Ocular Imaging

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Haemodynamics in the Retinal Vasculature during the Progression of Diabetic Retinopathy

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Introduction: Diabetic Retinopathy (DR) remains a major ocular disease, which can potentially lead to blindness if left untreated. The human retina is a very dynamic tissue, making it difficult to associate any changes with a disease and not with normal variability among people. 96 images from twenty-four subjects were used in this study, including the period of the three years before DR and the first year of DR (4 images per patient, one per year).
Methods: The images were firstly segmented to obtain the vascular trees, selecting the same segments in the entire four-year period, to make a meaningful comparison. The trees, which included a parent vessel and two children branches, were connected using an implemented semi-automated tool. Some hemodynamic features were calculated, using the geometric measurements from the segmentation. At the branching points, the fluid dynamics conditions were estimated under the assumptions of Pouiseuille flow: stiff, straight and uniform tube. Blood flow velocity (v), blood flow rate (Q), Reynolds number (Re), pressure (P) and wall sheer stress (WSS) were calculated, both for arteries and veins. Blood viscosity (mu=0.04 P), tube´s length (L) and diameter (D), were used to compute fluid resistance to flow (R=128 mu L / pi D^4) through each vessel. Based on previous studies, the boundary conditions adopted to solve the problem were P_CRA = P_CRV = 45mmHg. Q_CRA and Q_CRV were derived from v_CRA, d_CRA, v_CRV, d_CRV by using the formula Q=VA. WSS was computed as WSS=32muQ/d^3. Re was calculated as Re=v d rho/mu, where rho=1.0515 g/mL is the blood density. Each feature (response variable) was analysed by using a linear mixed model, with the levels of the disease being the fixed effects explanatory variable, and the patients being the random effect with a random intercept.
Results: Our study showed that veins were mostly affected during the last stages of the diabetic eye. Furthermore, the blood flow of both children and the Re in the small child branch were mostly affected in the arteries. Table 1 includes only the significant features, with the relevant p-values (a=0.05) and Akaike Information Criterion (AIC).
Conclusion: Alongside the already established importance of the retinal geometry, this study showed that the hemodynamic features can also be used as biomarkers of progression to DR. During this four-year period of the disease's progression, retina is adapting to the new underlying conditions.

Features	p-value (Satterthwaite´s approximation)	p-value (comparison with restricted model-Likelihood test)	P-value (wald chi-square)	AIC (with and without fixed effect, the lower the better)
Wssparent_veins , Wsschild1_veins , Wsschild2_veins	0.02 , <0.000 , 0.001	0.02 , <0.000 , <0.000	0.017 , <0.000 , <0.000	550.7/554.26 , 472.13/484.82 , 490.67/501.21
Vparent_veins , Vchild1_veins , Vchild2_veins	0.024 , <0.000 , 0.003	0.02 , <0.000 , 0.002	0.016 , <0.000 , 0.001	335.45/339.22 , 231.88/247.24 , 247.5/256.02
Reparent_veins , Rechild1_veins , Rechild2_veins	0.027 , <0.000 , 0.04	0.024 , <0.000 , 0.034	0.019 , <0.000 , 0.031	693.38/696.82 , 593.87/610.36 , 608.29/610.95
Qchild1_veins , Qchild2_veins	0.05 , 0.04	0.034 , 0.033	0.03 , 0.029	-204.06/-201.45 , -204.01/-201.48
Pressure_veins	0.02	0.017	0.014	444.03/448.15
Rechild2_arteries	0.017	0.015	0.012	800.08/804.53
Qchild1_arteries , Qchild2_arteries	0.012 , 0.011	0.01 , 0.009	0.008 , 0.009	-111.48/-106.21 , -110.36/-105.13

[The significant features (p-values a=0.05).]