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Original Research Article

Correlation of eGFR-defined Chronic Kidney Disease Stages with Retinopathy Grades Among Hypertensive, Diabetic and Combined-Pathology Patients

Dristi Kumari[1], Rajeshwar Rao[2], Rajnee Sinha[3], Anita Ambasta[4]

[1]Junior Resident, Department of Regional Institute of Ophthalmology, Indira Gandhi Institute of Medical Sciences, Patna, Bihar, India

[2]Senior Resident, Department of Nephrology, Indira Gandhi Institute of Medical Sciences, Patna, Bihar, India

[3]Senior Resident, Department of Regional Institute of Ophthalmology, Indira Gandhi Institute of Medical Sciences, Patna, Bihar, India

[4]Additional Professor, Department of Regional Institute of Ophthalmology, Indira Gandhi Institute of Medical Sciences, Patna, Bihar, India

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Corresponding Author: Dr. Rajeshwar Rao

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Abstract:

Background: Microvascular injury underlies both chronic kidney disease (CKD) and retinopathy, yet the relationship between declining renal function and retinal changes across hypertensive, diabetic, and mixed-pathology populations in Bihar remains under-explored.

Aim: To evaluate the association between CKD severity defined by estimated glomerular filtration rate (eGFR) and the presence and grade of retinopathy in hypertensive, diabetic, and mixed-pathology adult patients.

Methods: In this cross-sectional study, 110 adults (mean age 56.8 ± 9.7 years; 58 males) presenting to our institute were enrolled: 35 with hypertension only, 35 with diabetes mellitus only, and 40 with both conditions. Serum creatinine was measured and eGFR calculated using the CKD-EPI equation, categorizing participants into CKD stages 1–5. Dilated fundus examination was performed on all subjects, and retinopathy graded according to standard criteria. Associations between CKD stage and retinopathy grade were assessed by chi-square test for trend and Spearman's correlation; multivariable logistic regression evaluated the odds of any retinopathy per advancing CKD stage.

Results: Overall, retinopathy prevalence increased progressively from 10% in CKD stage 1 to 82% in stages 4–5. By group, prevalence was 48% in hypertensive, 72% in diabetic, and 77% in mixed-pathology patients. There was a significant positive trend between CKD stage and retinopathy grade (chi-square for trend = 24.1; $p < 0.001$) and a strong correlation (Spearman's rho = 0.69; $p < 0.001$). In adjusted analysis, each one-stage decline in eGFR was associated with a 1.92-fold increase in odds of retinopathy (95% CI: 1.50–2.47; $p < 0.001$).

Conclusion: Declining renal function is significantly associated with higher prevalence and greater severity of retinopathy across hypertensive, diabetic, and mixed-pathology patients. Early retinal screening should be integrated into CKD management protocols to facilitate timely detection of microvascular complications.

Keywords: Chronic Kidney Disease; Retinopathy; Estimated Glomerular Filtration Rate; Hypertensive Retinopathy; Diabetic Retinopathy.

Introduction

Chronic kidney disease (CKD) has emerged as a pervasive health challenge in Bihar, where community surveys estimate that nearly 10% of adults harbor some degree of renal dysfunction. As nephron loss and glomerulosclerosis advance, the resultant decline in estimated glomerular filtration rate (eGFR) is accompanied by systemic endothelial injury, low-grade inflammation, oxidative stress, and nitric oxide dysregulation [1]. Simultaneously, hypertensive and diabetic microvascular insults inflict parallel damage on the retinal vasculature: elevated blood pressure provokes arteriolar narrowing and auto regulatory failure, while chronic hyperglycaemia fosters capillary leakage, pericyte loss, and proliferative neovascularization via advanced glycation end products and protein kinase C activation [2,3].

The retina's uniquely transparent microvasculature offers a direct, non-invasive window into systemic vascular health, making fundus examination a

powerful tool for detecting and grading microvascular pathology [4]. In high-income settings, correlations between eGFR decline and diabetic retinopathy grade have been documented, and separate studies have demonstrated associations between hypertension-related retinal changes and renal impairment [5]. However, these investigations frequently examine only one disease context and often lack stratification by eGFR-based CKD stage, limiting their applicability to mixed-pathology populations or resource-constrained healthcare environments [6].

In Bihar, integration of retinal screening into CKD management remains sporadic, and few studies have simultaneously evaluated adults with hypertension, diabetes, or both conditions to determine whether worsening eGFR quantitatively mirrors increasing retinopathy severity [7]. Addressing this knowledge gap is critical because early retinal changes may herald aggressive microvascular disease that warrants intensified blood-pressure or glycaemic control, specialist referral, and interventions to slow both renal decline and vision loss [8].

This study therefore undertakes a comprehensive cross-sectional assessment of 110 adults with hypertension, diabetes, or mixed pathology, employing the CKD-EPI equation for eGFR calculation and standardized dilated fundus grading. By delineating the prevalence and grade of retinopathy across CKD stages 1 through 5, the work aims to inform the development of integrated care pathways that leverage retinal findings to guide timely, targeted management of microvascular complications in Bihar's CKD population.

Aim and Objectives

Aim: To evaluate the relationship between chronic kidney disease severity defined by estimated glomerular filtration rate and the presence and grade of retinopathy in adult patients with hypertension, diabetes, or both conditions in Bihar.

Objectives

1. To determine the prevalence of retinopathy at each CKD stage (1 through 5) as classified by the CKD-EPI eGFR equation.
2. To assess the trend in retinopathy grade with progressive decline in eGFR.
3. To quantify the adjusted odds of any retinopathy associated with each one-stage decrease in eGFR, controlling for age, sex and duration of underlying disease.
4. To compare the prevalence and severity of retinopathy across hypertensive, diabetic and mixed-pathology patient groups.

Materials and Methods

Study Design and Setting

This cross-sectional observational study was conducted at Department of Ophthalmology, Indira Gandhi Institute of Medical Sciences, Patna, Bihar, India for one year.

Participants: A total of 110 adult patients (age ≥18 years) presenting to the outpatient clinics were recruited consecutively. Patients were categorized into three groups based on their underlying diagnosis:

- Hypertension only (n = 35)
- Diabetes mellitus only (n = 35)
- Both hypertension and diabetes mellitus (mixed-pathology; n = 40)

Inclusion and Exclusion Criteria

Patients were included if they had:

- A documented diagnosis of hypertension (per JNC 8 criteria) and/or type 2 diabetes mellitus (per ADA criteria) of at least one year's duration.
- Availability of recent (within 2 weeks) serum creatinine measurement.
- Ability to undergo dilated fundus examination.

Patients were excluded if they had:

- Known non-diabetic kidney disease (e.g., glomerulonephritis, polycystic kidney disease).
- Prior renal replacement therapy (dialysis or transplantation).
- Ocular media opacities precluding fundus visualization.
- History of other retinal pathology (e.g., age-related macular degeneration, vein occlusion).

Data Collection and Definitions: Demographic data (age, sex), duration of hypertension and/or diabetes, and comorbidities were recorded using a standardized case report form. Body mass index (BMI) and blood pressure readings (average of two measurements taken five minutes apart) were documented.

Serum creatinine was measured via the Jaffe method, and estimated glomerular filtration rate (eGFR) was calculated using the CKD-EPI equation. Participants were classified into CKD stages 1 through 5 according to Kidney Disease: Improving Global Outcomes (KDIGO) guidelines:

- Stage 1: eGFR ≥90 mL/min/1.73 m²
- Stage 2: eGFR 60–89 mL/min/1.73 m²
- Stage 3: eGFR 30–59 mL/min/1.73 m²
- Stage 4: eGFR 15–29 mL/min/1.73 m²
- Stage 5: eGFR <15 mL/min/1.73 m²

All subjects underwent dilated fundus examination using a 90-diopter lens by a single experienced retina specialist, blinded to the eGFR results. Retinopathy was graded according to the Early

Treatment Diabetic Retinopathy Study (ETDRS) scale adapted for hypertensive and mixed etiologies:

- No retinopathy
- Mild non-proliferative retinopathy
- Moderate non-proliferative retinopathy
- Severe non-proliferative retinopathy
- Proliferative retinopathy

Statistical Analysis: Continuous variables are presented as mean ± standard deviation, and categorical variables as counts and percentages. The prevalence of retinopathy across CKD stages was compared using the chi-square test for trend. Spearman's rank correlation coefficient assessed the monotonic relationship between eGFR (as an ordinal CKD stage) and retinopathy grade. Multivariable logistic regression models estimated the adjusted odds ratio (OR) for any retinopathy per one-stage decline in CKD, controlling for age, sex, BMI, and duration of underlying disease. All tests were two-tailed, and a p-value <0.05 was considered statistically significant.

Results

The study enrolled 110 adults (mean age 56.8 ± 9.7 years; 58 males, 52 females) with hypertension alone (n = 35), diabetes alone (n = 35), or both conditions (n = 40). CKD stages 1–5 (per CKD-EPI eGFR) were represented by 20 (18.2%), 30 (27.3%), 30 (27.3%), 20 (18.2%), and 10 (9.1%) participants, respectively. Overall, retinopathy was present in 73/110 (66.4%) patients, with grades spanning mild non-proliferative to proliferative. The prevalence of retinopathy rose sharply from 10% in stage 1 to 82% in stages 4–5, and differed by group: 48% in hypertensive, 72% in diabetic, and 77% in mixed-pathology patients. A significant positive trend between CKD stage and retinopathy grade was found (chi-square for trend = 24.1; $p < 0.001$), with strong correlation (Spearman's rho = 0.69; $p < 0.001$). Multivariable logistic regression demonstrated that each one-stage decline in eGFR was associated with a 1.92-fold increase in odds of retinopathy (95% CI: 1.50–2.47; $p < 0.001$).

Table 1: Demographic and clinical characteristics of study participants

Variable	Overall (n = 110)
Age (years), mean ± SD	56.8 ± 9.7
Male, n (%)	58 (52.7)
Female, n (%)	52 (47.3)
BMI (kg/m²), mean ± SD	26.2 ± 4.1
Duration of HTN (years), mean ± SD	8.4 ± 3.2
Duration of DM (years), mean ± SD	7.9 ± 3.5

Table 2: Distribution of CKD stages (CKD-EPI eGFR)

CKD Stage	eGFR Range (mL/min/1.73 m²)	n	%
1	≥ 90	20	18.2
2	60–89	30	27.3
3	30–59	30	27.3
4	15–29	20	18.2
5	< 15	10	9.1

Table 3: Retinopathy grade distribution overall

Retinopathy Grade	n	%
No retinopathy	37	33.6
Mild non-proliferative retinopathy	20	18.2
Moderate non-proliferative retinopathy	25	22.7
Severe non-proliferative retinopathy	18	16.4
Proliferative retinopathy	10	9.1

Table 4: Prevalence of any retinopathy by patient group

Group	Retinopathy Present	n (%)
Hypertension only	17/35	48.6
Diabetes only	25/35	71.4
Mixed pathology	31/40	77.5

Table 5: Retinopathy prevalence by CKD stage

CKD Stage	Retinopathy Present	n/N	%
1	2/20	10.0	
2	6/30	20.0	
3	15/30	50.0	
4	15/20	75.0	
5	9/10	90.0	

Table 6: Chi-square test for trend between CKD stage and retinopathy grade

Test	Value	p-value
Chi-square for trend	24.1	< 0.001

Table 7: Spearman's rank correlation between CKD stage and retinopathy grade

Statistic	Spearman's rho	p-value
Correlation	0.69	< 0.001

Table 8: Adjusted odds of retinopathy per one-stage eGFR decline

Predictor	OR (95% CI)	p-value
One-stage decrease in CKD (eGFR)	1.92 (1.50–2.47)	< 0.001

Table 9: Mean eGFR by diagnostic group

Group	eGFR (mL/min/1.73 m²), mean ± SD
Hypertension only	61.3 ± 14.8
Diabetes only	54.7 ± 17.6
Mixed pathology	49.8 ± 19.9

Table 10: Distribution of retinopathy grades by diagnostic group

Grade	Hypertension (n=35)	Diabetes (n=35)	Mixed (n=40)
None	18	10	9
Mild NPDR	8	5	7
Mod NPDR	6	8	11
Severe NPDR	3	7	8
PDR	0	5	5

Table 1 describes participant demographics; Table 2 shows CKD stage distribution; Table 3 details overall retinopathy grades; Table 4 compares prevalence by group; Table 5 demonstrates increasing retinopathy with advancing CKD; Table 6 and Table 7 confirm a significant trend and correlation; Table 8 quantifies the odds of retinopathy per CKD stage decline; Table 9 contrasts mean eGFR across groups; and Table 10 illustrates how retinopathy severity varies by group. Collectively, these findings underscore a strong, graded association between declining renal function and worsening retinopathy in Bihari adults with hypertension, diabetes, or both conditions.

Discussion

The present study demonstrates a clear, graded relationship between declining renal function as reflected by eGFR-based CKD stage and both the prevalence and severity of retinopathy in adults with hypertension, diabetes, or mixed pathology [9]. Retinopathy prevalence rose from only 10% in patients with preserved glomerular filtration (CKD stage 1) to 90% among those with kidney failure (CKD stage 5), and the proportion of proliferative disease was markedly higher in advanced CKD. These findings underscore the shared microvascular pathophysiology linking the kidney and retina, driven by endothelial dysfunction, chronic inflammation, and oxidative stress [10].

Comparing diagnostic groups, mixed-pathology patients exhibited the highest retinopathy burden (77.5%), followed closely by the diabetic cohort (71.4%), whereas hypertensive-only patients showed a lower but still substantial prevalence (48.6%). This gradient suggests that coexisting hyperglycaemia and elevated arterial pressures exert a synergistic effect on microvascular injury. The mean eGFR was lowest in the mixed group, further indicating that dual pathology accelerates nephron loss and, by extension, retinal vascular compromise [11].

The strong positive trend (chi-square for trend = 24.1; $p < 0.001$) and significant Spearman's correlation ($\rho = 0.69$; $p < 0.001$) between CKD stage and retinopathy grade highlight the potential of fundus examination as a surrogate marker for systemic microvascular health [12]. Moreover, each one-stage eGFR decline conferred nearly double the odds of retinopathy (OR 1.92; 95% CI 1.50–2.47), even after adjusting for age, sex, BMI, and disease duration. This dose–response relationship reinforces the value of incorporating retinal screening into CKD care pathways, particularly for patients whose renal function is declining [13].

Mechanistically, chronic hyperglycaemia promotes advanced glycation end-product formation and activation of protein kinase C, which compromise endothelial integrity and increase vascular permeability. Hypertension augments these effects by exerting direct shear stress on arteriolar walls, leading to thickening and maladaptive remodelling. In advanced CKD, uraemic toxins and dysregulated nitric oxide metabolism further impair microvascular autoregulation. The retina, with its high metabolic demand and delicate capillary network, may thus serve as an early barometer for systemic vascular injury [14].

In resource-constrained settings such as Bihar, where routine fundus photography and nephrology referrals may be limited, targeting retinal screening to patients with declining eGFR could optimize the use of specialist resources. Early detection of even mild non-proliferative changes should trigger tighter blood-pressure and glycaemic control, dietary and lifestyle counselling, and timely ophthalmology consultation. Such integrated care could slow the progression of both CKD and sight-threatening retinopathy [15].

Despite the strengths of a well-characterized cohort and standardized grading protocols, this study has limitations. Its cross-sectional design precludes causal inference and temporal sequencing of kidney and retinal changes. The single-centre setting may limit generalizability, and despite blinding of the retina specialist to eGFR status, unmeasured confounders such as lipid profiles or smoking history could influence microvascular outcomes. Future longitudinal studies tracking eGFR decline alongside serial retinal imaging would clarify the predictive utility of retinopathy for CKD progression [16].

In conclusion, our findings reveal a robust, graded association between worsening renal function and severity of retinopathy across hypertensive, diabetic, and combined-pathology patients. Incorporating targeted retinal screening into CKD management could enable early identification of microvascular complications, guide therapeutic interventions, and ultimately improve both renal and visual outcomes in high-risk populations.

Conclusion

This cross-sectional study of 110 adults with hypertension, diabetes, or both conditions demonstrates a strong, graded association between declining renal function measured by eGFR and increasing prevalence and severity of retinopathy. Patients with mixed pathology exhibited the highest burden of retinal changes, and each one-stage decrease in CKD stage nearly doubled the odds of retinopathy, even after adjusting for key demographic and clinical variables.

These findings highlight the utility of dilated fundus examination as a practical, noninvasive marker of systemic microvascular injury in resource-constrained settings. Incorporating targeted retinal screening into routine CKD care pathways particularly for patients demonstrating eGFR decline could facilitate early identification of microvascular complications, prompt timely interventions to optimize blood-pressure and glycaemic control, and ultimately improve both renal and visual outcomes. Future longitudinal studies are warranted to evaluate whether retinal changes can predict CKD progression and to refine integrated management protocols across Bihar region.

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