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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[1] 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.[2-17] A technique of digital photogrammetry of the optic nerve head involving electronic scanning and digitizing of a pair of stereoscopic photographs[18-21] 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.[22] 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-

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nents: an optical head, containing all of the optical system and some of the electronics 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 monitor, 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 videoophthalmograph 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 operator to perform coarse manual alignment of the instrument with respect to the pupil. This subsystem also permits automatic fine continuous alignment.

A second subsection of the optical system 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 target is controlled by the operator to center the optic disk on the video screen.

The third optical subsystem illuminates 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 computers 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 pictures 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 corresponding points of the simultaneous stereoscopic 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 choosing four points at the horizontal and vertical 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 measuring 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 degrees. The mean of these 102 measurements is the vertical cup-disk ratio.

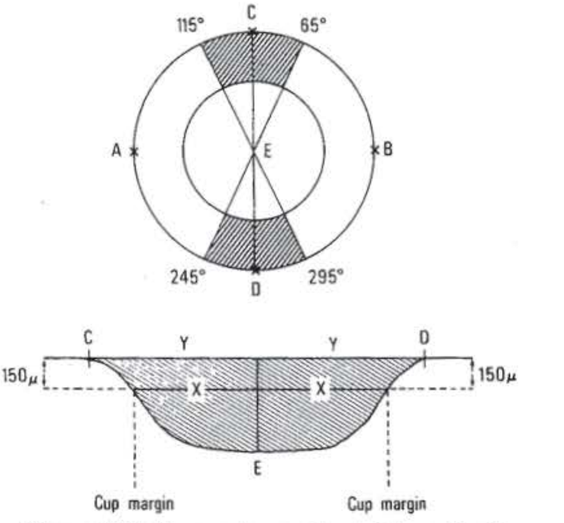

Figure (Mikelberg and associates). Schematic diagram of the optic disk. A, B, C, and D indicate optic disk margins; line C-D is the vertical optic disk diameter; X/Y is the cup-disk ratio. The upper cross-hatched area is the neuroretinal rim area and the lower cross-hatched area represents the cup volume.

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

Data	Mean ± S.D.	95% Confidence Interval	Coefficient of Variation
Interphotographic Study			
Cup-disk ratio	0.6 ± 0.067	0.055 to 0.085	11.2
Optic disk diameter	131 ± 3.2	2.6 to 4.0	2.4
Rim area	2,438 ± 432	357 to 547	17.7
Volume	138,993 ± 25,244	20,859 to 31,982	18.6
Intraphotographic Study			
Cup-disk ratio	0.61 ± 0.024	0.02 to 0.03	3.9
Optic disk diameter	130 ± 2.5	2.1 to 3.1	1.9
Rim area	2,390 ± 161	134 to 203	6.7
Volume	134,306 ± 3,324	2,757 to 4,186	2.5

observer differences of 0.2 or greater was 25% with contact lens biomicroscopy.[25] 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.[7,26]

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 compare the neuroretinal rim area measured by planimetry with the video-ophthalmographic measurements. These measurements will then be compared to the findings on psychophysical tests in an attempt to determine the usefulness of 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

1. Pederson, J. E., and Anderson, D. R.: The mode of progressive disc cupping in ocular hypertension and glaucoma. Arch. Ophthalmol. 98:490, 1980.

2. Saheb, N. E., Drance, S. M., and Nelson, A.: The use of photogrammetry in evaluation the cup of the optic nervehead for a study in chronic simple glaucoma. Can. J. Ophthalmol. 7:466, 1972.

3. Portney, G. L.: Photogrammetric categorical analysis of the optic nerve head. Trans. Am. Acad. Ophthalmol. Otolaryngol. 78:275, 1974.

4. ———: Photogrammetric analysis of volume asymmetry of the optic nerve head cup in normal, hypertensive, and glaucomatous eyes. Am. J. Ophthalmol. 80:51, 1975.

5. Johnson, C. A., Keltner, J. L., Krohn, M. A., and Portney, G. L.: Photogrammetry of the optic disc in glaucoma and ocular hypertension with simultaneous stereo photography. Invest. Ophthalmol. Vis. Sci. 18:1252, 1979.

6. Schirmer, K. E., and Kratky, V.: Photogrammetry of the optic disc. Can. J. Ophthalmol. 8:78, 1973.

7. Betz, P. H., Camps, F., Collignon-Brach, J., Lavergne, G., and Weekers, R.: Biometric study of the disc cup in open angle glaucoma. Graefes Arch. Clin. Exp. Ophthalmol. 218:70, 1982.

8. Holm, D., and Krakau, C. E. T.: A photographic method for measuring the volume of papillary excavations. Ann. Ophthalmol. 1:327, 1970.

9. Currie, G. D., and Leonard, C. D.: Photogrammetric measurement of the human optic cup. Photogrammetric Engineering Remote Sensing 42:807, 1976.

10. Schwartz, B., and Takamoto, T.: Biostereometrics in ophthalmology for measurement of the optic disc cup in glaucoma. Proc. Soc. Photo-optical Instrumentation Engineers 166:251, 1978.

11. Takamoto, T., Schwartz, B., and Marzan, G. T.: Stereo measurement of the optic disc. Photogrammetric Engineering Remote Sensing 45:79, 1979.

12. Takamoto, T., and Schwartz, B.: Topographic parameters of the optic disc by the radial section method. Proc. Am. Soc. Photogrammetry 1:238, 1979.

13. ———: Photogrammetric measurement of the optic disc cup in glaucoma. Int. Arch. Photogrammetry 23:732, 1980.

14. Crock, G.: Stereotechnology in medicine. Trans. Ophthalmol. Soc. U.K. 90:577, 1970.

15. Crock, G., and Parel, J. M.: Stereophotogrammetry of fluorescein angiographs in ocular biometrics. Med. J. Aust. 2:586, 1969.

16. Jonsas, C. H.: Stereophotogrammetric techniques for measurements of the eye ground. Acta Ophthalmol. 117(suppl.):3, 1972.

17. Schirmer, K. E.: Simplified photogrammetry of the optic disc. Arch. Ophthalmol. 94:1997, 1976.

18. Kottler, M. S., Rosenthal, A. R., and Falconer, D. G.: Digital photogrammetry of the optic nerve head. Invest. Ophthalmol. 13:116, 1974.

19. ———: Analog vs digital photogrammetry for optic cup analysis. Invest. Ophthalmol. 15:651, 1976.

20. Rosenthal, A. R., Kottler, M. S., Donaldson, D. D., and Falconer, D. G.: Comparative reproducibility of the digital photogrammetric procedure utilizing three methods of stereophotography. Invest. Ophthalmol. Vis. Sci. 16:54, 1977.

21. Rosenthal, A. R., Falconer, D. G., and Pieper, I.: Photogrammetry experiments with a model eye. Br. J. Ophthalmol. 65:881, 1980.

22. Cornsweet, T. N., Hersh, S., Humpries, J. C., Beesman, R. J., and Cornsweet, D. W.: Quantification of the shape and colour of the optic nerve head. In Breinin, G. M., and Siegel, I. M. (eds.): Advances in Diagnostic Visual Optics. Berlin, Springer-Verlag, 1983, p. 141.

23. Lichter, P. R.: Variability of expert observers in evaluating the optic disc. Trans. Am. Ophthalmol. Soc. 74:532, 1976.

24. Schwartz, J. T.: Methodologic differences and measurement of cup-disc ratio. Arch. Ophthalmol. 94:1101, 1976.

25. Leydhecker, W., Krieglestein, G. K., and Collani, E. V.: Observer variation in applanation tonometry and estimation of the cup disc ratio. In Krieglestein, G. K., and Leydhecker, W. (eds.): Glaucoma Update. New York, Springer-Verlag, 1979, p. 101.

26. Balazsi, A. G., Drance, S. M., Schulzer, M., and Douglas, G. R.: The area of the neuroretinal rim in glaucoma suspects and early chronic open angle glaucoma. Correlation with parameters of visual functions. Arch. Ophthalmol. In press.