

## Relationship between nocturnal intraocular pressure-related peak recorded by contact lens sensor and disease progression in treated glaucomatous eyes

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**Purpose:** The aim of this study is to study the association between Nocturnal Intraocular Pressure (IOP) related Peak recorded by a Contact Lens Sensor (CLS) and glaucoma progression in treated glaucomatous eyes. **Methods:** Institutional study in which forty glaucoma patients were recruited from glaucoma clinic. A total of 19 patients were labeled as progressors on current anti-glaucoma treatment despite controlled day time IOP whereas twenty one patients were clinically stable showing no progression. Worse eye of each patient was selected for placement of CLS. The timing of the highest signal (IOP related peak) was noted in 24 hour CLS graph and if it fell within the time frame of 11 pm to 5 am, it was labeled as 'nocturnal IOP related peak'. **Results:** Progressors were found to be significantly more prone to night spike than Non Progressors ( $\chi^2=6.812$ ;  $n = 40$ ;  $P = 0.009$ ), thus, showing a definite association between the two. Association between Nocturnal IOP related peak and various other variables like age, gender, mean daytime IOP and systemic illness was studied. A positive correlation was established between female gender and Nocturnal IOP related spike with a significantly higher proportion of females showing night spike than their male counterparts ( $\chi^2=5.763$ ;  $n = 40$ ;  $P = 0.016$ ). Other parameters did not show any significant relationship with Nocturnal IOP related spike. **Conclusion:** Dynamic 24 hour recording by CLS is beneficial in detecting nocturnal IOP-related peak, and thus, can potentially improve the clinical care of glaucoma patients, especially those showing progression.

**Key words:** Contact lens sensor, glaucoma, intraocular pressure

Intraocular pressure (IOP) is identified as a major risk factor for the development of glaucoma and is at present the only modifiable risk factor. Medical therapy is aimed at lowering IOP below a clinically determined target level in order to prevent or slow progression. Diurnal and postural variation of IOP is a well-known fact.<sup>[1,2]</sup> In addition to the absolute IOP level, IOP fluctuations and, in particular, peaks, have been well accepted as an independent risk factor for glaucoma progression.<sup>[3]</sup> Several studies have previously reported the association between IOP peak and visual-field decline in primary open angle glaucoma (POAG).<sup>[4]</sup>

Literature suggests that in a majority of normal subjects and glaucoma patients, the IOP peak is recorded during the nocturnal period during which IOP measurement is not routinely obtained.<sup>[2,5]</sup> There is also enough evidence to support that IOP measurements during routine office hours fail to detect IOP peak in up to 62% of glaucoma patients.<sup>[6,7]</sup> Nevertheless clinicians judge the therapeutic efficacy of IOP-lowering interventions on measurements obtained during the office hours. Therefore, potentially missing the highest 24 hour IOP reading is responsible for causing progression in treated glaucomatous eyes.

Although applanation tonometer is still considered the gold standard for measuring IOP, it does not provide information

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on 24 hour IOP behavior. Recently, a novel approach has been introduced to measure the circadian ocular volume change related to IOP dynamic behavior in glaucoma. The key element of this measurement method is a soft contact lens sensor (CLS) with an embedded micro fabricated strain gauge that allows the measurement of changes in ocular volume at the limbal region detecting the peak pattern of variation in IOP. The commercial product (SENSIMED Triggerfish®, Sensimed AG, Lausanne, Switzerland) obtained the CE mark in 2009<sup>[8]</sup> and was approved by FDA in 2016. CLS signal changes have been shown to be related to changes in IOP and to rhythmic oscillation in IOP resulting from the cardiac activity.<sup>[9,10]</sup> In another report, CLS was used to measure changes in limbal strain associated with face down position in patients with glaucoma and age-matched controls. Results from this study showed a sustained strain increase in glaucoma patients, especially those with past visual field worsening.<sup>[11]</sup> Moreover, certain CLS parameters were associated with the rate of visual field progression in treated glaucoma patients and a combination of these parameters provided better measures of goodness of fit than Goldmann applanation tonometry parameters in the same period.<sup>[12,13]</sup>

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Herein we describe the specific association between nocturnal IOP related peak recorded by CLS and glaucoma progression, aiming to help clinicians in better management of glaucoma patients who are showing progression despite medical treatment and controlled IOP during office hours.

## Methods

### Study design

This was a retrospective cohort study of 40 consecutive patients recruited from Glaucoma clinic of our hospital. Written informed consent was taken from all the participants. Ethical clearance was obtained from the institutional review board of our hospital.

### Study subjects

It was an institutional study. Out of 1012 glaucoma follow up patients, 40 subjects fulfilling our inclusion/exclusion criteria were recruited. Retrospective visual field data of these 40 patients were collected and analyzed. In this study, we purposefully selected nineteen patients who suffered from progressive glaucoma despite attaining target IOP by medical management during office hours whereas; the remaining twenty one patients selected were clinically stable on current medical treatment. Twenty four hour recordings of IOP-related patterns were prospectively collected for both Progressors and Non Progressors with a CLS system. Clinically applicable Target IOP range considered for Early, Moderate and Advanced Glaucoma was 15-17 mmHg, 12-15 mmHg and 10-12 mmHg, respectively.<sup>[14]</sup> The number of visits for IOP recording varied from minimum of 10 recordings to 30 depending upon the duration of follow up period. Most of the subjects (both Progressors and non-Progressors) were maintaining their respective target IOP during their follow up visits in glaucoma clinic. The IOP measured in office hours was recorded in sitting position by the standard Goldmann applanation technique. The well proven fact that the daytime IOP recorded in sitting position doesn't correlate well with the night time IOP in supine position<sup>[15]</sup> may explain the clinical progression noticed in few individuals (labelled as Progressors) despite a controlled daytime IOP. Such patients were suspected of experiencing nocturnal IOP peaks missed on routine daytime IOP recording done in sitting position and were then subjected to CLS placement for 24-hour IOP recording.

### Documenting progression on Humphrey visual field (HVF)

Subjects were classified as Progressors and Non-Progressors based on the Guided Progression Analysis(GPA)software by the Humphrey Visual Field (HVF) Analyzer (Carl Zeiss Meditec Inc., Dublin, CA).<sup>[16]</sup> Both Global Trend based Analysis using VFI [Visual Field Index] and Point wise Event based Analysis using GPA were employed to test Progression.<sup>[17]</sup>

Each patient underwent two baseline visual fields after ruling out the learning curve. For all patients, visual fields were repeated 4-6 monthly or earlier at clinician's discretion. The number of visual field tests performed for each subject ranged from minimum of 6 visual fields to 20. The GPA software assesses the repeatability of 3 or more points and gives a plain-language report of "likely progression" if 3 consecutive fields show change at the same 3 or more points. Besides the regular periodic field tests, subjects with clinically documented progression on Optic Nerve Head examination were then subjected to an additional visual field examination on same

day. If the fields of such subjects showed 'likely progression' on GPA, they were then classified as 'Progressors' in our study.

The following inclusion criteria were applicable: most of the study subjects were either primary open angle (POAG) or primary angle closure glaucoma (PACG) patients. Few patients diagnosed with combined mechanism glaucoma were also included. POAG was defined as the presence of an untreated IOP of >21 mm Hg, open anterior chamber angle on gonioscopy, glaucomatous optic disc damage on clinical examination (focal or diffuse neuroretinal rim thinning, localized notching, or nerve fiber layer defects), and corresponding visual field defects. PACG was defined as the presence of an occludable angle on gonioscopy (posterior trabecular meshwork not seen in at least 180 degrees of the total circumference of the angle in primary position), glaucomatous optic disc damage, and corresponding visual field defects. All patients were long term follow-ups of glaucoma ranging from 3-12 years with minimum follow-up period of 3 years. All enrolled subjects were on long term medical treatment for glaucoma. Each patient was using topical Prostaglandin anti-glaucoma medication either as monotherapy or in combination. Progressors with controlled office hour IOP were planned for Contact Lens Sensor placement within 2 days of notifying progression, following which further intervention either medical or surgical was undertaken. So treatment was not changed prior to CLS placement in any group.

Exclusion criteria included the presence of ocular disease other than primary glaucoma, spherical equivalent more than 4 diopters, a cylinder equivalent more than 2 diopters, and corneal or conjunctival abnormalities hindering adaptation of silicon contact lens. Patients who underwent any kind of ocular surgery in the past or during the course of study were excluded.

### Ophthalmological examination

On the first visit in glaucoma clinic, all subjects underwent complete ophthalmological examination consisting of medical history; best corrected visual acuity; central corneal thickness using ultrasonic pachymeter; detailed slit lamp evaluation and fundoscopic examination of optic disc and macula with 90D lens; dilated ophthalmoscopy; gonioscopy and Goldmann applanation tonometry during office hours. On each follow-up visit, medical history; best corrected visual acuity; slit lamp evaluation, fundoscopic examination and day time applanation tonometry were repeated for all individuals. Visual field defects were considered glaucomatous if at least 2 of the 3 Anderson's criteria ( $\geq 3$  Non-edged points in a cluster depressed to  $P < 5\%$ , 1 of which is depressed to  $P < 1\%$ , Glaucoma Hemifield Test outside normal limits, and pattern SD depressed to  $P < 5\%$ ) were fulfilled.<sup>[18]</sup> Optic disc examination and Visual field evaluation of all the patients were performed by a single physician. The visual fields of all these patients were evaluated for reliability. Fields with fixation losses and false-positive or false-negative response rates of >20% were considered as unreliable and excluded from the analysis. Baseline mean deviation in visual fields was noted for each patient after ruling out the learning curve and accordingly each patient was categorized into early, moderate or advanced glaucoma (Hodapp-Parish-Anderson criteria).<sup>[19]</sup>

Patients from both the groups were subjected to CLS placement in the worse eye. In case of Progressors with both eyes experiencing disease progression, the one with more advanced glaucoma was recruited for study. In case of

Progressors with only one eye showing disease progression and one being stable, the eye showing progression was subjected to CLS placement. Finally, in non-Progressors, CLS was placed in eye having more advanced glaucoma.

One week prior to placement of CLS, all patients were instructed to follow a regular sleeping pattern of 11 pm to 5 am. All patients underwent 24 hour ambulatory CLS monitoring during which they carried out their routine activities at home/work place and followed a regular sleeping pattern of 11 pm to 5 am. All subjects were instructed to continue instillation of Anti glaucoma medication after placement of CLS and maintain a diary of medication use. After 24 hours, the CLS was removed and the data retrieved from the recorder. IOP related peak was defined as the highest signal recorded in 24 hours CLS graph. The timing of IOP related peak was noted and if it fell within the time frame of 11 pm to 5 am, it was labeled as 'Nocturnal IOP-related peak'. Examiner assessing the CLS derived IOP graph was masked from the information on stable or progressing glaucoma to eliminate any bias at the level of examiner.

### Instrumentation

The CLS is a disposable silicone contact lens with an embedded microprocessor and a thin micro fabricated platinum titanium strain gauge. Total thickness of the strain gauge is 7 microns. The sensing resistive gauges in the device have a circular arc shape around the center, placed over a circumference of 11.5 mm diameter, which is the average of the corneoscleral junction position, where changes in IOP are assumed to induce maximum corneal deformation. Every 5 minutes, during a 30 second period, it records 10 measurements per second leading to 288 30-second periods with 300 data points each. Output signals from the CLS are in electronic units of millivolt equivalents (mVeq) whose mean 24-hour pattern have been correlated with the mean 24-hour tonometric curve.<sup>[10]</sup> The thickness of the sensor is less than 600 microns in the center and 250 microns in the periphery. Currently, 3 base curves are available (flat 9.0, medium 8.7 and steep 8.4). The CLS is powered by radiofrequency waves at 27 MHz from the external antenna, which is embedded in the patch applied around the patient's eye. The CLS sends back to the external antenna the monitoring data which is then transmitted by wire to a recorder worn around the waist. Although there are various other variables derived from CLS including Night Bursts Ocular Pulse Frequency [OPF], Night Bursts OPA [Ocular Pulse Amplitude], number of long Peaks sleep and Mean Peak ratio wake, herein, we describe the association between Nocturnal IOP related peak recorded by CLS and glaucoma progression. Fig. 1 represents the instrument being used by a patient.

### Statistical analysis

Baseline demographic and clinical characteristics in both Progressors and non-Progressors were analyzed using independent *t* test or chi square test. Variables which were measured on interval or ratio level were tested for their differences by independent *t* test, whereas the variables measured on nominal/ordinal level were tested by chi square test. The association between two variables like the presence of Nocturnal peak and glaucoma progression or Nocturnal Peak and age/gender/mean office hour IOP/systemic status was tested using chi square test.

As chi square test requires a large sample size of more than 30, we had taken 40 subjects who were long-term follow-ups



**Figure 1:** The wireless sensor is in place. A soft patch with antenna is applied around the eye and transmits the information to recorder that the patient wears in a pocket

of glaucoma on treatment with 19 of them being Progressors despite controlled mean office hour IOP, and 21 being clinically stable patients termed as non-Progressors.

Data were analyzed using SPSS [version 16] software. A *P* value < 0.05 was considered statistically significant.

Following were the outcomes of the study-

Primary outcome:

- Nocturnal IOP related Peak and Progression  
The primary outcome was to study the relationship between glaucoma progression and Nocturnal IOP related peak.

Secondary outcomes:

- Nocturnal IOP related Peak and Age
- Nocturnal IOP related Peak and Gender
- Nocturnal IOP related Peak and Mean office hour IOP
- Nocturnal IOP related Peak and Systemic illness.

## Results

The two groups of Progressors and non-Progressors were comparable in terms of mean age, gender, type of glaucoma, severity of glaucoma, duration of follow up, mean pachymetry, presence of systemic illness indicated by presence of Diabetes Mellitus and/or Hypertension and mean IOP recorded at various visits during day time [Table 1].

Table 2 summarizes the association of various parameters like Progression, age at presentation, gender, type of glaucoma/diagnosis, severity of glaucoma, mean office hour IOP, systemic disease (Diabetes Mellitus, Hypertension) with presence or absence of Nocturnal IOP related Peak.

1. It was found that glaucoma progression and Nocturnal IOP-related peak are mutually associated with Progressors being significantly more prone to night spikes than non-Progressors [ $\chi^2 = 6.812$ ;  $n = 40$ ;  $P < .009$ ]. Figs. 2a and b

**Table 1: Baseline demographic and clinical characteristics of Progressors and Non Progressors**

Parameters	Parameter subtype	Progressors	Non progressors	P
No. of eyes		19	21	
Age	MEAN±SD*	54.73±11.07	55.52±12.18	0.83
Gender	Males-No.[%]	12 [63.15%]	18 [85.71%]	0.1
	Females-No.[%]	7 [36.84%]	3 [14.28%]	
Diagnosis	PACG <sup>†</sup> -No.[%]	4 [21.05%]	5 [23.80%]	0.9
	POAG <sup>‡</sup> -No.[%]	13 [68.42%]	13 [61.90%]	
	Combined Mechanism Glaucoma-No.[%]	2 [10.52%]	3 [14.28%]	
Severity of glaucoma [H-A-P Criteria] <sup>§</sup>	Mild-No.[%]	5 [26.31%]	5 [23.80%]	0.57
	Moderate-No.[%]	6 [31.57%]	4 [19.04%]	
	Severe-No.[%]	8 [42.10%]	12 [57.14%]	
Follow up period	3-5 Years-No.[%]	5 [26.31%]	7 [33.33%]	0.58
	6-10 Years-No.[%]	10 [52.63%]	12 [57.14%]	
	>10 Years-No.[%]	4 [21.05%]	2 [9.52%]	
Pachymetry	MEAN±SD	527.31±28.18	530.61±29.15	0.71
Mean office hour IOP	MEAN±SD	13.57±2.16	13.04±2.06	0.43
Systemic status	No. of patients With DM <sup>  </sup> /HTN <sup>¶</sup>	10 [52.63%]	6 [28.57%]	0.12

\*Standard deviation; <sup>†</sup>Primary angle closure glaucoma; <sup>‡</sup>Primary open angle glaucoma; <sup>§</sup>Hodapp-Parrish-Anderson classification system<sup>12</sup>; <sup>||</sup>Diabetes Mellitus, <sup>¶</sup>Hypertension

**Table 2: Correlation between Nocturnal IOP Related Peak and Clinical and Demographic Parameters [Chi square test]**

Parameters	Parameter subtype	Nocturnal IOP related peak	No nocturnal IOP related peak	P
No. of eyes		23	17	
Progression	Progressors-No.[%]	15 [65.21%]	4 [23.52%]	<0.009
	Non Progressors-No.[%]	8 [34.78%]	13 [76.47%]	
Age	30-45 years-No.[%]	5 [21.73%]	3 [17.64%]	0.14
	46-60 years-No.[%]	8 [34.78%]	11 [64.70%]	
	61-80 years-No.[%]	10 [43.47%]	3 [17.64%]	
Gender	Males-No.[%]	14 [60.86%]	16 [94.11%]	0.02
	Females-No.[%]	9 [39.13%]	1 [5.88%]	
Diagnosis	PACG <sup>*</sup> -No.[%]	6 [26.08%]	3 [17.64%]	0.18
	POAG <sup>†</sup> -No.[%]	16 [69.56%]	10 [58.82%]	
	Combined Mechanism Glaucoma-No.[%]	1 [4.34%]	4 [23.52%]	
Severity Of Glaucoma [H-A-P Criteria] <sup>‡</sup>	Mild-No.[%]	4 [17.39%]	6 [35.29%]	0.37
	Moderate-No.[%]	7 [30.43%]	3 [17.64%]	
	Severe-No.[%]	12 [52.17%]	8 [47.05%]	
Mean Office Hour IOP [mmHg]	10-12-No.[%]	10 [43.47%]	5 [29.41%]	0.66
	13-15-No.[%]	7 [30.43%]	6 [35.29%]	
	16-18-No.[%]	6 [26.08%]	6 [35.29%]	
Systemic Status-No.[%]	DM/HTN [+] <sup>§</sup>	12 [52.17%]	4 [23.52%]	0.13
	DM/HTN [-] <sup>  </sup>	11 [47.82%]	13 [76.47%]	

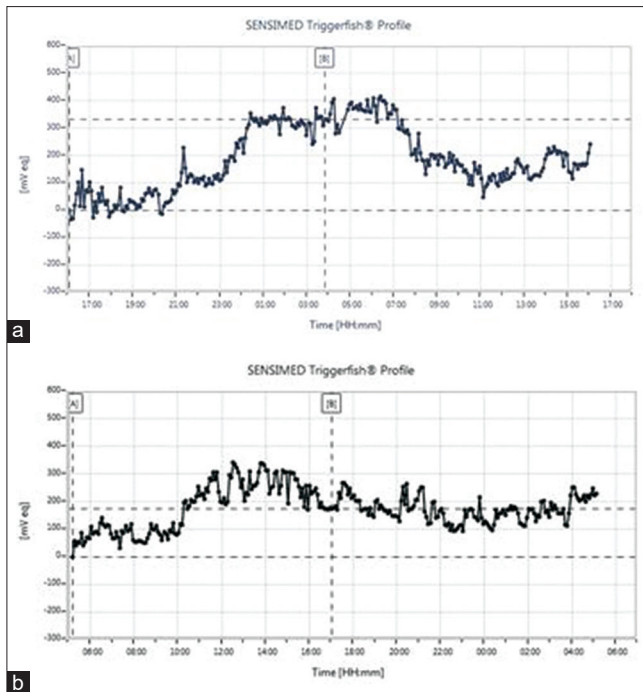
\*Primary angle closure glaucoma, <sup>†</sup>Primary open angle glaucoma, <sup>‡</sup>Hodapp-Parrish-Anderson classification system<sup>12</sup>, <sup>§</sup>No of patients with Diabetes Mellitus and/or Hypertension, <sup>||</sup>No of patients without Diabetes Mellitus and/or Hypertension

represent two typical curves: Fig. 2a represents 24 hour IOP related curve of one of the Progressors with night spike [Fig. 2a] and Fig. 2b represents 24 hour IOP related curve of one of the Non Progressors without night spike [Fig. 2b].

2. There was no association found between age group and Nocturnal spike status. All age groups [30-45,46-60,61-80 years] were equally susceptible to develop night spike [ $\chi^2=3.931$ ;  $n=40$ ;  $P=0.14$ ].

3. A positive correlation was noted between Nocturnal IOP-related Peak and female gender. The proportion of females showing a Nocturnal Peak was significantly more than males [ $\chi^2=5.763$ ;  $n=40$ ;  $P=0.016$ ].

4. We also studied the relationship between Nocturnal IOP-related Peak and mean IOP recorded during office hours at various visits in both Progressors and non-Progressors separately. In both the groups, there was found to be



**Figure 2:** (a): Graph showing 24 hour IOP curve of a 65 year old patient with Primary Open Angle Glaucoma (POAG). The peak is observed at 4 am in the morning. The patient was diagnosed with glaucoma progression on Guided Progression Analysis (GPA). (b): Graph depicting 24 hour IOP related curve of a 60 year old male patient suffering from POAG. Patient was clinically stable on anti-glaucoma medication. The curve shows a stable CLS profile during most of the time with no Nocturnal Peak

no significant association between the Nocturnal Peak and office hour mean IOP [Progressors-  $\chi^2=0.806$ ;  $n = 19$ ;  $P = 0.668$ ; non-Progressors-  $\chi^2=0.807$ ;  $n = 21$ ;  $P = 0.667$ ].

- Similarly, we did not find any significant association between Nocturnal IOP related Peak and Systemic illness like Diabetes and Hypertension [ $\chi^2=2.255$ ;  $n = 40$ ;  $P = 0.133$ ].

## Discussion

The SENSIMED Triggerfish device comes with a huge advantage of dynamic IOP-related measurement throughout 24 hours with a good safety and tolerability profile.<sup>[20]</sup> It overcomes the limitation of static tonometry by allowing a continuous 24 hour IOP-related monitoring without the need to wake up subjects that could induce possible posture and ocular hydrodynamic changes.

We studied the utility of the SENSIMED Triggerfish device in detecting Nocturnal peak in glaucoma patients on long term treatment and establishing its relationship with disease progression. Quite often, patients present in glaucoma clinics with disease progression and/or decreased vision despite having controlled office hour IOP recorded at various visits. In such patients, detecting 24 hour IOP related pattern is of paramount importance as it helps record any Nocturnal spike which is missed in static day time IOP measurements.

In this study, we found that there exists a definite association between Nocturnal IOP-related spike and disease progression in treated glaucomatous eyes. Patients showing glaucoma

progression on Guided Progression Analysis (GPA) of the Humphrey Visual Field (HVF) Analyzer were more prone to develop Nocturnal IOP-related peak than those patients who are clinically stable with no documented progression on visual field analysis. The data obtained was highly relevant and led to immediate treatment change in approximately half of the patients. We believe that this contact lens sensor has the potential to improve clinical care of glaucoma patients in the same way that continuous blood pressure monitoring or home measurements of blood glucose levels have done for patients with high blood pressure or diabetes.

Investigating the association between 55 variables extracted from the CLS signal and retrospective visual field mean deviation change, in open angle glaucoma patients, De Moraes *et al.* found 4 parameters associated with fast visual field progression. One described the nocturnal CLS signal, the second was related to ocular pulse frequency. Another one was related to ocular pulse amplitude and the last one was related to overall fluctuation. The best association was found with the mean peak ratio, highlighting those peaks likely to be clinically significant.<sup>[13]</sup> This association also appears to be better than Goldmann mean IOP measured multiple times during office.

Furthermore, we tested the association between Nocturnal Peak and demographic characteristics like age and gender of the patients. Although we did not find any significant association between age and Nocturnal Peak, there was a distinguishable relationship noted between gender and Nocturnal Peak. Females were clearly more likely to experience Nocturnal Peaks in 24 hour CLS recordings as compared to their male counterparts. This finding is in agreement to work done by Jeelani *et al.* stating that females have significantly higher mean IOP as compared to males.<sup>[21]</sup> In this study, Perkin appplanation tonometry was used to record day time IOP in healthy subjects above forty years of age. However, the physiological basis for this gender difference in IOP remains obscure although a hormonal influence has been suggested in literature.<sup>[22]</sup>

We tested the correlation between Nocturnal IOP-related peak and mean day time IOP recorded in sitting position at various visits in both Progressors and non-Progressors separately. Our study did not report any statistically significant correlation between Nocturnal Peak and mean day time sitting IOP in both the groups. Mosaed *et al.* evaluated the correlation between office hour IOP [both sitting and supine positions] and peak Nocturnal IOP in healthy and glaucomatous eyes.<sup>[15]</sup> They reported that supine IOP during office hours strongly correlates with peak Nocturnal IOP in Glaucoma subjects, thus, concluding that supine office hour IOP data can estimate magnitude of peak Nocturnal IOP. Similar to our study, the authors did not find any correlation between sitting IOP measurements taken during office hours and the peak Nocturnal IOP.

Finally, we evaluated the presence of association between Nocturnal IOP-related peak and systemic illness like diabetes and hypertension. Our study results did not show any positive correlation between diabetes/hypertension and Nocturnal elevation of IOP. Mitchell *et al.*<sup>[23,24]</sup> reported significant association between diabetes and IOP in healthy eyes with diabetic patients showing higher mean IOP. Similarly, in a population-based study, Klein *et al.*<sup>[25]</sup> described relationship between hypertension and IOP in a stating that higher blood pressure (both systolic and diastolic) is associated with higher IOP and vice versa. However,

in most such studies, only the day time IOP measurements have been taken into account and thus the results cannot be extrapolated to conclude any similar association between Nocturnal IOP and systemic status of glaucoma patients.

### Limitations and strengths

Our study is the first one to analyze the utility of Contact Lens Sensor in Indian population. It is not a routine practice to record 24-hour IOP pattern in majority ophthalmological setups in India. Our study emphasizes upon the need of 24-hour IOP recording especially in patients showing glaucoma progression with controlled or near target daytime IOP to rule out nocturnal IOP spike. Any nocturnal IOP spike in such patients demands more aggressive management and stringent measures to control other systemic risk factors like Diabetes and/or Hypertension which might contribute to glaucoma progression. Moreover, the accuracy of the IOP measurement by CLS as compared to standard IOP recording techniques and the relevance of the association found between nocturnal IOP peak and glaucoma progression despite the sample size justifies the applicability of this study in current medical practice in glaucoma management.

Our study had a limitation that visual field data was collected retrospectively for all the glaucoma patients. Further studies with prospective collection of visual field data after CLS recording ought to be conducted to evaluate its performance to possibly recognize the patients at highest risk of visual field progression. Smaller sample size restricts usage of multivariate analysis for studying relationship between Nocturnal spike and various other parameters. Also, we recorded daytime IOP in sitting position by Goldmann applanation tonometry, which is in consensus with the routine practice followed in majority ophthalmological setups globally. However, it is a well-known fact that the night time supine IOP pattern correlates much better with the supine daytime IOP pattern than the sitting daytime IOP pattern. Keeping this in mind, further studies recording daytime IOP in supine position may prove beneficial in detecting IOP peak in glaucoma Progressors. Finally, some important questions need to be answered such as the effect of Nocturnal changes in corneal thickness and ocular movements on the accuracy of this device.

### Conclusion

To summarize, the dynamic 24-hour IOP related recordings by CLS is beneficial in detecting nocturnal IOP related peaks, which are generally missed by the office hours IOP recording methods such as the Goldmann applanation tonometry. By establishing a positive association between nocturnal IOP related peaks and disease progression in treated eyes, this device may help in the early detection of progression in patients showing controlled IOP recordings in routine day time visits, thereby improving the clinical care of glaucoma patients.

### Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity but anonymity cannot be guaranteed.

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### Conflicts of interest

There are no conflicts of interest.

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