References

[1] Heick JD, Bay C, Dompier TP, Valovich McLeod TC. "The psychometric properties of the King-Devick test and the influence of age and sex in healthy individuals aged 14 to 24 years" in Athl Train Sports Health Care [Internet]. 2016; 8(5):222-9. Available from: http://dx.doi.org/10.3928/19425864-20160509-01.

[2] Jones RD, Donaldson IM, Timmings PL. "Impairment of high-contrast visual acuity in Parkinson's disease" in Mov Disord [Internet]. 1992; 7(3):232-8. Available from: https://pubmed.ncbi.nlm.nih.gov/1620141/.

[3] Jehangir N, Yu CY, Song J, Shariati MA, Binder S, Beyer J, et al. "Slower saccadic reading in Parkinson's disease" in PLoS One [Internet]. 2018; 13(1): e0191005. Available from: https://pubmed.ncbi.nlm.nih.gov/29364897/.

Retinal vascular tortuosity in glaucoma and diabetic retinopathy: correlation with vessel diameters

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Aim: Examination of the retinal vasculature provides us with much information about the relationship between vascular morphological changes and various systemic diseases that affect the eye and other systems and organs of the human body [1]. Several parameters are included in the changes suffered by the retinal vessels, such as the change in vascular caliber and the tortuosity of the vessels, among others [2]. Our objective is to study the diameters of the retinal blood vessels and their tortuosity, normally not measured, and to establish relationships between the findings in pathological retinas.

Experimental method: In this study, 45 retinas classified as healthy retinas, diabetic retinopathy (DR) and glaucoma (15 images in each group) were analyzed. Using the ARIA algorithm described in [3], the diameters of the retinal vessels were calculated. A MATLAB software program was developed to process these da-

ta and obtain the diameters of each detected vessel and calculate its tortuosity [4]. The joint probability distribution of the diameters and tortuosity were then calculated and their correlations between the different groups were analyzed (Pearson correlation R). All the images come from the same database captured with the same retinograph using a Canon CF-60 UVi mydriatic fundus camera [5]. The degree of pathology for each retina was quantified from previous authors' studies on the same images, based on vasculature complexity [6].

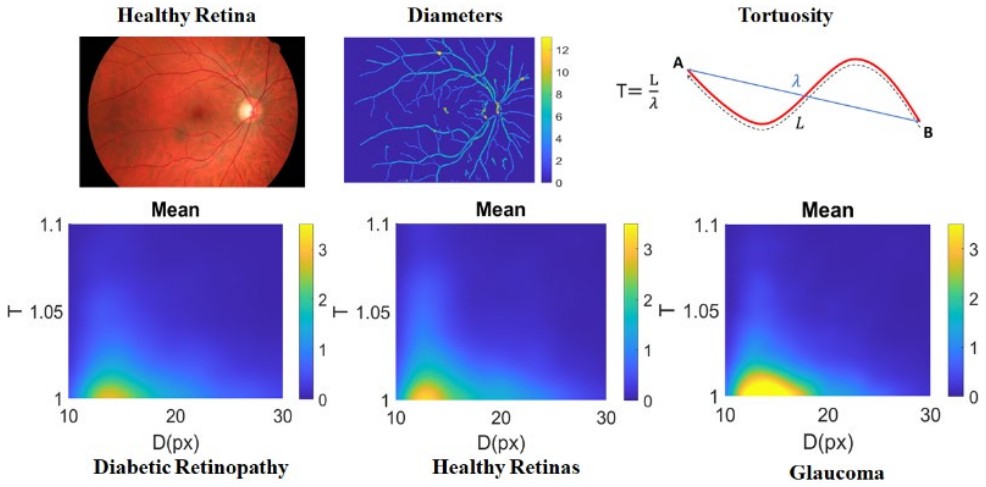

FIGURE 1. Mean probability distributions of the diameters and tortuosity.

Results: The joint probability density of diameters and tortuosity changes appreciably between healthy and glaucoma retinas, showing a decrease in both mean diameter and tortuosity for glaucoma. The changes are less appreciable for DR (see Figure 1), except in advanced stages. The control group only shows a significant ($p<0.05$) positive correlation for 13% of the cases ($R = 0.20$; $p = 0.0235$), increasing to 26% in DR ($R = 0.32$; $p = 0.0012$) and 40% in the case of glaucoma ($R = 0.22$; $p = 0.0183$).

Discussion: It has been shown that there is no great correlation between the diameters of the vessels and tortuosity in healthy retinas, while in the case of pathological retinas such as retinas with DR, it has been observed that as the pathology progresses (moderate-severe NPDR: non-proliferative Diabetic Retinopathy), a positive correlation appears between diameters and tortuosity. In the case of glaucoma, the diameters of the vessels decrease and become less tortuous, thereby establishing a positive correlation between both, more clearly visible. Tortuosity thus appears as an indicator of worsening pathology, appearing more commonly in the case of glaucoma. A possible factor that could affect the conclu-

sions is the duration of the disease when comparing the previous correlations between groups.

References

[1] Witt N, Wong TY, Hughes AD, Chaturvedi N, Klein BE, Evans R, McNamara M, Thom SAM, & Klein R. "Abnormalities of Retinal Microvascular Structure and Risk of Mortality from Ischemic Heart Disease and Stroke 7" in Hypertension, 2006; 47(5):975-81.

[2] Koh V, Cheung CY, Zheng Y, Wong TY, Wong W, & Aung T. "Relationship of Retinal Vascular Tortuosity with the Neuroretinal Rim: the Singapore Malay Eye Study" in Invest Ophthalmol Vis Sci, 2010; 51(7):3736-41.

[3] Bankhead P, Scholfield CN, McGeown JG, & Curtis TM. "Fast retinal vessel detection and measurement using wavelets and edge location. Refinement" in PLoS One, 2012; 7(3):e32435.

[4] Zaki WM, Zulkifley MA, Hussain A, Halim WH, Mustafa NB, & Ting LS. "Diabetic retinopathy assessment: towards an automated system" in Biomed. Signal Process. Control, 2016; 24:72-82.

[5] Budai A, Bock R, Maier A, Hornegger J, & Michelson G. "Robust vessel segmentation in fundus images" in Int J Biomed Imaging, 2013; 2013:154860.

[6] Igalla A, López Alonso JM. "Kull-back leibler distance between fractal dimension distributions: quantification of the pathological relevance of retinal images" in XII Reunion Española de Optoelectrónica, OPTOEL'21, 2021.