

EXTENDED REPORT

Retinal thickness decreases with age: an OCT study

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Br J Ophthalmol 2003;**87**:899–901

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Accepted for publication 12 November 2002

Background/aim: In three dimensional optic disc tomography a reference plane is required to calculate optic disc rim or cup values. The position of the reference plane often depends on the retinal thickness at the temporal disc margin. Originally it was assumed that the retinal thickness at the temporal disc margin is independent of age. The aim of the study was to check this hypothesis using optical coherence tomography, and additionally to determine the reproducibility of OCT measurements in this area.

Methods: 100 eyes of 100 healthy volunteers were included in this study. Three OCT scans were performed on each eye. The scans were aligned vertically and placed at the temporal edge of the optic disc. For each eye, the thickness of the whole retina as well as the thickness of the retinal nerve fibre layer were calculated together with their coefficients of variation. Thereafter retinal thickness and nerve fibre layer thickness were correlated with age.

Results: The mean retinal thickness was 249 (SD 22) μm . The mean nerve fibre layer thickness was 109 (22) μm . The mean coefficients of variation were 3.5% (total retinal thickness) and 8.0% (nerve fibre layer thickness). Both the total retinal thickness and the nerve fibre layer thickness were significantly correlated with age (total retina: $y = 269.5 - 0.53 \times x$; $R^2 = 0.133$; $p = 0.0002$, nerve fibre layer: $y = 126.8 - 0.44 \times x$; $R^2 = 0.094$; $p < 0.0019$).

Conclusions: Using OCT scans the total retinal thickness can be calculated with high reproducibility (coefficient of variation = 3.5%). The reproducibility of nerve fibre layer thickness measurements is clearly lower (coefficient of variation = 8.0%). Both the total retinal thickness and the nerve fibre layer thickness significantly decrease with age. This influence of the age related decrease in RNFL/retinal thickness on the reference plane, however, is negligible.

Confocal laser scanning tomography (Heidelberg retina tomograph, HRT) is a useful tool to monitor the progression of optic disc cupping in glaucoma or ocular hypertension. When optic disc parameters are calculated by the HRT, a reference plane is used.¹ The height of this reference plane depends on the retinal thickness at the temporal disc margin. It was assumed that the retinal thickness and the RNFL (retinal nerve fibre layer) thickness at this particular position do not decrease with age.

The purpose of the present study was to verify whether the latter hypothesis is right or wrong using optical coherence tomography (OCT: OCT 2000, Humphrey Instruments, San Leandro, CA, USA) In addition we wanted to determine the reproducibility of OCT measurements at the temporal disc margin.

SUBJECTS AND METHODS

Optical coherence tomography

Optical coherence tomography (OCT) is a non-invasive, non-contact method giving a cross sectional image of the retina and its substructures in a real time mode and in vivo.² The resolution of the OCT image is at about 1–15 μm . It provides details 10 times superior to an ultrasound-B scan.

Using the OCT, the retinal thickness is given by the distance between the first high reflective layer (that is, the vitreoretinal interface) and the retinal pigment epithelium (Fig 1). The RNFL thickness is calculated from the reflectivity distribution within the retina, using a special algorithm.

Physical details about the OCT technology—beam splitter, reference path, time delay, back scattering light from the tissue and detector, etc—are presented explicitly in the publications of Fujimoto and Hee.^{2,3}

Subjects

One hundred eyes of 100 healthy volunteers were examined between January and August 2000. Before inclusion into the

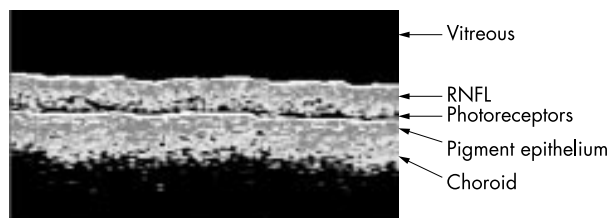


Figure 1 Normal OCT scan showing the human retina and its substructures as a false image.

study each subject was informed about the purpose of the study and the risks of the OCT examination. All subjects underwent a complete ophthalmic examination including slit lamp biomicroscopy, applanation tonometry, and binocular ophthalmoscopy after pupil dilatation. Exclusion criteria were any abnormalities of the disc or the retinal nerve fibre layer, particularly glaucoma-like cupping; family history of glaucoma, or any other hereditary eye disease; diabetes or other systemic disease possibly affecting the eye; history of intraocular surgery or any kind of laser therapy including refractive surgery; refractive error < -7.0 or > 5.0 D; visual acuity ≥ 0.6 .

Before recording the OCT image each eye of each subject was dilated with tropicamide 0.5%.

Three consecutive vertical scans of 2.3 mm length at the temporal disc margin were performed (Fig 2). The scans were placed as close as possible to the optic nerve head, but any overlap with the disc itself was avoided.

Statistics

Reproducibility data are expressed as the coefficient of variation (CV) = standard deviation/mean. The correlation

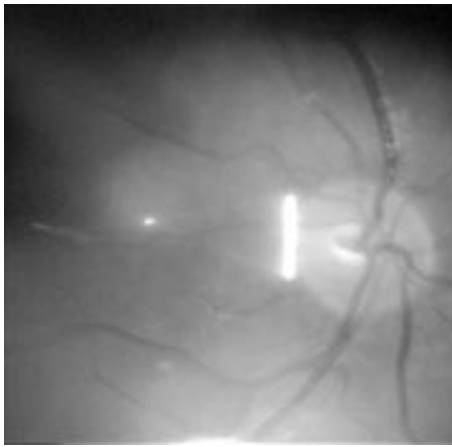


Figure 2 OCT scan line. This video picture shows the scan line placed at the temporal disc margin.

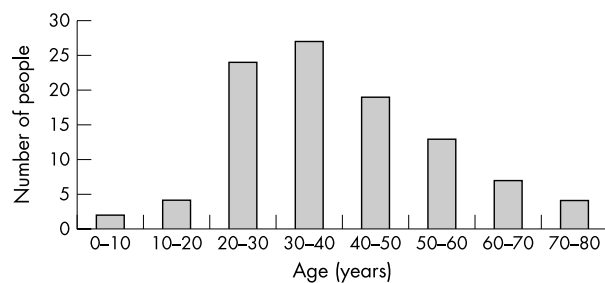


Figure 3 Age distribution of 100 volunteers examined in the study.

between RNFL/retinal thickness and age is presented as a linear regression together with the 95% confidence bands of the regression slope.

RESULTS

Baseline data

The age of the volunteers examined here ranged from 6 to 79 years with a mean of 39.5 years. Further details of the age distribution are shown in Figure 3. Seventy one volunteers were female. In this subgroup the mean age was 38.3 years; 29 volunteers were males. In this subgroup the mean age was 40.5 years.

The mean retinal thickness of all subjects was 249.0 (SD 21.8) μm (male 248.7 μm , female 249.2 μm). These values ranged from 191 μm and 310 μm , 95% of them were between 205.4 μm and 292.5 μm .

The mean RNFL thickness of all subjects was 109.6 (21.8) μm (male 109.3 μm , female 109.7 μm). These values ranged from 42 μm to 157 μm , 96% of them were between 66 μm and 153.2 μm .

Reproducibility of RNFL/retinal thickness data

The average coefficient of variation (CV) of the retinal thickness was 3.5%. In 95% of cases the CV was below 20%.

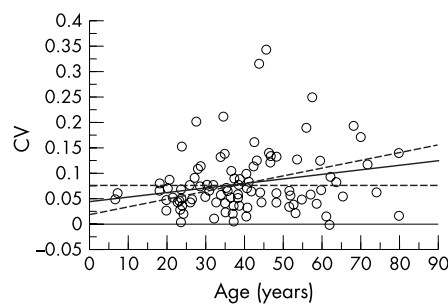
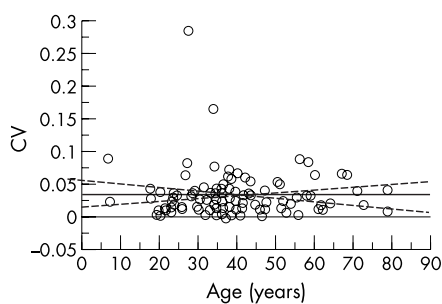


Figure 4 (Left) Correlation between CV (retinal thickness) and age ($y = 0.036 - 2.1 \times x$; $R^2 = 7.934$; $p = 0.9299$). (Right) Correlation between CV (RNFL thickness) and age ($y = 0.048 + 0.001 \times x$; $R^2 = 0.042$; $p = 0.0398$)

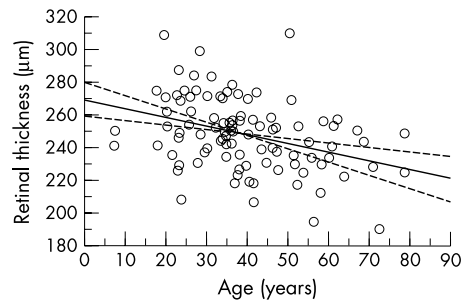


Figure 5 Regression plot of the retinal thickness versus age and 95% confidence bands of the regression slope ($y = 269.5 - 0.53 \times x$; $R^2 = 0.133$; $p = 0.0002$). Mean retinal thickness = 249 μm .

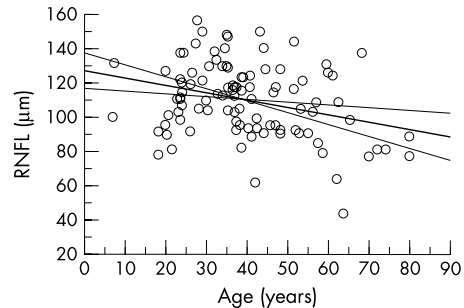


Figure 6 Regression plot of the RNFL thickness versus age and 95% confidence bands of the regression slope ($y = 126.8 - 0.44 \times x$; $R^2 = 0.094$; $p = 0.0019$). Mean RNFL thickness = 109 μm

The average CV of the RNFL thickness was 8.0%. In 95% of cases the CV was below 20%.

As can be seen from Figure 4, CV (RNFL thickness) increased slightly with age. This increase, however, was only slightly significant for RNFL thickness. The non-parametric Spearman rank correlation test again shows only a borderline significance ($R=0.1973$; $p = 0.0498$). The CV for retinal thickness showed no increase or decrease, so no significance could be found.

Correlation between RNFL/retinal thickness and age

We found a significant ($p=0.0002$) decrease of the retinal thickness with increasing age. On average, this decrease was 0.53 μm per year. Further details of the correlation between retinal thickness and age are presented in Figure 5. We also found a significant ($p=0.0019$) decrease of the RNFL thickness with increasing age. On average, this decrease was 0.44 μm per year. Further details of the correlation between RNFL thickness and age are presented in Figure 6.

How do the age related changes of the RNFL/retinal thickness affect the reference plane used in laser scanning tomography (HRT)?

If the retinal thickness decreases by 0.53 μm per year, the reference plane used by the HRT also descends by 0.53 μm per

Table 1 Impact of a 5 µm descent of the HRT reference plane. Data are presented as mean HRT values before descending the reference plane, absolute, and relative changes thereafter

	Average	Absolute change	Relative change
Cup area	1.07	-0.02	-0.019
C/D	0.34	-0.006	-0.018
Rim area	1.96	0.02	0.01
Cup vol	0.33	-0.008	-0.024
Rim vol	0.395	0.01	0.025
Cup shape measure	-0.24	0	0

year. Using our HRT database we calculated what happens to the disc parameters (cup area, C/D ratio, rim area, cup volume, and rim volume) if the reference plane descends by 5.3 µm, which simulates the average change after a 10 year interval of follow up. We found that the effect was negligible, and details are given in Table 1.

DISCUSSION

Reproducibility

Our study once again confirms the excellent reproducibility of retinal thickness measurements using the OCT. The average coefficient of variation was only 3.5%. The reproducibility of RNFL thickness measurements is slightly worse compared to retinal thickness measurements (CV=8%) but still sufficient for most clinical or scientific purposes.

Our reproducibility values are in good agreement with several other studies already published in the literature,^{2,4,5} although none of these studies used a vertical scan line adjacent to the optic disc.

Additionally, we did not find a significant deterioration of the OCT retinal thickness measurements with increasing age. Obviously, age is not a limiting factor in achieving reliable OCT retinal thickness data. RNFL measurements, however, slightly deteriorate with increasing age. This is not due to lens opacity, because lens opacity also would affect the measurements of the retinal thickness.

RNFL/retinal thickness and its correlation to age

The mean values of retinal or RNFL thickness are within the range already described in the literature. Schumann⁵ for example found a retinal thickness of 235.5 µm and a RNFL thickness of 91.5 µm in the temporal parapapillary area. In the study he used a circular OCT scan around the optic disc with a diameter of 3.37 mm. In another study he found a RNFL thickness of 126 µm in the temporal area, but this study included only 26 eyes.⁶

Histological studies evaluating the retinal thickness on the temporal side of the optic nerve head found different results varying from 170 µm to 360 µm.^{7,8}

We found a highly significant correlation of both the retinal and the RNFL thickness with age. The retinal thickness decreased by 0.53 µm per year, the RNFL thickness decreased by 0.44 µm per year. Obviously, about 80% of the changes in retinal thickness over time are caused by a shrinkage of the RNFL.

The question, whether there is a decrease in retinal and RNFL thickness with age has already been addressed in several other studies.^{1,5,9-11} A direct comparison is only possible with the study of Schumann *et al*,⁵ because they used OCT. Schumann⁵ examined 59 eyes of 33 subjects. He found a RNFL thickness decrease for the peripapillary RNFL thickness ($p < 0.03$) and the temporal RNFL thickness ($p < 0.0001$). Like in our study he did not find any differences between men and women.

Poinooswamy *et al*¹¹ examined 150 healthy volunteers of different ages using scanning laser polarimetry. They found a progressive reduction of the RNFL thickness with increasing age. The data presented in their study indicate a significant reduction of the RNFL thickness of 0.38 µm/year. In our study we found a very similar value of 0.43 µm per year. Balazsi *et al*¹ and Mickelberg *et al*⁸ counted the axons of 16 respectively 22 normal human eyes. They found an axon fibre loss in the optic nerve of 4909 and 5637, respectively, per year. This may be interpreted as a qualitative confirmation of our findings, because any loss of axons should lead to a decrease in RNFL thickness.

Jonas *et al*,⁹ using red free photographs, also found a correlation between the visibility of the retinal nerve fibre bundles and age. But there are a few studies that did not find a correlation between RNFL/retinal thickness and age. Varma *et al*⁸ performed histological examinations of 10 normal enucleated human eyes. They only found a significant correlation with age in the superior-nasal and inferior-temporal region. This, however, may be explained by the small number of eyes examined.

Repka and Quigley¹² also found no significant correlation between axon number and age, but they only examined 19 eyes (optic nerves) histologically.

Our study originally was designed to check the influence of age on the reference plane used by scanning laser tomographs like the HRT. A decrease of retinal thickness with increasing age must lead to a descending of this reference plane, thus changing optic disc parameters like neuroretinal rim area, cup to disc ratio, etc. A descending of the reference plane, for example, artificially enlarges the calculated values of the neuroretinal rim area. When it occurs over time, a glaucomatous narrowing of the rim could be missed in follow up examinations. Fortunately, the age related changes of the retinal thickness found in our study are very small, and their influence on optic disc parameters calculated by the HRT are negligible.

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Br J Ophthalmol 2003 87: 899-901

doi: 10.1136/bjo.87.7.899

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