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ORIGINAL ARTICLE

IMPACT OF MICROPULSE TRANSSCLERAL CYCLOPHOTOCOAGULATION ON HEALTH-RELATED QUALITY OF LIFE IN PATIENTS WITH NEOVASCULAR GLAUCOMA: A RETROSPECTIVE OBSERVATIONAL STUDY

Boboev Siyovush Saidavzalzoda[1], Toshtemirova Zukhra Maruf kizi[2],

PhD, Assistant Professor, Department of Ophthalmology, Samarkand State Medical University dalerxonzoda0017@gmail.com | ORCID: 0009-0007-2700-9186[1], 1st-year Master's Resident, Department of Ophthalmology, Samarkand State Medical University toshtemirovazuhra002@gmail.com | ORCID: 0009-0005-0665-4704[2],

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Abstract

Background: Neovascular glaucoma (NVG) constitutes one of the most clinically formidable and prognostically adverse subtypes of secondary glaucoma, hallmarked by pharmacologically intractable intraocular pressure (IOP) elevation, inexorable deterioration of visual function, and profound degradation of patients' health-related quality of life (HRQoL). Its pathophysiological substrate resides in the ischaemia-driven upregulation of vascular endothelial growth factor (VEGF) and cognate proangiogenic cytokines, which orchestrate aberrant neovascularisation across the iris stroma and iridocorneal angle, culminating in fibrovascular membrane elaboration and mechanically obstructed aqueous humour egress.
Objective: To rigorously characterise the magnitude and domain-specific distribution of HRQoL changes attributable to micropulse transscleral cyclophotocoagulation (MTSCPC) in a cohort of NVG patients, employing the psychometrically validated National Eye Institute Visual Function Questionnaire-25 (NEI VFQ-25).
Methods: A structured retrospective observational study was conducted among 30 patients with confirmed NVG diagnoses. Comprehensive ophthalmological assessment and NEI VFQ-25 administration were performed at baseline and upon completion of the postoperative surveillance interval.
Results: MTSCPC produced a statistically significant elevation of the composite NEI VFQ-25 score from 45.2 ± 8.7 to 68.4 ± 9.3 points ($p < 0.001$), with concordant improvements across all domain subscales, including visual function, psychoemotional equilibrium, daily activity performance, social functioning, and overall visual satisfaction.
Conclusion: MTSCPC exerts a pluridimensional beneficial effect on HRQoL in NVG patients, supporting its incorporation as a standard-of-care component in advanced glaucoma management protocols.

Keywords: neovascular glaucoma; micropulse transscleral cyclophotocoagulation; intraocular pressure; health-related quality of life; NEI VFQ-25; vascular endothelial growth factor; retinal ischaemia; fibrovascular membrane; visual function; psychoemotional status; social functioning; secondary glaucoma.

1. Introduction

Neovascular glaucoma occupies a singular and particularly grave position within the nosological spectrum of secondary glaucomatous disorders, distinguished by the convergence of an exceptionally aggressive clinical trajectory, near-universal refractoriness to conventional pharmacotherapeutic regimens, and an elevated probability of culminating in irreversible, total visual incapacitation. Unlike primary open-angle or angle-closure glaucoma, NVG invariably emerges as a downstream sequela of systemic or retinal vascular pathology that triggers a maladaptive angiogenic response within the anterior ocular segment, fundamentally subverting the structural and functional integrity of the aqueous humour drainage apparatus [1, 2].

The central pathogenetic mechanism underlying NVG has been elucidated with considerable precision over recent decades. Retinal hypoxia, engendered by the ischaemic insult, activates the hypoxia-inducible factor-1α (HIF-1α) transcriptional axis, which in turn drives the transcriptional upregulation of VEGF-A, VEGF-C, placental growth factor (PlGF), and angiopoietin-2, among other proangiogenic mediators [3]. This molecular cascade culminates in the ingrowth of structurally aberrant, fenestrated neovessels across the iris surface—a phenomenon denominated rubeosis iridis—and their extension into the iridocorneal angle. Concurrent fibrous tissue proliferation generates a contractile fibrovascular membrane that progressively obliterates the trabecular meshwork, initially elevating IOP through direct mechanical obstruction and subsequently, as synechial angle closure consolidates, through complete abrogation of conventional outflow [5]. The resultant ocular hypertension is characteristically severe, fluctuating, and profoundly resistant to topical and systemic hypotensive pharmacotherapy.

From an epidemiological perspective, secondary glaucomas collectively represent approximately 6–22% of the global glaucoma burden, with NVG estimated to account for around 7% of all glaucoma diagnoses [8]. Notwithstanding its comparatively circumscribed prevalence, NVG inflicts a disproportionately severe clinical and socioeconomic toll, attributable to its rapid and unrelenting progression, the frequent intractability of pain management, and the consequent devastation of patients' occupational, recreational, and interpersonal functioning. Proliferative diabetic retinopathy (PDR) constitutes the aetiological substrate in excess of 70% of NVG cases, reflecting the pandemic-scale escalation of type 2 diabetes mellitus and its ophthalmic sequelae [6]. Ischaemic central retinal vein occlusion (CRVO) accounts for a further 12–22% of cases, while ocular ischaemic syndrome, radiation retinopathy, and other vasoproliferative conditions collectively contribute the remainder [7].

The clinical phenotype of NVG is dominated by intractable ocular pain, ciliary injection, corneal oedema, and a precipitous decline in visual acuity that frequently terminates in no light perception [4]. The haemorrhagic and inflammatory dimensions of the condition compound the symptomatic burden, and the anterior chamber angle typically exhibits a characteristic neovascular frond pattern on gonioscopic examination. Without timely, effective, and sustained IOP reduction, glaucomatous optic neuropathy progresses unabated, and restoration of meaningful visual function becomes progressively unattainable.

The treatment landscape for NVG is inherently multidisciplinary and sequentially stratified. Anti-VEGF pharmacotherapy—delivered either intravitreally or via periocular routes—has emerged as a pivotal adjunctive intervention, capable of inducing rapid regression of iris and angle neovascularisation, thereby transiently improving the conditions for more definitive IOP-lowering procedures [3, 5]. Panretinal photocoagulation targets the ischaemic retinal drive underlying VEGF overproduction, addressing the pathogenetic root rather than merely its consequences. Filtering surgery—including trabeculectomy augmented by antimetabolites and glaucoma drainage device implantation—constitutes the established surgical armamentarium, though success rates in NVG are substantially lower than in primary glaucoma subtypes, and complication profiles are correspondingly more adverse [2].

Against this challenging therapeutic backdrop, micropulse transscleral cyclophotocoagulation (MTSCPC) has attracted sustained investigative interest as a minimally invasive, repeatable, and comparatively atraumatic modality for IOP reduction. The technological distinction between MTSCPC and its continuous-wave predecessor resides in the delivery architecture: laser energy is emitted in discrete microsecond-duration pulses—typically with a duty cycle of 31.3%—interspersed by thermal relaxation intervals that permit dissipation of accumulated heat and thereby confine the zone of tissue effect to the targeted ciliary epithelium, sparing the adjacent stroma, vasculature, and scleral collagen

[8, 10, 11]. This selective energy deposition translates clinically into a markedly attenuated incidence of hypotony, phthisis bulbi, and sympathetic ophthalmia—the most dreaded complications of conventional cyclodestructive therapy—while delivering equivalent or superior IOP reduction in controlled comparative studies [8, 12].

Notwithstanding the primacy accorded to objective clinical endpoints in the glaucoma literature, it has become increasingly recognised that tonometric and structural parameters alone furnish an incomplete and potentially misleading characterisation of therapeutic value from the patient's perspective. Health-related quality of life—operationalised through validated, multidimensional patient-reported outcome instruments—captures the experiential reality of living with a chronic, visually disabling condition in ways that IOP measurements and visual field indices cannot. The NEI VFQ-25, developed and psychometrically validated by the National Eye Institute, has been widely adopted as the methodological reference standard for HRQoL assessment in ophthalmic research, offering reliable domain-specific quantification of the functional, psychoemotional, and social ramifications of visual impairment [9, 11]. The present investigation was accordingly designed to provide a rigorous, domain-resolved assessment of the HRQoL impact of MTSCPC in a clinically characterised cohort of NVG patients.

2. Materials and Methods

2.1 Study Design and Setting. The investigation was structured as a single-centre, retrospective observational study conducted at two affiliated clinical facilities: the Department of Ophthalmology of the First Multidisciplinary Clinical Hospital of Samarkand State Medical University and the Professor A.A. Yusupov Eye Centre, both situated in Samarkand, Republic of Uzbekistan. The retrospective design was chosen to enable systematic characterisation of real-world clinical trajectories and patient-reported outcomes in a well-defined NVG cohort under conditions of routine clinical practice.

2.2 Study Population. The study cohort comprised 30 consecutively enrolled patients who received MTSCPC for NVG within the study period. Clinical data, including demographic variables, ophthalmic examination findings, treatment parameters, and follow-up assessments, were retrieved from structured archival medical records. Eligibility for inclusion required: (1) a clinically and instrumentally corroborated diagnosis of neovascular glaucoma, established on the basis of gonioscopic identification of angle neovascularisation, elevated IOP, and characteristic anterior segment findings; (2) persistently elevated IOP refractory to maximally tolerated topical and systemic hypotensive pharmacotherapy; and (3) the absence of absolute or clinically significant relative contraindications to laser-based ciliary body treatment. Patients harbouring coexistent ocular comorbidities with an independent capacity to materially influence visual function or NEI VFQ-25 scores—including advanced age-related macular degeneration, proliferative vitreoretinopathy, or corneal disease—were systematically excluded to preserve the internal validity of quality-of-life comparisons.

2.3 Ophthalmological Assessment Protocol. Each enrolled participant underwent a standardised, protocol-driven ophthalmic evaluation at baseline and at the conclusion of the postoperative surveillance period. The examination battery encompassed: (i) measurement of best-corrected visual acuity (BCVA) and uncorrected distance visual acuity using the Snellen chart; (ii) non-contact pneumatic applanation tonometry for IOP quantification, with measurements obtained at three time points and averaged; (iii) automated static threshold perimetry (Humphrey Field Analyser, 24-2 SITA Standard algorithm) for assessment of visual field mean deviation and pattern standard deviation; (iv) slit-lamp biomicroscopic examination of the anterior segment, with particular attention to corneal clarity, anterior chamber depth, iris neovascularisation grading, and lens status; (v) indirect binocular ophthalmoscopy for posterior segment evaluation, encompassing optic disc cup-to-disc ratio, neuroretinal rim integrity, retinal vascular architecture, and macular morphology; (vi) gonioscopic grading of the anterior chamber angle for neovascularisation extent, pigmentation, and degree of synechial closure; (vii) high-frequency ultrasound biomicroscopy (UBM) for delineation of ciliary body morphology and anterior segment topography; and (viii) standardised B-scan ocular ultrasonography for posterior segment structural characterisation in cases of media opacity.

2.4 MTSCPC Procedure. Micropulse transscleral cyclophotocoagulation was delivered utilising an 810 nm infrared diode laser system with a micropulse probe (MicroPulse P3®, IRIDEX Corporation, Mountain View, CA, USA). The procedure was performed under retrobulbar or peribulbar anaesthesia. Laser parameters were calibrated according to established institutional protocols, employing a duty cycle of 31.3%, with power settings individually titrated within the range of 2000–2500 mW and an

exposure time of 80 seconds per hemisphere, targeting the ciliary body zone 1.5–2.0 mm posterior to the limbus across 270–360 degrees. The procedural objective was selective, sublethal thermal modulation of the ciliary epithelium to attenuate aqueous humour secretion while preserving adjacent stromal and vascular structures.

2.5 Quality-of-Life Measurement. Health-related quality of life was systematically evaluated employing the National Eye Institute Visual Function Questionnaire-25 (NEI VFQ-25), a rigorously validated, 25-item self-administered instrument specifically designed to quantify the influence of visual dysfunction on diverse life domains. The NEI VFQ-25 generates subscale scores—each normalised to a 0–100 scale—across the following domains: general health, general vision, ocular pain, near activities, distance activities, vision-specific social functioning, vision-specific mental health, vision-specific role difficulties, vision-specific dependency, driving, colour vision, and peripheral vision, in addition to a composite summary score. Administration was conducted by trained research personnel at two discrete time points: immediately preceding MTSCPC (baseline) and at the conclusion of the postoperative follow-up interval. Patient responses were recorded under standardised conditions to minimise interviewer-induced response bias.

2.6 Statistical Analysis. Descriptive statistics were computed for all continuous variables, expressed as arithmetic means ± standard deviations (SD). The normality of score distributions was assessed using the Shapiro-Wilk test. Intra-group pre- to post-treatment comparisons of NEI VFQ-25 composite and domain scores were conducted using the paired-samples t-test for normally distributed variables. Statistical significance was defined as a two-tailed p-value below 0.05. All analyses were performed using IBM SPSS Statistics software (version 26.0).

3. Results

3.1 Baseline Quality-of-Life Profile. Pre-interventional NEI VFQ-25 assessment disclosed a substantially and uniformly impaired HRQoL profile across the study cohort. The mean composite score at baseline was 45.2 ± 8.7 points, a value indicative of severe, pervasive restriction of vision-dependent daily functioning and a pronounced adverse impact of the disease across all evaluated life domains. Individual domain scores at baseline exhibited a consistently depressed pattern: visual function 40.5 ± 7.8 points; psychoemotional status 42.1 ± 6.5 points; daily activities 39.3 ± 7.3 points; social functioning 46.7 ± 8.1 points; and overall visual satisfaction 50.0 ± 9.0 points. These baseline findings are congruent with the broader published literature demonstrating markedly attenuated HRQoL in patients with refractory glaucomatous conditions, particularly those accompanied by chronic algic symptomatology and advanced functional visual loss [8, 11].

Qualitative analysis of patient-reported responses at baseline corroborated the quantitative findings. The predominant experiential themes elicited included: persistent, debilitating ocular pain disproportionate to that reported in primary glaucoma; profound difficulties in executing near-vision tasks such as reading, writing, and digital device use; severely impaired mobility and spatial orientation in unfamiliar environments; occupational incapacitation and loss of economic independence; social withdrawal consequent upon embarrassment regarding visual disability; and pervasive anxiety, depressive ideation, and a subjective sense of irreversible deterioration.

3.2 Post-Interventional Quality-of-Life Outcomes. Following MTSCPC, a statistically significant and clinically substantive elevation of the NEI VFQ-25 composite score was documented, ascending from 45.2 ± 8.7 to 68.4 ± 9.3 points (mean change: +23.2 points; $p < 0.001$). This magnitude of improvement—representing a 51.3% relative increment relative to baseline—substantially exceeds the minimal clinically important difference thresholds reported for the NEI VFQ-25 in comparable glaucomatous populations, affirming the genuine experiential significance of the observed gains beyond their statistical relevance.

Domain-level analysis demonstrated uniformly positive post-interventional trajectories across all evaluated NEI VFQ-25 subscales, as summarised in Table 1. Visual function scores rose from 40.5 ± 7.8 to 72.3 ± 8.2 points (+31.8 points; $p < 0.001$), reflecting clinically meaningful enhancement of optical resolution, contraction of visual discomfort attributable to chronic anterior segment pathology, and expanded capacity for performance of vision-dependent instrumental activities of daily living. Psychoemotional subscale scores progressed from 42.1 ± 6.5 to 69.0 ± 7.6 points (+26.9 points; $p < 0.001$), corroborating a substantive reduction in anxiety-related affective dysregulation, irritability, and emotional exhaustion previously engendered by the combined burden of refractory pain and progressive visual deterioration, alongside a demonstrable reinforcement of patients' perceived

self-efficacy in navigating their condition.
Daily activity performance scores improved from 39.3 ± 7.3 to 66.7 ± 8.0 points (+27.4 points; $p < 0.001$), signifying restored functional independence in household task execution, improved visuospatial navigation competence, and facilitated re-engagement with previously abandoned occupational and recreational pursuits. Social functioning domain scores advanced from 46.7 ± 8.1 to 68.2 ± 9.1 points (+21.5 points; $p < 0.001$), reflecting broadened interpersonal engagement, measurable contraction of isolation-driven behavioural withdrawal, heightened communicative self-assurance, and more vigorous participation in communal activities previously precluded by disease-imposed limitations. Global visual satisfaction scores increased from 50.0 ± 9.0 to 75.0 ± 8.0 points (+25.0 points; $p < 0.001$), denoting consolidation of a distinctly more affirmative subjective appraisal of treatment-conferred gains and a reconstructed sense of optimism regarding the long-term trajectory of visual health.

Note: All between-timepoint comparisons were statistically significant at $p < 0.001$ (paired-samples t-test). SD = standard deviation; MTSCPC = micropulse transscleral cyclophotocoagulation.

Table 1. NEI VFQ-25 domain scores before and after MTSCPC (mean ± SD; n = 30)

NEI VFQ-25 Domain	Pre-MTSCPC (mean ± SD)	Post-MTSCPC (mean ± SD)	p-value
Composite score	45.2 ± 8.7	68.4 ± 9.3	< 0.001
Visual function	40.5 ± 7.8	72.3 ± 8.2	< 0.001
Psychoemotional status	42.1 ± 6.5	69.0 ± 7.6	< 0.001
Daily activities	39.3 ± 7.3	66.7 ± 8.0	< 0.001
Social functioning	46.7 ± 8.1	68.2 ± 9.1	< 0.001
Overall visual satisfaction	50.0 ± 9.0	75.0 ± 8.0	< 0.001

Note: All between-timepoint comparisons were statistically significant at $p < 0.001$ (paired-samples t-test). SD = standard deviation; MTSCPC = micropulse transscleral cyclophotocoagulation.

Figure 1. Figure 1

4. Discussion

The present investigation furnishes compelling empirical evidence that MTSCPC exerts a multidimensional and clinically substantive beneficial influence on HRQoL in patients with NVG, a finding that assumes particular significance given the historically limited and inconsistently reported patient-centred evidence base surrounding cyclodestructive interventions. The magnitude of improvement observed in the composite NEI VFQ-25 score—exceeding 23 points on a 100-point scale—is not merely statistically significant but represents a transformation in patients' lived experience of their condition that is perceptible and functionally consequential in everyday life.
The observed HRQoL gains are plausibly attributable to a convergence of mechanistic pathways. Primary among these is IOP reduction, which attenuates the ischaemic and compressive insult to the optic nerve head and, of more immediate symptomatic relevance, dramatically diminishes the algic burden that constitutes one of the most debilitating features of advanced NVG. The relationship between pain relief and psychoemotional improvement documented in the present study is consistent with the well-established reciprocal interaction between chronic pain, affective dysregulation, and social withdrawal in the context of chronic ophthalmic disease [9, 11]. The attenuation of algic intensity following IOP normalisation appears to function as a pivotal upstream mediator, whose downstream consequences ramify across the psychoemotional, social, and functional domains captured by the NEI VFQ-25.
The visual function domain improvement, rising from a severely impaired baseline of 40.5 to a moderate 72.3 points, warrants careful contextualisation. It is unlikely that this gain reflects substantial structural recovery of pre-existing glaucomatous optic neuropathy, given the well-established irreversibility of retinal ganglion cell loss. Rather, it is more parsimoniously interpreted as a composite of: reduction in IOP-related corneal oedema improving optical clarity;

diminished ocular surface inflammation reducing photophobia and visual discomfort; and the subjective perceptual benefits of pain relief, which has been shown to improve patients' self-rated visual capability independently of objective acuity measurements. These considerations underscore the importance of distinguishing between structural visual recovery and functional improvement in the context of quality-of-life research.

Comparison with the existing MTSCPC literature reveals substantial concordance between the present findings and those reported in prior investigations. Aquino et al. [8], in their seminal randomised exploratory study, demonstrated that micropulse cyclophotocoagulation achieved IOP reductions comparable to continuous-wave treatment while incurring a substantially lower incidence of vision-threatening complications, including hypotony and phthisis. Emanuel et al. [10] reported meaningful IOP reductions persisting at six-month follow-up in a refractory glaucoma cohort. Tan et al. [11] documented favourable IOP outcomes and safety profiles in an independent series, corroborating the generalisability of the micropulse approach across diverse clinical settings. The systematic review and meta-analysis published in 2023 [12] synthesised evidence from multiple independent cohorts and consistently affirmed the efficacy and tolerability of MTSCPC across a spectrum of glaucoma subtypes, including refractory secondary forms. Crucially, however, none of these investigations incorporated the NEI VFQ-25 as a primary or secondary outcome measure, rendering the present study a novel and methodologically distinct contribution to the evidence base.

The psychoemotional dimension of the post-MTSCPC improvement deserves particular scholarly attention. Chronic glaucoma, and NVG in particular, imposes a psychiatric burden that is systematically underappreciated in clinical practice. Published epidemiological data indicate that the prevalence of clinically significant depression and anxiety in glaucoma patients is two-to-three times that observed in age-matched control populations without visual impairment, and that the magnitude of psychological morbidity correlates more strongly with subjective visual disability—as captured by instruments such as the NEI VFQ-25—than with objective clinical severity metrics [9]. The present finding of a 26.9-point improvement in the psychoemotional subscale following MTSCPC therefore carries implications that extend well beyond ophthalmological practice, pointing to the potential for procedure-mediated reductions in psychiatric comorbidity that may, in turn, improve treatment adherence, reduce healthcare utilisation, and enhance overall health outcomes.

Several methodological limitations of the present study require transparent acknowledgement to enable appropriate contextualisation of the findings. The retrospective design, while well-suited to the characterisation of real-world clinical trajectories, precludes the random allocation of treatment and thereby introduces the possibility of unmeasured confounding. The relatively modest sample size of 30 patients, necessitated by the circumscribed NVG population available within the study period, limits statistical power for subgroup analyses and narrows the confidence intervals around point estimates of treatment effect. The absence of a concurrently followed control group—whether treated by alternative modalities or managed conservatively—prevents definitive attribution of the observed HRQoL gains to MTSCPC per se, as opposed to the general effects of medical attention, regression to the mean, or spontaneous disease fluctuation. The single-centre design, while ensuring procedural consistency, constrains generalisability to other geographical, demographic, and clinical contexts.

Future research should prioritise prospective, randomised, active-comparator-controlled trial designs, incorporating pre-specified sample sizes calculated to detect clinically important differences in NEI VFQ-25 composite scores, stratified subgroup analyses by aetiology (PDR versus CRVO versus other), and follow-up durations of at least 24 months.

5. Conclusion

The present retrospective observational investigation establishes that micropulse transscleral cyclophotocoagulation engenders statistically significant and clinically substantive improvements in health-related quality of life across all domains of the NEI VFQ-25 in patients with neovascular glaucoma. The pluridimensional character of the observed gains—spanning visual function, psychoemotional equilibrium, daily activity competence, social engagement, and global visual satisfaction—reflects the comprehensive therapeutic impact of IOP normalisation and pain attenuation on the totality of patients' lived experience. The favourable safety architecture of the micropulse modality, combined with its suitability for repeated application, further consolidates its position as a valuable and patient-centred intervention in the management of advanced NVG. These findings advocate for the systematic incorporation of validated patient-reported outcome measures

alongside objective clinical endpoints as a methodological standard in glaucoma treatment evaluation, and provide empirical grounding for the broader implementation of MTSCPC within multidisciplinary NVG management pathways.

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