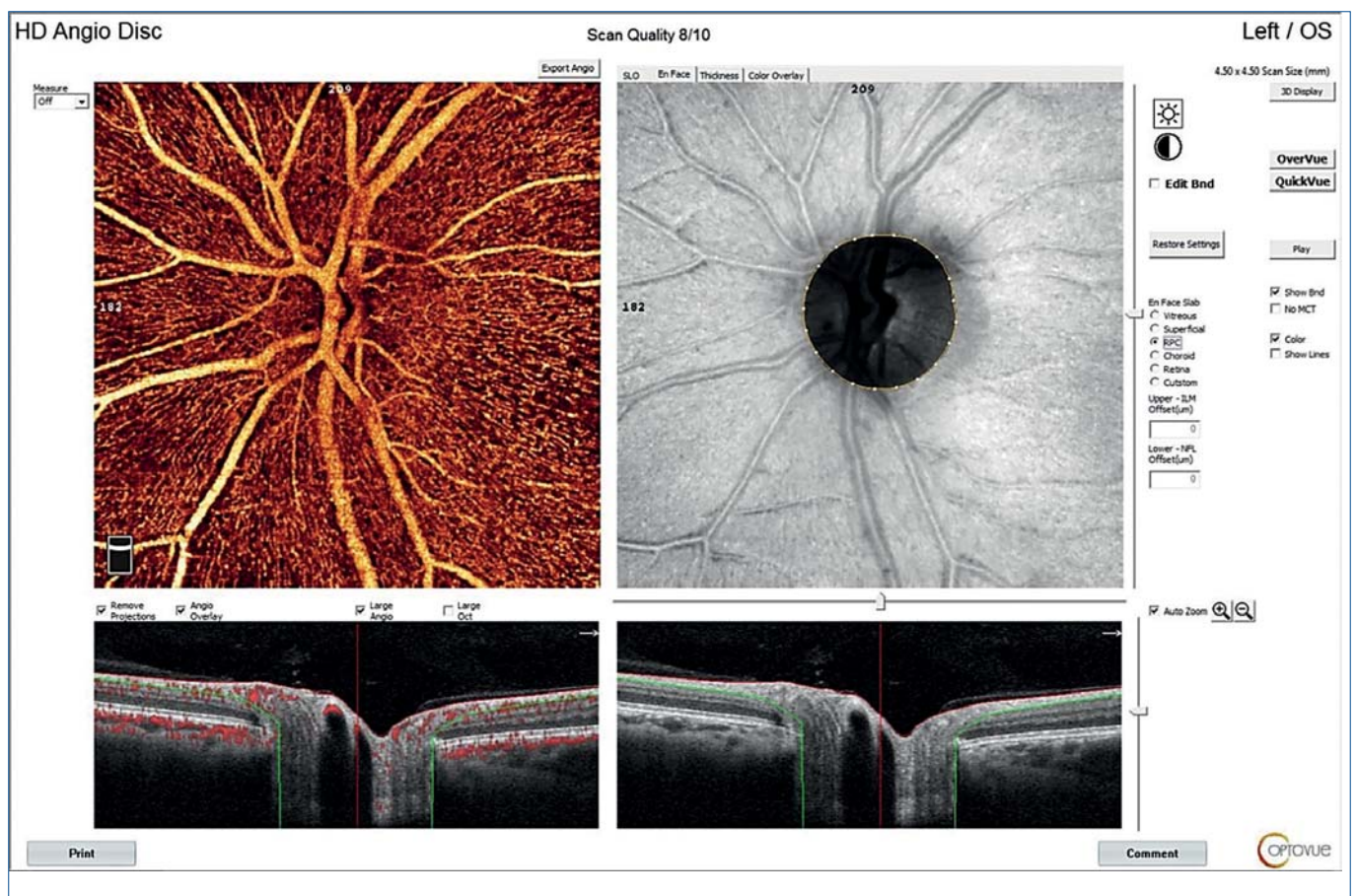


Figure 1. Radial peripapillary capillaries (RPC) are seen on the top left side a nice tiny and dense capillary meshwork which is symmetrical around the papilla, the large and major blood vessels are also seen, there are no drop outs inside and around the papilla. On the right side, the same picture but on the level of retinal pigment epithelium, there are no blood vessels, on the lower left image there we see OCTA scan with dense blood flow, on the right bottom image there is no blood flow

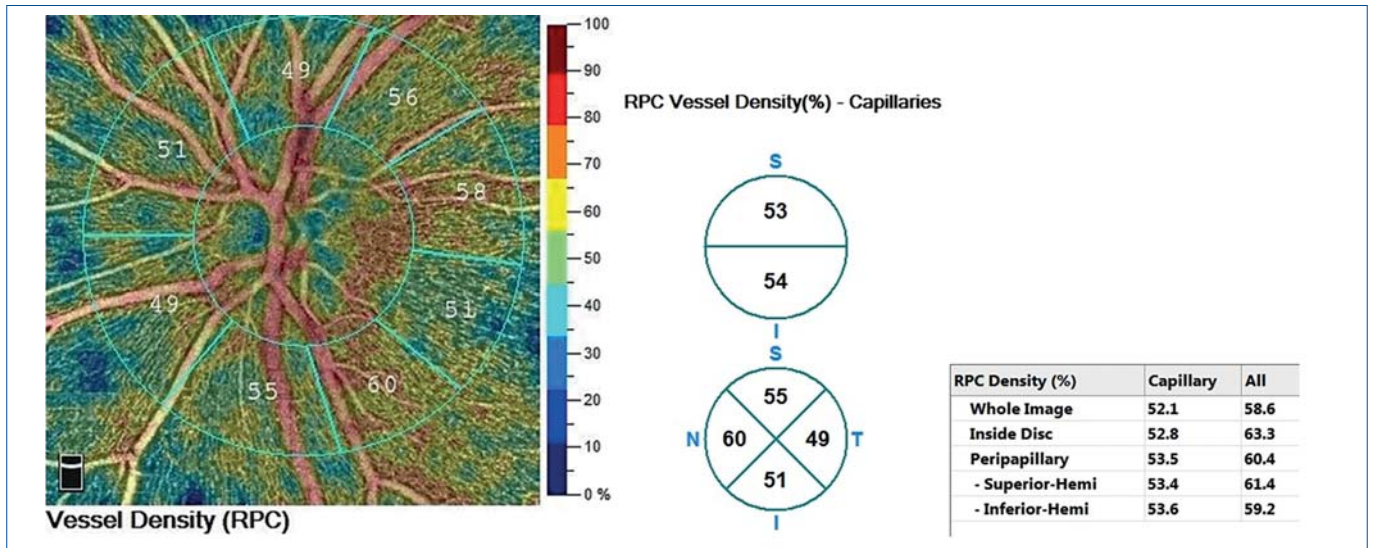


Figure 2. Peripapillary capillary density map offers the opportunity of evaluating density of blood vessels and flow through the optic nerve head (ONH). On the left side image presents yellow, orange and red colour which symbolize high blood flow. On the opposite side the green colour implies moderate flow and various shades of blue mean that the flow is decreased. In the middle we see numerical values that objectify earlier presented blood flow. The top circle presents the flow through the superior and inferior segment, and in the bottom one ONH is divided in four segments. On the right side, we see a table with numerical presentation of radial peripapillary capillaries density in percentage, divided in segments and both with inclusion and exclusion of major blood vessels.

Last few years we have got OCTA with which we could see thinny and dense capillaries in the disc and in the peripapillary area. The lamina cribrosa and its pores have been presented for the first time.

What brings the 2018?

It brings us radial peripapillary capillaries analysis (RPC). It's about a unique vascular plexus from the inner limiting membrane (ILM) to the posterior boundary of the RNFL. The capillaries run along relatively long straight paths and are limited to the posterior pole

where they seem to be associated highly with the superficial nerve fibers.

For the first time in 2018, we can do quantitative analysis of RPC. The new OptoVue software offers Radial Peripapillary Capillary Maps (PCD maps). They give us a custom image analysis that provides qualitative and quantitative analysis of the perfused peripapillary capillaries (3).

We can compare the angiography, vessel density and retinal nerve fiber layer (RNFL) thickness in a healthy eye and in a glaucomatous eye. In a normal eye with-

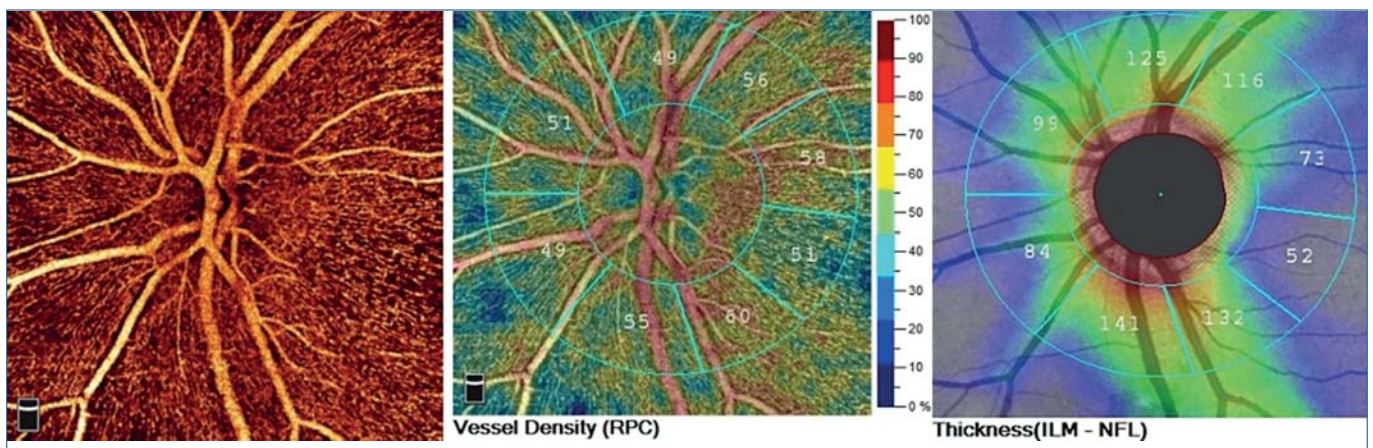


Figure 3. The upper row shows the angiography, capillary density mapping and RNFL thickness map of the healthy eye. On the top left image OCT angiography is presented with nicely dense capillary meshwork. In the middle RPC is almost 50% in each segment and there is prevalence of warm colours. Top right image shows map of thickness of RNFL with the average number over 90 microns.

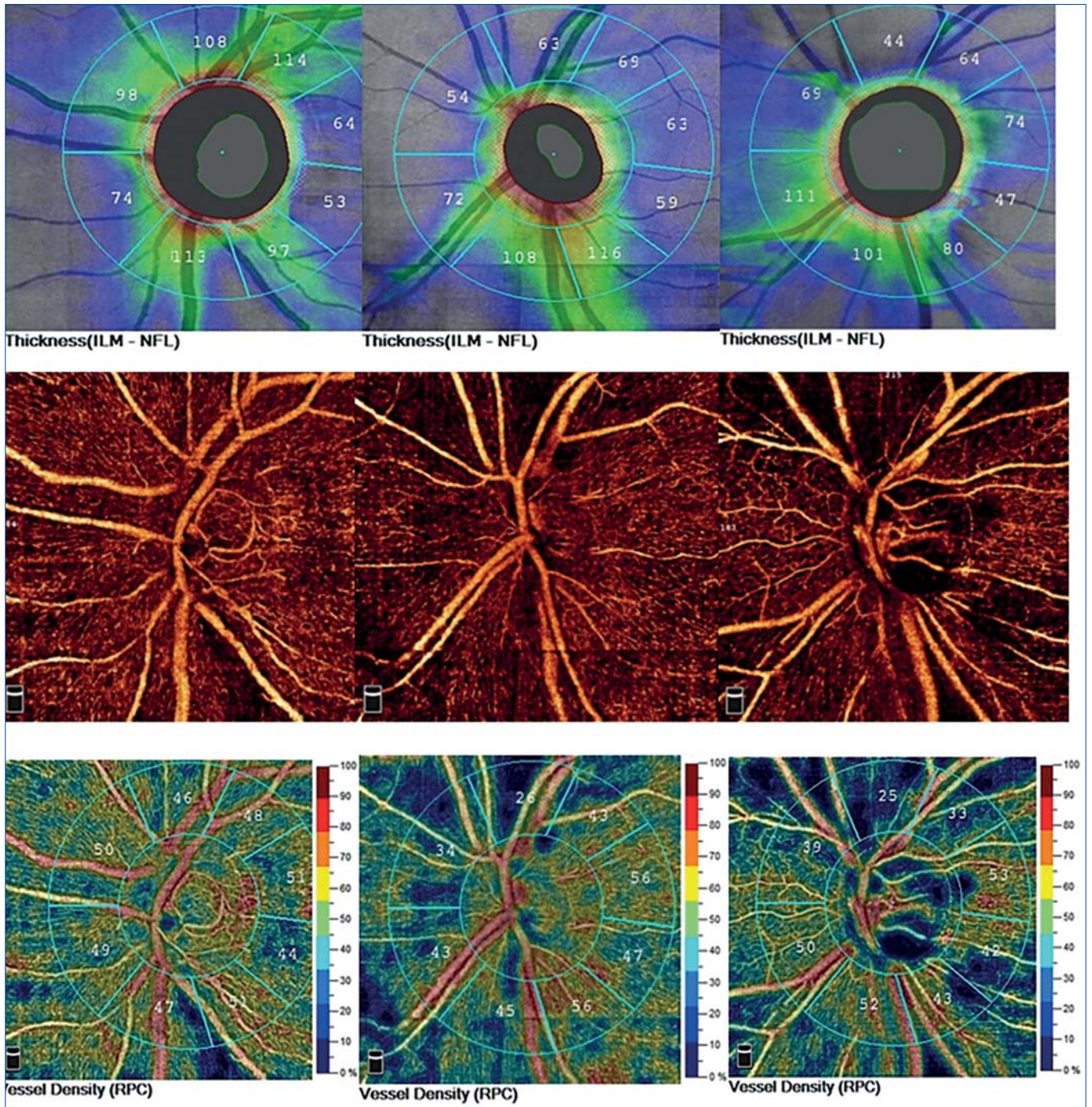


Figure 4. Progressive glaucoma changes are demonstrated in three columns, each containing RNFL thickness map, OCT angiogram and PCD map. In the top row RNFL changes are shown, in the first image we see incipient glaucoma case, most of the segments are thicker than 90 microns, the next one shows moderate glaucoma patient with a decrease in thickness with most of segments below 70 microns, and the last one shows advanced glaucoma deterioration of ONH. In the middle row we see OCT angiogram of incipient glaucoma on the left side with only a few vascular drop outs, the next image shows moderate glaucoma changes with larger zones of vascular drop outs and the right image shows advanced glaucoma with even larger zones of drop outs with loss of fine capillary meshwork. The bottom row shows PCD maps, on the first image we see incipient glaucoma, where the blood flow is still not decreased, the middle image of moderate glaucoma shows decrease in nasal and superior segment and the right image of advanced glaucoma shows decreased blood flow inside the disc and in most of peripapillary segments of ONH.

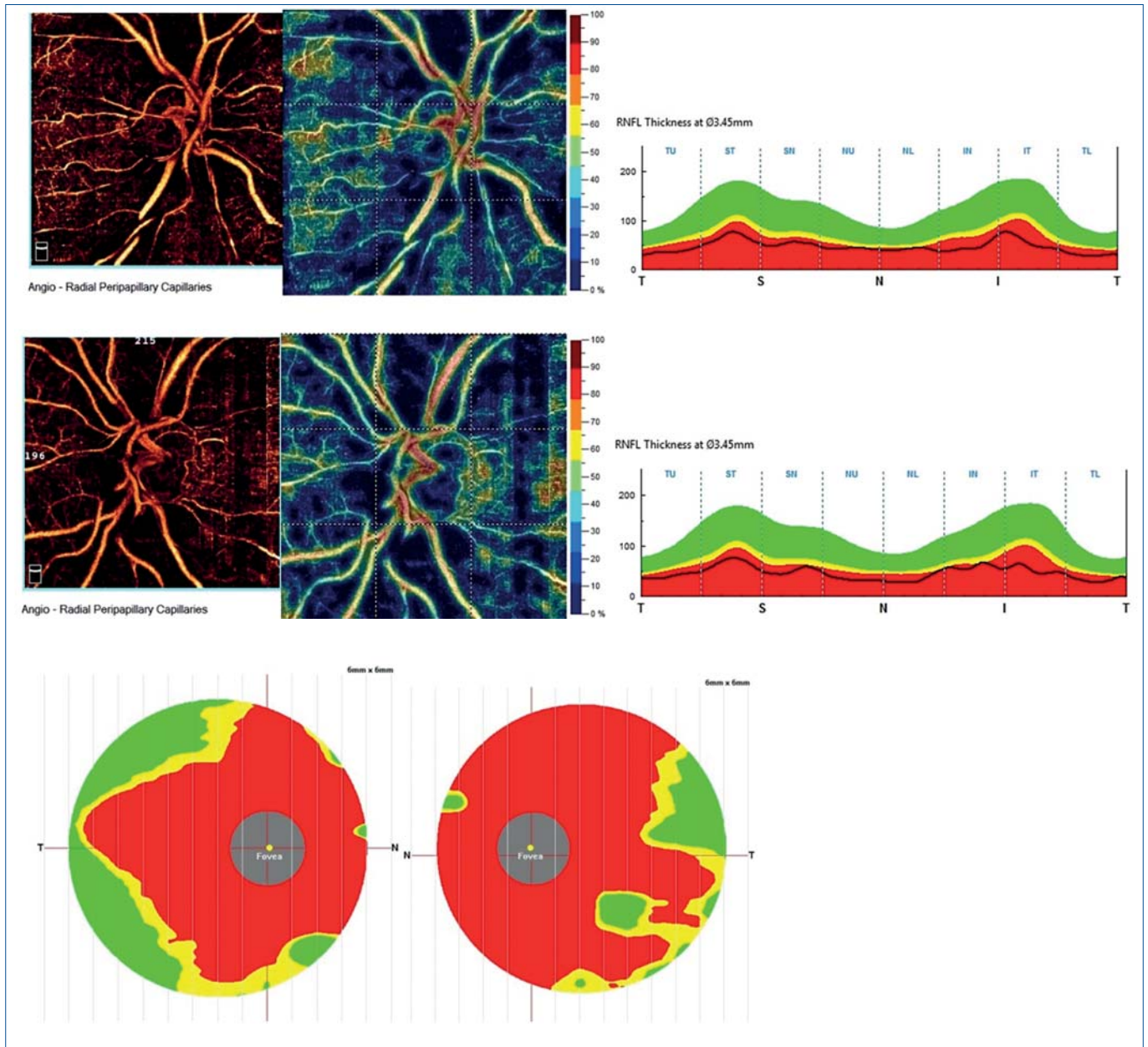


Figure 5. The importance of assessment of ganglion cellular body complex changes due to the glaucoma deterioration like drop out inside the disc and peripapillary, the lower RPC, the thinning of RNFL. On the top left image we see of both glaucomatous eyes with huge drop out inside papilla and peripapillary and dark colours on the PCD map, on the right side on the RNFL graph the line showing RNFL thickness is in the red zone (highly deteriorated). The bottom circle images presents the red zone inside fovea and macula which completely atrophic and disappeared. So, the changes in RPC flow, the thinning of RNFL directly correspond to changes in retinal ganglion cell/inner plexiform layer thickness.

out glaucoma we can see a gentle and very dense capillary network, warm red and orange colours on the PCD map and the normal RNFL thickness with the values over of 90 microns in average. In a glaucomatous eye we can notice in the angiogram the decreasing blood flow with the drop-outs in the superior, temporal and inferior peripapillary parts of the optic disc. On the PCD map the dark, blue colours are dominant and on the thickness picture there are decreasing of the RNFL values to 54 microns temporally.

How to follow up the changes in a case of progressive glaucoma?

We can follow up the changes in RNFL, in the OCT angiogram and in the PCD maps. All the changes should correspond to each other. As the glaucoma disease is progressing, the scans will show more changes and thinning of RNFL according to the dark and blue colours in the PCD maps and drop-outs in the OCT angiograms.

As the glaucoma syndrome is developing up, the

more obvious is the peripapillary drop out, as well as the drop out inside the disc. There is the prevalence of cold, blue colours in PCD maps and the thinning of peripapillary RNFL is present..

All of those findings should correspond to each other and should help us to understand the exact semiology of glaucoma disease.

OCTA also can help us in diagnosing and monitoring of other optic nerve diseases

Many other optic nerve head diseases and conditions, beside glaucoma, can be monitored with an OCTA. Such are papillitis, optic neuritis, ischemic optic neuropathies, tumors of the optic nerve head or papillar edema. All of those states cause RPC pattern changes or the changes of optic disc vascularisation. Most common change that can be observed on OCT angiography images is lower peripapillary capillary density. Furthermore, PCD maps can give an additional insight in state of the optic nerve head, so in papillar

edema it can show significant decrease of RPC density although RNFL thickness and capillary flow are increased. Many studies have shown that OCT-A can be helpful in differentiating disc swelling and other optic nerve head diseases.

Conclusion

- OCTA is an innovative new technology that can improve patient monitoring and facilitate our everyday practice. It is not capable of direct blood flow measurement, but it offers insight into the perfusion status of the peripapillary region by identifying perfused vessels and quantifying the overall density of perfused vessels.
- New mapping modalities, as colour maps, can easily identify regions of decreased perfused vessel density and they are today a very attractive imaging modality for assessing glaucoma and other optic nerve head diseases.
- Comparison of the capillary network density by OCTA and other available diagnostic procedures con-

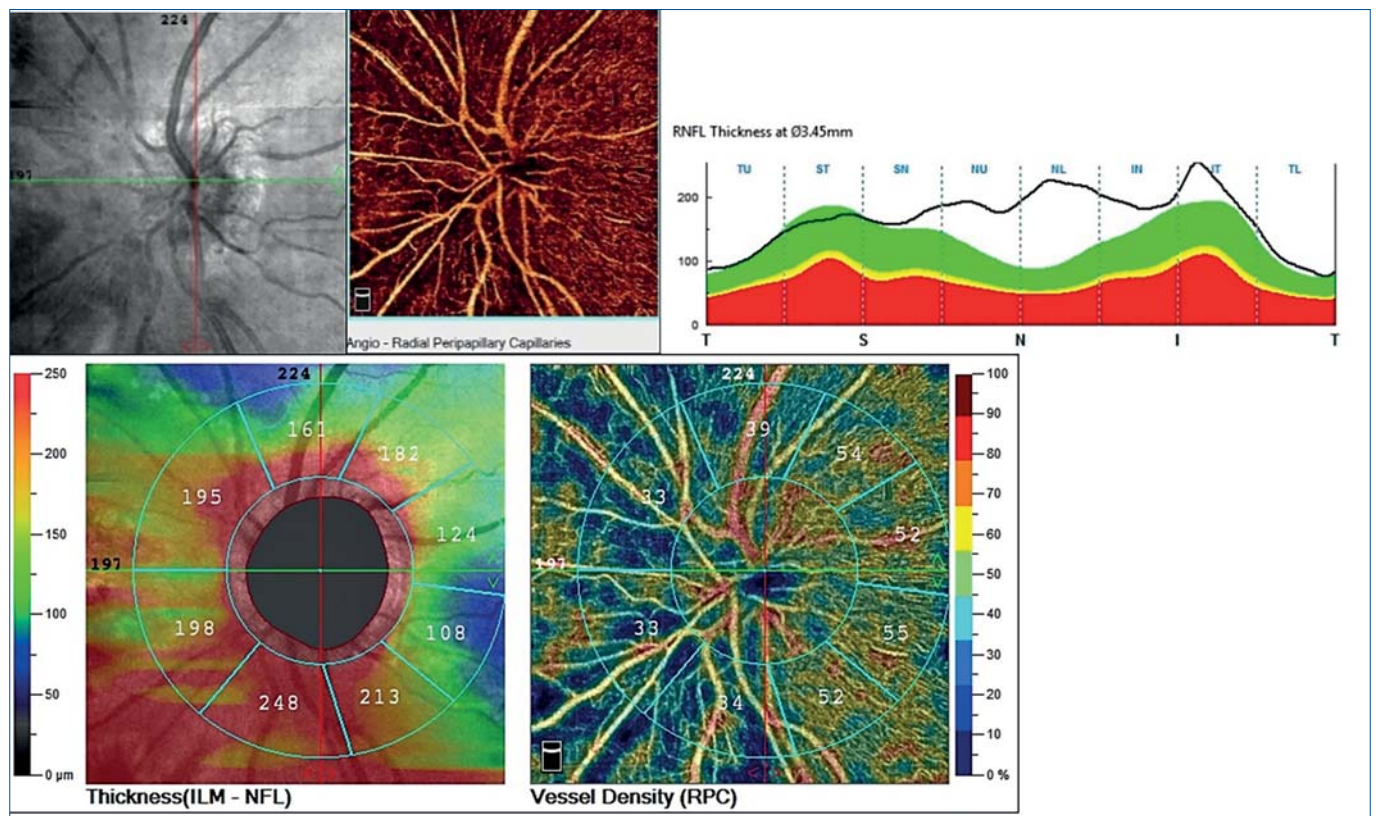


Figure 6. Optic neuritis is shown with the fundus photography in which the nasal part of the disc is uncertain, oedematous with tortuous blood vessels. In the angiogram on the top left image there are drop-outs nasally, superiorly and inferiorly. On the top right image, the RNFL graph superiorly, nasally and inferiorly we can see highly elevated black line presented the thickening of RNFL. On the RNFL thickness map and PCD map the warmly red and orange colours are dominant with values of RNFL over 160 to 248 microns. On vessel density map the blue and cold colours are dominant with decreased vessel density and the blood flow lower than 33%. The flow is extremely high and it cannot be detected by the OCTA software and oedema is making pressure on RPC.

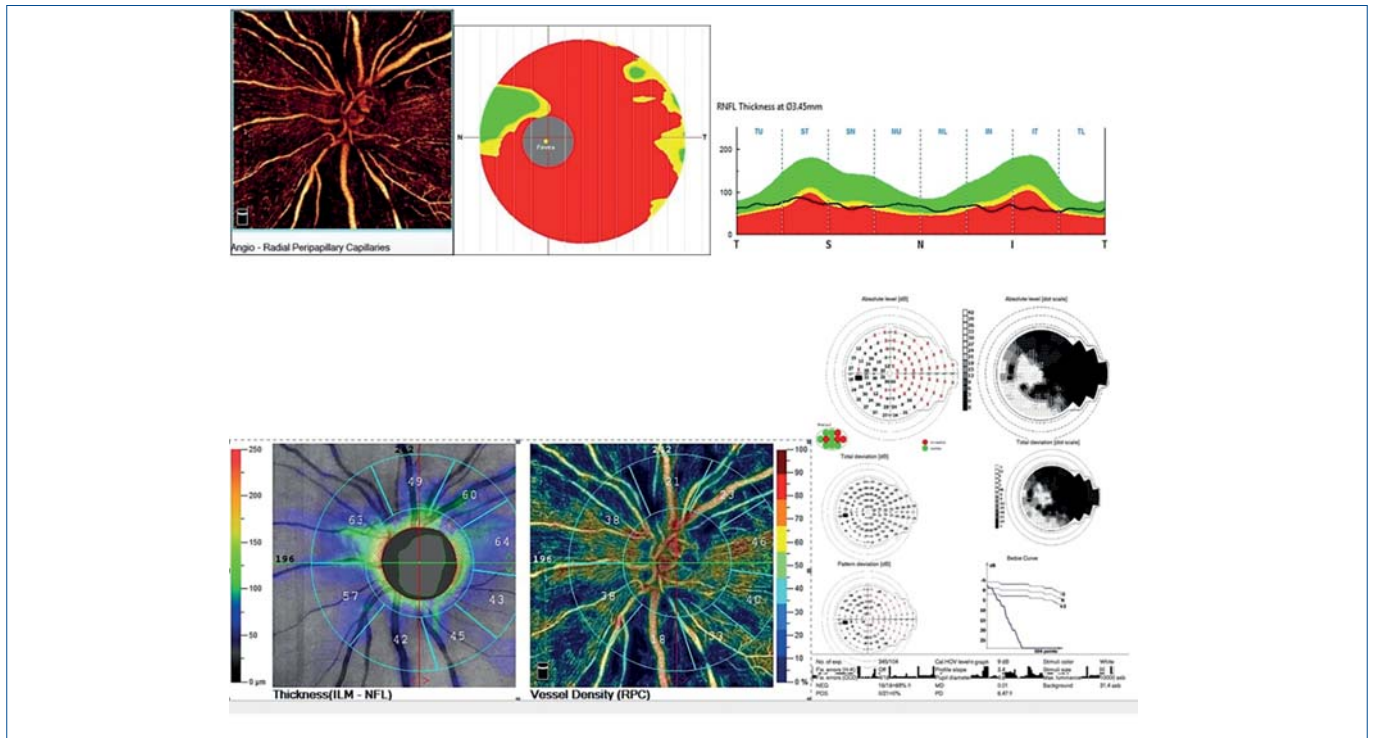


Figure 7. Ischemic optic neuropathy is presented as a big and widespread drop-out on the angiogram, and complete atrophy on GCC in macula of the affected eye. On the RNFL thickness graph the black line is under expected level (in the top row). On the bottom left there is serious decrease of RNFL thickness and cold and blue colours are dominant on RPC map. The visual field shows concentric arcuate scotoma on both eyes with serious deterioration of Bebie curve (bottom right).

tribute to easier defining the stage of glaucoma development and progression.

- PCD maps and new angiography technologies may provide an earliest functional sign of progressive optic nerve disease and new insights into the pathophysiology of glaucomatous damage.

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