Evaluating tortuosity in retinal fundus images of diabetic patients who progressed to diabetic retinopathy*

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***Abstract*—Tortuosity is believed to be an early indicator of the changes in the retinal vasculature during the progression of diabetes. Different methods have been proposed in literature but their application in progressed patients (from diabetes to DR) has been inadequate. In this study different metrics of tortuosity were measured using twenty fives diabetic patients in two time intervals; three to four years before DR and the first year of diabetic retinopathy. The standard deviation of the tortuosity measurements differed significantly showing an increase in the variability of tortuosity in the vasculature in the first year of DR by 19.6%.**

I. Introduction

Diabetes is a major systemic disease that, as it progresses, can lead to diabetic retinopathy (DR). This includes alterations both in the retinal vessel wall structure and the hemodynamic functionality (e.g. blood flow velocity, blood flow rate etc.). The exact mechanism and causality of tortuosity is yet unclear, finding subjects with increased tortuosity who can be both healthy and diabetic/DR. Therefore, our aim is to investigate whether tortuosity changes during the progression of diabetes, to what extent and how significant this is.

II. Methods

In this study, fifty retinal images from twenty-five diabetic patients that progressed to DR were evaluated (One image pre- and post- DR ranging from three to four years apart). The images come from a UK DR screening database having equally high image quality so that tortuosity could be measured equally in a reliable manner. First, the images were segmented using the method proposed by *Hunter et al.*, adjusted accordingly in order to get the coordinates of all the vessel segments [1]. The vessel-level tortuosity was evaluated using the curve-based method proposed by *Hart et al.* [2]. The image-level tortuosity was calculated by combining the vessel-level tortuosity and calculating the mean, median, 3rd quartile, and standard deviation. Regarding the statistical analysis, since the same patients are used for both groups, a paired t-test was used to evaluate whether the measured differences can be attributed to the progression of diabetes or to random observations. The Shapiro-Wilk normality test was chosen to determine whether our data set is well-modeled by a normal distribution and thus justify the use of a parametric test. The p-value was 0.47 so failed to reject the null hypothesis that the data are normally distributed.

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III. Results

As can be seen in table 1, the standard deviation of the tortuosity measurements differed significantly between the two groups, showing an increase in the variability of tortuosity in the first year of DR. This opens a new window in the exploration of the changes in the retinal vasculature since until now the focus was on whether there is an increase/decrease of tortuosity in different conditions, whereas these results give us the indication that the overall tortuosity might not differ significantly but the dispersion might be higher indicating that the tortuosity in the retina varies more in the DR condition.

TABLE I. Summary of the analysis

Tortuosity Metrics	**Analysis of the data for the two groups (pre-/post-DR)**			
	p-values (a=0.05) Df (1, 24)	***CI (95%)***	***Group means (SD) (pre-DR/post-DR)***	***Post – Pre SD***
Mean	0.254	-0.0421 0.0108	0.0353(0.0072)/ 0.0509(0.0645)	0.0641
Median	0.98	-0.0011 0.0011	0.0105(0.0026)/ 0.0105(0.0028)	0.0028
3rd quartile	0.706	-0.0035 0.0051	0.0339(0.0082)/ 0.0347(0.0083)	0.0107
Standard deviation	**0.024**	**-0.002 -0.0267**	**0.0742(0.02)/ 0.0886(0.024)**	**0.0299**

Conclusion

Multiple changes occur inside the retinal vasculature both normally and during the progression of diabetes. Identifying and quantifying multiple features and, more importantly, accurately associating them with the progression of diabetes remains a challenging procedure. Tortuosity and/or the variability of tortuosity, in addition to other features, could possibly be used as biomarkers of progression to DR. Our immediate future work includes the addition of more time intervals of diabetes in order to get a complete picture of how the vessels change until the first lesions appear.

References

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