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Retrospective analysis of risk factors for unplanned anterior vitrectomy during planned cataract ultrasonic phacoemulsification in Chinese adult patients

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Abstract

Background/Aims Although ultrasonic phacoemulsification cataract (CUP) surgery has been widely used for cataracts, unplanned vitrectomy (UAV) is sometimes required during CUP. Thus, the aim is to identify 16 risk factors (systematic: age, gender, the side of the eyes, smoking, hypertension, diabetes, coronary heart disease, and renal failure; local: filtering surgery history, glaucoma, old iritis, pupil adhesion, high myopia, lens hardness, zonular dehiscence, and combined trabeculectomy) as primary outcomes and to examine complications and visual acuity (VA) as secondary outcomes in Chinese age-related cataract patients undergoing UAV during routine CUP.

Methods A retrospective analysis of 676 cataract eyes as the first diagnosis was made. Eyes received CUP and intraocular lens (IOL) implantation or CUP/IOL combined with trabeculectomy. Vitrectomy and non-vitrectomy groups are divided based on eyes with or without UAV. Statistical analysis included Chi-square X^2 test to examine the correlation between the risk factors and UAV, visual acuity, and complications.

Results The average patient's age was 72 ± 9.6 years, and 385 patients had Grade III nucleus. Sixteen eyes received concomitant UAV during CUP in the vitrectomy group and 660 eyes without UAV in the non-vitrectomy group. No statistically significant difference in demographic data was detected between the two groups. Glaucoma, chronic iritis, filtration surgery, zonular rupture, and combined trabeculectomy were identified as risk factors for UAV ($p < 0.05$); However, UAV was positively correlated only with filtration surgery, zonular rupture, and combined trabeculectomy. Zonular abnormality was also identified as a risk factor within a subgroup of patients solely with a history of glaucoma ($n = 10$) attributed to UAV ($p = 0.00$). Complications included intra-operative malignant glaucoma (4 cases), zonular rupture (8 cases), posterior capsular rupture (3 cases), and rupture of both posterior capsule and zonules (1 case). Fourteen cases had improved visual acuity ($p < 0.05$) except for one with anterior chamber hemorrhage and one without lens implantation.

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Conclusion Our results demonstrated that filtration surgery history, zonular rupture, or combined trabeculectomy are risk factors for cataract patients undergoing UAV during routine CUP, suggesting that evaluating risk factors is critical to minimize the incidence of UAV and post-operative complications.

Keywords Cataract phacoemulsification, Anterior vitrectomy, Complications, Risk factors, Glaucoma, Zonules, Rupture, Filtration

Introduction

Cataract ultrasonic phacoemulsification (CUP) has emerged as the primary surgical intervention for the treatment of age-related cataracts [1]. Cataract phacoemulsification offers several advantages including minimal invasion with minimized surgical trauma, shortened operation time, and accelerated postoperative recovery, thus it has been widely used worldwide due to its effective and safe surgical techniques, and approaches with high efficiency [2–5].

Despite these advantages, some factors such as the multifaceted ocular conditions inherent in individual patients, trauma and inflammatory responses caused by the surgery itself, the surgeon's competency and proficiency, and limitations of surgical instruments could be attributed to unforeseen or emergent circumstances during cataract phacoemulsification [6, 7], posing continuous challenges to a surgeon's skills and decision-making acumen.

It is known that the normal vitreous is a gel-like substance mainly composed of collagen fibers and hyaluronic acid, accounting for 4/5 of the volume of the eyeball. It has a cushioning, supporting, and nourishing effect on the surrounding lens and retinal tissues and is also part of the refractive medium of the eye [8]. In ultrasonic phacoemulsification cataract surgery, any damage or absence of the vitreous anterior hyaloid membrane may lead to vitreous loss. The anterior vitreous can prolapse and block the iridocorneal incision, entering the anterior chamber, and it is even located at the limbal incision. With repeated surges in the anterior and posterior chambers, the vitreous can move, stretch, and leak, causing the posterior cortical vitreous to pull on the retina [9], which thus underscores the need for both clinicians and patients for comprehensive pre-operative preparation [10]. Moreover, ophthalmological and medical conditions such as cardiovascular and endocrine system diseases could aggregate risks and complications of unplanned anterior vitrectomy (UAV) during phacoemulsification. Although phacoemulsification produces effective outcomes, identifying the risk factors of UAV becomes essential to improve intraoperative management and reduce intra-operative and post-operative complications in the combined surgery. The potential impact of this study is paramount for patients to achieve better visual acuity and quality of life after surgery.

In the present study, we conducted a retrospective analysis of Chinese patients with age-related cataracts to identify 16 systemic and local risk factors as the primary outcome measures and to measure secondary outcomes including intraoperative and postoperative complications and visual acuity (VA) of the patients who require a UAV during cataract ultrasonic phacoemulsification (CUP) surgery.

Methods

Clinical data

A retrospective analysis of 676 eyes (460 patients) who underwent CUP for age-related cataracts in the Department of Ophthalmology in Tianjin Union Medical Center from July 2017 to April 2020. A total of 719 eyes underwent CUP surgery, among which the number of 698 eyes were admitted with age-related senile cataracts as their first diagnosis ($n = 698$), and those with cataracts diagnosed with other types of cataracts or other causes as the first diagnosis ($n = 21$) were excluded. Out of 698 eyes, six hundred seventy-six eyes with age-related cataracts as the first diagnosis and met the inclusion requirements ($n = 676$) were included; the following criteria were applied for exclusion: cases wherein anterior vitrectomy was pre-operatively discerned as necessary; a surgical history of ocular trauma ($n = 12$) or vitreoretinal surgery ($n = 6$); eyes with opacity of lens with partial lens subluxation ($n = 3$) or secondary to glaucoma ($n = 1$) leading to increased intraocular pressure and requiring emergency surgery ($n = 3$). Six hundred seventy-six eyes were further divided into a vitrectomy group and a non-vitrectomy group, based on eyes with or without UAV treatment (Fig. 1).

All completed routine preoperative ophthalmic examinations, and had no indications for surgical contraindications. Ethics approval for this study was obtained from the Ethics Committee of Tianjin Union Medical Center [Ethical approval time: 1st., August, 2024, Ethical code No. (2024) Quick Review No. (B13)]. Published research must comply with the guidelines for human studies and should include evidence that the research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. Written informed consent was obtained from all individuals included in this study.

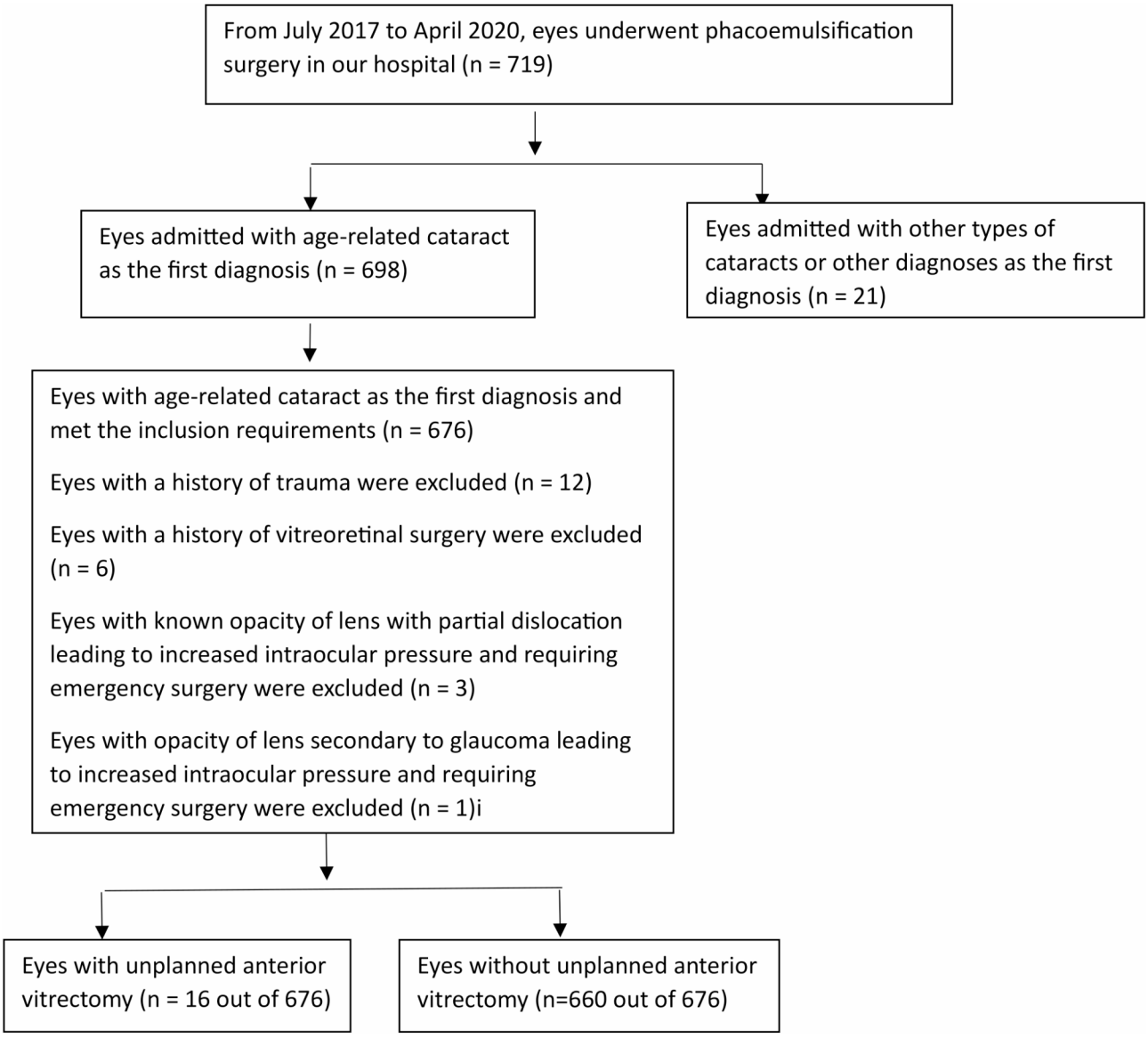

Fig. 1 A flow chart showing a propensity model to improve selection criteria for patient allocation to each group has been added in Diagram 1 in the revised version

Surgical methods

All surgeries were performed by the same surgeon with 30 years of experience in CUP. Under full mydriasis (0.1% tropicamide) and local anesthesia (propacaine eye drops), CUP was performed by using the Alcon Centurion phacoemulsification system. Depending on whether it was the left or right eye, a main corneal incision (2.4 mm) was made at 2:00 and 10:30, followed by sider-port paracentesis (1 mm) at 11:30 and 1:00. Under the aid of a capsular opening, the injection of the viscoelastic agent into the anterior chamber, continuous circular capsulorhexis, and hydro-dissection were performed. Phacoemulsification of the lens nucleus and irrigation and aspiration of the surrounding cortex were then conducted to remove the lens, followed by intraocular lens (IOL) implantation through the main incision after further injection of a viscoelastic agent into the chamber and capsular bag. The viscoelastic agent was subsequently aspirated, and all incisions were hydrated with a balanced salt solution and confirmed watertight at the end of the operation.

For the treatment with CUP combined with trabeculectomy, the preoperative procedures were the same as those in CUP. The surgery was performed under local anesthesia using the following technique: A conjunctival flap was made above the cornea with the conjunctival dome as the base, and a triangular scleral flap (4 mm x 3 mm) was created underneath the corneal margin as the base, extending to 1 mm inside the junctions of the

corneoscleral margin and the corneal transparent zone. Depending on the age and condition of Tenon's capsule, a 5-fluorouracil cotton pad was soaked under the scleral flap for 3–5 min, followed by thoroughly rinsed with saline. A scleral tunnel incision was made under the scleral flap to enter the anterior chamber, and a routine CUP and intraocular lens implantation were performed. Then trabeculectomy was performed, 1 mm × 2 mm trabecula and the surrounding iris were excised, and sutured both sides of the waist with the top covered with adjustable sutures, and the exposed ends were taken out through the conjunctiva. the scleral flap was closed with a suture in a watertight manner. The operation was completed after the closure of the conjunctival flap.

UAV in the vitrectomy group should be conducted when shallowing anterior chamber, increased intra-ocular pressure, and suspected malignant glaucoma occurs, or when vitreous prolapsed into the anterior chamber or entrapment in the surgical incision and path, phacoemulsification and aspiration should be immediately halted; Instead, a vitreous cutter (23G, 2000 r/s) was applied to remove the vitreous from the anterior chamber fully, trabecular meshwork around the iris peripheral incision. After the anterior vitreous was removed, the posterior capsular bag was incised. The subsequent operation was continued after ensuring that there was no residual vitreous in the anterior chamber, moreover, the intraocular pressure and patient's conditions were stable.

Observation and statistical indicators

Data were summarized from the 676 eyes that underwent UAV and those without UAV during cataract surgery. Sixteen risk factors including 8 systematic factors and 8 local factors were recorded. The systemic factors included the gender ratio, the ratio of left to right eyes, age, smoking history, hypertension, diabetes, coronary heart disease, and renal failure, and the local factors included a history of glaucoma, filtering surgery history, pupil adhesion, old iritis, high myopia, the degree of lens opacity, zonular dehiscence, and combined trabeculectomy. Reasons for performing UAV during the procedure were also recorded, and the principles behind the procedures and potential risk factors were analyzed. Best correct visual acuity (BCVA) was compared between preoperation and postoperation in patients undergoing UAV during cataract surgery using a standard logarithmic visual acuity chart.

Statistical methods

This retrospective case study used SPSS 23.0 for analysis. All BCVA results were recorded in decimal format but converted to logarithm of the minimum angle of resolution (logMAR) visual acuity for statistical analysis. The manual (Manual: refers to the ability to sense when shaking your hands in front of the eyes) recording was log0.005, and the index (Index: Identify the number of fingers in front of you) was recorded as log0.014 [11]. Paired T-tests were used as the statistical analysis method to compare preoperative visual acuity (a) with postoperative visual acuity 1 day (b) and 1 week after surgery (c), respectively.

All relevant factors associated with performing UAV during CUP were evaluated. Each risk factor was analyzed using chi-square X^2 test analysis. Row variables set for the test were vitrectomy or non-vitrectomy and the column variable was a risk factor examined, respectively. Significant indicators obtained from the results of the chi-square X^2 tests were further assessed to examine the correlation between vitrectomy and identified risk factors using unconditional logistic regression analysis, in which the dependent variable was whether anterior vitrectomy was performed during cataract surgery and the independent variables were the risk factors screened out from the chi-square X^2 tests.

A subgroup analysis was also conducted to further identify which factor is attributed to unplanned AU within an individual risk factor subgroup. A subgroup of patients solely with a history of glaucoma was taken as an example. Chi-square test analysis within this subgroup was performed to evaluate whether UAV is associated with a total of 9 local risk factors including a history of glaucoma filtration surgery, combined trabeculectomy surgery, posterior pupillary synechiae, lens hardness, a history of iris laser drilling, zonular abnormalities, primary open angle glaucoma (POAG), primary angle closure glaucoma (PACG), and old iritis. $P<0.05$ was considered statistically significant.

Results

Demographic data of all patients were collected (Table 1). Of 676 eyes, there were 324 right eyes and 352 left eyes, with a 277 males to 399 females ratio of 0.69 to 1. The age ranged from 31 years to 96 years with an average age of 72 ± 9.6 years, 277 patients were over 75 years and 399 patients were less than 75 years old. In terms of hardness of the nucleus cataracts, the majority of patients ($n=385$) had Grade III nucleus, followed by Grade IV ($n=131$), Grade II ($n=124$), and Grade V (mature and overmature) ($n=36$). Out of 676 eyes undergoing cataract surgery, the phacoemulsification time of more than 30 s was found in 72 eyes, and the time of less than 30 s was observed in 604 eyes; the phacoemulsification suction force of more than 450 mmHg was applied in 489 patients, and 187 patients had the force of less than 450 mmHg. Out of 676 eyes undergoing CUP, sixteen eyes receiving UAV treatment were divided into the vitrectomy group, and 660 eyes in the non-vitrectomy group did not receive UAV treatment (Table 1).

Table 1 A summary of statistical information on age, gender, hardness of the nucleus cataracts, and phacoemulsification parameters (time and Suction force) in patients with senile cataracts

Clinical characteristics		The number of eyes (*n*)
Age	>=75 years	227
	< 75 years	449
Gender	Male	277
	Female	399
Grade of lens opacity	GradeIInucleus	124
	Grade IIInucleus	385
	Grade IV nucleus	131
	Grade V nucleus (mature and overmature)	36
Phacoemulsification time	>=30 s	72
	< 30 s	604
Phacoemulsification suction vacuum force	>=450mmHg	489
	< 450mmHg	187
Unplanned anterior vitrectomy	performed	16
	Non/unperformed	660

Out of 676 cataract eyes, 634 eyes were performed under CUP and 42 eyes undergoing CUP combined with trabeculectomy (Table 2). Among 16 eyes receiving UAV treatment, seven cases accounting for 43% had zonular rupture during surgery, three cases (28.7%) experienced posterior capsule rupture, one case (6%) suffered both posterior capsule and zonular rupture, and 4 cases developed malignant glaucoma (25%) and had the posterior capsular bag incised after the anterior vitreous was removed during UAV, all of 4 cases had a history of angle-closure glaucoma and short eye axes (eye axis less than 22 mm), of which two underwent cataract surgery combined with trabeculectomy, one case occurred after filtration surgery and one case after peripheral iridotomy. Among the 4 patients, concurrent zonular rupture also occurred in two of the patients.

The anterior vitrectomy and planned surgery were all completed in 16 eyes. In 3 cases, a capsular tension ring was placed in the capsular bag; in 1 case, the IOL was placed in the ciliary sulcus; in 1 case, the lens was not implanted; and in the remaining cases, IOL was placed inside the capsular bag.

On the first post-operative day, eight cases had elevated intraocular pressure and one anterior chamber hemorrhage. After post-operative anti-inflammatory, anti-infective, pressure-lowering, and restorative treatments, these patients were successfully discharged when intraocular pressure returned to normal and stable. Discharge timings were recorded as follows: five cases were discharged on the first postoperative day, two cases on the second day, four cases on the third day, one case on the fourth day, three cases after one week, and one case after ten

Table 2 Chi-square test of 16 risk factors in the vitrectomy and non-vitrectomy group during cataract phacoemulsification surgery

Groups	Total	Eye Side		Sex		Age		Hypertension		Diabetes		Coronary Heart Disease		Smoking History		Kidney Dysfunction	
		OD	OS	M	F	≥ 75	< 75	Y	N	Y	N	Y	N	Y	N	Y	N
Vitrectomy	16	8	8	6	10	5	11	8	8	3	13	3	13	3	13	2	14
Non-vitrectomy	660	316	344	271	389	222	438	386	274	228	432	109	551	109	551	19	641
X^2		17.63		0.08		0.04		0.46		1.73		0.06		0.00		*2.14*	
p-Value		**1.00**		**0.78**		**0.85**		**0.50**		**0.19**		**1.00**		**1.00**		**0.14**	
Group	**Total**	**Glaucoma**		**Filtering Surgery History**		**Pupil Adhesion**		**Old Iritis**		**High Myopia**		**Lens Opacity Degree**		**Zonular Dehiscence**		**Combined Trabeculectomy**	
		Y	N	Y	N	Y	N	Y	N	Y	N	Mature/Over Mature	Immature	Y	N	Y	N
Vitrectomy	16	10	6	3	13	2	14	2	14	1	15	2	14	7	9	5	11
Non-vitrectomy	660	140	520	24	636	21	639	12	648	35	625	34	626	8	651	37	623
X^2		13.12		5.78		1.78		4.31		0		0.53		111.41		13.5	
P-Value		**0**		**0.02**		**0.18**		**0.04**		**1**		**0.57**		**0**		**0**	

Vitrectomy: unplanned anterior vitrectomy; Non-vitrectomy: eyes without unplanned anterior vitrectomy;
OD: oculus dexter; OS: oculus sinister; Y: Yes; N: No

Table 3 The BCVA of 16 patients undergoing unplanned anterior vitrectomy during cataract surgery was compared between preoperation and postoperation

		Mean	SD	95% confidence interval for difference		Sig. (Bilateral)
				Lower-bound	Upper-bound	
Paired t-test	**LogMAR1[a]- LogMAR2[b]**	0.55	0.89	0.078	1.03	**0.03**
Paired t-test	**LogMAR1[a]- logMAR3[c]**	0.78	0.88	0.32	1.25	**0.003**

logMAR BCVA: logarithm of the minimum angle of resolution for best corrected visual acuity; a: BCVA before surgery; b: BCVA 1 day after surgery; c: BCVA 1 week after surgery

Table 4 Unconditional logistic regression analysis of risk factors for UAV during cataract surgery

	Regression Coefficient	Standard Error	Wald	Degrees of Freedom	*P* Value	OR Value	OR 95% Confidence Interval	
							Lower Limit	Upper Limit
Glaucoma History	-0.03	0.89	0.001	1	**0.98**	0.97	0.17	5.52
Filtering Surgery History	1.97	0.97	4.13	1	**0.04**	7.20	1.07	48.26
Zonular Dehiscence	4.39	0.73	36.03	1	**0.00**	80.54	19.21	337.60
Combined Trabeculectomy	2.37	0.94	6.41	1	**0.01**	10.72	1.71	67.22
Chronic Iritis	1.77	1.01	3.06	1	**0.08**	5.85	0.81	42.35

days. Except for 1 case without implantation of the lens and 1 case with anterior chamber hemorrhage, a statistically significant difference was found in best corrected visual acuity (BCVA) between preoperation and 1 day and 7 days after surgery in the remaining 14 patients (the logMAR values of BCVA on day 1: 0.55 ± 0.89, $p = 0.02$; Day 7: 0.78 ± 0.87; $p = 0.003$, respectively; Table 3).

To identify potential risk factors for the indication of anterior vitrectomy during cataract phacoemulsification, we screened 16 factors based on the clinical data of the recruited patients, and consequently analyzed them using the Chi-square test. The results showed that no significant difference was found in gender, age, the side of the eyes, hypertension, diabetes, coronary heart disease, a history of smoking, and kidney dysfunction in both vitrectomy and non-vitrectomy groups ($p > 0.05$; Table 2). However, a history of glaucoma, filtration surgery, chronic iridocyclitis, zonular rupture, and combined trabeculectomy were shown to be statistically significant between the two groups ($p = 0.00$, $p = 0.01$, $p = 0.03$, $p = 0.00$; $p = 0.00$, respectively; Table 2). Furthermore, a univariate logistic regression analysis was made to determine positive or negative correlations of these five risk factors with the requirement of anterior vitrectomy during phacoemulsification. The results showed that filtration surgery history, zonular rupture, and combined trabeculectomy were three factors with statistical significance (coefficient = 1.97, $p = 0.04$; coefficient = 4.39, $p = 0.00$; coefficient = 2.37, $p = 0.01$, respectively; Table 4) but a history of glaucoma and chronic iritis without showing statistical significance ($p = 0.97$ and $p = 0.08$; Table 4).

We further identified risk factors for UAV within the subgroup of a history of glaucoma. The results of the chi-square test analysis showed that 10 eyes underwent UAV and 140 eyes did not receive UAV. A statistically significant difference was found in zonular abnormality, closely related to UAV ($p = 0.000$); However, no statistically significant difference was found in other factors (Table 5).

Discussion

In this study, our results showed that 16 out of 676 eyes were required for intraoperative simultaneous UAV due to the complications of zonular rupture (43%), posterior capsule rupture (28.7%), malignant glaucoma (25%), and combined posterior capsule rupture (6%). Through intraoperative treatments with IOL replacement and postoperative management, all the patients were discharged with significantly improved vision, normal intraocular pressure and stable conditions within 10 days after surgery, except for one without lens implantation and one with anterior hemorrhage, indicating that the majority of UAV cases have achieved successful clinical outcomes. Moreover, five risk factors including a history of glaucoma, filtration surgery history, chronic iritis, zonular rupture, and combined trabeculectomy were initially identified when compared between the two groups, suggesting that they were possibly attributed to the incidence of UAV during CUP. Nevertheless, a logistic regression study confirmed that only glaucoma filtration surgery, zonular dehiscence, and combined trabeculectomy positively correlated with UAV, further indicating that these three factors predispose patients to require UAV. In contrast, demographic data (gender, age, eye sides), hypertension, diabetes, cardiovascular heart disease, smoking history, and kidney dysfunction were not identified as the risk factors.

In this study, vitreous loss caused by the rupture of the zonules and the posterior capsule occurred in 12 eyes, accounting for 75% of eyes receiving UAV, and zonular

Table 5 Chi-square test of unplanned anterior vitrectomy in a subgroup of patients with a history of glaucoma during phacoemulsification surgery

Group	Total	Glaucoma filtering surgery history		combined trabeculectomy surgery		posterior pupillary synechiae		lens hardness		iris laser drilling history		zonular abnormalities		POAG[a]		PACG[b]		old iritis	
		Y	N	Y	N	Y	N	M	UM	Y	N	Y	N	Y	N	Y	N	Y	N
Unplanned anterior vitrectomy	10	3	7	5	5	1	9	1	9	0	10	6	4	2	8	5	5	1	9
Non-anterior vitrectomy	140	24	113	37	103	9	131	2	138	4	136	1	139	24	116	105	35	2	138
χ^2		0.32		1.54		0		0.49		-[c]		61.01		0		1.84		0.49	
Pvalues		**0.58**		**0.22**		**1**		**0.48**		**-**		**0**		**1**		**0.18**		**0.48**	

Vitrectomy: unplanned anterior vitrectomy; Non-vitrectomy: eyes without unplanned anterior vitrectomy; a: POAG (Primary Open Angle Glaucoma); b: PACG (primary angle closure glaucoma); c: The result cannot be calculated as there is an expected value in the table that is zero; Y: Yes; N: No; M: mature; UN: unmature

rupture is the risk factor most strongly and positively associated with UAV as demonstrated by logic regression analysis. It is known that the lens zonules as the fibrous tissues connecting the ciliary body to the equator of the lens are divided into three parts based on their location: two parts attached to the posterior lens capsule and one part originates from the flat part of the ciliary body attached to the anterior lens capsule. The lens zonules mainly maintain the position of the lens and precisely regulate the curvature of the lens's anterior surface [12]. While zonular rupture is mostly associated with trauma, angle-closure glaucoma, or Marfan syndrome etc. However, zonular abnormalities could occur in some patients during surgery even though the abnormalities are not presented preoperatively; Risk factors make the lens zonules vulnerable including high myopia, uveitis, glaucoma, old age, concurrent diabetes, pseudoexfoliation syndrome, and post-vitrectomy [13]. Moreover, intraocular stress-induced inflammation and pressure fluctuations in the anterior and posterior chambers during CUP can cause changes in the structure of the lens zonules, increasing their brittleness and exacerbating zonular damage [14]. Additionally, the scope of zonular damage could also be expanded due to improper surgical operation, such as removing the iris root during glaucoma surgery and separating pupillary adhesions with surgical instruments [15, 16]. This vitreous prolapse caused by zonular damage can thus cause complications such as vitreous liquefaction, posterior vitreous detachment, retinal detachment, macular edema, or exacerbates existing vitreoretinal diseases [9, 17], which worsens the patient's visual acuity. Furthermore, zonular dehiscence is also significantly attributed to the likelihood of posterior capsular rupture [1, 18], which is a serious complication during CUP, leading to a significant impact on surgical operations and postoperative visual function reconstruction. It has been reported that patients with pre-operative vision less than 20/200, nuclear grading greater than grade III, and males are more prone to intraoperative posterior capsule rupture [19]. Patients with a history of vitrectomy and glaucoma should be operated cautiously to reduce the risk of posterior capsule rupture.

The rupture of the zonules or posterior capsule can lead to vitreous prolapse, which should be suspected once trembling and sinking of the lens, the deepening of the anterior chamber, the brightness or folding of the posterior capsule, deformation of the pupil, curling up of the cortical edges, or IOL displacement occur intraoperatively. If the prolapse is not treated promptly, it can easily worsen postoperative vision due to complications, such as poor incision healing, deformation and displacement of the pupils, lens nucleus sinking, uveitis, and retinal detachment [20]. Consequently, post-capsular rupture or zonular dehiscence poses a challenge

during CUP. Therefore, the clinical significance of being aware of the potential rupture of the zonular or posterior capsule during CUP as a predisposing risk factor is paramount [21]. Full pre-operative preparations for UAV should be well made by both cataract patients who need thorough medical and ophthalmological examinations and surgeons who make preventive planning, including the selection of anesthesia method, preparation of drugs and surgical instruments such as special devices for implantation in the capsular bag, a proper choice of different lens system such as an aspheric macular lens for posterior capsular rupture [22, 23, 24] or better surgical approaches, a meta-analysis study has shown that coaxial microincisional phacoemulsification surgery had better efficacy in reducing short-term and long-term surgically induced astigmatism compared with that of standard incision phacoemulsification surgery in age-related cataract patients [25]. Whenever suspicion of potential risks of rupture such as vitreous prolapse into the anterior chamber or vitreous incarceration occurs during operationl, all operations should be stopped immediately, and the surgeons take timely detection and appropriate steps to perform UAV, consequently, reducing damage and maintaining zonular or capsule stability. The phacoemulsification needle should not be immediately withdrawn, a viscoelastic substance should be slowly injected from the side of the surgical incision to prevent further overflow of the vitreous to maintain anterior chamber stability. The vitreous in the anterior chamber should not be disturbed, instead, the vitrectomy cutter enters through the original incision. Lower infusion pressure should be applied to reduce vitreous traction, and the anterior vitreous should be completely removed and cleaned until the pupil returns to a circular shape, ensuring no deformation of the air bubble injected anteriorly [26].

Our study showed malignant glaucoma occurred in 25% of patients, indicating that malignant glaucoma is common in the combined CUP/IOL and UAV surgery. It has been reported that malignant glaucoma often occurs not only after filtration surgery for primary angle-closure glaucoma but also after any eye surgery, such as scleral buckling surgery and corneal transplantation [27, 28]. The features of malignant glaucoma include shallow central and peripheral anterior chamber, increased intraocular pressure without pupillary block, anterior rotation of the ciliary body, and the disappearance of the posterior chamber. The underlying mechanism includes forward displacement of the lens-iris diaphragm, leading to initial pupillary and iris-lens blockage, the disappearance of the posterior chamber, obstruction of aqueous outflow, backflow, and accumulation in the vitreous cavity, resulting in increasing vitreous volume and worsening forward displacement of the lens-iris septum, consequently, forming a vicious cycle [29]. It has been shown that short eye axis, chronic angle closure, high iris folds, relaxed zonules, filtration bleb leakage, and low intraocular pressure are all risk factors for its occurrence [30, 31]. Our study identifies filtration surgery history and combined trabeculectomy as important risk factors for performing UAV during CUP. Greater trauma, longer operating time, larger intraocular pressure fluctuations, and increased intraocular inflammation during combined surgery all contribute to the development of malignant glaucoma than those in normal cataract patients [32]. Our results align with the clinical manifestation of glaucoma showing hyperopia, shallow anterior chamber, short eye axis, and crowded angle area. Although drainage of retained aqueous humor to the subconjunctiva through trabeculectomy safely controls postoperative intraocular pressure, there is no significant difference in thickness and position of the lens and the length of the eye axis between preoperative and postoperative [33], indicating that filtration surgery does not eliminate the factors inducing malignant glaucoma as demonstrated in our results. In case CUP combined with trabeculectomy needs to be performed, it may be necessary to remove the trabecular meshwork, peripheral iridectomy area, nearby anterior hyaloid membrane, and vitreous, which makes the "anterior vitreous chamber-zonules-posterior chamber-peripheral iridectomy-anterior chamber-trabecular meshwork" pathway unobstructed. After trabecular filtration surgery, the occurrence and development of cataracts will accelerate in glaucoma patients due to changes in aqueous humor dynamics, surgical trauma, changes in filtration strength, and severe postoperative inflammatory reactions. Especially for patients with angle-closure glaucoma, the anterior chamber will become shallower after trabecular filtration surgery. Therefore, cataract surgery and anterior chamber reconstruction should be conducted as soon as possible while controlling intraocular pressure [34]. The performance of anterior vitrectomy during the surgery can effectively help the formation of the anterior chamber to reduce the difficulty of surgery [35].

UAV during CUP combined with IOL implantation is the most widely used surgery to treat malignant glaucoma that occurs during CUP. To prevent serious adverse consequences from damaging vision, the performance of UAV not only needs a doctor with extensive experience and training to take prompt action [36] but also requires full pre-operative assessment, including thorough ophthalmological examination, a history of medical conditions, filtering surgery history, old iridocyclitis and suspected zonular rupture. All these assessments have predictive value for evaluating the range and position of partial lens dislocation, direction and opening of an incision, and implantation of the capsular tension ring [37]. Vitrectomy has the advantage of both visibility and safety

as it quickly restores the anterior chamber and breaks the vicious cycle of ciliary body-lens-vitreous blockage, consequently, reducing intraocular pressure and the recurrence risk of aqueous humor misdirection due to vitreous adhesion to the anterior structures, and it also decreases vitreous volume and deepens the anterior and posterior chamber. The relief rate of simple CUP and IOL implantation was only 50% [38], while the rate is much higher (85%) in malignant glaucoma with CUP and UAV [39]. Nevertheless, no reoccurrence of malignant glaucoma was found in the patients undergoing UAV.

Although old iritis was not identified as a risk factor in this study, it has been shown that patients with a history of iritis undergoing intraocular surgery could aggravate inflammation by activating the underlying inflammatory process [40]. Malignant glaucoma and high intraocular pressure are prone to occur during the surgery, anterior vitrectomy can thus reduce the occurrence of surgical complications. Moreover, if the exudation on the surface of the iris increases and adhesion can occur after surgery, it will lead to pupil closure, IOL displacement, and even induction of acute angle-closure glaucoma in severe cases in case the surgery is mishandled, therefore, mydriasis and anti-inflammatory treatment are also critical during postoperation.

It is worthwhile to note the limitations of this study. Post-operative observation is too short to examine long-term outcomes of combined cataract surgery; and this study did not evaluate the different levels of surgeons and their skills, which could contribute to gaining different success rates or complications in performing the combined surgery [41]. Young cataract surgeons with insufficient surgical experience and skills, when facing patients with a history of filtering surgery, zonular rupture, and combined trabeculectomy, need to be fully prepared for intraoperative anterior vitrectomy to ensure smooth operation and satisfactory treatment outcomes [42]. Moreover, further prospective, comparative studies with large sample sizes of old adult Chinese patients from different medical centers are required to consolidate the evaluation of risk factors and efficacy of combined surgery in cataract management.

Conclusions

In summary, three important risk factors including glaucoma filtration surgery, zonular dehiscence, and combined trabeculectomy have been identified in the patients receiving anterior vitrectomy during phacoemulsification surgery, which lay the foundation for cataract surgeons to make better preoperative preparation and intraoperative management, prevent and reduce intraoperative and postoperative complications in the combined surgery, ultimately, help patients achieve better visual acuity and enhance quality of life.

Abbreviations

UAV	Unplanned anterior vitrectomy
CUP	Cataract ultrasonic phacoemulsification
VA	Visual acuity
BCVA	Best correct visual acuity
logMAR	Logarithm of the minimum angle of resolution

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Not applicable.

Author contributions
SYL is responsible for the study concepts & design, literature research, clinical studies, experimental studies, data acquisition & analysis, statistical analysis, manuscript preparation; YM is responsible for the guarantor of integrity of the entire study, definition of intellectual content, manuscript editing & review. All authors read and approved the final manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The surgical process was smooth for all patients, and no severe surgical complications occurred. Ethics approval for this study was obtained from the Ethics Committee of Tianjin Union Medical Center (Ethical approval time: 1st., August, 2024, Ethical code No. (2024) Quick Review No. (B13)). Published research must comply with the guidelines for human studies and should include evidence that the research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. Written informed consent was obtained from all individuals included in this study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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