



Comparison of Long-Term Effects Following Phacoemulsification Combined with Goniosynechialysis and Trabeculectomy in Patients with Primary Angle-Closure Glaucoma and Cataract

Yang Zhang · Gangwei Cheng · Yao Chen · Ailing Bian ·

Qi Zhou · Lüe Li · Shunhua Zhang

Received: May 29, 2023 / Accepted: September 19, 2023 / Published online: December 2, 2023
© The Author(s) 2023

ABSTRACT

Introduction: Goniosynechialysis (Phaco-GSL) is a logical therapeutic approach for patients with primary angle-closure glaucoma (PACG) and cataract. The aim of this study was to compare the long-term effectiveness and safety of Phaco-GSL and trabeculectomy (TRB) in the management of PACG with coexisting cataract.

Methods: A review was conducted on 96 Chinese patients (96 eyes) with PACG and cataract from Peking Union Medical College Hospital (PUMCH). Among them, 56 patients underwent Phaco-GSL, while 40 underwent TRB. Intraocular pressure (IOP), best corrected visual acuity (BCVA), use of supplemental antiglaucoma medical therapy, surgery success rates, and complications for both procedures were assessed.

Results: The average follow-up period was 50.3 ± 18.7 months in the Phaco-GSL group and 61.2 ± 15.1 months in the TRB group. At

the final follow-up, IOP decreased from 27.0 ± 11.1 mmHg to 13.5 ± 2.1 mmHg in the Phaco-GSL group and in the TRB group IOP decreased from 27.1 ± 7.7 mmHg to 16.5 ± 5.5 mmHg. The long-term postoperative IOP in the Phaco-GSL group was significantly lower than that in the TRB group. There was a statistically significant reduction in medication usage in both groups, with the TRB group having a higher number of postoperative medications at the final follow-up. The incidence of postoperative complications was significantly higher in the TRB group compared to the Phaco-GSL group.

Conclusions: Phaco-GSL is the recommended surgical approach for Chinese patients with primary angle-closure glaucoma (PACG) and cataract. Compared to traditional TRB, eyes undergoing Phaco-GSL show a reduced requirement for antiglaucomatous medications, improved management of IOP, decreased risk of complications, and higher long-term cumulative probability of treatment success for patients with PACG.

Keywords: Goniosynechialysis; Trabeculectomy; Phacoemulsification; Primary angle-closure glaucoma; Intraocular pressure

Y. Zhang · G. Cheng (✉) · A. Bian · Q. Zhou · L. Li · S. Zhang

Department of Ophthalmology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Dongdan Shuaifuyuan 1#, Beijing 100730, China
e-mail: ChengGW@pumch.cn

Y. Chen
Department of Ophthalmology, Beijing Tiantan Hospital, Capital Medical University, Beijing, China

Key Summary Points

Why carry out this study?

Primary angle-closure glaucoma (PACG) is a leading cause of blindness in Asia. Trabeculectomy (TRB) is a traditional method used to establish external filtration bleb for the treatment of PACG, but it carries the risk of complications. Phacoemulsification combined with goniosynechialysis (Phaco-GSL) has offered a rational therapeutic approach to restore the physiological internal drainage pathway for patients with PACG and cataracts.

This study aimed to compare the long-term efficacy and safety of Phaco-GSL and TRB as surgical approaches for Chinese patients with PACG, addressing the limited literature comparing their long-term outcomes.

What was learned from the study?

Phaco-GSL emerges as the recommended surgical approach for Chinese patients with PACG and cataracts.

Compared to traditional TRB, eyes undergoing Phaco-GSL demonstrate a decreased reliance on antiglaucomatous medications, improved management of intraocular pressure, reduced risk of complications, and higher long-term cumulative probability of positive outcomes.

closure of the AC angle, resulting from appositional or synechial adhesion of the peripheral iris to the trabecular meshwork (TM) [5–7]. The gradual increase in intraocular pressure (IOP) due to the closure of the AC angle can lead to irreversible blindness [3, 7]. Trabeculectomy (TRB) is a conventional treatment strategy for patients with PACG with extensive synechial angle closure or peripheral anterior synechiae (PAS). However, it carries the risk of various complications, including hypotony, flattening of the AC, choroid detachment, leakage, and infection of the filtration bleb, some of which can be sight-threatening [7–9].

Cataract extraction alone can reverse the anatomic predisposition to angle closure, but it does not address the issue of PAS. Increasing evidence has demonstrated that combining goniosynechialysis with phacoemulsification (Phaco-GSL) is an effective procedure for relieving pupillary block and deepening the depth of AC by removing the lens. Meanwhile, this technique also allows for the dissection of PAS by separating the peripheral iris from the AC angle wall, reopening the closed angle, and restoring physiological trabecular outflow [10]. Phaco-GSL is a logical therapeutic approach for patients with PACG and cataracts. It is known to improve IOP control with minimal complications and has gradually been adopted by many glaucoma surgeons [11–13].

Considering the limited availability of literature comparing long-term outcomes between Phaco-GSL and TRB, we conducted the present study to compare the long-term efficacy and safety of these two surgical approaches in Chinese patients with PACG.

METHODS

This retrospective comparative study was conducted at a single center. The study protocol was approved by the Institutional Review Board of Peking Union Medical College Hospital (s-k1352), and it adhered to the principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all subjects after an explanation of the nature of the

INTRODUCTION

Angle-closure glaucoma is a leading cause of blindness in Asia [1, 2], characterized by structural damage to the anterior chamber (AC) angle and optic nerve and associated visual dysfunction [3, 4]. Primary angle-closure glaucoma (PACG) is characterized by the permanent

study before their participation in the surgical procedures of this study.

A total of 56 patients (56 eyes) with PACG and coexisting cataract who had undergone Phaco-GSL, along with 40 patients (40 eyes) who underwent TRB, were enrolled in this study. They were followed up postoperatively at PUMCH in Beijing, PR China. The inclusion criteria were as follows: (1) age ≥ 40 years; (2) diagnosis of PACG with definitive glaucomatous optic neuropathy (GON) and associated visual field (VF) defects; (3) presence of coexisting cataract with nuclear sclerosis, cortical cataract, or subcapsular cataract, with best corrected visual acuity (BCVA) of 0.5 (LogMAR), or worse, or impact on daily activities; (4) elevated IOP (> 21 mmHg) with or without other antiglaucoma medications; (5) confirmation of synechial angle closure occluding > 180 degrees of the angle, as verified by indentation gonioscopy.

The exclusion criteria for this study were as follows: (1) secondary angle-closure glaucoma; (2) a history of prior eye surgery or ocular trauma; (3) severe systemic diseases such as uncontrolled diabetes; (4) the presence of concurrent retinal or optic neuropathy, ocular neovascularization diseases, or other ophthalmic conditions apart from glaucoma and cataract; (5) long-term use of topical or systemic steroids.

BCVA, IOP measured using a Goldmann applanation tonometer, number of antiglaucoma medications, presence of synechial/apposition angle closure observed through gonioscopy, slit-lamp examination, and fundus examination, and the mean defect (MD) of the VF measured using a standard automated perimeter (Octopus Field Analyzer 101; Switzerland) were assessed before the surgery, during follow-up and at the final follow-up evaluation. Based on the value of MD of VF, patients were divided into three groups: patients with a mild defect ($MD \geq -6$ dB), patients with moderate defect (-12 dB $\leq MD < -6$ dB), and patients with advanced defect (-20 dB $\leq MD < -12$ dB).

Surgical Technique

The surgeries were typically conducted using surface anesthesia with oxybuprocaine hydrochloride eye drops. In some cases, patients undergoing TRB received subconjunctival anesthesia in the operative field using 2% lidocaine without epinephrine. Patients with a VF radius of ≤ 10 degrees or a cup-to-disc area ratio of ≥ 0.9 underwent the procedure under general anesthesia.

Phaco-GSL Procedure

Standard phacoemulsification was performed through a 2.4-mm clear corneal incision at the 11 o'clock position, followed by posterior chamber intraocular lens (IOL) implantation. A dense viscoelastic substance was injected into the AC, and using the tension and thrust provided by the viscoelastic agent, the iris foot of the appositional PAS was pressed down until the TM was visible under direct guidance from the intraoperative gonioscope (VOLK). The goniosynechialysis spatula and Phaco-Emulsifier aspirator accessories were selectively used in areas with tightly adherent PAS. It was preferable to achieve an opening angle of no less than 270° with a clearly visible ciliary body band. The superior quadrant, which often presented technical challenges, was commonly left untreated. The Phaco-GSL procedure was performed gently to avoid mechanical damage to the iris or bleeding. Complete separation of PAS from all angles was not recommended. After the procedure, the viscoelastic substance was thoroughly removed, and paracenteses were hydrostatically sealed.

TRB Procedure

TRB was performed following the technique described by Carins [14]. A superior fornix-based conjunctival flap was created to expose the sclera. A 4×4 -mm scleral flap, dissected at $1/3$ thickness and based on the limbus, was prepared. A 1×2 -mm block of tissue was removed just anterior to the scleral spur to access AC, followed by a peripheral iridectomy.

The superficial flap was repositioned and secured using two fixation sutures and two adjustable sutures (10/0 nylon). The conjunctiva was tightly closed with 10/0 nylon sutures to ensure watertightness. Mitomycin C (MMC) was applied using soaked sponges under the scleral flap and conjunctiva (at a concentration of 0.04% and duration 1–2 min under the flap and 1 min under the conjunctiva).

All surgeries were performed by an experienced doctor proficient in both cataract and glaucoma surgery. The doctor strictly adhered to the standard protocol for each surgery.

Postoperatively, patients in both groups received treatment according to the following regimen: 1% prednisolone acetate drops (Pred Forte; Allergan, Irvine, CA) six times daily, with the dose gradually tapered over a minimum of 4 weeks. Additionally, ofloxacin ophthalmic solution (Santen Pharmaceutical Co., Osaka, Japan) was administered four times daily for 3 weeks. In the Phaco-GSL group, 2% pilocarpine was administered each night for at least 2 weeks. In the TRB group, atropine was added three times daily for a period of 1 to 4 weeks.

In the Phaco-GSL group, subsequent trabeculectomy with MMC was indicated if the IOP increased to more than 21 mmHg despite maximally tolerated medications. In the TRB group, suture lysis was performed if there was no bleb and IOP increased beyond 21 mmHg within 1 month after surgery. If IOP elevation was > 21 mmHg and the filtering bleb was encysted or showed signs of fibrosis, a needling procedure was carried out followed by a subconjunctival and subscleral injection of 5-fluorouracil (5 mg once daily for 3–5 consecutive days, depending on clinical response). Antiglaucoma medication was resumed based on the IOP level. Any postoperative complications were recorded if present.

“Complete success” was defined as IOP values ranging between 5 and 18 mmHg with a reduction of $\geq 20\%$ without the need for additional hypotensive medications or reoperation for glaucoma. “Qualified success” was defined as the same outcome, however, including subjects who required hypotensive medications postoperatively.

Statistical Analysis

All analyses were conducted using SPSS Statistics Premium v21 (IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as means \pm standard deviation (SD) for continuous variables, medians, and interquartile range for continuous variables with non-normal distribution and n (%) for categorical variables. Normality of data was assessed using the Kolmogorov-Smirnov test, and parametric or non-parametric tests were applied accordingly. Associations between two categorical variables were analyzed using the chi-squared test or Fisher’s exact test when any cell value was < 5 in cross tabulations. Continuous parameters were compared between the two groups using Mann-Whitney tests or t-tests. Repeated measurements of quantitative variables were compared using paired t-tests (for normally distributed differences in both groups) or Wilcoxon paired signed rank tests (otherwise). Kaplan-Meier survival analysis was performed to evaluate the cumulative probability of surgery success. BCVA was expressed as the logarithm of the minimal angle of resolution (LogMAR) for statistical analysis. Statistical significance was defined as $P < 0.05$.

RESULTS

A total of 96 eyes from 96 patients were included in the study. Among them, 56 eyes underwent Phaco-GSL, while 40 eyes underwent TRB. No statistically significant differences were observed between the two groups in terms of age, sex, baseline IOP, BCVA, axial length, proportion of VF, number and duration of preoperative antiglaucoma medication, and extent of PAS ($P > 0.05$), except for the follow-up time, as shown in Table 1.

The average follow-up period was 50.3 ± 18.7 months for the Phaco-GSL group and 61.2 ± 15.1 months for the TRB group. Both groups showed a significant reduction in IOP from baseline ($P < 0.001$). At the final follow-up, the mean IOP decreased from 27.0 ± 11.1 mmHg to 13.5 ± 2.1 mmHg in the Phaco-GSL group and from 27.1 ± 7.7 mmHg

Table 1 Demographic characteristics

	Phaco-GSL	TRB	<i>P</i> value
<i>N</i> (%)	56 (58.3)	40 (41.7)	
Male <i>N</i> (%)	25 (44.6)	24 (60.0)	0.547*
Age (mean ±SD, years)	58.7 ± 5.5	57.± 12.2	0.326 [†]
Pre-IOP (mean ±SD, mm Hg)	27.0 ± 11.1	27.1 ± 7.7	0.591 [†]
Axial length (mean ±SD, mm)	22.8 ± 1.2	22.7 ± 1.1	0.995 [†]
Pre-medications [<i>M</i> (<i>Q1</i> , <i>Q3</i>)]	3 (3,4)	4 (3,4)	0.088 [‡]
Medication duration [<i>M</i> (<i>Q1</i> , <i>Q3</i>)], (months)	48 (42,60)	36 (16,60)	0.236 [‡]
Pre-Op BCVA (LogMAR) (mean ±SD)	0.4 ± 0.2	0.3 ± 0.2	0.218 [†]
Pre-Op PAS [<i>M</i> (<i>Q1</i> , <i>Q3</i>)], (degrees)	270 (180,360)	180 (180,300)	0.205 [‡]
Pre-Op VF			
Mild	12	8	0.347
Moderate	16	8	0.096
Advanced	28	24	0.581
Follow-up duration (mean ±SD, months)	50.3 ± 18.7	61.2 ± 15.1	0.003 [†]

Phaco-GSL goniosynechialysis combined with phacoemulsification, *TRB* trabeculectomy, *IOP* intraocular pressure, *PAS* peripheral anterior synechiae; *BCVA* best corrected visual acuity, *VF* visual field, *SD* standard deviation, *M* median, *Q1* lower quartile, *Q3* upper quartile

*Chi-squared test

[†]*t* test

[‡]Wilcoxon two-sample test

to 16.5 ± 5.5 mmHg in the TRB group. During the early postoperative period, the IOP in the TRB group was significantly lower than that in the Phaco-GSL group at 1 day, 1 week, and 1 month post-operation ($P < 0.01$). However, the decrease in IOP in the Phaco-GSL group demonstrated a gradual trend, with no significant difference between the two groups from 3 to 18 months after the surgery. However, at the 24-month mark, the IOP in the TRB group was higher than that in the Phaco-GSL group. As a matter of fact, at the final follow-up, the IOP in the TRB group was significantly higher than that in the Phaco-GSL group ($P < 0.001$). The mean fluctuation in IOP reduction at the final follow-up was 44.4% (95% confidence interval [15], 38.3–50.4) in the Phaco-GSL group, while it was 41.5% (95% confidence interval [15], 35.3–47.8) in the TRB group (Table 2).

At the final follow-up, the complete success rates and qualified success rates were 53.6% (30/56) and 92.8% (52/56), respectively, in the Phaco-GSL group, whereas in the TRB group, they were 37.5% (15/40) and 70.0% (28/40), respectively. Kaplan-Meier survival analysis revealed a higher cumulative probability of success in the Phaco-GSL group compared to the TRB group ($P = 0.014$, log-rank test) (Fig. 1).

The number of antiglaucoma medications per patient decreased significantly in both groups, from two to four medications to 0–2 medications ($P < 0.001$). Moreover, there was a notable difference in the number of therapeutic medications used between the two groups at the final follow-up (Table 3).

At the final follow-up, a remarkable improvement in BCVA (logMAR) was observed in the Phaco-GSL group compared to baseline

Table 2 IOP at baseline and following Phaco-GSL and TRB

IOP (mmHg)	Phaco-GSL (mean ± SD) (n)	TRB (mean ± SD) (n)	P value
Preoperatively	27.0 ± 11.1(56)	27.1 ± 7.7(40)	0.953
1 day	21.1 ± 9.1(56)	10.4 ± 4.7(40)	< 0.001
1 week	15.6 ± 3.9(56)	9.7 ± 4.2(40)	< 0.001
1 month	15.2 ± 3.7(54)	13.1 ± 4.0(40)	0.004
3 months	14.1 ± 2.7(54)	13.2 ± 3.5(38)	0.227
6 months	14.4 ± 2.7(56)	13.8 ± 4.0(37)	0.450
12 months	14.0 ± 3.1(50)	14.3 ± 3.6(39)	0.675
18 months	13.4 ± 2.6(36)	14.2 ± 3.2(32)	0.176
24 months	13.2 ± 2.1(49)	15.4 ± 4.8(30)	0.009
36 months	13.6 ± 2.1(51)	16.2 ± 6.5(38)	0.012
48 months	13.7 ± 2.3(48)	14.8 ± 4.8(32)	0.353
60 months	13.1 ± 1.9(39)	15.8 ± 6.9(27)	0.082
72 months	12.1 ± 2.5(31)	15.7 ± 5.5(24)	0.095
84 months	11.0 ± 1.2(24)	14.7 ± 2.4(20)	0.10
Final follow-up	13.5 ± 2.1	16.5 ± 5.5	< 0.001

Phaco-GSL goniosynechialysis combined with phacoemulsification, *TRB* trabeculectomy, *IOP* intraocular pressure, *SD* standard deviation

(0.4 ± 0.2 vs 0.2 ± 0.2 , $t = -5.883$, $P < 0.001$). However, in the TRB group, no significant differences were observed when comparing pre- and postoperative visual acuity (0.3 ± 0.2 vs 0.3 ± 0.2 , $t = 0.488$, $P = 0.700$).

Intraoperative complications, such as hyphema and aqueous misdirection, were observed in both groups. In the Phaco-GSL group, mild hyphema was mainly attributed to the separation of PAS, and effective compression hemostasis was achieved using viscoelastic agents. One patient in the TRB group experienced hyphema resulting from iridectomy. Moreover, two patients in the Phaco-GSL group encountered posterior capsule rupture, and IOLs were successfully implanted in the ciliary sulcus.

In the early postoperative period, corneal edema was observed in six patients in the Phaco-GSL group and two patients in the TRB group. In these cases, close observation was

deemed appropriate. Shallow AC, choroidal detachment, and hypotony were common and severe complications in the TRB group, necessitating careful monitoring and specific treatments. Additionally, one case of malignant glaucoma occurred in each group, and both were successfully relieved by relaxing the ciliary muscle with atropine and performing combined intravitreal puncture.

In the long term after surgery, PAS recurrence was observed in eight patients from the Phaco-GSL group. Fortunately, no IOP rebound was reported following observation or the administration of anti-glaucoma drugs. On the other hand, in the TRB group, common long-term complications included bleb-related complications and cataract progression.

There were no significant differences in intraoperative complications between the two groups. However, the incidence of complications was significantly higher in the TRB group

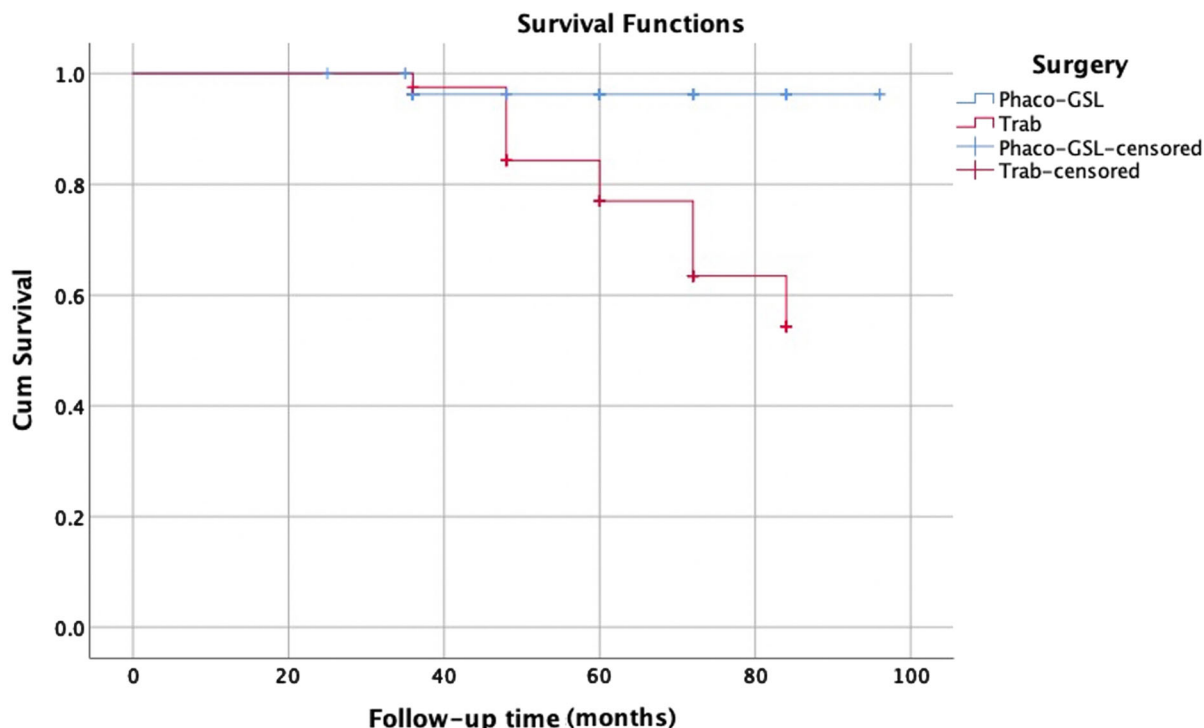


Fig. 1 Kaplan-Meier survival analyses comparing the success rates between the Phaco-GSL group and the TRB group. *Phaco-GSL* phacoemulsification combined with goniosynechialysis, *TRB* trabeculectomy

Table 3 Number of antiglaucoma medications before and after surgery in Phaco-GSL and TRB group

Glaucoma medications	Phaco-GSL [Median (Q1, Q3)]	TRB [Median (Q1, Q3)]	<i>P</i> value
Preoperatively	3(3,4)	4 (3,4)	0.088
Final follow-up	1(0,1)	1(0,2)	0.027

Phaco-GSL goniosynechialysis combined with phacoemulsification, *TRB* trabeculectomy, *Q1* lower quartile, *Q3* upper quartile
 Wilcoxon paired signed rank test between baseline and post-baseline values

compared to the Phaco-GSL group during both the early and late postoperative periods (Table 4).

DISCUSSION

TRB and Phaco-GSL are both commonly used surgical procedures for treating PACG with cataract. TRB involves creation an additional artificial filtering pathway, but it is often associated with a higher incidence of postoperative complications. In contrast, Phaco-GSL has been developed as a safer and better-received surgical intervention for patients with PACG. Its primary objective is to deepen the AC and reopen the anterior drainage angle. By stripping the PAS from the angle wall, Phaco-GSL aims to restore the normal physiological function of aqueous outflow. However, recent meta-analyses and multicenter studies have produced inconsistent results [16–19]. We believe that this inconsistency may be attributed to various factors, such as differences in surgical procedures and perioperative management, which must not be overlooked.

In this study, both groups demonstrated a significant decrease in IOP from baseline, with a

Table 4 Surgical complications associated with Phaco-GSL and TRB

Complications	Phaco-GSL <i>n</i> (%)	TRB <i>n</i> (%)	<i>P</i> value
Intraoperative			
Posterior capsule rupture	2 (3.6)	0 (0)	0.227
Hyphema	12 (21.4)	8 (20.0)	0.865
Aqueous misdirection	3 (5.3)	1 (2.5)	0.490
Total	17 (30.3)	9 (22.5)	0.393
Early postoperative (1 day to 1 month)			
Corneal edema	6 (10.7)	2 (5)	0.318
Shallow anterior chamber	1 (1.7)	8 (20)	0.003
Choroidal detachment	0 (0)	7 (17.5)	0.001
Hypotony	0 (0)	9 (22.5)	< 0.001
Malignant glaucoma	1 (1.7)	1 (2.5)	0.662
Total	8 (14.3)	27 (67.5)	< 0.001
Long-term postoperative (> 1 month)			
Bleb scarring/cystic bleb	0 (0)	14 (35)	< 0.001
Peripheral anterior synechiae	8 (14.3)	8 (19)	0.459
Cataract development and progression	0 (0)	12 (30)	< 0.001
Endophthalmitis	0	0	1.000
Total	8 (14.3)	34 (85)	< 0.001

Phaco-GSL goniosynechialysis combined with phacoemulsification, *TRB* trabeculectomy

notable trend towards better IOP outcomes observed in the Phaco-GSL group. Specifically, the Phaco-GSL group exhibited a significantly lower postoperative IOP and a greater IOP reduction at the final follow-up compared to the TRB group. The postoperative IOP in the Phaco-GSL group decreased steadily and exhibited a safer profile, in contrast to the rapid drop observed in the TRB group. Kaplan-Meier survival analysis indicated that the long-term surgical success rate of Phaco-GSL was superior to that of TRB. Tsai et al. [20] reported that combined phaco-trabeculectomy had similar effects on lowering IOP compared to trabeculectomy alone. In a meta-analysis conducted by Liu et al., which combined data from phaco-trabeculectomy and trabeculectomy, the pooled results demonstrated that Phaco-GSL had an

equivalent ability to lower IOP as Phaco-trabeculectomy/trabeculectomy [18]. Notably, previous studies had a follow-up duration of no more than 3 years. In this study, we conducted a longer postoperative follow-up, and the TRB group exhibited noticeably higher postoperative IOP compared to the Phaco-GSL group. We believe this difference may be related to long-term subconjunctival fibrosis after the TRB surgery [21].

Our findings present compelling evidence that both Phaco-GSL and TRB procedures resulted in a reduction in the number of antiglaucoma medications required by the patients. This result is consistent with previous studies that compared Phaco-GSL with Phaco-TRB [8]. Furthermore, a significant difference in the number of therapeutic medications was

observed between the two groups at the final postoperative follow-up. Specifically, the Phaco-GSL group maintained a lower IOP with fewer antiglaucoma medications compared to the TRB group.

Due to the unique anatomical characteristics of Chinese patients with PACG, including shallow AC, short axial length, more extensive and tightly adherent PAS, plateau iris configuration, thicker and anteriorly rotated ciliary body, constricted pupils, and zonular dialysis, Phaco-GSL surgery presents relatively greater challenges. The complexity of these cases demands a high level of surgical skill and experience to navigate through potential complications and ensure optimal outcomes. By recognizing and addressing these specific challenges, surgeons can enhance the safety and effectiveness of Phaco-GSL surgery for patients with PACG.

In this study, posterior capsule rupture occurred in two patients, and the IOL was implanted in the ciliary sulcus in the Phaco-GSL group. This, to some extent, resulted in an elevation of postoperative inflammatory response and an increased likelihood of PAS recurrence.

There is a relatively high risk of developing aqueous misdirection and malignant glaucoma in patients with PACG [22]. During the surgery in the Phaco-GSL group, three patients experienced aqueous misdirection, leading to the inability to form AC and a sustained increase in IOP. To address this condition, we performed ocular digital massage and pars plana puncture, effectively controlling the situation and preventing postoperative malignant glaucoma. In some cases, anterior vitrectomy was also necessary to manage the condition effectively.

We believe that preoperative ultrasound biomicroscopy (UBM) examination is beneficial in evaluating the condition of the ciliary body and posterior chamber, enabling the prospective identification of patients who may be prone to malignant glaucoma. Prior to surgery, a thorough assessment of surgical risk is essential. If required, anterior vitrectomy and iridionulo-hyalod-vitrectomy (IZHV) surgery can be combined simultaneously to effectively address the risk of angle closure caused by malignant glaucoma and establish a reserve of

open space in AC, ultimately leading to a more stable and successful outcome.

In this study, complications related to postoperative overfiltration and filtering bleb fibrosis were almost invariably encountered in the TRB group, in both the early and late periods. These complications included shallow AC (20%), choroidal detachment (17.5%), hypotony (22.5%), and bleb scarring/cystic bleb (35%), which were rarely observed in the Phaco-GSL group. However, it is essential to emphasize that Phaco-GSL does not rely on filtering blebs. Instead, it effectively addresses issues such as early postoperative bleb leakage and overfiltration as well as late postoperative bleb scarring.

Cataract development and progression were identified as the most prevalent complications of TRB. In a study conducted by Chen et al. [23] on an Asian population, 52 (21%) patients with PACG experienced increased cataract development after TRB, as determined during the 32-month follow-up visit. The higher incidence observed in our study (30%) can be attributed to the longer duration of follow-up.

Although there was a slightly higher incidence of intraoperative hyphema in the Phaco-GSL group, it was temporary and mild. Additionally, the recurrence rate of PAS was 14.3%, which is significantly better compared to the previously reported high recurrence rate of 83.3% after Phaco-GSL by Tian et al. [24].

We attribute the favorable postoperative outcomes of Phaco-GSL to the key advantages of surgical procedures; we also emphasize that glaucoma surgeons should carefully consider and address these factors during the surgery: (1) PAS separation should be performed with direct gonioscopy visualization in a minimally invasive manner. This approach can help avoid damage to other structures of the chamber angle as much as possible, ensuring that Phaco-GSL is not only more effective but also safer [17, 25]. (2) When feasible, it is recommended to use blunt separation methods, such as viscoelastics, and avoid using “cutting type” separation techniques. When using spatula and Phaco-Emulsifier aspirator accessories, it is crucial to target only the areas with extremely tight PAS. This approach effectively minimizes inflammation and hemorrhage, thereby

reducing the risk of PAS recurrence and preserving the function of the TM. These measures are essential for achieving long-term stabilization of IOP and improving the overall success rate of the surgery. (3) Performing a blunt and gentle procedure during Phaco-GSL significantly reduces irritation and damage to the ciliary body and ciliary zonule. This approach proves beneficial, especially in cases where narrowing or closure of the anterior chamber angle is caused by forward rotation of the ciliary body. Moreover, it enhances the stability of the IOL after surgery. (4) The flatness of the Asian nasal bone allows for a minimally invasive approach while maximizing the opening of PAS [26]. Forced separation of the full circumferential PAS is not recommended. Several studies, including the present one, have confirmed that an opening angle of at least 270° can effectively reduce IOP. It is crucial to avoid pseudo-opening of the AC, and we strongly recommend detecting the ciliary band under gonioscopy after GSL. (5) It should be combined with intensive anti-inflammatory treatment during the perioperative period to minimize recurrence of PAS and reduce the damage to the TM.

The specific duration and extent of angle closure that may lead to irreversible damage to the TM remain uncertain because of limited follow-up periods (from 2 to 12 months) in previous studies [18]. However, our study demonstrates that patients with a medical history of > 3 years still achieved favorable surgical results after undergoing Phaco-GSL. Therefore, even in cases with a long medical history, considering the advantage of Phaco-GSL in terms of postoperative complications compared with TRB, we recommend Phaco-GSL as the initial choice, and TRB can be selected if the operation fails.

To the best of our knowledge, this study represents the longest follow-up investigation comparing Phaco-GSL and TRB surgeries. Throughout this study, Phaco-GSL demonstrated several advantages over traditional TRB, including reduced medication usage, improved IOP control, lower incidence of complications, and higher cumulative probability of success during postoperative follow-up exceeding 50 months. These encouraging results suggest

that the Phaco-GSL can be considered a valid alternative to the conventional TRB method for patients with PACG. Nonetheless, it is crucial to acknowledge certain limitations of this study, such as being a single-center retrospective comparative study with a relatively small sample size. Therefore, to comprehensively evaluate and validate the safety and long-term efficacy of Phaco-GSL and to compare its outcomes with TRB, a multicenter, randomized, prospective study with a larger sample population is essential. Such future research will provide more robust evidence and insights into the benefits of Phaco-GSL as a surgical option for patients with PACG.

CONCLUSIONS

In conclusion, considering the long-term perspective, Phaco-GSL emerges as a safe and effective approach for managing patients with PACG and cataract. It can be considered a primary treatment option for effectively controlling IOP.

ACKNOWLEDGEMENTS

We thank the study participants.

Author Contribution. Yang Zhang and Yao Chen wrote the main manuscript text and prepared all figures. Lüe Li and Gangwei Cheng oversaw the project and assisted with the writing of the manuscript. Qi Zhou, Shunhua Zhang and Ailing Bian performed ophthalmic examinations. All authors reviewed the manuscript.

Funding. No funding or sponsorship was received for this study or publication of this article. The Rapid Service Fee was funded by the authors.

Data Availability. The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest. Yang Zhang, Gangwei Cheng, Yao Chen, Ailing Bian, Qi Zhou, Lüe Li, and Shunhua Zhang have nothing to disclose.

Ethical Approval. This study was approved by the Institutional Review Board of Peking Union Medical College Hospital (s-k1352) and conformed to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all subjects after an explanation of the nature of the study before their participation in the surgical procedures of this study.

Open Access. This article is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License, which permits any non-commercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc/4.0/>.

REFERENCES

- Lai JS, Liu DT, Tham CC, Li RT, Lam DS. Epidemiology of acute primary angle-closure glaucoma in the Hong Kong Chinese population: prospective study. *Hong Kong Med J*. 2001;7(2):118–23.
- Foster PJ. The epidemiology of primary angle closure and associated glaucomatous optic neuropathy. *Semin Ophthalmol*. 2002;17(2):50–8. <https://doi.org/10.1076/soph.17.2.50.14718>.
- Foster PJ, Buhmann R, Quigley HA, Johnson GJ. The definition and classification of glaucoma in prevalence surveys. *Br J Ophthalmol*. 2002;86(2):238–42. <https://doi.org/10.1136/bjo.86.2.238>.
- Quigley HA. Glaucoma. *Lancet*. 2011;377(9774):1367–77. [https://doi.org/10.1016/S0140-6736\(10\)61423-7](https://doi.org/10.1016/S0140-6736(10)61423-7).
- Wang N, Wu Z, Liu H. Mechanism and etiology of primary chronic angle closure glaucoma. *Yan Ke Xue Bao*. 1994;10(3):186–92.
- Wang N, Wu H, Fan Z. Primary angle closure glaucoma in Chinese and Western populations. *Chin Med J (Engl)*. 2002;115(11):1706–15.
- Gedde SJ, Chen PP, Muir KW, et al. Primary angle-closure disease preferred practice pattern(R). *Ophthalmology*. 2021;128(1):P30–70. <https://doi.org/10.1016/j.ophtha.2020.10.021>.
- Zhao XJ, Yang XX, Fan YP, Li BH, Li Q. Comparison of combined phacoemulsification, intraocular lens implantation, and goniosynechialysis with phacotrabeculectomy in the treatment of primary angle-closure glaucoma and cataract. *Asia Pac J Ophthalmol (Phila)*. 2013;2(5):286–90. <https://doi.org/10.1097/APO.0b013e318299df62>.
- Tham CC, Kwong YY, Baig N, Leung DY, Li FC, Lam DS. Phacoemulsification versus trabeculectomy in medically uncontrolled chronic angle-closure glaucoma without cataract. *Ophthalmology*. 2013;120(1):62–7. <https://doi.org/10.1016/j.ophtha.2012.07.021>.
- Qing G, Wang N, Mu D. Efficacy of goniosynechialysis for advanced chronic angle-closure glaucoma. *Clin Ophthalmol*. 2012;6:1723–9. <https://doi.org/10.2147/OPHTH.S34035>.
- White AJ, Orros JM, Healey PR. Outcomes of combined lens extraction and goniosynechialysis in angle closure. *Clin Exp Ophthalmol*. 2013;41(8):746–52. <https://doi.org/10.1111/ceo.12121>.
- Harasymowycz PJ, Papamatheakis DG, Ahmed I, et al. Phacoemulsification and goniosynechialysis in the management of unresponsive primary angle closure. *J Glaucoma*. 2005;14(3):186–9. <https://doi.org/10.1097/01.ijg.0000159131.38828.85>.
- Zhao J, Zhang C, Pazo EE, et al. Phaco-goniosynechialysis versus phaco-trabeculectomy in patients with refractory primary angle-closure glaucoma: a comparative study. *BMC Ophthalmol*. 2023;23(1):144. <https://doi.org/10.1186/s12886-023-02885-6>.
- Cairns JE. Trabeculectomy. Preliminary report of a new method. *Am J Ophthalmol*. 1968;66(4):673–9.
- Francis BA, Akil H, Bert BB. Ab interno Schlemm's Canal Surgery. *Dev Ophthalmol*. 2017;59:127–46. <https://doi.org/10.1159/000458492>.

16. Kameda T, Inoue T, Inatani M, Tanihara H, Japanese Phaco-Goniosynechialysis Multicenter Study G. Long-term efficacy of goniosynechialysis combined with phacoemulsification for primary angle closure. *Graefes Arch Clin Exp Ophthalmol*. 2013;251(3):825–30. <https://doi.org/10.1007/s00417-012-2091-8>.
17. Wang N, Jia SB. Phacoemulsification with or without goniosynechialysis for angle-closure glaucoma: a global Meta-analysis based on randomized controlled trials. *Int J Ophthalmol*. 2019;12(5):826–33. <https://doi.org/10.18240/ijjo.2019.05.20>.
18. Liu Y, Li W, Jiu X, et al. Systematic review and meta-analysis of comparing phacoemulsification combined with goniosynechialysis to other mainstream procedures in treating patients with angle-closure glaucoma. *Medicine (Baltimore)*. 2019;98(42): e17654. <https://doi.org/10.1097/MD.00000000000017654>.
19. Nguyen Xuan H, Nguyen Dinh N, Nguyen Thu H, et al. Comparing the safety and efficacy of phaco-goniosynechialysis with phacotrabeculectomy in the management of refractory acute primary closure angle glaucoma with cataract: a multicenter randomized trial. *J Glaucoma*. 2021;30(7):552–8. <https://doi.org/10.1097/IJG.0000000000001868>.
20. Tsai HY, Liu CJ, Cheng CY. Combined trabeculectomy and cataract extraction versus trabeculectomy alone in primary angle-closure glaucoma. *Br J Ophthalmol*. 2009;93(7):943–8. <https://doi.org/10.1136/bjo.2008.151803>.
21. Hitchings RA, Grierson I. Clinico pathological correlation in eyes with failed fistulizing surgery. *Trans Ophthalmol Soc U K*. 1983;103(Pt 1):84–8.
22. Shahid H, Salmon JF. Malignant glaucoma: a review of the modern literature. *J Ophthalmol*. 2012;2012: 852659. <https://doi.org/10.1155/2012/852659>.
23. Chen YH, Lu DW, Cheng JH, Chen JT, Chen CL. Trabeculectomy in patients with primary angle-closure glaucoma. *J Glaucoma*. 2009;18(9):679–83. <https://doi.org/10.1097/IJG.0b013e31819c4a07>.
24. Tian T, Li M, Pan Y, Cai Y, Fang Y. The effect of phacoemulsification plus goniosynechialysis in acute and chronic angle closure patients with extensive goniosynechia. *BMC Ophthalmol*. 2019;19(1):65. <https://doi.org/10.1186/s12886-019-1070-9>.
25. Sener H, Gulmez Sevim D, Evereklioglu C, et al. Efficacy and safety of different types of intraocular pressure-lowering surgeries in patients with primary angle closure (PAC) or PAC glaucoma: systematic review and network meta-analysis of randomized clinical trials. *Semin Ophthalmol*. 2023. <https://doi.org/10.1080/08820538.2023.2223292>:1-10.10.1080/08820538.2023.2223292.
26. Wen YF, Wong HM, Lin R, Yin G, McGrath C. Inter-ethnic/racial facial variations: a systematic review and bayesian meta-analysis of photogrammetric studies. *PLoS ONE*. 2015;10(8): e0134525. <https://doi.org/10.1371/journal.pone.0134525>.