Article

Impact of Individualized Nursing on Postoperative Recovery Following Trabeculectomy in Primary Open-Angle Glaucoma: A Retrospective Cohort Study

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AIM: Primary open-angle glaucoma (POAG) is one of the leading contributors to irreversible blindness. This study evaluated the impact of individualized nursing interventions in patients with POAG undergoing trabeculectomy.
METHODS: This retrospective analysis included 94 cases of POAG (94 eyes) undergoing primary trabeculectomy at the Department of Ophthalmology in Binzhou Medical University Hospital between January 2021 and December 2021. Based on the type of postoperative nursing care received, patients were allocated to either an individualized nursing group (n = 54), which received individualized nursing care, or a control group (n = 40), which received standard care. Individualized care comprised preoperative psychological assessment, tailored education, visual function rehabilitation, structured complication monitoring, lifestyle counseling, and remote follow-up support. Assessments were conducted at 1 week and at 1, 6, 12, 24, and 36 months postoperatively. Key outcomes included intraocular pressure (IOP), use of antiglaucoma medication, length of hospital stay, postoperative complications, and cumulative surgical success.
RESULTS: The individualized nursing group exhibited markedly shorter hospital stays (p = 0.007), lower IOP at 24 and 36 months (all $p < 0.05$), and fewer antiglaucoma medications at early time points (1 week and 1 month; all $p < 0.05$). Overall complications occurred less frequently in the individualized nursing group (p = 0.020). Kaplan–Meier analysis demonstrated a significantly higher cumulative surgical success rate in the individualized nursing group (p = 0.019). Multivariable Cox regression identified individualized nursing as an independent predictor of reduced surgical failure (hazard ratio (HR) = 0.519, p = 0.023).
CONCLUSIONS: Individualized nursing interventions significantly improve postoperative outcomes following trabeculectomy in POAG patients. Integrating individualized nursing care into routine clinical practice may enhance surgical success and reduce postoperative complications.

Keywords: primary open-angle glaucoma; trabeculectomy; individualized nursing; postoperative outcomes; intraocular pressure

Introduction

Glaucoma is a chronic, progressive disease of the optic nerve and a leading contributor to permanent blindness worldwide, affecting more than 76 million people, a number projected to exceed 110 million by 2040 [1,2]. The most prevalent subtype, primary open-angle glaucoma (POAG), accounts for approximately 70–75% of glaucoma diagnoses worldwide [3]. The hallmark features of POAG include progressive retinal ganglion cell degeneration and visual field deterioration, typically without early-stage symptoms [4]. The most significant modifiable risk factor is elevated intraocular pressure (IOP), and sustained IOP control remains the cornerstone of visual preservation in POAG management [5,6].

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Trabeculectomy, first introduced in 1968, continues to be regarded as the gold-standard surgical intervention for medically uncontrolled glaucoma, particularly in patients with advanced disease or insufficient response to pharmacological therapy [7,8]. Although trabeculectomy can significantly lower IOP, surgical success is highly dependent on the long-term maintenance of functional filtration blebs, appropriate modulation of postoperative wound healing, and timely identification of postoperative complications [9,10]. Notably, surgical outcomes are influenced not only by intraoperative technique but also by the quality of postoperative care, including medication adherence, bleb monitoring, patient education, and the prevention and management of complications [10,11].

However, conventional postoperative nursing care for glaucoma patients often adopts a passive, one-size-fits-all approach, emphasizing basic medication instructions and routine outpatient follow-up [12]. Such models may inadequately address patient-specific factors, including psychological distress, anxiety, limited disease awareness, and inconsistent self-care behaviors, all of which have been associated with poorer visual outcomes and reduced health-related quality of life in glaucoma patients [13]. Previous studies have reported that more than 30% of patients fail to use antiglaucoma medications correctly following surgery, and adherence to postoperative follow-up schedules remains suboptimal in a significant proportion of patients [14,15].

In recent years, individualized or patient-centered nursing has been increasingly incorporated into the management of chronic diseases [16]. Rooted in behavioral and psychosocial nursing frameworks, individualized nursing aims to tailor interventions according to each patient's clinical status, cognitive level, emotional condition, and lifestyle patterns [17]. For example, Anwaar *et al*. [18] reported that personalized psychological counseling combined with targeted medication instruction in cataract patients reduced preoperative anxiety and improved the accuracy of eye-drop administration. Similarly, a study involving patients with diabetic retinopathy demonstrated that individualized education and follow-up improved adherence to routine ophthalmic examinations and facilitated early detection of disease-related complications [19]. Collectively, these findings suggest that individualized nursing strategies may be especially helpful for ocular conditions that require long-term monitoring and self-management. However, evidence supporting the application of structured individualized nursing in patients undergoing trabeculectomy for POAG remains limited, especially in terms of long-term outcomes beyond 36 months.

Therefore, this study retrospectively evaluated the influence of individualized nursing interventions on postoperative recovery in patients with POAG undergoing trabeculectomy. Our findings are intended to provide robust evidence supporting the integration of individualized nursing approaches into postoperative glaucoma management pathways, with the aim of optimizing surgical outcomes and enhancing long-term continuity of care.

Methods

Study Design and Participants

This retrospective cohort study was conducted at the Department of Ophthalmology in Binzhou Medical University Hospital to evaluate the long-term effects of individualized nursing interventions on postoperative recovery in patients with POAG undergoing trabeculectomy. The diagnosis of POAG was established according to the 2020 European Glaucoma Society (EGS) Guidelines (5th Edition) [20]. Patients who underwent primary trabeculectomy between January 2021 and December 2021 were eligible, with postoperative follow-up of at least 36 months. Eligible cases were identified through the hospital's electronic medical records. A total of 94 patients (94 eyes) were enrolled and assigned to two groups based on the type of nursing care received: 54 patients received individualized nursing care (individualized nursing group), while 40 patients received routine perioperative care (control group). The study protocol was approved by the institutional ethics committee of Binzhou Medical University Hospital (Approval No.: 20250710154100035173), and due to the retrospective, non-interventional design, the requirement for informed consent was waived. The study flowchart is presented in Fig. 1.

Inclusion criteria: (1) confirmed diagnosis of POAG according to the 2020 European Glaucoma Society guidelines; (2) age $\geq$18 years; (3) receipt of primary trabeculectomy in one eye; (4) complete perioperative data and postoperative follow-up for $\geq$36 months; and (5) ability to communicate effectively and cooperate with nursing evaluation and follow-up.

Exclusion criteria: (1) secondary glaucoma, normal-tension glaucoma, or a history of ocular trauma; (2) prior intraocular surgery in the study eye; (3) coexisting retinal or optic nerve diseases that could affect visual function (e.g., diabetic retinopathy, age-related macular degeneration, optic atrophy of other etiologies); (4) severe systemic diseases that preclude compliance with postoperative care (e.g., end-stage cardiovascular disease, cognitive impairment); and (5) incomplete follow-up data or poor treatment compliance (defined as missing $\geq$2 scheduled postoperative visits within the first 6 months).

Surgical Procedure

All included patients underwent standard trabeculectomy performed by experienced glaucoma surgeons under strict aseptic conditions. Anesthesia was administered via either a peribulbar injection of 2% lidocaine (Hubei Tianyao Pharmaceutical Co., Ltd., Xiangyang, China) combined with 0.75% bupivacaine (AstraZeneca, Södertälje, Sweden) or topical application of preservative-free lidocaine gel (Alcon, Inc., Fort Worth, TX, USA), according to patient tolerance and surgeon preference. A superior rectus bridle suture was initially placed to rotate the globe inferiorly. In the superior quadrant, typically between the 10 and 2 o'clock positions, a fornix-based conjunctival flap was created to expose the sclera, and bipolar cautery was applied to achieve hemostasis. A rectangular partial-thickness scleral flap (approximately 3.5 mm $\times$ 3.5 mm, one-third to one-half scleral depth) was dissected anteriorly toward the clear cornea using a crescent blade (Alcon, Fort Worth, TX, USA). Under the scleral flap, a 1 mm $\times$ 2 mm trabecular block was excised using a Kelly Descemet punch (Duckworth & Kent, Herts, UK) or Vannas scissors (Storz, Tuttlingen, Germany) to establish controlled aqueous humor outflow from the anterior chamber. A peripheral iridectomy was then performed to prevent iris incarceration and pupillary block. The scleral flap was repositioned and secured with two to three 10-0 nylon sutures (Alcon, Fort Worth, TX, USA), with at least one releasable suture to allow postoperative IOP titration. The conjunctiva and Tenon's capsule were closed in a watertight fashion using 10-0 nylon or 8-0 Vicryl sutures (Johnson & Johnson, Somerville, NJ, USA). At the conclusion of the procedure,

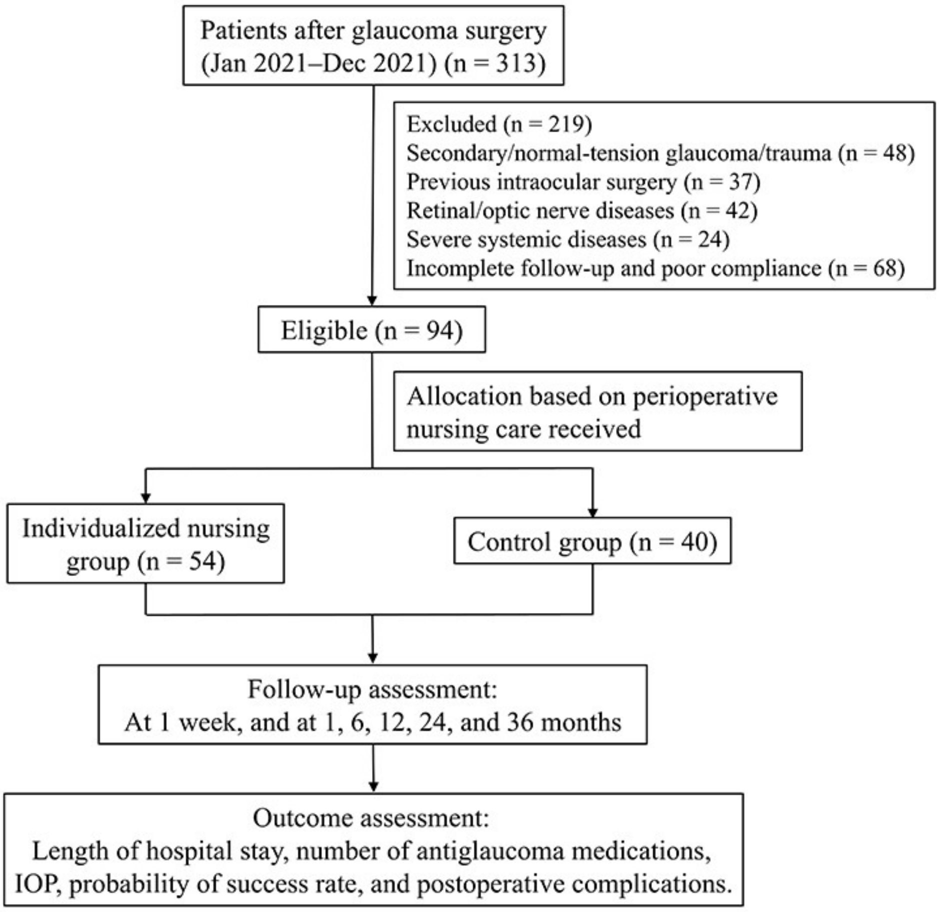

Fig. 1. The flowchart of this study. IOP, intraocular pressure.

0.3–0.5 mL of subconjunctival dexamethasone (2 mg/mL, North China Pharmaceutical Group, Shijiazhuang, China) and tobramycin (4 mg/mL, Alcon, Fort Worth, TX, USA) were injected into the inferior fornix. Intraoperative antimetabolites, including mitomycin-C (MMC; Kyowa Kirin Co., Ltd., Tokyo, Japan) or 5-fluorouracil (5-FU; Tianjin Kingyork Pharmaceutical Co., Ltd., Tianjin, China), were applied at the surgeon's discretion based on individual scarring risk.

All patients received standard postoperative management following the institutional glaucoma surgery guidelines. This regimen included topical corticosteroids (e.g., prednisolone acetate 1%, Allergan, Irvine, CA, USA) and topical antibiotics (e.g., moxifloxacin eye drops, Alcon, Fort Worth, TX, USA), administered four times daily for a minimum of four weeks. Additional IOP-lowering medications, including brimonidine tartrate (Allergan, Inc., Irvine, CA, USA), timolol maleate (Alcon, Fort Worth, TX, USA), and brinzolamide ophthalmic suspension (Alcon, Fort Worth, TX, USA), were prescribed as clinically indicated based on postoperative IOP levels and wound healing status. All medications and dosages were adjusted by the attending ophthalmologist according to individual clinical responses during follow-up.

Nursing Interventions

Patients in the control group received routine perioperative nursing care based on the hospital's standard clinical protocol for glaucoma surgery. Preoperatively, nurses provided a standardized health education brochure that outlined the basic surgical procedure and postoperative care instructions. However, no individualized psychological assessment or targeted education was conducted. Intraoperative nursing interventions were limited to routine support, including assistance with positioning and monitoring of vital signs. Postoperatively, patients received basic ward care, comprising administration of prescribed eye drops, monitoring of vital signs, and provision of general discharge instructions. No visual rehabilitation guidance, lifestyle counseling, or structured follow-up support was offered after discharge.

Patients in the individualized nursing group received a comprehensive, patient-centered nursing care plan implemented by a dedicated glaucoma nursing team. Preoperatively, each patient underwent a detailed nursing assessment covering medical history, psychological status, understanding of glaucoma, and self-care ability. Based on this assessment, nurses delivered tailored education using illustrated materials, videos, and face-to-face counseling to enhance disease understanding and alleviate anxiety. Patients showing signs of psychological distress received additional cognitive support, and referrals to psychological services were arranged when appropriate. Intraoperatively, nurses prioritized patient comfort through appropriate body positioning adjustments, especially for elderly patients or those with musculoskeletal limitations. Verbal reassurance was provided throughout the procedure to reduce anxiety. In selected cases, coordination with anesthesiologists allowed the use of mild sedatives to alleviate intraoperative stress, especially in patients with heightened nervousness.

Postoperatively, individualized nursing care was initiated within the first 24 hours. A specialized glaucoma nurse performed structured evaluations to identify early postoperative complications. Nurses provided step-by-step demonstrations on correct eye drop administration, appropriate intervals between medications, and proper hygiene techniques. Visual function rehabilitation was introduced gradually, starting with basic light-tracking and blinking exercises and progressing to simple visual tasks based on patient tolerance. In addition, lifestyle counseling was individualized to each patient's needs, addressing sleep posture, salt intake, rest routines, and protective behaviors to reduce eye strain. Emotional support was continuously provided through daily bedside interactions to monitor psychological well-being and enhance recovery confidence.

Upon discharge, patients were enrolled in a structured, individualized nursing intervention that lasted for at least three months. Nurses contacted patients every two weeks via telephone and WeChat to assess symptom progression, reinforce medication adherence, and deliver individualized education. Patients were encouraged to report any discomfort, visual changes, or signs of bleb malfunction. Visual infographics and instructional videos were shared remotely to support home-based care. In cases of concern, patients were promptly referred for in-person clinical evaluation. Follow-up records were systematically documented, and nursing strategies were adjusted accordingly to ensure optimal recovery. Detailed operational procedures of the individualized nursing intervention are provided in **Supplementary Table 1**.

Data Collection

Baseline demographic and clinical characteristics were recorded for each participant, including age, sex, body height, body weight, surgical eye (left or right), lens status (phakia, pseudophakia, or aphakia), baseline intraocular pressure (IOP), baseline number of antiglaucoma medications, and visual acuity expressed as logarithm of the minimum resolution (logMAR).

Postoperative outcomes were evaluated at 1 week and subsequently at 1, 6, 12, 24, and 36 months. The primary outcome measures included: (1) IOP at each follow-up time point; (2) number of antiglaucoma medications used at each follow-up; (3) length of hospital stay (days); and (4) incidence of postoperative complications. Visual success rates were additionally evaluated using cumulative probability analysis. Surgical success, calculated beginning from 6 months postoperatively, was defined based on IOP control with or without antiglaucoma medications, consistent with commonly accepted clinical criteria [21]. Complete success was defined as an IOP of 6–18 mmHg without antiglaucoma medications, while qualified success was defined as the same IOP range with or without such medications. Surgical failure was defined as an IOP $>$21 mmHg or $<$5 mmHg at two consecutive visits after 3 months, loss of light perception, or the requirement for glaucoma reoperation. Time to surgical failure was defined as the interval from the date of trabeculectomy to the first occurrence of surgical failure.

To clarify the follow-up schedule, short-term postoperative evaluations were primarily conducted at 1 week and 1 month, focusing on early recovery indicators such as length of hospital stay, early postoperative complications (including shallow anterior chamber, hyphema, wound leakage, choroidal detachment, and early bleb abnormalities), as well as early IOP fluctuations and changes in antiglaucoma medication use. Long-term follow-up assessments were performed at 6, 12, 24, and 36 months, with emphasis on sustained IOP control, the number of antiglaucoma medications, late-onset complications (e.g., bleb fibrosis or encapsulated bleb formation), and the cumulative probability of surgical success.

During the postoperative period following discharge, follow-up was conducted via telephone or WeChat. Adherence during the follow-up period was evaluated based on the completion of scheduled contacts and patient-reported medication use, as documented in the medical records.

Statistical Analysis

All statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Analyses at each predefined follow-up time point were conducted using available data only, and missing data were not imputed. The distribution of continuous variables was assessed using the Shapiro–Wilk test. Normally distributed variables were expressed as mean $\pm$ standard deviation (SD). Continuous variables with non-normal distributions were summarized as median (interquartile range, IQR) and compared using the Mann-Whitney U test. Categorical variables were expressed as counts (percentages) and compared using the chi-square test or Fisher's exact test, as appropriate. Between-group comparisons were performed using an independent-samples *t*-test. For within-group comparisons across multiple time points, one-way analysis of variance (ANOVA) was applied to normally distributed variables, whereas the Friedman test was used for non-normally distributed variables, with Bonferroni correction applied for post hoc multiple comparisons. Due to inconsistent follow-up schedules and incomplete longitudinal data at each time point, repeated measures analysis of variance was not employed.

Table 1. Baseline demographics and clinical characteristics of the study population.

Variable	Individualized nursing group (n = 54)	Control group (n = 40)	$t/\chi^2/Z$	p-value
Age (years)	64.4 ± 8.9	63.2 ± 9.5	0.618	0.538
Gender (male/female)	30/24	26/14	0.851	0.356
Height (cm)	165.2 ± 7.3	164.6 ± 7.4	0.392	0.696
Weight (kg)	68.9 ± 10.8	67.5 ± 11.1	0.614	0.541
Number of antiglaucoma medications	3.0 (3.0–4.0)	4.0 (3.0–5.0)	–1.550	0.121
Visual acuity (logMAR)	1.0 ± 0.4	1.0 ± 0.4	0.369	0.713
IOP (mmHg)	32.8 ± 6.9	31.6 ± 6.8	0.803	0.424
Surgical eye			0.354	0.552
Left	33 (61.1%)	22 (55.0%)		
Right	21 (38.9%)	18 (45.0%)		
Lens status			1.021	0.860
Phakia	6 (11.1%)	6 (15.0%)		
Pseudophakia	47 (87.0%)	34 (85.0%)		
Aphakia	1 (1.9%)	0 (0.0%)		
Follow-up duration (months), median (IQR)	37.7 (36.2–39.8)	37.4 (36.3–39.1)	0.812	0.313

Abbreviations: IOP, intraocular pressure; logMAR, logarithm of the minimum angle of resolution; IQR, interquartile range.

Table 2. Comparison of postoperative length of hospital stay between the two groups.

Variable	Individualized nursing group (n = 54)	Control group (n = 40)	t	p-value
Length of hospital stay (days)	5.6 ± 1.1	6.3 ± 1.4	–2.750	0.007

Notes: Values are expressed as mean ± standard deviation (SD). A p-value < 0.05 was considered statistically significant.

Kaplan–Meier survival analysis was used to estimate long-term surgical success, with time to surgical failure defined as the endpoint. Differences between groups were assessed using the log-rank test. Univariate and multivariate Cox proportional hazards regression analyses were performed to identify variables associated with time to surgical failure. Variables with $p < 0.10$ in univariate analysis were included in the multivariate Cox proportional hazards models. All statistical tests were two-sided, and a $p < 0.05$ was considered statistically significant.

Results

Baseline Characteristics

A total of 94 patients (94 eyes) were included in the final analysis, comprising 54 patients in the individualized nursing group and 40 patients in the control group (Table 1). No statistically significant differences were observed between the two groups in terms of age, gender distribution, height, weight, baseline IOP, baseline number of antiglaucoma medications, visual acuity (logMAR), lens status, surgical eye laterality, or follow-up duration (all $p > 0.05$), indicating that baseline demographic and clinical characteristics were comparable between the groups.

Length of Hospital Stay

A statistically significant reduction in postoperative hospitalization duration was observed in the individualized nursing group compared with the control group (5.6 ± 1.1 vs. 6.3 ± 1.4 days, p = 0.007; Table 2).

Number of Antiglaucoma Medications

Following surgery, both groups required fewer antiglaucoma medications (Table 3), with significant reductions observed compared with baseline values in each group ($p <$ 0.05). In the individualized nursing group, the median number of medications decreased from 3.0 (3.0–4.0) preoperatively to 1.0 (0.0–1.0) at 1 week and 1.0 (0.0–2.0) at 1 month postoperatively ($p < 0.05$, within-group). Although medication use gradually increased over time, it remained significantly lower than baseline through 36 months (2.0 (1.0–3.0), $p < 0.05$, within-group). A similar trend was observed in the control group, with medication use declining from 4.0 (3.0–5.0) to 1.0 (1.0–2.0) at 1 week and 1.5 (1.0–2.0) at 1 month ($p < 0.05$, within-group), followed by a gradual increase to 2.0 (1.0–3.0) at 36 months. Between-group comparisons revealed that the individualized nursing group required significantly fewer medications at both 1 week (p = 0.019) and 1 month (p = 0.024), whereas differences beyond 6 months were not statistically significant ($p > 0.05$).

IOP Control

Table 4 summarizes the post-operative IOP levels at different follow-up time points. Both groups demonstrated significant within-group reductions from baseline values (p < 0.05). In the individualized nursing group, mean IOP decreased from 32.8 ± 6.9 mmHg to 16.4 ± 3.2 mmHg at 1 week postoperatively. Long-term IOP remained stable, measuring 15.7 ± 2.7 mmHg at 6 months, 15.6 ± 2.5 mmHg at 12 months, 15.8 ± 2.5 mmHg at 24 months, and 16.5 ± 2.4 mmHg at 36 months. Similarly, the control

Table 3. Comparison of the number of antiglaucoma medications used at different time points.

Time Point	Individualized nursing group (n = 54)	Control group (n = 40)	Z	p-value
Preoperative	3.0 (3.0–4.0)	4.0 (3.0–5.0)	–1.550	0.121
1 week postoperative	1.0 (0.0–1.0)[a]	1.0 (1.0–2.0)[b]	–2.337	0.019
1 month postoperative	1.0 (0.0–2.0)[a]	1.5 (1.0–2.0)[b]	–2.256	0.024
6 months postoperative	1.0 (0.0–2.0)[a]	2.0 (1.0–2.0)[b]	–1.878	0.060
12 months postoperative	1.0 (1.0–2.0)[a]	2.0 (1.0–3.0)[b]	–1.116	0.265
24 months postoperative	1.0 (0.0–2.0)[a]	2.0 (1.0–3.0)[b]	–1.625	0.104
36 months postoperative	2.0 (1.0–3.0)[a]	2.0 (1.0–3.0)[b]	–1.418	0.156

Notes: Values are presented as median (interquartile range, IQR). [a] indicates a statistically significant change from baseline within the individualized nursing group, based on the Friedman test with Bonferroni-adjusted post hoc comparisons ($p < 0.05$). [b] indicates a statistically significant change from baseline within the control group, based on the Friedman test with Bonferroni-adjusted post hoc comparisons ($p < 0.05$). Between-group comparisons at each postoperative time point were performed using the Mann-Whitney U test. A p-value < 0.05 was considered statistically significant.

Table 4. Comparison of IOP between the two groups at different time points.

Time Point	Individualized nursing group (n = 54)	Control group (n = 40)	t	p-value
Preoperative	32.8 ± 6.9	31.6 ± 6.8	0.803	0.424
1 week postoperative	16.4 ± 3.2[a]	16.9 ± 3.5[b]	–0.747	0.457
1 month postoperative	15.7 ± 3.0[a]	16.2 ± 3.2[b]	–0.776	0.440
6 months postoperative	15.7 ± 2.7[a]	16.0 ± 2.5[b]	–0.714	0.477
12 months postoperative	15.6 ± 2.5[a]	16.3 ± 2.6[b]	–1.379	0.171
24 months postoperative	15.8 ± 2.5[a]	17.0 ± 2.4[b]	–2.349	0.021
36 months postoperative	16.5 ± 2.4[a]	17.8 ± 2.4[b]	–2.683	0.009

Notes: Values are presented as mean ± SD. [a] indicates a statistically significant change from baseline within the individualized nursing group, based on one-way ANOVA with Bonferroni correction ($p < 0.05$). [b] indicates a statistically significant change from baseline within the control group, based on one-way ANOVA with Bonferroni correction ($p < 0.05$). Between-group comparisons were performed at each time point using independent-samples t-tests. A p-value < 0.05 was considered statistically significant. ANOVA, analysis of variance.

Table 5. Univariate and multivariable Cox proportional hazards regression analyses for time to surgical failure.

Variable	Univariate HR (95% CI)	p-value	Multivariable HR (95% CI)	p-value
Group (intervention vs. control)	0.482 (0.281–0.829)	0.008	0.519 (0.295–0.914)	0.023
Age (≤64 vs. >64 years)	1.104 (0.659–1.848)	0.705	-	-
Baseline IOP (≤32 vs. >32 mmHg)	1.624 (1.009–2.617)	0.046	1.548 (0.949–2.525)	0.082
Baseline antiglaucoma medications (≤4 vs. >4)	1.492 (0.932–2.385)	0.096	1.413 (0.867–2.303)	0.166
Sex (male vs. female)	1.183 (0.702–1.995)	0.528	-	-
Lens status (phakia vs. pseudophakia/aphakia)	1.347 (0.699–2.598)	0.372	-	-
Surgical eye (right vs. left)	1.063 (0.632–1.789)	0.819	-	-

Notes: Variables with $p < 0.10$ in the univariate analysis were included in the multivariable Cox proportional hazards model. Cutoff values for age, baseline IOP, and the number of baseline antiglaucoma medications were defined based on median values. A p-value < 0.05 was considered statistically significant.

Abbreviations: HR, hazard ratio; CI, confidence interval.

group exhibited a reduction from 31.6 ± 6.8 mmHg to 16.9 ± 3.5 mmHg at 1 week, with values gradually increasing to 17.8 ± 2.4 mmHg by 36 months. Between-group analysis indicated significantly lower IOP values in the individualized nursing group at 24 months (p = 0.021) and 36 months (p = 0.009).

Cumulative Surgical Success Rate

Kaplan–Meier survival analysis revealed a higher cumulative probability of surgical success in the individualized nursing group throughout the 36-month follow-up period. Using the definition of qualified success (IOP between 6–18 mmHg with or without antiglaucoma medications), the individualized nursing group maintained surgical success more effectively than the control group (Fig. 2, p = 0.019).

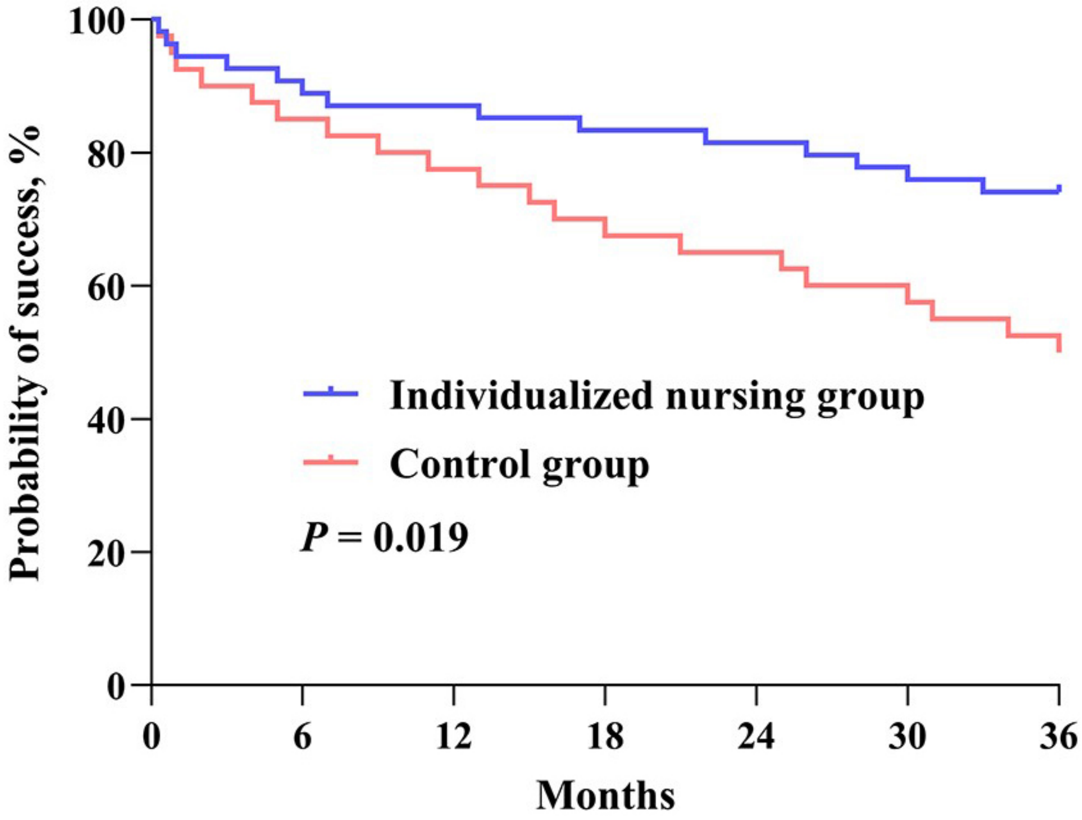

Fig. 2. Kaplan–Meier analysis of cumulative qualified surgical success over 36 months of follow-up. Qualified success was defined as an IOP of 6–18 mmHg with or without antiglaucoma medication, without the need for additional glaucoma surgery or loss of light perception. Numbers at risk (intervention vs. control) were 54/40 at baseline, 49/35 at 6 months, 47/31 at 12 months, 43/25 at 24 months, and 40/21 at 36 months. A *p*-value < 0.05 was considered statistically significant.

The numbers at risk (intervention vs. control) were 54/40, 49/35, 47/31, 43/25, and 40/21 at 0, 6, 12, 24, and 36 months, respectively.

Cox Regression Analysis for Time to Surgical Failure

Univariate Cox proportional hazards regression analysis showed that individualized nursing was significantly associated with a reduced risk of surgical failure (HR = 0.482, 95% CI: 0.281–0.829, $p = 0.008$). In addition, higher baseline IOP (>32 mmHg) was associated with an increased risk of surgical failure (HR = 1.624, 95% CI: 1.009–2.617, $p = 0.046$), while a greater number of baseline antiglaucoma medications (>4) demonstrated a borderline association with surgical failure (HR = 1.492, 95% CI: 0.932–2.385, $p = 0.096$). Multivariable Cox regression analysis demonstrated that individualized nursing remained independently associated with a lower risk of surgical failure after adjustment for baseline covariates (HR = 0.519, 95% CI: 0.295–0.914, $p = 0.023$). The association between baseline IOP and surgical failure was attenuated in the multivariable model and did not reach statistical significance (HR = 1.548, 95% CI: 0.949–2.525, $p = 0.082$) (Table 5).

Postoperative Complications

The incidence of postoperative complications was markedly lower in the individualized nursing group (20.4%) compared with the control group (42.5%) ($p = 0.020$). Both groups experienced complications such as hyphema, filtration failure, choroidal detachment, and bleb leakage. However, these events occurred more frequently in the control group. Notably, no cases of conjunctival wound dehiscence were observed in the individualized nursing group. As summarized in Table 6, all recorded complications were classified as mild to moderate in severity and were managed using standard clinical measures, including adjustments to topical therapy, topical or systemic corticosteroids, cycloplegic agents, pressure patching, bandage contact lens application, and close clinical observation. All complications either resolved completely or remained clinically stable during follow-up. Notably, no complication resulted in permanent vision loss or required reoperation in either group.

Discussion

Primary open-angle glaucoma (POAG) is a progressive optic neuropathy that requires long-term management, and trabeculectomy remains the gold-standard surgical option for patients with medically uncontrolled IOP [1,22]. However, postoperative outcomes depend not only on surgical technique but also on attentive follow-up and patient-centered postoperative management [23]. The present study demonstrates that individualized nursing interventions significantly improve postoperative recovery and long-term outcomes following trabeculectomy in patients with POAG. Compared with standard nursing care, patients receiving individualized nursing showed shorter hospital stays, lower IOP levels at 24 and 36 months, reduced use of antiglaucoma medications during the early postoperative period (1 week and 1 month), higher cumulative surgical success rates, and a lower incidence of postoperative complications. Multivariable Cox regression analysis further confirmed that individualized nursing was independently associated with a reduced risk of surgical failure during long-term follow-up.

Several mechanisms may explain the observed benefits of individualized nursing care. Comprehensive preoperative assessments of psychological status, disease awareness, and self-care ability enabled the delivery of tailored education through brochures, videos, and individualized counseling, thereby improving patient understanding and reducing anxiety, factors known to influence treatment adherence and surgical success [24,25].

Postoperatively, structured follow-up using telephone and WeChat facilitated early identification of complications, including bleb leakage and shallow anterior chamber formation. These proactive interventions likely contributed to the overall reduced postoperative complication rate observed in the individualized nursing group, while reinforcing correct eye drop administration and lifestyle modifications that support wound healing [26,27]. These proactive nursing measures likely contributed to improved IOP control and surgical outcomes, consistent with evidence from diabetic retinopathy management, which demonstrates that structured follow-up enhances treatment adherence and early complication detection [19].

Recent studies have highlighted the significance of effective postoperative management in sustaining long-term trabeculectomy outcomes. McGlumphy *et al*. [28] demonstrated that high postoperative medication adherence was associated with improved surgical success following glaucoma surgery. Another study reported that comprehensive, targeted nursing interventions can assist patients with glaucoma in correcting inappropriate behaviors, enhancing treatment adherence and quality of life, and alleviating psychological distress [29]. Consistent with these findings, our individualized nursing approach contributed to sustained IOP control, with statistically significant between-group differences primarily observed at 24-and 36-months post-intervention.

Although an a priori sample size calculation was not feasible due to the retrospective design, a post-hoc power analysis was performed to evaluate the adequacy of the sample size. Based on the observed between-group difference in IOP at 36 months (effect size d $\approx$ 0.55, $\alpha = 0.05$), the estimated statistical power exceeded 80%, suggesting that the study was sufficiently powered to detect clinically meaningful differences in long-term IOP control. While post-hoc power assessment does not replace prospective sample size determination, it provides additional support for the robustness of our findings, considering the inherent limitations of retrospective analyses.

In addition, visual rehabilitation exercises and continuous emotional support may have contributed to enhanced functional recovery and patient confidence, in agreement with studies in cataract and corneal surgery, which show that individualized rehabilitation improves postoperative visual outcomes and reduces psychological stress [30,31]. The continuity of nursing care beyond hospital discharge helped bridge the transition between inpatient treatment and home-based self-management, which is particularly critical for preserving bleb function and achieving stable IOP in chronic conditions such as glaucoma [32,33]. Moreover, sustained patient engagement throughout the perioperative period may promote positive health behaviors and improve long-term adherence, highlighting the value of integrating personalized support into routine care pathways [34].

Although the remote follow-up period in this study was limited to three months, this early intervention may have reinforced self-care practices and medication routines during a critical phase of wound healing, potentially contributing to the sustained benefits observed during long-term follow-up. Our findings are also consistent with previous ophthalmic research. Anwaar *et al*. [18] reported that personalized medication counseling in patients undergoing cataract surgery improved adherence and reduced anxiety, while Nassar *et al*. [35] found that individualized follow-up improved appointment compliance and early detection of postoperative complications. However, these studies primarily evaluated short-term outcomes, whereas the present study provides longitudinal data over 36 months, thereby offering stronger evidence for the durability of individualized nursing care.

Notably, the individualized nursing group showed clear short-term benefits in reducing the number of antiglaucoma medications, with significantly fewer drugs required at 1 week and 1 month postoperatively compared with the control group. This early advantage likely reflects the effects of structured education and close postoperative supervision provided during the initial nursing period. However, the magnitude of this improvement declined beyond the first year. For instance, the use of antiglaucoma medication increased from 0.9 at 1 month to 2.0 at 36 months, although it remained lower than that observed in the control group. This attenuation may be partly due to the discontinuation of intensive nursing support after the initial structured follow-up period. In the absence of sustained supervision, patients

Table 6. Comparison of postoperative complications between the two groups.

Complication	Group	n (%)	Severity	Clinical management	Outcome
Hyphema	Individualized nursing	2 (3.7%)	Mild–Moderate	Topical corticosteroids, activity restriction, close observation	Resolved
	Control	3 (7.5%)	Mild–Moderate	Topical corticosteroids, activity restriction, close observation	Resolved
Filtration failure	Individualized nursing	2 (3.7%)	Mild–Moderate	Adjustment of topical therapy, bleb massage, routine follow-up	Stable
	Control	4 (10.0%)	Mild–Moderate	Adjustment of topical therapy, intensified follow-up	Stable
Shallow/Flat anterior chamber	Individualized nursing	2 (3.7%)	Mild	Cycloplegic agents, temporary activity limitation, observation	Resolved
	Control	1 (2.5%)	Mild	Cycloplegic agents, observation	Resolved
Hypotony maculopathy	Individualized nursing	1 (1.9%)	Moderate	Adjustment of anti-inflammatory therapy, IOP monitoring	Resolved
	Control	0 (0.0%)	-	-	-
Choroidal detachment	Individualized nursing	2 (3.7%)	Mild–Moderate	Topical or systemic corticosteroids, close observation	Resolved
	Control	3 (7.5%)	Mild–Moderate	Topical or systemic corticosteroids, close observation	Resolved
Peripheral anterior synechiae	Individualized nursing	1 (1.9%)	Mild	Medical management, routine monitoring	Stable
	Control	3 (7.5%)	Mild–Moderate	Medical management, routine monitoring	Stable
Bleb leak	Individualized nursing	1 (1.9%)	Mild	Pressure patching, bandage contact lens, observation	Resolved
	Control	2 (5.0%)	Mild–Moderate	Pressure patching or bandage contact lens	Resolved
Conjunctival wound dehiscence	Individualized nursing	0 (0.0%)	-	-	-
	Control	1 (2.5%)	Mild–Moderate	Conservative wound care, close observation	Resolved
Total complications	Individualized nursing	11 (20.4%)	-	-	No permanent vision loss
	Control	17 (42.5%)	-	-	No permanent vision loss

Notes: The chi-square test was applied to compare the overall incidence of postoperative complications between the two groups (χ^2 = 5.381, p = 0.020). A p-value < 0.05 was considered statistically significant.

may experience difficulty maintaining adherence to prescribed treatment regimens and self-care practices [36]. This trend is consistent with findings from the STAR trial by Geidl *et al*. [37], which showed that patients with chronic obstructive pulmonary disease achieved early gains from structured rehabilitation but encountered challenges in sustaining physical activity after program cessation. Similarly, Qiu *et al*. [38] observed that medication adherence among cataract patients declined markedly after discharge once individualized nursing support was withdrawn. Collectively, these observations highlight a key challenge in chronic disease management: sustaining patient engagement and adherence beyond the initial phase of structured intervention [39]. In glaucoma, this challenge is particularly salient because disease progression is often asymptomatic, which may reduce patient motivation in the absence of overt symptoms [40,41].

In addition, multivariable Cox proportional hazards regression analysis identified individualized nursing as an independent predictor of time to surgical failure following trabeculectomy in patients with POAG. The independent protective effect of individualized nursing highlights the contribution of behavioral, educational, and management-related mechanisms in glaucoma care [42]. This finding is consistent with and extends previous evidence emphasizing the value of postoperative management and patient-centered care in determining long-term surgical outcomes in glaucoma [43,44]. Although higher baseline IOP and a greater number of antiglaucoma medications were associated with an increased risk of surgical failure in univariate analysis, consistent with previous reports indicating that more advanced disease severity compromises long-term bleb function [45], this association was attenuated after multivariable adjustment. This attenuation suggests that structured postoperative nursing and close follow-up may partially mitigate the adverse prognostic impact of elevated preoperative IOP [46]. Together, these findings highlight the dynamic interplay between baseline disease burden and the quality of postoperative care in shaping the temporal trajectory of surgical failure.

Nonetheless, several limitations should be acknowledged. First, the single-center, retrospective design may have introduced selection bias and limited the generalizability of the findings. Second, this study primarily relied on objective clinical parameters, including IOP, antiglaucoma medication use, and postoperative complications, because only these data were available in the retrospective dataset. Although baseline characteristics were statistically comparable between groups, potential confounding factors such as education level, socioeconomic status, and caregiver support could not be fully adjusted for. In addition, the relatively small sample size and limited number of outcome events constrained the robustness of multivariable regression and Cox proportional hazards analyses. Third, repeated-measures models were not applied because unequal follow-up intervals violated the sphericity assumption, which may have limited the potential to fully characterize longitudinal time-group interactions. Fourth, the feasibility and cost-effectiveness of implementing individualized nursing care were not assessed. Finally, adherence to remote nursing interventions was not quantitatively measured, making it difficult to determine their independent contribution to outcomes.

Future studies should address these limitations by employing larger, prospectively collected cohorts and applying multivariable and repeated-measures analytical approaches to better control for confounding and characterize time-dependent effects. Incorporation of standardized patient-reported outcome measures, including anxiety, treatment satisfaction, and vision-related quality of life, would allow for a more comprehensive evaluation of the effectiveness of individualized nursing. Moreover, feasibility and cost-effectiveness analyses are warranted to assess the scalability and sustainability of this approach in routine clinical practice. Multicenter randomized controlled trials, potentially integrated with digital health technologies such as mobile applications, artificial intelligence-based risk monitoring, and tele-nursing platforms, may further enhance patient adherence and long-term outcomes.

Conclusions

This study demonstrates that individualized nursing significantly enhances postoperative recovery in patients undergoing trabeculectomy for POAG. Compared with standard care, individualized interventions were associated with improved IOP control, reduced antiglaucoma medication use, shorter hospital stays, and lower complication rates over a 36-month follow-up period. These findings support the integration of individualized, patient-centered nursing approaches into glaucoma care pathways and highlight the value of continuity in postoperative nursing interventions. Future research should further explore the cost-effectiveness and scalability of individualized nursing models in multicenter settings. Additionally, integrating digital tools such as tele-nursing platforms and mobile health applications may help maintain long-term patient engagement and adherence.

Availability of Data and Materials

The used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

JLH contributed to the study concepts & design, definition of intellectual content, manuscript preparation & editing; SKZ contributed to the literature research, clinical studies and manuscript editing; YNS contributed to the data acquisition, data analysis, statistical analysis; XS was responsible for the data acquisition, data analysis and statistical analysis; LZ was the guarantor of the integrity of the entire study, contributed to the conception and design of the study, and manuscript review. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This research study obtained ethical approval from the ethics committee of Binzhou Medical University Hospital (Approval No.: 202507101541000353173). As this was a retrospective study using anonymized clinical data, the requirement for informed consent was waived by the ethics committee. The study conformed to the provisions of the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.62713/aic.4350.

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