Original Article

Comparing retinal sensitivities on blue-on-yellow and green-on-yellow perimetry in glaucoma suspects

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Purpose: To compare the retinal sensitivities between the blue-on-yellow perimetry (BYP)/short-wavelength automated perimetry (SWAP) and green-on-yellow perimetry (GYP) among patients with and without nuclear sclerosis among glaucoma suspects. **Methods:** After ophthalmic examination, patients were subjected to two perimetric tests: BYP and GYP. The visual field (VF) parameters were compared between the two perimeters ($p < 0.05$ was considered significant). **Results:** Fifty-five eyes of 39 patients with a mean age of 60.53 ± 9.70 years were included in the study. Twenty-one eyes had clear lens or pseudophakia. Twenty-six eyes had lower grades of nuclear sclerosis (NO2NC2, NO3NC3) and eight eyes had higher grades of cataract (NO4NC4, NO5NC5). The mean retinal sensitivity (RS) in BYP was 22.08 ± 5.02 (dB) and in GYP was 23.84 ± 5.50 (dB) ($p = 0.08$). The mean defect in BYP was -2.56 ± 4.40 (dB) and in GYP was -3.24 ± 5.05 (dB), pattern standard deviation (PSD) in BYP was 3.65 ± 1.91 (dB) and in GYP was 3.83 ± 1.99 (dB), and foveal threshold (FT) was 24.20 ± 4.32 (dB) in BYP and 28.10 ± 4.50 (dB) in GYP. The two perimeters showed good agreement by the Bland–Altman plot for all parameters. Fourteen eyes showed perimetric changes suggestive of glaucoma by BYP. In these, GYP had a sensitivity of 92.86% (95% CI of 66.13% to 99.82%) and specificity of 95.12% (95% CI of 83.47% to 99.40%). **Conclusion:** BYP and GYP show good agreement. They are comparable in clear media as well as in different grades of nuclear sclerosis. GYP showed good sensitivity and specificity compared to BYP.

Key words: Blue-on-yellow perimetry, glaucoma, green-on-yellow perimetry, nuclear sclerosis, short wavelength automated perimetry

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Primary open-angle glaucoma (POAG) is considered "a chronic, progressive, optic neuropathy that is accompanied by characteristic cupping and atrophy of the optic disc, visual field (VF) loss, open angles, and no obvious causative ocular or systemic conditions. In a majority of cases, the intraocular pressure (IOP) may be elevated above the statistically "normal" range, reflecting a reduced aqueous humor outflow facility."[1] Often, the patient is asymptomatic in the early stages and so assessment of optic nerve head morphology and the pattern of VF loss are the widely accepted means of detection of POAG.[2] These are also used for follow-up of disease progression.

The presently accepted mode to map the pattern of VF loss is automated static perimetry. The most popular of static perimetries is the standard automated perimetry (SAP) wherein a white stimulus of varying intensities is projected onto a white background of 31.5 apostilb.[3] SAP with its statistical analysis of the results is also considered sensitive enough to determine disease progression. However, it has been observed that at least 40% of nerve fiber layer (NFL) loss has occurred before VF changes are clinically appreciable on SAP.[4,5]

Blue signals, detected by the short-wavelength cones in the retina and processed by the blue-yellow bistratified ganglion cells project their axons to the interlaminar koniocellular layers of the lateral geniculate nucleus.[6,7] These K (konio-) ganglion cells represent a small proportion of the total ganglion cells (~20%) and the loss of even a few of these cells would interfere with the total function.[6,8] This has been investigated with BYP (blue-on-yellow perimetry)/SWAP (short wavelength automated perimetry).[9] The general pattern is that BYP defects, although similar in location and shape, appear earlier and are larger than SAP defects.[10-13]

POAG is common above the age of 40 years when the lens is also likely to exhibit nuclear sclerotic changes.[14] Blue light being shorter in wavelength is absorbed by a nuclear sclerotic lens.[15] BYP is therefore difficult to administer to patients or suspects of POAG who also have nuclear sclerosis.[16] The green light of a longer wavelength than blue is less likely to be absorbed by a nuclear sclerotic lens. There is adequate literature available on BYP and SAP while there is a paucity of literature on green-on-yellow perimetry (GYP).[17]

This study aims to compare the retinal sensitivities (RS) as determined by BYP and GYP in glaucoma suspects and also to

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determine if the retinal sensitivity is influenced by the presence of nuclear sclerosis.

Methods

This study was carried out among patients who had optic nerve head changes or VF changes attributable to glaucoma or high IOP on more than two consecutive recordings (glaucoma suspects) in the outpatients' ophthalmology department of a tertiary health eye care hospital. This study adhered to the tenets of the Declaration of Helsinki (IHEC: MGMCRI/Res/01/2019/77/IHEC/008). Patients with poor best corrected visual acuity that precludes record of reliable VFs and those with diseases of the retina and optic nerve which can affect retinal sensitivity like age-related macular degeneration, diabetic retinopathy, pathological myopia, were excluded.

Based on the prevalence rate of glaucoma from a previous study which was 3.51%, the sample size was calculated as 52 eyes.[18] After informed consent, detailed history including past history of trauma, comorbidities, systemic mediation use, or therapy for any eye conditions taken was noted. The ophthalmologic examination included a record of visual acuity by Snellen's chart and refraction by autorefractometer, IOP measurement (non-contact tonometer), examination by slit lamp biomicroscopy including classification of cataract if present by LOCS III[19] and posterior segment by +90 D lens.

All patients were given a trial of perimetry, and they were made aware of what is expected of them. The test was performed in an undilated state with the best refractive correction on APPA AUTOPERIMETER (20,SBI Officers' colony, First Street, Arumbakkam, Chennai (Madras) - 600 106, Tamil Nadu, INDIA) (AP901 CTS GLAUFIELD$_{LITE}$ SWAP). BYP or GYP was randomly administered first based on computer-generated random numbers. Depending on patient convenience, the other test was administered either on the same day after an interval of 30 min or on the next visit which was made within a week.

Results were charted on a Microsoft Excel sheet and statistically analyzed using MS excel/SPSS software {version 16.56 (21121100)}. Visual acuity that was measured by Snellen's chart was converted to logMAR values for statistical analysis. The Bland–Altman plots were used to determine the agreement between the two perimeters. A *P* value of < 0.05 was considered statistically significant.

Results

Ninety-four eyes of 51 patients were initially enrolled for the study. Of these, 39 eyes were excluded due to unreliable VFs despite repeating perimetry twice. Fifty-five eyes of 39 patients were finally included for analysis. With 28 males and 11 females, the mean age of the group was 60.53 ± 9.70 years (50.83–70.23 years).

The mean uncorrected visual acuity on logMAR was 0.55 ± 0.36 (0.19-0.91; Snellen's acuity of 20/32 to 20/160) and that of best corrected visual acuity was 0.32 ± 0.30 (0.02-0.62; Snellen's acuity of 20/20 to 20/80). The mean IOP was 17.00 ± 3.77 mm Hg (13.23-20.77 mm Hg). All the patients had a cup disc ratio of 0.5:1 and higher on fundus examination.

Of the 55 eyes analyzed, 16 had clear lenses (29%), 5 were pseudo phakic (9%), and the remaining had lenticular opacities. Based on Lens Opacities Classification System III (LOCS III) grading, the distribution of lenticular opacities was 10 with N02NC2 (18.1%), 16 with N03NC3 (29%), 7 with N04NC4 (12.7%), and 1 with NO5NC5 (1.8%).

On analysis of data obtained from BYP, the mean of retinal sensitivities (RS) was 22.08 ± 5.02 dB (17.06-27.10 dB), of mean defect (MD) was -2.56 ± 4.40 dB (-6.69 to1.84 dB), of pattern standard deviation (PSD) was 3.65 ± 1.92 dB (1.73-5.57 dB), and of foveal threshold (FT) was 24.20 ± 4.32 dB (19.88-28.52 dB).

In GYP, the mean RS was 23.84 ± 5.50 dB (18.34-29.34 dB), of MD was -3.24 ± 5.06 dB (-8.3 to -3.02 dB), of PSD was 3.84 ± 2.0 dB (1.84-5.84 dB), and of FT was 28.10 ± 4.51 dB (23.59-32.61 dB).

The mean RS, MD, and PSD values were comparable in BYP and GYP. The FT showed higher sensitivity in GYP compared to BYP ($p < 0.001$) [Table 1].

Among patients with clear ocular media (clear lens, pseudophakia), while MD (-0.36 ± 2.16 dB on BYP and -0.61 ± 2.21 dB on GYP) and PSD (2.77 ± 1.35 dB in BYP and 2.82 ± 1.63 dB in GYP) in GYP were comparable to BYP ($p = 0.71$, $P = 0.91$, respectively), the FT (26.07 ± 2.74 dB on BYP and 29.74 ± 2.34 on GYP, $P = 0.001$) and mean RS (24.93 ± 2.66 dB on BYP and 26.96 ± 2.84 dB on GYP, $P = 0.02$) were higher in GYP than BYP. Among patients with early nuclear sclerosis (NO2NC2, NO3NC3), FT (23.76 ± 4.31 dB on BYP and 27.77 ± 4.84 dB on GYP, $P = 0.003$) showed significantly greater sensitivity in GYP compared to BYP while the values of RS (20.9 ± 5.39 dB on BYP and 22.35 ± 5.93 dB on GYP, $P = 0.36$), MD (-3.45 ± 4.95 dB on BYP and -4.56 ± 5.71 dB on GYP, $P = 0.45$), and PSD (4.09 ± 2.02 dB on BYP and 4.47 ± 1.84 dB on GYP, $P = 0.47$) were comparable.

In the presence of denser cataracts (NO4NC4, NO5NC5), however GYP and BYP were comparable on all parameters of RS (18.45 ± 5.08 dB on BYP and 20.46 ± 5.77 dB on GYP, $P = 0.47$), MD (-5.41 ± 4.68 dB on BYP and -5.85 ± 5.61 dB on GYP, $P = 0.86$), PSD (4.52 ± 2.15 dB on BYP and 4.4 ± 2.46 dB on GYP, $P = 0.91$), and FT (20.74 ± 5.56 dB on BYP and 24.83 ± 6.04 dB on GYP, $P = 0.18$).

With increasing grades of nuclear sclerosis, both RS and FT were observed to gradually reduce [Fig. 1a and b]. The quantum of difference in the MD values of GYP and BYP was maximum in lower grade cataracts (NO2NC2, NO3NC3) compared to clear media and higher grade cataracts (NO4NC4, NO5NC5, P4) [Fig. 2a]. The PSD graph mirrored that observed with the MD graph. With increasing density of cataracts, the quantum of difference in PSD between BYP and GYP gradually increased up to nuclear sclerosis of grade NO3NC3 and reduced for higher densities of cataracts. However, the difference in PSD values obtained by GYP and BYP was not statistically significant [Fig. 2b]. The Bland–Altman plot also showed good agreement between GYP and BYP in the MS, FT, MD, and PSD [Fig. 3a-d].

Of the 55 eyes studied, 14 eyes showed field defects suggestive of glaucoma by BYP. With BYP considered as the gold standard, GYP had a sensitivity of 92.86% (95% CI of 66.13%-99.82%) and specificity of 95.12% (95% CI of 83.47%-99.40%). GYP had a high positive predictive value of 86.67% and a negative predictive value of 97.5%. The accuracy was 94.55%. Two by two table comparing BYP and GYP for the

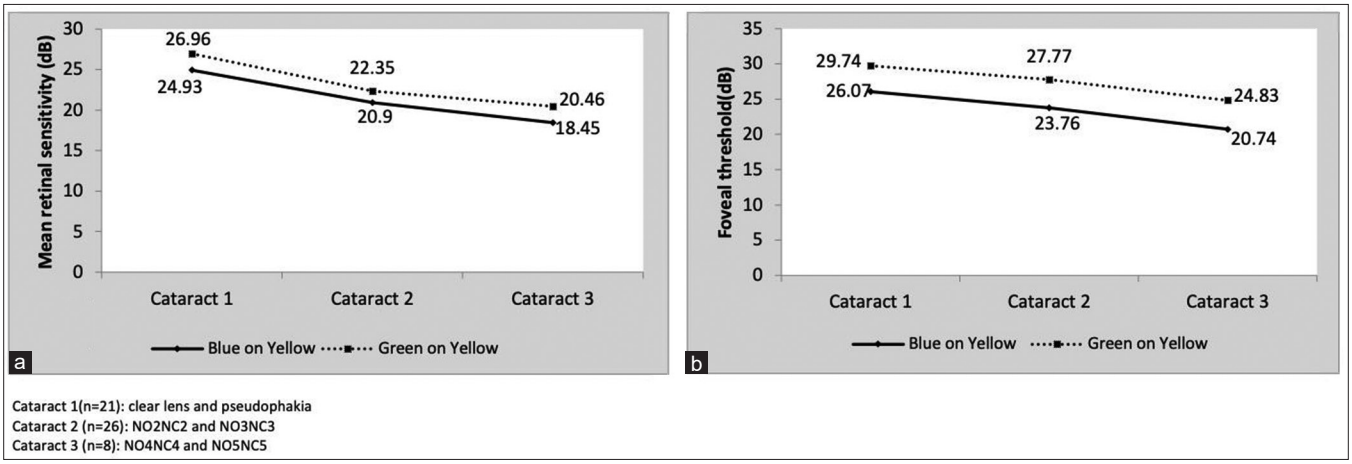

Figure 1: Comparison of mean retinal sensitivity (a) and foveal threshold (b) between BYP and GYP

Table 1: Comparison of perimetric indices of BYP and GYP

INDICES	Blue-on-Yellow perimetry		Green-on-Yellow perimetry		Mean Difference	Independent *t*-test	*P*
	Mean	Standard Deviation	Mean	Standard Deviation			
Mean retinal sensitivity (dB)	22.08	5.02	23.83	5.49	1.75±1.00	1.74	0.08
Mean defect (dB)	-2.56	4.40	-3.24	5.05	0.68±0.90	0.76	0.44
Pattern standard deviation (dB)	3.65	1.91	3.83	1.99	0.62±0.18	0.49	0.62
Foveal threshold (dB)	24.20	4.31	28.10	4.50	3.89±0.84	4.62	0.001

presence of VF defect is given in Table 2. It was further observed that the depth and extent of the defect were similar in the two perimeters compared.

Discussion

This study showed a good agreement between BYP and GYP and this agreement extended over clear media as well as different grades of nuclear sclerosis.

Mean RS, mean deviation, PSD, and FT are global indices that represent mathematical values of all the sensitivities plotted by the perimetry test. Mean RS is the mean sensitivity of all the retinal points tested. FT is the mean of all the locations of fovea tested on perimetry within 10° of the VF.[20] Higher values indicate normal functioning retinal ganglion cells, and lower values may indicate the presence of retinal or optic nerve disease or significant media opacity.[21,22] In this study, the mean RS by GYP was marginally higher than by BYP and in both, it showed a decrease with increasing nuclear sclerosis. This could mean more absorption by the sclerotic nucleus of both the blue and green light.

Mean deviation reflects the overall depression (deviation from normal values) of the field. All the obtained values of the test are added and divided by the number of test locations to give the mean value of the test. The same is done for the normal expected values stored in the computer database. The difference between the two values represents the MD. Normally it should not exceed −2 dB.[20] Subjects who require brighter stimuli will have negative MD values which are graded as abnormal at a *P* value of 5, 2, 1, or 0.5%. This suggests glaucomatous damage.[23] This value is also influenced by media opacities.

Table 2: Comparison of detection of visual field defect by BYP and GYP

	BYP		Grand Total
	YES	NO	
GYP			
YES	13	2	15
NO	1	39	40
Grand Total	14	41	55

PSD reflects the degree of difference of the measured VF pattern (shape) from the normal hill of vision. A small PSD reflects a smooth uniform hill of vision, while a large PSD value reflects an irregular hill of vision. It best reflects the glaucomatous changes when excluding generalized depression. If there is an overall depression (all test values are reduced from normal due to cataract), then this value is subtracted from all test points, leaving behind clustered field loss (localized defects), which may be due to glaucoma. In the absence of field defects, the sensitivity at various points when compared with the age-matched normal gives a PSD value of 0. The largest PSD will be registered for focal, deep VF defects. Near-normal and severely damaged VFs will both have low PSD. Deviations of less than 5 dB may be noteworthy near the fovea, while deviations of more than 10 dB may occur in the peripheral field before an abnormality is expected.[23,24]

Different studies have compared different perimetric parameters to determine the superiority of one perimetry over another. Yet the multiple studies involving SAP, SWAP, and frequency-doubling technology (FDT) have been inconclusive.[10,25,26] While it is difficult to state categorically

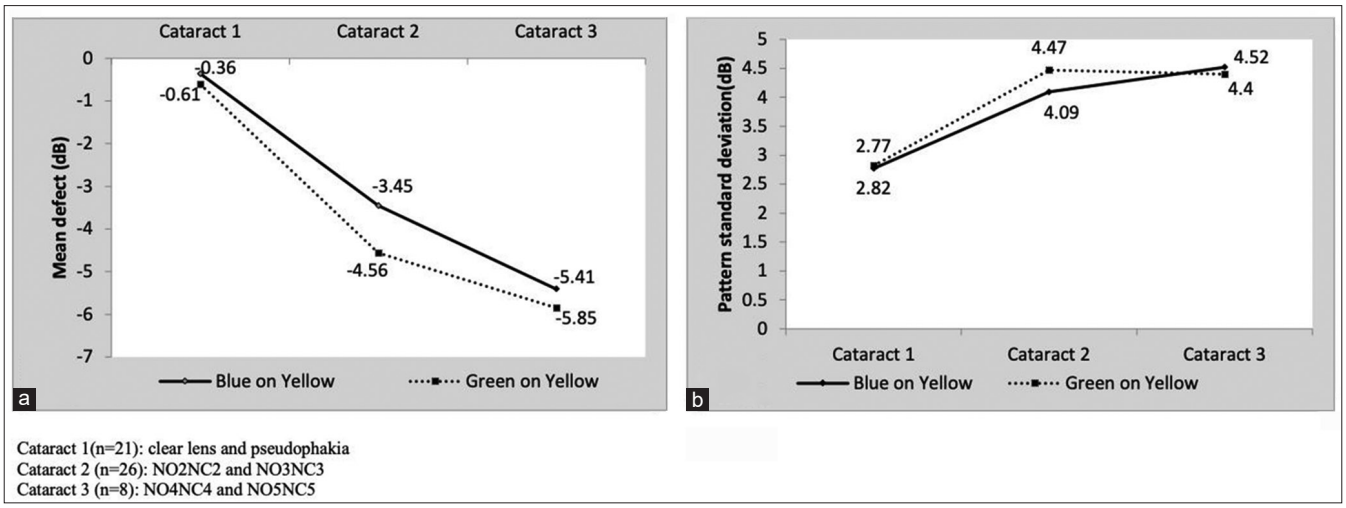

Figure 2: Comparison of the mean defect (a) and pattern standard deviation (b) between BYP and GYP

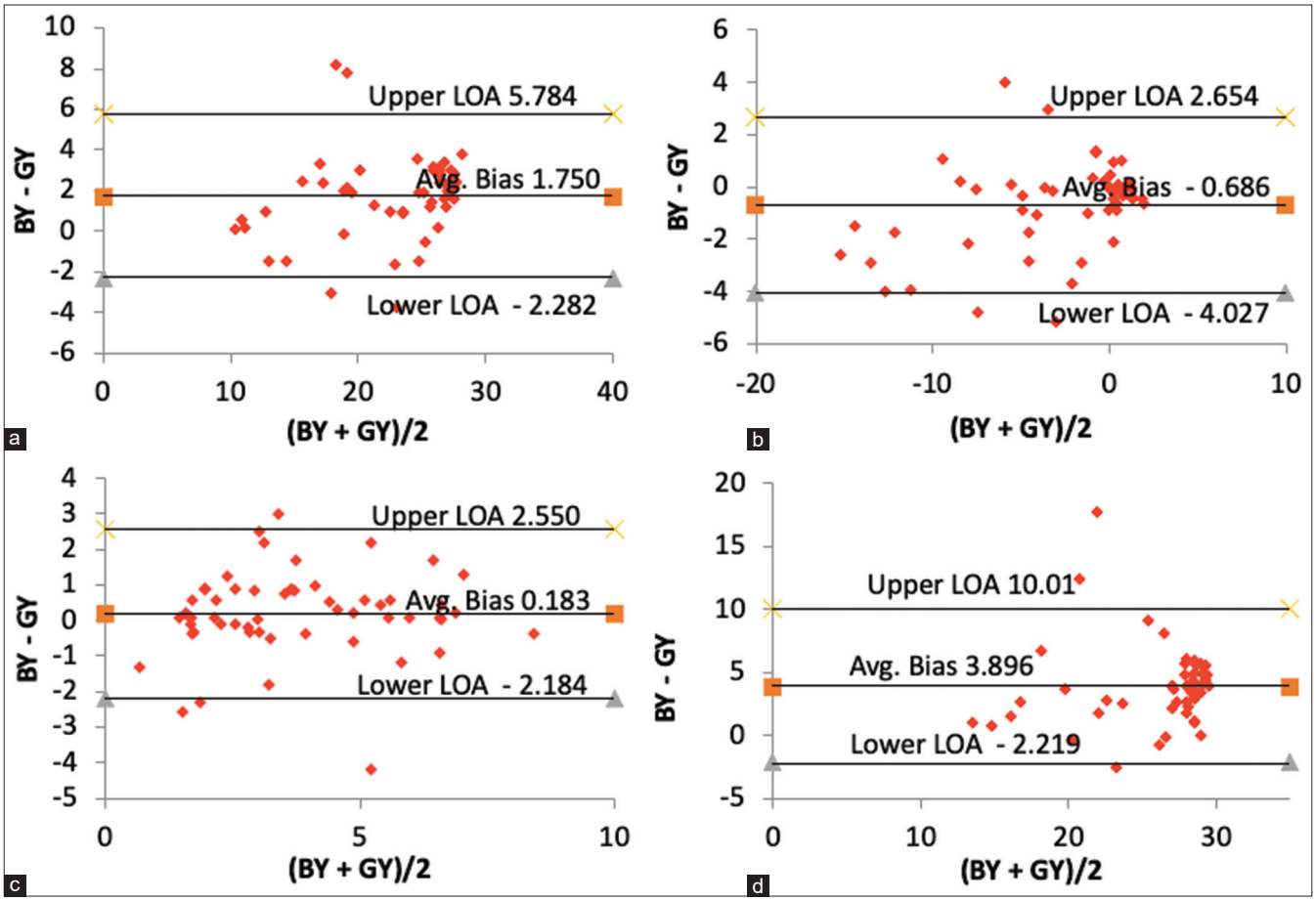

Figure 3: Bland-Altman plots of retinal sensitivity (a), mean defect (b), pattern standard deviation (c), and foveal threshold (d) of BYP and GYP

the superiority of one perimetry over another in glaucoma detection by such data alone, in our present study, it may be safe to state that the GYP had good sensitivity and specificity. Also, the depth and extent of the defects observed were similar in both BYP and GYP in patients with clear media as well as nuclear sclerosis. BYP shows good agreement in the population studied in nuclear sclerosis.

Normative BYP indices of MS, MD, and PSD in BYP (central 30°) were observed to be 21.23 ± 2.96 dB, -3.94 ± 2.20 dB, and 3.13 ± 0.72 dB, respectively.[27] These values are close to what was observed in the present study. Further, even though GYP showed high sensitivity and specificity, it is to be noted that only 14 patients showed perimetric changes suggestive of glaucoma. So, it may be prudent to state that the agreement

between GYP and BYP is observed in a non-glaucomatous population and not extrapolate the results to include glaucoma patients.

The role of perimetry in glaucoma is to detect the functional loss of retinal ganglion cells based on structural loss. This is important in planning the treatment. Difficulties in mapping the VF may occur when the stimuli presented in perimetric tests cannot be perceived by the patient due to media opacities (lenticular). Typically, the stimuli in BYP are more likely to be absorbed by the cataractous lens compared to that in SAP. This poses a challenge in monitoring the progression of the disease by SWAP.[28]

Since glaucoma is a disease that takes a longer course, cataract formation is likely to interfere with accurate VF charting during the course of the disease. The visually significant, higher-grade cataracts are more likely to be surgically managed for cataracts. Further monitoring of glaucoma progression in these patients would take place with clear media (pseudophakia).[9,29] In patients with lower-grade cataracts (NO2NC2, NO3NC3), if they have good vision, cataract surgery is likely to be postponed. These are the patients for whom, in the presence of a cataract, glaucoma monitoring would be required. There is a greater quantum of separation between GYP and BYP in MD and PSD values observed in lower grade cataracts compared to clear media and denser cataracts. A sclerotic lens that is more likely to absorb a shorter wavelength of light (blue spectrum) than the medium wavelength (green spectrum), would explain this observation in lower grades of nuclear sclerosis.[30] In higher grades of cataracts, the loss by absorption is likely to be more global and hence the absence of difference in the perimetric indices. Further studies are required to establish definitely the advantage of GYP in patients with nuclear sclerosis and glaucoma.

There are some limitations to the study. GYP was compared with only BYP. Comparison with a more popular SAP would have added greater value to the study. This was not done in this study to avoid patient fatigue due to frequent repetitive perimetry. Patients with higher grades of cataract with vision adequate to perform reliable perimetry were less in number, thus limiting the generalizability of the results to patients with lesser grades of nuclear sclerosis. This study was carried out among glaucoma suspects. The number of patients who showed VF changes suggestive of glaucoma was only one-fourth. Similar studies among glaucoma patients would be required before GYP can be accepted as an alternative to the existing SAP and BYP.

Conclusion

There was a good agreement between the RSs obtained by BYP and GYP. This agreement extended over clear media as well as different grades of nuclear sclerosis.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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