Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.7 No. 2 (2026): June 2026 Issue
https://doi.org/10.51168/sjhrafrica.v7i2.2641
Original Article

Effect of hemodialysis on intraocular pressure and ocular perfusion pressure in end-stage renal disease patients admitted at a tertiary care hospital: A hospital-based comparative observational study.

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Abstract

Background

Hemodialysis produces rapid osmotic, fluid-volume and systemic hemodynamic changes that may influence intraocular pressure (IOP) and ocular perfusion pressure (OPP) in end-stage renal disease (ESRD).

Objectives

To evaluate the effect of hemodialysis on IOP and OPP among ESRD patients and compare these changes with age- and gender-matched controls.

Methods

This hospital-based comparative observational study was conducted at Dr YSR Kidney Research Centre and Super Speciality Hospital, Palasa, from October 2025 to March 2026. It included 50 ESRD patients undergoing hemodialysis and 50 controls. IOP, systolic blood pressure, diastolic blood pressure, mean arterial pressure (MAP) and OPP were assessed before and after hemodialysis in cases and across a corresponding observation period in controls.

Results

The mean age was 53.2 ± 10.8 years in cases and 52.4 ± 10.2 years in controls; males constituted 64.0% and 60.0%, respectively. Diabetes mellitus (44.0% vs 16.0%) and hypertension (78.0% vs 20.0%) were more frequent among cases. Mean average IOP decreased from 16.9 ± 3.0 to 14.9 ± 2.6 mmHg, MAP from 103.2 ± 10.3 to 90.1 ± 9.6 mmHg, and OPP from 51.9 ± 7.4 to 45.2 ± 7.1 mmHg. An OPP reduction of at least 5 mmHg occurred in 68.0% of cases compared with 10.0% of controls.

Conclusion

Hemodialysis was associated with significant reductions in IOP and OPP. OPP reduction appeared mainly related to intradialytic systemic blood pressure decline.

Recommendations

Baseline ophthalmic screening and intradialytic blood pressure surveillance are advisable in high-risk ESRD patients.

Keywords: *End-stage renal disease; Hemodialysis; Intraocular pressure; Ocular perfusion pressure; Glaucoma; Ultrafiltration*

Submitted: April 11, 2026, Accepted: May 7, 2026, Published: June 29, 2026

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Introduction

End-stage renal disease (ESRD) is a chronic systemic condition requiring renal replacement therapy for survival. Hemodialysis remains one of the most widely used modalities for patients with advanced renal failure [2]. During each dialysis session, removal of uremic solutes and excess fluid is accompanied by changes in serum osmolality, plasma colloid osmotic pressure, blood pressure and intravascular volume [2]. These systemic alterations have implications beyond renal physiology. The eye is a closed compartment with delicate fluid regulation, and rapid

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systemic changes can influence aqueous humor dynamics, ocular blood flow and retinal perfusion. Earlier studies have reported variable intraocular pressure (IOP) responses during hemodialysis, ranging from significant elevation to reduction or minimal change [3, 4].

IOP is determined by the balance between aqueous humor production and outflow, episcleral venous pressure and ocular structural characteristics. In hemodialysis patients, a rapid reduction in plasma osmolality can create an osmotic gradient between plasma and intraocular compartments. This mechanism has been linked to transient IOP elevation, especially when aqueous outflow is impaired [7]. In contrast, ultrafiltration and increased plasma colloid osmotic pressure can reduce IOP by decreasing ocular fluid content and systemic volume load [6]. These competing effects partly explain the inconsistent findings across published studies. Anterior chamber angle status, glaucoma susceptibility, diabetes mellitus, previous ocular surgery, dialysate composition, ultrafiltration volume and timing of measurement also influence observed IOP behavior [5].

Ocular perfusion pressure (OPP) reflects the pressure gradient supporting ocular blood flow and is commonly estimated from systemic blood pressure and IOP. A decrease in OPP can compromise optic nerve head perfusion, particularly in eyes with impaired autoregulation or pre-existing glaucomatous damage. Hu et al. reported simultaneous IOP elevation and OPP reduction during hemodialysis, suggesting a clinically important ocular vascular stress during treatment. Barbosa et al. reported no overall significant change in IOP or OPP during hemodialysis, but highlighted lower diastolic perfusion pressures in some patients [4]. These contrasting observations underline the need for setting-specific studies that evaluate both pressure components rather than IOP alone.

In clinical nephrology units, attention is usually focused on systemic hemodynamic stability, uremic clearance and dialysis adequacy. Ocular pressure monitoring is not routinely integrated into dialysis care, even though ESRD patients commonly carry additional ocular risk factors such as diabetes mellitus, hypertension and vascular disease. Undetected IOP fluctuation or OPP reduction during hemodialysis can be relevant in patients with glaucoma suspects, narrow angles, optic nerve vulnerability or recurrent intradialytic ocular symptoms [13,14].

The present study was undertaken with the objective of evaluating the effect of hemodialysis on IOP and OPP in patients with ESRD admitted at Dr YSR Kidney Research Centre and Super Speciality Hospital, Palasa. The study also aimed to compare hemodialysis-related ocular pressure changes with corresponding measurements in age- and gender-matched controls, and to explore whether ultrafiltration volume and dialysis duration were associated with the magnitude of ocular pressure variation.

Methodology

Study design, setting, and period

This was a hospital-based comparative observational study with paired pre- and post-hemodialysis assessment in cases and a time-matched observation in controls. The study was conducted at Dr YSR Kidney Research Centre and Super Speciality Hospital, Palasa, a tertiary-care renal centre providing nephrology consultation, inpatient care and maintenance hemodialysis services, in collaboration with ophthalmology services at Government Medical College, Srikakulam. The study period was six months, from October 2025 to March 2026. The final analysis included 100 participants.

Study participants, case ascertainment and control selection

The study population comprised 50 patients with ESRD receiving maintenance hemodialysis and 50 age- and gender-matched controls without ESRD. Cases were ascertained by consecutive screening of adult ESRD patients admitted or scheduled for maintenance hemodialysis in the dialysis unit during the study period. ESRD status and hemodialysis eligibility were verified from nephrology records, dialysis charts and treating nephrologist documentation. Controls were selected during the same period from adults attending the ophthalmology outpatient department for minor non-glaucomatous complaints or refractive evaluation, after excluding renal failure and major ocular pathology. For each eligible case, one control from the same broad age stratum and gender category was recruited where feasible. Cases were evaluated during a routine hemodialysis session, while controls underwent ocular and systemic assessment at baseline and again after a comparable four-hour observation interval. Demographic details, clinical history, systemic hypertension, diabetes mellitus, hemodialysis duration and relevant ocular history were recorded using a structured proforma.

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Eligibility criteria

Participants were included after obtaining informed consent and confirming adequate cooperation for ocular assessment. Cases with baseline IOP within the normal range were considered eligible. Individuals with diagnosed glaucoma, elevated IOP, previous ocular surgery, retinal photocoagulation, severe ocular media opacity or systemic illness interfering with study compliance were excluded. Controls with known renal failure, glaucoma or major ocular pathology affecting IOP assessment were not included.

Study size

The planned sample size was 100 participants, comprising 50 hemodialysis cases and 50 controls in a 1:1 ratio. As no prior institutional data were available for hemodialysis-related ocular pressure changes, the sample size was finalized pragmatically according to eligible ESRD patient availability during the six-month study period. It was also considered statistically adequate to detect a clinically relevant paired mean IOP change of approximately 2 mmHg; assuming an expected standard deviation of 4 mmHg for paired IOP differences, 80% power and a two-sided alpha of 0.05, the minimum required number of cases was about 34. The sample was increased to 50 cases and 50 controls to improve precision, support between-group comparison and compensate for possible incomplete paired readings.

Bias

Selection bias was minimized by consecutive screening of eligible hemodialysis patients and age- and gender-matched recruitment of controls from the same study period. Measurement bias was reduced by using the same rebound tonometer, prespecified assessment time points and a uniform measurement protocol for both groups. The ophthalmic assessment was performed by trained personnel using a structured proforma. Confounding by ocular disease was limited through exclusion of diagnosed glaucoma, elevated baseline IOP, previous ocular surgery, retinal photocoagulation, severe media opacity and major ocular pathology. Data-entry errors were reduced by cross-checking clinical proformas with dialysis records before statistical analysis.

Ocular and systemic measurements

IOP was measured using a handheld rebound tonometer. In cases, measurements were obtained approximately 30 minutes before hemodialysis and within 30 minutes after completion of the hemodialysis session. For controls, IOP was recorded at baseline and after the observation period. Systolic and diastolic blood pressure were measured using a standard sphygmomanometer at the same time points. Mean arterial pressure was calculated as diastolic blood pressure plus one-third pulse pressure. OPP was calculated as two-thirds of mean arterial pressure minus IOP, consistent with commonly used clinical estimation methods in hemodialysis-related ocular perfusion studies [1,4].

Biochemical and dialysis variables

Relevant biochemical data including blood urea, serum creatinine, random blood glucose and serum electrolytes were recorded where available. Ultrafiltration volume during the hemodialysis session was documented for cases. Duration of hemodialysis therapy was categorized as less than one year, one to three years and more than three years. These variables were assessed for their relationship with IOP and OPP changes.

Statistical analysis

Data were entered and analyzed using SPSS version 20. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequency and percentage. Paired t-test was used for within-group pre- and post-session comparisons. Independent t-test and chi-square test were applied for between-group comparisons. Repeated-measures analysis was considered for time-dependent IOP assessment where applicable. Pearson correlation coefficient was used to assess the relationship between ultrafiltration volume, duration of hemodialysis and ocular pressure changes. A p-value less than 0.05 was considered statistically significant.

Ethical considerations

The study was conducted after obtaining approval from the Institutional Ethics Committee of Government Medical College,
Srikakulam(IEC2025D/GMC&GGH/SKLM/181025/07).
The study was carried out at Dr YSR Kidney Research Centre and Super Speciality Hospital, Palasa. Written informed consent was obtained from all participants before enrolment. The study followed routine ethical principles for observational clinical research. Patient confidentiality was maintained throughout data collection and analysis, and no personal identifiers were included in the manuscript. Ocular and systemic assessments were non-invasive and were performed without altering the routine clinical haemodialysis prescription.

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Results

A total of 130 individuals were screened during the study period. Of 64 potentially eligible ESRD patients undergoing hemodialysis, 50 were confirmed eligible, completed paired pre- and post-hemodialysis assessments and were included in the final analysis. Of 66 potential controls assessed during the same period, 50 fulfilled age- and gender-matching requirements, completed baseline and four-hour assessments and were analysed. Reasons for non-participation or exclusion are shown in Figure 1. The final study population comprised 100 participants, including 50 hemodialysis patients and 50 controls. The two groups were comparable with respect to age and gender distribution. Among the hemodialysis group, hypertension and diabetes mellitus were more frequent than in controls. The mean duration of hemodialysis was 2.8 ± 1.6 years. The baseline demographic and clinical profile is presented in Table 1.

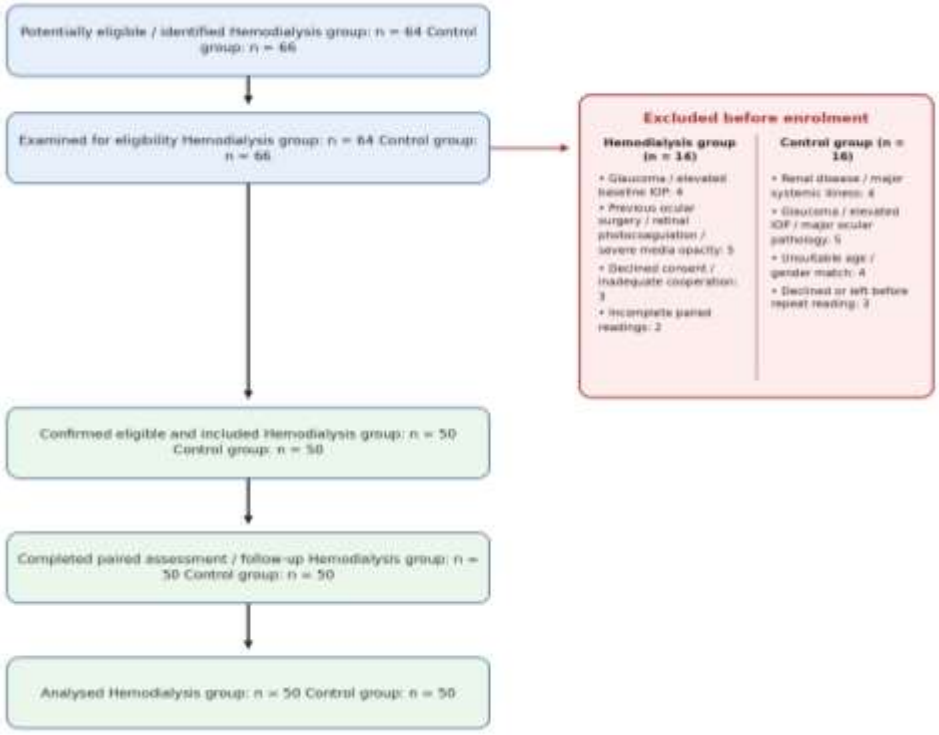

Figure 1: Participant Flow diagram

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Table 1: Baseline demographic and clinical profile of the study population

Variable	Category	Cases, n=50	Controls, n=50	p-value
Age, years	Mean ± SD	53.2 ± 10.8	52.4 ± 10.2	0.71
Age group	≤40 years	9 (18.0%)	10 (20.0%)	0.94
	41–50 years	14 (28.0%)	13 (26.0%)	
	51–60 years	17 (34.0%)	16 (32.0%)	
	>60 years	10 (20.0%)	11 (22.0%)	
Gender	Male	32 (64.0%)	30 (60.0%)	0.68
	Female	18 (36.0%)	20 (40.0%)	
Diabetes mellitus	Present	22 (44.0%)	8 (16.0%)	0.002
Hypertension	Present	39 (78.0%)	10 (20.0%)	<0.001
Duration of hemodialysis	<1 year	10 (20.0%)	—	—
	1–3 years	23 (46.0%)	—	
	>3 years	17 (34.0%)	—	

The mean IOP was higher in hemodialysis patients before dialysis compared with controls. Following hemodialysis, a significant reduction in IOP was observed in both eyes. The mean average IOP decreased from 16.9 ± 3.0 mmHg before hemodialysis to 14.9 ± 2.6 mmHg after hemodialysis, with a mean reduction of 2.0 ± 1.4 mmHg. In contrast, controls showed no meaningful change in IOP over the observation period. The comparison of IOP between cases and controls is shown in Table 2

Table 2: Comparison of intraocular pressure between cases and controls

IOP parameter	Cases: Pre-hemodialysis	Cases: Post-hemodialysis	Mean change	Controls: Baseline	Controls: 4-hour reading	p-value for change between groups
Right eye IOP, mmHg	17.1 ± 3.2	15.0 ± 2.8	-2.1 ± 1.6	15.5 ± 2.4	15.3 ± 2.3	<0.001
Left eye IOP, mmHg	16.8 ± 3.1	14.8 ± 2.6	-2.0 ± 1.5	15.3 ± 2.3	15.1 ± 2.2	<0.001
Average IOP, mmHg	16.9 ± 3.0	14.9 ± 2.6	-2.0 ± 1.4	15.4 ± 2.3	15.2 ± 2.2	<0.001

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Hemodialysis was associated with a significant fall in systemic blood pressure parameters. Mean arterial pressure decreased from 103.2 ± 10.3 mmHg before hemodialysis to 90.1 ± 9.6 mmHg after hemodialysis. Although IOP declined after dialysis, OPP also decreased significantly because of the larger fall in systemic blood pressure. The mean OPP reduced from 51.9 ± 7.4 mmHg before hemodialysis to 45.2 ± 7.1 mmHg after hemodialysis. Blood pressure and OPP changes are summarized in Table 3

Table 3: Blood pressure and ocular perfusion pressure changes

Parameter	Cases: Pre-hemodialysis	Cases: Post-hemodialysis	p-value	Controls: Baseline	Controls: 4-hour reading	p-value
Systolic blood pressure, mmHg	144.8 ± 17.2	124.6 ± 15.8	<0.001	126.2 ± 11.6	125.4 ± 11.2	0.38
Diastolic blood pressure, mmHg	82.4 ± 9.6	72.8 ± 8.8	<0.001	78.0 ± 8.4	77.5 ± 8.2	0.44
Mean arterial pressure, mmHg	103.2 ± 10.3	90.1 ± 9.6	<0.001	94.1 ± 7.9	93.6 ± 7.6	0.42
Average IOP, mmHg	16.9 ± 3.0	14.9 ± 2.6	<0.001	15.4 ± 2.3	15.2 ± 2.2	0.11
Ocular perfusion pressure, mmHg	51.9 ± 7.4	45.2 ± 7.1	<0.001	47.3 ± 5.8	47.2 ± 5.6	0.79

Clinically relevant ocular changes were more frequent among hemodialysis patients. An IOP reduction of more than 2 mmHg was observed in 56.0% of cases compared with 8.0% of controls. A reduction in OPP of at least 5 mmHg was noted in 68.0% of hemodialysis patients, whereas only 10.0% of controls showed a similar reduction. The distribution of clinically relevant ocular changes is presented in Table 4.

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Table 4: Distribution of clinically relevant ocular changes

Ocular parameter	Cases, n=50	Controls, n=50	p-value
IOP reduction >2 mmHg	28 (56.0%)	4 (8.0%)	<0.001
IOP increase after session/observation	4 (8.0%)	3 (6.0%)	0.69
OPP reduction ≥5 mmHg	34 (68.0%)	5 (10.0%)	<0.001
Post-hemodialysis OPP <40 mmHg	11 (22.0%)	3 (6.0%)	0.02

The mean ultrafiltration volume among hemodialysis patients was 2.4 ± 0.7 litres. Greater ultrafiltration volume showed a significant correlation with reduction in OPP (r = -0.42, p = 0.003). A weaker but statistically significant correlation was also observed between ultrafiltration volume and IOP reduction (r = -0.28, p = 0.049). Duration of hemodialysis was not significantly associated with the magnitude of IOP change.

Overall, hemodialysis produced a significant reduction in IOP among patients with ESRD. However, OPP also decreased significantly after hemodialysis, mainly due to the fall in systemic blood pressure. These findings indicate that hemodialysis-related hemodynamic changes can influence ocular pressure dynamics and ocular perfusion status in ESRD patients.

Discussion

The present study evaluated the effect of hemodialysis on IOP and OPP in ESRD patients and compared these findings with controls. Cases and controls were comparable for mean age (53.2 ± 10.8 years vs 52.4 ± 10.2 years, p = 0.71) and gender distribution (males: 64.0% vs 60.0%, p = 0.68), supporting the adequacy of matching. The key finding was that hemodialysis produced a significant fall in average IOP by 2.0 ± 1.4 mmHg, from 16.9 ± 3.0 mmHg before hemodialysis to 14.9 ± 2.6 mmHg after hemodialysis (p < 0.001), while controls showed no meaningful change over the observation period (15.4 ± 2.3 to 15.2 ± 2.2 mmHg, p = 0.11). MAP also decreased significantly from 103.2 ± 10.3 to 90.1 ± 9.6 mmHg (p < 0.001), producing a parallel reduction in OPP from 51.9 ± 7.4 to 45.2 ± 7.1 mmHg (p < 0.001). Clinically relevant OPP reduction of at least 5 mmHg occurred in 34/50 (68.0%) hemodialysis patients compared with 5/50 (10.0%) controls (p < 0.001), and post-hemodialysis OPP below 40 mmHg was observed in 11/50 (22.0%) cases. These statistics indicate that ocular pressure dynamics during hemodialysis cannot be interpreted using IOP alone because systemic blood pressure decline can reduce the perfusion gradient available to the optic nerve head and retina.

The reduction in IOP observed in this study is consistent with reports by Kilavuzoglu et al., Jung et al. and Dinc et al., who described post-hemodialysis decreases in IOP or related ocular parameters [6-8]. Liakopoulos et al. also emphasized that IOP changes during hemodialysis are variable and may be influenced by fluid removal, osmotic shifts, aqueous outflow status and individual ocular characteristics [12]. Ultrafiltration, reduction in body weight and increased plasma colloid osmotic pressure are plausible explanations for the IOP decline observed in the present study [7,11]. The significant correlation between ultrafiltration volume and OPP reduction in the present study supports the concept that volume removal and intradialytic hemodynamic change are important determinants of ocular perfusion. However, the weak correlation between ultrafiltration and IOP reduction suggests that additional mechanisms, including angle anatomy, osmolality shifts and ocular autoregulation, also contribute.

In contrast, Hu et al. documented increased IOP with decreased OPP during hemodialysis, and the meta-analysis by Chen et al. emphasized the heterogeneity of IOP response across studies. Tawara et al. showed that eyes with impaired aqueous outflow can develop marked IOP elevation when serum osmolality decreases rapidly [10]. Wang et al. further demonstrated that anterior chamber angle structure influences IOP response during hemodialysis [9]. These findings explain why patients with glaucoma, narrow angles,

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previous ocular surgery or diabetic proliferative changes require greater vigilance than low-risk participants. The present study excluded diagnosed glaucoma and elevated baseline IOP, which probably contributed to the overall post-dialysis IOP decline rather than an IOP rise.

The fall in OPP is clinically meaningful. OPP integrates systemic blood pressure and IOP, and low perfusion pressure has been implicated in glaucoma progression and optic nerve vulnerability. In the present study, 68.0% of hemodialysis patients had OPP reduction of at least 5 mmHg, and 22.0% had post-hemodialysis OPP below 40 mmHg. Barbosa et al. observed lower diastolic perfusion pressure in selected patients despite absence of overall IOP or OPP change, highlighting the importance of identifying vulnerable subgroups rather than relying only on mean values. Recurrent OPP reduction across dialysis sessions can be relevant in patients with systemic hypertension, diabetes, anemia or optic nerve susceptibility.

These findings have practical implications for integrated nephrology and ophthalmology care. Routine dialysis units generally monitor blood pressure and ultrafiltration targets but do not assess ocular parameters. The present findings suggest that ESRD patients with ocular symptoms, glaucoma risk factors, recurrent intradialytic hypotension or large ultrafiltration volumes benefit from baseline ophthalmic assessment and selective IOP monitoring. Case-based literature also supports dialysis prescription modification, osmolality-aware strategies and ophthalmic intervention in patients with symptomatic ocular dialysis disequilibrium [13,14].

The generalizability of these findings is strongest for adult ESRD patients undergoing conventional hemodialysis in tertiary-care hospital settings with similar dialysis duration, comorbidity pattern and exclusion of established glaucoma. The results are less directly transferable to patients with narrow angles, advanced glaucoma, recent intraocular surgery, peritoneal dialysis, hemodiafiltration or markedly different dialysate sodium and ultrafiltration protocols. Multicentre validation can improve external applicability.

Conclusion

Hemodialysis produced a significant reduction in IOP among ESRD patients, but this was accompanied by a significant reduction in OPP due to a larger fall in systemic blood pressure. The findings indicate that post-dialysis IOP reduction does not necessarily imply improved ocular hemodynamic safety. OPP reduction was frequent and was associated with ultrafiltration volume, suggesting that intradialytic systemic hemodynamic changes influence ocular perfusion. ESRD patients, particularly those with diabetes, hypertension, glaucoma risk, ocular symptoms or larger ultrafiltration requirements, require periodic ophthalmic evaluation. Collaborative monitoring between nephrology and ophthalmology services can support early identification of patients at risk of dialysis-related ocular perfusion stress and optic nerve vulnerability.

Limitations

This was a single-centre observational study with a modest sample size. Ocular measurements were limited to pre- and post-hemodialysis readings, without continuous intradialytic monitoring. Anterior chamber angle grading, visual field testing and retinal nerve fiber layer assessment were not included. Biochemical correlations were limited by availability of complete laboratory data for all participants.

Recommendations

Patients with ESRD undergoing hemodialysis should receive baseline ophthalmic evaluation, especially when diabetes, systemic hypertension, glaucoma suspicion, narrow angles, eye pain, headache or visual fluctuation is present. Dialysis units should record intradialytic blood pressure patterns and consider ocular referral when recurrent hypotension, high ultrafiltration volume or ocular symptoms occur. Selective IOP monitoring before, during and after dialysis can help identify vulnerable patients. Future studies should include gonioscopy, optical coherence tomography, visual field testing, serum osmolality, dialysate sodium profile and longitudinal follow-up to determine whether repeated OPP reduction contributes to glaucoma progression or retinal ischemic complications.

Acknowledgement

The authors acknowledge the support of the nephrology, ophthalmology and dialysis unit staff for facilitating patient assessment and data collection. The authors also thank all participants for their cooperation during ocular and systemic evaluation. No external financial support was received for this study.

Abbreviations

BP: Blood pressure
CKD: Chronic kidney disease
DBP: Diastolic blood pressure
ESRD: End-stage renal disease
HD: Hemodialysis

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IOP: Intraocular pressure
MAP: Mean arterial pressure
OPP: Ocular perfusion pressure
RBS: Random blood sugar
SBP: Systolic blood pressure
SD: Standard deviation
SPSS: Statistical Package for the Social Sciences

Source of funding

The study had no funding.

Conflict of interest

The authors declare no conflict of interest.

Author Contributions

Dr. P. Sarat Jyotsna contributed to the conception and design of the study, clinical evaluation of end-stage renal disease patients, supervision of haemodialysis-related data collection, interpretation of nephrology-related findings, and critical revision of the manuscript for important intellectual content.

Dr. Boddepalli Nagendra Naidu contributed to study design, methodology development, sample size planning, epidemiological inputs, statistical analysis, interpretation of results, manuscript drafting, and coordination of the overall research work. He also contributed to final manuscript review and approval.

Dr. Chatti Ramakrishna contributed to ophthalmological assessment, intraocular pressure evaluation, interpretation of ocular perfusion pressure findings, screening of eligible participants based on ocular criteria, and review of ophthalmology-related scientific content in the manuscript.

Data availability

Data Available on request

Author Biography

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https://doi.org/10.51168/sjhrafrica.v7i2.2641
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PUBLISHER DETAILS

Student's Journal of Health Research (SJHR)
(ISSN 2709-9997) Online
(ISSN 3006-1059) Print
Category: Non-Governmental & Non-profit Organization
Email: studentsjournal2020@gmail.com
WhatsApp: +256 775 434 261
Location: Scholar's Summit Nakigalala, P. O. Box 701432, Entebbe Uganda, East Africa