Increase of Peak Intraocular Pressure During Sleep in Reproduced Diurnal Changes by Posture
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Objective: To characterize diurnal intraocular pressure (IOP) changes in primary open-angle glaucoma by reproducing IOPs based on patient posture.

Methods: In 148 patients with untreated primary open-angle glaucoma who had IOPs recorded during clinic hours that were less than 21 mm Hg (average, 14.8±3.2 mm Hg), we measured IOP by noncontact tonometry every 2 hours from 6 AM to midnight and every 3 hours from midnight to 6 AM with patients sitting and supine. The IOP was reproduced by designating the sitting IOP as measurements taken when the patient was awake and the supine IOP as measurements taken when the patient was asleep for each individual. The reproduced diurnal IOP was composed of 12 measurements that included 2 to 4 IOP levels measured with the patients supine and the rest while they were sitting.

Results: The peak of sitting diurnal IOP (mean±SD) for 148 patients was 16.0±2.7 mm Hg, which was significantly lower than the peak of supine IOP (18.9±3.9 mm Hg) or the reproduced IOP (17.5±3.6 mm Hg) (P<.001 for both comparisons). The average reproduced IOP at each measurement time peaked at 3 AM during sleep; with sitting diurnal IOP or supine diurnal IOP, the peak IOPs were at noon. Twenty-nine patients (20%) with an IOP less than 21 mm Hg during clinic hours had a reproduced IOP of 21 mm Hg or greater while asleep, compared with only 5 patients (3%) when the patients were sitting only.

Conclusions: In patients with primary open-angle glaucoma and IOPs less than 21 mm Hg during clinic hours, 20% of patients had a reproduced IOP of 21 mm Hg or greater, compared with only 3% who had an IOP of 21 mm Hg or greater while sitting. Intraocular pressures peaked in most patients during sleep.
reproduced the 24-hour diurnal IOP of patients by choosing the sitting IOP for the period when they were awake and by choosing the supine IOP for the period of sleep. We believe that this reproduced diurnal IOP is of importance when treating patients with glaucoma.

METHODS

Our study adhered to the tenets of the Declaration of Helsinki, and approval of the study was obtained from the institutional review board of Hara Eye Hospital, Utsunomiya, Japan. All patients received a detailed explanation of the study, including the necessity for an examination, after which they provided written informed consent.

In our hospital, we measured the diurnal IOP levels of 431 patients with glaucoma who attended the Hara Eye Hospital from May 7, 2001, to September 30, 2003. The study included 148 eyes of 148 patients with untreated primary open-angle glaucoma (POAG) who had IOPs recorded during clinic hours that were less than 21 mm Hg.

The criteria for a diagnosis of glaucoma were a normal open angle; a glaucomatous optic disc with excavation, a rim defect, hemorrhage, notching, a nerve fiber layer defect, and a vertical cup-disc ratio of 0.7 or more; and visual field defects corresponding to glaucomatous optic disc damage. Patients were excluded if the untreated IOP measured during normal clinic hours (10AM to 10PM; midnight; 3, 6, 8, and 10AM; and noon the following day) was greater than 21 mm Hg.

Finally, patients were excluded if they had another ocular or systemic disease that could damage the optic disc; if they were taking corticosteroids, which can increase IOP; or if they had undergone a previous ocular surgery. We also excluded those patients who had corneal abnormalities resulting from refractive surgery.

The patient ages ranged from 18 to 86 years (mean ± SD age, 59.9±15.1 years). All were hospitalized in a private room to undergo all 12 IOP measurements. All patients maintained their normal sleep/wake schedule without hospital restrictions. For example, we confirmed with each patient the time he or she went to bed and the time he or she arose. Because of this confirmation, 12 measurement time points can be classified on the basis of whether each patient was awake or asleep.

We measured the IOP levels in both eyes of all 148 patients and included the IOP value of the left eye of each patient in the study.

After measurement of the diurnal IOP changes while sitting and supine, each patient had 3 different diurnal IOP values: the sitting diurnal IOP, the supine diurnal IOP, and the reproduced diurnal IOP change, which was based on the combined readings from the 2 positions. The average, the peak, and the fluctuation of each diurnal IOP change were analyzed.

The difference in the IOP values obtained with the patient sitting and supine at each measurement time was analyzed by the paired t test. The difference was considered significant at P<.01.

We also analyzed the time at which the peak IOP value was recorded for the sitting diurnal IOP and the reproduced diurnal IOP.

RESULTS

We found no significant change in IOP values between the left and the right eyes of each patient (P=.52, paired t test).

The average, peak, and fluctuation of the 3 diurnal IOP values obtained for sitting diurnal IOP, supine diurnal IOP (Figure 1), and reproduced diurnal IOP from the combined values of both postures (Figure 2) for the 148 eyes are shown in the Table.

For sitting diurnal IOP, the average 24-hour IOP ranged from 8.2 to 19.3 mm Hg (mean±SD, 13.9±2.5 mm Hg), the peak ranged from 10.0 to 23.0 mm Hg (mean±SD, 16.0±2.7 mm Hg), and the fluctuation ranged from 2.0 to 7.7 mm Hg (mean±SD, 4.1±1.3 mm Hg). For supine diurnal IOP, the average 24-hour IOP ranged from 8.1 to 23.0 mm Hg (mean±SD, 15.4±3.2 mm Hg, P<.001), the peak ranged from 10.0 to 29.0 mm Hg (mean±SD, 18.9±3.9 mm Hg, P<.001), and the fluctuation ranged...
from 2.0 to 16.3 mm Hg (mean ± SD, 6.4 ± 2.5 mm Hg, P < .001). There was a significant difference between the sitting and supine IOP values at each measurement.

For the reproduced diurnal IOP changes, the average reproduced 24-hour IOP ranged from 8.0 to 19.8 mm Hg (mean ± SD, 14.3 ± 2.6 mm Hg, P < .001), the peak ranged from 10.0 to 29.0 mm Hg (mean ± SD, 17.5 ± 3.6 mm Hg, P < .001), and the fluctuation ranged from 2.0 to 17.3 mm Hg (mean ± SD, 5.7 ± 3.6 mm Hg, P < .001). There was a significant difference in the average, peak, and fluctuation of the 24-hour IOP values between the sitting IOP and the reproduced IOP.

The measurement times at which the peak sitting IOP was recorded for each patient were distributed throughout the day and night (Figure 3), but the reproduced diurnal IOP tended to be high at midnight and at 3 and 6 AM (Figure 4). In this study, 29 eyes (20%) had a reproduced IOP of 21 mm Hg or greater compared with only 5 eyes (3%) with an IOP of 21 mm Hg or greater when the patients were sitting only. All of the 29 eyes had IOPs that peaked during sleep.

In the latest prevalence study from Japan, the prevalence of POAG, the most common type of glaucoma, was reported to be 3.9% in the population older than 40 years, and the IOP levels of most (92%) of these patients were 21 mm Hg or less.

For practical purposes, the IOP obtained during daily clinic hours is used as the standard for the treatment of patients with glaucoma; however, it is well known that there are diurnal changes in IOP levels in humans. Great IOP fluctuations across 24 hours have been reported to increase the risk of progression of visual field loss. Therefore, the diurnal peak and trough IOPs and the fluctuations during 24 hours are important considerations in the treatment of glaucoma. To reduce the fluctuations that occur in 24 hours, it is important to determine the value and measurement time of the peak IOP. In most previous reports, the diurnal IOP was measured only with the patient sitting, which we believe to be insufficient when determining diurnal IOP changes. It is important to also include the supine IOP value because the IOP measured with the patient sitting and that measured with the patient supine differ within the same individual. Therefore, we are convinced that diurnal IOP changes should be reproduced with consideration for the posture of the patients.

In this study, we used a noncontact tonometer because of the possibility that the anterior corneal epithelium could be injured after 24 measurements with a contact applanation tonometer. To obtain the correct IOP,
Yamagami et al2 reported that in 114 patients with POAG, the peak occurred at 3 AM and the trough at 8 PM in the averaged data from all subjects. In all 148 patients, the times at which the peak IOP was recorded were scattered equally across 24 hours when the patients were sitting only, but the peak IOPs were concentrated during sleep for the reproduced IOP.

The onset and duration of sleep varied among the patients. All subjects were asleep at 3 AM and most of the patients were asleep at midnight and 6 AM (Figure 5).

In this study, the reproduced diurnal IOP was composed of 12 measurements that included 2 to 4 IOP levels measured with the patients supine and the rest while they were sitting. We found significant differences in the average and peak IOPs and in the fluctuations in IOP values across 24 hours between the reproduced IOP and the IOP measured when the patients were sitting. As a result, when 2 to 4 IOP values were changed from the sitting IOP measurement to the supine IOP measurement, the IOP values were significantly different. This indicated that the IOP measured with the patients supine while asleep played an important role.

In this study, the average peak IOP was 16.0 mm Hg while the patient was sitting, 18.9 mm Hg while the patient was supine, and 17.5 mm Hg when the value was based on the combined measurements from both postures. In the data obtained from each patient, the times at which the peak IOP was recorded were distributed across the 24 hours when the patients were sitting only, but the peak reproduced IOPs tended to be concentrated at night. More than 10% of the patients whose IOP was less than 21 mm Hg during clinic hours when sitting only had a reproduced IOP that was 21 mm Hg or higher. These results should be considered when setting the target IOP in patients with POAG and represent one of the most important factors for controlling IOP and for treating glaucoma.

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REFERENCES