

OCTA - A NOVEL IMAGING TECHNIQUE FOR GLAUCOMA

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I. INTRODUCTION

Glaucoma is a progressive degeneration of Retinal Ganglion Cells (RGC) that causes changes in the Optic Nerve Head (ONH) leading to visual field constriction. Worldwide, glaucoma is stated as the second leading cause of irreversible blindness^(1, 2, 3). In India, 11.2 million people with age more than 40 years were living with glaucoma⁽⁴⁾. By 2050, studies estimated that 6 million people may lead to blind as a consequence of being undiagnosed in early-stage. Glaucomatous damage is a preventable disorder, therefore early detection and improved techniques in glaucoma diagnosis are primordial⁽⁵⁾

II. PATHOGENESIS OF GLAUCOMA

The pathophysiology of glaucoma is considered to be multifactorial. According to various theories, high intraocular pressure and vascular deregulation are effective threat factors for glaucoma. It stresses within and across the lamellar region with subsequent damage to the bundle of RGC axons and disruption of Axonal transport, modified microcirculation in the lamellar region, and changes in lamellar glial and connective tissue. Multiple stresses such as RGC axon, endothelial cells, and astrocytes are likely to contribute to glaucoma, though progression mechanisms have not been completely understood.⁽⁹⁾ These degenerations of the nerves and cell bodies result in visual field loss, and also cause deformation and remodeling of the optic disc⁽¹⁰⁾.

The most commonly used theories in the pathogenesis of glaucoma are mechanical theory and vascular theory. First, raised Intra Ocular Pressure (IOP) is a modifiable risk factor to control the progression of glaucoma. The second mechanism is that vascular factors play a role in decreased ocular perfusion leading to hypoxia causing accumulation of Reactive Oxygen Species (ROS) in the ONH. This ischemic mechanism contributes to RGC apoptosis and glaucomatous neural damage^(7, 8). Diagnosis is frequently delayed due to being asymptomatic in the early stages and progressing to symptomatic in later stages. So, early detection, periodic treatment, and regular follow-up are crucial in glaucoma patients.

III. OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY (OCTA)

OCTA is an advanced imaging technology in the field of glaucoma diagnosis and management. It is non – invasive technique based on the principle of low-coherence interferometry performed to visualize the retinal and choroid vasculature in the absence of Intra Venous (IV) dye injection.

IV. PRINCIPLE

OCTA compares consecutive OCT b-scans gained at same location to identify the motion changes and construct a blood flow map. OCTA detects blood vessels by detecting the erythrocyte movement in the OCT reflectance signal. This allows for the visualization and quantification of blood flow in the retinal layers and optic nerve head. It helps to recognize the vascular changes initiated by glaucoma. The commercially available OCTA device use different types of algorithms – SSADA (Spilt spectrum amplitude decorrelation angiography), OMAG -C (OCT Microangiography Complex), and OCTARA (OCTA ratio analysis).

OCTA can evaluate the blood flow using various vascular parameters to investigate the glaucoma suspects, including vascular density and perfusion density in the ONH, selected layers of the macula, peripapillary area, and the optic disc flow index⁽⁹⁾. Selective Capillary perfusion is measured which gives important information in the glaucomatous process. The commonly used parameters are vessel density which represents the percentage of the area by red blood cell movement.

V. UTILIZATION OF OCTA IN GLAUCOMA

- 1. Assessment of ONH Perfusion:** OCTA can assess the blood flow in the ONH, Reduced blood flow in this area has been associated with glaucoma progression.
- 2. Peripapillary Vessel Density Measurement:** OCTA can quantify the density of blood vessels around the optic nerve head, providing valuable information about the health of the retinal vasculature. Lower vessel density has been linked to glaucoma and can serve as an indicator of disease severity.
- 3. Macular Vascular Changes:** OCTA can visualize the macular region, which is crucial for central vision. Changes in the macular vasculature have been observed in glaucoma patients and can offer insights into disease progression.
- 4. Detecting Microvascular Abnormalities:** In glaucoma, there may be microvascular abnormalities that are not evident with traditional imaging techniques. OCTA's high resolution enables the detection of these subtle changes, helping clinicians identify early signs of glaucoma.
- 5. Monitoring Disease Progression: Regular** OCTA imaging can aid in monitoring the progression of glaucoma over time. Comparing sequential scans allows clinicians to identify changes in vascular patterns and assess treatment efficacy.
- 6. Differentiating Glaucoma from Other Optic Neuropathies:** OCTA may be helpful in distinguishing glaucoma from other ocular conditions.

VI. PARAMETERS AVAILABLE IN OCTA ⁽¹¹⁾

Many parameters are available in OCTA to differentiate the glaucomatous eye from the normal eye.

- 1. Vessel Density (VD):** It is also known as vessel area density or capillary density. It is represented as a ratio of the area of blood vessels in an image to the area of percentage which shows non-perfusion. This parameter can detect ischemic area and vascular drop-out zones in retinal and choroid. The early changes of disease occur at the capillary level so OCTA can be used as an early diagnostic tool.
- 2. Blood Vessel Caliber (BVC):** This parameter has alternate names of vessel diameter, vessel width, or vessel diameter index are the other names of BVC. It measures vessel dilation or attenuation caused by different ocular pathologies. This is calculated in the ratio of vessel area to the length of the vessel.
- 3. Blood Vessel Tortuosity (BVT):** In normal vasculature and flow, blood vessels travel smoothly in the tissue to transport the blood efficiently. Due to some ocular pathologies, blood vessels may not be smooth causing vessel tortuosity which causes abnormal blood transport. BVT measures the degree of distorted vessels in the specific area.
- 4. Vessel Perimeter Index (VPI):** VPI measures the ratio of the total contour length of blood vessel boundaries to the total area of blood vessels in the segmented blood vessel map. It is a quantitative parameter that shows the ischemia and vessel dropout caused due to different ocular conditions.
- 5. Foveal Avascular Zone (FAZ):** The foveal avascular zone is a zone free of any vasculature in the fovea. The enlargement in the FAZ is a pathological sign and occurs due to different ocular conditions such as DR and vein occlusions. FAZ enlargement is caused by the drop out of parafoveal and perifoveal capillaries which can be captured by OCTA.
- 6. Branchpoint Analysis (BPA):** Bifurcation in vascular structure can be affected by decreased blood transport. BPA measures angle and width features of the blood vessels. Vessel branching angles and child branching angles are measured to quantify the bifurcation in vascular structure. This parameter can be used to classify diabetic retinopathy objectively.
- 7. Flow analysis:** Flow analysis includes Flow Index (FI), Flow Void (FV), adjusted FI, vascular connectivity, and other parameters. These are developed to detect the changes in the blood flow. Every pixel of the image that is captured by OCTA has its decorrelation value recorded. The Flow Index (FI) is the average decorrelation value within a particular region of the retina.

VII. OCTA FEATURES IN DIFFERENT TYPES OF GLAUCOMA

- 1. Primary open-angle glaucoma (POAG):** The reduction of microvascular density within the RNFL layer in the parapapillary retina in POAG eyes. The microvascular network of the parapapillary retina has undergone localized attenuation. This represents the RNFL

loss that occurs concurrently with capillary aging. Circumpapillary VD (cpVD) loss was found to be a more valuable diagnostic criteria than macular VD (mVD) loss for POAG. mVD decreases faster than GCC thinning, which correlates with disease severity. This parameter is useful for evaluating progress

- 2. Primary Closed Angle Glaucoma:** In comparison to controlled eyes, vessel density in the superotemporal RNFL thickness was significantly lower in PAC eyes.
- 3. Normal-tension Glaucoma :** For NTG patients, different studies found mVD loss can be used as a diagnostic utility than compared to cpVD loss. Macular intercapillary area enlargement could be a potential biomarker for early NTG

Limitation of OCTA

- Projection artifacts and motion artifacts are common limitations of OCTA
- Sometimes, the SSDA algorithm provides poor-quality images of the macular regions and optic disc.
- For OCTA, the scan period ranges from 3 to 6 seconds, which may induce a higher incidence of motion artifact. Patients with advanced glaucoma or dense cataract may face difficulty in fixing will result in poor quality results.
- OCTA does not account for vascular attenuation and dropout.

VIII. CONCLUSION

Undiagnosed and untreated glaucoma can lead to visual impairment, visual field loss and also cause economic burden to the society. Early glaucoma detection remains a challenge in the community. A comprehensive assessment, including visual field testing, structural OCT, and clinical examination, is essential for the accurate diagnosis and management of glaucoma. However, OCTA vascular biomarkers with clinical structural measurements also aid in the early diagnosis of glaucoma. As reviewing the literature, the utility and availability of OCTA among Indian eye care practitioners was less. So, the clinical significance of OCTA in India should evolve for early diagnosis of glaucoma.

REFERENCES

- [1] George, R., Ramesh, S. V., & Vijaya, L. (2010). Glaucoma in India: estimated burden of disease. *Journal of glaucoma*, 19(6), 391-397
- [2] Shon, K., Wollstein, G., Schuman, J. S., & Sung, K. R. (2014). Prediction of glaucomatous visual field progression: pointwise analysis. *Current eye research*, 39(7), 705-710.
- [3] Kanski, J. J., & Bowling, B. (2011). *Clinical ophthalmology: a systematic approach*. Elsevier Health Sciences.
- [4] Bojikian, K. D., Chen, P. P., & Wen, J. C. (2019). Optical coherence tomography angiography in glaucoma. *Current opinion in ophthalmology*, 30(2), 110-116.
- [5] Saxena R, Singh D, Vashist P Glaucoma: An emerging peril Indian J Community Med 2013 38 135 7
- [6] Yanagi, M., Kawasaki, R., Wang, J. J., Wong, T. Y., Crowston, J., & Kiuchi, Y. (2011). Vascular risk factors in glaucoma: a review. *Clinical & experimental ophthalmology*, 39(3), 252-258.
- [7] Ko ML, Peng PH, Ma MC, Ritch R, Chen CF. Dynamic changes in reactive oxygen species and antioxidant levels in retinas in experimental glaucoma. *Free Radic Biol Med* 2005; 39: 365–73.
- [8] Fard, M. A., & Ritch, R. (2020). Optical coherence tomography angiography in glaucoma. *Annals of Translational Medicine*, 8(18).
- [9] Weinreb, R. N., Aung, T., & Medeiros, F. A. (2014). The pathophysiology and treatment of glaucoma: a review. *Jama*, 311(18), 1901-1911.

- [10] Nickells, R. W., Howell, G. R., Soto, I., & John, S. W. (2012). Under pressure: cellular and molecular responses during glaucoma, a common neurodegeneration with axonopathy. *Annual review of neuroscience*, 35, 153-179.
- [11] Yao, X., Alam, M. N., Le, D., & Toslak, D. (2020). Quantitative optical coherence tomography angiography: a review. *Experimental Biology and Medicine*, 245(4), 301-312.
- [12] Yarmohammadi, A., Zangwill, L. M., Diniz-Filho, A., Suh, M. H., Manalastas, P. I., Fatehee, N., ... & Weinreb, R. N. (2016). Optical coherence tomography angiography vessel density in healthy, glaucoma suspect, and glaucoma eyes. *Investigative ophthalmology & visual science*, 57(9), OCT451-OCT459.
- [13] Bojikian, K. D., Chen, P. P., & Wen, J. C. (2019). Optical coherence tomography angiography in glaucoma. *Current opinion in ophthalmology*, 30(2), 110-116.
- [14] Lee, E. J., Lee, K. M., Lee, S. H., & Kim, T. W. (2016). OCT angiography of the peripapillary retina in primary open-angle glaucoma. *Investigative ophthalmology & visual science*, 57(14), 6265-6270.
- [15] Lee, S. Y., Son, N. H., Bae, H. W., Seong, G. J., & Kim, C. Y. (2021). The role of pattern electroretinograms and optical coherence tomography angiography in the diagnosis of normal-tension glaucoma. *Scientific reports*, 11(1), 12257.
- [16] Chang, P. Y., Wang, J. Y., Wang, J. K., Yeh, S. C., & Chang, S. W. (2020). Asymmetry analysis of optical coherence tomography angiography macular perfusion density measurements in preperimetric and perimetric glaucoma. *Scientific Reports*, 10(1), 14781.
- [17] Rao, H. L., Pradhan, Z. S., Weinreb, R. N., Riyazuddin, M., Dasari, S., Venugopal, J. P., ... & Webers, C. A. (2017). Vessel density and structural measurements of optical coherence tomography in primary angle closure and primary angle closure glaucoma. *American journal of ophthalmology*, 177, 106-115.