The Clinical Use of Diurnal Variation of Intraocular Pressures

A General Overview and Study Results

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March 17, 1989

In the United States, between 900,000 and 2,000,000 people suffer from glaucoma. The disease glaucoma is usually thought to consist of a combination of optic disc changes, visual field defects and high intraocular pressure. These signs of glaucoma result in severe visual impairment or legal blindness in 15% of the affected people. (1)

This paper gives a brief overview of the signs of glaucoma, concentrating on the effects of high intraocular pressure. More specifically, the diurnal variation of intraocular pressure will be reported on. The second half of the paper details the results of a study that I did. The study was a modified diurnal variation study in which the amount of variation in intraocular pressure in a day was compared to the peak pressure found that day.

Intraocular pressure (IOP) is the tissue pressure of the contents of the eye. The mean IOP is about 15 mm Hg. Like blood pressure, IOP does not fit a gaussian or bell curve but has a frequency peak at relatively low pressure and tails off to higher pressures. In other words, the pressure- frequency curve is skewed to the right. (2)

Signs of intraocular pressure that are signals of possible glaucoma include high IOP, abnormal difference of IOP between the two eyes, and abnormal variation of IOP with time.

There is a definite relationship between the level of the intraocular pressure and damages to the optic nerve head with resultant changes of the visual field in glaucoma. (3) If the IOP is high enough for a long enough period of time, the person will lose visual field in a characteristic pattern. However, disc cupping procedes visual field changes.

As the retinal ganglion cell nerve fibers leave the eye to become the optic nerve, they pass through the cribiform lamina in the sclera. Uusally a small cup is present at this position where the fibers leave. With an increase in IOP, this region tends to bow outward forming a larger cup. This is referred to as a cupped optic disc. The cupping is enhanced by actual loss of nerve fibers, glia cells, and capillaries producing pallor of the optic disc.

The effect of high intraocular pressure on visual field is to cause scotomas in the Bjerrum area arching from the blind spot over and under the point of fixation. With time, these scotomas enlarge and extend to the nasal horizontal meridian of the visual field where, if they do not match up, a nasal step is produced. The scotomas may broaden and eventually vision can be restricted to only a few degrees around the fixation point.

High intraocular pressure is almost always due to decreased aqueous outflow. IOP's in the 20 to 30 mm Hg range, referred to as ocular hypertension, over long periods may eventually cause field loss. By definition, ocular hypertension is a potentially damaging IOP with no detectable field loss. Most patients with IOP's between 21 and 30 mm Hg do not have visual field defects or significant optic disc changes. Very few will develop glaucomatous field loss. (4) In another study, it was noted that very few optic nerves were damaged by pressures of 24 to 30 mm Hg even over a period of ten years.(5) Phelps said that treatment of ocular hypertension to lower IOP and prevent visual field loss has not been proven to be clinically effective. (6)

Intraocular pressures in the teens may result in glaucomatous field loss. This is referred to as low tension glaucoma. By definition, low tension glaucoma is normal IOP with glaucomatous field loss. Armaly stated that 50% of the eyes that will develop glaucomatous damage will have intraocular pressure less than 20 mm Hg. (7) However, most experts feel that the greater the IOP, the greater the probability of glaucoma.

Although primary open- angle glaucoma is a bilateral condition, it generally appears in one eye before the other. A difference in the intraocular pressures between the two eyes of 3 mm Hg or more indicates a greater suspicion of glaucoma.

Intraocular pressure can vary due to many factors. There is a small seasonal variation. IOP is highest in the winter and lowest in the summer. Females have a slightly higher IOP than males; (about 0.7 mm Hg). IOP tends to increase with age, but this is largely due to the tendency of blood pressure to increase with age. Blood pressure and IOP are somewhat correlated. (8) IOP also varies throughout the course of the day. This is the diurnal variation.

Huguenin, using digital techniques in 1899, is believed to be the first to report a variation in intraocular pressure during the course of the day. Maslenikow confirmed that there is a diurnal variation of IOP by using an applanation tonometer in 1904. (9)

Several explanations have been put forward over the years as to the cause of diurnal variation of intraocular pressure. Some claimed it was the change in the size of the pupil throughout the day, eye and lid movements during the day as opposed to immobility during sleep, or changing body posture. However, variation persists after the use of miotics and mydriatics and after surgical relief in glaucoma. Sudden reversal of habits does not change the pattern of diurnal variation until a considerable period has elapsed. It is not caused by diurnal rhythms in the arterial pressure since these show variations different from ocular variations. (10)

It is now believed that diurnal variation is due principally to a variation in the rate of aqueous production, while the degree of resistance to outflow remains relatively constant. (11) Plasma cortisol levels seem to be important in determining the normal diurnal rhythm and it is probable that several hormonal influences affect directly or indirectly to keep both eyes at similar pressures. (12) Spontaneous diurnal variations of pressure usually run parallel in the two eyes. The amplitude of the fluctuation of the IOP between the two eyes may be different, but usually not the timing of the fluctuation. The variation in the rate of aqueous production in both eyes simultaneously must result from a systemic controlling influence reaching both eyes. (13)

In 1962, Duke- Elder described the types of diurnal variation curves found. First, he described a falling curve where the highest pressure is early in the morning, 4:00 to 6:00 A.M., and it slowly drops off. Second was a rising curve, where the peak occurs in the late afternoon between 4:00 and 6:00 p.m. Third was a double curve with one peak in the morning and one peak in the afternoon. He claimed that pressure is highest in the morning before getting out of bed in most patients. It falls in two steps: a sharp fall occurring soon after rising in the morning and a slow decrease until late in the evening. The pressure also rises in two steps during the night: a slow rise for the first six hours followed by a sharp rise increasing to a maximum before waking. (14) According to Spalton, peak pressures usually occur around midday and lower pressures result during sleep. (15)

Originally, high pressure in the morning was thought to be due to mydriasis during sleep in a darkened room causing drainage interference. However, Adler demonstrated that the eye is miotic during sleep. Also, the fluctuation is constant even if the person is in a lighted or darkened room for 24 hours.

Diurnal variation of intraocular pressures has been the subject of many studies in the past. Most of these studies have dealt with the question of what is a " normal" diurnal variation, and how much does the IOP have to vary to signal possible glaucoma. In a study by Drance in 1960, normal patients had an average diurnal variation of 3 to 4 mm Hg, while untreated primary open- angle glaucoma patients had a mean diurnal variation of 11 mm Hg. (16) Chandler wrote that in a normal patient, the IOP varies by not more than 2 to 3 mm Hg throughout the day and night. In the usual glaucoma patient, the pressure varies up and down in a diurnal pattern that seems to be an exaggeration of the slight variation detectable in normal eyes. He concluded by stating that in some glaucomatous patients, the pressure shows little variation and remains elevated at all times. (17)

With primary open- angle glaucoma, it is not unusual to observe a peak in the intraocular pressures at various times during the day. The type of curve in a glaucoma patient is not as important as the fact that the variation may be large and that the IOP may reach its maximum value at any time during the day or night. Diurnal variation of IOP also persists in the final stages of a glaucomatous eye after all vision has been lost.

A study was done by Kitazawa where the intraocular pressure was measured hourly for 24 hours in 40 patients in order to determine the diurnal variation. Twelve patients were classified as normal, 14 as ocular hypertensives, and 14 as having primary open- angle glaucoma. The patients with glaucoma had discontinued medications 96 hours prior to the study. On the average, the highest IOP was measured at 2:00 p.m. for normals, 1:00 to 2:00 p.m. for the ocular hypertensives, and at noon for the patiets with glaucoma. The lowest IOP was measured at 2:00 A.M. for normals, 4:00 A.M. for the ocular hypertensives, and 1:00 A.M. for the patients with glaucoma. The maximum pressure was usually measured between 10:00 A.M. and 6:00 p.m. in all of the groups. The lowest IOP was measured between 1:00 A.M. and 5:00 A.M. in all of the groups. On the average, the diurnal variation was 6.5 mm Hg +/- 0.28 with a maximum diurnal variation of 11 mm Hg for the normal group, 8.05 mm Hg +/- 0.50 with a maximum diurnal variation of 16 mm Hg in the ocular hypertensive group, and 15.8 mm Hg +/- 1.70 with a maximum diurnal variation of 34 mm Hg in the group with primary open- angle glaucoma. (18)

A study was done at the University of Illinois College of Medicine and the Wheaton Eye Clinic that involved 24 patients with primary open- angle glaucoma and intraocular pressures less than 22 mm Hg. They were instructed in the use of a self-tonometer and told to take five measurements daily of their IOP's between awakening and bedtime for three to six days. Typically, the patients showed a diurnal pattern that was repeated from day to day. The pressures were usually higher in the morning and lower in the evening. Several patients experienced their highest reading before 8:00 A.M. A few experienced their highest reading in the afternoon. Also, a few patients had a diurnal curve that showed no pattern but varied markedley from day to ady. (19)

A study by Smith of diurnal variation was performed on 400 eyes with visual field defects and 400 eyes without visual field defects. Goldmann tonometry was done every two hours from 5:00 A.M. to 3:00 p.m. Of the patients with visual field defects, 114 had their highest IOP from 5:00 A.M. to 7:00 A.M., and 136 had their highest IOP from 11:00 A.M. to 1:00 p.m. Of the patients without field defects, 148 had their highest IOP between 5:00 A.M. and 7:00 A.M., and 100 had their highest IOP between 11:00 A.M. and 1:00 p.m. Of the patients with field defects, 128 had their lowest IOP between 7:00 A.M. and 9:00 A.M., and 108 had their lowest IOP between 1:00 p.m. and 3:00 p.m. Of the patients without field defects, 128 had their lowest IOP between 7:00 A.M.

and 9:00 A.M., and 120 had their lowest IOP between 9:00 A.M. and 11:00 A.M. (20)

The purpose of my study was to determine whether it is practical for an optometrist to use diurnal variation as a means for diagnosing ocular hypertension and primary open- angle glaucoma versus a normal patient in the office setting. I tried to do so by showing that the diurnal variation increased in proportion to the mean intraocular pressure. I wanted to prove my results with only two pressure readings on a patient in a single day. I do not feel it is realistic that an optometrist can measure the IOP's of a patient every two hours for a complete day unless the patient is very cooperative.

The sample for the study included 24 patients who ranged in age from ten to 64. There were 13 females and 11 males in the study. Since most of the previous studies on diurnal variation showed that the highest intraocular pressure reading occurred in the morning, the first IOP reading on each patient in the study took place between 8:00 A.M. and 9:00 A.M. This hour also correlates with the hour that most optometry offices open in the morning. The second IOP reading on each patient took place between 4:00 p.m. and 5:00 p.m. of the same day. The pressure readings were collected by using a Goldmann applanation tonometer.

RESULTS:

Of the 17 patients in the study who had their highest measured pressure under 20 mm Hg, the mean diurnal variation between the two readings was 2.75 mm Hg. Ten of these 17 patients had no clinically significant change in their pressures.

Of the seven patients with their highest measured pressure between 20 mm Hg and 30 mm Hg, the mean diurnal variation was 3.75 mm Hg. However, only considering the five patients with IOP's measured from 24 mm Hg to 30 mm Hg, the mean diurnal variation between the two readings jumped to 5.29 mm Hg.

Only two of the patients in the study of those who registered clinically significant variations had their higher of the two pressure readings in the afternoon.

DISCUSSION:

The results of the study show the trend that the diurnal variation of the intraocular pressures did increase in proportion to the mean intraocular pressure. This trend is similar to the results shown by Kitazawa. However, the values of the diurnal variations that I found were not as great as those found by Kitazawa.

Can I conclude positively from my study that diurnal variation does increase as the mean intraocular pressure increases? Probably not, although the results are favorable. Being limited by size, this study does not lend itself well to conclusive statistical analysis. It is obvious, though, that diurnal variation is an important factor when measuring intraocular pressures. It is important to keep in mind the time of day that a reading is taken and to record this time. That way, the optometrist can use the proven trends of diurnal variation to better predict the patient's diagnosis and prognosis.

SUMMARY:

The level of the intraocular pressure is basic to the diagnosis of glaucoma. However, a single measurement of IOP may fail to demonstrate an elevated IOP due to the variation in pressure which occurs during the 24 hour day. A single measurement in the usual office setting may well miss the peak IOP on many people. Eskridge feels that the first clinical evidence of primary open- angle glaucoma is a greater than average diurnal variation in IOP. He says a diurnal variation greater than 7 mm Hg is an indication of possible glaucoma. (21) Therefore, there is a need for frequent and repeated intraocular pressure measurements.

STUDY RESULTS

Patient	Age	Sex	A.M. Reading in mm Hg		P.M. Reading in mm Hg	
			OD	OS	OD	OS
1	10	F	21	19	19	19
2	34	F	25	23	22	20
3	23	M	17	17	17	16
4	22	F	18	19	17	16
5	25	F	11	13	10	12
6	23	F	12	13	12	13
7	37	M	17	16	13	13
8	32	M	16	15	12	13
9	23	M	17	18	16	17
10	24	F	15	14	14	14
11	22	F	18	18	15	15
12	23	M	13	11	12	12
13	24	M	13	13	15	13
14	23	F	10	9	9	10
15	25	M	10	10	12	10
16	24	M	13	13	13	14
17	39	F	21	22	20	22
18	43	M	14	14	12	11
19	52	F	18	19	15	15
20	40	F	17	16	14	15
21	64	F	28	30	22	22
22	61	M	15	18	18	24
23	49	F	24	20	22	18
24	60	M	20	22	26	28

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