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Use of intravitreal antiviral injection during vitrectomy in the treatment of acute retinal necrosis: anatomic and visual outcomes

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Abstract

Purpose To investigate whether intravitreal antiviral injection (IAI) during vitrectomy reduces the postsurgical retinal detachment (RD) rate and improves the visual prognosis of patients with acute retinal necrosis (ARN).

Methods This retrospective cohort study included ARN patients treated at a tertiary hospital between January 2013 and December 2020. Patients who underwent pars plana vitrectomy (PPV) alone or combined with intraoperative IAI were classified in PPV-only group and PPV + IAI group, respectively. The incidence of postsurgical RD and the best corrected visual acuity (BCVA) between the groups was compared. A multivariate Cox hazard analysis was employed to explore the risk factors of postsurgical RD. A multivariate logistic regression analysis was applied to assess the impact of intraoperative IAI on preventing severe vision loss (SVL).

Results Fifty-seven eyes with ARN with a median follow-up of 18.5 months were included in the study. There was no significant association between intraoperative IAI during vitrectomy and a reduced risk of postsurgical RD (hazard ratio [HR], 2.65; 95% CI, 0.71–9.89) or SVL at the 6-month follow-up visit (odds ratio [OR], 0.92; 95% confidence interval [CI], 0.25–3.35). Better baseline best-corrected visual acuity (BCVA) was identified to associate with a higher risk of postsurgical RD (HR, 0.33; 95% CI, 0.14–0.81) and a lower risk of SVL at 6 months (OR, 2.28; 95% CI, 1.10–4.89).

Conclusion We did not observe a significant effect of intraoperative IAI on the anatomic and visual outcomes of ARN patients in this study. Intraoperative IAI may not be a necessary treatment option for ARN patients who receive vitrectomy.

Keywords Acute retinal necrosis, Intraoperative intravitreal injection, Pars plana vitrectomy, Retinal detachment, Visual outcome

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Introduction

Acute retinal necrosis (ARN) is a rare, rapidly progressive, and potentially vision-threatening syndrome, which includes panuveitis, vitritis, occlusive retinal periarteritis, and peripheral retinal necrosis. The disease is mainly caused by varicella-zoster virus (VZV) or herpes simplex virus (HSV) infection [1], and less commonly found causative pathogens include cytomegalovirus (CMV) and Epstein-Barr virus (EBV) [2, 3]. It is typically characterized by rapidly spreading peripheral yellow-white necrotic foci, vitreous haze, and retinal arteriolar occlusion [4]. One of the most severe complications of ARN is retinal detachment (RD), which can result in poor visual prognosis without prompt surgical repair [5, 6].

The primary therapeutic regimen for ARN begins with intravenous acyclovir, followed by oral antiviral medicines [7]. Intravitreal antiviral injection (IAI) has been regarded as an effective adjunctive treatment in recent years. It allows for a high concentration of the antiviral medication to be delivered directly to the site of the infection, thus reducing systemic side effects and strengthening the efficacy of the treatment. Surgical interventions are reserved for patients who develop severe vitritis or retinal detachment. Pars plana vitrectomy (PPV) is the most commonly adopted procedure in such circumstance.

The visual outcome of ARN is generally undesirable; thus, finding out the therapeutic factors associated with the prognosis is of great importance in guiding clinical practice. Despite the wide application of intravitreal antiviral injection, the effectiveness of this adjunctive treatment has not been proven and it remains unclear whether intraoperative IAI affects the outcomes Therefore, we carried out this study to explore the efficacy of intravitreal injection of antivirals at the end of vitrectomy.

Methods

Study design and subjects

This was a single-center, retrospective cohort study. Patients diagnosed with ARN were retrospectively recruited from the Eye Hospital of Wenzhou Medical University from January 2013 and December 2020.

The main selection criteria were (1) patients with diagnosis made according to the clinical characteristics following the standard diagnostic criteria proposed by the American Uveitis Society [4], with or without PCR confirmation, and (2) received both initial systemic antiviral treatment and surgical treatment (PPV) in our hospital. The main exclusion criteria were (1) had other vision-threatening diseases (e.g., glaucoma) before the diagnosis of ARN was made, (2) did not receive any surgical treatment during the whole follow-up period, (3) received surgical treatment in other hospitals, (4) with a follow-up period less than 3 months, and (5) incomplete surveillance data. Both eyes were included if eligible. The inclusion and exclusion process was shown in Fig. 1. The study followed the tenets of the Declaration of Helsinki and was approved by the Human Ethics Committee Institutional Review Board (IRB) of the Eye Hospital of Wenzhou Medical University before commencement (approval number: 2022-207-K-162). Informed consent was waived since the data analyzed in this study were deidentified. This study adhered to the reporting guidelines outlined in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [8].

Treatment

Antiviral treatments were given to all patients once the diagnosis of ARN was made. From 2013 to 2016, the routine therapy in our center was intravenous acyclovir (750 mg, thrice daily) for 5–10 days, followed by oral acyclovir (200–400 mg, five times daily) for over 6 weeks. Since 2017, the general antiviral regimen has been switched to intravenous acyclovir (750 mg, thrice daily) or oral valacyclovir (2 g, thrice daily) followed by oral acyclovir (200 mg, five times daily) or valacyclovir (900 mg, thrice daily). Intravitreal ganciclovir (4.0 mg/0.1 mL) was administered before PPV in some of the patients as adjunctive therapy. From 2013 to 2020, 0.1% ganciclovir eye drops or 0.15% eye gels were routinely applied to all affected eyes, administered four times a day.

Other medications like intravenous dexamethasone (5–10 mg daily), oral prednisone (40–60 mg daily), aspirin (100 mg daily), or topical steroid eye drops or injection were individualized according to the patient's condition.

All patients in the study underwent standard 3-port pars plana vitrectomy with complete removal of the central and peripheral vitreous because of the presenting retinal detachment or severe vitritis. A portion of patients received an additional injection of intravitreal ganciclovir (2.0 mg/0.1 mL) positioned 3.5 mm posterior to the limbus immediately after PPV was completed. Laser photocoagulation was applied to the boundary between the healthy retina and the area affected by necrosis. Other combined procedures during PPV were adopted as needed.

Follow-up

Patients were instructed to visit the outpatient department at 1 week, 1 month, 3 months, and 1 year post-surgery. Visual acuity and intraocular pressure (IOP) were measured at each visit. Routine eye examinations, including slit lamp and ultra-widefield fundus photography, were part of the follow-up plan. Any conditions or complications such as RD were to be documented by the doctors during the follow-up period.

Data collection

Data on demographics (gender and age at diagnosis), ocular findings, and the treatment were collected. When

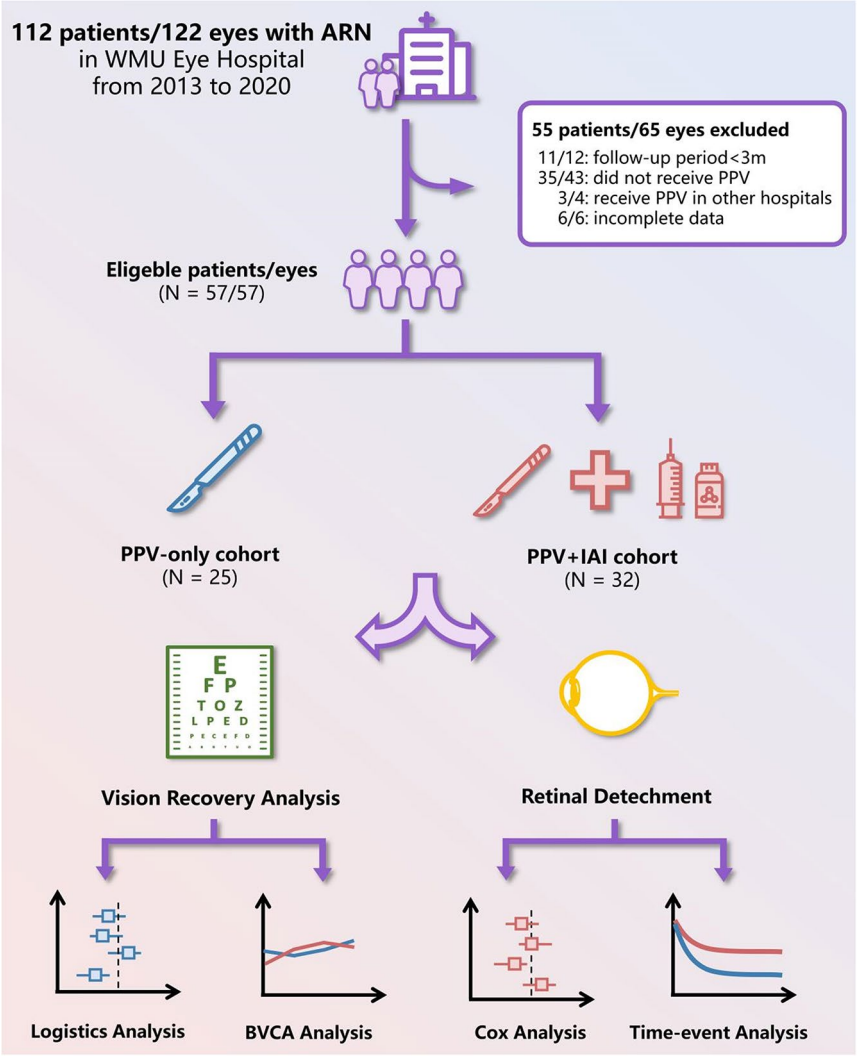

Fig. 1 Flowchart illustrating the inclusion and exclusion of study participants

available, data regarding the causative virus were also included. Whether the patient was immunocompromised was noted, including a history of AIDS, malignant tumors, autoimmune diseases, organ transplantation, or long-term systemic steroid or immunosuppressant use. We also reviewed the patients' history of diabetes mellitus, as it may influence their immunological status.

Medical records were reviewed to obtain data on best-corrected visual acuity (BCVA) at different time points (at diagnosis, and 1 week, 1 month, 3 months, 6 months, and 1 year after PPV), the patient-reported duration of symptoms before the diagnosis, and the diagnosis-to-surgery interval. The occurrence of RD was determined according to the results of the preoperative examination or the operation note. Panoramic fundus photography of the included patients was assessed to evaluate the zone (1, 2 and 3) and extent (1, <25%; 2, 25-50%; 3, 50-75%; and 4, >75%) of the affected retina, and the optic nerve involvement was assessed as well. BCVA measured using the Snellen chart was collected and converted to the logarithm of the minimum angle of resolution (logMAR) scale for further statistical analysis. For patients whose vision was qualitatively graded, logMAR values were assigned as follows: counting fingers (CF)=2.0, hand motion (HM)=2.3, light perception (LP)=2.7, or no light perception (NLP)=3.0, respectively. LogMAR value≥1.0 (Snellen visual acuity≤20/200) was defined as severe vision loss (SVL), referring to the World Health Organization's report on blindness and vision impairment [9]. Zone 1 involvement was defined as necrotic foci presenting on the central retina (3000 μm within the fovea or 1500 μm within the optic disc). Zone 2 was defined as the midperipheral area of the retina, extending from the border of zone 1 to the equator. Zone 3 was the peripheral part anterior to the equator [10].

Statistical analysis

The demographic characteristics were based on patient assessments, while the effectiveness of the tested therapeutic factors was evaluated through eye-based analysis. Continuous data are presented as mean±standard deviation (SD) or median and interquartile range (IQR) according to the data distribution. Categorical data are presented as percentages. Tested therapeutic variables were vitrectomy alone (PPV-only group) vs. vitrectomy combined with intraoperative intravitreal ganciclovir injection (PPV+IAI group) based on systemic antiviral treatment. The primary outcome variables were the postsurgical RD (defined as RD that happened after PPV, regardless of the retinal status before surgery) rate and the incidence of SVL (logMAR value≥1.0) at the 6-month visit. Comparisons between groups were made using the independent t-test for normally distributed quantitative variables, the Mann-Whitney U test for abnormally distributed quantitative variables, and Pearson's chi-square test for categorical data. Univariate logistic regression analyses were performed to evaluate the efficacy of reducing the incidence of SVL at the 6-month visit, after adjusting for the confounding factors. The statistically significant variables as well as clinically important variables were included in the following multivariate logistic regression analyses. The cumulative risk of RD after vitrectomy was calculated for both groups. Univariate and multivariate Cox regression analysis was used to estimate the hazard ratio (HR) while controlling for the confounding factors. A two-sided *P* value of less than.05 was considered statistically significant. Analyses were conducted with the use of SPSS, version 26.0 (IBM Corp., Armonk, NY, USA), and R software, version 4.1.0 (R Project for Statistical Computing).

Results

Patient characteristics

A total of 112 patients (122 eyes) were screened for eligibility, and 57 patients (63.2% male) and 57 eyes that met the criteria were retrospectively enrolled in the study (Fig. 1). Of all eyes, 68.4% (39/57) were diagnosed based on clinical manifestations, while the causative agents were confirmed by PCR testing to be VZV and HSV in 28% (16/57) and 4% (2/57) of the patients, respectively. No pathogen could be identified despite aqueous aspiration in 2 patients.

Thirty-two eyes were in the PPV+IAI group, and twenty-five were in the PPV-only group. Demographic features for these cases are summarized in Table 1. The average patient age at the time of ARN diagnosis was 49.4±11.6 years. The median patient-reported duration of symptoms before diagnosis was 20.0 days (IQR 20.0 days), with no significant difference between the PPV+IAI group and PPV-only group (median 16.5 days, IQR 19.0 days vs. median 20.0 days, IQR 32.0 days, *P*=.32). None of the patients were identified as being immunosuppressed. Five patients (8.7%) had a history of diabetes at the time of ARN diagnosis, comprising 3 patients (9.4%) in the PPV+IAI group and 2 patients (8.0%) in the PPV-only group (*P*=1.00).

Overall, RD occurred in 61.4% of patients before PPV, and there was no significant difference between the groups with and without intraoperative intravitreal antiviral injection (62.5% vs. 60.0%, *P*=.85). More than half of the patients presented zone 2 involvement at diagnosis, and necrotic retinitis spreading over four quadrants occurred in 63.2% of the patients on their first visit. There was no significant difference in the zone (*P*=.32) and extent (*P*=.97) of necrotic foci between groups. Redness and oedema of the optic disc were seen in 33 patients (57.9%), 18 (56.3%) in the PPV+IAI group, and 15 (60.0%) in the PPV-only group, respectively (*P*=.78).

Forty-one out of 57 patients (71.9%) were treated with intravenous antiviral agents, and 54 out of 57 patients (94.7%) received oral antiviral therapy. In addition, 50.9% of the patients (29/57) were administered steroid pills orally, while only 17.5% (10/57) received intravenous glucocorticoids. Periocular triamcinolone injection or dexamethasone implant injection was adopted in 14 cases (24.6%). No statistical significance existed between groups in the treatments mentioned above (Table 1). During operation, silicone oil tamponade was performed in all but 1 case (98.2%). Laser photocoagulation was combined in 36 eyes (63.2%), cataract surgery in 30 eyes (56.2%), membrane peeling in 16 eyes (28.1%), and cryotherapy in 7 eyes (12.3%). Fourteen patients (26.4%) received intravitreal triamcinolone during surgery. The combined surgical procedures mentioned were comparable in the two groups (Table 1) except for laser photocoagulation (75.0% vs. 48.0%, *P*=.04).

The median follow-up period was 18.5 months (IQR 23.5 months), with a median follow-up time of 15.7 months in the PPV+IAI group and 23.9 months in the PPV-only group (*P*=.08).

Anatomic outcome

Nine patients (28.1%) in the PPV+IAI group and only three patients (12.0%) in the PPV-only group developed RD after the surgery (*P*=.14). The Kaplan-Meier plot of the risk of postsurgical RD are shown in Fig. 2. In the univariate Cox regression analysis (Fig. 3), baseline BCVA (HR,0.31; 95% CI, 0.12–0.81; *P*=.02) appeared to be a significant prognostic factor, while intraoperative IAI showed marginal significance (HR, 2.73; 95% CI, 0.73–10.13; *P*=.13). In multivariate Cox analysis (Fig. 3), intraoperative IAI (HR, 2.65; 95% CI, 0.71–9.89; *P*=.15) was not significantly related to the outcome after controlling for the confounding factor.

Table 1 Demographics and clinical characteristics of 57 eyes of 57 patients with acute retinal necrosis for both the total cohort and subgroups of treatment

		Total	PPV + IAI	PPV-only	*P* value
No. of patients/eyes		57/57	32/32	25/25	-
Gender, male		36 (63.2)	20 (62.5)	16 (64.0)	0.91
Laterality, right		35 (61.4)	21 (65.6)	14 (56.0)	0.46
Age, years*		49.4 ± 11.6	48.6 ± 11.3	50.6 ± 12.1	0.52
Baseline BCVA, logMAR†		1.0 (1.8)	1.0 (1.8)	1.0 (1.8)	0.93
Symptom duration, days†		20.0 (20.0)	16.5 (17.0)	20.0 (32.0)	0.32
Diagnosis to surgery, days†		6.0 (9.0)	5.0 (6.0)	7.0 (11.0)	0.89
Symptom to surgery, days†		31.0 (21.0)	27.5 (21.0)	32.0 (26.0)	0.24
RD before PPV		35 (61.4)	20 (62.5)	15 (60.0)	0.85
Zone					0.32
	1: central	19 (33.3)	9 (28.1)	10 (40.0)	
	2: midperipheral	32 (56.1)	19 (59.4)	13 (52.0)	
	3: peripheral	6 (10.5)	4 (8.0)	2 (8.0)	
Involved retina					0.97
	< 25%	1 (1.8)	0 (0.0)	1 (4.0)	
	25-50%	7 (12.3)	4 (12.5)	3 (12.0)	
	50-75%	13 (22.8)	8 (25.0)	5 (20.0)	
	> 75%	36 (63.2)	20 (62.5)	16 (64.0)	
Optic nerve involvement		33 (57.9)	18 (56.3)	15 (60.0)	0.78
Occlusive vasculitis		52 (91.2)	29 (90.0)	23 (92.0)	1.000
Medication					
	Oral antivirals	54 (94.7)	31(96.9)	23 (92.0)	0.83
	Intravenous antivirals	41 (71.9)	21 (65.6)	20 (80.0)	0.23
	Oral steroids	29 (50.9)	17 (53.1)	12 (48.0)	0.70
	Intravenous steroids	10 (17.5)	4 (12.5)	6 (24.0)	0.43
	Regional steroids injection	14 (24.6)	6 (18.8)	8 (32.0)	0.25
	Preoperative IAI	27 (47.4)	14 (43.8)	13 (52.0)	0.54
	Aspirin	19 (33.3)	9 (28.1)	10 (40.0)	0.35
Intraoperative procedures					
	Oil tamponade	56 (98.2)	31 (96.9)	25 (100.0)	1.00
	Laser photocoagulation	36 (63.2)	24 (75.0)	12 (48.0)	0.04
	Cataract surgery	30 (52.6)	17 (53.1)	13 (52.0)	0.93
	Intravitreal steroids injection	14 (24.6)	7 (25.0)	7 (28.0)	0.81
	Cryotherapy	7 (12.3)	3 (9.4)	4 (16.0)	0.73
	Membrane peeling	16 (28.1)	6 (18.8)	10 (40.0)	0.08

PPV = pars plana vitrectomy; IAI = intravitreal antiviral injection; BCVA = best-corrected visual acuity; logMAR = logarithm of minimal angle of resolution; RD = retinal detachment

Data are given as number (%) unless otherwise stated

*Data given as mean ± SD.

†Data given as median (interquartile range)

Visual outcome

Regarding the visual outcome, BCVA measured at 1 week, 1 month, 3 months, 6 months and 1 year after PPV in the two groups were shown in Table 2. There was no statistically significant difference in the severe vision loss rate at different time points between groups. The result of univariate logistic regression analysis was shown in Fig. 4. Better baseline BCVA and more injections of intravitreal antivirals before PPV were identified to be significantly related to a reduced risk of severe vision loss. In multivariate logistic regression analysis (Fig. 4), intraoperative IAI was not a significant protective factor for severe vision loss at the 6-month visit (OR, 0.92; 95% CI, 0.25–3.35; *P*=.90). Worse initial BCVA was a significant risk factor for severe vision loss (OR, 2.28; 95% CI, 1.06–4.89; *P*=.04).

Discussion

In the present study, we evaluate the therapeutic efficacy of IAI in patient with ARN. Our results revealed that there was no significant correlation between application of intraoperative use of IAI and lower rate of RD. Also, there was insufficient evidence suggesting that intraoperative use of IAI may improve the visual outcome.

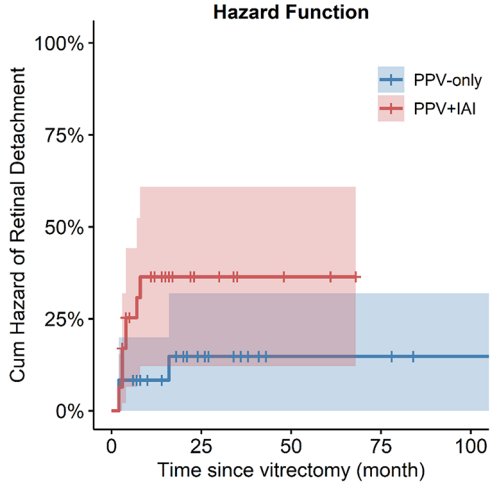

Fig. 2 Cumulative risk curve for retinal detachment after vitrectomy by month, comparing groups with and without intraoperative use of intravitreal antiviral injection

Table 2 Clinical outcomes of patients with acute retinal necrosis for both the total cohort and subgroups of treatment

	Total	PPV + IAI	PPV-only	*P* value
Follow-up period, months	18.5 (23.5)	15.7 (24.1)	23.9 (23.9)	0.08
BCVA at 1 week, logMAR	1.0 (1.3)	1.3 (1.3)	0.8 (0.8)	0.66
BCVA at 1 month, logMAR	0.8 (1.2)	1.0 (1.2)	0.8 (1.2)	0.67
BCVA at 3 months, logMAR	0.8 (0.5)	1.0 (0.9)	0.8 (0.7)	0.93
BCVA at 6 months, logMAR	0.8 (1.1)	0.8 (1.5)	0.8 (1.0)	0.96
BCVA at 1 year, logMAR	0.9 (0.9)	0.8 (0.8)	1.0 (1.4)	0.55
Severe vision loss at 6 months*	24 (48.0)	12 (48.0)	12 (48.0)	1.00
RD after PPV*	12 (21.1)	9 (28.1)	3 (12.0)	0.14

PPV=pars plana vitrectomy; IAI=intravitreal antiviral injection; BCVA=best-corrected visual acuity; logMAR=logarithm of minimal angle of resolution; RD=retinal detachment. Data are given as median (interquartile range) unless otherwise stated.*Data given as number (%)

ARN is a sight-threatening disease with a low incidence rate [11]. Although we know its viral-infectious etiology and despite various therapeutic approaches that are taken to save patients' vision, the prognosis of the disease remains poor. Therefore, treatment strategies from which patients can benefit to the greatest extent are always what doctors and researchers are concerned about. Previous studies have delved into comparing the outcomes of patients subjected to various treatment strategies. Yalcinsoy et al. conducted a study [6], scrutinizing the rates of RD in two patient cohorts undergoing vitrectomy, with or without laser photocoagulation (LPC). Their investigation revealed that the adjunctive use of prophylactic LPC alongside vitrectomy failed to yield significant benefits in averting RD development. Baltinas and colleagues [12] undertook a comparative analysis of severe vision loss and retinal detachment rates among patients initially administered either intravenous acyclovir or oral valacyclovir therapy. Their findings underscored the clinical equivalence of oral valacyclovir to intravenous therapy in managing acute retinal necrosis. Nevertheless, the potential benefits of intraoperative intravitreal antiviral injections remain insufficiently studied. In the present study, we found that intraoperative IAI did not reduce the risk of SVL at 6 months in our analysis. The result is in line with a previous study by Choi et al. [13], in which no statistically significant

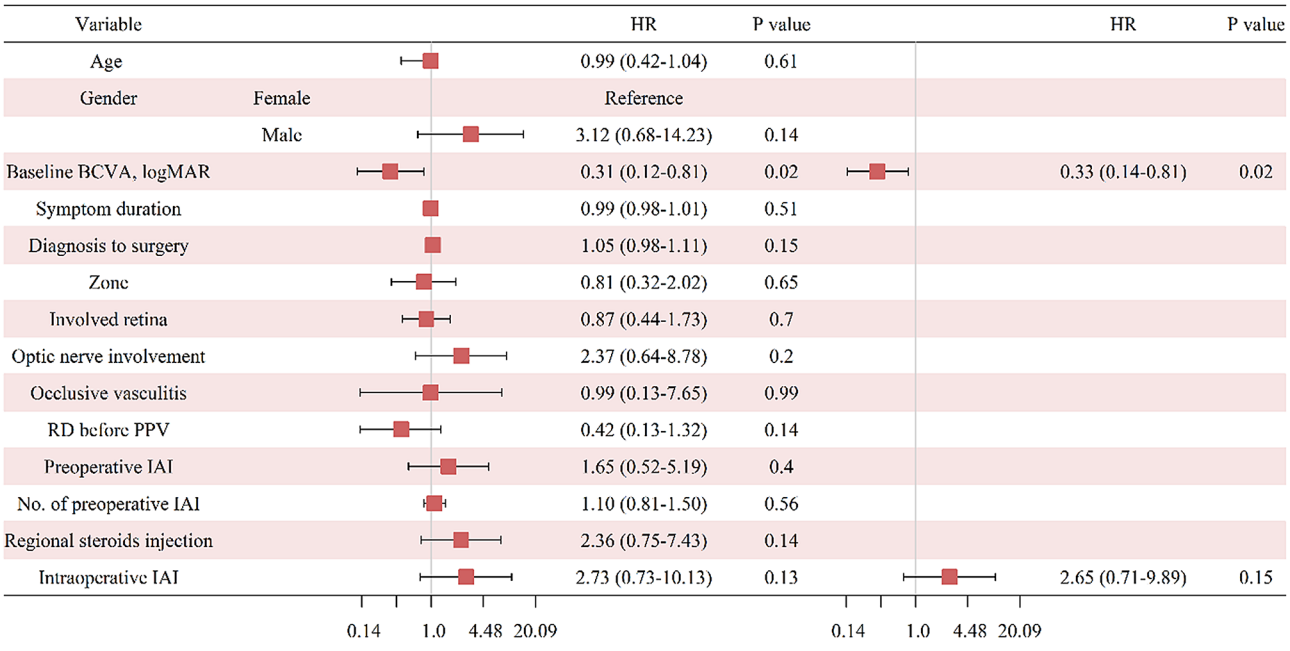

Fig. 3 Univariate and Multivariate Cox Hazard Analysis Factors for Postsurgical RD of Acute Retinal Necrosis

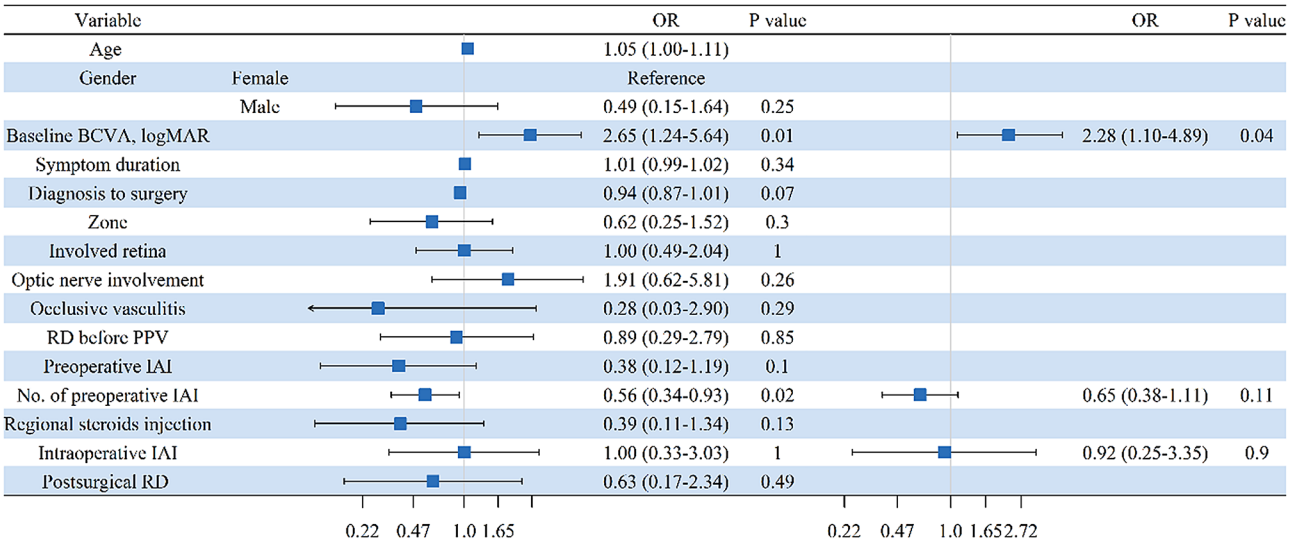

Fig. 4 Univariate and Multivariate Logistic Regression Analysis of Factors for Severe Vision Loss at 6-month Visit of Acute Retinal Necrosis

association was observed between intraoperative IAI and decreased risk of final visual loss (defined as final visual acuity < 20/200 in Snellen). Regarding factors associated with visual outcomes, worse baseline BCVA was found to be significantly correlate with a higher risk of SVL at the 6-month follow-up based on our research. This finding is consistent with the results of Tibbetts et al.'s study [14], which identified initial visual acuity as a risk factor for final visual outcomes using multivariate linear regression analysis (OR, 2.13; P=.001). Similarly, Paolo et al. [15] reported that initial BCVA was associated with poor final vision (P<.05) in their linear regression model. Risseeuw et al. [16] also came to the same conclusion, although they did not present detailed data. Although RD can be addressed by surgical treatment, recurrence of RD may still occur in some patients. Since this may happen in both who had or had not developed RD before the surgery, postsurgical RD was studied in our research. We performed the univariate and multivariate Cox regression analysis to reveal the effectiveness of intraoperative IAI in reducing the risk of postsurgical RD while controlling for potential confounding factors. However, the results demonstrated that the anatomic outcome did not seem to be associated with this practice. Although postsurgical RD was not studied in previous research, several studies investigated the effectiveness of intraoperative IAI in preventing retinal detachment. In one study [13], no association was found between intraoperative IAI and late-onset RD (P=.26), while in another research [16], the use of IAI was borderline statistically significant related to a higher risk of RD.

Moreover, in our study regarding postsurgical RD, we found that better baseline BCVA was associated with a higher risk of postsurgical RD, which was counterintuitive. We suppose this to be the result of the delay of surgical treatment in patients with better baseline visual acuity, and our data supported this hypothesis. Further studies are needed to confirm whether mediating variables such as treatment delay were included in the analysis and led to a confusing result.

Our study included the use of corticosteroids and aspirin as part of the treatment regimen for some patients. We administered corticosteroids cautiously, typically reserving their use for patients with severe inflammation due to the potential effects on viral activation. While acknowledging the risk of steroids worsening viral replication and accelerating retinitis progression [17], it is crucial to control inflammation to prevent even more adverse outcomes. As suggested in the literature, steroids should be used under the cover of antiviral drugs, with topical steroids started during the initial treatment phase and oral steroids added 24–48 h after the initiation of antiviral therapy [18]. In our practice, systemic, periocular, or intravitreal steroids were introduced 48–72 h after starting antiviral therapy if necessary. Moreover, the decision to use aspirin was based on factors such as the presence of occlusive vasculitis, the doctor's discretion, the patient's general health condition, and the patient's preference. Previous clinical evidence suggested that aspirin may have a potential role in reducing vascular thrombosis and preventing further propagation of retinal ischemia and necrosis [19]. It should be noted that the majority of studies on the effectiveness of steroids and aspirin in ARN patients are case reports or case series, and there is a lack of high-level evidence-based studies supporting their use [18]. Further research is necessary to establish clear guidelines and evidence for the use of these treatments.

The limitations of our study may include the following aspects. First, since this is a retrospective cohort study, loss of data and selection bias were almost inevitable because

of the nature of the study. In addition, patients included in this study were primarily diagnosed based on clinical presentations, with only a minority undergoing PCR testing of aqueous humor samples to detect viral nucleic acid and confirm the etiological agents, indicating another limitation in this research. Moreover, the practice of intraoperative IAI was subject to the surgeon's discretion, potentially introducing bias. Next, the sample of the study is small due to the rarity of the disease, which may result in false-negative errors when we perform the statistical analysis. Therefore, the results should be cautiously interpreted, and a prospective multicenter trial is warranted in the future. Lastly, our study lacks variables that evaluate the short-term effect of intraoperative ganciclovir injection. Previous studies showed that drugs were cleared faster in vitrectomised and oil-filled eyes [20, 21]. Thus, the long-term effects of intraoperative injection might be limited. A prospective study could be designed to include variables such as the viral load of the vitreous or aqueous samples obtained several days after the surgery to investigate the short-term benefits of the treatment.

In conclusion, our study found no association between the intraoperative use of IAI and the anatomic and visual outcomes for patients with ARN, suggesting intravitreal antiviral injection during the operative period of vitrectomy might not be necessary. Prospective studies should be performed to better reveal the role of intraoperative IAI in the treatment of ARN in the future.

Author contributions

R.W. conceptualized the study. B.G. and Z.Z. were responsible for the methodology. B.G. and H.Z. conducted formal analysis and investigation. B.G., J.M., and C.D. collectively prepared the original draft. Z.L. conducted the review and editing process. R.W. provided supervision throughout the project.

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Data availability

The data and materials used in this study are available upon request from the corresponding author.

Declarations

Ethics approval and consent to participate

The research adhered to the principles outlined in the Declaration of Helsinki and obtained approval from the Institutional Review Board (IRB) of the Human Ethics Committee at the Eye Hospital of Wenzhou Medical University before initiation (approval number: 2022-207-K-162). Informed consent was exempted due to the deidentification of the analyzed data as approved by the Institutional Review Board of the Human Ethics Committee at the Eye Hospital of Wenzhou Medical University.

Consent for publication

It is confirmed that this is a retrospective study using deidentified data, and therefore, specific consent for publication was not applicable.

Conflict of interest

All authors declare no conflicts of interest they may have with publication of the manuscript or an institution that is mentioned in the manuscript or is important to the outcome of the study presented.

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