# Randomized Trial of Early Phacoemulsification versus Peripheral Iridotomy to Prevent Intraocular Pressure Rise after Acute Primary Angle Closure

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***Purpose:*** To compare the efficacy of early phacoemulsification versus laser peripheral iridotomy (LPI) in the prevention of intraocular pressure (IOP) rise in patients after acute primary angle closure (APAC).

***Design:*** Prospective randomized controlled trial.

***Participants:*** Sixty-two eyes of 62 Chinese subjects, with 31 eyes in each arm.

***Methods:*** Subjects were randomized to receive either early phacoemulsification or LPI after aborting APAC by medications. Patients were followed up on day 1; week 1; and months 1, 3, 6, 12, and 18. Predictors for IOP rise were studied.

***Main Outcome Measures:*** Prevalence of IOP rise above 21 mmHg (primary) and number of glaucoma medications, IOP, and Shaffer gonioscopy grading (secondary).

***Results:*** Prevalences of IOP rise for the LPI group were 16.1%, 32.3%, 41.9%, and 46.7% for the follow-ups at 3, 6, 12, and 18 months, respectively. There was only one eye (3.2%) in the phacoemulsification group that had IOP rise at all follow-up time points ($P<0.0001$). Treatment by LPI was associated with significantly increased hazard of IOP rise (hazard ratio [HR], 14.9; 95% confidence interval [CI], 1.9–114.2; $P = 0.009$). In addition, a maximum IOP at presentation $>$ 55 mmHg was associated with IOP rise (HR, 4.1; 95% CI, 1.3–13.0; $P = 0.017$). At 18 months, the mean number of medications required to maintain IOP $\leq$ 21 mmHg was significantly higher in the LPI group (0.90$\pm$1.14) than in the phacoemulsification group (0.03$\pm$0.18, $P<0.0001$). Mean IOP for phacoemulsification group (12.6$\pm$1.9 mmHg) was consistently lower than that of the LPI group (15.0$\pm$3.4 mmHg, $P = 0.009$). Mean Shaffer grading for the phacoemulsification group (2.10$\pm$0.76) was consistently greater than that of the LPI group (0.73$\pm$0.64, $P<0.0001$).

***Conclusion:*** Early phacoemulsification appeared to be more effective in preventing IOP rise than LPI in patients after abortion of APAC. High presenting IOP of $>$55 mmHg is an added risk factor for subsequent IOP rise. For patients with coexisting cataract and presenting IOP of $>$55 mmHg, early phacoemulsification can be considered as a definitive treatment to prevent IOP rise. *Ophthalmology 2008;115:1134–1140 © 2008 by the American Academy of Ophthalmology.*

Acute primary angle closure (APAC) is a severe and symptomatic ocular hypertension caused by abrupt occlusion of the drainage angle by iris tissues, as a consequence of an exaggerated pupillary block. It is common in Asians, with a reported prevalence of 1.5% in Guangzhou Chinese 50 years or older.[1,2] The crude incidence of APAC glaucoma in Hong Kong is reported to be 10.4 per 100 000 per year in the $\geq$30-year-old population.[3]

Traditional treatment modalities for APAC include the use of intraocular pressure (IOP)–lowering medications and relief of pupillary block by laser peripheral iridotomy (LPI).[4] Despite initial successes, 38% to 58% of these patients had persistently raised IOP subsequently.[5,6] This may be due to an extensive residual appositional closure after LPI, potentially as a result of an anteriorly positioned

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ciliary body.[7] Other possible causes include direct trabeculum damage and development of peripheral anterior synechiae (PAS) as a result of the inflammatory response or prolonged angle closure during the acute attack.[7]

Recent evidence suggests that the crystalline lens has an important role in the angle configuration. The lens may narrow the angle by pushing the peripheral iris anteriorly, and this effect will be more marked if the lens is also cataractous. Cataract may be a major contributing factor in angle closure, as many presenting APAC patients are elderly and have concomitant cataracts. Previous and recent studies have shown the potential use of extracapsular cataract extraction (CE) or phacoemulsification in the management of an acute attack of APAC.[8] The short-term pressure control appeared to be good.[9,10] As the role of CE by phacoemulsification in the prevention of IOP rise after an acute attack of APAC is yet unclear, we conducted a prospective randomized controlled trial to compare the efficacy of early cataract extraction by phacoemulsification versus traditional LPI.

## Materials and Methods

The study was conducted at Hong Kong Eye Hospital, a university-based tertiary eye center. Patients were prospectively recruited between February 2004 and August 2005. The study followed the declaration of Helsinki and the International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals for Human Use–Good Clinical Practice guidelines. Approval from the institutional review board was obtained. Informed written consent was obtained from all participants.

### Inclusion and Exclusion Criteria

The inclusion criteria were:

1. Age $\geq$ 50 years.
2. Diagnosis of APAC based on (a) presence of at least 2 of the symptoms ocular or periocular pain, nausea and/or vomiting, and history of intermittent blurring of vision with halos; (b) IOP $>$ 40 mmHg (by Goldmann applanation tonometry) and the presence of at least 3 of the signs of conjunctival injection, corneal epithelial edema, middilated unreactive pupil, shallow anterior chamber (AC), glaucomflecken, and iris atrophy; and (c) no evidence of secondary glaucomas such as neovascular glaucoma, phacomorphic glaucoma, and uveitic glaucoma.
3. Acute primary angle closure able to be aborted by topical and systemic antiglaucomatous medications.
4. Presence of cataract with best-corrected visual acuity (VA) worse than 20/30.
5. No contraindication for cataract or laser iridotomy operation.

The exclusion criteria were (1) ophthalmic diseases other than glaucoma and cataract, (2) APAC aborted by means other than conventional topical and systemic antiglaucomatous medications, (3) pseudophakic or aphakic patients, and (4) inability to attend regular follow-up assessment or to give informed written consent.

### Randomization

All eligible patients were randomized into early phacoemulsification with posterior chamber intraocular lens (IOL) implantation or LPI. The randomization code was generated using a permuted block size of 4 by a statistician not otherwise involved in the trial. A sequentially numbered, opaque, sealed envelope containing the assigned treatment option was drawn by a research assistant after consent was obtained.

### Primary and Secondary Outcomes

The primary outcome was the prevalence of IOP rise, which is defined as occurrence of IOP $>$ 21 mmHg after weaning off glaucoma medications, at 18 months. Secondary outcomes included (1) mean number of glaucoma medications required to maintain IOP $\leq$ 21 mmHg at 18 months; (2) mean Shaffer gonioscopy grading of 4 quadrants; (3) extent of PAS, measured in degrees; (4) vertical cup-to-disc ratio (VCDR); (5) visual field (VF) indices (mean deviation [MD] and pattern standard deviation [PSD]); (6) IOP; (7) logarithm of the minimum angle of resolution (logMAR) VA; and (8) presence of atonic pupil, defined as the presence of iris ischemic changes (any identifiable areas of iris whirling or stromal atrophy)[11] plus a dilated and hyporeactive pupil.

### Procedures

All patients received either phacoemulsification or LPI within days after the abortion of the APAC attack, as soon as the IOP decreased to below 21 mmHg and the inflammation had settled sufficiently for safe intervention.

Phacoemulsification with IOL implantation was performed by a single surgeon (DSCL) under topical or peribulbar anesthesia. A temporal 3.5-mm clear corneal incision was used. An additional puncture for the insertion of the spatula was made at the limbus. After phacoemulsification and meticulous polishing of the posterior capsule and anterior capsular rim, a foldable 5.5-mm IOL (MA30BA, AcrySof, Alcon, Fort Worth, TX) was implanted in the capsular bag. Postoperative treatment included a combination of prednisolone acetate 1% (Pred Forte, Allergan, Irvine, CA), starting from 6 to 8 times daily depending on clinical needs, and ofloxacin 0.3% (Tarivid, Santen, Osaka, Japan) 4 times daily, tapered over 1 month.

Laser peripheral iridotomy was performed under topical anesthesia using the sequential argon:yttrium–aluminum–garnet (YAG) laser technique.[12] Postoperative treatment included prednisolone acetate 1% 4 times daily, tapered over 2 weeks. Supplementary laser iridotomy was performed in case of small or closed iridotomy.

Our protocol mandated that eyes with untreated IOP $>$ 21 mmHg were treated with antiglaucomatous medications to maintain IOP $\leq$ 21 mmHg. We added glaucoma medications in the following order: starting with $\beta$-blockers, followed by prostaglandin analogs, carbonic anhydrase inhibitors, then pilocarpine and, lastly, adrenergic agonists.

### Study Assessment

After the study treatment, patients were followed up at day 1; week 1; months 1, 3, 6, 9, and 12; and then every 6 months for 4 years. Visual acuity, IOP, gonioscopy, disc assessment, VF examination, and specular microscopy were determined or performed shortly after successful abortion of attack but before phacoemulsification or LPI, and at 3, 6, 9, 12, and 18 months after the phacoemulsification or LPI. Ocular biometry such as AC depth, lens thickness, and axial lengths were also determined before intervention (Storz Compuscan LT, St. Louis, MO).

All IOPs were measured with Goldmann applanation tonometry. The median of 3 readings was taken. Gonioscopy was first

Table 1. Baseline Demographics and Presenting Clinical Features of All Subjects

| | Phacoemulsification Group (N = 31) | LPI Group (N = 31) | *P* Value (2 Tailed) |
|---|---|---|---|
| Baseline demographics | | | |
| Age (yrs) | 72.3 ± 7.3 | 69.0 ± 7.8 | 0.222* |
| Gender (male:female) | 5:26 | 8:23 | 0.349† |
| Presenting clinical features | | | |
| Onset of self-reported symptom to consultation (days) | 3.1 ± 3.7 | 2.2 ± 2.5 | 0.861* |
| Time needed to abort the attack (hrs) | 11.4 ± 9.0 | 9.1 ± 6.9 | 0.505* |
| Time between abortion of attack and phacoemulsification or LPI (days) | 5.7 ± 3.3 | 4.3 ± 2.7 | 0.037* |
| Maximum IOP at presentation (mmHg) | 59.7 ± 8.7 | 57.9 ± 11.8 | 0.521* |
| IOP immediately before intervention (mmHg) | 15.8 ± 1.3 | 15.7 ± 1.4 | 0.688* |
| Mean Shaffer gonioscopy grading | 0.28 ± 0.46 | 0.40 ± 0.55 | 0.314* |
| Vertical cup-to-disc ratio | 0.41 ± 0.15 | 0.36 ± 0.09 | 0.319* |
| logMAR visual acuity | 0.573 ± 0.404 | 0.485 ± 0.432 | 0.314* |
| Snellen visual acuity equivalent | 20/75 | 20/61 | NA |
| Preoperative spherical equivalent (diopters) | 0.94 ± 1.88 | 0.70 ± 1.15 | 0.488* |
| No. of eyedrops immediately before intervention | 0.39 ± 0.61 | 0.42 ± 0.85 | 0.946* |
| Axial length (mm) | 22.42 ± 0.87 | 22.46 ± 0.57 | 0.876* |
| Anterior chamber depth (mm) | 2.11 ± 0.51 | 1.97 ± 0.25 | 0.690* |
| Lens thickness (mm) | 5.35 ± 0.42 | 5.16 ± 0.69 | 0.596* |

IOP = intraocular pressure; logMAR = logarithm of the minimum angle of resolution; LPI = laser peripheral iridotomy; NA = not applicable.
Mean ± standard deviation.
*Mann–Whitney *U* test.
†Chi-square test.

carried out using a Goldmann 2-mirror gonioscope in a dark room. The examination was performed according to published standards at high magnification (×16–×25) and a low level of illumination that permitted a view of the angle.[13] The drainage angle was graded as the numerical mean of the Shaffer grading in each of the 4 quadrants. We employed the 5-point Shaffer grading (0–4), where grade 0 denoted a completely occluded angle, grade 2 or less was considered occludable, and grade 3 or more as open. The extent of PAS was measured in number of clock hours detected on indentation gonioscopy using a Posner lens. *Peripheral anterior synechiae* was defined as abnormal adhesions of the iris to the angle that are at least half a clock hour wide and are present to the level of the anterior trabecular meshwork or higher. Gonioscopy was performed by a single investigator (DYLL) for standardization.

The VCDR was taken to be the longest vertical cup diameter divided by the longest vertical disc diameter. Vertical disc diameter was determined when the media was clear, with a Volk 90-diopter lens using a magnification factor of 1.3.[14] Features consistent with glaucomatous optic neuropathy were noted.

All subjects underwent static automated white-on-white threshold perimetry (program 24-2, Swedish Interactive Threshold Algorithm standard, model 750, Humphrey Instruments, Dublin, CA), and the first reliable VF was used in our analysis.

Specular microscopy was performed for both eyes. Yttrium–aluminum–garnet capsulotomy was performed whenever necessary. The rate of YAG capsulotomy was noted. All cataracts were graded with the Lens Opacities Classification System III (LOCS III).[15]

### Sample Size Calculations and Statistical Methods

The sample size was calculated based on our pilot study of prevalence of IOP rise—5% and 35% in the phacoemulsification and LPI groups, respectively. Assuming an $\alpha$ of 0.05 and power of 80%, 24 subjects would be needed in each group. Assuming a default rate of 20%, we estimated at least 30 subjects would be required. All analyses were performed using SPSS for Windows (StatLab, version 13.0, SPSS, Inc., Chicago, IL). Continuous variables were expressed as mean (± standard deviation), and categorical variables as individual counts and proportions. Univariate analyses were performed using the Mann–Whitney *U* test and chi-square test with Yates continuity correction as appropriate. To minimize the potential for type I error due to multiple comparisons, we used $P<0.01$ as the critical value to determine statistical significance. A Cox proportional hazard model was constructed to determine the significance of various predictors for IOP rise. Independent variables were chosen based on both empirical and statistical (from univariate results) associations with IOP rise. Significance for changes of −2 log likelihood was employed for both entry and removal tests. Probabilities at entry and removal in the forward stepwise option were set at 0.05 and 0.10, respectively. Partial residuals were plotted against time to test the proportional hazard assumption. The critical value of significance for the hazard model was set at $P<0.05$.

## Results

Sixty-two eyes of 62 Chinese subjects were recruited, with 31 eyes in each arm (phacoemulsification and LPI). Two patients, one in the phacoemulsification group and the other in the LPI group, passed away at the 17th and 17.5th months, respectively. They both died of carcinoma of the lung, which we cannot relate to our study interventions.

### Intraocular Pressure Rise and Univariate Analysis

Baseline demographics and presenting clinical features are shown in Table 1. There were no significant differences in the baseline demographics, duration of attack, time needed to abort the attack, time between abortion of attack to phacoemulsification or LPI,

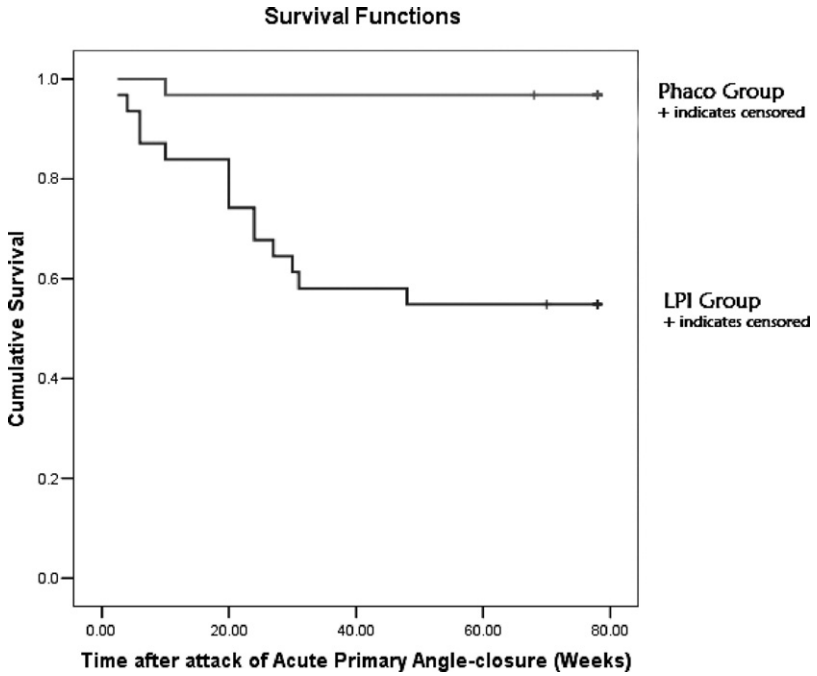


**Figure 1.** Kaplan–Meier survival curve for intraocular pressure (IOP rise) in the phacoemulsification (phaco) and laser peripheral iridotomy (LPI) groups. A test of equality of survival distributions with Mantel–Cox log rank ($P<0.0001$), Breslow ($P<0.0001$), and Tarone–Ware ($P<0.0001$) statistics showed a significant difference in survival between the two groups.

maximum IOP, mean Shaffer gonioscopy grading, VCDR, ocular biometry, VA, and refractive status between the 2 groups at presentation. Mean LOCS III scores were 2.90±1.55 (nuclear opalescence), 2.95±1.31 (nuclear color), 1.76±1.53 (cortical), and 0.74±0.84 (posterior) for the phacoemulsification group and 2.74±1.19 (nuclear opalescence), 2.74±1.10 (nuclear color), 1.76±1.49 (cortical), and 0.84±0.93 (posterior) for the LPI group. The *P* values were not significant for these scores (*P*s = 0.718, 0.595, 0.999, and 0.717 for nuclear opalescence, nuclear color, cortical, and posterior, respectively).

All patients (except the 2 deceased) had a minimum of 18 months of postintervention follow-up. Prevalences of IOP elevation at 18 months were 3.3% (1/30 eyes) and 46.7% (14/30 eyes) in the phacoemulsification and LPI groups, respectively ($P<0.0001$). A Kaplan–Meier survival analysis is shown in Figure 1. A test of equality of survival distributions showed a significant difference between the 2 groups (Mantel–Cox log-rank, $P<0.0001$). Baseline demographics, presenting clinical features, and treatment groups were tested for potential association with IOP rise. Results are summarized in Table 2. Treatment group and maximum IOP at presentation were statistically associated with IOP rise.

Table 3 shows the serial secondary outcomes for the phacoemulsification and LPI groups. The angle was significantly more open after phacoemulsification compared with LPI ($P<0.0001$) across all postintervention time points. Mean Shaffer gonioscopy gradings were 2.10±0.76 for the phacoemulsification group and 0.73±0.64 for the LPI group at 18 months. The extent of PAS (in degrees) at 18 months was significantly greater in the LPI group than in the phacoemulsification group (228.6±89.2 vs, 101.3±74.6, $P<0.0001$). There were no statistically significant differences in logMAR VA, VCDR, MD, and PSD on VFs between the 2 groups at 18 months. There was a significant difference in the mean number of glaucoma medications required to maintain IOP < 21 mmHg between the phacoemulsification group (0.03±0.18) and LPI group (0.90±1.14) ($P<0.0001$) at 18 months.

## Multivariate Risk Factor Analysis

In a Cox proportional hazard model for IOP rise, choosing treatment by LPI instead of phacoemulsification (hazard ratio [HR],

Table 2. Univariate Analysis between Baseline Demographics, Presenting Clinical Features, Treatment Group, and Intraocular Pressure (IOP) Rise

| Dependent Variable | Independent Variables | *P* Value |
|---|---|---|
| | Baseline demographics | |
| | Age | 0.947* |
| | Gender | 0.074† |
| IOP rise | Presenting clinical features | |
| | Time from self-reported onset to consultation | 0.432* |
| | Time needed to abort the attack | 0.358* |
| | Time between abortion of attack and phacoemulsification or LPI | 0.025* |
| | Maximum IOP at presentation | 0.005* |
| | logMAR visual acuity | 0.863* |
| | Mean preoperative Shaffer gonioscopy grading | 0.191* |
| | Vertical cup-to-disc ratio | 0.052* |
| | Presence of atonic pupil | 0.185† |
| | Axial length | 0.419* |
| | Anterior chamber depth | 0.074* |
| | Lens thickness | 0.951* |
| | Treatment group (phacoemulsification vs. LPI) | <0.0001* |

logMAR = logarithm of the minimum angle of resolution; LPI = laser peripheral iridotomy.
*Mann–Whitney *U* test.
†Chi-square test.

Table 3. Serial Outcomes for the Phacoemulsification

| Time (mos) | Group | Cumulative Rates of IOP Rise | IOP (mmHg)* | Shaffer Gonioscopy Grading* |
|---|---|---|---|---|
| 3 | Phacoemulsification | 3.2% | 12.2 ± 2.7 | 2.20 ± 0.67 |
| | LPI | 16.1% | 14.9 ± 4.5 | 0.88 ± 0.76 |
| | *P* value | 0.086† | 0.026‡ | <0.0001‡ |
| 6 | Phacoemulsification | 3.2% | 12.7 ± 3.1 | 2.11 ± 0.58 |
| | LPI | 32.3% | 15.2 ± 4.6 | 0.96 ± 0.71 |
| | *P* value | 0.003† | 0.017‡ | <0.0001‡ |
| 12 | Phacoemulsification | 3.2% | 12.1 ± 2.6 | 1.98 ± 0.72 |
| | LPI | 45.2% | 15.3 ± 3.7 | 0.83 ± 0.70 |
| | *P* value | <0.0001† | 0.002‡ | <0.0001‡ |
| 18§ | Phacoemulsification | 3.3% | 12.6 ± 1.9 | 2.10 ± 0.76 |
| | LPI | 46.7% | 15.0 ± 3.4 | 0.73 ± 0.64 |
| | *P* value | <0.0001† | 0.009‡ | <0.0001‡ |

dB = decibel; IOP = intraocular pressure; logMAR VA = logarithm of the minimum angle of resolution visual acuity; PAS = peripheral anterior
*Mean ± SD.
†Chi-square test.
‡Mann–Whitney *U* test.
§n = 30 for the phacoemulsification and LPI groups, from 17 and 17.5 months onwards, respectively, as a result of patient death from cancers.

14.9; 95% confidence interval [CI], 1.9–114.2; $P = 0.009$) and maximum IOP on presentation (>55 mmHg) (HR, 4.1; 95% CI, 1.3–13.0; $P = 0.017$) were associated with a significantly increased hazard of IOP rise. Omnibus tests of model coefficients revealed a good performance of the model with inclusion of these 2 variables ($P<0.0001$ for both variables). A plot of partial residuals against time confirmed the proportional hazard assumption.

### Phacoemulsification and Laser Peripheral Iridotomy–Related Complications

For the phacoemulsification group, numbers of complications were as follows: intraoperative corneal edema (12 eyes), posterior capsular rupture (1 eye), intraoperative bleeding from iris root (1 eye), postoperative fibrinous AC reaction (7 eyes), and visually significant posterior capsular opacification (5 eyes). All these complications were manageable. There were no suprachoroidal hemorrhages or endophthalmitis. For the LPI group, 1 eye had closed iridotomy and 3 eyes had small iridotomies that required supplementary laser.

## Discussion

Our study offers supporting evidence that early phacoemulsification reduced significantly the risk of IOP rise in patients after abortion of APAC attack. Laser peripheral iridotomy, the conventional treatment, was associated with an IOP rise prevalence of 46.7% and HR of 14.9 compared with phacoemulsification. Table 4 summarizes the reported prevalences of IOP rise after APAC. Our study supported that early phacoemulsification was more effective than reported modalities of treatment, such as conventional LPI or argon laser peripheral iridoplasty, in the prevention of IOP rise. We propose that this might be related to the significantly more opened angle after phacoemulsification compared with LPI across all postintervention time points (Table 3). Recent evidence suggests that, after relief of pupillary block by LPI, residual angle closure or residual plateau iris configuration may occur in up to 38.6% of post-APAC patients.[16,17] Cataract extraction was reported to be effective in resolving such residual angle closure, attenuating the anterior positioning of the ciliary process, and lowering IOP at 3 months after APAC. We have shown that this angle-opening effect persisted for at least 18 months after phacoemulsification. The wider angle might have provided more outflow facility and a lower IOP—the mean IOP was consistently lower in the phacoemulsification group than in the LPI group across all time points (Table 3), and statistical significance ($P<0.01$) was reached at 12 and

Table 4. Reported Prevalence of Intraocular Pressure (IOP) Rise after Acute Primary-Angle Closure (APAC) in the Literature

| Study | Treatment | Prevalence of IOP Rise at Different Follow-up Time Points | | |
|---|---|---|---|---|
| | | ≤6 mos | ≥12 and < 18 mos | ≥18 mos |
| Aung et al (2001)[6] | Medications + LPI | 44.5% (6 mos) | 49.0%(12mos) | 58.1% (50 mos) |
| Lai et al (2002)[21] | ALPI + LPI | 20.0% (6 mos) | 30.0%(12mos) | 30.0% (33 mos) |
| Lim et al (2004)[22] | Medications + LPI | 34.1% (4 mos) | 41.3%(12mos) | NA |
| Lai et al (2006)[23] | ALPI + LPI | NA | 19.5%(15mos) | NA |
| Lai et al (2006)[23] | Medications + LPI | NA | 31.6%(16mos) | NA |
| Present study (2007) | Medications + LPI | 32.3% (6 mos) | 45.2%(12mos) | 46.7% (18 mos) |
| Present study (2007) | Medications + early phacoemulsification | 3.2% (6 mos) | 3.2%(12mos) | 3.3% (18 mos) |

ALPI = argon laser peripheral iridoplasty; LPI = laser peripheral iridotomy; NA = not available.

and Laser Peripheral Iridotomy (LPI) Groups

| PAS (Degrees)* | logMAR VA* | VCDR* | Mean Deviation (dB)* | Pattern Standard Deviation (dB)* |
|---|---|---|---|---|
| 26.5 ± 41.5 | 0.275 ± 0.244 | 0.56 ± 0.19 | −12.01 ± 9.49 | 5.30 ± 2.65 |
| 52.2 ± 84.3 | 0.334 ± 0.243 | 0.45 ± 0.13 | −6.77 ± 6.08 | 4.19 ± 2.65 |
| 0.804‡ | 0.225‡ | 0.011‡ | 0.033‡ | 0.082‡ |
| 47.4 ± 59.9 | 0.265 ± 0.232 | 0.59 ± 0.18 | −11.95 ± 10.12 | 4.57 ± 2.53 |
| 102.3 ± 106.8 | 0.376 ± 0.248 | 0.46 ± 0.12 | −8.75 ± 7.33 | 4.84 ± 2.61 |
| 0.109‡ | 0.091‡ | 0.006‡ | 0.309‡ | 0.777‡ |
| 80.0 ± 75.7 | 0.301 ± 0.235 | 0.62 ± 0.20 | −9.25 ± 9.27 | 4.19 ± 2.62 |
| 174.2 ± 107.1 | 0.322 ± 0.225 | 0.54 ± 0.16 | −7.97 ± 7.41 | 4.46 ± 3.35 |
| 0.002‡ | 0.451‡ | 0.086‡ | 0.741‡ | 0.857‡ |
| 101.3 ± 74.6 | 0.280 ± 0.241 | 0.61 ± 0.15 | −8.47 ± 10.45 | 4.14 ± 2.50 |
| 228.6 ± 89.2 | 0.380 ± 0.297 | 0.60 ± 0.15 | −7.51 ± 7.91 | 3.83 ± 2.46 |
| <0.0001‡ | 0.214‡ | 0.703‡ | 0.675‡ | 0.551‡ |

synechiae; VCDR = vertical cup-to-disc ratio.

18 months. It should be noted that many patients in the LPI group were receiving antiglaucomatous medications, and if $\alpha$ was set as 0.05 instead of 0.01, statistical significance would be reached across all time points.

The beneficial effect of phacoemulsification is also seen in the significant difference in the mean number of glaucoma medications between phacoemulsification group (0.03) and LPI group (0.90). Therein lie the benefits of avoiding adverse effects of glaucoma medications and costs. Finally, evidence suggested that, at 12 months after APAC, LPI treatment is complicated by significant cataract progression, especially of the posterior subcapsular type.[18] Early phacoemulsification does not have this long-term complication.

Our analysis also revealed that a maximum presentation IOP of >55 mmHg confers an HR of 4.1 to IOP rise. This agrees with the literature.[9,10] In a study of angle-closure subjects by Hayashi et al, preoperative IOP was significantly higher in eyes that failed to have IOP controlled after phacoemulsification.[9] Further studies are needed to see whether the higher IOP and associated ischemia and inflammation might have resulted in more severe damage to the trabecular meshwork.

The risk–benefit ratio of phacoemulsification in eyes with good VA (20/40 or better) after abortion or in those with no cataract is a subject of debate.[19,20] In the present study, we included only cases that had cataract. Further study seems warranted to address the above issue in eyes with no or early cataract.

The optimal timing for performing phacoemulsification is yet unclear. Conceptually, it would be optimal to have the phacoemulsification done after the eye has become quiet but before the setting in of significant PAS with or without IOP rise. Approximately 1 month after the abortion of the APAC may be a good time, but further studies are needed.

Our data substantiate the importance and need for vigilant follow-up after LPI, especially during the first year, where most of the IOP rises occurred (Fig 1). Of note, in our cohort IOP rise could occur up to 48 weeks after LPI.

Our study had certain limitations. Although the sample size was calculated a priori, the overall sample was small and this could have limited our power for the secondary outcomes. Take logMAR VA, for example: although VA was persistently better in the phacoemulsification group, this did not reach statistical significance. We feel that similar limitations apply to interpretation of other secondary outcomes such as VCDR and field indices. Other limitations include potential recall bias of self-reported duration of symptoms, reliability of the preoperative data obtained when the cornea was still edematous, and the relatively brief follow-up. Phacoemulsification was performed by a single experienced surgeon in this study, and the results may not be generalizable to the less experienced. Finally, our conclusions apply to those who had their attack successfully aborted medically before study interventions and may not be valid for other scenarios, such as unaborted APAC.

## References

1. He M, Foster PJ, Ge J, et al. Prevalence and clinical characteristics of glaucoma in adult Chinese: a population-based study in Liwan District, Guangzhou. Invest Ophthalmol Vis Sci 2006;47:2782–8.
2. Foster PJ, Oen FT, Machin D, et al. The prevalence of glaucoma in Chinese residents of Singapore: a cross-sectional population survey of the Tanjong Pagar district. Arch Ophthalmol 2000;118:1105–11.
3. Lai JS, Liu DT, Tham CC, et al. Epidemiology of acute primary angle-closure glaucoma in the Hong Kong Chinese population: prospective study. Hong Kong Med J 2001;7:118–23.
4. Robin AL, Pollack IP. Argon laser peripheral iridotomies in the treatment of primary angle closure glaucoma: long-term follow-up. Arch Ophthalmol 1982;100:919–23.

5. Lam DS, Lai JS, Tham CC, et al. Argon laser peripheral iridoplasty versus conventional systemic medical therapy in treatment of acute primary angle-closure glaucoma: a prospective, randomized, controlled trial. Ophthalmology 2002;109: 1591–6.
6. Aung T, Ang LP, Chan SP, Chew PT. Acute primary angle-closure: long-term intraocular pressure outcome in Asian eyes. Am J Ophthalmol 2001;131:7–12.
7. Yeung BY, Ng PW, Chiu TY, et al. Prevalence and mechanism of appositional angle closure in acute primary angle closure after iridotomy. Clin Experiment Ophthalmol 2005; 33:478–82.
8. 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.
9. Hayashi K, Hayashi H, Nakao F, Hayashi F. Effect of cataract surgery on intraocular pressure control in glaucoma patients. J Cataract Refract Surg 2001;27:1779–86.
10. Liu CJ, Cheng CY, Wu CW, et al. Factors predicting intraocular pressure control after phacoemulsification in angle-closure glaucoma. Arch Ophthalmol 2006;124:1390–4.
11. Loon SC, Chew PT, Oen FT, et al. Iris ischaemic changes and visual outcome after acute primary angle closure. Clin Experiment Ophthalmol 2005;33:473–7.
12. Ho T, Fan R. Sequential argon-YAG laser iridotomies in dark irides. Br J Ophthalmol 1992;76:329–31.
13. Aung T, Lim MC, Chan YH, et al. Configuration of the drainage angle, intraocular pressure, and optic disc cupping in subjects with chronic angle-closure glaucoma. Ophthalmology 2005;112:28–32.
14. Crowston JG, Hopley CR, Healey PR, et al. The effect of optic disc diameter on vertical cup to disc ratio percentiles in a population based cohort: the Blue Mountains Eye Study. Br J Ophthalmol 2004;88:766–70.
15. Chylack LT Jr, Wolfe JK, Singer DM, et al. The Lens Opacities Classification System III. Arch Ophthalmol 1993;111:831–6.
16. Nonaka A, Kondo T, Kikuchi M, et al. Cataract surgery for residual angle closure after peripheral laser iridotomy. Ophthalmology 2005;112:974–9.
17. Nonaka A, Kondo T, Kikuchi M, et al. Angle widening and alteration of ciliary process configuration after cataract surgery for primary angle closure. Ophthalmology 2006;113:437–41.
18. Lim LS, Husain R, Gazzard G, et al. Cataract progression after prophylactic laser peripheral iridotomy: potential implications for the prevention of glaucoma blindness. Ophthalmology 2005;112:1355–9.
19. Nolan W. Lens extraction in primary angle closure. Br J Ophthalmol 2006;90:1–2.
20. Tan GS, Hoh ST, Husain R, et al. Visual acuity after acute primary angle closure and considerations for primary lens extraction. Br J Ophthalmol 2006;90:14–6.
21. Lai JS, Tham CC, Chua JK, et al. Laser peripheral iridoplasty as initial treatment of acute attack of primary angle-closure: a long-term follow-up study. J Glaucoma 2002;11:484–7.
22. Lim LS, Aung T, Husain R, et al. Acute primary angle closure: configuration of the drainage angle in the first year after laser peripheral iridotomy. Ophthalmology 2004;111:1470–4.
23. Lai JS, Tham CC, Chua JK, et al. To compare argon laser peripheral iridoplasty (ALPI) against systemic medications in treatment of acute primary angle-closure: mid-term results. Eye 2006;20:309–14.