Journal of Clinical and Nursing Research, 2024, Volume 8, Issue 11
http://ojs.bbwpublisher.com/index.php/JCNR
Online ISSN: 2208-3693
Print ISSN: 2208-3685

Clinical Observation of Carteolol Hydrochloride Eye Drops Combined with Travoprost Eye Drops in the Treatment of Open-Angle Glaucoma

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Abstract: *Objective:* To analyze the therapeutic effects of carteolol hydrochloride (CAR) eye drops combined with travoprost (TRA) eye drops in the treatment of open-angle glaucoma (OAG). *Methods:* A total of 72 OAG patients (87 eyes) hospitalized between October 2020 and October 2023 were randomly divided into two groups. The combination group received CAR and TRA eye drops, while the control group received CAR eye drops alone. Treatment outcomes were compared in terms of total efficacy rate, visual acuity, intraocular pressure, visual function indicators, hemodynamic parameters, and ocular surface damage indicators. *Results:* The combination group showed a higher total efficacy rate compared to the control group. After 3 months of treatment, the combination group had better visual acuity, lower intraocular pressure, higher mean sensitivity, lower mean defect, lower resistance index, and higher end-diastolic velocity and peak systolic velocity compared to the control group ($P < 0.05$). Additionally, the combination group exhibited higher corneal fluorescein staining scores, shorter tear breakup time, and lower Schirmer tear test values compared to the control group ($P < 0.05$). *Conclusion:* The combination of CAR and TRA eye drops improves visual acuity, effectively reduces intraocular pressure, enhances visual function, regulates ocular hemodynamics, and mitigates ocular surface damage in OAG patients, demonstrating superior therapeutic efficacy.

Keywords: Carteolol hydrochloride eye drops; Travoprost eye drops; Open-angle glaucoma; Visual acuity; Intraocular pressure

Online publication: November 28, 2024

1. Introduction

The primary cause of glaucoma is elevated intraocular pressure (IOP), which leads to optic nerve damage and subsequent manifestations such as intraocular ischemia, vision loss, and blurred vision [1]. Open-angle glaucoma (OAG) is a common subtype of glaucoma characterized by symptoms of glaucoma despite an open anterior chamber angle. OAG develops gradually, with complex etiological factors such as hemodynamic abnormalities,

genetic predisposition, and improper eye use. These factors disrupt the integrity of the retinal nerve fiber layer, cause significant optic disc cupping, and may even lead to blindness in severe cases.

Carteolol hydrochloride (CAR) eye drops are commonly used in the treatment of OAG. They block β2-adrenergic receptors located in the epithelial cells of the ciliary muscle region, thereby regulating aqueous humor secretion and controlling IOP. CAR eye drops have strong affinity and exhibit sympathomimetic effects, offering high safety during use [2]. However, the efficacy of CAR eye drops as a monotherapy is limited and cannot fully restore ocular physiological function.

Travoprost (TRA) eye drops, derived from prostaglandin analogs, activate prostaglandin F2α receptors (FP receptors) to inhibit the uveoscleral pathway and promote aqueous humor outflow. This increases the space between ciliary muscles, achieving IOP reduction. This study included 72 OAG patients (87 eyes) to evaluate the therapeutic effects of CAR combined with TRA eye drops.

2. Materials and methods

2.1. General information

A total of 72 patients with open-angle glaucoma (OAG), accounting for 87 eyes, were treated between October 2020 and October 2023 and were randomly divided into two groups using a random number table.

Combination group: 36 patients (42 eyes), including 21 males (25 eyes) and 15 females (17 eyes). Six cases involved both eyes and 30 cases involved one eye. Patient ages ranged from 27 to 55 years, with a mean age of 38.65 ± 4.19 years. The duration of illness ranged from 2 to 17 months, with a mean duration of 9.85 ± 1.75 months.

Control group: 36 patients (45 eyes), including 22 males (27 eyes) and 14 females (18 eyes). Nine cases involved both eyes and 27 cases involved one eye. Patient ages ranged from 25 to 58 years, with a mean age of 38.70 ± 4.23 years. The duration of illness ranged from 1 to 18 months, with a mean duration of 10.13 ± 1.82 months.

No statistically significant differences were found between the two groups regarding baseline data ($P > 0.05$).

Inclusion criteria: Open anterior chamber angle, intraocular pressure > 20 mmHg, with symptoms such as optic disc cupping and retinal fiber layer damage; suitability for eye drop treatment; complete clinical data; normal mental status; informed consent and agreement to participate.

Exclusion criteria: Presence of other ophthalmic diseases; liver or kidney dysfunction; immunological diseases or malignancies; psychiatric disorders; withdrawal from the study.

2.2. Methods

(1) Control group: Treated with CAR eye drops (manufactured by China Otsuka Pharmaceutical Co., Ltd., approval number H10970025, 5 mL: 0.1 g). One drop was applied twice daily for 3 months.

(2) Combination group: In addition to CAR eye drops, patients were given TRA eye drops (manufactured by ALCON Cusi, S.A., import license number H20181024, 2.5 mL: 0.1 mg). One drop was applied once daily at bedtime for 3 months.

2.3. Observation indicators

(1) Visual acuity and intraocular pressure: Visual acuity was assessed using a standard international vision chart, while intraocular pressure was measured using a non-contact tonometer. Patients were instructed

to focus on the red indicator inside the instrument, with adjustments made to ensure proper focus and automatic measurement of intraocular pressure values.

(2) Visual function indicators: A fully automated perimeter was used in a darkroom to assess the visual field, calculating mean sensitivity (MS) and mean defect (MD).

(3) Hemodynamic indicators: Central retinal artery resistance index (RI), end-diastolic velocity (EDV), and peak systolic velocity (PSV) were assessed using color Doppler ultrasonography.

(4) Ocular surface damage indicators:

(a) Corneal fluorescein staining (FLs): Fluorescein dye was applied to the corneal area to assess epithelial cell damage. A 4-grade scoring system (0–3) was used, where 0 indicated no staining and 3 indicated ulceration.

(b) Tear breakup time (BUT): Fluorescein sodium solution was instilled into the conjunctival sac. Patients blinked four times and then gazed straight ahead. The time from the last blink to the appearance of a black spot on the cornea was recorded as BUT. A value ≥ 10 seconds indicated tear film stability.

(c) Schirmer tear test (STT): Standard filter paper strips were folded and placed in the outer third of the conjunctival sac, with the patient's eyes closed for 5 minutes. The strip was removed, and wetting > 10 mm was considered positive.

The above indicators were assessed before and after 3 months of treatment.

2.4. Evaluation criteria for efficacy

(1) Significant effect: Intraocular pressure reduction of 5.1–10.0 mmHg.

(2) Initial effect: Intraocular pressure reduction of 1.0–5.0 mmHg.

(3) No effect: Intraocular pressure reduction < 1.0 mmHg, or an increase in intraocular pressure.

2.5. Statistical analysis

Data were analyzed using SPSS 28.0 software. Continuous data were expressed as mean ± standard deviation (SD) and analyzed using *t*-tests. Categorical data were expressed as [*n* (%)] and analyzed using chi-squared tests. Statistical significance was set at $P < 0.05$.

3. Results

3.1. Comparison of overall effectiveness rates between groups

Table 1 shows that the overall effectiveness rate was significantly higher in the combination group compared to the control group ($P < 0.05$).

Table 1. Comparison of overall effectiveness rate between groups [*n* (%)]

Group	Eyes	Significant effect	Initial effect	No effect	Total effective rate
Combination	42	21 (50.00)	18 (42.86)	3 (7.14)	39 (92.86)
Control	45	20 (44.44)	15 (33.33)	10 (22.22)	35 (77.78)
χ^2	-	-	-	-	3.887
P	-	-	-	-	0.049

3.2. Comparison of visual acuity and intraocular pressure between groups

Before treatment, visual acuity and intraocular pressure levels were comparable between the two groups ($P > 0.05$). After 3 months of treatment, the combination group showed significantly better visual acuity and lower intraocular pressure compared to the control group ($P < 0.05$), as shown in **Table 2**.

Table 2. Comparison of visual acuity and intraocular pressure between groups before and after treatment (mean ± SD)

Group	Eyes	Visual acuity		Intraocular pressure (mmHg)	
		Before	After	Before	After
Combination	42	2.45 ± 0.39	4.52 ± 0.40	23.89 ± 3.16	18.27 ± 2.05
Control	45	2.46 ± 0.31	4.08 ± 0.37	23.92 ± 3.18	20.97 ± 2.11
t	-	0.133	5.330	0.044	6.047
P	-	0.895	0.000	0.965	0.000

3.3. Comparison of visual function indicators between groups

Before treatment, the visual function indicators were comparable between the two groups ($P > 0.05$). After 3 months of treatment, the combination group had significantly better visual function indicators than the control group ($P < 0.05$), as shown in **Table 3**.

Table 3. Comparison of visual function indicators between groups before and after treatment (mean ± SD, dB)

Group	Eyes	MS		MD	
		Before	After	Before	After
Combination	42	13.65 ± 2.18	18.69 ± 2.24	13.71 ± 2.05	9.42 ± 1.56
Control	45	13.69 ± 2.27	16.02 ± 2.17	13.74 ± 2.09	11.56 ± 1.67
t	-	0.084	5.646	0.068	6.165
P	-	0.933	0.000	0.946	0.000

3.4. Comparison of hemodynamic indicators between groups

Before treatment, the hemodynamic indicators were similar between the two groups ($P > 0.05$). After 3 months of treatment, the combination group showed significantly better hemodynamic indicators than the control group ($P < 0.05$), as shown in **Table 4**.

Table 4. Comparison of hemodynamic indicators between groups before and after treatment (mean ± SD)

Group	Eyes	RI		EDV (cm/s)		PSV (cm/s)	
		Before	After	Before	After	Before	After
Combination	42	0.77 ± 0.18	0.61 ± 0.15	7.88 ± 1.29	10.58 ± 1.43	2.72 ± 0.53	3.77 ± 0.61
Control	45	0.79 ± 0.21	0.71 ± 0.19	7.84 ± 1.32	9.17 ± 1.39	2.74 ± 0.50	3.11 ± 0.59
t	-	0.475	2.712	0.143	4.663	0.181	5.129
P	-	0.636	0.008	0.887	0.000	0.857	0.000

3.5. Comparison of ocular surface damage indicators between groups

Before treatment, the ocular surface damage indicators were comparable between the two groups ($P > 0.05$). After 3 months of treatment, the combination group showed significantly better results than the control group ($P < 0.05$), as shown in **Table 5**.

Table 5. Comparison of ocular surface damage indicators between groups before and after treatment (mean ± SD)

Group	Eyes	FLs (point)		BUT (s)		STT (mm)	
		Before	After	Before	After	Before	After
Combination	42	2.12 ± 0.57	2.81 ± 0.39	6.78 ± 1.19	5.81 ± 0.73	7.44 ± 1.17	6.81 ± 0.82
Control	45	2.14 ± 0.53	2.55 ± 0.31	6.80 ± 1.21	6.19 ± 0.78	7.49 ± 1.24	7.18 ± 0.76
t	-	0.170	3.454	0.078	2.342	0.193	2.184
P	-	0.866	0.001	0.938	0.022	0.847	0.032

4. Discussion

The pathological manifestations of open-angle glaucoma (OAG) include elevated intraocular pressure (IOP) and optic nerve damage. The underlying mechanisms are as follows:

(1) Mechanical theory: Elevated IOP disrupts axonal transport, leading to rapid apoptosis of retinal ganglion cells, optic nerve atrophy, and visual field defects.

(2) Vascular theory: Damage to ocular vasculature causes impaired blood supply, resulting in optic nerve degeneration and altered ocular blood flow parameters, leading to severe ischemia of the optic nerve [3].

Based on these mechanisms, IOP-lowering treatments are essential to slow the progression of visual function damage and alleviate symptoms in OAG patients.

CAR eye drops are one of the treatment options for OAG. They reduce aqueous humor production, effectively controlling IOP [4]. As a non-selective β2 receptor blocker, CAR eye drops exhibit a high affinity for β receptors, similar to adrenaline agonists, and avoid side effects like reduced heart rate, ensuring high safety during treatment. TRA eye drops activate FP receptors, enhancing receptor activity to relax ciliary muscles and facilitate aqueous humor outflow [5]. This helps address aqueous humor drainage obstruction, reducing its accumulation and pressure on the ocular wall, thus preventing optic nerve atrophy and preserving visual fields and acuity.

The results indicate that the total effectiveness rate in the combination group (92.86%) was significantly higher than in the control group (77.78%) ($P < 0.05$). This aligns with findings by Lian *et al.* [6], supporting the reliability and validity of the present study. After 3 months of treatment, the combination group demonstrated better visual acuity, lower IOP, higher MS, and lower MD levels compared to the control group ($P < 0.05$).

The superior outcomes of the combination therapy can be attributed to the pharmacokinetics of TRA eye drops. Administered topically, TRA components are widely distributed within corneal stromal tissue, increasing drug concentration in the affected areas and enhancing bioavailability [7]. Corneal epithelial esterases continuously hydrolyze the drug, producing a significant amount of free prostaglandin acid, which dilates outflow pathways in the sclera and cornea, degrades extracellular matrix, and relaxes ciliary muscles. This increases aqueous humor outflow and reduces IOP [8]. Combined with CAR eye drops, this treatment protects optic nerve function, restores visual acuity, and effectively lowers IOP, yielding superior therapeutic outcomes.

The combination group demonstrated lower RI levels and higher EDV and PSV levels compared to the control group ($P < 0.05$). TRA eye drops strongly activate prostaglandin receptors, dilating ocular capillaries and restoring blood flow. Additionally, the drug enhances vascular endothelial growth factor activity, accelerating neovascularization [9]. When combined with CAR eye drops, the treatment enhances localized effects, synergistically improving anterior chamber lymphatic circulation and ocular hemodynamics.

The combination group exhibited higher FLs scores, shorter BUT, and lower STT values compared to the control group ($P < 0.05$). The combination therapy improved tear film stability and increased tear secretion, moisturizing the ocular surface and alleviating irritation to prevent ocular surface damage. Furthermore, the treatment expanded small ocular blood vessels, regulated microcirculation, and improved ocular tissue metabolism, thus protecting the ocular surface [10].

5. Conclusion

In conclusion, the combination of CAR and TRA eye drops significantly improves visual acuity and IOP in OAG patients. It comprehensively enhances visual function and hemodynamic indicators while preventing ocular surface damage. This treatment demonstrates notable clinical efficacy and offers significant advantages in therapeutic application.

Disclosure statement

The author declares no conflict of interest.

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