In Vivo Assessment of Choroid in Diabetic Retinopathy by Enhanced Depth Imaging in Spectral Domain Optical Coherence Tomography

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Purpose: The aim of this study was to measure the largest hyporeflective (LHR) lumen in the choroid and subfoveal choroidal thickness (SFCT) in patients with diabetic retinopathy (DR) and in control subjects using enhanced depth imaging (EDI) spectral domain optical coherence tomography (SD-OCT).

Design: This was a prospective, cross-sectional study.

Methods: This was a study of 240 eyes of DR patients (n = 120) and control subjects (n = 120) matched for age, sex, and refractive error. The LHR lumens of the choroidal vessels and SFCT were measured by EDI SD-OCT. Further intergroup classification into nonproliferative and proliferative DR, with or without macular edema, was done.

Results: The mean diameter of the LHR lumen in DR patients (139.24 ± 35.53 μm) was significantly smaller (P < 0.01) than in control subjects (186.37 ± 26.43 μm). The mean SFCT was also significantly less (P < 0.01) in patients with diabetes (277.15 ± 32.24 μm) as compared with control subjects (313.68 ± 25.13 μm). There was no significant intergroup variation.

Conclusions: Patients with DR showed smaller LHR lumen and SFCT as compared with control eyes. In vivo assessment of the choroid in DR is possible using EDI SD-OCT.

Key Words: EDI SD-OCT, diabetic choroidopathy, diabetic retinopathy, subfoveal choroidal thickness

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layer, we detected hyporeflective lumen in all eyes. The lumens in the choroidal layer were taken as surrogates for choroidal vessels, as an assumption.\textsuperscript{13}

All discernible hyporeflective lumens in the choroid, within a zone of 4500 \( \mu \text{m} \) centered on the fovea, were assessed, and the larger lumens were localized. Then, the diameters of the larger lumens were measured. Among these, the 3 largest lumens were averaged. The diameter of each hyporeflective lumen was assessed perpendicular to the Bruch membrane. The region of measurement did not differ between the study group and the control group. If the measurements of the 2 examiners differed by more than 15\%, the examiners performed the measurement again together. If the difference between both measurements was more than 15\%, the mean of the 2 values was used for statistical analysis.

The eyes of patients with diabetes were graded according to the Early Treatment Diabetic Retinopathy Study\textsuperscript{14} classification into nonproliferative and proliferative retinopathy. They were then further grouped on the basis of the presence or absence of diabetic macular edema.\textsuperscript{15} They were divided into 4 groups: nonproliferative DR with diabetic macular edema (group A), nonproliferative DR without diabetic macular edema (group B), proliferative DR with diabetic macular edema (group C), and proliferative DR without diabetic macular edema (group D).

Statistical analysis was performed using SPSS for Windows version 19.0 (IBM-SPSS, Chicago, Ill). Measurements are presented as mean ± SD. The study group was compared with the control group using Student test for unpaired samples. Inter-group variations were measured using analysis of variance.

RESULTS

A total of 240 eyes of patients with diabetes (\( n = 120 \)) and control subjects (\( n = 120 \)) were included in the study. Among the diabetic patients, 108 were male and 12 were female. The mean age was 60.33 years, ranging from 47 to 69 years. The study population included 48 eyes in group A, 24 in group B, 32 in group C, and 16 in group D. One hundred twenty eyes of patients with no diabetes served as control subjects.

On comparing the characteristics of individuals with diabetes mellitus and control subjects, there was no statistical difference in age, sex, axial length, or IOP (Table 1).

The average duration of diabetes at presentation was 13.64 ± 2.75 years. The group-wise distribution of duration was 11.40 ± 7.81 years for group A, 12.25 ± 5.47 years for group B, 17.60 ± 8.36 years for group C, and 13.33 ± 9.56 years for group D. The intergroup comparison of duration was not statistically significant (\( P = 0.43 \)).

The average LHR lumen was tabulated for the various groups. It was 132.48 ± 15.53 \( \mu \text{m} \), 144.42 ± 18.04 \( \mu \text{m} \), 134.08 ± 15.27 \( \mu \text{m} \), and 146 ± 22.90 \( \mu \text{m} \) for groups A, B, C, and D, respectively. The average LHR lumen for normal subjects was 186.37 ± 26.43 \( \mu \text{m} \). The mean diameter of the LHR lumen was significantly (\( P < 0.01 \)) smaller in eyes of patients with diabetes (139.24 \( \mu \text{m} \)) as compared with the control group (186.37 \( \mu \text{m} \)). The intergroup comparisons among patients with diabetes were not significant (\( P = 0.19 \)) (Table 2; Figs. 2–5).

The mean SFCT was 277.15 \( \mu \text{m} \) in patients with diabetes and 313.69 \( \mu \text{m} \) in control subjects. The mean SFCT was also significantly less (\( P < 0.01 \)) in patients with diabetes. In intergroup measurement, the SFCT was 274.62 ± 43.27 \( \mu \text{m} \) in group A, 273.42 ± 18.94 \( \mu \text{m} \) in group B, 262.56 ± 41.24 \( \mu \text{m} \) in group C, and 298 ± 53.29 \( \mu \text{m} \) in group D. The difference among the groups was not statistically significant (\( P = 0.15 \)) (Table 2; Figs. 2–6).

DISCUSSION

Yang et al\textsuperscript{13} conducted a study to measure the hyporeflective lumen in the choroid of patients with central serous chorioretinopathy. They presumed these hyporeflective lumens to be choroidal vessels and showed their engorgement in affected eyes. A multitude of previous studies have established the metabolic changes produced and growth factors released in the diabetic

![FIGURE 1. Measurement of SFCT and LHR lumen.](image-url)
Kimmelstiel-Wilson disease. Small choroidal blood vessels have thickened basement membranes.

We assessed the SFCT. It was 277.15 ± 32.24 μm in patients with diabetes and 313.68 ± 25.13 μm in control subjects. We saw a significant thickness reduction (P < 0.01) in patients with diabetes. This might be a consequence of the thinning and dropout of the choroidal vessels as seen by the luminal narrowing, leading to an overall decrease in choroidal thickness.

The LHR lumen noted in the patients with diabetes in our study was 139.24 ± 35.53 μm. This was significantly smaller (P < 0.01) than that in the control subjects (186.37 ± 26.43 μm). This supports the luminal narrowing and dropout of the choroidal vessels seen by electron microscope.

As hypothesized by Querques et al in their study of EDI OCT in type 2 diabetes, decreased choroidal thickness at the fovea may be a reason for the development of macular edema. The reduced SFCT, probably due to the dropout of the choriocapillaris (and determining increased vascular resistance), may cause retinal hypoxia. In fact, it is the role of the choroidal vasculature, especially the choriocapillaris, to provide nutrients to the RPE and outer retinal layers in the foveal region. Because of tissue hypoxia, vascular endothelial growth factor expression increases in the RPE, pericytes, and microvascular endothelial cells and may induce the breakdown of the blood-retinal barrier, which is the basis of diabetic macular edema.

We also noted that cases with and without diabetic macular edema showed a difference of lumen thickness that was not statistically significant (P = 0.10), but on close observation, the subjects with macular edema had smaller lumens. This could be similar to DR, where there is a decrease in the vascular caliber of the veins, and these changes are all related to progressive capillary nonperfusion and retinal ischemia. They are also markers of an increased risk of progressing to proliferative disease. The choroidal changes may be inferred as a duplication of retinopathy.

Thus, in our study, we have tried to establish a simple, noninvasive, and less time-consuming method for simultaneous in vivo morphological assessment of the choroid in cases of DR and its correlation with the retinopathy.

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**TABLE 2. Average LHR Lumen and SFCT Measurements in Groups and Control Subjects**

<table>
<thead>
<tr>
<th>Group</th>
<th>NPDR With DME (Group A)</th>
<th>NPDR Without DME (Group B)</th>
<th>PDR With DME (Group C)</th>
<th>PDR Without DME (Group D)</th>
<th>Control Subjects</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHR lumen, μm</td>
<td>132.48 ± 15.53</td>
<td>144.42 ± 18.04</td>
<td>134.08 ± 15.27</td>
<td>146.00 ± 22.90</td>
<td>186.37 ± 26.43</td>
<td>0.19</td>
</tr>
<tr>
<td>SFCT, μm</td>
<td>274.62 ± 43.27</td>
<td>273.42 ± 18.94</td>
<td>262.56 ± 41.24</td>
<td>298.00 ± 52.29</td>
<td>313.68 ± 25.13</td>
<td>0.15</td>
</tr>
</tbody>
</table>

NPDR indicates Nonproliferative Diabetic Retinopathy; PDR, Proliferative Diabetic Retinopathy; DME, Diabetic Macular Oedema.

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**FIGURE 2.** Comparison of choroidal characteristics.

**FIGURE 3.** Intergroup comparison of choroidal characteristics.

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Further study is necessary to determine if the changes in the choroid appear before the retinopathy and if they can act as an early marker for impending retinopathy.

REFERENCES


