Relationship between short wavelength perimetry and central corneal thickness values in ocular hypertensive subjects

Z. DADACI[1], B. BOZKURT[2], M.T. IRKEÇ[1], M. ORHAN[1], U. ARSLAN[3]

[1]Department of Ophthalmology, Hacettepe University Faculty of Medicine
[2]Private practice
[3]Department of Biostatistics, Hacettepe University Faculty of Medicine, Ankara - Turkey

PURPOSE. *To evaluate the results of short wavelength perimetry (SWAP) of ocular hypertensive (OHT) patients and correlate these findings with central corneal thickness (CCT) measurements.*

METHODS. *Thirty-seven OHT patients with a mean age of 50.2±8.2 (SD) years and 30 control subjects with a mean age of 50.3±8.5 (SD) years were included in this study. A questionnaire was applied to patients to evaluate the demographic risk factors that may predict glaucoma development. After a detailed ophthalmologic examination, achromatic and short wavelength perimetries and ultrasonic pachymetry were performed and the results were compared between the two groups with Student t test and Mann-Whitney U test. A p value <0.05 is considered as statistically significant.*

RESULTS. *Mean CCT was higher in the OHT group (right eye; 558.13±28.39 µm and left eye; 558.94±27.30 µm) when compared with the control subjects (524.66±30.53 µm and 525.86±30.46 µm, respectively) (p<0.01). A significant positive correlation was found between CCT measurements and intraocular pressure (r=0.5, p<0.001). Four right eyes (10.8%) and five left eyes (13.5%) of OHT patients had defects in SWAP. OHT patients with SWAP abnormalities had significantly lower CCT measurements in right (527.25±17.34 µm) and left eye (528.80±13.60 µm) when compared with OHT patients without SWAP defects (561.87±27.29 µm and 563.65±25.92 µm, respectively) (p<0.05). Significant correlations were found between CCT and SWAP MD, PSD, and CPSD (p<0.05).*

CONCLUSIONS. *OHT patients with SWAP abnormalities had significantly lower CCT measurements than those without. CCT is considered as a risk factor for the development of glaucomatous damage in OHT patients. (Eur J Ophthalmol 2006; 16: 667-73)*

KEY WORDS. *Central corneal thickness, Ocular hypertension, SWAP*

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INTRODUCTION

Ocular hypertension (OHT) is an elevated intraocular pressure (IOP) with no other signs of glaucomatous optic nerve damage and visual field defect (1). In Roscommon (2) and Blue Mountain Eye Surveys (3), the prevalence of OHT was reported as 3.6% and 3.7%, respectively, in subjects older than 49 years, which is considerably higher than the prevalence of glaucoma. The risk for developing glaucoma is higher in patients with OHT, when compared with the normal population (4, 5). In a multicenter study of Ocular Hypertension Treatment Study (OHTS) group (6), age, vertical and horizontal cup-disc (C/D) ratios, IOP, and central corneal thickness (CCT) were defined as risk fac-

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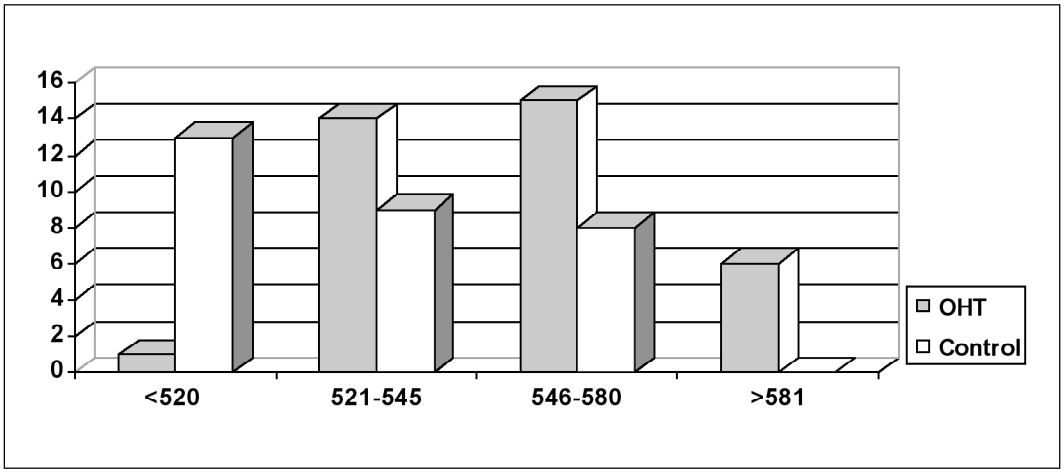

Fig. 1 - *Distribution of central corneal thickness (µm) among the ocular hypertension (OHT) and control groups.*

tors that predict the development of glaucoma in patients with OHT. Treatment can delay or prevent the development of glaucoma in nearly half of the patients with OHT (7). On the other hand, only a minority of patients with OHT eventually develop glaucomatous damage and delaying treatment avoids the cost and adverse effects of therapy (8, 9). Therefore, identification of patients with OHT carrying risk factors for glaucoma and earlier recognition of damage is important for initiation of the treatment at an early stage, which could conceivably improve the prognosis.

The diagnosis of OHT depends mainly on the clinical measurements of IOP. Goldmann and Schmidt (10) assumed CCT to be 500 µm and emphasized that variation in thickness could affect the measurements. Many studies had demonstrated a positive correlation between IOP and CCT (11-15). IOP may be overestimated in thick corneas and these patients currently classified as having OHT may be at much lower risk for glaucoma development.

It was recognized that up to 20–40% of retinal ganglion cells were damaged before the development of characteristic visual field defects in standard achromatic automated perimetry (16, 17). However, visual field tests specific to subgroups of ganglion cells could detect defects in the visual function at an earlier stage (18, 19). One of these tests is short wavelength perimetry (SWAP), which specifically shows the function of small bistratified ganglion cells. In some studies, it was demonstrated that SWAP could detect functional visual field losses 3 to 5 years earlier than standard perimetry methods (20, 21).

The purpose of our study was to evaluate the results of SWAP of patients with OHT and correlate these findings with CCT measurements.

METHODS

All patients were evaluated at the Hacettepe University Faculty of Medicine between May 2003 and April 2004. Thirty-seven OHT patients and 30 healthy subjects with normal achromatic visual field results who met the inclusion criteria described below were enrolled in this study. The study protocol was approved by the Ethics Committee for Human Research of Hacettepe University Faculty of Medicine and informed consent was obtained from all participants.

A questionnaire was applied to patients to evaluate the demographic and clinical risk factors that may predict glaucoma development. All subjects underwent a comprehensive ophthalmic examination including best-corrected visual acuity, slit-lamp biomicroscopy, Goldmann applanation tonometry, dilated funduscopic examination with a 90-diopter lens, and visual field analysis with standard achromatic perimetry and SWAP. OHT who met the following criteria were enrolled: IOP of 21 mmHg or greater on at least two occasions, best-corrected visual acuity of 20/20, optic nerve head C/D ratio of 0.6 or less and the difference between eyes less than 0.2, spherical refraction between ±5.0 diopters and cylinder correction between ±3.0 diopters, and at least two normal standard achromatic automated visual fields. The control group had the same criteria except that they had IOP measurements less than 21 mmHg on at least two occasions. The subjects were excluded if they had a history of previous intraocular surgery including cataract extraction, any ocular disease or trauma that may lead to secondary elevation of IOP, or systemic or neurologic diseases or drugs

that may affect visual field results. Eyes with narrow angles and pseudoexfoliation material were also excluded. All subjects had to have reliable standard achromatic perimetry and SWAP test results (fixation losses, false-positive and false-negative results of 25% or less). As media opacities (especially lens yellowing) affect SWAP test results, patients with visual acuity less than 20/20 were not included in the study.

As IOP shows diurnal variation (22), we took IOP measurements of all subjects at 9:00 am and 4:00 pm on the same day and repeated the measurements at least on two different days. For statistical analysis, we used mean IOP (mean of all measurements) and maximum IOP (maximum IOP measured) levels for each subject.

Standard achromatic automated perimetry was performed using the program 30-2 (Humphrey Instruments, San Leandro, CA, USA) full-threshold strategy, with a 31.5 apostilb background illumination and size III white target. SWAP was performed using a modified Humphrey visual field program with 30-2 full-threshold strategy, in which 440 nm size V blue stimulus is projected onto a 100/cd/mµ bright yellow background illumination. At least two consecutive abnormal results were required to define a test abnormal. Statpac-like Analysis for Glaucoma Evaluation (SAGE) criteria were used for evaluation of standard achromatic and blue on yellow (B-Y) perimetry test results (23). SAGE criteria for abnormal perimetry are pattern standard deviation worse than 1%, a glaucoma hemifield test result outside normal limits, one hemifield cluster (at least two abnormal adjacent points located horizontally or vertically) worse than 1%, two hemifield clusters worse than 5%. Peripheric points were not evaluated in the 30-2 test and all abnormalities were confirmed on a subsequent test.

Each patient's CCT was measured at least five times with an ultrasonic pachymeter (Quantel Medical, POCKET), 5 minutes after Goldmann applanation tonometry and the mean was used for the statistical analysis.

For comparison of categorical variables such as sex and demographic properties between the groups, chi-square test was used. Student's t-test was used to compare age, IOP, and CCT measurements between the groups. For variations with significant deviation from normality assumption, Mann-Whitney U test was used. Pearson or Spearman correlation tests were used to evaluate the relation of CCT with IOP and MD, PSD, and CPSD of SWAP. All statistical analyses were performed for right and left eyes separately. A p value less than 0.05 was considered statistically significant. All statistical analyses were performed using software SPSS for Windows version 11.5.

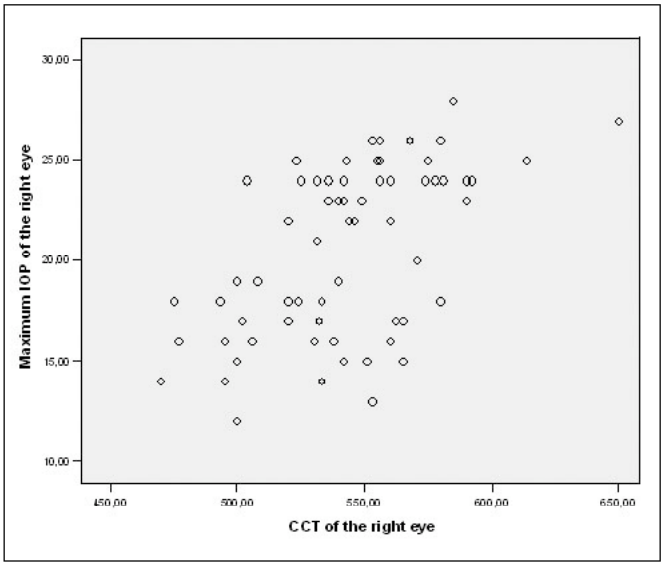

Fig. 2 - *Scatter graph showing the correlation of central corneal thickness (CCT) with the maximum intraocular pressure (IOP) of the right eyes.*

RESULTS

There were 14 men with a mean age of 50.92±6.91 years and 23 women with a mean age of 50±9.49 years within the OHT group. The control group included 14 men (mean age = 51.25±8.37 years) and 16 women (mean age = 49±8.33 years). The age and sex did not differ between the OHT and control group. There were no statistically significant differences according to systemic diseases, family history of glaucoma, and smoking years between the OHT and control group patients ($p>0.05$) (Tab. I).

Mean CCT was higher in the OHT group (right eye; 558.13±28.39 µm and left eye; 558.94±27.30 µm) when compared with the control subjects (524.66±30.53 µm and 525.86±30.46 µm, respectively) ($p<0.01$). The mean of CCT measurements, maximum and average IOP values of left and right eyes in OHT and control groups according to sex are given in detail in Table II. The distribution of CCT in the OHT and control groups are shown in Figure 1. CCT of the right and left eyes showed a positive correlation with maximum IOP ($r=0.557$, $r=0.513$, respectively) ($p<0.001$) (Fig. 2) and average IOP ($r=0.516$, $r=0.530$, respectively) ($p<0.001$).

SWAP MD, PSD, and CPSD values of OHT and control groups are shown in Table III. All patients had normal standard achromatic visual field results. Four right eyes (10.8%) and five left eyes (13.5%) of OHT patients had abnormalities in SWAP (Tab. IV). All subjects in the control group had normal SWAP. OHT patients with SWAP abnormalities had significantly lower CCT measurements in right eye (mean±SD; 527.25±17.34 µm) and in left eye (mean±SD; 528.80±13.60 µm) when compared with OHT patients with normal SWAP results (right eye 561.87±27.29 µm, left eye 563.65±25.92 µm) (p=0.019 and 0.006, respectively). The relationship between demographic and clinical risk factors and abnormal SWAP results are shown in Table V. Also, significant correlations were found between CCT and MD (right eyes r=0.454, p=0.005; left eyes r=0.476, p=0.003), PSD (right eyes r=–0.310, p=0.062; left eyes r=–0.474, p=0.003), and CPSD (left eyes; r=–0.401, p=0.031) of SWAP in the OHT group.

TABLE I - DEMOGRAPHIC PROPERTIES OF OCULAR HYPERTENSION (OHT) AND CONTROL SUBJECTS

	OHT (n=37)	Control (n=30)	p
Male	14 (37.83)	14 (46.66)	0.632
Age, yr	50.2±8.2	50.3±8.5	0.942
Hypertension	11 (29.72)	7 (23.33)	0.756
Diabetes	6 (16.21)	3 (10)	0.721
Coronary artery disease	3 (8.10)	0	0.247
Migraine	1 (2.70)	1 (3.33)	1
Hypotension	5 (13.51)	2 (6.66)	0.447
Thyroid disease	3 (8.10)	6 (20)	0.280
Family history	9 (24.32)	3 (10)	0.230
Smoking years	8.91±17.58	6.90±15.14	0.132

Values are n (%) or mean ± SD

TABLE II - MEAN ± SD CENTRAL CORNEAL THICKNESS (CCT) AND MAXIMUM AND AVERAGE INTRAOCULAR PRESSURE (IOP) VALUES OF LEFT AND RIGHT EYE IN OCULAR HYPERTENSIVE (OHT) GROUP AND CONTROL GROUP ACCORDING TO SEX

	OHT group			Control group		
	Female (n=23)	Male (n=14)	p	Female (n=16)	Male (n=14)	p
CCT right	559.74±30.12	555.50±26.17	0.666	525.87±32.15	523.28±29.7	0.821
CCT left	560.52±28.92	556.36±25.22	0.659	527.56±31.5	523.78±30.14	0.741
Maximum IOP right	24.04±1.63	24.14±1.29	0.848	16.31±1.66	16.57±2.24	0.720
Maximum IOP left	23.65±1.46	24.28±2.05	0.281	16.31±1.53	16.42±2.10	0.863
Average IOP right	23.13±1.17	23±1.42	0.764	15.75±1.94	15.85±2.2	0.888
Average IOP left	22.69±1.27	22.93±1.5	0.617	15.65±1.86	15.50±2.13	0.832

TABLE III - COMPARISON OF SWAP MAIN INDICES IN OCULAR HYPERTENSIVE (OHT) PATIENTS AND CONTROL GROUP

	OHT		Control		p
	Right	Left	Right	Left	Right/left
MD	–2.76±3.47	–2.60±3.56	–1.47±2.78	–1.74±2.92	0.102/0.289
PSD	3.35±1.14	3.33±0.90	3.21±0.64	3.08±0.61	0.860/0.412
CPSD	2.21±1.49	2.59±1.17	1.90±1.06	1.72±1.13	0.454/0.012

Values are mean ± SD

DISCUSSION

OHT patients have a greater risk for developing primary open angle glaucoma than the normal population, but only a small proportion of them develop glaucoma each year (0.5–4%/year) (8, 9). Early glaucomatous damage can be demonstrated with more sensitive methods such as SWAP and imaging technologies. In OHT subjects with risk factors or demonstrable early glaucomatous damage, treatment can be initiated earlier to prevent glaucomatous progression and to protect vision.

In the literature, there are conflicting reports about the relationship between systemic risk factors and glaucoma (24-28). In this study, we could not show any difference between the OHT group and the healthy subjects with regard to systemic diseases, family history of glaucoma, and smoking. Except CCT, there was no relationship between B-Y field defects and other demographic and clinical risk factors. However, the sample size in our study was too small to come to a solid conclusion.

In our study, 10.8% of the right eyes and 13.5% of the left eyes of OHT patients had SWAP abnormalities. In their prospective study, Johnson et al (20) reported that SWAP could detect glaucomatous visual field loss 3 to 5 years earlier than standard achromatic perimetry. Five of the nine eyes with SWAP defects at the beginning of the study developed achromatic field losses over 5 years, but none of the eyes with initially normal B-Y visual fields developed achromatic visual field deficits. In a large population of OHT patients, Demirel and Johnson (29) demonstrated that the prevalence of visual field defects was higher with B-Y perimetry, but the incidence of new deficits was similar with both B-Y and standard achromatic perimetries. They concluded that both tests showed the same disease process, but B-Y perimetry can detect the visual field loss at an earlier stage. Also in a recent study by Spry et al (30), SWAP was found to be among the best perimetric techniques for detection of early glaucomatous functional loss and provides good discrimination between normal subjects and glaucoma suspects.

The accurate measurement of IOP is a cornerstone of the diagnosis and management of glaucoma. It has been clearly shown that IOP measurements assessed by applanation tonometry may be overestimated or underestimated in thick or thin corneas, respectively (11-15). OHT patients tend to have higher CCT values compared to POAG and normal controls (13-15). In the OHTS group, a thin cornea was shown to be an important risk factor for the conversion from OHT to POAG (6). Recently, a corre-

TABLE IV - DISTRIBUTION SWAP DEFECTS IN THE OCULAR HYPERTENSIVE (OHT) GROUP ACCORDING TO SAGE CRITERIA

n=37	Right eye	Left eye
PSD <1%	—	—
Glaucoma hemifield test GHT outside normal limits	3	3
<%1 One hemifield cluster	1	2
<%5 Two hemifield clusters	3	5
Total	4	5

TABLE V - THE RELATION OF DEMOGRAPHIC AND CLINICAL RISK FACTORS AND SWAP DEFECTS IN THE OCULARH YPERTENSION GROUP

n=37	SWAP abnormality p (right/left)*	n=37	SWAP abnormality p (right/left)*
Gender	0.625/1	CCT	0.015/0.002
Age*	0.339/0.397 (t-test)	Refraction†	0.759/0.461
Hypertension*	1/0.623	IOP max†	0.189/0.033
Diabetes*	0.115/0.177	IOP mean†	0.038/0.041
CAD*	0.298/0.362		
		C/D vertical†	0.288/0.748
Migraine*	1/1		
Hypotension*	1/1		
		C/D horizontal†	0.199/0.680
Family history*	1/1		

CAD = Coronary artery disease; *Chi-square test; †Mann-Whitney U test

lation between thin CCT and severity of glaucoma has also been suggested (31, 32). In the study of Jonas et al (33) CCT was found to be significantly related with the presence of optic nerve damage, but the progression of glaucomatous damage was not related with CCT. Intervisit measurement variability of pachymetry may have important implications as part of the glaucoma management, since CCT values may fluctuate diurnally (34, 35) and in long-term period (36, 37). Therefore, it would be better to take a second CCT measurement in the follow-up examination at a similar daytime period.

In our study, OHT patients have thicker corneas than the healthy subjects. Interestingly, OHT patients with SWAP abnormalities had significantly lower CCT measurements (528.02 µm) than OHT patients without (562.76 µm), which is very similar to the measurements of the control group (525.26 µm). There were no differences in regard to mean IOP level between OHT patients with SWAP abnormalities (right and left eyes; 22±0.70 and 21.60±1.08 mmHg, respectively) and OHT subjects with normal SWAP (right and left eyes; 23.21±1.25 and 22.96±1.30 mmHg, respectively). These findings suggest that OHT patients with thinner CCT measurements presented more abnormal visual field results with SWAP and a higher risk for glaucoma development.

In conclusion, OHT patients with lower CCT measurements should be followed up closely for the development of glaucoma and in this aspect, SWAP may help clinicians detect the functional damage much earlier than traditional standard automated perimetry.

The study protocol was approved by the Ethics Committee for Human Research of Hacettepe University Faculty of Medicine (06.11.2003, LUT 03/31).

Proprietary interest: none.

Reprint requests to:
Murat T. Irkeç, MD
Department of Ophthalmology
Hacettepe Hastanesi Goz AD
Sihhiye 06100, Ankara, Turkey
mirkec@isnet.net.tr

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