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.

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D IURNAL VARIATIONS IN INTRAOCULAR PRESSURE (IOP) are important for the treatment of glaucoma. However, in most reports, the diurnal changes in IOP have been measured only while the patients were sitting.1-7 Intraocular pressure levels have been reported to differ in the same individual (healthy individuals and those with glaucoma) when measured with the patient sitting or supine, and IOPs have been reported to be higher with the patient supine than when sitting.8,14 While awake, individuals usually are either standing or sitting, and during sleep one third or one quarter of the day is spent supine.

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In studies of healthy individuals and those with glaucoma, IOP measurements have been reported to be higher when subjects were supine compared with sitting. Liu et al9-11 measured IOP levels with individuals sitting and supine while awake (sitting or standing) and when supine while sleeping, and reported that most subjects had a peak IOP around midnight or in the early morning when supine.

In our clinic, we measured the diurnal changes in IOP in patients with glaucoma who were sitting and supine at all measurement points. On the basis of these data, we...
reproduced the 24-hour diurnal IOP of patients by choosing the sitting IOP for the period when they were awake and 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 they were under 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.

The patient ages ranged from 18 to 86 years (mean ± SD, 59.9 ± 15.1 years). All were hospitalized in a private room to undergo all IOP measurements. All patients maintained their normal sleep/wake schedule without hospital restrictions. For example, between 9 PM and 6 AM, use of an indoor reading light by the patients was permitted after the hospital lights were turned off.

The IOP measurements were recorded at noon; 2, 4, 6, 8, and 10 PM; midnight; 3, 6, 8, and 10 AM; and noon the following day. The IOP was measured with a mobile noncontact tonometer (PULSAIR 2000; Keeler Co, Windsor, England). The patients assumed the supine position and remained so for 30 minutes while the IOP was measured. The nighttime IOP level with the patient supine and asleep was measured under a dim red light; the patient then was awakened and allowed to relax for 30 minutes, and the IOP was measured with the patient sitting on the bed. The measurement was calculated 3 times and averaged if the difference in the IOP measurements was 3 mm Hg or less. When the difference was greater than 3 mm Hg, the IOP was measured until the difference in the 3 consecutive values was 3 mm Hg or less.

The IOP of the patients was measured 12 times over the course of 24 hours. The diurnal IOP was the result of 12 IOPs that were measured at each time point. At each measurement time point, there are 2 types of IOP values: one is the IOP measured with the patient sitting, and the other is the IOP measured with the patient supine. Sitting diurnal IOP indicates all 12 IOPs measured while the patient was sitting. Supine diurnal IOP indicates all 12 IOPs measured with the patient supine. At the time of hospitalization, 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. By using these data, we made a new diurnal IOP change, reproduced diurnal IOP, that considered each patient’s posture. In the reproduced diurnal IOP, if the measurement point belonged to the period when the patient was awake, the sitting IOP was selected as the IOP value representative of that time. If the measurement point belonged to the period during sleep, the supine IOP was selected as the IOP representative of that time.

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 (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

![Figure 1. Diurnal intraocular pressure (IOP) changes when measured with the patients sitting or supine, presented as mean±SD. There is a significant (P<.001) difference between the sitting IOP and the supine IOP at all measurements. In the averaged IOP data obtained from 148 patients, the peak IOP was recorded at noon while patients were sitting only or supine only.](https://jamanetwork.com/ by a Non-Human Traffic (NHT) User on 12/13/2019)
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.

### Table. Average, Peak, and Fluctuation of 3 Diurnal IOP Values Obtained With Patients Sitting Only and Supine Only, and Reproduced From Combined Measurements From Both Postures

<table>
<thead>
<tr>
<th>IOP, Mean ± SD, mm Hg</th>
<th>Average</th>
<th>Peak</th>
<th>Fluctuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting</td>
<td>13.9 ± 2.5</td>
<td>16.0 ± 2.7</td>
<td>4.1 ± 1.3</td>
</tr>
<tr>
<td>Supine</td>
<td>15.4 ± 3.2*</td>
<td>18.9 ± 3.9*</td>
<td>6.4 ± 2.5*</td>
</tr>
<tr>
<td>Reproduced</td>
<td>14.3 ± 2.6*</td>
<td>17.5 ± 3.6*</td>
<td>5.7 ± 3.6*</td>
</tr>
</tbody>
</table>

Abbreviation: IOP, intraocular pressure.

*Indicates a significant ($P<.001$) difference from the values obtained while the patients were sitting.

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,
the measurement was calculated 3 times and averaged if the difference in the IOP measurements was ≤ 3 mm Hg or less. As a result, in most cases, there were few deviations or fluctuations from the measured IOP values at any measurement time.

In the averaged IOP data obtained from all 148 patients while sitting only, the peak IOP was recorded at 10 AM and the trough IOP was recorded at 10 PM (Figure 1). In a previous study of Japanese patients with glaucoma, Yamagami et al. reported that in 114 patients with POAG, the average IOP was 14.1 mm Hg. In that study, the peak IOP was recorded during regular clinic hours rather than at night, and most peak IOP values were measured at 10 AM. Many diurnal IOP studies have reported that the IOP tended to be high during daytime clinic hours and low at night. This tendency was observed in the measurements obtained with the patients in a single position.

In our study, the same tendency was observed when the patients were sitting only or supine only. However, in our reproduced diurnal IOP, which was based on the combined values from both postures, 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