To study utility of laser speckle flowgraphy (LSFG) using Vasoptics for detection of early glaucoma

Aim: To compare ONH perfusion and macular microcirculation with Vasoptics and Optical coherence tomography angiography (OCTA) in early POAG and PACG.

Methods: Fundus imaging with Vasoptics and OCTA for blood flow velocity indices and vascular density parameters was performed on 60 eyes of normals, POAG and PACG (20 each). Kruskal-Wallis test was used for statistical analysis. AI analysis with validated random forest classifier was used for prediction.

Results: In Vasoptics peak blood flow velocity of inferior ONH was higher in normals 7.21[6.25to7.47] than in PAOG and PACG 6.24[5.66 to 6.61] with p= 0.02. Superior, central ONH and macular parameters on vasoptics; superficial disc and deep macular parameters on OCTA showed similar trend. AI analysis of Vasoptics parameters classified the eyes with an AUC of 0.94 and a precision of 0.84.

Conclusion: Dynamic blood flow parameters on Vasoptics along with vessel density parameters on OCTA help improve precision for detecting early glaucoma.

Introduction

Glaucoma can progress despite well-controlled intraocular pressure (IOP), indicating other factors may be involved. Research suggests that optic nerve head (ONH) blood flow abnormalities could contribute to glaucoma pathogenesis. Non-invasive technologies like Laser Speckle Flowgraphy (LSFG) and optical coherence tomography angiography (OCTA) were used in this study to assess ocular blood flow in normal subjects and individuals with mild to moderate primary glaucoma.

LSFG(XyCAM RI), is a non-invasive method that measures blood flow in the ONH, retina, and choroid using laser speckle patterns. It captures continuous retinal images for 6 seconds, deriving the Blood Flow Velocity Index (BFVi) and other parameters. Simultaneously, it records heart rate and blood oxygen saturation. LSFG distinguishes between arterial and venous blood flow and shows a strong correlation between BFVi waveforms and pulse oximeter data. It is portable and stable but may not be suitable for individuals with rapid eye movements. LSFG offers comfortable and user-friendly assessment of ONH blood flow.

OCTA is a non-invasive imaging technique that visualizes retino-choroidal blood flow using amplitude-decorrelation angiography. It quantifies absolute blood flow but faces limitations in ONH due to artifacts and capillary orientation. Peripapillary vessel density (VD) is an alternative measure useful for detecting glaucoma progression. Current OCTA technology scans the optic disc and macula, generating 3x3 mm volumetric scans. Key aspects include the radial peripapillary capillary slab (RPC) and the choroidal slab. Parameters like flow index and vessel density are used to assess

ocular circulation. Topcon DRI OCT Triton device is employed for viewing, imaging, and measuring vessel densities in this study . In summary, both LSFG and OCTA are valuable tools for understanding blood flow dynamics in the eye.

Materials and methods

This study is a comparative, prospective, cross-sectional observational study conducted on 60 subjects divided into three groups: two diseased groups and one normal group, each with 20 subjects. The diseased groups comprised of patients with mild to moderate Primary Open Angle Glaucoma (POAG) and Primary Angle Closure Glaucoma (PACG), respectively, while the remaining group comprised of normal subjects. All study subjects underwent various evaluations for glaucoma, including refraction, tonometry, slit-lamp examination, gonioscopy, dilated fundus examination, visual fields, OCT RNFL imaging for ocular blood flow parameters with OCTA for- 9 quadrant fundus photos,12x 12 macula radial scan, 3D RNFL Scan, 3x3 OCTA macula scan, 3x3 OCTA disc scan and XyCAMRI imaging for Optic disc centre. Writtern consent is taken as the machine is for research puprpose in India. Blood pressure was also measured before XyCAM RI imaging. Patients diagnosed with glaucoma as per the guidelines from International Society of Geographical and Epidemiological glaucoma (ISGEO) classification working group whose has perimetric findings and disc findings confirmative of glaucoma were included in the diseased groups. Subjects with advanced glaucoma significant media opacity or any ocular conditions like uveitis or retinal pathology were not included in the study.

Data entry was done on Excel worksheets to obtain mean values and standard deviation values. The non-parametric Kruskal Wallis ANOVA test was done to calculate the significance of each parameter between normal POAG and PACG groups. Vasoptic and OCTA ocular blood flow parameters were analyzed between three groups using MedCalc software v22.001 (MedCalc Inc). Both Vasoptic and OCTA ocular blood flow parameters of normal subjects were compared with those of mild to moderate glaucoma POAG and PACG patients. Further AI analysis with validated random forest classifier was done for prediction.

In this study, various ocular blood flow parameters are evaluated in patients with POAG and PACG compared to normal subjects using LSFG and OCTA technologies. The results showed significant differences between the three groups in terms of XyCAMRI and OCTA parameters. AI analysis was also used for prediction purposes.

RESULTS AND ANALYSIS

The study involved 60 patients divided into three groups: Normal, PACG, and POAG, with 20 patients in each group. The median age, height, and weight were recorded for each group. The Kruskal-Wallis ANOVA test was applied to find significant differences among the groups. Age and height were found to be significantly different among the groups, while weight was not significantly different.

It was observed that IOP of the diseased groups POAG and PACG was significantly higher than normal subjects. Mean Deviation, Pattern Standard Deviation, Visual Field Index of the diseased groups POAG and PACG were also significantly different from normal subjects.

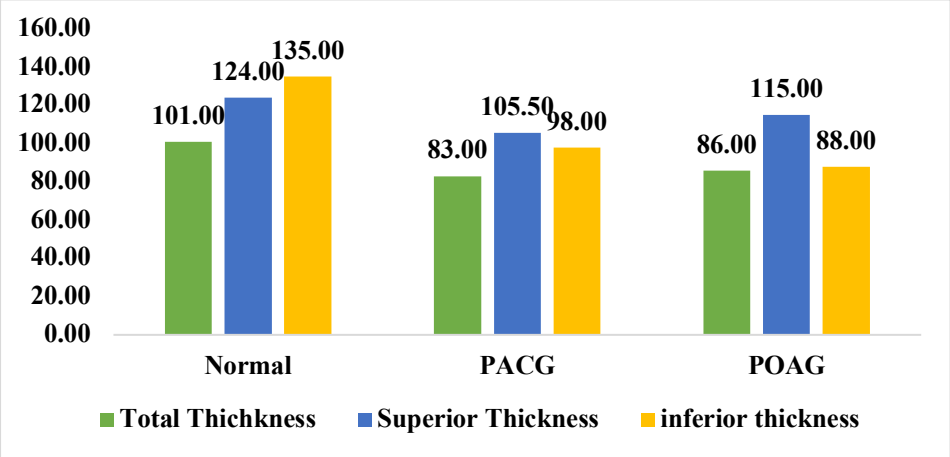

Figure: 1 -Graphical representation of comparision of OCT Parameters among Normal, PACG and POAG

Figure 1 showed a comparison of OCT RNFL parameters. Total Thickness and Inferior Thickness were significantly lower in diseased groups PACG and POAG when compared to the Normal Group. The vertical CDR was also significantly different between normal and diseased groups.

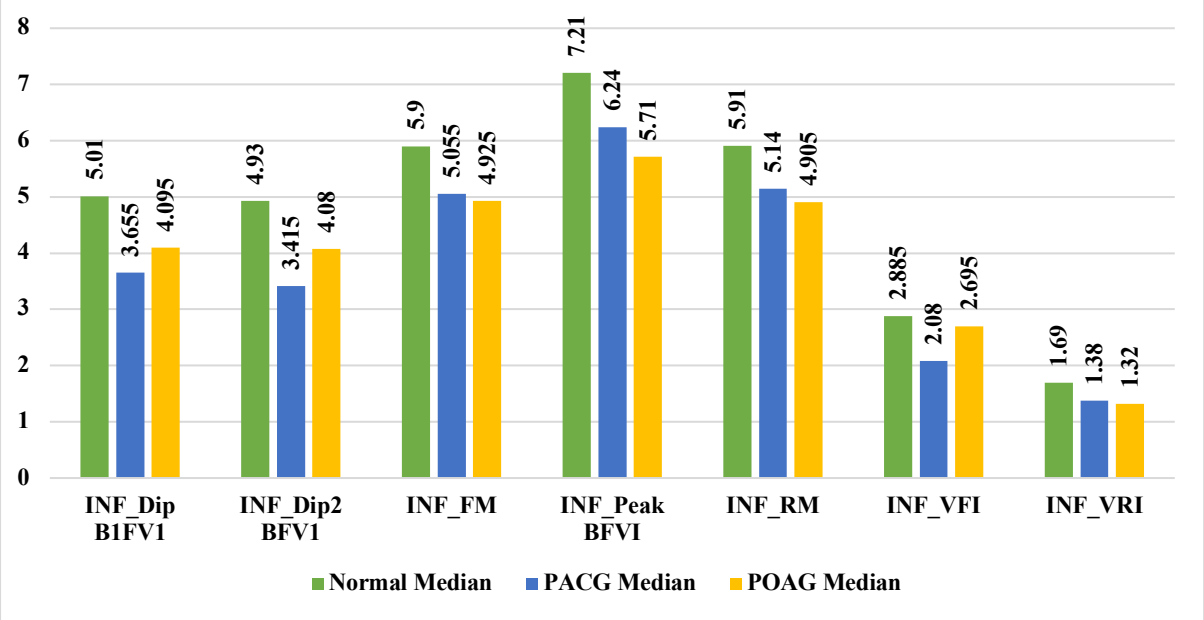

Figure: 2-Graphical representation of comparision of LSFG Parameters of INF ONH among Normal, PACG and POAG

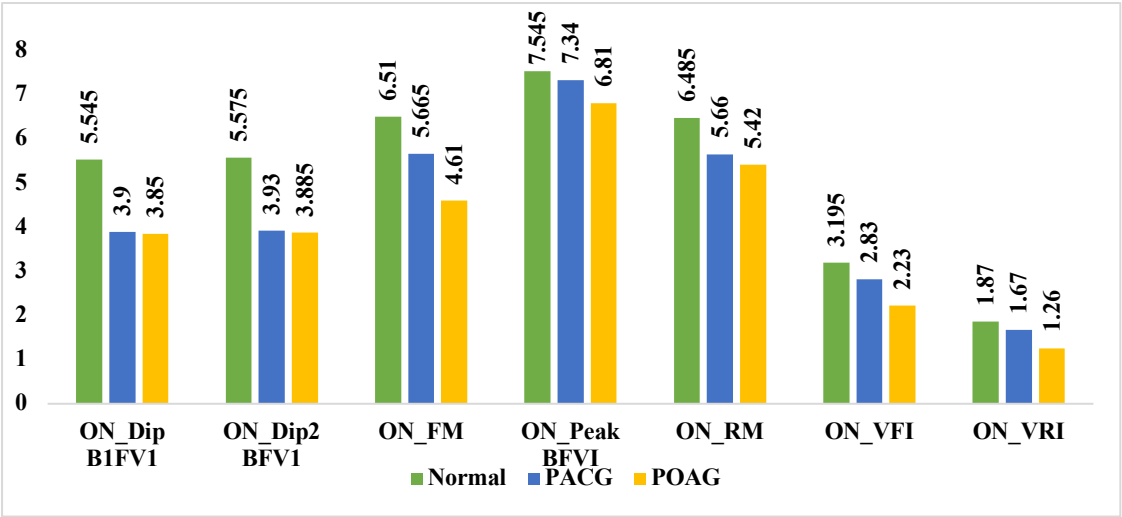

Figure: 3 Graphical representation of comparision of LSFG Parameters of Central ONH among Normal, PACG and POAG

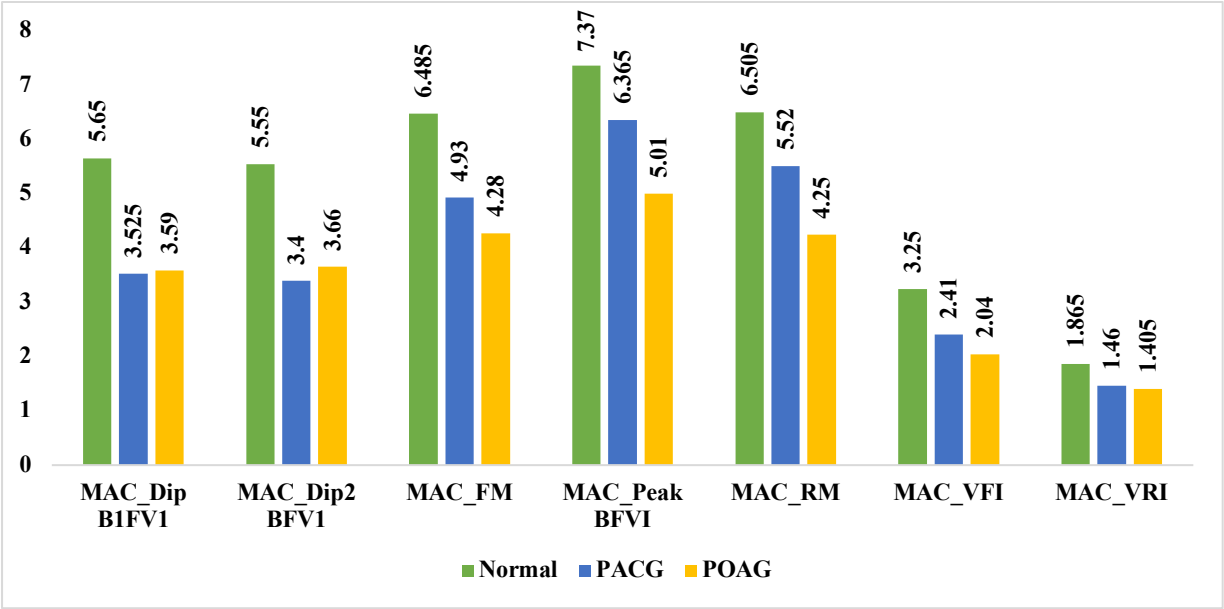

Figure: 4 -Graphical representation of comparision of LSFG Parameters of macula among Normal, PACG and POAG

Figures 2,3,4 are graphical representations showed a comparison of inferior ONH, central ONH, Macular vasoptic blood flow parameters respectively. Several parameters were found to be significantly different in diseased groups POAG and PACG when compared to normal subjects.

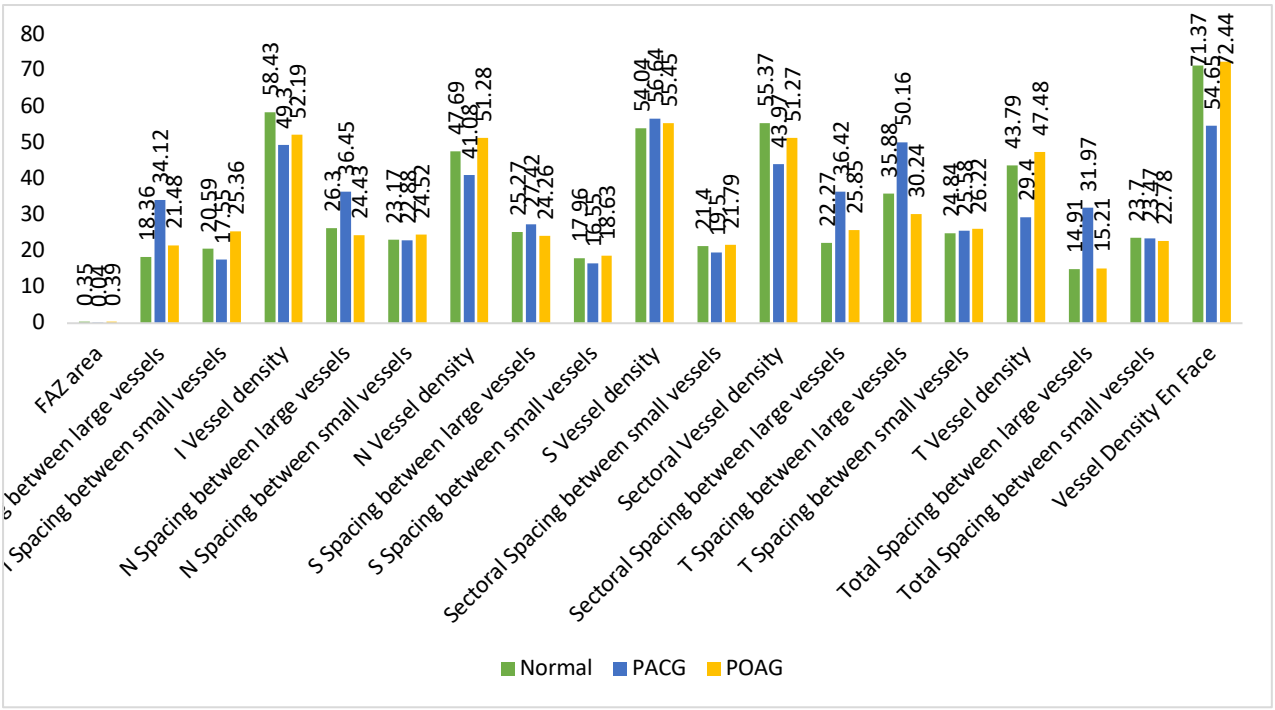

Figure: 5-Graphical representation of comparision of OCTA parameters of superficial disc among Normal, PACG and POAG

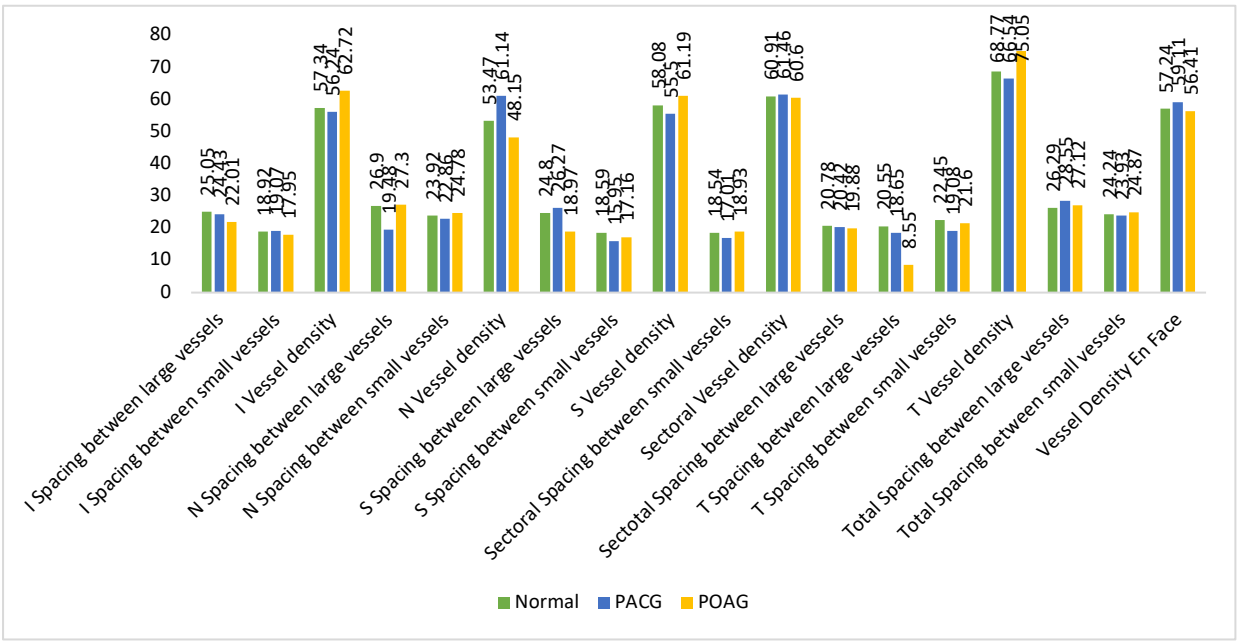

Figure: 6 -Graphical representation of comparision of OCTA parameters of deep macula among Normal, PACG and POAG

Figure 5 , 6 show graphical representation of comparison of OCTA parameters of superficial disc, deep macula respectively between normal and diseased groups PACG and POAG. Several OCTA parameters were found to be significantly different in diseased groups PAOG and POAG when compared to Normal Group with $P < 0.05$.

Overall, the study found significant differences in various parameters between normal subjects and those with PACG or POAG.

DISCUSSION

Ocular blood flow is essential for maintaining eye health, as it provides oxygen and nutrients to the retinal and ocular tissues while removing metabolic waste. Detecting ocular vascular disorders, such as glaucoma, at an early stage is crucial in understanding ocular blood flow. Laser speckle flowgraphy (XyCAMRI) and OCTA (Optical Coherence Tomography Angiography) are two advanced and non-invasive technologies available for reliable measurement of ocular blood flow. In this study, we investigated and compared optic nerve head perfusion and macular micro-circulation in three distinct groups of subjects: normal eyes, mild to moderate primary open-angle glaucoma (POAG) eyes, and mild to moderate primary angle-closure glaucoma (PACG) eyes. Laser speckle flowgraphy was used to evaluate the dynamic blood flow patterns in the optic nerve head (ONH) and macula region by analyzing these blood flow parameters within the three study groups.

Noteworthy changes were observed in several blood flow parameters within different regions of the optic nerve head (ONH) and macula among individuals diagnosed with primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG). These reduced blood flow parameters were found to be interconnected with recognized risk factors and characteristic features of glaucoma. Blood flow parameters associated with ONH and macular regions demonstrated comparable values between the POAG and PACG patient groups and the healthy control group.

A thorough analysis of blood perfusion using several OCTA parameters was conducted, including vessel density and distances between small and large vessels in different regions. There was a noteworthy decrease in vascular parameters for the superficial disc, deep macula as compared to deep disc among diseased groups, suggesting a connection between elevated IOP and superficial disc changes.

Dynamic blood flow metrics obtained via laser speckle flowgraphy offer valuable insights into dynamic ocular blood flow patterns among glaucoma patients. Incorporating both LSFG and OCTA assessments for individuals suspected of having glaucoma presents a promising approach that may elevate the diagnostic process by elevating both sensitivity and specificity. This combined methodology holds potential to enable early glaucoma diagnosis before visual field defects onset, facilitating timely intervention.

Study limitations include a small sample size, absence of normal tension glaucoma patients, no IOP-matched control group, time-consuming image capture, and exclusion of glaucoma patients with dense cataracts or pseudophakia, which may affect quality of imaging.

CONCLUSION

Dynamic blood flow metrics measured with laser speckle flowgraphy and the static parameters measured with OCTA provide early information regarding ocular blood flow dynamics increasing both sensitivity and specificity to diagnose primary glaucoma at an earlier stage

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