

Effect of optic disc size or age on evaluation of optic disc variables

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Abstract

Aims/background—It has been reported that the number of optic nerve fibres decrease with age, and the cup/disc (C/D) ratio increases as the optic disc size increases. Consequently, the normal value of the optic disc variables measured by an optic disc analyser may change according to the optic disc size or age. The effect of individual variations in optic disc size or age on interpretation of optic disc variables was investigated.

Methods—Topographic optic disc variables of 104 normal Asian adults of both sexes aged 40 to 68 were measured using a confocal scanning laser ophthalmoscope (TopSS, Laser Diagnostic Technologies, Inc). Fourteen variables were evaluated according to the optic disc size or age. Statistical analysis was done by regression analysis.

Results—With an increase in optic disc size, the increase in cup shape, effective area, 1/2 depth area, C/D ratio, neuroretinal rim area, volume above, volume below, and 1/2 depth volume were statistically significant ($p < 0.05$). However, contour variation, mean contour depth, average depth, maximum depth, average slope, and maximum slope were not affected ($p > 0.1$). Age did not have any significant influence on optic disc variables ($p > 0.1$).

Conclusion—Optic disc size, but not age, should be considered in the interpretation of optic disc variables.

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Optic disc examination, which is one of the important examinations in the diagnosis of glaucoma, has been performed by ophthalmoscope, aspherical lens, or photograph.¹⁻³ Recently, with the development of the confocal scanning laser ophthalmoscope, sophisticated three dimensional analysis of the optic disc became available.⁴⁻⁵ However, it is only useful for detecting optic disc changes in the progression of glaucoma, and needs more studies if it is to be used in the diagnosis of glaucoma, because the mean optic disc variable values among normal subjects and glaucoma patients overlap considerably.

Normal values for threshold perimetric analysis are dependent on patient age and retinal location,⁶⁻⁸ therefore it could be postulated

that the optic disc variables should also be evaluated according to the optic disc size or age.

It has been reported that as the optic disc size increases, the neuroretinal rim area also increases.⁹⁻¹⁰ Therefore, the normal values of other optic disc variables measured by optic disc analyser may change depending on optic disc size. It has also been reported that the number of optic nerve fibres decrease with age, therefore we attempted to observe the change in optic disc variables with increase in age using subjects with similar optic disc sizes to eliminate the error by the individual variation of optic disc size.

Subjects and methods

One hundred and four normal Asian adults of both sexes visiting Samsung Medical Center for routine physical examination were enrolled into this study. These individuals had no history of ocular disease.

Baseline images were created by the average of three images measured by confocal scanning laser ophthalmoscope (TopSS, Laser Diagnostic Technologies Inc). This instrument projects a near infrared diode laser beam (wavelength 780 nm) on the retina and optic disc, and records the reflected light. From the measured reflectivity intensities it calculates topographic maps, and produces three dimensional images of the optic disc by multiple optical sectioning of the object; a series of two dimensional transverse optical section images parallel to the object's surface is recorded and the focal plane is moved in consecutive steps. Such a tomographic series forms a three dimensional image of the object, which consists of 32 image planes of 256×256 pixels each. After each acquisition, the instrument verifies that blinking, exposure, range of depth, offset, and saturation were correct. Three images per eye centred on the optic disc were obtained in a single session, and the three depth values obtained for each pixel were averaged to produce a baseline topographic image. By determining the margin of the optic disc from the obtained topographic image, 14 optic disc variables are automatically measured. They are: contour variation, the difference between the maximum height and the minimum height values along the defined margin of the optic disc; mean contour depth, the average of all the height values along the defined margin of the optic disc; cup shape, the position of the centre of gravity of the cup; effective area, the area of optic cup; 1/2 depth area, the area of all points half way between the cup margin and the bottom; cup/disc ratio,

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Table 1 Values of the optic disc variables in 104 normal subjects

Variable (unit)	Mean	SD
Contour variation (mm)	0.370	0.095
Mean contour depth (mm)	-0.009	0.078
Cup shape	-0.058	0.031
Effective area (mm ²)	1.101	0.407
1/2 depth area (mm ²)	0.436	0.232
C/D ratio*	0.433	0.116
NRRA† (mm ²)	1.401	0.355
Volume above (mm ³)	0.227	0.081
Volume below (mm ³)	-0.262	0.145
1/2 depth volume (mm ³)	-0.053	0.037
Average depth (mm)	-0.220	0.075
Maximum depth (mm)	-0.536	0.185
Average slope (degree)	31.244	6.016
Maximum slope (degree)	77.455	4.496

*C/D = cup/disc; †NRRA = neuroretinal rim area.

calculated by dividing the effective area by the total optic disc area; neuroretinal rim area, the difference between the total optic disc area and the effective area; volume above, the volume of all tissue or structure within the neuroretinal rim area; volume below, the volume of the cup below the effective area; 1/2 depth volume, the volume of the cup below the 1/2 depth area; average depth, the average of the differences in height values at the reference plane and the corresponding height values within the cup; maximum depth, average of the lowest 5% of all the height values; average slope, the average of the slope values for all the pixels within the optic disc; and maximum slope, the maximum slope value for all the pixels within the optic disc. To determine the volumetric reproducibility, a total of three independent sets of images of optic disc were obtained for each 10 individuals. From this the mean of the average standard deviation and the coefficient of variation were calculated.

For evaluating the effect of individual variation in the optic disc size or age on optic disc variables, one eye of each subject was chosen randomly and used for analysis. Only those images having less than 4 degrees contour tilt were included to exclude tilted high myopic discs. The spherical equivalent of refractive error of the subjects included was less than -3 dioptres, and intraocular pressure measured by non-contact tonometer (Topcon CT-50) was less than 21 mm Hg.

The cup margin was defined at 100 µm below the retinal reference plane as recommended by the instrument manufacturer. Scan

Table 2 Volumetric reproducibility of optic disc variables measured by TopSS

Variable	SD	CV * (%)
Contour variation (mm)	0.039	8.3
Mean contour depth (mm)	0.012	7.3
Cup shape	0.028	7.9
Effective area (mm ²)	0.047	3.9
1/2 depth area (mm ²)	0.062	6.8
C/D ratio†	0.019	4.0
NRRA‡ (mm ²)	0.057	4.7
Volume above (mm ³)	0.017	8.9
Volume below (mm ³)	0.023	4.0
1/2 depth volume (mm ³)	0.018	8.3
Average depth (mm)	0.019	4.3
Maximum depth (mm)	0.049	5.0
Average slope (degree)	1.225	2.9
Maximum slope (degree)	0.829	1.4

*CV = coefficient of variation; †C/D = cup/disc; ‡NRRA = neuroretinal rim area.

angle was selected at 10°, and scan depth and scan offset were adjusted at 3 mm and 3, respectively. The optic disc margin was defined by changing the shape of ellipse and fitting the best ellipse around the scleral ring.

Fourteen optic disc variables were evaluated according to the optic disc size or age. To determine the effect of optic disc size on the optic disc variables, we observed the change of each optic disc variable as the optic disc size increased in the 104 subjects. To evaluate the effect of age on optic disc variables, we analysed the variability of each optic disc variable as age increased in the 77 subjects with optic disc sizes equal to or greater than 2 mm² and equal to or less than 3 mm².

Statistical analysis was done by regression analysis.

Results

The mean (SD) optic disc size of 104 subjects was 2.502 (0.524) mm² and ranged from 1.417 mm² to 4.024 mm²; other values of optic disc variables are shown in Table 1.

The volumetric reproducibility which was expressed by mean standard deviation and coefficient of variation of the three measurements that made up a baseline image in each of 10 subjects ranged from 0.012 to 1.125, and from 1.4% to 8.9%, respectively (Table 2).

With increase in optic disc size the increases in cup shape, effective area, 1/2 depth area, C/D ratio, neuroretinal rim area, volume above, volume below, and 1/2 depth volume were statistically significant. However, contour variation, mean contour depth, average depth, maximum depth, average slope, and maximum slope were not affected (Table 3).

The mean (SD) age of 77 subjects used for analysing the effect of age on optic disc variables was 52.4 (6.8) years and ranged from 40 to 68 years. Age did not seem to have any statistically significant influence on optic disc variables (Table 4).

Discussion

Since optic disc change precedes visual field defect in glaucoma patients, examination of the optic disc is thought to be more valuable than the visual field test for early detection of glaucoma.¹¹⁻¹³ The interobserver variation is smaller in determining the margin of optic disc than that of cupping,¹⁴ therefore reproducibility and accuracy in evaluating the optic disc with an optic disc analyser, which measures the variables automatically only by determination of the optic disc margin, could be much higher than with an ophthalmoscope or a photograph where the examiner needs to decide on all of the variable data himself. In addition, the optic disc analyser could perform the volumetric evaluation of the optic disc.

The reproducibility of measurements of the optic nerve head with the TopSS was excellent and comparable with other types of optic disc analyser such as the Heidelberg retina tomograph. The mean coefficient of variation for multiple examinations in normal subjects with

Table 3 Effect of disc size on optic disc variables

Variable	Equation	p Value	R*
Contour variation	$y = 0.348 + 0.009x$	0.630	0.045
Mean contour depth	$y = 0.033 - 0.017x$	0.251	-0.114
Cup shape	$y = -0.019 - 0.015x$	0.008	-0.259
Effective area	$y = -0.329 + 0.572x$	0.001	0.736
1/2 depth area	$y = -0.232 + 0.267x$	0.001	0.603
C/D ratio†	$y = 0.288 - 0.058x$	0.007	-0.263
NRRA‡	$y = 0.330 + 0.428x$	0.001	0.632
Volume above	$y = 0.024 + 0.081x$	0.001	0.525
Volume below	$y = 0.049 - 0.124x$	0.001	-0.448
1/2 depth volume	$y = 0.014 - 0.027x$	0.001	-0.381
Average depth	$y = -0.202 - 0.007x$	0.618	-0.045
Maximum depth	$y = -0.575 + 0.016x$	0.657	0.045
Average slope	$y = 27.073 + 1.667x$	0.141	0.145
Maximum slope	$y = 77.431 + 0.010x$	0.991	0.000

*R = correlation coefficient; †C/D = cup/disc; ‡NRRA = neuroretinal rim area.

Table 4 Effect of age on optic disc variables

Variable	Equation	p Value	R*
Contour variation	$y = 0.265 + 0.002x$	0.134	0.173
Mean contour depth	$y = -0.112 + 0.002x$	0.220	0.141
Cup shape	$y = -0.079 + 0.001x$	0.405	0.095
Effective area	$y = 1.296 - 0.005x$	0.413	-0.095
1/2 depth area	$y = 0.688 - 0.005x$	0.131	-0.173
C/D ratio†	$y = 0.536 - 0.002x$	0.332	-0.114
NRRA‡	$y = 0.988 + 0.009x$	0.150	0.167
Volume above	$y = 0.152 + 0.001x$	0.399	0.118
Volume below	$y = -0.397 + 0.002x$	0.342	0.109
1/2 depth volume	$y = -0.100 + 0.001x$	0.154	0.164
Average depth	$y = -0.265 + 0.001x$	0.627	0.055
Maximum depth	$y = -0.231 - 0.006x$	0.076	-0.205
Average slope	$y = 30.113 + 0.034x$	0.739	0.045
Maximum slope	$y = 72.987 + 0.097x$	0.191	0.152

*R = correlation coefficient; †C/D = cup/disc; ‡NRRA = neuroretinal rim area.

the Heidelberg retina tomograph has been reported as 4.8% for neuroretinal rim area, 3.4% for cup area, 4.6% for cup volume, and 4.0% for maximal depth.¹⁵ The corresponding values using the TopSS were 4.7%, 3.9%, 4.0%, and 5.0%, respectively.

The optic disc size varies individually,^{16 17} and as the optic disc size increases the neuroretinal rim area also increases.^{9 10} Therefore, it could be hypothesised that the optic disc size could influence other variables measured by an optic disc analyser.

It has been reported that the neuroretinal rim area decreases with age,¹⁸⁻²² but other studies show that there is no change in neuroretinal rim area with age.^{23 24} The reason for this contradiction in results is that data were analysed irrespective of the optic disc size. If most of the subjects included in the old age group had large optic disc sizes, the neuroretinal rim area would not be decreased, even though the neuroretinal rim area may decrease with age.

The best way to check the variation in optic disc variables with age is to follow up some volunteers over a period of time. However, it is impossible in this kind of cross sectional study, and if we perform a longitudinal study, it needs a long follow up time. Therefore, in this study, we evaluated the influence of age on optic disc variables using the subjects with similar optic disc sizes to minimise errors which could be derived from the individual optic disc size variations.

Optic disc variables related to area or volume were influenced by optic disc size; however, those related to depth were not affected by optic disc size. It could be said that as optic

disc size increases, the cup is widened but not deepened. Hence, the depth change of cup could also be a good clue in the detection of glaucomatous optic disc.

Our results indicate that age is not a necessary factor in the evaluation of optic disc variables. In other words, the cup is not enlarged or deepened with age. It correlates well with the studies that there is no statistically significant decrease in the number of nerve fibres with age.²⁵⁻²⁷ Other studies have shown that nerve fibres decrease by 4000 to 12 000 fibres per year.²⁸⁻³⁰ Even though there may be loss of nerve fibres, they may be replaced by glial or other tissue, and thus not detected by topographic evaluation.

In this study we included a subject with less than 4 degrees of contour tilt because we used only the reference plane in the determination of the cup; evaluation of the tilted disc in the myopic eye using the reference cup is recommended rather than using the reference plane because in these tilted discs the plane will be higher than the lower side of the optic nerve head and the resulting volumetrics will be higher than the actual values. Further study is necessary to determine factors affecting the optic disc variables in myopic tilted discs.

In conclusion, optic disc size but not age should be considered in the determination of normal values of optic disc variables. If normal values of each optic disc variable were determined using a large number of samples, the optic disc analyser could be useful not only for early detection of progression of glaucoma but also for early diagnosis of glaucoma.

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