

# Computerized Optic Disc Analysis with Adjunct Stereoscopic Viewing of Disc Photographs

Young J. Hong and Dong H. Shin<sup>1</sup>

*We have investigated the potential usefulness of stereoscopic viewing of optic disc photographs in marking the disc margin in computerized analysis with the Rodenstock Analyzer in 48 eyes of 26 patients with ocular hypertension or primary open-angle glaucoma. Marking of the disc margin without (Method 1) and with the aid of stereoscopic viewing of disc photographs (Method 2) three consecutive times by one observer at the same sitting, and three subsequent topographic analyses of each method were done on each of 48 eyes. The mean intraphotographic variabilities of such optic disc parameters as rim area, disc area, and cup volume with Method 2 were significantly less than those with Method 1 overall and in 16 eyes (33%) with poor video images having an ill-defined disc margin ( $p < 0.05$  for each), but not in 32 eyes (67%) with clear video images having a well-defined disc margin. Furthermore, the mean paired differences of rim area, disc area and cup volume between the two methods (Method 1 minus Method 2) were also statistically significant overall and in eyes with poor video images ( $p < 0.05$  for each).*

**Key Words:** Computerized optic disc analysis, disc photograph, glaucoma, ocular hypertension

Several studies have shown that computerized video image analysis can be a reliable and reproducible method for measurement of optic disc parameters including cup/disc ratio, neuroretinal rim area, disc area and cup volume (Mikelberg *et al.* 1984; Caprioli *et al.* 1986; Shields *et al.* 1987). Reliable and reproducible optic disc analysis using computerized video image analysis requires precise marking of the disc margins on the video monitor. Accurate disc margin marking is difficult, however, when the quality of the optic disc image on the video monitor is poor due to various causes including media opacity and inadequate pupillary dilatation. The computerized analysis is therefore dependent on both the photographic imaging and the accuracy of the disc margin marking performed by the operator. In an attempt to obtain more accurate measurement and to minimize the intraphotographic variability during optic disc analysis with the Rodenstock Optic Nerve Head Analyzer (RONA), we have investigated the potential usefulness

of adjunct stereoscopic viewing of the disc photographs in marking of the disc margin.

## SUBJECTS AND METHODS

Forty-eight eyes of 26 patients with primary open-angle glaucoma or ocular hypertension were randomly selected (Table 1). All subjects had stereoscopic color optic disc photographs taken with a fundus camera (Zeiss FF-3C) as well as an optic disc analysis with RONA. Details of the instrument (RONA) and definitions of parameters which were calculated by the instrument have been previously described (Mikelberg *et al.* 1984; Caprioli *et al.* 1986; Shields *et al.* 1987; Cornsweet *et al.* 1983).

In the optic disc analysis with RONA, the operator

Table 1. Patient characteristics

No. of patients	26
No. of eyes	48
Age (mean $\pm$ SD, years)	48.7 $\pm$ 17.0
Sex : Male/Female	10/16
Race: White/Black	15/11
Patients with ocular hypertension	12
Patients with primary open-angle glaucoma	14
Eyes with cataract	20

Received June 4, 1990

Accepted August 30, 1990

Department of Ophthalmology, Yonsei University College of Medicine, Seoul, Korea

The Kresge Eye Institute<sup>1</sup>, Wayne State University School of Medicine, Detroit, Michigan, U.S.A.

Address reprint requests to Dr. Y J Hong, Department of Ophthalmology, Yonsei University College of Medicine, C.P.O. Box 8044, Seoul, Korea, 120-752

registers the images to achieve exact alignment of the paired stereoscopic images without any vertical and horizontal disparities after taking 6 paired simultaneous stereo images. The operator then marks four cardinal points of the optic disc margin with a light pen. These four points are extrapolated by the computer into an ellipse, which represents the disc margin.

In our present study, the optic disc images of 48 eyes were reviewed and then divided, on the basis of their quality, into two groups: 32 eyes (67%) with clear video images having a well-defined disc margin, and 16 eyes (33%) with poor video images having an ill-defined disc margin. After registration of the video images, marking of the disc edge without (Method 1) and with the aid of stereoscopic viewing of color disc photographs (Method 2) three consecutive times by one observer at the same sitting, and three subsequent topographic analyses of each method were done on each of 48 eyes. The topographic parameters analyzed included horizontal disc diameter, cup/disc ratio, rim area, disc area and cup volume.

We calculated the mean intraphotographic variabilities for each topographic parameter and compared them between the two methods.

We then calculated the mean paired difference between the two methods, defined as Method 1 minus Method 2, for each optic disc parameter using the paired t-test.

## RESULTS

Table 2 shows the mean intraphotographic variabilities of the topographic parameters of the optic disc as analyzed by RONA without (Method 1) and with (Method 2) the input of adjunct stereoscopic viewing of color disc photographs. The mean intraphotographic variabilities of horizontal disc diameter, rim area, disc area, and cup volume with Method 2 were significantly less than those with Method 1 overall (1.0% to 2.3% vs 2.0% to 3.8%,  $p < 0.05$  with respect to each parameter). However, the mean intraphotographic variability of cup/disc ratio was not significantly different between the two methods. The largest values for the mean intraphotographic variance of each parameter with Method 2 (3.0% to 7.8%) were also significantly less than those with Method 1 (15.2% to 29.0%). In 16 eyes

**Table 2. Mean intraphotographic variabilities of each optic disc parameter without and with adjunct stereoscopic viewing of color disc photographs (n=48)**

Optic Disc Parameter	Mean±S.D. Intraphotographic Variability*		
	Method 1	Method 2	p value
Disc diameter horizontal	2.0±2.4 (15.2)	1.0±1.3 (4.6)	.011
Cup/Disc ratio	2.1±3.0 (15.5)	1.3±1.6 (5.5)	.080
Rim area	3.8±3.4 (22.1)	2.3±1.8 (7.8)	.009
Disc area	3.3±4.1 (29.0)	1.6±1.2 (5.2)	.008
Cup volume	2.1±3.0 (20.7)	1.0±0.8 (3.0)	.031

\* Parentheses indicate the largest intraphotographic variability of each parameter.

**Table 3. Comparison of mean intraphotographic variabilities of each parameter in eyes with clear and poor video images between Method 1 and 2\***

Optic Disc Parameter	Mean±S.D. Intraphotographic Variability					
	Poor Video Image (n=16)			Clear Video Image (n=32)		
	Method 1	Method 2	p value	Method 1	Method 2	p value
Disc diameter horizontal	3.3±3.4	1.4±1.5	.049	1.4±1.2	0.9±1.1	.073
Cup/Disc ratio	3.0±3.6	1.3±1.5	.098	1.8±2.5	1.4±1.6	.401
Rim area	5.8±4.6	2.5±1.7	.015	2.8±1.7	2.2±1.8	.203
Disc area	5.7±6.2	1.8±1.4	.024	2.1±1.2	1.5±1.2	.065
Cup volume	3.6±4.5	1.1±0.8	.047	1.4±1.2	0.9±0.8	.104

\* Measurement of each disc parameter without (Method 1) and with (Method 2) the aid of stereoscopic viewing of color disc photographs.

**Table 4. Mean ( $\pm$ SD) paired difference in each optic disc parameter between the two methods in eyes with clear and poor video images\***

Disc Parameter	Clear Video Image (n=32)	Poor Video Image (n=16)	Overall (n=48)
Disc diameter horizontal (mm)	.015 $\pm$ .038	.076 $\pm$ .06**	.035 $\pm$ .056**
Cup/Disc ratio	.002 $\pm$ .018	.006 $\pm$ .024	.003 $\pm$ .020
Rim area (mm <sup>2</sup> )	.008 $\pm$ .047	.043 $\pm$ .050*	.020 $\pm$ .054*
Disc area (mm <sup>2</sup> )	.018 $\pm$ .057	.107 $\pm$ .056**	.048 $\pm$ .071**
Cup volume (mm <sup>3</sup> )	.005 $\pm$ .011	.015 $\pm$ 0.14**	.010 $\pm$ .013**

\* Mean paired difference between the two methods {a disc parameter without adjunct stereoscopic viewing of color photographs (Method 1) minus that with (Method 2)}.

\*  $p < 0.05$ , \*\*  $p < 0.001$

with poor video images, the intraphotographic variabilities of horizontal disc diameter, rim area, disc area and cup volume with Method 2 were also significantly less than those with Method 1 (1.1% to 2.5% vs 3.3% to 5.8%,  $p < 0.05$  with respect to each parameter). However, in 32 eyes with clear video images, there was no statistically significant difference in the intraphotographic variabilities of each optic disc parameter between the two methods (0.9% to 2.2% vs 1.4% to 2.8%,  $p > 0.05$  with respect to each parameter) (Table 3).

Table 4 shows the mean paired differences between the two methods (Method 1 minus Method 2) of each optic disc parameter. The mean paired differences of horizontal disc diameter, rim area, disc area and cup volume were statistically significant overall and in eyes with poor video images ( $p < 0.05$  for each), but not in eyes with clear video images.

## DISCUSSION

Histological studies and clinical observations of the optic disc in glaucoma patients have shown that structural changes at the optic disc usually, albeit not invariably, predate measurable visual field abnormalities (Shin *et al.* 1976; Pederson and Anderson 1980; Quigley *et al.* 1982). Therefore, a careful assessment of the optic disc for detection and quantification of a small change is of utmost importance in the diagnosis and management of glaucoma, especially in its early stage (Spaeth and Varma 1987). For this reason, more accurate methods of documenting the optic disc appearance over time have been developed. Such methods are expected to help us recognize small increments of progression during the course of the disease which would lead to better care for the ocular hypertensive glaucoma suspects as well as those with

manifest disease (Douglas *et al.* 1987). Computerized videographic image analysis of the optic disc, one of these methods, provides information on such parameters as vertical and horizontal disc diameters, vertical and horizontal cup/disc ratios, neuroretinal rim area, disc area and cup volume in a rapid and reproducible manner (Mikelberg *et al.* 1984; Caprioli *et al.* 1986; Shields *et al.* 1987). This method is comparable to the currently used photogrammetric method in reproducibility, but does not require a trained photogrammetrist (Mikelberg *et al.* 1986; Douglas *et al.* 1987). The mean intraphotographic variabilities of the optic disc parameters without the aid of stereoscopic viewing of color disc photographs in our present study were similar to those of previous reports by Mikelberg *et al.* (1984), Caprioli *et al.* (1986), and Shields *et al.* (1987) except for that of cup volume.

Determination of the level of real change that can be reliably detected with a technique is directly influenced by its variability. Therefore, a smaller variability and a more accurate method for measurement of a parameter will result in a higher probability of determining a trend. In computerized image analysis of the optic disc, accurate marking of the disc margin on the video image of the optic disc is crucial. Accurate marking, however, is difficult when the quality of the optic disc image on the video monitor is poor due to various causes including media opacity and the inability to dilate the pupil adequately ( $< 5$  mm), findings that are common in elderly glaucoma patients with varying degrees of cataract and chronic use of miotic drugs. Of the 48 eyes in this study, sixteen eyes with poor video images had media opacities such as early to moderate cataract and central epithelial defects of the cornea secondary to applanation tonometry or ultrasound probe application on topical anesthesia, or inability to dilate the pupil adequately. It is true that the intraphotographic variability which is primarily due to

the interactive marking of the disc margin by the operator represents only a portion of the total variability. However, it is important and worthwhile to minimize this variability with the aid of stereoscopic viewing of color disc photographs, which can readily be obtained with a fundus camera at the times of optic disc analysis with RONA, as this study points out.

In our study, we found that adjunct stereoscopic viewing of color disc photographs was of no value when dealing with clear video images having a well-defined disc margin. However, the use of stereoscopic photographs in the analysis of optic discs that had poor video images with an ill-defined disc margin significantly reduced the mean intraphotographic variabilities of horizontal disc diameter, rim area, disc area and cup volume. Furthermore, the mean paired difference between two measurements (Method 1 minus Method 2) of horizontal disc diameter, rim area, disc area or cup volume was statistically significant overall and in eyes with poor video images. This finding demonstrates, that, without the use of stereoscopic disc photographs in optic disc analysis with RONA, the operator tends to mark four cardinal points on the outside of the actual optic disc margin, and with less consistency, especially in eyes with poor video images. Furthermore, in our experience, the quality of the video images of the optic disc is always worse than that of the stereoscopic color photographs for ascertaining the disc margin in eyes with media opacity or inadequate pupillary dilatation.

We believe that the operator may reduce the variability and enhance the accuracy by taking several precautions in optic disc analysis with RONA. To get the best quality paired video images, the patient's pupils should be dilated adequately (5 mm or more), and care has to be taken to avoid corneal epithelial defects during application of a probe for measurement of axial length and/or of intraocular pressure. If the view of the disc is not optimal, it is difficult to register video images and mark the disc margin precisely, resulting in a questionable or unreliable topographic map and profile of the optic disc and variable optic disc parameters. When comparing two consecutive disc images of a patient's eye over time, the optic disc images should be placed at the same location with respect to the fixed reference level on the video monitor. Any shifting of the optic disc image with respect to the fixed reference level on the video monitor will result in increased variability in cup volume, rim area and cup/disc ratio (Shields *et al.* 1987). Furthermore, for good registration of the images, the 6 paired video images should be taken at

the same head posture. Registration of video images is easily performed with the use of a keyboard for vertical and horizontal disparities, but not for oblique disparities. When comparing serial disc images of a patient's eye over time, the disc images should be analyzed at the same sitting. For accurate marking of the optic disc margin, the adjunct use of stereoscopic viewing of color disc photographs is recommended in eyes with poor video images.

## REFERENCES

- Caprioli J, Klingbeil U, Sears M, Pope B: Reproducibility of optic disc measurements with computerized analysis of stereoscopic video images. *Arch Ophthalmol* 104:1035-1039, 1986
- Cornsweet TN, Hersh S, Humphries JC, Beesmer RJ, Cornsweet DW: *Quantification of shape and color of the optic nerve head*. In Breinin GM, Siegel IM, eds. *Advances in Diagnostic Visual Optics*. Berlin, Springer-Verlag, 1983, 141
- Douglas GR, Drance SM, Mikelberg FS, Wijsman K, Schulzer M, Schwartz B, Takamoto T, Nagin P: *Optic nerve head analysis using the Rodenstock Analyzer*. In Kriegstein GK, ed. *Glaucoma Update III*. New York, Springer-Verlag, 1987, 106-111
- Mikelberg FS, Douglas GR, Schulzer M, Airaksinen PJ, Wijsman K, Mawson D: The correlation between cup-disc ratio, neuroretinal rim area, and optic disk area measured by the video-ophthalmograph (Rodenstock Analyzer) and clinical measurement. *Am J Ophthalmol* 101:7-12, 1986
- Mikelberg FS, Douglas GR, Schulzer M, Cornsweet TN, Wijsman K: Reliability of optic disc topographic measurements recorded with a video-ophthalmograph. *Am J Ophthalmol* 98:98-102, 1984
- Pederson JE, Anderson DR: The mode of progressive disc cupping in ocular hypertension and glaucoma. *Arch Ophthalmol* 98:490-495, 1980
- Quigley HA, Addicks EM, Green WR: Optic nerve damage in human glaucoma: III. Quantitative correlation of nerve fiber loss and visual field defect in glaucoma, ischemic neuropathy, papilledema, and toxic neuropathy. *Arch Ophthalmol* 100:135-146, 1982
- Shields MB, Martone JF, Shelton AR, Ollie AR, MacMilan J: Reproducibility of topographic measurements with the optic nerve head analyzer. *Am J Ophthalmol* 104:581-586, 1987
- Shin DH, Kolker AE, Kass MA, Kaback MB, Becker B: Long-term epinephrine therapy of ocular hypertension. *Arch Ophthalmol* 94:2059-2060, 1976
- Spaeth GL, Varma R: Assessment of the glaucomatous patient. *Eye* 1:29-39, 1987