Optical Coherence Tomography Disc Assessment in Optic Nerves With Peripapillary Atrophy

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Abstract

BACKGROUND AND OBJECTIVE—Optical coherence tomography (OCT) is able to determine the optic disc margin automatically. The aim of this study was to investigate the accuracy of the automatic OCT optic nerve head measurements in the presence of peripapillary atrophy.

PATIENTS AND METHODS—This was a cross-sectional, retrospective study. Thirty-one subjects with peripapillary atrophy underwent optic nerve head scanning with OCT version 3. Nineteen of the eyes were classified clinically as having glaucoma, nine had suspected glaucoma, and three were normal. Automatic OCT results were compared with manual tracing results.

RESULTS—Significant differences were found between most OCT optic nerve head automated and manual disc assessment parameters; however, good agreement was found between the two methods for all parameters (intraclass correlation, 0.71 to 0.94). Areas under receiver operator characteristics curves for clinical status were similar for all parameters with both methods.

CONCLUSION—Automated OCT optic nerve head analysis may be used in the clinical setting in the presence of peripapillary atrophy; however, caution should be used when comparing individual results with population-derived optic nerve head results.

INTRODUCTION

Glaucoma is a group of optic neuropathies in which there is damage to retinal ganglion cells and the nerve fiber layer with a characteristic appearance of the optic nerve head. This damage may precede visual field defects, which occur later in the course of disease.1–5 Early diagnosis and the ability to detect progression of glaucoma are of great significance because the damage caused is largely irreversible. Several technologies to assist in early detection and following the progression of glaucoma are now available and can provide objective quantitative analysis. These include several imaging modalities that are capable of scanning the optic nerve head. Confocal scanning laser ophthalmoscopy and scanning laser biomicroscopy both require manual tracing of the optic disc margin. On the other hand, optical coherence tomography...
(OCT) is able to determine the optic disc margin automatically. A previous cross-sectional study found high correlation between results of automated and manual tracing of the optic nerve margin as measured by OCT in normal subjects and patients with glaucoma. The automated definition of the optic disc margin as determined by OCT is dependent on the analysis algorithm’s recognition of the termination of the retinal pigment epithelium/choriocapillaris. However, the accuracy of the OCT optic nerve head automated measurements in the presence of peripapillary atrophy, where the retinal pigment epithelium/choriocapillaris edge does not overlay the disc margin, is questionable. Moreover, the frequency and size of peripapillary atrophy has been shown to be larger in eyes with glaucoma than in normal eyes. The aim of this study was to investigate the effect of peripapillary atrophy on OCT optic nerve head measurements.

PATIENTS AND METHODS

Participants of the study were consecutively recruited from the glaucoma service at New England Eye Center, Tufts-New England Medical Center, Boston, Massachusetts, between January and July 2002. All subjects underwent comprehensive ophthalmic examination including visual acuity testing, slit-lamp biomicroscopy, indirect ophthalmoscopy, visual field testing, confocal scanning laser ophthalmoscopy, and OCT examinations. All tests were completed within 6 months of each other. Eyes with a refractive error of more than −6.0 diopters were excluded from the study to eliminate confounding findings due to elongated axial length. The inclusion criteria required the presence of overt peripapillary beta zone atrophy, characterized as a central zone of chorioretinal atrophy with visible large choroidal vessels and sclera, with the widest diameter being no less than one-quarter of the disc diameter. Institutional Review Board/Ethics Committee approval was obtained for the study and all participants gave their approval to participate in the study. This study followed the principles of the Declaration of Helsinki.

The study group consisted of 31 eyes, of which 19 eyes were classified clinically as having glaucoma, 9 as having suspected glaucoma, and 3 as normal. The mean age of the subjects was 63.5 ± 12.1 years, the mean refractive error was −1.52 ± 2.66 diopters, and the mean horizontal and vertical cup-to-disc ratio as determined clinically was 0.7 ± 0.2. Visual field defects, as described below, were present in 14 of 31 eyes.

Visual Field Testing

All subjects underwent Humphrey full-threshold 24-2 achromatic perimetry (Carl Zeiss Meditech, Dublin, CA), Swedish Interactive Thresholding Algorithm standard 24-2 perimetry (Carl Zeiss Meditech), or Frequency Doubling Technique N-30 perimetry (Welch Allyn, Skaneateles Falls, NY, and Carl Zeiss Meditech). A reliable visual field test was defined as one with fewer than 30% fixation losses, false-positive responses, or false-negative responses. Normal visual field test results were defined as having no cluster of three or more adjacent points depressed more than 5 dB or two adjacent points depressed more than 10 dB. Glaucomatous visual field defects were defined as typical arcuate defects, paracentral scotomata, or a nasal step consisting of clusters of depressed points as defined earlier.

Confocal Scanning Laser Ophthalmoscopy

All confocal scanning laser ophthalmoscopy scans were conducted using the Heidelberg Retina Tomograph (HRT) (software version 2.01; Heidelberg Engineering GmbH, Heidelberg, Germany). HRT scans were used only for preliminary identification of eyes with peripapillary atrophy. Three scans of 15° × 15° were done in one sitting. One of the investigators (GW), experienced with this device, evaluated all HRT reflectance maps to identify eyes that may have qualified for the study. All eyes with peripapillary atrophy chosen from the HRT screening
were confirmed with clinical findings. No further analysis was conducted using the HRT results.

**Optical Coherence Tomography**

OCT is a noninvasive technology that provides high-resolution measurements and cross-sectional imaging of the retina and nerve fiber layer. This technique is similar to an ultrasound B-scan but gathers data from optical differences using scattered light instead of sound waves, the details of which are discussed elsewhere. All subjects’ eyes were scanned with Stratus OCT (software version A1.0; Carl Zeiss Meditech) after dilating the pupils with 1% tropicamide and 2.5% phenylephrine. Optic nerve head analysis was constructed from six consecutive, equally spaced scans in a radial spoke pattern centered on the optic nerve head. The optic nerve head margin was determined automatically at the termination of the retinal pigment epithelium/choriocapillaris.

Three observers independently analyzed the optic nerve head scans to determine subjectively the optic nerve head margin. This was done by manual placement of the cursor to the retinal pigment epithelium/choriocapillaris edge for each of the six radial scans for each eye. Each observer analyzed the optic nerve head scans twice at least 3 days apart using the method described earlier. The observers were masked to each other and between assessments. The following OCT optic nerve head parameters were used for the analysis: disc area, cup area, rim volume, and cup volume.

**Analysis**

Shrout–Fleiss reliability of a random set of intra-class correlations (ICC) was performed to compare measurements obtained for each optic nerve head parameter within a given observer. The average of the two measurements from each observer was used to analyze the agreement between observers. The mean of all six observer measurements was used to analyze the agreement between observer and automatic measurements. In both cases, the Shrout–Fleiss reliability of a random set of mean scores’ ICC was performed to compare measurements for each optic nerve head parameter between observers and between observers and automatic measurements. Analysis of variance (ANOVA) was used to compare manual values obtained between individual raters. Receiver operator characteristics (ROC) curve analysis was used to compare manual and automatic disc results to clinical diagnoses and the presence of visual field deficits.

## RESULTS

**Intra-observer and Inter-observer Agreements**

All three observers demonstrated good intra-observer agreement with an ICC of greater than 0.75 for all parameters except rim volume, where in one instance the agreement was as low as 0.43 (Table 1). Statistically significant inter-observer differences were found when comparing the mean of the two measurements of all parameters between the observers ($P < .05$), but good agreement was found between observers (ICC $> 0.86$) (Table 2).

**Automated and Manual Agreements**

Figure 1 demonstrates an example of failed automated detection of the optic nerve head margin where manual correction imposed a substantial change in the measured parameters.

Statistically significant differences were found comparing the mean of all six manual measurements with the mean of the automated measurements for all of the parameters ($P < .05$), with the exception of rim volume ($P = .84$). The calculated power to detect a difference
of 0.5 mm² in disc area in 31 eyes was 89%. Good agreement was found between the two methods for all parameters (ICC > 0.71) (Table 3, Fig. 2).

**ROC Analysis**

Areas under ROC curves were calculated to determine the ability of the automated and the manual determination of the optic disc margin to detect glaucomatous abnormalities based on either the clinical classification or the presence of visual field defects (Table 4, Fig. 3). Due to the small number of normal subjects (n = 3), the clinical comparison was done between glaucoma and nonglaucoma, including suspected glaucoma in the nonglaucoma group. On the basis of this clinical classification, the area under ROC curves ranged between 0.53 and 0.64 using the automated determination and 0.49 and 0.70 using the manual determination. Based on visual field defect, the ranges were 0.56 to 0.70 and 0.61 to 0.73, respectively.

**DISCUSSION**

OCT is unique in its ability to detect the optic nerve head margin in an automated fashion. A previous cross-sectional study reported high correlation between OCT optic nerve head measurements obtained by automatic and manual determination of the optic disc margin. Given that the definition of the disc margin is based on the detection of the retinal pigment epithelium/choriocapillaris border, the presence of peripapillary atrophy may induce a significant misalignment of the disc margin read by OCT. Although the previous study may have contained subjects with peripapillary atrophy, the percentage was small in comparison with those without this pathology. Our study aimed to investigate the automatic disc assessment of OCT in discs with peripapillary atrophy.

Peripapillary atrophy is more frequently observed and is more extensive in patients with glaucoma compared with normal individuals. Other studies reported high correlation between peripapillary atrophy, optic disc damage, and mean visual field loss. Although peripapillary atrophy is known to be prevalent in highly myopic eyes, these eyes were not qualified for this study to eliminate confounding findings due to the elongated axial length. This study was designed to include only those patients with peripapillary atrophy related to glaucoma.

Despite the difficulty of defining the optic disc margin in the presence of peripapillary atrophy, good intra-observer agreements were shown for the manually corrected OCT optic nerve head measurements (Table 1). Although statistically significant differences were detected in the mean measurements between observers, they did demonstrate good inter-observer agreement (ICC = 0.86 to 0.97) (Table 2). The similar intra-observer and inter-observer agreement is contradictory to previous studies, where higher agreement was found within observers than between observers in optic nerve head assessment.

Statistically significant differences were found when comparing the mean measurements of the three observers with the automated determinations of the disc margin, whereas good correlations (ICC = 0.71 to 0.94) were found between the two methods (Table 3, Fig. 2). This finding suggests that the automatic optic nerve head measurements are in agreement with the results obtained by manual detection of the disc margin, but that the actual measures are not interchangeable. This is due to the fact that the automated determination of the disc margin identified a larger disc area than the manual determination and thereafter all parameters related to disc size were subsequently larger than those measured manually.

ROC curve analysis was performed to assess whether manual OCT adjustments lead to better discrimination between groups as determined by clinical evaluation and visual field findings. The manual determination of the disc margin did not improve the ability to distinguish between
groups for either the clinical assessment or the visual field evaluation (Table 4, Fig. 3). Similar areas under ROC curves were reported in a previous study where OCT optic nerve head parameters were evaluated in 159 eyes. The low ROC values emphasize the need for multiple parameters for glaucoma evaluation.

A significant difference between OCT optic nerve head results obtained by automated and manual disc margin determination was found in patients with peripapillary atrophy. Good agreement between the two methods was achieved and there was no difference in the area under ROC curves for distinguishing between groups as defined by clinical diagnosis and presence of visual field defect. Thus, the automated feature of the OCT optic nerve head analysis can be used in the clinical setting in the presence of peripapillary atrophy but the measurements should be evaluated with caution when compared with population study results.

References


Figure 1.
(A) Failure of automatic optical coherence tomography recognition of the termination of the retinal pigment epithelium/chorio-capillaris (left cursor) followed by (B) manual correction in each of six radial scans.
Figure 2.
Bland–Altman plot comparing manual and automated cup volumes.
Figure 3.
Receiver operator characteristics curve analysis comparing manual and automated cup areas for the presence of visual field defects.
### TABLE 1
Intra-observer Intraclass Correlation of Optical Coherence Tomography Optic Nerve Head Measurements as Determined by Manual Detection of Optic Disc Margin

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Observer 1</th>
<th>Observer 2</th>
<th>Observer 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disc area, mm²</td>
<td>0.91</td>
<td>0.93</td>
<td>0.96</td>
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<tr>
<td>Cup area, mm²</td>
<td>0.85</td>
<td>0.84</td>
<td>0.85</td>
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<tr>
<td>Rim volume, mm³</td>
<td>0.76</td>
<td>0.52</td>
<td>0.43</td>
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<tr>
<td>Cup volume, mm³</td>
<td>0.96</td>
<td>0.93</td>
<td>0.96</td>
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</table>

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TABLE 2
Mean Optical Coherence Tomography Optic Nerve Head Parameters for Each Observer, Inter-observer Analysis of Variance (ANOVA), and Intraclass Correlations (ICC) Between Observers

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Observer 1</th>
<th>Observer 2</th>
<th>Observer 3</th>
<th>ANOVA</th>
<th>ICC</th>
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<tr>
<td>Disc area, mm²</td>
<td>2.23</td>
<td>1.89</td>
<td>1.86</td>
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<td>Cup area, mm²</td>
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<td>1.07</td>
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<td>Rim volume, mm³</td>
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<td>Cup volume, mm³</td>
<td>0.34</td>
<td>0.28</td>
<td>0.24</td>
<td>&lt;.0001</td>
<td>0.97</td>
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</tbody>
</table>
### TABLE 3

Student’s *t* Test and Intraclass Correlation (ICC) Comparison of Mean Automated and Manual Optical Coherence Tomography Optic Nerve Head Parameters

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Automated</th>
<th>Manual</th>
<th>P</th>
<th>ICC</th>
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<tr>
<td>Disc area, mm²</td>
<td>2.45</td>
<td>1.99</td>
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<td>Cup area, mm²</td>
<td>1.35</td>
<td>1.11</td>
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<td>Rim volume, mm³</td>
<td>0.17</td>
<td>0.17</td>
<td>.84</td>
<td>0.82</td>
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<tr>
<td>Cup volume, mm³</td>
<td>0.37</td>
<td>0.29</td>
<td>&lt; .0001</td>
<td>0.94</td>
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**TABLE 4**

Area Under the Receiver Operator Curves Using Automated or Manual Determination of the Optic Disc Margin for Distinguishing Between Groups Based on Clinical Diagnosis and Presence of Visual Field Defect

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Clinical Classification</th>
<th>Visual Field Defect</th>
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<tr>
<td></td>
<td>Automated</td>
<td>Manual</td>
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<tr>
<td>Disc area, mm$^2$</td>
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<td>0.67</td>
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<tr>
<td>Cup area, mm$^2$</td>
<td>0.53</td>
<td>0.52</td>
</tr>
<tr>
<td>Rim volume, mm$^3$</td>
<td>0.63</td>
<td>0.70</td>
</tr>
<tr>
<td>Cup volume, mm$^3$</td>
<td>0.57</td>
<td>0.49</td>
</tr>
</tbody>
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