Original Article

Effect of cataract surgery on intraocular pressure in supine and lateral decubitus body postures

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Purpose: To investigate the effect of phacoemulsification on intraocular pressure (IOP) in different recumbent body postures including supine and lateral decubitus (LD) positions. **Materials and Methods:** This prospective, observational study included patients who had no glaucoma and who had planned to undergo phacoemulsification and intraocular lens implantation in one eye. Before and 1 month after cataract surgery, IOP was measured in both eyes using the Tono-Pen AVIA. We measured IOP in the sitting, supine, and LD (with the operated eye placed on the lower side) positions. IOP was measured 10 min after assuming each position in a randomized sequence. The Wilcoxon signed-rank test was used to compare the IOP changes before and 1 month after phacoemulsification in all postures. **Results:** Twenty-nine patients participated in this study. Postoperative IOP was lower than the preoperative IOP when measured by Goldmann applanation tonometry in the sitting position (13.8 ± 1.9 mmHg vs. 12.6 ± 2.1 mmHg, $P = 0.007$). The postoperative IOP was lower than the preoperative IOP for the supine and LD positions. The average IOP reduction of the operated eye was 0.6 mmHg, 1.7 mmHg, and 3.0 mmHg in the sitting, supine, and LD positions, respectively (sitting vs. supine, $P = 0.048$; sitting vs. LD, $P = 0.001$; supine vs. LD, $P = 0.028$). In the nonoperated eye, IOP did not change significantly after surgery (all $P > 0.05$). **Conclusions:** Cataract surgery lowered IOP in the sitting position as well as in the supine and LD positions. Such postoperative IOP reductions were greater in the recumbent positions than in the sitting position.

Key words: Cataract, intraocular pressure, lateral decubitus position, phacoemulsification, posture

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Cataract and glaucoma are the leading causes of blindness worldwide.[1] Since increased age is a major risk factor for both of these entities, many glaucoma patients often have concurrent cataract. Furthermore, long-term use of glaucoma medications and filtering surgery has been shown to facilitate the early development of cataract in glaucomatous eyes.[2,3]

The current treatment for cataract is surgical removal of the cataractous lens, whereas the mainstay of glaucoma treatment is the lowering of intraocular pressure (IOP) by means of medications, laser, or surgery.[4] In terms of IOP reduction, glaucoma filtering surgery has often been shown to be superior to medication or laser treatment; however, among these therapeutic options, medication is usually the first choice because the surgical means may lead to complications that may threaten visual function.[5] Thus, glaucoma surgery is generally deferred until the nonsurgical means fail to lower the IOP sufficiently enough to prevent the progression of glaucomatous optic neuropathy.[6]

In addition to the vision-improving effects obtained by elimination of the media opacity, cataract surgery has been shown to provide modest IOP-lowering effects in eyes with or without glaucoma.[7-10] Moreover, Kim *et al*.[11] demonstrated that the mean IOP decreased without significant change in diurnal IOP fluctuation after phacoemulsification in nonglaucomatous eyes. Some researchers proposed cataract surgery as a therapeutic option for glaucoma.[7,12,13] However, IOP measurements in most of the previous studies had been obtained in the sitting position. Therefore, they may not reflect the IOP changes induced by postural alterations that may occur outside standard office hours.

Various factors have been found to be associated with cyclic IOP fluctuations, including diurnal cardiac rhythms, aqueous production, and different body postures.[14,15] More recent studies have taken into account the postural variations in IOP and showed elevations of IOP with habitual body postures such as supine or lateral decubitus (LD) position.[16-19] Such posture-induced IOP rises have been associated with severity of glaucomatous optic neuropathy as well as with progression of glaucoma.[18-21]

What is not currently known is whether cataract surgery has an effect on the IOP change with recumbent postures. The present study compared the effects of phacoemulsification on IOP in the sitting, supine, and LD positions. The results may enlighten us about the additional effect of cataract surgery on IOP control in the recumbent positions.

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Materials and Methods

This is a prospective, observational study approved by the Institutional Review Board, and the study was conducted according to the tenets of the Declaration of Helsinki. Informed consent was obtained from individuals before study enrollment.

Patients who were scheduled to undergo unilateral phacoemulsification were included in this study. All individuals were older than 40 years. They underwent comprehensive ophthalmic examinations of both eyes. Axial length (AL) and anterior chamber depth (ACD) were measured using an IOLMaster (Carl Zeiss Meditec, Jena, Germany). Central corneal thickness (CCT) was measured using a specular microscope SP-2000P (Topcon, Tokyo, Japan).

Individuals were excluded if they met any of the following criteria: (1) Preoperative IOP >20 mmHg; (2) trabecular meshwork invisible in any quadrant on static gonioscopy; (3) refractive error exceeding 6 diopters (D) spherical equivalent or 3 D of astigmatism; (4) history of ocular disease or trauma; (5) previous ocular surgery except uncomplicated cataract surgery of the contralateral eye; or (6) glaucomatous optic disc changes such as excavation, thinning or notching of the neuroretinal rim, or disc hemorrhages. Individuals were excluded from the analysis if they had surgical complications during or after phacoemulsification, such as posterior capsular rupture, intraocular lens (IOL) placement in the ciliary sulcus, or postoperative IOP spike. Unexpected cataract surgery of the contralateral eye within 1 month was also considered a reason for exclusion.

Patients were treated with topical 0.5% levofloxacin and 0.1% diclofenac sodium for four times a day starting 3 days before surgery. Surgery was performed by a single surgeon at a single surgical center from May 2014 to September 2014. After making a 2.2-mm incision in the temporal clear cornea, phacoemulsification was performed. A single-piece acrylic foldable posterior chamber IOL was implanted in the capsular bag in all cases. Then, the ophthalmic viscoelastic agent was removed and the incision site was closed by stromal hydration with no suture. All patients received topical 0.5% levofloxacin and 1% prednisolone acetate for 4 weeks.

A single observer measured IOP using a single Tono-Pen AVIA (Reichert Inc., Depew, NY, USA) in both eyes. IOP readings were always obtained after calibration of the Tono-Pen and in the right eye first. The IOP value for each posture was the mean of two consecutive measurements that were within 2 mmHg and that had <5% error as indicated on the Tono-Pen or the median of three measurements if the first two differed by 3 mmHg or more.

The patients underwent IOP measurements in different body postures from 7 to 11 a.m. on the day of surgery. To assign a randomized sequence of IOP measurements in different body postures (sitting, supine, or LD), every patient was asked to pick up one card, where a different body posture was written on the back, one after another until all the three cards were opened.

First, each patient was asked to sit on a chair under dim light conditions and undergo IOP measurement with a Goldmann applanation tonometer (GAT). Then, the patient was asked to assume and maintain each of the body postures in the randomized sequence predetermined in an aforementioned manner. We measured IOP 10 min after adopting each posture. All participants rested their head on a soft pillow to keep the head parallel to the bed and they were instructed to neither turn their heads nor bury their eyes into the pillow. The aforementioned process of IOP measurements was repeated 1 month after phacoemulsification surgery.

Statistics

A pilot study revealed that the standard deviation (SD) of the IOP reduction after cataract surgery of the operated eye was 2.8 mmHg in LD position (2.4 mmHg for supine position and 1.8 mmHg for sitting position). A sample size calculation, using G*Power software (version 3.0.10; Universität Kiel Dusseldorf, Germany) with $\alpha = 0.05$, determined that 28 patients would be required to detect an IOP difference of >1.6 mmHg in the operated eye at an SD of 2.8 mmHg with a power of 80%. Accounting for the loss of follow-up to be about 20%, we estimated a final sample of 35 patients in this study.

All statistical analyses were performed using SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). Wilcoxon signed-rank test was used to compare IOP changes after cataract surgery in different body postures. The amount of IOP changes after surgery with different body postures was compared using the Friedman test. We performed Spearman's correlation analysis to evaluate the relationship between IOP change and ocular biometric parameters, with the change of IOP as a dependent parameter and the ocular biometric parameters as independent parameters. *P* values were considered statistically significant at values <0.05 unless the Bonferroni correction method for multiple comparisons was used, in which case a $P < 0.017$ was considered statistically significant.

Results

Of the 35 patients recruited in this study, 5 patients were excluded due to loss to follow-up and one patient was excluded due to unanticipated phacoemulsification of the contralateral eye within 1 month. Twenty-nine patients remained in the study for data analysis. Sixteen patients were male and 13 were female, with a mean age of 64.2 ± 9.1 years (range: 50–83). Patient characteristics are summarized in Table 1.

Table 2 lists the IOP measurements obtained in the different body postures and shows the statistical differences of IOP changes before and after cataract surgery. For the operated eye, all IOPs measured in different body postures showed significant reduction after phacoemulsification ($P < 0.01$), except the IOP measured by Tono-Pen in the sitting position ($P = 0.266$). However, the amount of postoperative IOP change measured by Tono-Pen in the sitting position was significantly different between the operated and the nonoperated eyes (−0.6 ± 2.5 mmHg vs. 0.5 ± 2.2 mmHg, $P = 0.045$). Neither significant difference was found for the nonoperated eye in the sitting position ($P = 0.253$) nor in the recumbent positions. The amount of IOP reduction in the operated eye was significantly different among the various body postures ($P < 0.001$, Friedman test). Although these differences were not always significant in each pair of comparisons with Bonferroni correction, in which case a $P < 0.017$ was considered statistically significant, the amount of IOP reduction was significantly larger in LD position than that in sitting position (sitting vs. supine, $P = 0.048$; sitting vs. LD, $P = 0.001$; supine vs. LD, $P = 0.028$).

The mean postoperative IOP reduction in the operated eye was 3.0 ± 3.5 mmHg in the LD position, 1.7 ± 2.5 mmHg in the supine position, and 0.6 ± 2.5 mmHg in the sitting position.

When compared between the preoperative and postoperative measurements, the posture-induced IOP elevations obtained by changing from the sitting to the supine or LD position were significantly reduced after the surgery [Table 3]. Before the surgery, IOP was higher (+2.0 ± 1.8 mmHg) in the supine position than in the sitting position. However, after the surgery, this posture-induced IOP elevation was reduced to 0.8 ± 2.0 mmHg (P = 0.048). Such perioperative reduction in IOP rise was also noted for changing body posture from the supine to the LD position (P = 0.028).

Table 4 shows the Spearman's correlation analysis performed to evaluate the association between ocular biometric parameters and IOP reduction. Higher preoperative IOP was correlated with larger IOP reduction after phacoemulsification in every body posture. Furthermore, the IOP difference in the LD position showed the strongest correlation coefficient (Spearman's rho = −0.730) [Fig. 1]. However, preoperative ACD, AL, CCT, and body mass index did not correlate with the IOP differences in the supine and LD positions.

Table 1: Baseline demographics of the patients who underwent phacoemulsification

Demographics	Value
Age (year)	
Mean±SD (range)	64.24±9.11 (50-83)
Gender (%)	
Male	16 (55.2)
Female	13 (44.8)
Eye (%)	
Right	14 (48.3)
Left	15 (51.7)
Preoperative IOP by GAT (mean±SD, mmHg)	13.8±1.9
AL (mean±SD, mm)	23.53±1.03
ACD (mean±SD, mm)	3.34±0.48
CCT (mean±SD, µm)	538.86±34.88
BMI (mean±SD, kg/m²)	23.39±2.90

IOP: Intraocular pressure, GAT: Goldmann applanation tonometer, AL: Axial length, ACD: Anterior chamber depth, CCT: Central corneal thickness, BMI: Body mass index, SD: Standard deviation

Discussion

A number of previous studies reported mean IOP reductions ranging from 1.5 to 8.3 mmHg after phacoemulsification in eyes with or without glaucoma.[7-13] Recent studies also demonstrated that phacoemulsification decreased diurnal IOP fluctuations in patients with pseudoexfoliation syndrome with open or occludable angles and decreased nocturnal IOP fluctuation in patients with primary angle closure.[22,23] However, such IOP reductions may not always occur after phacoemulsification, and cataract surgery may even raise IOP postoperatively.[8,24] In the present study, we found that IOP was reduced (from 13.8 ± 1.9 mmHg to 12.6 ± 2.1 mmHg) after phacoemulsification when measured by GAT in the sitting position (P = 0.007). Although the Tono-Pen IOP readings in the sitting position did not show a significant IOP reduction after cataract surgery (P = 0.266), the amount of postoperative IOP change obtained with Tono-Pen differed significantly between the operated and the nonoperated eyes (−0.6 ± 2.5 mmHg vs. 0.5 ± 2.2 mmHg, P = 0.045).

In addition to postoperative IOP reduction in the sitting position, we also found that phacoemulsification reduced IOP in the recumbent postures. To the best of our knowledge, this is the first study to look at the IOP changes in the supine and LD postures after phacoemulsification in nonglaucomatous eyes. In this study, the amount of postoperative IOP reductions was greater in the recumbent positions than in the sitting position (1.7 ± 2.5 mmHg vs. 0.6 ± 2.5 mmHg, P = 0.048; 3.0 ± 3.5 mmHg vs. 0.6 ± 2.5 mmHg, P = 0.001) and was greater in the LD position than in the supine position (3.0 ± 3.5 mmHg vs. 1.7 ± 2.5 mmHg, P = 0.028). Moreover, the posture-induced IOP elevation was also reduced after cataract surgery. By

Table 2: Intraocular pressure in different body postures and biometric parameters before and after phacoemulsification

	Preoperative	Postoperative	P*
IOP of operated eye (mean±SD, mmHg)			
Sitting, by GAT	13.8±1.9	12.6±2.1	0.007
Sitting, by Tono-Pen‡	14.6±1.5	14.1±2.1	0.26
Supine, by Tono-Pen‡	16.6±2.1	14.9±1.8	0.002
LD†, by Tono-Pen‡	19.5±3.1	16.5±2.1	<0.001
IOP of contralateral eye (mean±SD, mmHg)			
Sitting, by GAT	13.4±2.3	13.7±1.7	0.25
Sitting, by Tono-Pen§	14.2±1.7	14.8±2.2	0.56
Supine, by Tono-Pen§	16.4±2.0	16.4±2.4	0.24
LD†, by Tono-Pen§	18.0±3.0	17.2±2.5	0.94
Mean CCT (mean±SD, µm)	538.86±34.87	538.07±38.96	0.82
Mean ACD (mean±SD, mm)	3.34±0.48	4.34±0.60	<0.001
Mean AL (mean±SD, mm)	23.53±1.03	23.43±1.05	<0.001

*Wilcoxon signed-rank test, †The eye to be operated (or operated) was placed on the lower side, ‡,§Comparison of IOP changes among body postures (‡P<0.001, §P=0.087, Friedman test). IOP: Intraocular pressure, GAT: Goldmann applanation tonometer, LD: Lateral decubitus, CCT: Central corneal thickness, ACD: Anterior chamber depth, AL: Axial length, SD: Standard deviation

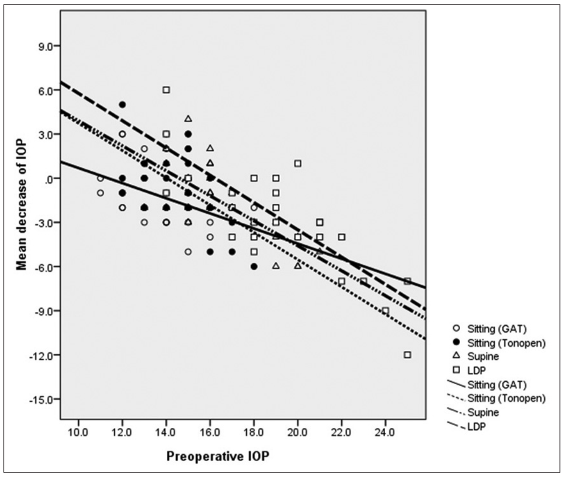

Figure 1: Correlation between preoperative intraocular pressure and mean decrease of intraocular pressure after phacoemulsification of the operated eye in different body postures. Note that the higher preoperative intraocular pressure was correlated with larger intraocular pressure reduction in every position. IOP: Intraocular pressure, GAT: Goldmann applanation tonometer

Table 3: Posture-induced intraocular pressure changes before and after phacoemulsification

	IOP differences (mean±SD, mmHg)		
	Preoperative	Postoperative	*P**
Operated eye			
Supine position versus sitting position	2.0±1.8	0.8±2.0	0.048
LD position (lower eye) versus supine position	2.8±2.8	1.6±1.7	0.028
Contralateral eye			
Supine position versus sitting position	2.1±2.0	1.7±2.1	0.369
LD position (upper eye) versus supine position	1.7±2.4	0.8±2.0	0.060

*Wilcoxon signed-rank test. IOP: Intraocular pressure, LD: Lateral decubitus, SD: Standard deviation

changing from the sitting to the supine position, IOP increased by 2.0 ± 1.8 mmHg before the surgery, whereas this elevation was reduced to 0.8 ± 2.0 mmHg at 1 month after cataract surgery ($P = 0.048$). Similar postoperative mitigation of posture-induced IOP elevation was also found between the supine and LD positions. Thus, these findings suggest that uncomplicated cataract surgery may also be beneficial for IOP management during the night time.

The mechanisms underlying the IOP reduction after cataract surgery are not yet fully understood. Possible explanations include (1) increased aqueous outflow by widening of the anterior chamber angle, increased postoperative ACD, and/or an increase in prostaglandin production after surgery[13,25,26] and (2) reduction of aqueous production resulting from traction on the ciliary body due to fibrosis and contraction of the posterior lens capsule.[27] Some researchers have proposed that extraction of the cataractous lens allows the anterior lens capsule to assume a more posterior location, thereby exerting zonular traction on the ciliary body and scleral spur.[7,28] The increased posterior traction on the scleral spur may expand the trabecular meshwork and Schlemm's canal, leading to enhanced aqueous outflow. As to the greater reduction of IOP in the recumbent postures found in the present study, we are not able to fully explain the mechanisms. However, we speculate that the increase in outflow facility after cataract surgery may allow for greater accommodation of increased IOP, helping to prevent its rise after lying down or in the decubitus position.

Posture-induced IOP changes have been widely reported by previous studies. Usually, IOP is elevated when the body posture is altered from the sitting to a recumbent (supine or LD or prone) position.[16-19] Such posture-induced IOP alterations have been reported to be higher in glaucoma patients compared to normal controls,[29,30] and these IOP changes have been associated with progression of glaucoma.[18-21] Moreover, Sawada and Yamamoto also reported that successful trabeculectomy reduced the posture-induced IOP changes and that measuring these changes could be a method for assessing the bleb's filtering function.[31] Therefore, information on the IOP not only in the sitting position but also in the recumbent positions may improve our understanding of the effects of cataract surgery on IOP and glaucoma. A recent study

Table 4: Spearman correlation analysis between preoperative ocular parameters and intraocular pressure changes before and after phacoemulsification

Preoperative factors	Spearman's rho			
	ΔIOP in sitting position (GAT)	ΔIOP in sitting position (Tono-Pen)	ΔIOP in supine position	ΔIOP in LD position
IOP in sitting position (GAT)	−0.517*	0.025	−0.260	0.014
IOP in sitting position (Tono-Pen)	−0.143	−0.496*	−0.254	−0.076
IOP in supine position	−0.149	−0.277	−0.684*	−0.332
IOP in LD position	0.116	−0.353	−0.421**	−0.730*
ACD	−0.383**	−0.162	−0.018	0.152
AL	−0.213	0.121	−0.074	0.018
CCT	0.075	0.175	−0.039	0.095
BMI	−0.462**	−0.342	−0.065	−0.202

*$P<0.01$, **$P<0.05$. IOP: Intraocular pressure, ΔIOP: IOP changes between preoperative IOP and postoperative IOP, GAT: Goldmann applanation tonometer, LD: Lateral decubitus, ACD: Anterior chamber depth, AL: Axial length, CCT: Central corneal thickness, BMI: Body mass index

investigated the effect of cataract surgery on the circadian IOP pattern in primary angle closure glaucoma patients using the contact lens sensor known as Triggerfish® (Sensimed, Lausanne, Switzerland).[23] This study demonstrated that the mean range of IOP fluctuations during the nocturnal period was significantly decreased after cataract surgery although 24-h IOP fluctuation was not significantly changed. The nocturnal IOP reduction after surgery may be explained by our findings of the greater IOP-reducing effects in recumbent postures. However, our results need to be verified in open-angle glaucoma patients.

There are some limitations to the present study. First, the sample size of the study population was small. Second, only nonglaucomatous eyes were included in this study. Thus, the present findings cannot be directly applicable to glaucoma patients who have a coexisting diagnosis of cataract. Third, one may criticize the discrepant results between the perioperative IOP readings obtained by two different tonometers in the sitting position. However, the amount of IOP change between the operated and nonoperated eyes was significantly different when IOP was measured using Tono-Pen in the sitting position. Fourth, the short duration (10 min) of maintaining each position may also be a limitation. Hence, the current finding may not be extrapolated into the effect of longer duration supine or LD position on IOP. Finally, the postural variations in IOP were checked only once at 1 month after cataract surgery. Multiple checkups of IOP variations in different postures over a longer-term postoperative period are needed.

Conclusions

We have shown that phacoemulsification significantly reduced IOP of the nonglaucomatous eye in the supine as well as in the LD body postures. In addition, our findings suggest that phacoemulsification may help to reduce posture-induced IOP elevations during the night time. However, further studies are required to investigate the effect of phacoemulsification on posture-induced IOP variations in eyes with glaucoma.

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Conflicts of interest

There are no conflicts of interest.

References

1. Pascolini D, Mariotti SP. Global estimates of visual impairment: 2010. Br J Ophthalmol 2012;96:614-8.
2. Levene RZ. Uniocular miotic therapy. Trans Sect Ophthalmol Am Acad Ophthalmol Otolaryngol 1975;79:OP376-80.
3. AGIS (Advanced Glaucoma Intervention Study) Investigators. The Advanced Glaucoma Intervention Study: 8. Risk of cataract formation after trabeculectomy. Arch Ophthalmol 2001;119:1771-9.
4. Stamper RL, Lieberman MF, Drake MV. Medical treatment of glaucoma: General principles. In: Becker-Shaffer's Diagnosis and Therapy of the Glaucomas. 8th ed. Philadelphia: Mosby; 2009. p. 346.
5. Allingham RR, Damji KF, Freedman SF, Moroi SE, Rhee DJ. Principles of medical therapy and management. In: Shields Textbook of Glaucoma. 6th ed., Ch. 27. Philadelphia: Lippincott Williams & Wilkins; 2011. p. 392.
6. Burr J, Azuara-Blanco A, Avenell A, Tuulonen A. Medical versus surgical interventions for open angle glaucoma. Cochrane Database Syst Rev 2012;(9). DOI: 10.1002/14651858. CD004399.pub3.
7. Poley BJ, Lindstrom RL, Samuelson TW, Schulze R Jr. Intraocular pressure reduction after phacoemulsification with intraocular lens implantation in glaucomatous and nonglaucomatous eyes: Evaluation of a causal relationship between the natural lens and open-angle glaucoma. J Cataract Refract Surg 2009;35:1946-55.
8. Mansberger SL, Gordon MO, Jampel H, Bhorade A, Brandt JD, Wilson B, *et al*. Reduction in intraocular pressure after cataract extraction: The ocular hypertension treatment study. Ophthalmology 2012;119:1826-31.
9. Tham CC, Kwong YY, Leung DY, Lam SW, Li FC, Chiu TY, *et al.* Phacoemulsification versus combined phacotrabeculectomy in medically uncontrolled chronic angle closure glaucoma with cataracts. Ophthalmology 2009;116:725-31.e1-3.
10. Slabaugh MA, Bojikian KD, Moore DB, Chen PP. The effect of phacoemulsification on intraocular pressure in medically controlled open-angle glaucoma patients. Am J Ophthalmol 2014;157:26-31.
11. Kim KS, Kim JM, Park KH, Choi CY, Chang HR. The effect of cataract surgery on diurnal intraocular pressure fluctuation. J Glaucoma 2009;18:399-402.
12. Lam DS, Leung DY, Tham CC, Li FC, Kwong YY, Chiu TY, *et al.* Randomized trial of early phacoemulsification versus peripheral iridotomy to prevent intraocular pressure rise after acute primary angle closure. Ophthalmology 2008;115:1134-40.
13. Mathalone N, Hyams M, Neiman S, Buckman G, Hod Y, Geyer O. Long-term intraocular pressure control after clear corneal phacoemulsification in glaucoma patients. J Cataract Refract Surg 2005;31:479-83.
14. Perlman JI, Delany CM, Sothern RB, Skolnick KA, Murray D, Jacobs RW, *et al*. Relationships between 24h observations in intraocular pressure vs. blood pressure, heart rate, nitric oxide and age in the medical chronobiology aging project. Clin Ter 2007;158:31-47.
15. Sit AJ, Nau CB, McLaren JW, Johnson DH, Hodge D. Circadian variation of aqueous dynamics in young healthy adults. Invest Ophthalmol Vis Sci 2008;49:1473-9.
16. Lee JY, Yoo C, Jung JH, Hwang YH, Kim YY. The effect of lateral decubitus position on intraocular pressure in healthy young subjects. Acta Ophthalmol 2012;90:e68-72.
17. Malihi M, Sit AJ. Effect of head and body position on intraocular pressure. Ophthalmology 2012;119:987-91.
18. Lee JY, Yoo C, Kim YY. The effect of lateral decubitus position on intraocular pressure in patients with untreated open-angle glaucoma. Am J Ophthalmol 2013;155:329-35.e2.
19. Kim KN, Jeoung JW, Park KH, Lee DS, Kim DM. Effect of lateral decubitus position on intraocular pressure in glaucoma patients with asymmetric visual field loss. Ophthalmology 2013;120:731-5.
20. Liu JH, Zhang X, Kripke DF, Weinreb RN. Twenty-four-hour intraocular pressure pattern associated with early glaucomatous changes. Invest Ophthalmol Vis Sci 2003;44:1586-90.
21. Kiuchi T, Motoyama Y, Oshika T. Relationship of progression of visual field damage to postural changes in intraocular pressure in patients with normal-tension glaucoma. Ophthalmology 2006;113:2150-5.
22. Rao A. Diurnal curve after phacoemulsification in patients with pseudoexfoliation syndrome and cataract. Semin Ophthalmol 2012;27:1-5.
23. Tojo N, Otsuka M, Miyakoshi A, Fujita K, Hayashi A. Improvement of fluctuations of intraocular pressure after cataract surgery in primary angle closure glaucoma patients. Graefes Arch Clin Exp Ophthalmol 2014;252:1463-8.
24. Slabaugh MA, Bojikian KD, Moore DB, Chen PP. Risk factors

for acute postoperative intraocular pressure elevation after phacoemulsification in glaucoma patients. J Cataract Refract Surg 2014;40:538-44.

25. Meyer MA, Savitt ML, Kopitas E. The effect of phacoemulsification on aqueous outflow facility. Ophthalmology 1997;104:1221-7.
26. Hayashi K, Hayashi H, Nakao F, Hayashi F. Changes in anterior chamber angle width and depth after intraocular lens implantation in eyes with glaucoma. Ophthalmology 2000;107:698-703.
27. Nonaka A, Kondo T, Kikuchi M, Yamashiro K, Fujihara M, Iwawaki T, *et al.* Angle widening and alteration of ciliary process configuration after cataract surgery for primary angle closure. Ophthalmology 2006;113:437-41.
28. Johnstone MA. The aqueous outflow system as a mechanical pump: Evidence from examination of tissue and aqueous movement in human and non-human primates. J Glaucoma 2004;13:421-38.
29. Krieglstein G, Langham ME. Influence of body position on the intraocular pressure of normal and glaucomatous eyes. Ophthalmologica 1975;171:132-45.
30. Tsukahara S, Sasaki T. Postural change of IOP in normal persons and in patients with primary wide open-angle glaucoma and low-tension glaucoma. Br J Ophthalmol 1984;68:389-92.
31. Sawada A, Yamamoto T. Effects of trabeculectomy on posture-induced intraocular pressure changes over time. Graefes Arch Clin Exp Ophthalmol 2012;250:1361-6.