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Evaluation of Contrast Sensitivity And Chromatic Vision In Patients With Primary Open Angle Glaucoma

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Abstract

Purpose: This study aimed to assess contrast sensitivity and acquired color vision deficiency in patients with primary open-angle glaucoma and to evaluate their correlations with visual field parameters.

Methods: The current study included 100 patients with primary open-angle glaucoma and 40 healthy control subjects. The 100 glaucoma patients were divided into 3 groups (mild, moderate and sever). Ophthalmic examination included best corrected visual acuity (BCVA), gonioscopy, slit lamp biomicroscopy, visual field assessment by perimetry and intraocular pressure was measured using Goldmann applanation tonometry. Contrast Sensitivity evaluated by the Pelli-Robson chart and the Mesotest II b. Color vision was evaluated by the Farnsworth- panel D15.

Results: The mean age of the studied cases was 52.61±14.86 years with male to female ratio 50.2/49.8. Cup-To-Disc (C/D) ratio was statistically significant increase in severe cases followed by moderate and lastly mild glaucoma subgroups. There was highly statistically significant increase in the mean C/D ratio among cases with glaucomatous eyes compared to normal .There was a significant correlation between worsening visual field indeces and decreased contrast sensitivity. Color vision was demonstrated to be significantly correlated according to severity, duration of affection, age and uncontrolled IOP.

Conclusion: Mesotest II b is a better alternative to conventional reliable and reproducible Pelli Robson chart test for assessment of contrast sensitivity in patients with glaucoma.

Keywords: Primary Open-Angle Glaucoma, Contrast Sensitivity , Color Vision, IOP, Visual Field.

Abbreviations:
POAG: primary open angle glaucoma
IOP: intraocular pressure
CS: contrast sensitivity
MD: mean deviation
C/D : cup/disc

Introduction

Open-angle glaucoma (OAG) is a chronic, progressive, and irreversible multifactorial optic neuropathy that is characterized by open angle of the anterior chamber, typical optic nerve head changes, progressive loss of peripheral vision for which intraocular pressure (IOP) is an important risk factor. The disease is usually bilateral, but asymmetry is often seen depending on the etiology [1,2].

Patients with early glaucoma often complain of more severely compromised visual quality than would be expected despite their good documented visual acuity. This discrepancy is most likely due to glaucomatous damage causing a decrease in the ability to perceive contrasting boundaries, which we will call contrast sensitivity function (CSF) [3].

Contrast sensitivity (CS) is an important aspect of visual function. Contrast sensitivity plays a role in many aspects of vision, specifically motion detection, visual field, pattern recognition, dark adaptation, and visual acuity. It affects what patients can do in their daily life. Contrast sensitivity is the ability to detect subtle differences in shading and patterns [4,5].

Color vision is the ability to discriminate a light stimulus as a function of its wavelength. The sense of color is the end result of the absorption of several light stimuli from the three different types of cones and the following process and transmission of the sensory signal to the occipital cortex via the optic tract [6].

A lot of authors suggested that the biggest defects in patients suffering from advanced glaucoma or ocular hypertension occur in the blue–yellow spectrum rather than the red–green spectrum [7, 8]. Also, the defects in color vision among patients complaining of chronic simple glaucoma, especially a long the blue-yellow axis, were also reported [9].

The aim of this study was to correlate contrast sensitivity and color vision with the severity of glaucoma according to visual field parameters in patients with primary open-angle glaucoma.

Patients and Methods

Study Population

This was a prospective observational cross-sectional and analytical study. This study included 100 patients with primary open-angle glaucoma and 20 healthy control subjects attended to glaucoma clinic of Mansoura ophthalmic center in the period from January 2019 till January 2021.

Ethics And Consent

This study was approved by Mansoura medical research ethics committee, faculty of medicine, Mansoura university (Code number: MS/19.02.511) and informed consent was obtained from participant in the study after assuring confidentiality.

Inclusion criteria included for control eyes; no history or evidence of ocular disease, surgery or laser. No family history of glaucoma, intraocular pressure (IOP) of 21 mmHg or less by Goldmann applanation tonometry, normal optic nerve head appearance based on clinical stereoscopic examination. Criteria of POAG eyes including an age above 40 years, best corrected visual acuity ≥ 6/60, refractive error within ± 6.0 diopters equivalent sphere and within ± 3.0 diopters astigmatism, or less than 2.0 diopter anisometropia, open anterior chamber angle , glaucomatous changes on Humphrey 24-2 visual field test, and evidence of glaucomatous optic nerve head damage

Exclusion criteria included an angle closure glaucoma and secondary glaucoma, and previous intraocular surgery or laser therapy. Patient conditions that may lead to reduction of contrast sensitivity such as cataract and hazy media with subsequently reduction in mean deviation. Also, unreliable visual field tests (fixation loss rate more 20% or false-negative or false positive error rates more 25 %).Previous ocular infection, inflammation or trauma and evidence of vitreoretinal disease or diabetic retinopathy were excluded.

Ocular Examination

Ophthalmic examination included Best corrected visual acuity (BCVA) that measured by landolt's broken ring chart then converted to logMAR, Gonioscopy, slit lamp biomicroscopy (Haag Streit BP 900) (Haag-Streit, Koeniz, Switzerland) was used to assess corneal clarity, depth of the anterior chamber, pupillary reaction, shape, regularity and lens morphology, slit lamp biomicroscopy using 90D lens to assess the retina and optic nerve head, intraocular pressure was measured using Goldmann applanation tonometry. Contrast Sensitivity evaluated by the Pelli-Robson chart (distributed by HS -Clement clarke) and the Mesotest II b (Oculus, Germany). Color vision was evaluated by the Farnsworth- panel D15 (F-D15) THE Farnsworth-panel D15 (F-D15) test.

Visual Field Testing

The patients underwent central 24-2 full threshold automated perimetry by Humphrey (2003 Carl Zeiss Meditec, Germany). Minimum criteria for diagnosing acquired glaucomatous damage included a Glaucoma Hemifield Test outside normal limits on at least two consecutive visual fields; or a cluster of three or more non-edge points in a location typical for glaucoma, all of which are depressed on the pattern deviation plot at a $p < 5\%$ level and one of which is depressed at a $p < 1\%$ level on two consecutive fields; or a corrected pattern standard deviation that occurs in less than 5% of normal fields on two consecutive fields [10].

Statistical Analysis And Data Interpretation

Data were fed to the computer and analyzed using IBM SPSS Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0.(Armonk, NY: IBM Corp). Qualitative data were described using number and percent. Quantitative data were described using mean, standard deviation for parametric data after testing normality using Kolmogrov-Smirnov test. The two groups were compared with Student'test for parametric data and Mann Whitney test for non-parametric data. Pearson (parametric) and Spearman (non-parametric) correlations were used to correlate continuous data. Significance of the obtained results was judged at the (0.05) level.

Results

Total of 181 eyes of 100 of primary open-angle glaucoma patients were classified according to disease severity into 3 sub-groups; 93 eyes mild group, 54 eyes moderate group and 34 eyes severe group .

The mean age of the patients with POAG was 52.61±14.86 years; 112 eyes (50.2%) were male and 111 eyes (49.8%) were female. The mean C/D ratio was 0.619±0.163. The mean visual function tests were 2.01±1.2, 2.09±1.21, 1.78±1.1, 1.13±0.68, 1.67±0.97, 1.42±0.94, 0.969±0.897, 0.693±0.80 for Occulus 1:23, Occulus 1:5, Occulus 1:2.7, Occulus 1:2, Occulus 1:23, Occulus 1:5, Occulus 1:2.7, Occulus 1:2, Respectively. While contrast sensitivity and Pelli-Robson, visual field mean deviation(MD), BCVA, and IOP were 2.15±1.34, -4.49±4.46, 1.49±0.25 and 21.14±2.53 respectively as shown in (Table 1).

	N=223	
Age/years mean±SD	52.61±14.86	
Gender N. (%)		
Male	112	50.2
Female	111	49.8
C/D	0.619±0.163	
Occulus 1:23	2.01±1.2	
Occulus 1:5	2.09±1.21	
Occulus 1:2.7	1.78±1.1	
Occulus 1:2	1.13±0.68	
Mesoboic		
Occulus 1:23	1.67±0.97	
Occulus 1:5	1.42±0.94	
Occulus 1:2.7	0.969±0.897	
Occulus 1:2	0.693±0.80	
Pelli-Robson mean±SD	2.15±1.34	
MD (db) mean±SD	-4.49±4.46	
IOP (mmHg) mean±SD	21.14±2.53	
BCVA mean±SD	1.49±0.25	

Table 1: Descriptive statistics of the all studied cases

Regarding the demographic characteristics of the all studied groups, both groups demonstrated insignificant differences as regards age and gender (P>0.05). There was statistically significant increase in the mean C/D ratio among cases with glaucomatous eyes compared to normal ones (0.673±0.124 versus 0.391±0.105) (P<0.001). Regarding the visual function tests according to degree of glaucoma severity in the sub groups, glaucomatous eyes were associated with a highly significant increase in Occulus 1:23 (F), Occulus 1:5 (F), Occulus 1:2.7(F), Occulus 1:2(F), Occulus 1:23 (M), Occulus 1:2.7(M), Occulus 1:5 (M), Occulus 1:2(M), Pelli-Robson and MD compared to normal ones (P<0.001).

However, there was highly statically significant increase in IOP among cases with glaucomatous eyes compared to normal ones (P<0.001). Also, was a statistically significant increase in BCVA among glaucomatous eyes compared to normal ones (P<0.05). There were significant negative correlations among all occlusal scores and Pelli-Robson score, IOP, C/D ratio and BCVA (P<0.05) (Table 2). However, there were statistically significant positive correlations among all occlusal scores and mean deviation in all studied groups (P<0.05) (Table 3).

	Normal	Glaucomatous eyes	test of significance
	n=42	n=181	
Age/years mean±SD	48.59±18.36	53.54±13.81	t=1.97 p=0.052
Gender N(%) Male Female	20(47.6) 22(52.4)	92(50.8) 89(49.2)	χ^2=0.140 p=0.708
Funduscopy mean±SD	0.391±0.105	0.673±0.124	t=13.67 p<0.001*
Occulus 1:23 (F)	4.23±0.02	1.49±0.62	t=28.58 p<0.001*
Occulus 1:5 (F)	4.34±0.03	1.58±0.61	t=29.32 p<0.001*
Occulus 1:2.7(F)	3.69±0.57	1.34±0.71	t=20.11 p<0.001*
Occulus 1:2(F)	1.43±0.67	1.06±0.67	t=3.29 p=0.001*
Occulus 1:23 (M)	3.09±0.64	1.34±0.71	t=14.73 p<0.001*
Occulus 1:5 (M)	2.76±0.63	1.11±0.70	t=13.95 p<0.001*
Occulus 1:2.7(M)	2.26±0.63	0.669±0.65	t=14.33 p<0.001*
Occulus 1:2(M)	1.95±0.62	0.496±0.57	t=14.68 p<0.001*
Pelli-Robson	4.63±0.02	1.58±0.66	t=29.86 p<0.001*
MD (db)	-1.46±1.18	-5.19±4.65	t=5.16 p<0.001*
IOP (mmHg)	16.79±1.61	22.15±1.37	t=22.08 p<0.001*
BCVA	1.39±0.11	1.52±0.28	t=2.90 p=0.004*

t: Student t test, χ2=Chi-Square test

Table 2: Demographic characteristics, C/D ratio distribution, visual function tests, and mean best corrected visual acuity distribution according to degree of severity of the all studied groups

		Occlusal score 1F	Occlusal score 2F	Occlusal score 3F	Occlusal score 4F	Occlusal score 1 Mesopic	Occlusal score 2 Mesopic	Occlusal score 3 Mesopic	Occlusal score 4 Mesopic
Pelli-Robson score	r	.919**	.883**	.769**	.584**	.749**	.744**	.727**	.638**
	p	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
IOP	r	-.538**	-.543**	-.519**	-.308**	-.503**	-.491**	-.493**	-.443**
	p	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Funduscopy	r	-.580**	-.623**	-.565**	-.340**	-.543**	-.534**	-.517**	-.427**
	p	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Mean deviation	r	.398**	.468**	.362**	.243**	.342**	.335**	.309**	.224**
	p	<.001	<.001	<.001	<.001	<.001	<.001	<.001	.001
BCVA	r	-.130	-.076	-.241**	-.080	-.221**	-.214**	-.296**	-.196**
	p	.054	.262	.001	.234	.001	.001	.001	.003

r: Spearman correlation coefficient **statistically significant if p≤0.01

Table 3: Correlation between occlusal score and visual information among all studied cases

The three studied subgroups demonstrated insignificant differences as regards age and gender . Regarding C/D ratio according to degree of severity the sub-groups, there were highly statistically significant differences among the three studied groups as well as among each other's as regards C/D being significantly increased in severe followed by moderate and lastly mild (P<0.001).

There were highly statistically significant differences among the three studied groups as regards Occulus 1:23, Occulus 1:5, Occulus 1:2.7, Occulus 1:2, Occulus 1:23, Occulus 1:5, Occulus 1:2.7, MD and Pelli-Robson (P<0.001). However, there were no statistically significant differences among the three studied groups as regards both Occulus 1:2 and IOP being non-significant (P>0.05). There were highly statistically significant differences as regards BCVA among the three studied groups as well as within groups (P<0.001).

Regarding the relation between color vision affection and degree of severity, there were highly statistically significant differences among the three studied groups (P<0.001), also highly statistically significant differences were reported within groups (P<0.001) except for comparison between mild & moderate being non-significant (P=1) (Table 4).

	Mild	Moderate	Severe	test of significance	within group significance
	N=93	N=54	N=34		
Age/years mean±SD	53.22±11.91	51.59±17.34	57.53±11.86	F=2.0 P=0.138	P1=0.491 P2=0.119 P3=0.05
Gender N(%) Male Female	50(53.8) 43(46.2)	22(40.7) 32(59.3)	20(58.8) 14(41.2)	χ^2=3.39 P=0.184	P1=0.128 P2=0.61 P3=0.098
Fundoscopy mean±SD	0.611±0.10	0.695±0.102	0.804±0.093	F=48.51 P<0.001*	P1<0.001* P2<0.001* P3<0.001*
Photoboic					
Occulus 1:23	1.64±0.60	1.49±0.57	1.09±0.57	F=10.62 P<0.001*	P1=0.169 P2<0.001* P3=0.002*
Occulus 1:5	1.75±0.60	1.56±0.53	1.15±0.54	F=13.78 P<0.001*	P1=0.05* P2<0.001* P3=0.001*

Occulus 1:2.7	1.56±0.77	1.17±0.58	1.02±0.48	F=10.79 P<0.001*	P1=.001* P2<0.001* P3=0.333
Occulus 1:2	1.24±0.72	0.916±0.57	0.774±0.485	F=8.38 P<0.001*	P1=0.004* P2<0.001* P3=0.314
Mesoboic					
Occulus 1:23	1.56±0.77	1.17±0.58	1.024±0.48	F=10.79 P<0.001*	P1=0.001* P2<0.001* P3=0.333
Occulus 1:5	1.33±0.77	0.936±0.57	0.794±0.48	F=10.59 P<0.001*	P1=0.001* P2<0.001* P3=0.333
Occulus 1:2.7	0.856±0.73	0.485±0.55	0.454±0.33	F=8.49 P<0.001*	P1=0.001* P2=0.002* P3=0.820
Occulus 1:2	0.459±0.059	0.406±0.47	0.239±0.26	F=2.30 P=0.103	P1=0.542 P2=0.03* P3=0.139
Pelli-Robson	1.64±0.599	1.77±0.68	1.10±0.56	F=13.03 P<0.001*	P1=0.208 P2<0.001* P3<0.001*
MD (db)	-1.63±0.91	-7.04±1.85	-12.03±4.52	F=282.06 P<0.001*	P1<0.001* P2<0.001* P3<0.001*
IOP (mmHg)	22.05±1.43	22.16±1.48	22.39±0.92	F=0.774 P=0.463	P1=0.656 P2=0.216 P3=0.431
BCVA mean±SD	1.61±0.10	1.68±0.12	**0.995±0.14**	F=45.51 P<0.001*	P1<0.001* P2<0.001* P3<0.001*
Color vision Tritan Total loss	93(100) 0	54(100) 0	4(11.8) 30(88.2)	MC P<0.001*	P1=1.0 P2<0.001* P3<0.001*

F: One Way ANOVA test, P: overall significance *statistically significant if p≤0.05. P1: difference between mild & moderate, P2: difference between mild & severe, P3: difference between moderate & severe

Table 4: Demographic characteristics, C/D ratio distribution, visual function tests, and mean best corrected visual acuity distribution according to degree of severity of the studied sub groups

Discussion

Glaucoma is a leading cause of irreversible blindness. It is an insidious disease that damages retinal ganglion cells, which results in characteristic optic nerve and visual field changes. It is estimated that˛80 million individuals will be affected by glaucoma by 2020. Of those,˛11 million are expected to be bilaterally blind from glaucoma by 2020. Given the significant limitations that advanced disease places on individuals and their quality of life, early detection of glaucoma is critical so that timely interventions can be made [11, 12].

Regarding the demographic characteristics of the studied cases, the current study showed that the three studied groups (Mild Moderate and sever) demonstrated insignificant differences as regards age and gender. In agreement to the present study results, evaluated one hundred and twenty-one eyes of 121 glaucoma patients were examined (94 eyes with early defects and 27 with moderate defects). Sixty-four patients were females (52.9%) and 57 were males (47.1%). The two groups did not differ with respect to age or sex. Pupil size did not differ between the groups [13].

Interestingly, the current study demonstrated cup/disc ratio distribution according to the degree of severity of POAG. There were highly statistically significant differences among the three studied groups as well as among each other's as regards cup/disc ratio being significantly increased in severe followed by moderate and lastly mild (P<0.001).

The current study evaluated the visual function tests according to degree of glaucoma severity. There were highly statistically significant differences among the three studied groups as regards Occulus 1:23, Occulus 1:5, Occulus 1:2.7, Occulus 1:2, Occulus 1:23, Occulus 1:5, Occulus 1:2.7, MD and Pelli-Robson **(P<0.001).** However, there were no statistically significant differences among the three studied groups as regards both Occulus 1:2 and IOP being non-significant (P>0.05).

Bambo et al. performed contrast sensitivity evaluation indicating statistical differences of the Pelli-Robson and CSV1000E parameters (photopic luminance; all frequencies) between patients with early and moderate POAG (P < 0.05). The CSV1000E test performed with mesopic luminance and glare conditions also revealed statistically significant differences in all frequencies, except 12 cpd between patients with early and moderate defects (P < 0.05) [13].

The current study revealed that there were highly statistically significant differences as regards mean best corrected visual acuity distribution (BCVA) among the three studied groups as well as within groups (P<0.001). Similarly, Bambo et al. found that the BCVA (decimal notation), among mild and moderate POAG patients, was (1.07 ± 0.23) and (0.94 ± 0.20) respectively with statistically significant difference (P=0.016) [13].

The present study evaluated the relation between color vision affection and degree of severity. There were highly statistically significant differences between the three studied groups (P<0.001), also highly statistically significant differences were reported within groups (P2 and P3<0.001) except for comparison between mild & moderate being non-significant (P1=1). Another study by Francois and Verriest, in patients with primary open angle glaucoma reported a prevalence of 60% for blue-yellow defects in contrast to only 3% for red-green defects [14].

In disagreement to our results, Bambo et al. suggested that patients with glaucoma manifest signs of deteriorating color discrimination ability (CCI > 1 in both groups), but they did not detect differences in color discrimination according to disease severity or a significant correlation between the results of color perception testing and visual field indexes [13]. Moreover, age could have a potentially strong effect on the deterioration of CCI, as suggested in [15].

Several theories have been introduced to explain tritan-like defects in glaucoma, such as a greater susceptibility of blue-yellow sensitive ganglion cells to IOP-related damage due to their morphology and connectivity to second-order neurons [16].

Regarding the C/D ratio distribution among studied groups, there was highly statistically significant increase in the mean cup/disc among cases with glaucomatous eyes compared to normal ones (0.673±0.124 versus 0.391±0.105) (P<0.001).

As regard the visual information distribution among studied groups, glaucomatous eyes were associated with a highly significant increase in Occulus 1:23 (F), Occulus 1:5 (F), Occulus 1:2.7(F), Occulus 1:2(F), Occulus 1:23 (M), Occulus 1:2.7(M), Occulus 1:5 (M), Occulus 1:2(M), Pelli-Robson and MD compared to normal ones (P<0.001). However, there was highly statistically significant increase in IOP among cases with glaucomatous eyes compared to normal ones (P<0.001).

Weinreb et al. reported that increased IOP is not a diagnostic requirement of glaucoma, although IOP is a risk factor for the development and progression of glaucoma [17].

As regard the mean best corrected visual acuity distribution among studied groups. There was a statistically significant increase in BCVA among glaucomatous eyes compared to normal ones (P<0.05).

As regard the correlation between occlusal score and visual information among studied cases. There were significant negative correlations among all occlusal scores and Pelli-Robson score, IOP, Funduscopy and BCVA (P<0.05). However, there were significant positive correlations among all occlusal scores and mean deviation (P<0.05).

The present results were consistent with other findings, such as those by Hawkins et al. and Wilensky et al. who reported a significant correlation between the mean deviation as measured with the Humphrey perimeter and the Pelli-Robson contrast sensitivity scores [18,19].

Conclusion

Mesotest II b is a better alternative to conventional reliable and reproducible Pelli Robson chart test for assessment of contrast sensitivity in patients with glaucoma. There was a moderate correlation between worsening visual field indeces and decreased contrast sensitivity. Color vision was demonstrated to be significantly correlated according to the severity, duration of affection, age and uncontrolled IOP.

Declarations

Conflict of Interest

All authors have no conflicts of interest that are directly relevant to the content of this review.

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Reviewer Disclosures

No relevant financial or other relationships to disclose.

Declaration of Interest

No financial affiliations or financial involvement with any organization or entity with a financial competing with the subject matter or materials discussed in the review.

Consent for publication

Not applicable

Availability of Data

All data generated during this review are included in this study

Standards of Reporting

CONSORT guidelines were followed

Authors contributions

Authors interpreted and discussed the data, and wrote the first version of the manuscript. All authors read and approved the final manuscript.

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