Perspective

Role of Phacoemulsification in Angle Closure Glaucoma

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Abstract

Cataract or clear lens extraction has been suggested as a treatment option for different spectrums of primary angle closure diseases. It might reduce the risk of progression of angle closure and/or glaucoma by helping to open the angle and control the intraocular pressure (IOP). Conventionally, medically uncontrolled primary angle closure glaucoma was treated with trabeculectomy or phacotrabeculectomy and acute primary angle closure was treated with laser peripheral iridotomy. However, recent randomized controlled trials have demonstrated greater promise of phacoemulsification cataract surgery alone for control of the IOP. In this report we review the current literature to evaluate the impact of cataract surgery upon preventing and controlling primary angle closure diseases. (***Eye Science 2011; 26: 121-131***)

Keywords: angle closure glaucoma; cataract; phacoemulsification; phacotrabeculectomy

Primary angle closure is responsible for half of all glaucoma blindness worldwide[1]. It is uncommon in European populations with a prevalence of 0.1% according to one previous study[2]. However, the prevalence of occludable angle in Asia is relatively high and reported to be up to 10.2% of total population[3]. In Asia, most cases detected were of the chronic type, making primary angle closure glaucoma (PACG) up to five times as common as primary open angle glaucoma (POAG)[4]. In PACG physical or degenerative changes in the trabecular meshwork resulting from iridotrabecular contact (ITC) lead to high intraocular pressure (IOP) and consecutive glaucomatous optic neuropathy.

Recently, Foster et al[5] classified angle closure based on the natural history of the disease for use in prevalence surveys and other epidemiological research (Table 1). In this classification occludable angle is defined as an angle in which the posterior trabecular meshwork cannot be seen for 270° or more in primary gaze.

Some anatomical and dynamic variables have been identified as risk factors for the development of angle closure[6-7] (Table 2). For example, a shallow anterior chamber is recognized as a major risk factor. Although it was shown that angle closure eyes had shorter axial length than controls[8-9], some recent studies have emphasized the role of the lens in creating a shallower anterior chamber. A thicker lens[10-11] and a more anteriorly placed lens have been shown to be associated with angle closure[12].

Nongpiur et al recently showed that a greater lens vault increases the risk of angle closure by 48 times compared with a smaller lens vault and this finding was independent of lens thickness and lens position. They demonstrated that the partial lens that is located anterior to the plane of the angles plays an important role in the pathogenesis of angle closure by pushing the peripheral iris toward the trabecular meshwork[13]. Increased lens thickness and forward movement of the lens occurs with age[14], which helps explain why PACG is typically found in older patients.

Role of cataract surgery

It has been reported that phacoemulsification results in a reduction in IOP in normal and glaucomatous eyes.A range of reduction between 0.63 to 2.0

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Table 1 International Society Geographic and Epidemiological Ophthalmology (ISGEO) classification of primary angle closure

	Definition
Primary angle closure suspect (PACS)	ITC in 3 or more quadrants; No PAS, normal IOP, disc and field
Primary angle closure(PAC)	ITC in 3 or more quadrants with either raised IOP and/or primary PAS; normal IOP, disc and field
Primary angle closure glaucoma (PACG)	ITC in 3 or more quadrants, evidence of glaucomatous damage to optic disc and visual field
Acute primary angle closure glaucoma(APAC)	Presence of at least 2 of the following symptoms: ocular or periocular pain, nausea and/or vomiting, an antecedent history of intermittent blurring of vision with haloes Presenting IOP of >21mmHg and the presence of at least 3 of the following signs: conjunctival injection, corneal epithelial edema, mid-dilated unreactive pupil, and shallow anterior chamber

Note: IOP, intraocular pressure; PAS, peripheral anterior synechiae; ITC, iridotrabecular contact

Table 2 Factors and mechanisms associated with angle closure glaucoma

Factors/ Mechanism
Anatomical factors:
Anterior chamber-width, area and volume
Iris-thickness, area, and curvature
Lens-lens vault
Altered physiology/dynamic factors:
Iris-changes in volume with dilation
Choroid-choroidal expansion/effusion

mm Hg has been reported in recent studies[15-17].The exact mechanism of the decrease in IOP after phacoemulsification has been unknown. Widening of angle and improvement in aqueous outflow plays a role especially in patients with a low aqueous outflow facility (occludable angle)[7, 18]. Removal of the lens can deepen the anterior chamber and relieve the crowding of the angle. Several studies reported improvement in anterior chamber depth (ACD) and deepening of the angle following phacoemulsification using ultrasound biomicroscopy (UBM)[19-20]. More recently, anterior segment optical coherence tomography (AS-OCT)measurements have been shown to be more reproducible than those from UBM[21]. These reports revealed a significant increase in angle parameters after cataract surgery in angle closure open angle patients[22-25]. This effect is more pronounced in angle closure eyes. In 2007, Dawczynski et al, comparing ACG eyes and POAG eyes with AS-OCT, demonstrated that after cataract extraction, ACD and anterior chamber angle increased significantly in both two groups. However, the changes in POAG eyes were not as many as those in the PACG group[26].

Several studies showed that the degree of IOP reduction is negatively correlated with ACD[27-28]. In our recent study, we reported that the reduction of IOP was proportional to the increase in angle width in both narrow and open angles. In narrow angles the reduction was greater per 0.1 increase in angle opening distance at 500 μ[29]. Compared with laser peripheral iridotomy (LPI), lens extraction has a more potent effect on deepening of the AC and widening of the angle, to facilitate outflow[30].Theoretically widening of angle can prevent the formation of peripheral anterior synechiae (PAS) in these eyes.

Another possible explanation for the improved outflow facility after cataract surgery could be an increase in prostaglandin release[31-32]. Increased traction on the trabecular meshwork after cataract surgery (owing to IOL in the bag causing stretching of the zonules) may also play a role by opening up the trabecular spaces[32]. Another theory for the IOP lowering is that the ultrasound energy transmitted to the trabecular meshwork causes cytokine modulation, resulting in increased permeability[33].

Acute primary angle closure

Most attacks of acute primary angle closure (APAC)can be controlled with LPI[34].However, about one third of these angles may still have residual angle closure[35]. Although acute and chronic pressure elevations are rare in fellow eyes of APAC after iridotomy[36-37], the same is not true for the eyes that have the acute attack. Several case series have shown that between 40% and 60% of those eyes, despite patent iridotomies, will develop chronic pressure elevations requiring glaucoma eye drops[30,38].This may be due to an extensive residual appositional closure after LPI, potentially as a result of an anteriorly positioned ciliary body[38]. Another possible explanation might be

direct trabecular damage and development of PAS as a result of the inflammatory response or prolonged angle closure during the acute attack[39]. Lens growth after APAC has been measured and shown to be one of the reasons for the development of PACG, despite successful LPI in these patients[40].

Previous and recent studies have shown the potential use of phacoemulsification in the management of an APAC attack. The short-term pressure control appeared to be good[28,41] To evaluate long-term pressure control, Lam et al designed a prospective, controlled comparative clinical trial, and found that phacoemulsification of a visually significant cataract after aborting the acute attack was superior to LPI (47% vs. 3%, respectively) in preventing IOP > 21 mmHg at 18 months, and decreased the need for medications. Mean Shaffer grading for the phacoemulsification group was consistently greater than that of the LPI group. No patients in the LPI group needed glaucoma surgery, though[30].

However, phacoemulsification in an inflamed eye with a shallow anterior chamber and suspected residual corneal edema can be difficult. Optimum timing of cataract surgery in the acute stages of an ACG attack remains to be determined. Some authors suggest performing the operation a month after controlling the acute attack[42].

Chronic angle closure glaucoma vs. APAC

Initial phacoemulsification performed to provide short-term control of IOP is more efficacious in patients with APAC than in those with chronic angle closure glaucoma (CACG), especially when PAS is greater than 180 degrees[41,43-46], This is not surprising as this group of patients would have the greatest amount of pupillary block and appositional angle closure, as well as the highest baseline IOP. A large percentage of eyes have controlled IOP without medication postoperatively, even in eyes with extensive PAS preoperatively[47].

Post APAC glaucoma

Phacoemulsification seems to be effective and safe for the management of refractory APAC that is unresponsive to laser iridotomy and medical therapy[48]. Razeghinejad evaluated combined cataract and viscogoniosynechialysis in eleven patients with refractory angle closure glaucoma and reported a decrease in mean IOP from 39.4 mmHg to 13.4 mmHg over 7 months[49].Recent evidence suggests that after relief of pupillary block by LPI, residual angle closure or residual plateau iris configuration may occur in up to a third of post-APAC patients. Cataract extraction was reported to be effective in resolving such residual angle closure, attenuating the anterior positioning of the ciliary processes, and lowering IOP at 3 months after APAC[20,35].

While there is good evidence that phacoemulsification in APAC patients reduces the risk of recurrence of acute angle closure or developing chronic glaucoma, there have been no RCTs or case-control studies evaluating clear lens extraction in the management of the disease[42]. However, in a nonrandomized prospective study by Jacobi et al, lens extraction was performed mainly for glaucoma control in APAC and the lenses were removed even if they were clear and patients had good visual acuity. They reported a high rate of IOP control without medications postoperatively (67–72%) and few manageable complications[41].

Fellow eye

Following a patent LPI there was no APAC in fellow eyes with LPI over the following years in one study[37]. The rate of APAC in fellow eyes where the angle does not open post-LPI is also unknown but calculated to be a rate of 5.0%[42]. Chronic pressure elevations are also rare in fellow eyes treated with LPI[37].

Thus, it might not be rational to do cataract surgery because of risks and costs of incisional intervention[42].

Primary angle closure glaucoma

Several studies have demonstrated efficacy of cataract extraction in chronic angle closure glaucoma[46,50-54]. In most of these studies, the cases had visually significant cataract in addition to PACG of different severity, chronicity, and PAS. A high proportion (67% to 72%) of those medically controlled before surgery had normal IOP postoperatively on no medications[48,50-52,54]. In a prospective study it was shown that cataract surgery leads to additional 2.8 mmHg reduction in IOP for patients with CACG as compared with those undergoing LPI alone[55].

Residual angle closure after iridotomy was shown to occur in about one-third of narrow angle cases, which is more common in eyes with PAC and poorly controlled IOP or glaucomatous optic neuropathy. Recent evidence indicates that a large and anteriorly positioned lens is responsible for residual angle clo sure and elevated IOP in post-iridotomy eyes[35,56-57]. In 2005, Nonaka et al[35] reported that cataract surgery in these eyes reduced post-iridotomy IOP by 4.5 mmHg. By UBM assessment, all the eyes with post-iridotomy residual angle closure had angle closed in at least 2 quadrants before cataract surgery but the angle widened and became open in all quadrants after cataract surgery.

Phacoemulsification vs. phacotrabeculectomy

In the past the preferred practice was to perform cataract extraction combined with trabeculectomy in PACG patients who had a visually significant cataract in association with uncontrolled IOP to reduce the possible harmful effects of post-cataract surgery IOP elevation as well as control the IOP in long-term[32,51]. Early IOP spikes may also occur in about one third of eyes after a combined procedure, though[51]. Glaucomatous disc progression after post-operative pressure spike has been reported after both procedures[51,58].

In 1998, Gunning reported a long term decrease in IOP with combined phacotrabeculectomy (15 mmHg) and phacoemulsification alone (12 mmHg). The mean number of medications required for such control was lower in the combined surgery group, however, with equal proportion of patients (68%) obtaining IOP control[50].

Recently, two prospective RCTs have compared phacoemulsification with combined phacotrabeculectomy in patients with medically controlled 52 or uncontrolled PACG[53]. The results showed that combined phacotrabeculectomy might be more effective than phaco alone in controlling IOP in CACG eyes with cataract, but the difference appeared marginal and was mainly in a lower requirement for glaucoma drugs. However, none of the patients in the phacoemulsification alone group demonstrated progression during the 2-year follow-up period, whereas 16.7% of CACG eyes in the phacotrabeculectomy group demonstrated progression[53]. Based on these studies, it can be proposed that phacoemulsification alone is a reasonable surgical alternative to combined phacotrabeculectomy in CACG eyes, whether the preoperative IOP is medically controlled or not.

In 2010, Tham et al used UBM to document anatomic effects of phacoemulsification versus combined phacotrabeculectomy on the drainage angle in PACG. Interestingly, phacoemulsification alone resulted in greater opening of the drainage angle and greater deepening of anterior chamber than combined phacotrabeculectomy[58]. Combined surgery was shown to be associated with more postoperative complications (anterior chamber shallowing requiring anterior chamber reformation, conjunctival wound leak, hyphema, hypotony, and choroidal detachment) compared with phacoemulsification alone[7,32,50,59].

Predicting factors for success

Although a high proportion of patients have good postoperative IOP control without medications, the factors that are likely to be associated with poor outcomes are unclear. Some earlier studies reported that changes in IOP after cataract surgery are greater in eyes with less PAS. In 2005, Euswas and Warrasak divided angle-closure patients into two groups: group 1 included those with less than 180 degrees of PAS, whereas group 2 between 180 and 270 degrees of PAS. Those studies demonstrated a 3 mmHg greater IOP reduction postoperatively in patients from group 1 versus those in group 2 (5 vs. 2 mmHg, respectively)[60]. Thus, timing of lens extraction in eyes with residual angle closure after PI may be critical because repeated appositional closure may increase the extent of synechial closure. This may result in modest IOP reduction when cataract surgery is not performed earlier[28]. However, Liu et al showed that phacoemulsification has similar IOP reducing effect in PACG and PACS, indicating that early lens extraction may not be necessary for residual angle closure. Eyes with more than 270 degrees of PAS were noted in 17% of their patients and eyes with total PAS were excluded from their study[28]. Another study also showed no clear correlation of change in IOP with the extent of angle closure[51]. Recently, Shams et al published the results of phacoemulsification in PAC, PACG, and narrow angles after 7 months. In contrast to several earlier reports, in their studies the

observed reduction in postoperative IOP in eyes with PAC was significantly greater in the presence of a higher preoperative IOP, a larger number of glaucoma medications, narrower iridotrabecular angle width, and evidence of glaucomatous optic neuropathy. Eyes with >180 degrees of PAS preoperatively also achieved a significantly greater reduction in IOP postoperatively compared with those with less PAS. They proposed that lens extraction seems to have a beneficial effect on IOP control in PAC, and is especially efficacious in more advanced cases[61].

Preoperative factors associated with long-term IOP control after cataract surgery in PAC cases were evaluated by Liu et al[28]. After a mean follow-up of 3 years, postoperative IOP decreased an average of 20%. Higher IOP and deeper ACD before surgery were associated with higher postoperative IOP over the follow up period. They showed that the multiplication product IOP x ACD accounted for up to half of the IOP variations 1 year after surgery, and eyes with this index ≤ to 35 were more likely to achieve postoperative IOP readings of less than or equal to 12 mmHg than those with an index more than 35. This indicates that the lens in eyes with a shallower preoperative anterior chamber plays a more predominant role in causing angle closure, so lens removal in such eyes will result in lower postoperative IOP. Like other studies[28,50,62], they found the preoperative gonioscopic finding was not a determinant of long-term postoperative IOP.

Possible explanations for the lack of correlation with angle adhesions might be: 1) it is difficult to assess the extent of PAS in eyes with a large lens and shallow anterior chamber[62]; and 2) gonioscopic findings may not truly reflect the extent of damage in the trabecular outflow pathway, and there might be loss of trabecular cells and irregular architecture of the trabeculum in areas away from visible PAS[63]. Although the mentioned studies indicate that the magnitude of IOP reduction following cataract surgery is positively related to the level of preoperative IOP, this phenomenon may be related to regression to the mean[17].

Phacoemulsification and goniosynechialysis

Some authors believe that in patients with CACG and firmly established synechiae, the trabecular meshwork may remain occluded by PAS despite the anterior chamber deepening after removal of the lens. Surgical goniosynechialysis has been used effectively to release PAS in patients with angle closure glaucoma[64–67].

Combined phacoemulsification and viscogoniosynechialysis seems to be an effective surgical procedure in the treatment of patients with CACG and angle restoration whether controlled or uncontrolled by medication[48,68]. A reduction in IOP and PAS in >90% (n=52 eyes) was observed for those who had developed acute angle closure within the last 6 months and whose pressure was not controlled with LPI. In 2001, Lai et al reported the results of phacoemulsiflcation and goniosynechialysis followed by diode laser peripheral iridoplasty to the inferior half of the angle in patients with CACG and total synechial angle closure. UBM evaluation after surgery showed that the superior angle, where no goniosynechialysis was performed, remained closed. In contrast, the inferior angle in all patients was opened up by the goniosynechialysis. One recent randomized controlled trial compared combined phacoemulsification/goniosynechialysis and phacoemulsification and revealed that after 1 year the former group had greater reduction in IOP than the latter group[66]. This might suggest clinical efficacy of goniosynechialysis in patients who have CACG with total synechiae[69].

Complications like iridodialysis, postoperative inflammation, postoperative intraocular pressure spike, hyphema, and transient corneal edema have been found after goniosynechialysis. Recurrence of PAS, although uncommon, has been reported[64,69].

Plateau iris

Plateau iris refers to an angle appearance in which the iris root angulates forward from its insertion point and then centrally, leading to a narrow/closed angle but a deep central anterior chamber[70]. Large ciliary bodies and/or anteriorly rotated ciliary processes have been shown by UBM to hold the peripheral iris in contact with angle[71]. This non-pupillary block mechanism may be responsible for a significant proportion of angle closure in Asians[72]. In 2008, Kumar reported the prevalence of plateau iris in a cohort of

PACS cases using UBM. Interestingly, plateau iris was found in about one third of the patients after LPI[73].

The role of cataract surgery in plateau iris is not entirely clear. In 2003, a study evaluated the UBM appearance of the anterior segment before and after cataract extraction in eyes with plateau iris syndrome and demonstrated that following phacoemulsification, although the ACD increased, the iridociliary contact remained unchanged. They proposed that the zonular attachments to the capsular bag maintained apposition of the pars plicata to the iris and these two moved together after cataract surgery.

In contrast, some studies showed that even for the eyes with plateau iris syndrome, cataract surgery results in slit opening of the drainage angle[20]. Nonaka et al used UBM for evaluation of the anterior segment in PAC and reported that cataract surgery attenuates the plateau iris factor of PAC by repositioning of the ciliary processes in a more posterior location. Harasymowycz et al evaluated the effectiveness of phacoemulsification and goniosynechialysis in managing acute and subacute PAC unresponsive to conventional therapy. Plateau iris was the underlying mechanism for angle closure in 3 of 21 cases. Although they reported a reduction in mean IOP of 25 mmHg (62%) after surgery, a comparison between these two groups could not be done due to the very small number of plateau iris cases[48].

Since a considerable portion of patients have mixed mechanism for angle closure[73-74], some authors have postulated that lens extraction may be preferable as a treatment of these eyes. They believe that cataract surgery has the ability to relieve angle closure by attenuating various causative factors, such as pupillary block, lens-associated, and plateau iris[7, 20].

Primary angle closure/suspect

LPI is the most effective intervention for the majority of cases of primary angle closure (PAC) and primary angle closure suspects (PACS)[75]. Although there is a theoretical long-term risk of cataract formation due in part to the disturbance of normal aqueous flow[76], a recent study showed no evidence that prophylactic LPI is independently associated with cataract progression[77].

Shin et al[78] compared the effect of phacoemulsification in an open angle group with a narrow angle group.The mean decrease in IOP was statistically significantly greater in the narrow angles than in the open angles. Poley et al[79] found that the decrease in IOP after phacoemulsification in narrow angles was proportional to the preoperative IOP. They concluded that the aging crystalline lens is a major cause of adult glaucoma and that phacoemulsification may help prevent and treat it[78-79].

Approximately one in three eyes has shown PAS progression over 3 years after LPI. The probability of progression was shown to be higher in the eyes that exhibited some degree of plateau iris. In these eyes PAS may continue to progress despite a patent LPI[80]. It is not clear whether lens extraction will prevent progression of PAS.In a population-based cohort of PAC subjects, Thomas et al reported that 28.5% progressed to PACG over 5 years. However, they couldn't identify any features that predicted progression[34]. Based on the results of other studies, it seems that cataract extraction alone will lead to more successful IOP control than LPI[42]. Although cataract surgery is effective in resolving the residual angle closure after iridotomy and lowering the IOP[35], the authors suggest that cataract extraction might be a preferred procedure mostly for visual reasons.

One study in Europe showed 22% of PACS progressed to PAC over 5 years; and none of them evolved into PACG. The incidence of APAC is very low (0.1% per year). In these eyes, the mechanism of angle closure is thought to be predominantly pupillary block, and can be safely prevented by LPI[34]. However about a half of all angle-closure in China is caused by multiple mechanisms, with only one third related to pure pupillary block[73-74]. Plateau iris configuration and wide variation in iris structure and insertion have been found in these eyes[72]. That's why YAG laser iridotomy is often not effective in preventing progression of angle closure in Asians[81]. In a recent study[82] on Vietnamese, 3.8% of PACS progressed to PACG over years. Cataract surgery was a significant factor associated with non-progression in PACS eyes. Thus, lens extraction seems to play a protective role in PACS eyes, especially among Asians.

Epidemiologic evidence

Epidemiologic studies have demonstrated that the rate of primary angle closure disease may be decreasing. In England rates of patients with PACG have started to decline recently, after a long period of increases in rates of patients undergoing cataract surgery. Although other explanations are possible, a study by Keenan et al supports the hypothesis that cataract surgery may reduce the likelihood of acute angle closure[83]. Systematic screening for angle closure, followed by LPI if indicated, may play a role in reduction of blindness due to angle closure in some populations, though[84].

Using 8 years of nationwide registry data, a study in Taiwan assessed the relationship between the total numbers of cataract surgeries performed and admissions for APAC. Significant inverse relationships were noted between the monthly APAC admission rates and the monthly cataract operation rates[85]. No significant inverse relationship was observed for the >70-year old age group.

Recently, Chan et al estimated the effect of this surgery on the incidence of PACG. Of 4153 eyes available for analysis, 261 eyes were either PACS or PAC.They showed a 38.0 % relative reduction in the incidence of PACG in the adult population and concluded that in populations with a high prevalence of both visually significant cataract and angle-closure disease, quality cataract extraction can have a dual role of visual restoration and reduction in the incidence of angle-closure disease in the population[86].

Complications

Intraocular surgery in patients with angle closure is more challenging than in an open angle subject because of the shallow AC, potential presence of posterior synechiae, and in cases of APAC, atonic pupil and residual corneal edema. The reported intra-and post-operative complications are iris trauma, posterior capsule rupture, thermal burns at the wound, and postoperative inflammation (16–40%)[30,32,41,48,52,69,87–88]. Immediate postoperative pressure spikes, which occur in 10% ~60% of cases, may compromise optic nerve function.

Some studies reported corneal decompensation after uneventful cataract surgery in eyes with PACG[51]. Ko et al demonstrated that the corneal endothelial cell loss 3 months after surgery was greater in eyes with occludable (18.0%) than in normal open angles (5%). They found that eyes with a narrower working space for phacoemulsification, such as those with a shallower ACD and shorter axial length, are at a greater risk for mechanical contact and thus may lose more corneal endothelial cells after surgery[89]. However, another study showed that endothelial cell counts are not significantly diminished following lens surgery compared to preoperatively[45]. In spite of difficulties of performing phacoemulsification in PACG eyes, the surgical complication rate is acceptable in most reports[51,54].

Conclusion

Several randomized studies have demonstrated the efficiency and safety of cataract extraction for the treatment of PACG or APAC and cataract[30,52–53,58–59], Moreover, cataract surgery provides the opportunity to 'kill two birds with one stone', restoring vision and eliminating a narrow angle[86]. It helps prevent or delay the progression along the primary angle closure spectrum, and reduces the incidence of PACG particularly in regions where angle closure is prevalent[86].

Although many studies suggested cataract extraction for patients with angle closure, only a few articles assessed the role of clear lens extraction[41,46,50]. There is a lack of evidence especially in relation to the relative benefit-to-risk profile of clear lens extraction for angle closure.Such studies are in their early stages or in the planning phase at this time. Some RCTs are needed to compare effect of early lens extraction and conventional therapy (iridotomy, medical therapy and then filtering surgery) in PACG patients. The results of such studies might be worthy of changing preferred practice pattern in management of PACD.

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