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Clinical Observation of Pars Plana Therapeutic Vitreous Aspiration for Intraoperative High Intraocular Pressure in Primary Angle-Closure Glaucoma

Keywords: Pars plana therapeutic vitreous aspiration; Angle-closure glaucoma; Intraocular pressure

Abstract

Objective: To investigate the safety and technical feasibility of pars plana therapeutic vitreous aspiration (VP) combined with glaucoma surgery for the management of intraoperative high intraocular pressure (IOP) in primary angle-closure glaucoma (PACG).

Methods: A retrospective study. Patients with PACG who underwent intraoperative VP at the Department of Ophthalmology, Chengdu Integrated TCM& Western Medicine Hospital from July 2022 to January 2026 were enrolled and followed up for 3 months. Pre- and postoperative IOP, as well as intraoperative and postoperative complications were recorded. The primary endpoint was to evaluate the technical feasibility and improvement of intraoperative surgical conditions of VP during PACG surgery; intraoperative surgical facilitation, postoperative intraocular pressure, complications and visual acuity were designated as secondary outcomes.

Results: A total of 64 patients (71 eyes) were included, consisting of 41 patients (43 eyes, 60.56%) with acute primary angle-closure glaucoma, 16 patients (19 eyes, 26.76%) with chronic primary angle-closure glaucoma, and 7 patients (9 eyes, 12.68%) with PACG after prior glaucoma surgery. The mean IOP preoperative surgery was 24.59 ± 12.34 mmHg. 2. VP: a 1-mL syringe was used to puncture the vitreous cavity at 3.5 mm posterior to the limbus, with a mean aspirated volume of 0.21 ± 0.11 mL. Puncture was performed in the superotemporal quadrant in 35 eyes (49.29%), inferotemporal quadrant in 13 eyes (18.31%), superonasal quadrant in 14 eyes (19.72%), and inferonasal quadrant in 9 eyes (12.68%). The success rate of VP: 65 eyes (91.55%) achieved successful puncture in the first attempt, 5 eyes (7.04%) succeeded on the second attempt, and 1 eye (1.41%) failed all four puncture attempts. 3. Complications: no intraoperative complications such as vitreous hemorrhage or choroidal hemorrhage occurred. Early postoperative complications included hyphema in 2 eyes (2.82%) and vitreous hemorrhage in 1 eye (1.41%); all hemorrhages resolved within one month. Postoperative elevated IOP occurred in 8 eyes (11.27%). The postoperative IOP values at postoperative day 1, week 1, month 1 and month 3 were 18.48 ± 6.98 mmHg, 15.90 ± 8.26 mmHg, 16.28 ± 6.78 mmHg and 15.39 ± 3.64 mmHg, respectively, with model-estimated reductions from baseline and corresponding 95% confidence intervals reported at each follow-up time point.

Conclusion: VP is technically feasible when performed during PACG surgery and may facilitate smooth surgical performance. Limited by the retrospective study design and the absence of quantitative data for intraocular pressure and anterior-chamber depth immediately after the procedure, this study is insufficient to confirm its independent IOP-lowering efficacy. Its clinical value remains to be further validated in comparative studies.

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Introduction

Primary angle-closure glaucoma (PACG) is a group of diseases characterized by acute or chronic elevation of intraocular pressure resulting from primary angle closure, leading to optic disc changes and visual field damage [1]. Acute primary angle-closure glaucoma (APACG) is a special subtype of PACG classified according to its acute onset characteristics. Clinically, acute angle-closure glaucoma predominantly occurs in eyes with markedly bowed iris and narrow anterior chamber angles, where relative pupillary block is more pronounced. In the presence of precipitating factors, resistance to aqueous humor flow from the posterior chamber to the anterior chamber through the pupil increases, causing elevated posterior chamber pressure, shallowing of the anterior chamber, and further elevation of intraocular pressure [2,3]. Due to the unique anatomical features of PACG-affected eyes and the frequent coexistence of multiple pathogenic mechanisms [4,5], surgical management is technically challenging. From July 2022 to January 2026, we performed pars plana therapeutic vitreous aspiration (VP) prior to filtering surgery or combined phacoemulsification–trabeculectomy in PACG eyes at our hospital. This approach yielded satisfactory outcomes, effectively reducing surgical difficulty and the incidence of complications. We report our experience as follows.

Subjects and Methods

Subjects

This was a retrospective study involving 64 patients (71 eyes) admitted to our hospital with a diagnosis of "angle-closure glaucoma"

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from July 2022 to January 2026, who underwent VP during anti-glaucoma surgery. All surgeries were performed by a single experienced surgeon.This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Chengdu Integrated Traditional Chinese and Western Medicine Hospital (Approval No. HXKT-065, 2025). Written informed consent was obtained from the patients and their families.

Methods

Medical and Laser Treatment

All patients received topical and systemic intraocular pressure-lowering medications upon admission. After medical treatment, intraocular pressure decreased and corneal clarity was restored, and laser peripheral iridectomy was performed. In cases where intraocular pressure remained uncontrolled despite medical therapy and corneal edema persisted, anterior chamber paracentesis was performed to reduce corneal edema, followed by laser peripheral iridectomy.

In this study, "intraoperative high IOP" was defined as an intraoperative clinical state characterized by shallowing and poor sustainability of the anterior chamber, forward shift of the iris-lens diaphragm, and increased globe tension. This diagnosis was made after excluding other causes such as excessive viscoelastic agent and pupillary block. In some eyes, IOP had been normalized by preoperative medication, laser or anterior-chamber paracentesis, while intraoperative posterior-segment hypertension could still occur. VP was triggered according to these comprehensive intraoperative manifestations instead of a single numerical IOP cutoff.

Surgical Procedures

Based on the surgical principles for PACG outlined in the Chinese expert consensus on the diagnosis and treatment of primary glaucoma [1,6], and taking into account the diverse pathogenic mechanisms in individual patients, the preoperative extent and range of angle opening, the presence of indications for cataract surgery, and patient preference, the following surgical approaches were performed (Table 1): VP combined with micro-incisional trabeculectomy and peripheral iridectomy (stab incision glaucoma surgery, SIGS); VP combined with phacoemulsification with intraocular lens implantation (PEI) and goniosynechialysis (GSL); VP combined with ultrasound cycloplasty (UCP); and VP combined with phacoemulsification, intraocular lens implantation, trabeculectomy, and peripheral iridectomy (Trab). All patients presented with shallow anterior chambers and elevated intraocular pressure during surgery, which increased surgical difficulty and risk. Therefore, after excluding contraindications such as retinal detachment and suprachoroidal hemorrhage, VP was performed intraoperatively prior to the primary procedure.

(1) VP procedure: After topical anesthesia and subconjunctival infiltration anesthesia, a 1- mL syringe fitted with a 26-gauge needle (Sichuan Shuanglu Medical Devices Co., Ltd.) was used. Puncture was performed perpendicularly to the sclera at the pars plana, 3.5 mm posterior to the limbus. Once the needle entered the vitreous cavity to a depth of 2–4 mm, the depth and angle of the needle were adjusted, and gentle intermittent forward-backward movements were applied for trial aspiration. The maximum total intravitreal insertion depth of the needle did not exceed 15 mm. Liquefied vitreous was slowly aspirated, with the volume of vitreous fluid withdrawn ranging from 0.1 to 0.6 mL according to the intraocular pressure. (Figure 1). Success of VP in this study was defined by intraoperative subjective clinical observations: decreased globe tension, smooth injection of viscoelastic material into the anterior chamber, and visually deepened anterior chamber. No instrumental quantitative measurements of IOP or ACD immediately before and after VP were available. After VP, the anti-glaucoma surgery was commenced. The aspiration sites included the superotemporal, inferotemporal, inferonasal, or superonasal quadrants, which were determined based on operative exposure, prior surgical scars, local anatomical features and the surgeon's clinical judgment rather than random assignment. If no fluid was obtained on the first attempt, a second puncture was performed at a site 3–4 clock hours away; if the second attempt was unsuccessful, a third puncture was performed at another site 3–4 clock hours away, until vitreous fluid was aspirated with consequent reduction in intraocular pressure and deepening of the anterior chamber. If aspiration remained unsuccessful after the fourth attempt, the procedure was abandoned. After each needle withdrawal, the puncture site was gently compressed with a moist cotton swab against the ocular wall. If intraocular pressure increased and the anterior chamber shallowed during surgery, anterior vitrectomy was performed as necessary.

(2) SIGS in 42 eyes [7] : Following VP, a 2.2 mm corneal puncture knife was inserted through the conjunctiva at a site 1.5 mm posterior to the superior limbus, tunneling into the lamellar sclera and advancing 0.5 mm into the clear cornea before entering the anterior chamber. A scleral punch was then used to excise the inner corneal lip and trabecular tissue, followed by peripheral iridectomy.

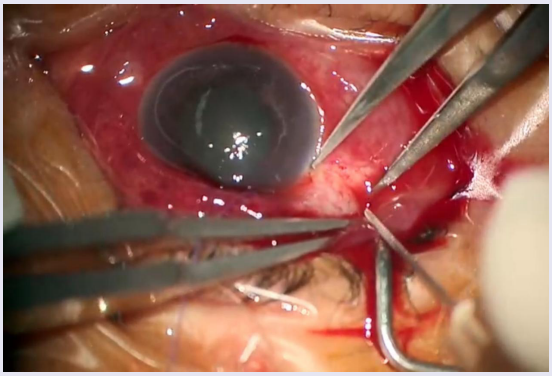


Figure 1: VP in the surgery.

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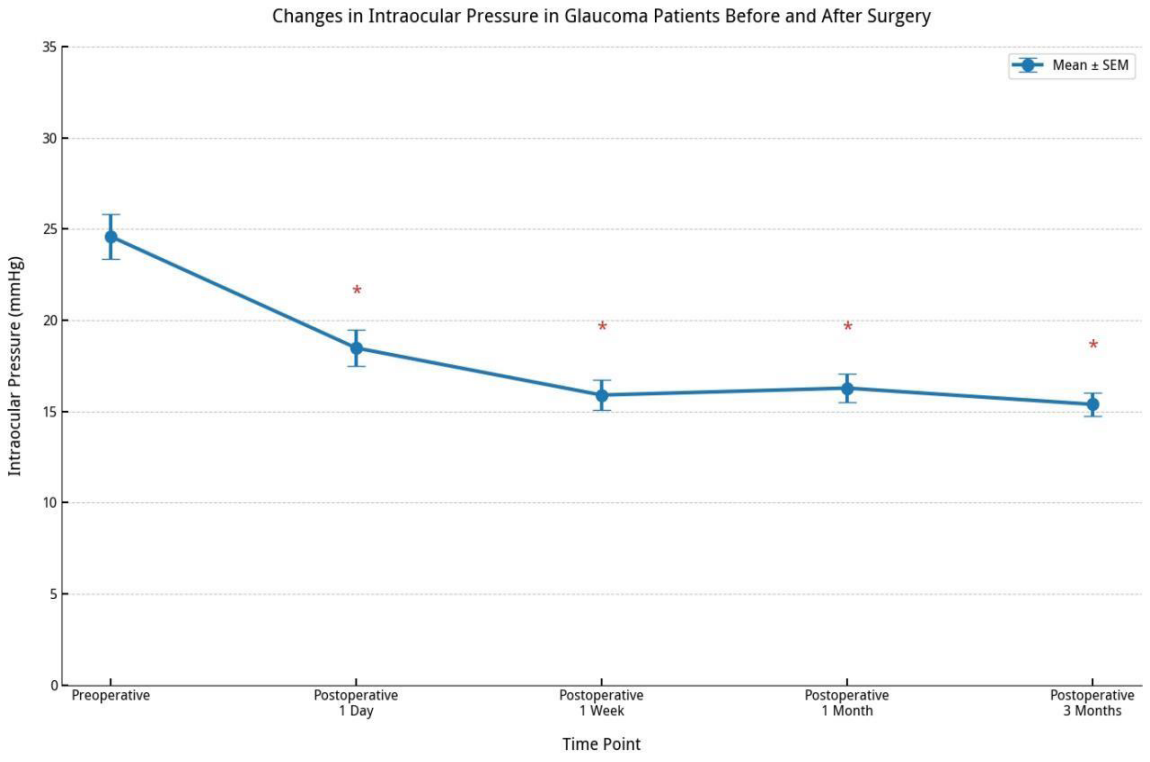


Figure 2: Changes in IOP before and after surgery.
Remarks: * significantly different from preoperative.

(3) PEI+GSL in 20 eyes: After VP, phacoemulsification and intraocular lens implantation were performed. Following lens implantation, viscoelastic was used to support the anterior chamber, and goniosynechialysis was performed under gonioscopic guidance.

(4) PEI+Trab in 3 eyes: After VP, a 3×4 mm scleral flap was created. Phacoemulsification and intraocular lens implantation were performed, followed by goniosynechialysis under gonioscopic guidance. A trabecular punch was then used beneath the scleral flap to excise a 2×2 mm piece of trabecular tissue, and peripheral iridectomy was performed.

(5) UCP in 6 eyes: After VP, the eye was stabilized using a fixation ring, and the vacuum system was activated. The probe was inserted into the fixation ring, and the procedure was performed under saline bath irrigation while maintaining stable vacuum pressure throughout. Upon treatment initiation, the transducer was activated sequentially in a clockwise manner, with each treatment sector lasting 8 seconds. The treatment encompassed 8 to 10 sectors.

Observation Indicators

The following data were collected and statistically analyzed: axial length; preoperative peak intraocular pressure; intraocular pressure, and anterior chamber depth at 1 day preoperatively, and at 1 day, 1 week, 1 month, and 3 months postoperatively; as well as intraoperative and postoperative complications. The primary endpoint was to evaluate the technical feasibility and improvement of intraoperative surgical conditions of pars plana therapeutic vitreous aspiration applied during PACG surgery. Intraoperative surgical facilitation, postoperative intraocular pressure, complications and visual acuity were designated as secondary outcomes

Statistical Methods

Statistical analysis was performed using SPSS version 27.0 software. Longitudinal postoperative intraocular pressure data were analyzed using linear mixed-effects models incorporating patient-level random intercepts and nested eye-level random intercepts to account for clustering of bilateral eyes from the same patient. Seven patients contributed bilateral eyes. All available observations were included without imputation of missing values. The Holm method was applied for multiple comparison adjustment. Continuous data were presented as mean ± standard deviation, along with model-estimated absolute changes from baseline, 95% confidence intervals and percentage reductions. Categorical data were reported as counts and percentages. A P value ≤ 0.05 was considered statistically significant.

Results

Patient Demographics

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Table 1: Surgical indications and selection criteria for the four glaucoma procedures.

surgical procedure	indications and selection criteria	cases eye %
VP+SIGS	without cataract indications ; inadequate IOP control on combined medical treatment; goniosynechialysis alone is assessed to be insufficient to lower IOP	42eyes (59.15%)
VP+PEI+GSL	cataract ; inadequate IOP control on combined medical treatment and coexisting	20eyes (28.17%)
VP+PEI+Trab	high baseline IOP; further increases after pupillary dilation	3eyes (4.23%)
VP+UCP	poor general health; no residual visual function in the affected eye; refractory IOP with persistent ocular pain despite multiple treatments	6eyes 8.45%

Note: categorical variables are expressed in percentage of eyes.

Table 2: General Information of Reserch Subjects.

n	gender eye %		age x ±s (years)	glaucoma type eye %					
				APACG	CPACG	anti-glaucoma surgery for PACG 9eyes 26.76%			
	male	female				Trab	MG	PEI	UCP
64cases 71eyes	13eyes 18.31%	58eyes 81.69%	69.24±10.04	43 60.56%	19 26.76%	5eyes 7.04%	2eyes 2.82%	1eye 1.41%	1eye 1.41%

Note: categorical variables are expressed in percentage of eyes.

Table 3: Ophthalmic Biometric and Intraocular Pressure (*Mean*±*SD*).

preoperative biometric measurement	result
axial length (AL, mm)	23.30±0.88
central anterior chamber depth (ACD, mm)	1.66±0.47
central corneal thickness (CCT, μm)	583.47±78.61
Pre-treatment IOP (mmHg)	48.55±10.41
1 day before surgery IOP (mmHg)	15-44, 24.59±12.34

A total of 64 patients (71 eyes) were enrolled, including 51 females (58 eyes, 81.69%) and 13 males (13 eyes, 18.31%). The age at onset ranged from 48 to 88 years, with a mean of 69.24 ± 10.04 years old. Among the operated eyes, 43 eyes (60.56%) had acute primary angle-closure glaucoma (APACG); 19 eyes (26.76%) had chronic primary angle-closure glaucoma (CPACG); and 9 eyes (12.68%) had undergone prior anti-glaucoma surgery for angle-closure glaucoma, including 2 eyes (2.82%) with malignant glaucoma (MG) after anti-glaucoma surgery, 1 eye (1.41%) after phacoemulsification with intraocular lens implantation (PEI), 5 eyes (7.04%) after trabeculectomy (Trab), and 1 eye (1.41%) after ultrasound cycloplasty (UCP) (Table 2).

Preoperative ocular parameters measured by IOL-Master 700 showed an axial length (AL) ranging from 19.91 mm to 24.42 mm, with a mean of 23.30 ± 0.88 mm. Ultrasound biomicroscopy (UBM) revealed a preoperative central anterior chamber depth (ACD) ranging from 0.78 to 2.87 mm, with a mean of 1.66 ± 0.47 mm. The preoperative central corneal thickness (CCT) was 583.47 ± 78.61 μm. The presenting intraocular pressure on admission ranged from 18 to 61 mmHg, with a mean of 48.55 ± 10.41 mmHg. A mean of 3.75 types of topical and systemic intraocular pressure-lowering medications were used. In 48 eyes, corneal clarity was restored after medical treatment, and laser peripheral iridectomy was performed. In 23 eyes, intraocular pressure remained uncontrolled despite medical

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Table 4: Preoperative IOP Statistics (n=71eyes).

segmented IOP	cases eye %
IOP <21 mmHg	29eyes (40.85%)
21<IOP<30 mmHg	15eyes (21.13%)
30<IOP<40 mmHg	22eyes (30.99%)
IOP>40 mmHg	5eyes 7.04%

Note: categorical variables are expressed in percentage of eyes.

Table 5: Success rate of vitreous paracentesis.

observation indicators	cases
sample size	71eyes
Successfully VP	70eyes
Successfully VP once	65eyes 91.55%
Successfully VP twice	5eyes 7.04%
VP failed 4 times	1eye 1.41%
volume of vitreous fluid aspirated	0.1~0.6ml Mean 0.21±0.11ml

Note: categorical variables are expressed in percentage of eyes.

Table 6: Percentage by VP Quadrant n=71eyes).

Quadrant of VP	cases %
superotemporal	35 49.30%)
inferotemporal	13 (18.31%)
superonasal	14 (19.72%)
inferonasal	9 (12.68%)

Note: categorical variables are expressed in percentage of eyes.

Table 7: Longitudinal IOP and between-group differences by glaucoma subtype.

Time point	APACG (n=49) Mean ± SD (n)	CPACG (n=19) Mean ± SD (n)	Difference in change (mmHg; 95% CI)	Adjusted P
Pre 1d	24.64 ± 13.22 (42)	23.58 ± 10.67 (18)	Reference	—
Post 1d	17.94 ± 6.87 (47)	18.32 ± 5.77 (19)	-1.45 (-7.37 to 4.47)	1.000
Post 1w	17.33 ± 10.93 (44)	14.90 ± 5.14 (18)	1.44 (-4.58 to 7.45)	1.000
Post 1mon	15.59 ± 7.08 (34)	17.92 ± 5.28 (13)	-2.38 (-8.96 to 4.21)	1.000
Post 3mon	14.11 ± 2.66 (24)	18.18 ± 4.04 (11)	-4.53 (-11.59 to 2.53)	0.834

Overall time × glaucoma subtype interaction: P = 0.512.
Note. Observed IOP values are mean ± SD (mmHg); numbers in parentheses indicate available eyes at each time point. Between-group differences are LMM-estimated differences in IOP change from preoperative day −1 (APACG minus CPACG), with unadjusted 95% confidence intervals. Adjusted P values use the Holm method across four postoperative comparisons. Negative differences indicate a greater IOP reduction in APACG. APACG, acute primary angle-closure glaucoma; CPACG, chronic primary angle-closure glaucoma; LMM, linear mixed-effects model.

therapy with persistent corneal edema; anterior chamber paracentesis was performed to reduce corneal edema, followed by laser peripheral iridectomy. The intraocular pressure on the day before surgery ranged from 15 to 44 mmHg, with a mean of 24.59 ± 12.34 mmHg (Table 3).

In the study sample, 29 eyes (40.85%) had preoperative intraocular pressure below 21 mmHg; 15 eyes (21.12%) had pressure between 21 and 30 mmHg; 22 eyes (30.99%) had pressure between 30 and 40 mmHg; and 5 eyes (7.04%) had pressure above 40 mmHg (Table 4).

Following vitreous paracentesis, the surgical procedures performed in the 71 eyes were as follows: micro-incisional trabeculectomy in 42 eyes, phacoemulsification combined with goniosynechialysis in 20 eyes, phacoemulsification combined with goniosynechialysis and trabeculectomy in 3 eyes, and ultrasound cycloplasty in 6 eyes (Table 1).

VP Outcomes

Among the 71 eyes included, successful vitreous aspiration with deepening of the anterior chamber was achieved in 70 eyes. Of these, 65 eyes (91.55%) were successfully aspirated on the first attempt, 5 eyes (7.04%) on the second attempt, and 1 eye (1.41%) failed to yield vitreous fluid even after four puncture attempts. The volume of vitreous fluid aspirated ranged from 0.1 to 0.6 mL, with a mean of 0.21 ± 0.11 mL (Table 5).

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Table 8: Longitudinal intraocular pressure changes in the overall cohort and after excluding nine eyes with previous glaucoma surgery.

Time point	Overall cohort: change (95% CI)	Adjusted P	Excluding prior surgery: change (95% CI)	Adjusted P
Day 1	-6.08 (-8.75 to -3.41)	<0.001	-5.89 (-8.85 to -2.93)	<0.001
Week 1	-7.64 (-10.36 to -4.92)	<0.001	-8.00 (-11.00 to -4.99)	<0.001
Month 1	-7.86 (-10.82 to -4.91)	<0.001	-7.68 (-10.94 to -4.42)	<0.001
Month 3	-8.83 (-12.10 to -5.56)	<0.001	-9.15 (-12.74 to -5.56)	<0.001

Table 9: Longitudinal changes in intraocular pressure after surgery.

Time point	Eyes with IOP data, n	Estimated IOP (mmHg)	Change from baseline (mmHg; 95% CI)	IOP reduction (%)	Holm-adjusted P
Pre 1d	62	24.49	Reference	—	—
Post 1d	68	18.41	-6.08 (-8.75 to -3.41)	24.83	<0.001
Post 1w	64	16.86	-7.64 (-10.36 to -4.92)	31.18	<0.001
Post 1mon	48	16.63	-7.86 (-10.82 to -4.91)	32.11	<0.001
Post 3mon	35	15.66	-8.83 (-12.10 to -5.56)	36.05	<0.001

Table 10: Sensitivity analysis of longitudinal IOP changes in all eyes with and without prior anterior chamber paracentesis by linear mixed-effects models.

Time point	Prior paracentesis, ΔIOP (95% CI)	No prior paracentesis, ΔIOP (95% CI)	Difference in ΔIOP (95% CI)	Holm-adjusted P
Baseline (n=22/40)	Reference	Reference	—	—
Day 1 (n=23/45)	-6.83 (-11.34 to -2.32)	-5.67 (-8.98 to -2.37)	-1.16 (-6.75 to +4.43)	1.000
Week 1 (n=22/42)	-7.48 (-12.05 to -2.91)	-7.70 (-11.08 to -4.33)	+0.22 (-5.46 to +5.91)	1.000
Month 1 (n=19/29)	-7.39 (-12.16 to -2.62)	-8.24 (-12.00 to -4.49)	+0.85 (-5.21 to +6.92)	1.000
Month 3 (n=14/21)	-10.02 (-15.26 to -4.78)	-8.12 (-12.31 to -3.94)	-1.90 (-8.61 to +4.81)	1.000
Overall time × paracentesis interaction: P = 0. 927.Values are estimated changes from baseline (mmHg), 95% Wald confidence intervals. Difference = prior paracentesis minus no prior paracentesis. n = observed eyes at that visit (yes/no); baseline eye counts may be lower than cohort sizes. Patient-level random intercept and eye-within-patient variance component; maximum-likelihood estimation. Holm correction across four follow-up contrasts.				

Table 11: Sensitivity analysis of longitudinal IOP changes in APACG eyes with and without prior anterior chamber paracentesis.

Time point	Prior paracentesis, ΔIOP (95% CI)	No prior paracentesis, ΔIOP (95% CI)	Difference in ΔIOP (95% CI)	Holm-adjusted P
Baseline (n=22/13)	Reference	Reference	—	—
Day 1 (n=23/17)	-6.79 (-11.94 to -1.63)	-5.87 (-12.32 to +0.57)	-0.91 (-9.17 to +7.34)	1.000
Week 1 (n=22/15)	-7.41 (-12.64 to -2.19)	-8.71 (-15.40 to -2.02)	+1.30 (-7.20 to +9.80)	1.000
Month 1 (n=19/11)	-7.44 (-12.89 to -1.99)	-10.53 (-17.76 to -3.30)	+3.09 (-5.95 to +12.14)	1.000
Month 3 (n=14/7)	-10.07 (-16.04 to -4.09)	-11.50 (-19.84 to -3.16)	+1.43 (-8.83 to +11.70)	1.000
Overall time × paracentesis interaction: P = 0. 920.Values are estimated changes from baseline (mmHg), 95% Wald confidence intervals. Difference = prior paracentesis minus no prior paracentesis. n = observed eyes at that visit (yes/no); baseline eye counts may be lower than cohort sizes. Patient-level random intercept and eye-within-patient variance component; maximum-likelihood estimation. Holm correction across four follow-up contrasts.				

Aspiration Sites

The selection of pars plana entry quadrant was determined based on operative exposure, prior surgical scars, local anatomical features and the surgeon's clinical judgment, rather than random assignment. The distribution of vitreous aspiration sites across quadrants was as follows: superotemporal quadrant in 35 eyes (49.30%), inferotemporal quadrant in 13 eyes (18.31%), superonasal quadrant in 14 eyes (19.72%), and inferonasal quadrant in 9 eyes (12.68%) (Table 6).

Intraocular Pressure

We performed a subgroup analysis stratified by glaucoma subtype, including 49 eyes with acute primary angle-closure glaucoma (APACG) and 19 eyes with chronic primary angle-closure glaucoma (CPACG).

A linear mixed-effects model showed no significant time-by-subtype interaction (P = 0.512). Furthermore, no significant between-group differences in IOP reduction were observed at any postoperative time point after Holm correction.

The two eyes with malignant glaucoma were excluded from the

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inferential subgroup comparison because of the extremely small sample size and were retained for descriptive analysis. Previous glaucoma surgery was considered a clinical characteristic rather than a separate disease subtype, as it may overlap with APACG or CPACG. (Table 7).

We performed a sensitivity analysis after excluding the nine eyes with a history of previous glaucoma surgery. We refitted the same linear mixed-effects model in the remaining cohort and compared the estimated postoperative intraocular pressure changes with those from the full cohort. The sensitivity results are provided in (Table 8). This analysis evaluates the robustness of the longitudinal findings to the inclusion of previously operated eyes. After excluding eyes with prior glaucoma surgery, the magnitude of IOP reduction at each time point was broadly similar to that observed in the full cohort, indicating robustness of the study findings.(Table 9).Subgroup analysis revealed no significant difference in longitudinal IOP changes between eyes with and without prior anterior chamber paracentesis (time-by-group interaction, P = 0.927). Similar results were observed in the sensitivity analysis restricted to eyes with acute angle-closure glaucoma (P = 0.920).(Table 10) (Table 11).

The postoperative intraocular pressures at 1 day, 1 week, 1 month, and 3 months were 18.48 ± 6.98 mmHg, 15.90 ± 8.26 mmHg, 16.28 ± 6.78 mmHg, and 15.39 ± 3.64 mmHg, respectively. Model-estimated reductions from baseline were statistically significant at all postoperative time points (P < 0.05; (Table 9) (Figure 2). Postoperative ocular hypertension occurred in 8 eyes (11.27%), which were treated with intraocular pressure-lowering medications (mean of 2.3 types). Among these, 3 eyes achieved pressure control, while 5 eyes (7.04%) with uncontrolled intraocular pressure required repeat anti-glaucoma surgery. Postoperative shallow anterior chamber with hypotony occurred in 1 eye (1.41%), and shallow anterior chamber with ocular hypertension occurred in 1 eye (1.41%); both cases were managed conservatively with satisfactory intraocular pressure control and restoration of anterior chamber depth.

Complications

No intraoperative complications such as vitreous hemorrhage or choroidal hemorrhage occurred in any patient. In the early postoperative period, hyphema was observed in 2 eyes (2.82%) and vitreous hemorrhage in 1 eye (1.41%). No clinically significant change in visual acuity was detected in any of these three eyes during the follow-up period. Quantitative logMAR visual acuity trajectories were as follows: one eye with a baseline visual acuity of 1.0 (logMAR 0.0) showed logMAR visual acuities of 0.30, 0.40, 0.22 and 0.10 at postoperative day 1, week 1, month 1 and month 3, respectively; the other eye with hyphema had a baseline of no light perception (NLP, logMAR 3.1) and maintained NLP throughout follow-up; and the eye with vitreous hemorrhage had a baseline of hand motion (HM, logMAR 2.6) and retained light perception (LP, logMAR 3.0) from postoperative day 1 to month 3. All hemorrhages resolved within 1 month postoperatively following symptomatic and supportive treatment. Postoperative dilated fundus examination was routinely performed in all eyes to screen for peripheral retinal breaks and retinal detachment; no retinal tear, retinal detachment, vitreous incarceration, endophthalmitis, lens injury or macular lesions were identified in this cohort.

Discussion

Angle-closure glaucoma is characterized by distinctive anatomical features, including shallow anterior chamber, relatively large and thick lens, narrow angle entrance, and short axial length, which collectively contribute to a relatively anterior lens position and crowding of the anterior segment [2]. In recent years, advances in clinical and basic research have deepened our understanding of the pathogenic mechanisms underlying PACG, leading to its classification into the following five types [1]: (1) Pure pupillary block type: the pupillary margin is located anterior to the line connecting the scleral spurs, with increased pupillary block force. When the pupillary block force exceeds the aqueous pressure in the posterior chamber, aqueous outflow from the posterior to the anterior chamber through the pupil is obstructed, resulting in elevated posterior chamber pressure, forward bowing of the peripheral iris, and consequent narrowing or even closure of the angle; (2) Plateau iris type [8]: central anterior chamber depth is normal, but the peripheral iris is thickened with a steep configuration at the angle entrance, leading to angle narrowing or closure, while the peripheral iris remains flat without forward bowing; (3) Ciliary body anterior position type: the ciliary body is positioned anteriorly, pushing the peripheral iris toward the angle and causing angle narrowing or closure;(4) Lens-induced type: abnormal positioning of the lens and its zonules with anterior displacement, reducing anterior chamber volume and leading to angle closure; (5) Choroidal expansion type: choroidal vasodilation and increased blood volume due to various factors (e.g., postural changes, emotional fluctuations, etc.), resulting in choroidal expansion and thickening, which pushes the iris–lens diaphragm forward, displacing the iris anteriorly against the trabecular meshwork, and causing angle narrowing or closure; (6) Partial ciliary block type: the ciliary ring in PACG eyes is significantly smaller than that in healthy individuals, and a subset of patients exhibit partial ciliary block. Consequently, PACG patients are prone to develop complete ciliary block after trabeculectomy, and some patients may still experience shallow anterior chamber and progressive angle closure due to partial ciliary block even after phacoemulsification combined with goniosynechialysis.

In nearly half of PACG patients in China, multiple pathogenic mechanisms coexist [4,5,8]. After relieving pupillary block factors, non-pupillary block factors should be carefully evaluated and managed accordingly. Clinically, acute angle-closure glaucoma predominantly occurs in eyes with markedly bowed iris and narrow

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angles, where relative pupillary block is more pronounced. In the presence of precipitating factors, resistance to aqueous humor flow from the posterior chamber to the anterior chamber through the pupil increases, leading to elevated posterior chamber pressure. This predisposes to reverse shallowing of the anterior chamber, and further elevation of intraocular pressure [2,3].

During an acute angle-closure attack, topical and systemic intraocular pressure-lowering medications should be administered promptly to rapidly reduce intraocular pressure. The choice of surgical procedure should be individualized based on the underlying pathogenic mechanisms, the extent and range of angle opening, the presence of indications for cataract surgery, and the surgical expertise available at the institution. With advances in the understanding of PACG pathogenesis and the development of phacoemulsification techniques, for patients with coexisting cataract who respond poorly to combined intraocular pressure-lowering medications, phacoemulsification with intraocular lens implantation combined with goniosynechialysis under gonioscopic guidance is the preferred approach. In patients with high baseline intraocular pressure that further increases after pupillary dilation, phacoemulsification combined with intraocular lens implantation and trabeculectomy is recommended [9]. For patients without cataract indications who respond poorly to combined medical therapy and are assessed to have insufficient intraocular pressure reduction with goniosynechialysis alone, combined trabeculectomy is advised [10,11]. For PACG patients with poor general health, no residual visual function in the affected eye, and persistent ocular pain with intraocular pressure refractory to multiple treatments, ultrasound cycloplasty (UCP) combined with VP was performed in this study [1,12]. A multicenter, randomized controlled trial involving 155 patients with primary angle closure and 263 patients with PACG across five countries demonstrated that clear lens extraction yielded superior comprehensive outcomes compared with peripheral iridectomy, and it has been recommended as a preferred treatment for PACG [13]. However, given the vast territory of China, the uneven socioeconomic development, and the varying levels of technical expertise and equipment availability among ophthalmic institutions across different regions, the risks associated with lens extraction surgery are higher than those of peripheral iridectomy or laser therapy [14]. Furthermore, patient preferences and needs vary considerably. Therefore, clear lens extraction has not yet been widely adopted. Nevertheless, for PACG cases where non-pupillary block factors—particularly lens-related factors (lens-induced type)—are the predominant pathogenic mechanism, clear lens extraction combined with goniosynechialysis may be considered after comprehensive evaluation based on the institution's surgical expertise in cataract extraction and patient preference [1,15,16]. Accordingly, in the 71 eyes included in this study, individualized anti-glaucoma surgical approaches were adopted after detailed analysis of the underlying pathogenic mechanisms and preoperative and intraoperative findings.

In PACG patients, the anatomical characteristics of short axial length and shallow anterior chamber, together with elevated intraocular pressure in some cases, increase the difficulty and risk of filtering surgery or combined phacoemulsification–trabeculectomy, predisposing to complications such as corneal endothelial injury, posterior capsular rupture, vitreous prolapse, and explosive suprachoroidal hemorrhage. Therefore, preoperative control of intraocular pressure and deepening of the anterior chamber are crucial for improving surgical success rates and reducing complications. Preoperative intravenous infusion of mannitol can lower intraocular pressure through its hyperosmotic dehydrating effect; however, some patients still present with shallow anterior chamber after infusion. Moreover, mannitol should be used with caution in elderly patients, particularly those with hypertension, cardiac insufficiency, renal insufficiency, or electrolyte disturbances. In addition, excessive dehydration may cause neuropsychiatric symptoms such as headache and agitation, leading to poor cooperation during surgery. If intraocular pressure cannot be controlled or shows no decreasing trend, anterior chamber paracentesis may be performed prior to surgery to release aqueous humor and reduce intraocular pressure. However, in patients with elevated vitreous cavity pressure, lowering the anterior chamber pressure increases the pressure gradient between the anterior chamber and the vitreous cavity, resulting in further shallowing of the anterior chamber [17]. This increases the risk of radial capsular tears during capsulorrhexis and posterior capsular rupture [15]; such patients often require combined vitrectomy to complete the anti-glaucoma procedure, which significantly increases surgical difficulty, risk, and cost. The use of viscoelastic agents helps maintain the anterior chamber and protect the corneal endothelium, but it does not fundamentally deepen the anterior chamber. Over-reliance on viscoelastic agents for anterior chamber maintenance may also artificially elevate intraocular pressure during surgery, leading to complications associated with high intraocular pressure.

In 1864, Chandler et al. [18] first proposed vitreous aspiration during surgery for patients with malignant glaucoma, which could effectively reduce vitreous pressure. However, as the puncture was performed beneath a scleral flap using an 18-gauge needle of relatively large diameter, the procedure carried a considerable risk of lens injury and excessive vitreous traction, with subsequent increased risks of postoperative cataract and retinal detachment. Since then, VP has gradually matured, with improved safety and expanded indications. In addition to its use in malignant glaucoma, it has also been applied in anterior segment surgery, as well as for diagnostic vitreous aspiration in conditions such as endophthalmitis and intraocular tumors.

This study included 64 PACG patients (71 eyes) with intraoperative posterior-segment hypertension, which needs to be differentiated from pupillary block and classic aqueous misdirection (malignant glaucoma). The core pathogenesis of classic aqueous misdirection/

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malignant glaucoma is abnormal accumulation of aqueous humor within the vitreous cavity, leading to vitreous hydration and expansion that drives sustained forward displacement of the iris-lens diaphragm. In contrast, patients in this cohort mainly presented with acute isolated intraoperative posterior-segment hypertension: multiple intraoperative factors raised vitreous cavity pressure, pushing the iris-lens diaphragm forward and resulting in a shallow, poorly maintained anterior chamber. Some cases were complicated by concomitant pupillary block but had not developed the complete pathological cascade of malignant glaucoma; reverse flow of aqueous humor into the vitreous cavity was not necessarily present. Without timely intervention, this intraoperative condition carries a potential risk of further progression to aqueous misdirection.Therefore, in this study, a 1-mL empty syringe connected with a 26-G needle was used to perform VP at 3.5 mm posterior to the limbus as an alternative to conventional vitrectomy. During aspiration, the needle bevel was oriented upward. After perpendicular insertion into the vitreous cavity to a depth of 2.0–4.0 mm, gentle small forward-backward movements were performed for trial aspiration. With slight angulation, further needle advancement did not exceed 15 mm.We hypothesize several causes for unsuccessful aspiration of liquefied vitreous during VP:1) the needle tip fails to reach the liquefied vitreous pocket and remains within solid non-liquefied vitreous; 2) although the needle enters a liquefied region, high viscosity of liquefied vitreous or obstruction by vitreous fibrils impedes fluid withdrawal into the syringe; 3) the needle tip apposes the vitreous membrane or retinal surface, leading to valve-like occlusion during aspiration; 4)the needle enters the canal of Cloquet, yet the volume of liquefied vitreous in this space is too small to be aspirated. Needle entry into the canal of Cloquet represents only one hypothesis and cannot be confirmed or refuted merely based on unsuccessful aspiration. Intraoperative imaging (e.g., intraoperative anterior-segment OCT) would be required to verify the needle tip location.So the needle was then gradually withdrawn with intermittent aspiration until removal, after which a different puncture site was selected for a second attempt.The puncture technique used in this study was similar to that described by Yuan Jiuming et al. [19]; however, our puncture success rate was 98.59%, compared with 91.2% in the former study. The possible reason for this difference may be that we used a 26-gauge needle for aspiration, whereas the former study used a 27-gauge needle. The mean aspirated fluid volume in this study was only 0.21 ± 0.11 mL. The aspirated fluid was predominantly liquefied vitreous and may contain a small amount of aqueous humor that seeped into the pocket; this volume is small relative to the total vitreous volume. VP targets a localized vitreous fluid pocket rather than the entire vitreous cavity. The posterior segment of the eye is a confined space with limited distensibility. Even withdrawal of a small volume of fluid from this focal pocket can reduce pressure within this local compartment, alleviate the mechanical forward pushing force exerted on the iris-lens diaphragm, increase anterior chamber depth, and facilitate the smooth progression of subsequent surgical procedures.

Sethi H et al. [20] performed puncture using only a 23-gauge or 26-gauge needle without a syringe plunger during cataract surgery in eyes with crowded anterior segment structures, allowing passive drainage of vitreous fluid and avoiding retinal traction. However, needle puncture alone requires precise entry into a vitreous liquefaction cavity for successful drainage; otherwise, multiple explorations may be necessary. Nossair A.A. et al. [21] used a 27-gauge needle connected to a 5-mL syringe to aspirate 0.2 mL of vitreous fluid during phacoemulsification in cataract eyes with shallow anterior chamber, and reported no complications such as retinal traction. The authors consider that VP effectively addresses shallow anterior chamber secondary to short axial length, angle closure, intumescent cataract, or intraoperative reverse aqueous flow,thereby reducing corneal endothelial cell injury and lowering the risk of posterior capsule rupture. Kuriakose T et al. [22] reported that in eyes with glaucoma with high intraocular pressure or intumescent cataract, angle-closure glaucoma, or other conditions with potential aqueous misdirection, vitreous aspiration using a 30-gauge needle through the pars plana before or during anterior segment surgery can effectively reduce vitreous pressure. Multiple domestic studies have also confirmed that in patients with persistent high intraocular pressure secondary to cataract or glaucoma, performing vitreous aspiration prior to combined phacoemulsification–trabeculectomy or trabeculectomy can rapidly reduce intraocular pressure and reform the anterior chamber. However, the syringes and needles used vary across studies. For example, Dong Baoying et al. [23] used a 2.5-mL syringe with a 23-gauge needle for vitreous aspiration, while Huang Zhijian et al. used a No. 20 blade for entry into the vitreous cavity followed by aspiration with an 18-gauge needle; Wang Yulei and Lu Shiheng et al. used a No. 7 needle. In a small number of eyes, complications such as vitreous hemorrhage occurred [24–27]. In addition, VP has been used in penetrating keratoplasty (PKP) or triple procedures combining PKP, extracapsular cataract extraction, and intraocular lens implantation [28–30] to effectively lower vitreous pressure. It has also been applied for diagnostic puncture in uveitis, endophthalmitis [30], and other intraocular infections [31,32], with a low complication rate and favorable safety profile.

The capacity of the syringe and the size of the needle are correlated with surgical maneuverability; larger sizes are more difficult to control [33]. Compared with the aforementioned studies, the 1-mL syringe used in this study generates sufficient negative pressure to aspirate vitreous fluid, while offering better controllability than the conventional 2-mL or 5-mL syringes, facilitating the surgeon's control over the puncture process and avoiding excessive vitreous traction or lens injury. In addition, the 26-gauge needle used in this study has an outer diameter of 0.46 mm and an inner diameter of 0.25 mm, which allows aspiration of vitreous fluid while minimizing ocular trauma and vitreous traction, demonstrating a favorable safety profile [34].

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In addition, PACG patients are at high risk for malignant glaucoma, which most commonly occurs after filtering surgery [35,36]. Studies have suggested that severe postoperative inflammation is one of the contributing factors [2]. It is proposed that severe postoperative inflammation may lead to ciliary body congestion and edema, further narrowing the pre-existing ciliary ring space in PACG patients and obstructing normal aqueous humor flow. Meanwhile, inflammation increases exudation, leading to elevated anterior chamber pressure, which in turn compresses the vitreous and facilitates aqueous entry into the vitreous cavity, forming a vicious cycle and increasing the risk of malignant glaucoma [37,38]. Although various treatment modalities are available, their outcomes are often unsatisfactory, making prevention particularly important. The most critical preventive measures include lowering intraocular pressure before surgery and maintaining anterior chamber stability during surgery [36]. VP may reduce vitreous cavity volume, lower posterior-segment pressure, and deepen the anterior chamber intraoperatively, which may theoretically reduce the risk of progression to aqueous misdirection (malignant glaucoma); however, this potential effect remains only a hypothesis [39].

Intraoperatively, no complications such as vitreous hemorrhage or choroidal hemorrhage occurred in any patients. In the early postoperative period, hyphema was observed in 2 eyes (2.82%) and vitreous hemorrhage in 1 eye (1.41%). All hemorrhages were absorbed within 1 month after surgery following symptomatic and supportive treatment. These intraoperative findings and the low incidence of severe hemorrhagic complications suggest that VP may reduce operative difficulty and improve the safety of surgical manipulation during PACG surgery.

There are several limitations in the present study. First, due to intraoperative equipment constraints, quantitative measurements of intraocular pressure and anterior-chamber depth immediately after VP could not be obtained.A complete IOP trajectory from admission → immediate pre-VP → immediate post-VP → postoperative follow-up cannot be constructed. We can only compare admission IOP with the IOP measured one day before surgery to evaluate the IOP-lowering effect of preoperative interventions including medications, anterior-chamber paracentesis and laser therapy after admission.In addition, objective tonometry immediately before VP was unavailable; VP was initiated based on composite intraoperative clinical signs without a quantitative IOP cutoff value. Only indirect intraoperative visual signs were available, which cannot directly verify the physiological changes induced by VP itself.Second, pooled statistical analysis of postoperative anterior-chamber depth and corneal endothelial cell counts was not feasible, as four different subsequent glaucoma surgical procedures were adopted in this cohort. For patients receiving VP combined with PEI+GSL or PEI+Trab, anterior-chamber depth increased significantly after lens removal, accompanied by a statistically significant reduction in corneal endothelial cell density [40]. In eyes treated with VP plus SIGS or UCP, anterior-chamber depth only changed mildly under the influence of filtering efficacy and the effect of UCP ultrasound energy on the anterior chamber angle[41]; such changes were far less prominent than those following lens extraction. Given the substantial inter-procedure differences in impacts on anterior chamber depth and corneal endothelial cell count, pooled statistical analysis of preoperative, intraoperative and postoperative anterior chamber depth and corneal endothelial parameters was not conducted across all cases. Another important limitation is the absence of a control group. Because VP was used as an emergency rescue procedure for intraoperative posterior-segment hypertension in PACG eyes, it was not clinically or ethically feasible to establish a well-matched control group undergoing the same glaucoma operations without VP. Therefore, the present study cannot determine whether VP is causally associated with intraoperative parameters, operative time, complications, postoperative IOP, or the need for anterior vitrectomy, and further comparative studies are required. But, VP alleviates elevated posterior-segment pressure and stabilizes the anterior chamber intraoperatively, which may theoretically reduce the risk of progression to aqueous misdirection (malignant glaucoma). However, the lack of a control group and limited sample size mean this remains merely a hypothesis, and the absence of new malignant glaucoma cases in our follow-up cannot confirm preventive efficacy.

Although intraoperative subjective observations, including softening of the globe and easy injection of viscoelastic material into the anterior chamber, may suggest potential intraocular pressure reduction and anterior-chamber deepening after VP, these are only indirect intraoperative findings. Without objective quantitative measurements, they cannot serve as direct evidence to confirm the independent intraocular-pressure-lowering efficacy of VP and correlation analysis between aspirated volume and immediate changes in IOP or ACD cannot be performed. It is expected that with the popularization of intraoperative anterior-segment OCT and other imaging techniques in the future, VP can be performed under image-guided precise localization of liquefied vitreous regions to further improve surgical safety. Meanwhile, quantitative detection of intraocular pressure, anterior-chamber depth and vitreous volume before and after VP can be achieved, providing more robust evidence for the safety and efficacy of VP in PACG surgery. Furthermore, this retrospective case series evaluated complications based on available medical records and fundus documentation. Although dilated fundus examinations were routinely performed postoperatively for all eyes, tiny peripheral retinal degeneration or minute retinal breaks might still be missed. No severe adverse events including retinal tear, retinal detachment, vitreous incarceration, endophthalmitis, lens injury and macular lesions were observed in this cohort. Nevertheless, limited sample size and retrospective data restrict our capacity to rule out under recording of rare or delayed complications. Furthermore, quadrant selection was non-random and determined by anatomical

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and operative factors, which may introduce potential selection bias. Meanwhile, we do not claim that VP itself exerts a protective effect on the corneal endothelium. In the absence of specular microscopy data of corneal endothelial cell density, this notion remains only a hypothesis. In addition, our cohort exhibited clinical heterogeneity between APACG and CPACG cases. Subgroup sample sizes were limited, which may reduce statistical power to detect subtle intergroup differences in IOP trajectories. The two malignant glaucoma eyes were limited to descriptive analysis without inferential comparison. Prior glaucoma surgery was treated as a clinical characteristic rather than a separate diagnostic subgroup and may introduce confounding effects. Given the heterogeneity of surgical procedures performed in the included eyes, postoperative visual acuity varied substantially. Therefore, we only reported the visual acuity outcomes of the three eyes that developed hyphema or vitreous hemorrhage. Despite the occurrence of hyphema or vitreous hemorrhage in these three eyes, no clinically significant change in visual acuity was observed during the follow-up period. Accordingly, the overall safety profile of VP cannot be fully established in the present study, and its long-term complication risks require further validation in larger prospective studies with extended follow-up.

In conclusion, pars plana therapeutic vitreous aspiration performed with a 1-mL syringe and a 26-G needle is technically feasible and can facilitate surgical procedures during PACG glaucoma surgery. Nevertheless, constrained by the inherent limitations of this retrospective uncontrolled study, the absence of objective immediate post-VP measurements, and heterogeneity of subsequent glaucoma surgeries, the independent intraocular-pressure-lowering effect of VP cannot be confirmed in our study. Based on observations from this case series, this technique demonstrates certain clinical application potential. Its definite clinical value awaits further evaluation in subsequent prospective comparative studies.

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