Factors Predicting Intraocular Pressure Control After Phacoemulsification in Angle-Closure Glaucoma

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Objectives: To investigate whether the presence of glaucomatous optic neuropathy affects the reduction of intraocular pressure (IOP) after phacoemulsification in postiridotomy eyes with primary narrow angles, and to evaluate the preoperative factors associated with postoperative IOP control in primary angle-closure glaucoma (PACG).

Methods: Patients with PACG undergoing phacoemulsification were prospectively enrolled and received a complete ophthalmic examination. Diurnal IOP was measured 1 day before and 3 months after surgery. For comparison, patients with primary angle closure or angle closure suspect (PAC/S) undergoing phacoemulsification were also enrolled.

Results: Postoperative reduction of IOP was significant in the PACG group (n=29; P=.001) and in the PAC/S group (n=28; P<.001), with no significant difference between the groups. The number of glaucoma medications used decreased in both groups (both, P<.001). Multiple regression analysis for the PACG group showed that there was a positive correlation between postoperative IOP and preoperative factors of mean IOP (P=.001) and the anterior chamber depth (P=.03).

Conclusions: The reduction of IOP 3 months after phacoemulsification is significant and is similar in extent in postiridotomy eyes with and without glaucomatous optic neuropathy. A higher postoperative IOP in PACG is associated with a higher preoperative IOP and with a deeper preoperative anterior chamber depth.

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Primary angle-closure glaucoma (PACG) may account for half of the subjects with primary glaucoma worldwide, and it is 2 to 3 times more likely to cause visual impairment than is primary open-angle glaucoma. Population-based studies have shown that most cases of PACG are asymptomatic, whereas chronic PACG may develop after the resolution or precede the occurrence of an acute attack of angle closure. Predisposing factors for PACG primarily relate to a crowded anterior segment. Laser iridotomy effectively alleviates pupillary block, which is the mechanism responsible for angle closure in most cases. However, even with iridotomy, many eyes with established glaucomatous optic neuropathy (GON) require medication or surgical treatment to control the intraocular pressure (IOP). Accumulating evidence indicates that a large and anteriorly positioned lens is responsible for residual angle closure and elevated IOP in postiridotomy eyes. Meanwhile, researchers have shown that there is substantial reduction of the average IOP in PACG after lens extraction with extracapsular cataract extraction or after lens extraction with phacoemulsification. However, it is unknown whether the IOP-reducing effect of lens extraction in eyes with residual angle closure would diminish with the development of GON. If that were the case, then early surgery should be recommended. Moreover, the aforementioned studies also reported cases that required more glaucoma medication or filtering surgery immediately after cataract surgery. Little is known about prognostic factors that would predict poor IOP control after cataract surgery in postiridotomy eyes with PACG.

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In this prospective interventional study, we compared the postoperative reduction in IOP and glaucoma medication 3 months after phacoemulsification between postiridotomy eyes with and without GON. Moreover, preoperative factors that are associated with postoperative IOP control were identified in PACG.
Patients with PACG who underwent phacoemulsification between July 1, 2003, and October 31, 2004, were eligible for study. The diagnosis of PACG was based on elevated IOP (≥20 mm Hg), an occludable anterior chamber angle in which the posterior trabecular meshwork was visible for a circumference of less than 90°, and glaucomatous optic disc changes with or without visual field defects. The optic disc changes included asymmetric cupping between the eyes of greater than 0.2 or cup elongation with excavation of the neuroretinal rim. For comparison, we also enrolled eyes with narrow angles but without GON (which constituted primary angle closure or primary angle closure suspect [PAC/S] as proposed by Foster et al) undergoing phacoemulsification during the same period. Eyes with angle closure secondary to other ocular anomalies were excluded. All subjects had undergone laser iridotomy at least 3 months before phacoemulsification. With varying degrees of lens opacity, some of the patients had surgery for cataract-related visual impairment, whereas the others had surgery for progressive cup elongation or for large IOP fluctuation (>6 mm Hg) that was noted during regular visits, although these patients were taking 2 or more glaucoma medications. The institutional review board approved the study, and informed consent was obtained from all subjects.

All patients received a complete ophthalmic examination within 2 weeks before surgery. The anterior chamber angle was graded as follows: 4 represented a wide open angle with the ciliary band visible; 3, an angle with the scleral spur visible; 2, an angle with the posterior trabecular meshwork visible; 1, an angle in which only the Schwalbe line is visible; and 0, an angle without visible angle structure. The average angle width was calculated by adding the grade in each quadrant and dividing the sum by 4. Ocular biometrical measurements regarding length and thickness were obtained by using a biometer (AL-1000; Tomey Corp, Nagaya, Japan) and an ultrasound pachymeter (DGH-550; DGH Technology Inc, Frazer, Pa). We excluded eyes with corneal anomalies that might influence IOP measurements, peripheral anterior synechia (PAS) circumferentially up to the Schwalbe line, visual field defects involving central vision, or a history of incisional ocular surgery.

One masked ophthalmologist (C.-W.W.) measured IOP in triplicate at 8 AM, noon, and 4 PM 1 day before surgery using a calibrated Goldmann tonometer. Glaucoma medication therapy, if any, was maintained until 1 week postoperatively and then, except for pilocarpine hydrochloride and prostaglandin analogues, was gradually tapered on the basis of changes in IOP. Pilocarpine therapy was discontinued 2 weeks before surgery, and prostaglandin analogue therapy was replaced with oral acetazolamide sodium after surgery and continued for as long as 4 weeks. Surgery was performed by 1 surgeon (C.J.L.), and the procedure consisted of clear cornea phacoemulsification with in-the-bag implantation of an acrylic intraocular lens (Acrysof; Alcon Laboratories Inc, Houston, Tex). In eyes with small synechial pupils, chondroitin sulfate–sodium hyaluronate (Viscoat; Alcon Surgical, Puurs, Belgium) was used to separate the iris from the lens. We measured the IOP 4 to 8 hours after surgery and the following morning. After each measurement, oral acetazolamide or intravenous mannitol infusion could be given immediately to patients whose IOP was high enough to jeopardize their optic nerve.

Patients were examined 1 and 2 weeks and 1, 2, and 3 months after surgery. Three months after phacoemulsification, a complete ophthalmic examination and diurnal IOP measurement were again conducted by the same examiners.

Statistical analyses were performed by using Stata statistical software (StataCorp, College Station, Tex). The Shapiro-Wilk test was used to assess the normality of the data. Differences between PACG and PAC/S were evaluated with the unpaired t test or the Wilcoxon rank sum test for continuous variables and with the Fisher exact test for categorical variables. Differences between preoperative and postoperative values were assessed by means of the paired t test or the sign test. Multiple linear regression analysis was performed to determine the preoperative factors related to postoperative IOP control in PACG. Demographic (age and sex), clinical (history of acute attack, IOP, number of glaucoma medications, average angle width, average angle width on indentation, cup-disc ratio, and pattern standard deviation of Humphrey Visual Field Analyzer model 750, program 24-2 [Humphrey-Zeiss, San Leandro, Calif]), and biometrical (corneal radius, central corneal thickness, anterior chamber depth [ACD], lens thickness, and axial length) factors significant at P < .05 in univariate regression analysis, as well as factors relevant to aqueous drainage pathway (ACD, lens thickness, and average angle width on indentation) were included in the analysis. After assessing the collinearity among these factors, a backward stepwise regression analysis was performed for further factor selection. The final model adopted was the most parsimonious one that was believed to adequately explain the data.

In consideration of the effect of glaucoma medication on postoperative IOP readings, we also performed multivariate regression analysis in which IOP adjusted for the number of glaucoma medications was used as another outcome of interest. This adjusted IOP was the regression residual derived from a general linear regression model that used IOP as the dependent variable and the number of glaucoma medications as the independent variable. This analysis helps to estimate how postoperative IOP would compare had everyone taken the same number of glaucoma medications.

RESULTS

We included 32 patients (32 eyes) with PACG and 28 patients (28 eyes) with PAC/S, all of Sino-Mongoloid ethnic background. Three patients with PACG were excluded from the final analyses because 2 failed to complete the diurnal measurement and 1 experienced vitreous loss. The preoperative data are listed in Table 1 and show better visual acuity, a greater cup-disc ratio, a larger pattern standard deviation, and a longer axial length in patients with PACG than in patients with PAC/S. Patients with PACG were also taking more glaucoma medications than were patients with PAC/S.

The postoperative course was uneventful in all eyes, and mean visual acuity improved in both groups (both, P < .001). The mean ± SD postoperative IOP was 16.9 ± 5.4 mm Hg 4 to 8 hours after surgery and 14.3 ± 4.1 mm Hg the following morning in the PACG group. These measurements did not differ significantly from those in the PAC/S group (18.2 ± 6.2 mm Hg [P = .41] and 15.4 ± 4.8 mm Hg [P = .36], respectively). A postoperative rise in IOP of greater than 6 mm Hg developed within 24 hours in 6 eyes with PACG (21%) and 4 eyes with PAC/S (14%) (P = .73).

Three months later, the mean IOP at each time decreased significantly in the PACG group, with an amount of reduction not significantly different from that in the PAC/S group (Table 2). The diurnal variation of IOP also decreased significantly (P = .005) in the PACG group. Meanwhile, the number of glaucoma medications was reduced to 0.83 ± 0.89 in the PACG group (P < .001) and
We demonstrated that the reduction of IOP 3 months after phacoemulsification was significant and similar in ex-
operative follow-up. Hayashi and associates\textsuperscript{16} studied the effect of phacoemulsification on IOP control in glaucoma and found that, for eyes with angle closure, the preoperative IOP is significantly higher in eyes with surgical failure than it is in eyes with surgical success. This agrees with our finding that higher postoperative IOP is associated with higher preoperative IOP. In contrast, Issa et al\textsuperscript{24} found that the reduction of IOP after phacoemulsification correlated positively with the preoperative IOP. Their study was performed on nonglaucomatous patients who supposedly had unimpaired trabecular outflow facility. Irregular architecture of the trabecular meshwork with an overall loss of trabecular cells has been demonstrated in areas away from visible PAS in eyes with chronic PACG,\textsuperscript{22} indicating that gonioscopic evaluation of the extent of PAS may not truly reflect the extent of damage in the trabecular outflow pathway. This notion is supported by a study\textsuperscript{23} that investigated the relationship between drainage angle configuration and untreated IOP in 275 postiridotomy eyes with chronic PACG. Although the untreated IOP was significantly correlated with average angle width ($r=−0.23$) and average clock hours of PAS ($r=0.22$), the small $r^2$ value suggests that the gonioscopic findings explain only part of the changes in IOP. It is possible that eyes with higher preoperative IOP despite treatment with glaucoma medications are those with more compromised trabecular outflow, which eventually leads to higher postoperative IOP.

Using ultrasound biomicroscopy and A-scan ultrasonography to study PACG, Sihota et al\textsuperscript{26} showed that the trabecular iris angle is positively correlated with the ACD. Moreover, another report\textsuperscript{27} and our study have demonstrated that there is a negative correlation between preoperative ACD and postoperative widening of the drainage angle. Accordingly, a large lens may hinder the access of aqueous humor to the drainage angle and may play a more predominant role in causing elevation of IOP in eyes with a shallower ACD. This situation may account for our finding of a positive correlation between preoperative ACD and postoperative IOP readings. Another possible explanation is that the change in the force directed toward the ciliary body because of capsular bag contraction after phacoemulsification, which may result in reduced aqueous production, is greater in eyes with a shallower preoperative ACD. This notion is supported by a study of 103 nonglaucomatous eyes without problems of narrow rows in which the reduction of IOP after phacoemulsification was inversely related to preoperative ACD.\textsuperscript{29}

All the patients enrolled in our study were of Sino-Mongoloid ethnic background; thus, it is unknown whether the findings could be extrapolated to patients with PACG patients who are of other ethnicity. Our results may not be applicable to patients with total PAS, who were excluded from our analysis. The drainage angle configuration was not evaluated with ultrasound biomicroscopy because the device was not available. Our study is also limited by the small sample size and the short duration of postoperative follow-up.

In conclusion, the reduction of IOP 3 months after phacoemulsification was significant and was comparable between eyes with PACG and eyes with PAC/S. However, 17 (59\%) of the eyes with PACG still needed glaucoma medication, whereas none of the eyes with PAC/S were receiving medication 3 months after phacoemulsification. The preoperative IOP and ACD readings were helpful in predicting the control of IOP after phacoemulsification in the PACG group. Further studies on a larger population of different ethnicity and with a longer duration of follow-up are needed to determine the long-term effect of phacoemulsification in PACG.

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### Table 2. Changes in IOP and Number of Glaucoma Medications 3 Months After Surgery*

<table>
<thead>
<tr>
<th>Comparison</th>
<th>PACG Group</th>
<th>(n = 29)</th>
<th>P Value</th>
<th>PAC/S Group</th>
<th>(n = 28)</th>
<th>P Value</th>
<th>Between-Group Comparison</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 AM</td>
<td>1.2 ± 3.7</td>
<td>$&lt;.001$</td>
<td>2.8 ± 3.7</td>
<td>$&lt;.001$</td>
<td>.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noon</td>
<td>2.1 ± 3.5</td>
<td>.003</td>
<td>2.8 ± 4.1</td>
<td>.001</td>
<td>.67</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 PM</td>
<td>1.7 ± 4.1</td>
<td>.03</td>
<td>3.6 ± 4.6</td>
<td>$&lt;.001$</td>
<td>.30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average of the 3 readings</td>
<td>2.1 ± 3.1</td>
<td>.001</td>
<td>3.1 ± 3.8</td>
<td>$&lt;.001$</td>
<td>.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diurnal variation</td>
<td>1.3 ± 2.3</td>
<td>.008</td>
<td>0.5 ± 1.8</td>
<td>.15</td>
<td>.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of glaucoma medications</td>
<td>1.1 ± 1.0</td>
<td>$&lt;.001$</td>
<td>0.6 ± 0.9</td>
<td>$&lt;.001$</td>
<td>.02</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: IOP, intraocular pressure; PACG, primary angle-closure glaucoma; PAC/S, primary angle closure or primary angle closure suspect.

*Changes are calculated as the postoperative value minus the preoperative value and expressed as mean ± SD.

### Table 3. Final Multivariate Regression Model Assessing the Relationship Between the Average of the 3 IOP Readings 3 Months After Surgery and Preoperative Factors*

<table>
<thead>
<tr>
<th>Preoperative Factor</th>
<th>Coefficient (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years</td>
<td>−0.14 (−0.31 to 0.03)</td>
<td>.10</td>
</tr>
<tr>
<td>Preoperative IOP in millimeters of mercury</td>
<td>0.58 (0.26 to 0.90)</td>
<td>.001</td>
</tr>
<tr>
<td>Anterior chamber depth in millimeters</td>
<td>4.80 (0.47 to 9.14)</td>
<td>.03</td>
</tr>
<tr>
<td>Lens thickness in millimeters</td>
<td>1.32 (−1.44 to 4.08)</td>
<td>.33</td>
</tr>
</tbody>
</table>

Abbreviations: ACD, anterior chamber depth; IOP, intraocular pressure.

*Model $r^2 = 53\%$. 

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