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Original Article

Reduction of intraocular pressure and improvement of vision after cataract surgeries in angle closure glaucoma with concomitant cataract patients

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Abstract: Objective: This study is to compare the efficacy of three different cataract surgeries in eyes with angle closure glaucoma (ACG) with concomitant cataract. Methods: A retrospective comparative analysis of 106 ACG patients (112 eyes) with concomitant cataract was conducted between February, 2012 and February, 2014. Clinical outcomes of ACG patients with concomitant cataract underwent phacoemulsification and intraocular lens implantation (group A, n = 34, 36 eyes, angle closure < 180°); combined phacoemulsification, intraocular lens implantation, and goniosynechialysis (group B, n = 43, 45 eyes, angle closure, 180°~270°); and combined phacoemulsification, intraocular lens implantation, and trabeculectomy (group C, n = 29, 31 eyes, angle closure > 270°) were compared during a 6-month follow-up. Results: There were no statistical differences among the 3 groups in pre-operative or post-operative average visual acuity (VA), intraocular pressure (IOP), anterior chamber depth (ACD), and angle opening distance (AOD) (all $P > 0.05$). Post-operative VA, IOP, ACD, AOD and the degree of angle opening in the 3 groups were all improved as compared with pre-operative levels (all $P < 0.05$). No statistical difference was detected among the 3 groups in the incidence of complications ($\chi^2 = 0.376$, $P = 0.829$). Conclusion: Phacoemulsification alone, combined phacoemulsification/goniosynechialysis, and combined phacoemulsification/trabeculectomy provide safe, effective, predictable, and stable options of cataract surgery for treatment of ACG with concomitant cataract.

Keywords: Angle closure glaucoma, cataract, phacoemulsification, intraocular lens implantation, goniosynechialysis, trabeculectomy

Introduction

Angle closure glaucoma (ACG) is typically characterized by closure of the anterior chamber drainage angle, thereby blocking the outflow of aqueous humor, with resultant elevated intraocular pressure (IOP) and the development of progressive irreversible optic neuropathy causing peripheral vision loss [1]. ACG, a leading cause of blindness worldwide, affects 3.9 million people worldwide, and has a higher prevalence in Asia [2]. There are multiple risk factors for ACG, including hyperopia, a short axial length of the eyeball, an anterior chamber length of less than 2.5 mm, inhabitant of Eskimo and Southeast Asia, age over 40 years (due to thickened lens and shallow anterior chamber depth), females (because of their tendency to shallower anterior chambers), and a family history of ACG [3]. The visual field loss in ACG patients may be related, at least in part, to the elevated IOP; therefore, it is of great importance to reduce IOP for ACG treatment [4]. The standard initial ACG management is lowering IOP medically, which is followed by laser peripheral iridotomy (LPI), relieving pupil block, the predominant mechanism of ACG; however, long-term IOP control after LPI is poor [5].

When ACG coexists with cataract, which is a clouding of the lens or opacity inside the eye leading to a decrease in vision and may even result in visual loss because opacification of the lens obstructs light from passing and being focused on the retina at the back of the eye, accumulated studies have reported the apparent IOP-lowering effect of cataract extraction alone by phacoemulsification [6-8]. However, cataract extraction alone for the treatment of ACG with concomitant cataract is today a subject of arguable discussion [1]. Combined phacoemulsification/trabeculectomy (phaco-trabeculectomy) is one option for the management of the patient with ACG and cataract, providing early visual rehabilitation, reducing the risk of early severe post-operative IOP elevation, decreasing complication occurrence, and may supply long-term reduction of IOP and decrease the need for glaucoma medication [9]. It is considered as a safe, reasonable, quick and effective treatment for ACG patients with concomitant cataract [10]. Combined phacoemulsification/goniosynechialysis (phaco-goniosynechialysis) is another preferred way in treating ACG with concomitant cataract, with high efficacy and less surgical complications [11]. Although the immediate management of ACG, a common ophthalmic emergency requiring early recognition followed by definitive treatment, is comprehensively noticed and the results have been extensively reported in the past, there is still considerable variation in how oculists undertake definitive treatment for ACG patients with concomitant cataract [12, 13].

Our present study aims to compare the efficacy in visual rehabilitation, IOP control, anterior chamber depth (ACD), angle opening distance (AOD), the degree of angle closure and surgical complications, using phacoemulsification alone, combined phaco-goniosynechialysis, and combined phaco-trabeculectomy, respectively, in eyes with medically controlled ACG with concomitant cataract.

Materials and methods

Ethics statement

The study was approved by the ethics committee of Dongying City People's Hospital. The written informed consent was provided by each eligible patient and the study conformed to the Declaration of Helsinki [14].

Subjects

A retrospective comparative analysis of 106 patients (112 eyes) with ACG with concomitant cataract was conducted between February, 2012 and February, 2014 in Dongying City People's Hospital. Of these patients, there were 40 males (40 eyes) and 66 females (72 eyes), with an age range of 44~79 years (mean age, 61.24 ± 6.15 years). Pre-operative gonioscopy revealed interrupted areas of peripheral anterior synechiae (goniosynechiae) in all patients, with angle closure ranging from II to IV. Inclusion criteria were: (1) visual acuity (VA) < 0.6; (2) presence of phacoscotasmus in slit lamp examination; (3) occurrence of angle closure at different degrees by gonioscopy; and (4) diagnosis of primary angle closure glaucoma (PACG) according to the diagnostic criteria formulated by Chinese Medical Association Ophthalmology Branch Glaucoma Group [15]. Patients, who had (1) open angle glaucoma; (2) neovascular glaucoma (NVG) or other secondary glaucoma; (3) history of anti-glaucoma surgery or other ophthalmologic surgeries; or (4) systemic diseases that might affect prognosis, such as poor glycemic control in diabetic patients, and serious cardiopulmonary disease accompanied by PACG, were excluded. All patients received gonioscopy and divided into 3 groups according to different degrees of angle closure: group A (n = 34, 36 eyes, degree of angle closure < 180°), treated with phacoemulsification and intraocular lens implantation; group B (n = 43, 45 eyes, degree of angle closure, 180°~270°), treated with combined phacoemulsification, intraocular lens implantation, and goniosynechialysis; and group C (n = 29, 31 eyes, degree of angle closure > 270°), treated with combined phacoemulsification, intraocular lens implantation, and trabeculectomy. Statistical differences in gender or age were not apparent among group A, group B and group C (all $P > 0.05$).

Surgical procedure

All patients received initially pre-operative routine IOP control, and were treated with medical treatments as following: intravenous drip of 250 ml mannitol (20%) at 30 min before surgery; administration of compound tropicamide eye drops at 10 min before surgery for fully mydriasis; administration of 2.5 ml lidocaine (2%) and 2.5 ml bupivacaine for ocular anesthesia, and full massage on the eyeball. In the group A, scleral tunnel incision (3.0 mm) was performed after successful anesthesia, at 2.0 mm above the upper edge of the cornea. Then cataract extraction was performed using a standardized clear-corneal approach: viscoelastic agent was injected at the 3-o'clock position 360° circumferentially in the angles to deepen the anterior chamber for hydrodissection; and then phacoemulsification of the lens was carried out by using the cataract ultrasonic emulsification instrument (Alcon, Beijing) to

Table 1. Pre-operative and post-operative visual acuity (VA) in the three treatment groups

Group		Group A (36 eyes)	Group B (45 eyes)	Group C (31 eyes)
Pre-operative	< 0.1	3	6	10
	0.1-0.2	9	8	9
	0.2-0.3	6	11	6
	0.3-0.4	12	12	3
	> 0.4	6	8	3
Post-operative	< 0.1	0	0	1
	0.1-0.2	3	2	3
	0.2-0.3	6	7	7
	0.3-0.4	9	8	5
	> 0.4	18	28	15

Group A, angle closure < 180°, treated with phacoemulsification and intraocular lens implantation; group B, angle closure range, 180°~270°, treated with phacoemulsification and intraocular lens implantation combined with goniosynechialysis; group C, angle closure > 270°, treated with phacoemulsification and intraocular lens implantation combined with trabeculectomy.

completely pump residual cortex. After viscoelastic reinjection, in-the-bag implantation of a standard foldable intraocular lens (IOL) was performed. Also, the group B received cataract extraction with the way utilized in the group A, and then viscoelastic injection was performed 360° circumferentially along the angle of anterior chamber, the anterior chamber angle was separated with scleral root fixed, following by replacement of viscoelastic agent and watertight cataract incision closure. Similarly, the phacoemulsification and intraocular lens implantation were performed in the group C, and then the scleral incision was enlarged to 3.0 × 3.0 mm, trabeculae (1.0 × 1.0 mm) and iris anterior synechia were excised. Limbus-based conjunctival flaps were closed with a continuous running, single-layer closure of 10-0 polyglactin suture on a tapered vascular needle. After wound closure, all patients in these 3 groups were routinely administrated with antibiotic for the prevention of infection, and all eyes were treated post-operatively with anti-inflammatory Tobradex drops.

Outcome measures

All patients received a 6-month follow-up. During the follow-up, post-operative VA, ACD, IOP, the degree of angle closure, and post-operative complications were observed and recorded. Name and type of all medicines administrated in all patients were recorded. IOP was measured by using noncontact air-puff tonometry (tonometer CT-80, TOPCON, Japan), and average of three measurements was obtained. Ultrasound biomicroscopy (UBM) laser profilometry was utilized to detect the degree of angle closure, ACD (vertical distance from the inner surface of the corneal anterior chamber to the anterior lens surface), and AOD (the distance between 2 crossover points of the inner surface of the cornea and the anterior surface of the iris through a circle, whit scleral spur as the center of the circle and a radius of 500 μm).

Statistical analysis

SPSS 19.0 statistical software was used for data analysis. Measurement data were presented as mean ± standard deviation (x ± s). The *t* test was applied to compare the data between groups, and the χ^2 test to compare enumeration data. A $P < 0.05$ was considered as statistically significant.

Results

Comparison of VA

No statistically significant differences were observed among the 3 groups in VA at the pre-operative visit ($\chi^2 = 12.84$, $P = 0.118$). After the surgery, VA of patients in the group A, group B and group C all increased as compared with the pre-operative level, showing statistical significance ($\chi^2 = 12.43$, $P = 0.014$; $\chi^2 = 22.40$, $P < 0.001$; $\chi^2 = 18.94$, $P < 0.001$, respectively), while no statistical differences existed among the 3 groups in terms of post-operative VA ($\chi^2 = 5.61$, $P = 0.691$) (**Table 1**).

Comparison of IOP

There existed no obviously statistical differences among the 3 groups in IOP pre-operatively (F = 1.913, $P = 0.034$). At each time point after the surgery, IOP improved in group A, group B and group C as compared with the pre-operative IOP, which showed statistical significance (all $P < 0.05$). Additionally, no statistical differences existed among the 3 groups in terms of post-operative IOP at each time point (all $P > 0.05$) (**Table 2**).

Comparison of ACD

The pre-and post-operative ACD findings in the three treatment groups are summarized in **Table 3**. No statistically significant differences in ACD were observed among the 3 groups

Table 2. Pre-operative and post-operative intraocular pressure (IOP) in the three treatment groups (mm Hg)

	Group A (36 eyes)	Group B (45 eyes)	Group C (31 eyes)	F	*P*
Pre-operative	19.82 ± 1.85	20.25 ± 2.12	20.91 ± 2.89	1.913	0.034
1 week after surgery	13.23 ± 1.26*	13.41 ± 1.38*	14.12 ± 2.13*	2.896	0.060
1 month after surgery	13.15 ± 1.28*	13.46 ± 1.52*	14.02 ± 2.05*	2.454	0.091
3 months after surgery	13.28 ± 1.36*	13.53 ± 1.63*	14.14 ± 2.12*	2.223	0.113
6 months after surgery	13.69 ± 1.35*	13.60 ± 1.78*	14.28 ± 2.25*	1.434	0.242

Group A, angle closure < 180°, treated with phacoemulsification and intraocular lens implantation; group B, angle closure-range, 180°~270°, treated with phacoemulsification and intraocular lens implantation combined with goniosynechialysis; group C, angle closure > 270°, treated with phacoemulsification and intraocular lens implantation combined withtrabeculectomy; *, compared to pre-operative IOP, *P* < 0.05.

Table 3. Pre-operative and post-operative anterior chamber depth (ACD) in the three treatment groups (mm)

	Group A (36 eyes)	Group B (45 eyes)	Group C (31 eyes)	F	*P*
Pre-operative	1.81 ± 0.15	1.79 ± 0.12	1.75 ± 0.13	1.741	0.180
Post-operative	3.14 ± 0.23	3.11 ± 0.28	3.25 ± 0.29	2.631	0.078
t	29.06	29.07	26.28	-	-
P	< 0.001	< 0.001	< 0.001	-	-

Group A, angle closure < 180°, treated with phacoemulsification and intraocular lens implantation; group B, angle closure-range, 180°~270°, treated with phacoemulsification and intraocular lens implantation combined with goniosynechialysis; group C, angle closure > 270°, treated with phacoemulsification and intraocular lens implantation combined withtrabeculectomy.

pre-operatively (F = 1.741, *P* = 0.180). Post-operative ACD in all patients of group A, group B and group C was higher than the pre-operative ACD (t = 29.06, *P* < 0.001; t = 29.07, *P* < 0.001; t = 26.28, *P* < 0.001, respectively). Additionally, no statistically significant differences in post-operative ACD among the 3 groups were detected (F = 2.631, *P* = 0.078).

Comparison of AOD

Similarly, we found no significantly statistical differences among the 3 groups in pre-operative AOD (F = 2.508, *P* = 0.086). Compared with the pre-operative AOD, post-operative AOD increased in all patients of the group A, group B and group C (t = 26.27, *P* < 0.001; t = 34.31, *P* < 0.001; t = 26.98, *P* < 0.001, respectively). In addition, there were no statistically significant differences among the 3 groups in terms of post-operative AOD (F = 2.862, *P* = 0.062) (**Table 4**).

Comparison of the degree of angle closure

After the surgery, open angle was observed, while no obvious goniosynechiae presented in the group A; goniosynechiae appeared in both group B and group C, with angle closure < 180°. In addition, the degree of angle opening post-operatively in all patients increased as compared with the pre-operative level.

Surgical complications

After the surgery, anterior chamber fibrin exudation occurred in the group A (1 eye), group B (2 eyes) and group C (1 eye), which disappeared after administrating with dexamethasone and tobramycin eye drops. Occurrence of corneal bedewing was observed in 2 eyes in the group A, 3 eyes in the group B and 3 eyes in the group C; and recovery was achieved through conservative treatment. No statistical difference was detected among the group A, group B and group C in the term of the incidence of complications (8.33% vs. 11.11% vs. 12.90%, $\chi^2 = 0.376$, *P* = 0.829).

Discussion

To describe and evaluate an appropriate cataract surgery managing ACG with concomitant cataract, our present study compared the efficacy of phacoemulsification alone, combined phaco-goniosynechialysis, and combined pha-

Table 4. Pre-operative and post-operative angle opening distance (AOD) in the three treatment groups (mm)

	Group A (36 eyes)	Group B (45 eyes)	Group C (31 eyes)	F	*P*
Pre-operative	0.106 ± 0.023	0.098 ± 0.021	0.095 ± 0.019	2.508	0.086
Post-operative	0.275 ± 0.031	0.265 ± 0.025	0.259 ± 0.028	2.862	0.062
t	26.27	34.31	26.98	-	-
P	< 0.001	< 0.001	< 0.001	-	-

Group A, angle closure < 180°, treated with phacoemulsification and intraocular lens implantation; group B, angle closure range, 180°~270°, treated with phacoemulsification and intraocular lens implantation combined with goniosynechialysis; group C, angle closure > 270°, treated with phacoemulsification and intraocular lens implantation combined with trabeculectomy.

co-trabeculectomy for ACG with concomitant cataract, and found that all these 3 cataract surgeries resulted in improvement in VA, IOP, ACD, AOD, the degree of angle opening, and surgical complication, demonstrating that all these 3 cataract surgeries might have roles in the treatment of ACG eyes with concomitant cataract. Nevertheless, the question of when to perform which cataract surgery to achieve the best results remains unresolved. According to our grouping method, these results also confirmed that phacoemulsification alone might be more suitable for ACG eyes with angle closure < 180°, combined phaco-goniosynechialysis might be more suitable for ACG eyes with angle closure of 180°~270°, and combined phaco-trabeculectomy might be more suitable for ACG eyes with angle closure > 270°.

In ACG patients with concomitant cataract, the evidence is strong that cataract surgery improves IOP control and decreases the risk for IOP spikes and acute attacks in the future, but the mechanisms of IOP-lowering by cataract surgery in ACG eyes remain unclear [16]. It has been documented that cataract surgery may be preferable to phaco-goniosynechialysis or phaco-trabeculectomy [17]. The pathophysiological mechanisms of action in ACG mainly include pupillary block and plateau iris configuration, and the primary goal of ACG treatment is to relieve the pupillary block that accelerates the cascade of events which results in anatomic angle closure [18]. Therefore, the potential mechanisms of IOP-lowering might be explained with that the widening of the drainage angle, together with the reduced extent of observed synechial angle closure as documented in our study, might facilitate aqueous outflow through any remaining functional segments of the trabecular meshwork [1]. In-the-bag implantation of an IOL might stretch the zonules, and thus in turn create traction on the trabecular meshwork and open up the trabecular spaces to facilitate aqueous outflow might also partly contribute to the IOP-lowering [19]. Goniosynechialysis effectively lowers the IOP by means of a mechanical stripping of goniosynechiae from the angle wall, and combining goniosynechialysis with lens extraction by phacoemulsification increases the effectiveness of goniosynechialysis [20]. A previous study of Chen et al. have presented surgical success rates of phaco-goniosynechialysis, and reported that 30 of 32 eyes (93.8%) achieved an IOP value ≤ 21 mm Hg at the final visit without the use of ocular hypotensive agents [18]. It has been well-acknowledged that cataract extraction by phacoemulsification and IOL implantation, together with goniosynechialysis has certain advantages: (1) goniosynechialysis is performed to release the mechanical block of the trabecular meshwork and is relatively safe because of the absence of a filtering bleb; (2) goniosynechialysis separates the iris from the angle wall, which allows the aqueous humor to have access to the trabecular meshwork; (3) this procedures have fewer postoperative complications [21]. Also, in the study of Tham et al., they demonstrated that higher preoperative IOP and enhanced requirement for glaucoma drugs relate to IOP control failure in PACG eyes with cataract, and phacotrabeculectomy is more likely to achieve IOP control [22]. In the report of Saleh et al., it has also been proven that the trabeculectomy facilitates minimally invasive and effective glaucoma surgery, which spares the conjunctiva and does not preclude subsequent standard filtering procedures, and combined phacoemulsification and phacoemulsification is a safe, effective, and stable alternative for patients with cataracts and glaucoma [23].

In addition, our study addressed secondary outcome measures such as VA, UBM anatomical parameters (ACD and AOD), the degree of angle opening, and surgical complications. Based on the data from our study, all these 3 cataract surgeries decrease the extent of documentable synechial angle closure in ACG eyes with concomitant cataract. It was believed that the deepening of the anterior chamber with viscoelastic and hydrostatic pressure during the procedure might actually strip open some pre-existing goniosynechiae, which might explain the decrease in synechial angle closure observed after these 3 cataract surgeries [1]. Abnormal biometric findings have long been studied in patients with ACG and these UBM anatomical parameters are characteristically smaller in ACG eyes; for example, in a retrospective series, Nonaka et al. demonstrated an increase in ACD, AOD500, and TCPD after cataract surgery in 31 eyes with primary angle closure or PACG, which, to our knowledge, is the first prospective study to formally evaluate the anatomical effect of clear lens extraction in Asian ACG eyes [24]. Also, the 3 cataract surgeries significantly increased the AOD and the ACD on UBM examination in our study.

Meanwhile, our results found no apparently correlation of phacoemulsification alone, combined phaco-goniosynechialysis or combined phaco-trabeculectomy with surgical complications, implying that these cataract surgeries are effective in the treatment of ACG with concomitant cataract. This may, in part, be explained by the thinner profile of posterior chamber intraocular lenses compared with the clear or cataractous natural lens of the eye and may be one additional advantage of combined surgery in the patient with controlled or uncontrolled IOP and cataract; additionally, surgical complications may also be related to the operator [25]. In accordance with our results, Jacobi et al. documented that intra-operative and post-operative complications of primary phacoemulsification and intraocular lens implantation were few and manageable [26].

In summary, all our cases of phacoemulsification alone, combined phaco-goniosynechialysis, and combined phaco-trabeculectomy resulted in substantial visual recovery, excellent IOP control, improved UBM examination results, and decreased extent of synechial angle closure with few complications. These results provide safe, effective, predictable, and stable options of cataract surgery for treatment of ACG with concomitant cataract. In addition, our results indicated that these 3 cataract surgeries have different applicable conditions with phacoemulsification alone for ACG eyes with angle closure < 180°, combined phaco-goniosynechialysis for ACG eyes with angle closure of 180°~270°, and combined phaco-trabeculectomy for ACG eyes with angle closure > 270°. However, there are several limitations to our study, such as notably a small sample population and a relatively short follow-up time, and larger clinical trials with long-term follow-up will be necessary to establish the actual effectiveness and safety of phacoemulsification, combined phaco-goniosynechialysis, and combined phaco-trabeculectomy.

Disclosure of conflict of interest

None.

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