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RELIABILITY OF OPTIC DISK TOPOGRAPHIC MEASUREMENTS RECORDED WITH A VIDEO-OPHTHALMOGRAPH

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The video-ophthalmograph records the topography of the optic disk via simultaneous stereoscopic images which are stored and analyzed with the help of a microcomputer. This information is used to generate the vertical cup-disk ratio, the vertical optic disk diameter, the cup volume, and the neuroretinal rim area. To determine the reliability of the data, we recorded information for one eye of each of five patients ten times to determine the interphotographic error variance. We also analyzed one photograph for each of five patients ten times to determine the intraphotographic variance attributable to repeated analysis of the same photograph. The interphotographic and intraphotographic coefficients of variation were 2% to 18% and 2% to 7% respectively for these measurements.

The topography of the optic nerve head is of the utmost importance in the diagnosis and monitoring of the progression of glaucoma. Pederson and Anderson showed that progressive disk cupping can precede measurable visual field defects in glaucoma. Serial stereoscopic photographs are useful in monitoring changes in optic disk topography, but a rapid, reliable technique of quantitating these changes is lacking.

Previous investigators have used photogrammetry to characterize the topography of the optic disk. These techniques have the drawback of needing the extraction of data from stereoscopic pairs of photographs by a skilled photogrammetrist. A technique of digital photogrammetry of the optic nerve head involving electronic scanning and digitizing of a pair of stereoscopic photographs makes it unnecessary for a skilled photogrammetrist to perform the labor-intensive translation from the stereoscopic pairs.

The Rodenstock video-ophthalmograph records the topography of the optic disk by recording simultaneous stereoscopic video images which are stored and analyzed with the help of a microcomputer. This technique does not require skilled operators and also has the advantage of bypassing the photographic process. Additionally, the results of optic disk measurements are available rapidly and sequential comparisons can be extracted from the digitized information.

MATERIAL AND METHODS

The instrument—The video-ophthalmograph consists of seven major compo-
ponents: an optical head, containing all of
the optical system and some of the electron­
sics along with the support for the
patient’s head and chin; the operator’s
desk, the pedestal of which contains most
of the electronics; a televideo CRT moni­
tor, on which the operator’s instructions
are displayed; a televideo keyboard on
which the operator can type information
and instructions; another CRT monitor
on which the results are displayed; a light
pen which the operator uses to control
the instrument; and a floppy disc drive to
store the results.

The optical system of the video­
ophthalmograph performs three general
functions. First, it illuminates the eye
with infrared light and forms an image of
the iris and pupil on an infrared-sensitive
television camera, permitting the opera­
tor to perform coarse manual alignment
of the instrument with respect to the
pupil. This subsystem also permits auto­
matic fine continuous alignment.

A second subsection of the optical sys­
tem provides a fixation target for the
patient. This target is a flashing white
spot bright enough to be seen even when
the eye is brightly illuminated with the
measuring light. The position of the tar­
get is controlled by the operator to center
the optic disk on the video screen.

The third optical subsystem illumin­
ates the fundus with light and forms a
simultaneous stereoscopic pair of images
of the fundus on a sensitive television
camera. The lights, motors, and cameras
in the optical head are controlled by two
computers inside the desk. These com­
puters are controlled by the keyboard and
the light pen. While the instrument is on
all of the pictures and data are stored on a
hard disc. At the end of a data-taking
session the operator can store the pic­
tures and data on 8-inch floppy discs.

Methods—Once the pictures and data
are stored, the computer calculates the
depths of points on the optic disk by
measuring the distance between corre­
sponding points of the simultaneous ste­
reoscopic pairs, giving depth values with
a theoretical sensitivity of 12 µm. This is
performed for 1,600 points on the optic
disk. The computer then calculates the
vertical cup-disk ratio, neuroretinal rim
area, cup volume, and vertical diameter
of the optic disk (Figure). The operator
indicates the optic disk margin by choos­
ing four points at the horizontal and ver­
tical margins to which the computer fits an
ellipse that defines the edge. To calculate
the vertical cup-disk ratio the computer
defines the cup margin by subtracting
150 µm from the level at the optic disk
margin along one meridian and then mea­
suring the distance from the center of the
optic disk along that meridian to that
defined depth. This is repeated 51 times
superiorly each degree along radii from
65 to 115 degrees and inferiorly each
degree along radii from 245 to 295 de­
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The neuroretinal rim is the area between the cup margin and the optic disk edge for the meridians between 65 and 115 degrees superiorly and 245 to 295 degrees inferiorly. The volume of the cup is determined by forming an imaginary plane defined by the average of the top 16 points along each of eight vertical lines superiorly and the bottom 16 points along each of eight vertical lines inferiorly and measuring the volume under this retinal plane. The diameter of the optic disk is equal to the distance from the top to the bottom of the optic disk. The units of measurement are not absolute because the technique does not take into account the axial length of the eye.

To determine the reliability of the data obtained with the video-ophthalmograph, we recorded the data for one eye of each of five patients ten times at the same sitting. We then analyzed the ten records to generate the vertical cup-disk ratio, vertical optic disk diameter, cup volume, and neuroretinal rim area. These data were then analyzed statistically to determine the interphotographic error variance. We also analyzed one record for each of the five patients ten times. These data were analyzed statistically to determine the intraphotographic error variance attributable to repeated analysis of the same record.

RESULTS

We calculated the percent error as a proportion of the mean (coefficient of variation) as follows: C.V. = standard deviation ÷ mean of sample. The coefficient of variation in the interphotographic and intraphotographic studies respectively was 11.2% and 3.9% for the cup-disk ratio, 2.4% and 1.9% for the optic disk diameter, 17.7% and 6.7% for the neuroretinal rim area, and 18.6% and 2.5% for the cup volume. The standard deviations for the cup-disk ratio were 0.067 and 0.024 for interphotographic and intraphotographic studies respectively (Table).

DISCUSSION

The video-ophthalmograph provides a quick and reliable method of determining the vertical cup-disk ratio and recording any changes in this measurement. Current clinical techniques produce interobserver and intraobserver differences in the cup-disk ratio.23-25 The frequency of intraobserver differences of 0.2 or greater was 28% in an experienced group of ophthalmologists.25 The frequency of inter-

### TABLE
ANALYSIS OF VARIANCE

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean ± S.D.</th>
<th>95% Confidence Interval</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interphotographic Study</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cup-disk ratio</td>
<td>0.6 ± 0.067</td>
<td>0.055 to 0.085</td>
<td>11.2</td>
</tr>
<tr>
<td>Optic disk diameter</td>
<td>131 ± 3.2</td>
<td>2.6 to 4.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Rim area</td>
<td>2,438 ± 432</td>
<td>337 to 547</td>
<td>17.7</td>
</tr>
<tr>
<td>Volume</td>
<td>138,993 ± 25,244</td>
<td>20,859 to 31,982</td>
<td>18.6</td>
</tr>
<tr>
<td><strong>Intraphotographic Study</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cup-disk ratio</td>
<td>0.61 ± 0.024</td>
<td>0.02 to 0.03</td>
<td>3.9</td>
</tr>
<tr>
<td>Optic disk diameter</td>
<td>130 ± 2.5</td>
<td>2.1 to 3.1</td>
<td>1.9</td>
</tr>
<tr>
<td>Rim area</td>
<td>2,390 ± 161</td>
<td>134 to 203</td>
<td>6.7</td>
</tr>
<tr>
<td>Volume</td>
<td>134,306 ± 3,324</td>
<td>2,757 to 4,186</td>
<td>2.5</td>
</tr>
</tbody>
</table>
observer differences of 0.2 or greater was 25% with contact lens biomicroscopy. The video-ophthalmograph provides an objective means of recording this measurement with a standard deviation of 0.067. Therefore, with this instrument only 5% of repeat cup-disk measurements will differ by more than ± 0.13 (2 S.D.) and only 0.3% differ by ± 0.2 or more (3 S.D.).

Cup volume and neuroretinal rim area are quantities that cannot be easily estimated in a routine clinical examination. It has been shown that neuroretinal rim area may be more valuable than the cup-disk ratio in determining the presence of glaucomatous damage.  

Now that the reproducibility of this technique has been determined, we intend to correlate the cup-disk ratio recorded clinically with that obtained on the video-ophthalmograph. We plan to use this machine in differentiating normal subjects from patients with any stage of glaucoma.

Although the intraphotographic error is small enough to be acceptable, the interphotographic error is significant enough that it must be taken into account when measuring change in the optic disk as a feature of glaucoma. Attempts to reduce interphotographic errors should be made.

REFERENCES


