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PRESSURE- TO- CORNEA INDEX: A NOVEL INDEX TO ASSESS THE SEVERITY OF GLAUCOMA

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ABSTRACT **Purpose:** To determine the correlation between pressure-to-cornea index (PCI) and both optic disc and visual field changes in Primary open angle glaucoma (POAG) patients

2.To evaluate the role of pressure-to-cornea index in assessing the severity of POAG.

Design: This was a cross -sectional study

Methods:

Setting: It was an institutional study

Study Population: 70 eyes of 35 patients with POAG were recruited.

Inclusion Criteria: Age ≥ 40 years, baseline IOP >21mmHg, open angles on gonioscopy, glaucomatous optic disc changes and visual field defects

Exclusion Criteria: Patients who are currently on treatment for glaucoma, patients with secondary glaucoma or anterior segment diseases, opaque ocular media, uncontrolled Diabetes mellitus, chronic contact lens wear, previous corneal surgery, trauma, optic nerve disease and patients with high myopia (> -6D).

Observation procedure: After collecting demographic details, anterior segment examination, Goldmann applanation tonometry, gonioscopy, perimetry by Humphrey field analyzer using SITA standard 30-2 program and pachymetry were done. PCI was calculated.

Main Outcomes Measured: Mean Deviation (MD) of HFA and cup disc ratio were correlated with PCI. Glaucoma severity was graded using Canadian guidelines and was also correlated with PCI. **Results:** Significant Correlations were observed between CDR and PCI (p=0.001) and MD and PCI (p=0.002). Glaucoma severity was also significantly associated with PCI (p=0.001). **Conclusions:** Our study showed that PCI can be correlated with structural and functional changes in POAG. Hence PCI can be regarded as a single risk factor for measuring glaucoma severity.

KEYWORDS : Glaucoma, Iop, Central Corneal Thickness, Visual Fields, Pressure-cornea-index, Mean Deviation, Cup Disc Ratio

INTRODUCTION

Glaucoma is the second most prevalent cause of irreversible but preventable blindness, accounting for nearly 8% of blindness globally.[1] India contributes to the highest (23.5%) regional burden of global blindness. Glaucoma contributes to 12.8% of blindness in India.[2]

Primary open-angle glaucoma (POAG) is the most prevalent type of glaucoma and is characterized by raised intraocular pressure, loss of peripheral visual field, and a characteristically excavated optic disc [3]. In POAG, intraocular pressure (IOP) is the main risk factor for the development and progression of glaucoma. The IOP measurement method and the central corneal thickness (CCT) are two factors that affect the IOP value.[4] Goldman applanation tonometer (GAT) is the gold standard for measuring IOP.The upper range of normal for adults is 21 mmHg on applanation tonometry.[5]

CCT itself is an independent risk factor for developing glaucomatous optic nerve head damage and more importantly a thin CCT has been identified as a predictor of glaucoma progression [6,7]. Ultrasound Pachymetry is currently the gold standard method employed to measure CCT.[6]. The normal corneal thickness ranges from 0.7 to 0.9 mm at the limbus to 0.49 to 0.56 mm at the centre.[4]

True IOP may be underestimated in a thinner cornea, while a thicker cornea gives a falsely elevated IOP reading. A certain proportion of perfectly normal people are thus labelled as glaucoma suspects or ocular hypertensives.[8]

In an attempt to integrate IOP and CCT into a single risk factor, a new glaucoma index, called Pressure to cornea index (PCI) was introduced.

Pressure to Cornea Index (PCI)

In most of the tonometers, most notably the GAT, thin corneas underestimate the true IOP, while thick corneas overestimate. In the literature, a number of conversion tables have been offered to account for this variable; however, no formula has been demonstrated to be superior till today. Instead of attempting to adjust for IOP measurement error, a new glaucoma index, the PCI was introduced to combine IOP and CCT into a single risk factor [9,10].

PCI is defined as the ratio between untreated IOP in mm of Hg and CCT in mm[3][9,10].

PCI = Untreated IOP (mm of Hg)/ CCT^3 (mm).

A PCI range of 120–140 is proposed as the upper limit of "normality".[9]

Individual susceptibility to glaucomatous damage may be more accurately reflected by PCI than by IOP or CCT alone. A low PCI indicates "low risk of pressure-related damage", while a high PCI suggests "increased risk of pressure-related damage".[9,11] PCI may better reflect the individual susceptibility to glaucomatous damage than either of the integrated parameters, IOP and CCT alone.[9]Thus the present study is to find the correlation between the PCI and degree of glaucomatous damage by assessing the optic disc (OD) and visual field (VF) changes in POAG patients and to evaluate the role of pressure-to-cornea index in assessing the severity of POAG

Methods.

A Cross -sectional study was conducted in the Department of Ophthalmology at a tertiary care centre after ethical committee clearance.

Inclusion Criteria:

Patients satisfying following criteria were included in the study.

1. Age above 40 years
2. Baseline IOP >21mmHg
3. Open angles on gonioscopy
4. Glaucomatous optic disc changes –if any one or more of following features was present.

a. Increased cup disc ratio (cup: disc ratio ≥0.5)

b. Neuroretinal rim thinning in any quadrant of the disc.

c. Notching of inferior or superior temporal area of optic nerve head.
d. Laminar dot sign
e. Bayonetting sign
f. Hemorrhages on the disc

5. Glaucomatous visual field defects

Exclusion Criteria:
1. Patients who are currently on treatment for glaucoma as their baseline IOP may not be available.
2. Patients diagnosed to have secondary glaucoma
3. Evidence of any anterior segment pathology like conjunctivitis, keratitis or acute uveitis.
4. Presence of opaque ocular media (as in cataract, corneal opacities)
5. Patients with Uncontrolled Diabetes mellitus since poor glycemic control can cause increased corneal thickness.
6. History of previous corneal surgery
7. History of chronic contact lens wear
8. History of previous corneal trauma
9. Any history of previous optic nerve disease
10. Patients with High myopia (> -6D)

After applying inclusion and exclusion criteria, 35 Patients who had bilateral POAG, hence 70 eyes were recruited into the study. Well-informed written consent was taken. Using a structured questionnaire, socio-demographic details, clinical history and examination findings of patients were entered into a proforma. Anterior segment examination was done using torch light and slitlamp. Baseline IOP was measured by Goldmann applanation tonometry between 9 am and 12 pm on at least 2 occassions and average was taken. CCT was also measured during the same visit by pachymetry (canon TX-20 P) and PCI was calculated. Gonioscopic examination was done for the assessment of the angles. Visual field examination was done by Humphrey field analyser using SITA standard 30-2 program on 2 separate visits before considering them as reliable and suitable for the study. Mean Deviation (MD) of HFA was graded using Hodapp-Parrish-Anderson criteria into early, moderate and severe defects and was correlated with PCI.

Hodapp-Parrish-Anderson criteria for Glaucoma severity [12]

	Early defect	Moderate defect	Severe defect
Mean deviation	< -6 dB	-6dB to -12 dB	> -12dB

Dilated Fundus Examination was done by slit lamp biomicroscopy with +90 D lens and Cup disc ratio (CDR) was estimated clinically. Vertical CDR was measured using the optic disc scan by Spectral domain OCT. Based on CDR, glaucoma was graded as mild, moderate and severe according to Canadian guidelines and was also correlated with PCI.

Canadian Guidelines [13]
Mild – C:D Ratio <0.65 or mild VF defect not within 10◦ of fixation
Moderate-C:D Ratio 0.7 -0.85 or VF defect not within 10◦ of fixation or both
Severe-C:D Ratio >0.9 or VF defect within 10◦ of fixation or both[37]

Statistical Procedure:
The statistical analysis in this study was conducted using Jamovi 2.6.26, an open-source statistical software. The associations between PCI and continuous variables like IOP, CCT, CDR, mean deviation (MD) and glaucoma severity were analyzed using appropriate statistical tests, with a significance level of $p < 0.05$ set to determine statistical significance.

RESULTS
70 eyes of 35 patients were included.

Table 1: Distribution Of Age, IOP And CCT Among The Study Population

Age (years)	Frequency (number)	Percentage (%)
41-50	3	8.6
51-60	17	48.6
61-70	13	37.1
>70	2	5.7
IOP (mm of Hg)		
21-30	63	90
>30	7	10
CCT (mm)		
0.49- 0.56	59	84.3
>0.56	11	15.7
Total No: of eyes	70	100

The age of the participants ranged from 41 to 75 years, with a mean age of 59.5±7.5 years.The majority of the participants (48.6%) belonged to the 51-60 years age group. The average IOP was 26.8±4.0 mm Hg, with values ranging from 22 to 38 mm of Hg. The average CCT was 0.55±0.02 mm, ranging from 0.52 to 0.59 mm.

Table 2: Pressure-to-cornea Index (PCI) Distribution Among The Study Population

PCI	Frequency (No:)	Percentage (%)
<120	6	8.6
120-140	9	12.9
140-160	21	30
160-180	22	31.4
180-200	5	7.1
>200	7	10
Total	70	100

Among the 70 eyes included in the study, the average PCI was 164.1±33.0, with values ranging from 112.8 to 278.2. Most of the results fell in the PCI range of 160-180 (31.4%) followed by the 140-160 range (30%). The highest PCI values above 200 were seen in 10% of eyes.

Table 3: Cup-disc-ratio (CDR) And Mean Deviation (MD) Distribution Among The Study Population

	Frequency (No:)	Percentage (%)
CDR		
Mild (≤0.65)	19	27.1
Moderate (0.7-0.85)	40	57.2
Severe (≥0.9)	11	15.7
MD		
Early(<-6dB)	8	11.4
Moderate (-6dB to -12dB)	43	61.4
Severe (>-12dB)	19	27.1
Total	70	100

Majority (57.2%) had moderate optic disc damage while severe changes were observed only in 15. The average MD was -11.4±7.0 dB, ranging from -31 to -5.0 dB. Most of the eyes (61.4%) had moderate visual field loss, while only 27.1% had severe loss.

Table 4: Association Of Pressure-to-cornea Index (PCI) With Intraocular Pressure (IOP) And Central Corneal Thickness (CCT)

	N	Pressure-to-Cornea Index		t test	
		mean	SD	t	p
IOP (mm of Hg)					
21-30	63	156.2	21.7	8.577	0.001
>30	7	235.0	34.3		
CCT (mm)					
0.49- 0.56	59	169.8	31.7	3.590	0.001
>0.56	11	133.8	22.7		

A highly significant association was found between IOP and PCI and also between IOP and CCT. PCI was significantly lower in participants with a CCT >0.56 mm compared to those with thinner corneas (t=3.590, p=0.001).

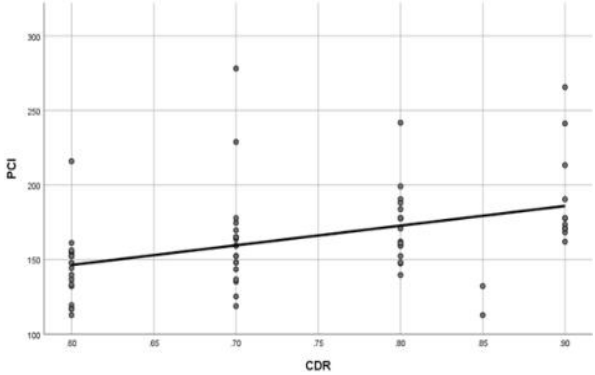

Figure 1: Correlation Between PCI And CDR

A significant Correlation was observed between CDR and PCI (F=8.933, p=0.001) (Figure 1). Patients with severe optic nerve damage (CDR ≥0.9) had the highest PCI (192.0±33.8), while those with mild damage (CDR ≤0.65) had the lowest PCI (144.6±22.9).

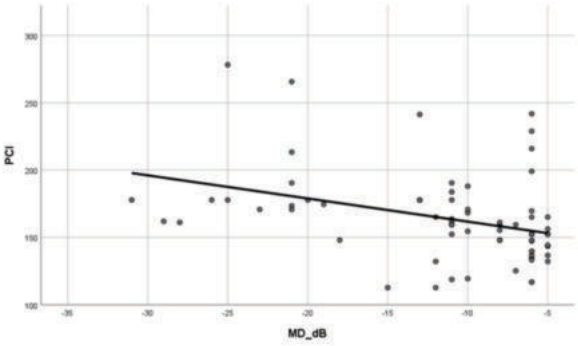

Figure 2: Correlation Between PCI And MD

A significant Correlation was observed between MD and PCI (F=6.909, p=0.002) (Figure 2). Participants with severe visual field defects had the highest PCI (185.8±39.3), followed by those with moderate loss (157.6±28.4) and early-stage glaucoma (147.9±10.8).

So based on the above findings, glaucoma severity was significantly associated with PCI (F=8.933, p=0.001). Patients with severe glaucoma had the highest PCI (192.0±33.8), followed by those with moderate (165.7±31.4) and mild disease (144.6±22.9).

DISCUSSION

The present study assessed the correlation between a novel index called Pressure-to-Cornea Index (PCI) and structural and functional changes in POAG. The severity of glaucomatous damage in primary open-angle glaucoma (POAG) patients and its association with PCI was also assessed. The study meticulously characterized the demographic and clinical profiles of the participants, providing a comprehensive understanding of the study population.

The demographic profile of participants in our study revealed a significant concentration of cases between 51-60 years with a mean age of 59.5±7.5 years .In a cross sectional study of PCI in patients with POAG, Normal tension glaucoma and ocular hypertension by Iliev et al, mean age (yrs) was found to be 65.0±11.0[9] .In another study, assessing correlation between PCI and structural and functional measures of glaucoma, Franco et al found the mean age to be 65.9 ± 23.0 years.[10]

The average IOP was 26.8±4.0 mm Hg in our study similar to that in the study by Iliev et al (26.3±4.3).[9] The mean IOP measured by Applanation tonometry in POAG group was 25.72 ±3.53 in the study by Shah S et al.[11] The elevated IOP levels observed in the study population highlights the critical role of IOP reduction in preventing the progression of glaucoma and preserving visual functions. In the study by Franco et al, the mean IOP was only 19.7 ±5.1 mm Hg which was lower compared to our study.[10]

The average CCT was 0.55±0.02 mm in our study which was similar to the study by Shah S et al (0.52 ± 0.03mm), Iliev et al (0.53±0.03 mm) and Franco et al (0.53±0.04 mm)[11,9,10].

Among the 70 eyes included in our study, the average PCI was 164.1±33.0 whereas it was 173.6±40.9 in the study by Iliev et al and 182.13 ± 35.61 in study by Shah S et al.[9,10] Most of the results fell in the PCI range of 160-180 (31.4%) followed by the 140-160 range (30%) in our study. Only a smaller proportion (12.9%) in our study had a PCI between 120-140 compared to that with the study by Iliev et al (15.7%).[9] In our study, only 8.6% had a PCI below 120 which was similar to the study by Iliev et al (6.7%).[9] Higher PCI values above 200 were seen in 10% of eyes in our study.

On assessing CDR, majority (57.2%) of POAG patients in our study had moderate optic disc damage, whereas (27.1%) had mild changes. Severe changes were observed in 15.7%. The median C/D ratio was 0.8 (range, 0.3–1.0) in the study by Franco et al and 0.7 in the study by Shah S [10,11]. The predominance of moderate optic disc damage in the study population highlights the potential for early intervention to slow disease progression and preserve visual function.

In our study, the average MD was -11.4±7.0 dB, ranging from -31 to -5.0 dB. The mean values of the MD from automated perimetry were -9.9 ± 7.6 dB in the study by Franco et al and -8.37± 8.45 dB in the study by Shah S et al which was similar to our study.[10,11] The average MD was 5.1±4.5 dB in the study by Iliev et al which was slightly lower than our study.[9] In our study, most of the eyes (61.4%) had moderate visual field loss, while (27.1%) had severe loss. Only 11.4% had early visual field defects. The high prevalence of moderate to severe visual field loss underscores the importance of routine screening and early intervention to prevent further visual impairment.

On assessing severity of glaucoma in our study, majority (57.1%) had moderate glaucoma, while 27.1% had mild glaucoma. Severe glaucoma was seen in 15.7%. The predominance of moderate glaucoma in the study population reinforces the need for proactive screening and early treatment strategies to prevent the progression to severe disease and its associated visual impairment.

A highly significant association was found between IOP and PCI (p=0.001) which was similar to the study by Iliev et al(p<0.001). Participants with an IOP of 21-30 mmHg had a mean PCI of 156.2±21.7in our study while in the study by Iliev et al it was 167.6±31.8. In our study, those with IOP >30 mmHg showed a markedly higher PCI of 235.0±34.3.

PCI was significantly lower in participants with a CCT >0.56 mm compared to those with a thinner cornea (p=0.001). Participants with CCT 0.49-0.56 mm had a mean PCI of 169.8±31.7, while those with CCT >0.56 mm had a lower PCI of 133.8±22.7.

A significant Correlation was observed between CDR and PCI (p=0.001) in our study. Patients with severe optic nerve damage (CDR ≥0.9) had the highest PCI (192.0±33.8), while those with mild damage (CDR ≤0.65) had the lowest PCI (144.6±22.9).

Similar to our study, a significant correlation was found between PCI and CDR (P = 0.006) in the study by Franco et al and Shah S(P=0.000).[10,11]

The significant association between CDR and PCI suggests that higher PCI values may correlate with advanced glaucomatous damage, reinforcing its potential role in glaucoma severity assessment.

A statistically significant correlation was observed between MD and PCI (p=0.002) in our study. Higher PCI values were seen in patients with lower MD. The more impaired the visual function, the lower the MD value. Participants with severe visual field defects had the highest PCI (185.8±39.3), followed by those with moderate visual field defects (157.6±28.4) and early defects (147.9±10.8). The PCI showed a statistically significant negative correlation with MD (P = 0.003) in the study by Franco et al and by Shah S et al(P=0.000) [10,11].The significant association between visual field loss and PCI suggests that PCI increases as glaucoma progresses, aligning with its potential as a severity marker. This can help in the management and monitoring of glaucoma.

Glaucoma severity was significantly associated with PCI (p=0.001). Patients with severe glaucoma had the highest PCI (192.0±33.8), followed by those with moderate (165.7±31.4) and mild disease (144.6±22.9). The strong correlation between PCI and glaucoma severity highlights PCI's potential as a glaucoma severity marker and emphasizes its clinical utility in tracking the course of the disease.

CONCLUSION

Our study showed a statistically significant correlation between PCI and CDR, MD and glaucoma severity. Therefore, instead of considering IOP and CCT as two distinct components, PCI can be thought of as a single risk factor for predicting the risk of pressure related optic nerve damage as it correlates with both structural and functional changes. Hence PCI can be used as a supplementary tool for identifying high risk patients. Recently measurement of corneal biomechanics by Corneal hysteresis using Ocular Response Analyser is gaining importance as a predictor of glaucomatous optic nerve head damage. But it requires an additional equipment which is costly and is not readily available whereas PCI can be calculated using readily available equipments and is also cost effective. Hence PCI can be integrated into clinical practice thereby helping in improving

diagnostic accuracy and allowing for more individualized treatment plans for POAG.

Limitations Of Our Study

- This study evaluates only a small group of representative population and hence the findings may not reflect the universal population.
- We had taken into account only the cup disc ratio as a measure of glaucomatous optic disc damage. The relative disc size, area, neuroretinal rim width and Retinal nerve fiber layer defects (RNFL) were not assessed.
- PCI only reflects the interplay between IOP and CCT. It doesn't take into account other factors which may contribute to glaucoma pathogenesis.
- PCI cannot be used to assess the severity of glaucoma but only predicts the risk of structural and functional damage.
- Our study only evaluated POAG patients. A comparison study including Normal tension glaucoma, Ocular hypertension and glaucoma suspects would be helpful to understand the variation among the groups.
- Large population sample and longitudinal studies with multiple follow-ups are needed in the future for more accurate prognostic results, to consider the role of PCI as a glaucoma severity indicator.
- Furthermore, research should be done on how other ocular and systemic factors affect PCI and how it relates to glaucoma.

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