Journal of Clinical & Experimental Ophthalmology

Yassein et al., J Clin Exp Ophthalmol 2016, 7:2
DOI: 10.4172/2155-9570.1000536

Research Article Open Access

The Value of Water Drinking Test as a Clue for Short Term Intraocular Pressure Fluctuation

Yassein HA, Hamdi MM*, Abdelshafik MA and Galal AS

Ophthalmology Department, Faculty of Medicine, Ain Shams University, Egypt

***Corresponding author:** Momen Mahmoud Hamdi, Ophthalmology Department, Faculty of Medicine, Ain Shams University, Egypt, Tel: +20222698828; E-mail: momen.ibrahim@magrabi.com.sa

Received date: January 14, 2016; **Accepted date:** March 22, 2016; **Published date:** March 29, 2016

Copyright: © 2016 Yassein HA, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Abstract

Purpose: To assess the relations between the intraocular peaks detected during water drinking test (WDT) and modified diurnal tension curve (mDTC) in glaucomatous and non-glaucomatous eyes. Likewise to assess reliability of WDT as a reliable substitute.

Patients and methods: Forty eyes from forty participants (21 males and 19 females) were recruited in this prospective cross-sectional study; twenty participants with known Primary Open Angle Glaucoma and the other twenty participants with non- glaucomatous healthy eyes which served as control. Four IOP measurements were taken at 8:00 am, 12:00 pm, 4:00 pm and 8:00 pm which represented the mDTC, while WDT was represented by a single measurement of IOP before ingestion of one liter of water over five minutes, followed by three IOP measurements after ingestion of this amount of water at thirty minute intervals. The data collected were statistically evaluated using the statistical package for social science (SPSS) program for presence of a correlation between the two methods.

Results: The IOP peaks and fluctuations detected during the WDT were strongly correlated to peaks and fluctuations observed during the mDTC. 90% of participants had a peak IOP at 8:00 am, while 7.5% had a peak IOP at 12:00 pm, 2.5% at 4:00 pm and none of the participants had IOP peak at 8:00 pm during the mDTC. In the WDT, 87.5% of the participants had a peak IOP after 30 minutes of ingesting one liter of water, while 12.5% had a peak IOP after 60 minutes. None of the participants had IOP peak after 90 minutes of ingesting one liter of water.

IOP fluctuation in mDTC ranged from: 1-4.5 mmHg in 95% of normal participants, 7-11 mmHg in 83.3% of glaucoma suspects, 1.5-5 mmHg in SST subgroup and 4-11 mmHg in the glaucoma on medication subgroup. There were relatively similar results in the WDT fluctuation, whereas 38 cases out of 40 (95%) showed a difference of ± 2 mmHg or less between the two methods.

Conclusion: Intraocular pressure peaks and fluctuations detected during the water drinking test could be used in clinical practice to estimate the peaks and fluctuations observed during the modified diurnal tension curve.

Keywords: Water drinking test; Intraocular pressure; Intraocular pressure fluctuation; Modified diurnal tension curve

Introduction

Elevated intraocular pressure (IOP) is a major risk factor for the development of glaucoma. So the therapeutic strategies designed to reduce the IOP remain the principal method of treatment to slow down the changes in the optic nerve head and visual field (VF) [1].

The measurement of IOP taken at a single time point during office hours can render an incomplete picture of IOP owing to the diurnal variability of IOP [2]. The IOP profile would be better assessed by a twenty-four hour daily tension curve (DTC) [3]. It can estimate IOP peaks and fluctuations to provide the practitioner with more reliable information regarding the short-term IOP profile. However, this monitoring may be unfeasible and time consuming for both patients and physicians; thus, it may be a restricted tool in clinical practice [4].

Retrospective analyses of diurnal IOP measurements generated by home tonometry and during clinic hours suggested a significant association between the range and peak of IOP measurements and progression of VF damage [3,5].

The modified diurnal tension curve (mDTC) emerged as an alternative method that involves IOP measurements every 2 or 3 hours during office hours. It is more feasible and may provide better information than single IOP measurements [4].

Another possible way to assess the IOP is the water drinking test (WDT), which is used to evaluate the eye ability to deal with a transient IOP elevation by observing how high the IOP rises and how long it takes to return to baseline [6,7]. The aim of WDT is to stress the trabecular meshwork (TM) by increasing episcleral venous pressure (EVP), secondary to an increase in central and peripheral venous pressure, with resulting transient negative aqueous outflow [8]. This then would lead to increased IOP as a result of the reduced outflow facility from a decreased pressure gradient across the TM [7].

Water drinking test is done by imbibing a volume of water over a short period, with IOP measurements compared before and for some time afterward. It has been either a fixed volume of one liter of water or variable, such as 10 ml/kg body weight in 5 minutes, with no fluid ingestion to be allowed 2 hours before the test. This often will lead to increase of IOP after about 30 minutes [6]. Previous studies described that IOP peaks detected during the WDT seem to correlate well with the peaks detected during DTC [9]. Thus, WDT may have an important role in the assessment of the quality of treatment and the probability of progression [6].

The WDT may differentiate drugs that can produce equivalent IOP reductions in steady-state situations from those which may have different abilities to dampen IOP peaks, as showed by Susanna et al. [10]. Medications capable of preventing greater or undetected IOP peaks, or both, may have an additional benefit in glaucoma treatment [2]. Studies proved that mean IOP peak and percentage of IOP variation during WDT were significantly higher in patients with VF progression compared with patients who did not progress [11].

The aim of this work is to assess the relation between the intraocular pressure (IOP) peaks detected during the water drinking test (WDT) and the modified diurnal tension curve (mDTC) in both normal and glaucomatous eyes. It also assesses whether WDT is a reliable substitute for mDTC as well as the practicality of WDT being a fast test that can be easily performed at the office to study IOP fluctuations.

Patients and Methods

This is an interventional study that comprised forty eyes from forty participants, they were subdivided into two major groups:

The first major group included twenty eyes from subjects with POAG and who were again subdivided to three subgroups: group A are POAG controlled medically (Glaucoma Subjects on medication); group B are POAG controlled surgically (Glaucoma Subjects with SST); and group C are Glaucoma suspects (subjects with suspicious optic disc/ glaucomatous changes or high IOP). The second major group comprised twenty eyes from healthy non-glaucomatous volunteers.

A detailed case history was taken for each subject with emphasis stress on previous past ocular surgical history, ocular medications, ocular trauma, systemic hypertension and chronic renal diseases.

The study excluded patients with the narrow or occludable anterior chamber angle, systemic hypertension, congestive heart failure or chronic renal impairment.

Detailed anterior segment examination was performed using the Haag-Streit slit Lamp model BM 900, Koeniz, Switzerland. Gonioscopy was done to exclude angle closure glaucoma using Volk Gonioscopy 3 mirror lens by Volk Optical Inc., Mentor, Ohio, USA. Fundus examination was done by Volk 90D lens by Volk Optical Inc., Mentor, Ohio, USA., to detect any optic nerve head glaucomatous changes eg., notching, thinning or pallor of the neuroretinal rim, cupping of the optic disc, parapapillary atrophy. IOP was measured by a single unmasked operator using the Shin-Nippon Goldmann's applanation tonometer by Ajinomoto Trading Inc., Tokyo, Japan.

The data were collected from glaucoma clinics in Ain Shams University hospitals in the period between August 2014 and April 2015. This study adheres to the tenets of the Declaration of Helsinki. Informed consents were taken from all the patients and ethical approval was taken.

Measurements of IOP were carried out at 8:00 am, 12:00 pm, 4:00 pm and 8:00 pm for readings of mDTC. Measurements of IOP for WDT were taken before and after the ingestion of 1 liter of water over 5 minutes. Subjects were instructed to abstain from fluid for two hours before coming to the research clinic. Readings were taken at 30 minutes interval for 90 minutes

Both measurements could be done on the same day, especially with inpatient subjects when the WDT was done directly after the last reading of mDTC i.e. around 8:00 pm. While outpatient subjects were submitted to the mDTC in the first visit and WDT in the second visit.

Data were collected, revised, coded and entered to the statistical package for social science (SPSS) version 20 and the following were done: Qualitative data were presented as numbers and percentages while quantitative data were presented as means, standard deviations and ranges. The comparison between the fluctuations of two methods (mDTC & WDT) was done by using paired t-test, and the relation between peaks and fluctuations was examined by Pearson correlation. The confidence interval was set to 95% and the margin of error accepted was set to 5%. The p-value was considered significant as the following: when $p>0.05$: Non significant, $p<0.05$: Significant and $p<0.01$: Highly significant.

Results

As regards age and sex distribution of the 40 participants; 21 (52.5%) were males and 19 (47.5%) were females. The percentage of females was higher than males in glaucoma suspect subgroup (83.3% and 16.7% respectively) and the opposite was true for glaucoma with subscleral trabeculectomy (SST) where percentage of males was higher than females (71.42% and 28.58% respectively), while the other subgroups showed relative similar percentages. The mean age of the included participants was 55.1 years. The whole studied group was classified into four subgroups (Table 1). Twenty participants (50%) of the studied sample were free from glaucoma (normal subgroup). Six participants (15%) were suspected to have glaucoma (glaucoma suspect subgroup) and fourteen participants (35%) were previously diagnosed to have glaucoma; of those, seven (17.5%) underwent SST followed by medical treatment (glaucoma with SST), while the remaining seven (17.5%) were medically controlled without surgery (Glaucoma on medication).

		Patient [n (%)]	Age (mean & SD)
Group	Whole sample	40 (100%)	55.10 ± 14.18
	Normal subgroup	20 (50%)	55.30 ± 13.30
	Glaucoma suspect	6 (15%)	61.30 ± 7.03
	Glaucoma on medication	7 (17.5%)	51.70 ± 19.34
	Glaucoma with SST	7 (17.5%)	52.70 ± 16.34

Table 1: Descriptive statistics of the studied sample as regards their glaucoma diagnosis.

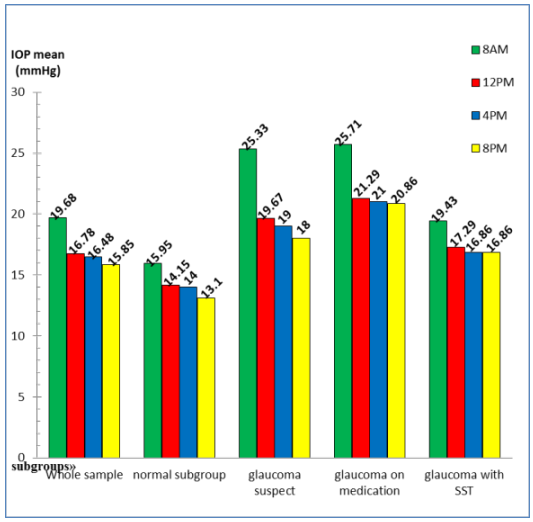

Figure 1: IOP values during the mDTC.

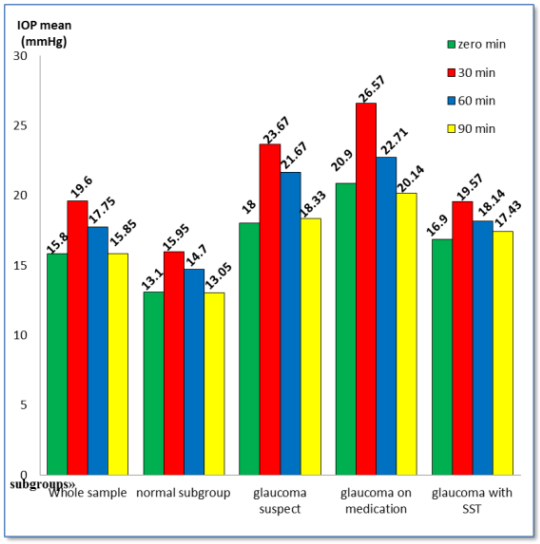

Figure 2: IOP values during WDT.

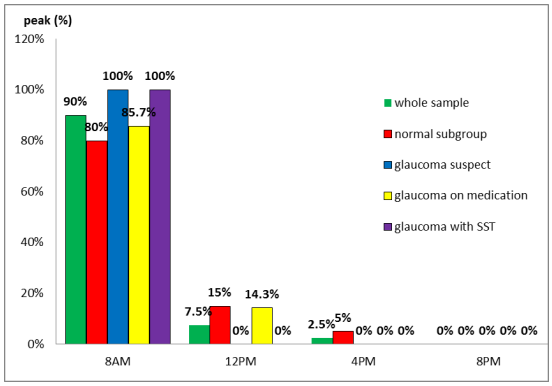

Figure 3: mDTC peak's frequency in relation to time.

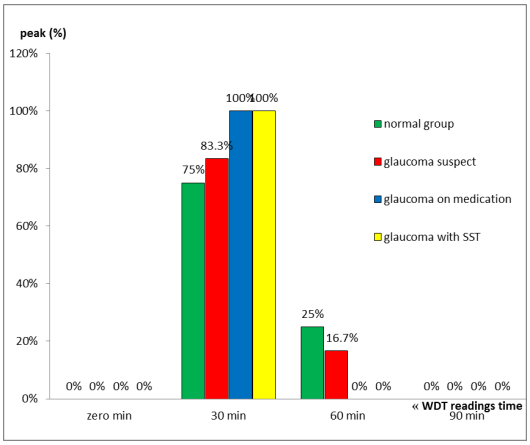

Figure 4: Peak's frequency in WDT readings.

mDTC readings time	Whole group	Normal subgroup	Glaucoma suspect	Glaucoma on medication	Glaucoma with SST
	Mean+SD (mmHg)	Mean+SD (mmHg)	Mean+SD (mmHg)	Mean+SD (mmHg)	Mean+SD (mmHg)
8 AM	19.68 ± 5.86	15.95 ± 2.92	25.33 ± 2.66	25.71 ± 7.20	19.43 ± 4.16
12 PM	16.78 ± 4.74	14.15 ± 2.18	19.67 ± 4.80	21.29 ± 6.58	17.29 ± 3.69
4 PM	16.48 ± 4.47	14..00 ± 2.17	19.00 ± 3.35	21.00 ± 6.63	16.86 ± 3.24
8 PM	15.85 ± 4.63	13.1 ± 2.30	18.00 ± 2.53	20.86 ± 6.96	16.86 ± 2.97

Table 2: Description of mDTC IOP readings (mean and SD) among different subgroups.

WDT Readings time	Whole group	Normal subgroup	Glaucoma suspect	Glaucoma on medication	Glaucoma with SST
	Mean +SD (mmHg)	Mean +SD (mmHg)	Mean +SD (mmHg)	Mean +SD (mmHg)	Mean +SD (mmHg)
Zero min.	15.85 ± 4.63	13.1 ± 2.29	18.00 ± 2.53	20.86 ± 6.96	16.86 ± 2.97
30 min.	19.6 ± 5.72	15.95 ± 2.92	23.67 ± 1.63	26.57 ± 7.02	19.57 ± 4.04
60 min.	17.75 ± 5.3	14.7 ± 2.58	21.67 ± 5.24	22.71 ± 7.14	18.14 ± 3.58
90 min.	15.85 ± 4.73	13.05 ± 2.56	18.33 ± 3.39	20.14 ± 6.96	17.43 ± 3.10

Table 3: Description of WDT readings (mean and SD) among different subgroups.

mDTC Reading time	Whole group [n (%)]	Normal subgroup [n (%)]	Glaucoma suspect [n (%)]	Glaucoma on medication [n (%)]	Glaucoma with SST [n (%)]
8 AM	36 (90%)	16 (80%)	6 (100%)	6 (85.7%)	7 (100%)
12 PM	3 (7.5%)	3 (15%)	0 (0%)	1 (14.3%)	0 (0%)
4 PM	1 (2.5%)	1 (5%)	0 (0%)	0 (0%)	0 (0%)
8 PM	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Table 4: Frequency and percent of peak IOP measured during (mDTC) in relation to time.

WDT readings time	Whole group [n (%)]	Normal group [n (%)]	Glaucoma suspect [n (%)]	Glaucoma on medication [n (%)]	Glaucoma with SST [n (%)]
Zero min.	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
30 min.	35 (87.5%)	15 (75%)	5 (83.3%)	7 (100%)	7 (100%)
60 min.	5 (12.5%)	5 (25%)	1(16.7%)	0 (0%)	0 (0%)
90 min.	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Table 5: Frequency and percent of peak IOP measured during WDT in relation to time.

Intraocular pressure values during the mDTC and WDT

The IOP values varied according to the time during the day. The highest mean of mDTC IOP readings was at 8:00 am; while the highest mean of WDT IOP readings was at 30 minutes.

Peak's frequency as regards the time of the day and WDT readings

Measurements of IOP for diurnal variation test showed that 90% of the participants had IOP peak at 8:00 am, while 7.5% was at 12:00 pm, 2.5% at 4:00 pm and none at 8:00 pm as shown in Table 4. Measurements of IOP for WDT showed that 87.5% of the participants had IOP peak after 30 minutes of drinking one liter of water, while 12.5% was after 60 minutes and none after 90 minutes. The data are presented in table 5 and Figures 3 and 4.

Correlation of mDTC peaks with WDT peaks

The water drinking test peaks were significantly correlated with the mDTC peaks (Figure 5), and there was no significant difference between the mean of mDTC and WDT peaks (Table 6). IOP fluctuation range varied according to the type of the subgroups; ranging from 1-4.5 mmHg in 95% of normal participants, 7-11 mmHg in 83.3% of glaucoma suspect subgroup. Glaucoma with SST subgroup showed a range of 1.5-5 mmHg at the same levels of normal subgroup. The range of glaucoma on medication subgroup (4-11 mmHg) was varied to occupy the area from normal subgroup levels to glaucoma suspect levels (Table 7).There were relatively similar results in the WDT fluctuation (Table 8), whereas 38 cases out of 40 (95%) showed a difference of ± 2 mmHg or less between the two methods (Table 9).

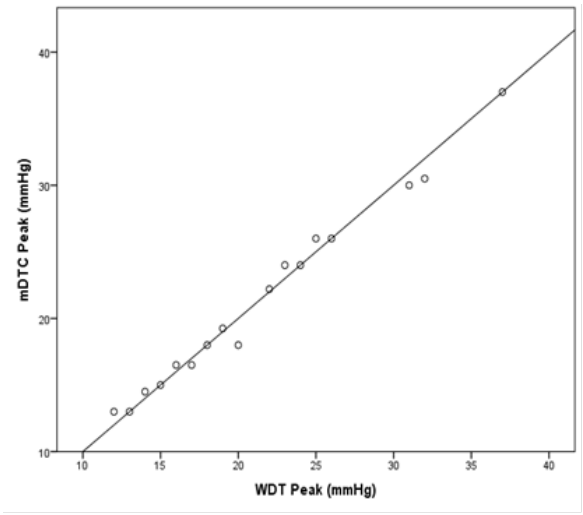

Figure 5: Correlation between IOP peaks during WDT and mDTC (whole sample). Pearson correlation Coefficient r=0.9; 95% confidence interval; p-value<0.001.

The WDT fluctuations were significantly correlated with the mDTC fluctuations (Figure 6), and there was no significant difference between the mean of mDTC and WDT fluctuations (Table 10). Since there were no peaks in the 90 minutes reading of WDT (Table 5 and Figure 4), a suggestion may be possible to compare the mDTC fluctuation with the amount of rise of the IOP during the first 60 minutes of WDT to reduce the time required to do the WDT. The 0-60 minutes IOP rise in WDT was significantly correlated with the mDTC fluctuations (Figure 7), as well there was no significant difference between the mean of mDTC and WDT fluctuations (Table 11).

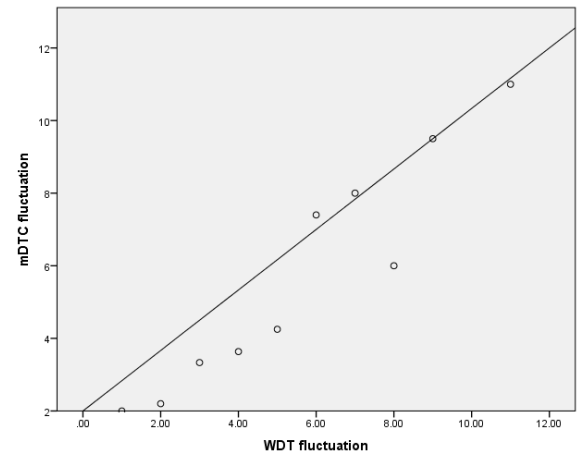

Figure 6: Correlation between IOP fluctuation during WDT and mDTC (whole group). Pearson correlation Coefficient r=0.835; 95% confidence interval; p-value<0.01.

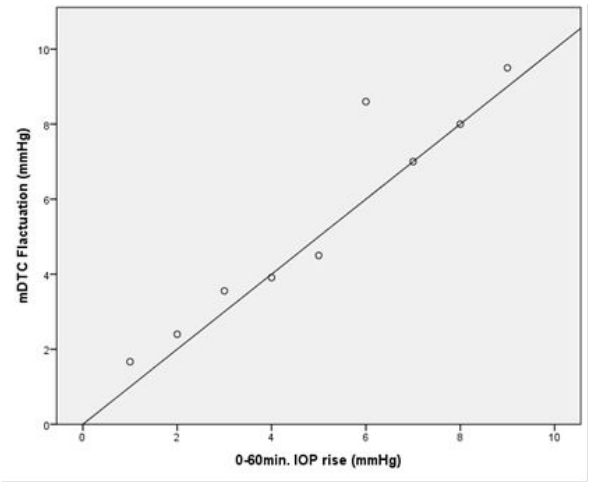

Figure 7: Correlation between mDTC fluctuations with 0-60 minute IOP rise (whole group). Coefficient r=0.856; 95% confidence interval; p-value<0.01.

Discussion

Glaucoma may progress even after IOP control has been achieved [5]. One hypothesis suggests IOP spikes as a cause, these are not detected by usual one time office measurements. Studies demonstrated that almost one third of patients with single IOP measurements taken at office hours had pressure peaks only detected by a 24-hour IOP curve [12].

This 24 hours fluctuation is likely to be caused by changes in aqueous flow rate, EVP, trabecular outflow, and other factors of these, the most important variables are aqueous flow rate and EVP. In glaucomatous eyes, the IOP fluctuation response to challenges such as the WDT probably differs from normal eyes; the abnormally low (pressure sensitive) trabecular outflow facility may result in both the peak and the duration of IOP elevation being prolonged. The mean range of IOP circadian fluctuation is between 3 mmHg and 6.5 mmHg, with a maximum reported range of 11 mmHg. Normal eyes (on average) are likely to have low pressure (recorded in the sitting position) in the night and have the highest pressures early in the morning, before decreasing gradually throughout the day. There is a nearly 70% chance of capturing the peak IOP between 08:00 and 16:00 [13].

The most obvious difference in diurnal IOP fluctuation between untreated glaucomatous eyes and eyes of normal subjects is the greater mean IOP range in the glaucomatous eyes [13,14].

The 24-hour measurement of IOP would be ideal to detect IOP peaks. However, time constraints and costs are major problems. Alternate methods are required to detect any IOP fluctuations and peaks, so the modified diurnal IOP measurement has become a common office practice because of its practicality [15].

	mDTC peak		WDT peak		Paired t-test	p-value
	Mean	SD	Mean	SD		
Normal subgroup	16.16	2.63	16.11	2.83	0.236	>0.05 (no significant difference)
Glaucomatous participants	23.65	5.53	23.65	5.79	0	>0.05 (no significant difference)
Whole sample	19.95	5.68	19.98	5.85	0.158	>0.05 (no significant difference)

Table 6: Comparison between IOP peak measured by mDTC and WDT for whole group and each subgroup separately.

Fluctuation of IOP (mmHg)	Normal subgroup		Glaucoma suspect		Glaucoma on medication		Glaucoma with SST	
	No. of pt.	(%)	No. of pt.	(%)	No. of pt.	(%)	No. of pt.	(%)
1.00	1	(5%)	0	(0%)	0	(0%)	0	(0%)
1.50	0	(0%)	0	(0%)	0	(0%)	1	(14.3%)
2.00	1	(5%)	0	(0%)	0	(0%)	3	(42.9%)
2.50	1	(5%)	0	(0%)	0	(0%)	1	(14.3%)
3.00	6	(30%)	0	(0%)	0	(0%)	0	(0%)
3.50	2	(10%)	0	(0%)	0	(0%)	0	(0%)
4.00	6	(30%)	0	(0%)	1	(14.3%)	1	(14.3%)
4.50	2	(10%)	0	(0%)	0	(0%)	0	(0%)
5.00	1	(5%)	0	(0%)	2	(28.5%)	1	(14.3%)
6.50	0	(0%)	1	(16.7%)	0	(0%)	0	(0%)
7.00	0	(0%)	2	(33.3%)	1	(14.3%)	0	(0%)
8.00	0	(0%)	2	(33.3%)	1	(14.3%)	0	(0%)
11.00	0	(0%)	1	(16.7%)	2	(28.5%)	0	(0%)
Range	1-5 mmHg		6.5-11 mmHg		4-11 mmHg		1.5 – 5 mmHg	

Table 7: The range of mDTC fluctuation in the different subgroups.

Fluctuation of IOP (mmHg)	Normal group		Glaucoma suspect		Glaucoma on medication		Glaucoma with SST	
	No. of pt.	(%)	No. of pt.	(%)	No. of pt.	(%)	No. of pt.	(%)
1.00	0	(0%)	0	(0%)	0	(0%)	1	(14.3%)
1.50	1	(5%)	0	(0%)	0	(0%)	1	(14.3%)
2.00	1	(5%)	0	(0%)	0	(0%)	1	(14.3%)
2.50	2	(10%)	0	(0%)	0	(0%)	0	(0%)
3.00	5	(25%)	0	(0%)	0	(0%)	1	(14.3%)
3.50	2	(10%)	0	(0%)	0	(0%)	1	(14.3%)
4.00	5	(25%)	0	(0%)	2	(28.5%)	1	(14.3%)
5.00	3	(15%)	0	(0%)	0	(0%)	1	(14.3%)
5.50	0	(0%)	0	(0%)	1	(14.3%)	0	(0%)

6.00	0	(0%)	2	(33.3%)	1	(14.3%)	0	(0%)
6.50	0	(0%)	1	(16.7%)	0	(0%)	0	(0%)
7.00	0	(0%)	1	(16.7%)	0	(0%)	0	(0%)
7.50	0	(0%)	1	(16.7%)	1	(14.3%)	0	(0%)
8.00	1	(5%)	0	(0%)	0	(0%)	0	(0%)
9.00	0		1	(16.7%)	1	(14.3%)	0	(0%)
11.00	0		0	(0%)	1	(14.3%)	0	(0%)
Range	1.5-8 mmHg		6-9 mmHg		4-11 mmHg		1-5 mmHg	

Table 8: The range of fluctuation in WDT in different subgroups.

Difference (mmHg)	Normal subgroup		Glaucoma suspect		Glaucoma on medication		Glaucoma with SST	
	No. of pt.	percent	No. of pt.	percent	No. of pt.	percent	No. of pt.	percent
0	4	(20%)	0	(0%)	2	(28.5%)	1	(14.3%)
± 0.5	5	(25%)	0	(0%)	2	(28.5%)	3	(42.8%)
± 1	7	(35%)	5	(83.3%)	2	(28.5%)	2	(28.5%)
± 1.5	2	(10%)	0	(0%)	0	(0%)	0	(0%)
± 2	1	(5%)	0	(0%)	1	(14.3%)	1	(14.3%)
-/+ 3.5	1	(5%)	0	(0%)	0	(0%)	0	(0%)
-/+ 4.5	0	(0%)	1	(16.7%)	0	(0%)	0	(0%)

Table 9: The difference of values of fluctuation between mDTC and WDT among different studied subgroups.

	mDTC fluctuation		WDT fluctuation		Paired t-test	p-value
	Mean	SD	Mean	SD		
Normal subgroup	3.4	0.94	3.7	1.42	1.1	>0.05 (no significant difference)
Glaucomatous participants	5.85	3.1	5.5	2.7	1.02	>0.05 (no significant difference)
Whole sample	4.63	2.57	4.6	2.32	0.111	>0.05 (no significant difference)

Table 10: Comparison between IOP fluctuation by mDTC and WDT for whole group and each subgroup separately.

	mDTC fluctuation		0-60 min. IOP rise		Paired t-test	p-value
	Mean	SD	Mean	SD		
Normal subgroup	3.4	0.94	3.1	0.97	1.83	>0.05 (no significant difference)
Glaucomatous participants	5.85	3.1	5.1	2.34	1.92	>0.05 (no significant difference)
Whole sample	4.63	2.6	4.1	2.04	2.48	>0.05 (no significant difference)

Table 11: Comparison between IOP fluctuation by mDTC and 0-60 min IOP rise for whole group and each subgroup separately.

The WDT was first described as a diagnostic test for glaucoma; a 6–8 mmHg rise in IOP was considered to confirm the diagnosis. It may reflect IOP fluctuations and peaks [16]. The current understanding of the physiology behind the WDT is incomplete; however, theories involving both inflow and outflow mechanisms have been proposed. The inflow theory postulates that changes in the blood ocular osmotic pressure gradient could lead to hydration of the vitreous and increased aqueous production, but this has not been confirmed [17]. The outflow

theory stipulates that water consumption leads to increased EVP, secondary to an increase in central and peripheral venous pressure, with resulting transient negative aqueous outflow [17]. This then would lead to increased IOP as a result of the reduced outflow facility from a decreased pressure gradient across the TM [7].

In this study, we tried to compare peaks and fluctuations of IOP collected from the mDTC with those collected from WDT. WDT was also assessed as a reliable test to perform at the office.

The highest mean of mDTC IOP readings in our results was in the morning (Table 2 and Figure 1), which was consistent with the results of other studies such as Liu et al. study which proved that the mean IOP was significantly higher in the late nocturnal period than in the diurnal/wake period for both the sitting and the supine IOP's [18]. Meanwhile, WDT readings showed that the highest mean of WDT readings was at 30 minutes readings (Table 3 and Figure 2) in a similar way to the results obtained by Kerr et al. [19].

The peaks of 90% of patients in mDTC were at 8:00 am (Table 4 and Figure 3) agreeing with Cheng and Sun study recently in 2015 [20]. In the WDT, the peaks of 87.5% of patients were at 30 minutes readings (Table 5 and Figure 4), so it could be possible to depend on the first two readings in the clinical practice when there is no time to complete the full test.

The WDT peaks were strongly correlated (p-value<0.001) with the mDTC peaks (Figure 5), beside that, there was no significant difference in paired t-test (p-value>0.05) between the mean of mDTC and WDT peaks (Table 6). That was similar to the results of a study of Kumar et al. which proved that peak IOP measured during diurnal testing showed strong correlation with peak IOP during WDT, and the mean peak IOP measured by diurnal testing was not statistically different from that measured by WDT [9].

Each subgroup in our sample had certain pattern as regards the range of IOP fluctuation of mDTC (Table 7). The glaucoma with SST subgroup had a range of fluctuation (1.5-5 mmHg) that was similar to normal subgroup range (1-5 mmHg) and both of them showed a range less than that of glaucoma on medications (4-11 mmHg), while the glaucoma suspect subgroup showed the highest range of IOP fluctuation (6.5-11 mmHg). These values were relatively similar to the WDT readings values (Table 8), when 95% of the participants showed a difference of ± 2 mmHg or less between the two methods (Table 9).

The WDT fluctuations were significantly correlated (p-value <0.01) with the mDTC fluctuations (Figure 6), while Kumar et al. study showed poor correlation [9]. The cause of this inconsistency may be due to the small size of our sample. Besides, there was no significant difference on t-test (p-value>0.05) between the mean of mDTC and WDT fluctuations (Table 11) agreeing with Kumar et al. study [9].

This study included surgically controlled glaucomatous patients who were not assessed in Kumar's study.

Since there were no peaks in the 90 minutes IOP reading of WDT at all (Table 5, Figure 4), a suggestion may be possible to compare the mDTC fluctuation with the amount of rise of the IOP during the first 60 minutes of WDT to reduce the time required to perform the test. That resulted in significant correlation between the 0-60 minutes IOP rise and the mDTC fluctuations (Figure 7), there was as well no significant difference between the mean of mDTC and WDT fluctuations (Table 11). Hence, a "modified" water drinking test can be suggested in the practice when the time is restricted, which means reducing the WDT into zero and 60 minutes readings only, to minimize the time required to do the test, and the times of using the tonometry.

It is important to consider the limitations of this study such as participant's cooperation for repeated measurements with Goldmann's applanation tonometry needing very cooperative people as well as the possible discomfort to drink large amount of water in a short period of time. Thus, further studies are needed to confirm our results in the different studied subgroups in a larger population.

The recently censored contact lenses to measure the IOP may be more accurate during the mDTC and even WDT instead of Goldmann's applanation tonometry, because of perfect repeated automated IOP readings. However this type of lenses are still not available in our community.

Conclusion

Intraocular pressure peaks and fluctuations detected during the water drinking test were strongly correlated to peaks and fluctuations observed during the modified diurnal tension curve. IOP peaks and fluctuations during WDT test could be used in clinical practice to estimate the peaks and fluctuations observed during the mDTC, and to reduce both the required time and needed effort in the currently used methods. The importance of this study is in the assessment of patho-physiology of diurnal fluctuation in IOP

References

1. Mansouri K, Weinreb R (2012) Continuous 24-hour intraocular pressure monitoring for glaucoma--time for a paradigm change. Swiss Med Wkly 142: w13545.
2. Barkana Y, Anis S, Liebmann J, Tello C, Ritch R (2006) Clinical utility of intraocular pressure monitoring outside of normal office hours in patients with glaucoma. Arch Ophthalmol 124: 793-797.
3. Asrani S, Zeimer R, Wilensky J, Gieser D, Vitale S, et al. (2000) Large diurnal fluctuations in intraocular pressure are an independent risk factor in patients with glaucoma. J Glaucoma 9: 134-142.
4. Vasconcelos-Moraes CG, Susanna R Jr (2008) Correlation between the water drinking test and modified diurnal tension curve in untreated glaucomatous eyes. Clinics (Sao Paulo) 63: 433-436.
5. Collaer N, Zeyen T, Caprioli J (2005) Sequential office pressure measurements in the management of glaucoma. J Glaucoma 14: 196-200.
6. Goldberg I, Clement CI (2010) The water drinking test. Am J Ophthalmol 150: 447-449.
7. De Moraes CG, Reis AS, Cavalcante AF, Sano ME, Susanna R Jr (2009) Choroidal expansion during the water drinking test. Graefes Arch Clin Exp Ophthalmol 247: 385-389.
8. Susanna R Jr, Hatanaka M, Vessani RM, Pinheiro A, Morita C (2006) Correlation of asymmetric glaucomatous visual field damage and water-drinking test response. Invest Ophthalmol Vis Sci 47: 641-644.
9. Kumar RS, de Guzman MH, Ong PY, Goldberg I (2008) Does peak intraocular pressure measured by water drinking test reflect peak circadian levels? A pilot study. Clin Experiment Ophthalmol 36: 312-315.
10. Susanna R Jr, Sheu WP, Latin American Glaucoma Society (2004) Comparison of latanoprost with fixed-combination dorzolamide and timolol in adult patients with elevated intraocular pressure: an eight week, randomized, open label, parallel-group, multicenter study in Latin America. Clin Ther 26: 755-768.
11. Susanna R Jr, Vessani RM, Sakata L, Zacarias LC, Hatanaka M (2005) The relation between intraocular pressure peak in the water drinking test and visual field progression in glaucoma. Br J Ophthalmol 89: 1298-1301.
12. Drance SM (1963) diurnal variation of intraocular pressure in treated glaucoma. Significance in patients with chronic simple glaucoma. Arch Ophthalmol 70: 302-311.

13. Kotecha A, Lim S, Garway-Heath D (2009) Tonometry and Intraocular Pressure Fluctuation. In: Shaarawy TM, Sherwood MB, Hitchings RA, Crowston J (eds) Glaucoma Medical Diagnosis & Therapy. (1stedn). Elsevier Saunders, China, pp: 103-113.
14. Kitazawa Y, Horie T (1975) Diurnal variation of intraocular pressure in primary open-angle glaucoma. Am J Ophthalmol 79: 557-566.
15. Zeimer RC, Wilensky JT, Gieser DK, Welch DB, Mori MT, et al. (1986) Application of a self-tonometer to home tonometry. Arch Ophthalmol 104: 49-53.
16. Roth JA (1974) Inadequate diagnostic value of the water-drinking test. Br J Ophthalmol 58: 55-61.
17. Diestelhorst M, Krieglstein GK (1994) The effect of the water-drinking test on aqueous humor dynamics in healthy volunteers. Graefes Arch Clin Exp Ophthalmol 232: 145-147.
18. Liu JH, Bouligny RP, Kripke DF, Weinreb RN (2003) Nocturnal elevation of intraocular pressure is detectable in the sitting position. Invest Ophthalmol Vis Sci 44: 4439-4442.
19. Kerr NM, Danesh-Meyer HV (2010) Understanding the mechanism of the water drinking test: the role of fluid challenge volume in patients with medically controlled primary open angle glaucoma. Clin Experiment Ophthalmol 38: 4-9.
20. Cheng J, Sun X (2015) Distribution of peak intraocular pressure in 24-hour and correlation between peak nocturnal intraocular pressure with diurnal intraocular pressure level in primary open angle glaucoma patients. Zhonghua Yan Ke Za Zhi 51: 103-108.