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Risk factors associated with Indian type 2 diabetes patients with chronic kidney disease: CITE study, a cross-sectional, real-world, observational study

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Abstract

Background Type 2 diabetes (T2DM) is the leading cause of chronic kidney disease (CKD) worldwide. Identifying clinical and laboratory associations with chronic kidney disease (CKD) in type 2 diabetes (T2DM) can help physicians target modifiable risk factors. In light of limited data from India, the CITE (CKD in Indian T2DM Evaluation) study was conducted.

Methods The multicenter, cross-sectional CITE study included 3,325 patients from 28 centres across India over a three-month period. CKD was defined as a persistent decline in kidney function (eGFR < 60 ml/min/1.73 m^2 for ≥ 3 months) or an elevated urine albumin-to-creatinine ratio (UACR) in at least two samples. Descriptive statistics summarised patient characteristics, while logistic regression analyses identified significant risk factors for CKD.

Results The prevalence of CKD in T2DM was 32%, with a median patient age of 59.9 years and 60.72% having a T2DM duration > 10 years. Reduced eGFR (< 60 ml/min/1.73 m^2) was associated with older age (OR: 2.47, 95% CI 2.11–2.88, $P < 0.001$), longer T2DM duration (OR: 2.28, 95% CI 1.77–2.93, $P < 0.001$), higher HbA1c (OR: 1.039, 95% CI 1.001–1.079, $P = 0.046$), and elevated SBP (OR: 1.005, 95% CI 1.002–1.009, $P = 0.003$). Macroalbuminuria (UACR > 300 mg/g) was linked to non-vegetarian diet (OR: 1.95, 95% CI: 1.59–2.40, $P < 0.001$) and tobacco use (OR: 1.42, 95% CI: 1.17–1.73, $P < 0.001$). CKD increased comorbidity odds.

Conclusion The CITE study highlights the prevalence of CKD (32%) in Indian patients with T2DM and identifies clinical and laboratory factors associated with CKD, including age ≥ 60 years, T2DM duration, SBP, HbA1c, tobacco use, non-vegetarian diet, and comorbidities. Longitudinal studies are needed to confirm these associations and evaluate causality.

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Keywords CKD, T2DM, Cross-sectional study, Logistic regression analysis

Introduction

Type 2 diabetes (T2DM) mellitus is one of the most common chronic diseases, accounting for significant global morbidity and mortality. The global prevalence of T2DM in 2021 was estimated at 6.1% (529 million patients), with an additional 9.1% having impaired glucose tolerance and 5.8% having impaired fasting glucose. This equates to a total of 762 million individuals with pre-diabetes who are likely to contribute to the existing disease burden [1, 2]. Chronic kidney disease (CKD) is the most common comorbidity associated with T2DM, with a prevalence ranging between 20% and 30% [3]. The development of CKD in the context of T2DM can lead to end-stage kidney disease (ESKD), renal failure, and cardiovascular death in the long term [4]. In Asia, the prevalence of CKD is estimated to be higher (34%) due to the greater prevalence of metabolic disorders [5].

The START-INDIA multi-centre study estimates the prevalence of CKD to exceed 40%, whereas a single-centre cross-sectional study from New Delhi, India, reports a prevalence of 34.4% [6, 7]. Increasing age, advanced duration of diabetes, smoking, obesity, and hypertension have been identified as associated risk factors in a meta-analysis of global data [8]. However, limited and heterogeneous data from India suggest advanced age, high body mass index (BMI), and duration of diabetes as significant predictors, with no association observed with glycemic control [9].

The heterogeneity in prevalence data globally and within India can be attributed to the diagnostic criteria used for chronic kidney disease (CKD), which often involve an estimated glomerular filtration rate (eGFR) of less than 60 ml/min/1.73 m^2 without accounting for the urine albumin-to-creatinine ratio (UACR).

In light of these discrepancies, the CITE study was initiated in India to identify CKD in T2DM patients using the American Diabetes Association (ADA) and Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines. These guidelines define CKD as a UACR > 30 mg/g in at least two out of three readings and/or an eGFR < 60 ml/min/1.73 m^2 persistent for three months [10]. This cross-sectional analysis is the first in India to identify significant clinical and laboratory risk associations related to CKD in patients with T2DM.

Materials and methods

Study population

T2DM patients aged 18 years and older were screened for CKD to assess the prevalence and associated risk factors. The study aimed to assess the prevalence of CKD in T2DM patients and to identify clinically relevant attributes associated with CKD. The 28 participating centres were selected to represent India's diverse geographical and demographic profile, including urban and semi-urban clinics from eastern (e.g., Kolkata), western (e.g., Mumbai), and southern (e.g., Chennai) regions. These centres comprised a mix of tertiary hospitals, private diabetes clinics, and endocrinology practices, reflecting the distribution of T2DM care in India. (Supplementary Table 1) Data were collected from 15th December 2023 to 15th March 2024. The study was registered with the Open Science Framework (OSF) Registries (https://doi.org/10.17605/OSF.IO/BRF6U).

The Park Clinic Ethics Committee, Kolkata, India (Approval Code: PCE/2023/12/01), approved the study protocol on 23rd December 2023. Given the inclusion of numerous individual practicing physicians without access to local ethics committees, a centralized approval was obtained to ensure uniformity and compliance across all 28 centers.

Inclusion Patients aged 18 years or older with a confirmed diagnosis of T2DM attending participating clinics between December 15, 2023, and March 15, 2024.

Exclusion Patients with missing data (lacking two out of three abnormal UACR values or eGFR < 60 mL/min/1.73 m^2, persistent for ≥ 3 months), those on renal replacement therapy, those with non-diabetic kidney disease (NDKD), or those with acute renal insufficiency.

Data collection and evaluation

Patients with type 2 diabetes (T2DM) visiting the 28 participating clinics between 15th December 2023 and 15th March 2024 were screened for chronic kidney disease (CKD) using spot urine albumin-to-creatinine ratio (UACR, mg/g) and estimated glomerular filtration rate (eGFR, ml/min/1.73 m^2), calculated using the CKD-EPI equation, following American Diabetes Association (ADA) and Kidney Disease Outcomes Quality Initiative (KDOQI) recommendations [11]. Laboratory data (UACR and eGFR) were collected prospectively during clinic visits from 15th December 2023 to 15th March 2024. For patients with initial eGFR < 60 ml/min/1.73 m^2 or UACR > 30 mg/g, persistence was verified using prior medical records (within the past 6 months) or a second sample within the study period. Significant albuminuria was classified as microalbuminuria (UACR 30–300 mg/g) or macroalbuminuria (UACR > 300 mg/g). Urine samples with substantial pus cells or red blood cells, indicating urinary tract infections or hematuria, were excluded.

After obtaining written informed consent through a standardized form, data on persistently elevated UACR and reduced eGFR, along with baseline history, demographic parameters, laboratory values, and medication history, were recorded and entered into a pre-approved Excel sheet. A steering committee defined the data entry parameters, integrating global guidelines and regional considerations.

The **primary outcome** was the prevalence of CKD in T2DM patients, defined as UACR > 30 mg/g in at least two of three readings and/or eGFR < 60 ml/min/1.73 m^2 persistent for ≥ 3 months. The **secondary outcome** was the identification of clinical and laboratory risk factors associated with CKD, including age, T2DM duration, glycated hemoglobin (HbA1c), systolic blood pressure (SBP), dietary habits, tobacco use, and comorbidities. **Outcome measures** included UACR (mg/g) from spot urine samples, eGFR (ml/min/1.73 m^2) calculated using the CKD-EPI equation, and comorbidity status assessed from clinical history and records.

Relevant clinical history included hypertension, dyslipidemia, T2DM duration, dietary habits (vegetarian vs. non-vegetarian), tobacco use, and current glycemic status (HbA1c, %). Associated comorbidities recorded were atherosclerotic cardiovascular disease (ASCVD), heart failure, peripheral vascular disease, retinopathy, and diabetic neuropathy, based on documented diagnoses in patient records.

Statistical analysis

Statistical analyses were performed using DATAtab (Online Statistics Calculator, DATAtab e.U., Graz, Austria) and R Studio (R Core Team, 2024, R version 4.2.3). Descriptive statistics were reported as percentages for categorical variables (e.g., gender, tobacco use) and as mean with standard deviation (SD) or median with interquartile range (IQR) for continuous variables (e.g., HbA1c, SBP), depending on data distribution assessed via the Kolmogorov-Smirnov test.

Analytical statistics were used to evaluate associations with chronic kidney disease (CKD), using UACR (mg/g) and eGFR (ml/min/1.73 m^2) as dependent variables. Binomial logistic regression was conducted to assess predictors of eGFR < 60 ml/min/1.73 m^2, while multinomial logistic regression analysis was used for UACR categories (microalbuminuria: 30–300 mg/g; macroalbuminuria: >300 mg/g). Variables exhibiting multicollinearity (variance inflation factor, VIF > 5), such as systolic blood pressure (SBP), diastolic blood pressure (DBP), hypertension status, and HbA1c categories (< 7% vs. ≥7%), were excluded from specific regression models where they overlapped significantly with other predictors (e.g., continuous HbA1c or SBP) to avoid confounding. Model significance was evaluated using the chi-squared statistic, with a significance level of $p < 0.05$ (95% confidence interval). For continuous variables like HbA1c and SBP, we assumed a linear relationship with CKD outcomes in the logistic regression models, analyzing the effect per unit increase (e.g., per 1% increase in HbA1c). Nonlinear associations were not explored in this study due to its exploratory nature. This study adheres to the STROBE guidelines for reporting observational studies, and a completed STROBE checklist is provided as a supplementary file.

A sample size of 3,325 achieved a statistical power of 0.90, calculated using G*Power software assuming a 34% CKD prevalence (based on prior Indian data [Ref 6, 7]), an alpha of 0.05, and an effect size of 0.15 for logistic regression analyses of key risk factors (e.g., age, T2DM duration).

Given the multiple predictors tested in the binomial and multinomial logistic regression analyses, there is a potential risk of false positives due to multiple comparisons. However, adjustments such as the Bonferroni method or False Discovery Rate (FDR) correction were not applied, as this was an exploratory study aimed at identifying key associations for further investigation, and the majority of significant findings had P-values well below 0.001, reducing the likelihood of Type I errors.

Results

A total of 10,915 patients with type 2 diabetes (T2DM) were screened, of whom 3,493 were diagnosed with chronic kidney disease (CKD) based on the pre-specified diagnostic criteria. After excluding patients with missing data, 3,325 data points (4.8% exclusion, defined as lacking required UACR or eGFR values for CKD diagnosis) were included in the final analysis. (Fig. 1)

The overall prevalence of CKD in patients with T2DM was 32%. The median age of the patients was 59.9 (12.1) years, with 64.6% being male. Among the cohort, 60.72% had a T2DM duration exceeding 10 years, 77.62% were non-vegetarians, and 20.21% used tobacco. The median BMI was 25.78 (4.98) kg/m^2, median HbA1c was 7.7% (2.3), median systolic blood pressure (SBP) was 138.4 (26) mmHg, and median diastolic blood pressure (DBP) was 80 (14) mmHg. Obesity, defined as a BMI ≥ 25 kg/m^2, was observed in 57.74% of patients, with only 31.46% achieving an HbA1c < 7.0%. Additionally, 73.86% of CKD patients with T2DM had a history of hypertension (HT), although only 41.08% achieved the target blood pressure of < 130/80 mmHg (Table 1).

Within CKD categories, 62.56% had microalbuminuria, 28.75% had macroalbuminuria, and 45.5% had an eGFR < 60 ml/min/1.73 m^2. Among patients with microalbuminuria, 28.27% had an eGFR < 60 mL/min/1.73 m^2. A minority (8.69%) of CKD patients had normoalbuminuria (Fig. 2).

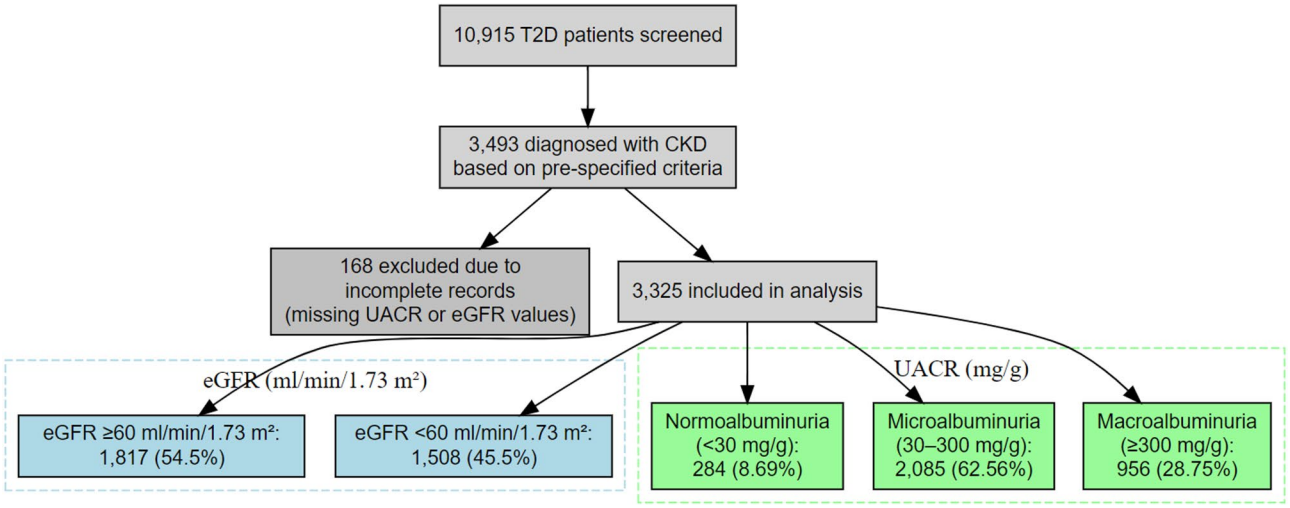

Fig. 1 Patient selection flowchart for T2DM patients with CKD in the CITE study, illustrating the screening of 10,915 patients, diagnosis of 3,493 CKD cases, exclusion of 168 patients, and categorization based on eGFR (mL/min/1.73 m^2) and UACR (mg/g) levels

Binary logistic regression analysis: eGFR categories and associated clinical attributes

The continuous variables systolic blood pressure (SBP), diastolic blood pressure (DBP), and glycated haemoglobin (HbA1c), along with the categorical variables' hypertension status and HbA1c categories (<7% and ≥7%), demonstrated significant multicollinearity issues, as indicated by variance inflation factors (VIF) greater than 5. As a result, these confounding variables were excluded where applicable.

The analysis revealed significantly increased odds of having an eGFR < 60 ml/min/1.73 m^2 in patients aged ≥ 60 years (odds ratio [OR]: 2.47, 95% confidence interval [CI] 2.11–2.88, $P < 0.001$) and in those with a T2DM duration of more than 10 years (OR: 2.28, 95% CI 1.77–2.94, $P < 0.001$). (Table 2) Additionally, each 1% increase in HbA1c was associated with 4% higher odds of eGFR < 60 ml/min/1.73 m^2 (95% CI 1.00–1.08, $P = 0.046$), and each mmHg increase in SBP was linked to 0.5% increased odds of worsening renal function (95% CI 1.002–1.009, $P = 0.003$). (Fig. 3)

The regression model was statistically significant (χ^2 statistic = 310.5, df = 5, $p < 0.001$).

Multinomial logistic regression analysis: UACR categories and associated clinical attributes

There were significant odds of macroalbuminuria (UACR > 300 mg/g) associated with age ≥ 60 years (odds ratio [OR]: 1.34, 95% confidence interval [CI] 1.13–1.59, $P = 0.001$), a non-vegetarian diet (OR: 1.95, 95% CI 1.59–2.40, $P < 0.001$), tobacco use (OR: 1.42, 95% CI 1.17–1.73, $P < 0.001$), and HbA1c ≥ 7% (OR: 1.32, 95% CI 1.11–1.57, $P = 0.001$). (Table 2) Additionally, for each mmHg increase in SBP, there was a 1% increase in the odds of macroalbuminuria (95% CI 1.002–1.009, $P = 0.003$). The regression model was statistically significant (chi-squared statistic = 113.96, degrees of freedom [df] = 5, $P < 0.001$).

For microalbuminuria, only a T2DM duration of > 5 years was significantly associated (OR: 1.42, 95% CI 1.09–1.84, $P = 0.009$).

Clinical and laboratory variables strongly correlating with CKD, defined as a combination of eGFR < 60 ml/min/m2 and UACR > 30 mg/g, included age ≥ 60 years, female gender, a T2DM duration of > 10 years, tobacco use, HbA1c, and SBP. This regression model was also significant (chi-squared statistic = 203.6, df = 7, $P < 0.001$).

Multinomial and binary logistic regression analysis: comorbidities and associated clinical attributes

Binary logistic regression was conducted using eGFR as the dependent variable. For every 1 ml/min/1.73 m^2 reduction in eGFR below 60 ml/min/1.73 m^2, there was a significant increase in the odds of retinopathy (OR: 2.16, 95% CI 1.71–2.72, $P < 0.001$), neuropathy (OR: 1.22, 95% CI 1.02–1.47, $P = 0.029$), atherosclerotic cardiovascular disease (ASCVD) (OR: 1.59, 95% CI 1.33–1.92, $P < 0.001$), and heart failure (HF) (OR: 3.88, 95% CI 2.61–5.76, $P < 0.001$). (Table 3) The regression model was statistically significant (χ^2 statistic = 86.82, df = 4, $p < 0.001$).

Multinomial logistic regression was conducted using UACR as the dependent variable. In the presence of macroalbuminuria, significant associations were found with ASCVD (OR: 1.27, 95% CI 1.05–1.54, $P = 0.014$), HF (OR: 1.87, 95% CI 1.34–2.61, $P < 0.001$), and retinopathy (OR: 2.14, 95% CI 1.71–2.68, $P < 0.001$). No significant association was observed between neuropathy and the study variables. The regression model was statistically significant (χ^2 statistic = 85.53, df = 4, $p < 0.001$). The significant variables associated with eGFR < 60 ml/min/1.73 m^2 and UACR > 300 mg/g are summarised in Fig. 4.

Table 1 Baseline characteristics of patients with type 2 diabetes and chronic kidney disease (CKD)

Categorical variables	*N* (%)	Continuous variable	Median	IQR
Age ≥60 years	1906(57.32)	UACR (mg/g)	115.7	269.81
Male	2148(64.6)	eGFR	65	47
T2DM duration > 10 years	2019(60.72)	HbA1c	7.7	2.3
Non-vegetarian diet	2581(77.62)	BMI (kg/m^2)	25.78	4.98
HbA1c < 7%	1046(31.46)	SBP (mm of Hg)	138.4	26
BMI≥25 kg/m^2	1920(57.74)	DBP (mm of Hg)	80	14
BMI 23.0–24.9 kg/m^2	668(20.09)			
Tobacco use (Yes)	672(20.21)			
Hypertension	2456(73.86)			
ASCVD	653(19.64)			
HF	167(5.02)			
Retinopathy	384(11.54)			
Neuropathy	649(19.52)			
Lipid Profile	Not collected*			
Hemoglobin (g/dl)			12.5	1.8
Albumin (g/dl)			4.0	0.5
Metformin	2,369 (71.24)			
Insulin	1,345 (40.45)			
SGLT2-i	2,220 (66.76)			
GLP1-RA	132 (3.97)			
NS-MRA	32 (0.96)			
RAASB	1,932 (58.11)			

Percentages represent the number of patients on each medication class, based on available records; $n = 3,325$. Additional medication data (e.g., sulfonylureas, DPP-4 inhibitors) were collected but not tabulated due to space constraints and are available upon request from the corresponding author

* Data were not collected due to logistical constraints (e.g., a 12-hour fasting requirement for most lipid profile components was not feasible across most clinics) and inconsistent availability in patient records, including for LDL cholesterol, which does not require fasting

No significant associations were identified between comorbidities and microalbuminuria (UACR 30–300 mg/g).

Discussion

Global prevalence data and risk associations

Type 2 diabetes (T2DM) is the most common metabolic disorder, responsible for significant health morbidity and mortality. According to global estimates, the prevalence of macrovascular complications is approximately 32.2%, with atherosclerotic cardiovascular disease (ASCVD) accounting for 21.2% [12]. Heart failure (HF) prevalence ranges between 19% and 26%, while retinopathy and neuropathy prevalence stand at 27% and 26.71%, respectively [13–15]. The global prevalence of chronic kidney disease (CKD) in T2DM is around 25%, further amplifying the burden of T2DM-associated comorbidities [16]. Key factors associated with CKD in T2DM include advanced age, smoking, hypertension, obesity, and ASCVD [17]. A cross-sectional study from Thailand identified advanced age, uncontrolled diabetes, retinopathy, and elevated uric acid levels as significant risk factors [18]. Similarly, data from China and Palestine reported significant associations with advanced age, hypertension, T2DM duration, comorbidities, and poor glycemic control [19, 20].

Indian prevalence data and risk associations

The START-INDIA study primarily aimed to determine the prevalence of CKD in T2DM patients, but risk attributes were not assessed [6]. A single-centre, cross-sectional study identified advanced age, T2DM duration, and body mass index (BMI) as significant risk factors [9]. An observational study conducted in Delhi and Bhubaneswar found obesity to contribute significantly to CKD development and progression in T2DM patients. At the same time, a retrospective analysis from South India concluded that all T2DM patients with proteinuria had retinopathy, with contributing factors being HbA1c and systolic blood pressure (SBP) [10, 21].

CITE study findings

This is the first pan-Indian study to identify significant clinical and laboratory findings, as well as CKD-related comorbidities, in T2DM patients. The overall prevalence of CKD in patients with T2DM was 32%, calculated as 3,493 diagnosed cases out of 10,915 screened patients.

Most patients (60.72%) had a duration of T2DM exceeding 10 years, with a male predominance. Median HbA1c and blood pressure values were 7.7% and 138/80 mmHg, respectively. Most patients were obese and followed a non-vegetarian diet.

The predominant type of CKD identified was the albuminuric variety, with 62.56% diagnosed with microalbuminuria and 28.75% with macroalbuminuria. Compromised kidney function, defined as an eGFR of less than 60 ml/min/1.73 m², was observed in 45.5% of patients, while a small minority (8.69%) had non-albuminuric chronic kidney disease (CKD).

Significant variables associated with an eGFR of less than 60 ml/min/1.73 m² included HbA1c, systolic blood pressure (SBP), age of 60 years or more, and duration of type 2 diabetes (T2DM) of more than 10 years. For every 1% increase in HbA1c and a 1 mmHg increase in SBP, there was a 4% and 0.5% increase in the odds of worsening renal function, respectively. Each 1 ml/min/1.73 m² reduction in eGFR was associated with significantly increased odds of retinopathy, neuropathy, ASCVD, and HF.

In macroalbuminuric CKD, significant associations were observed with age ≥ 60, a non-vegetarian diet, tobacco use, and poor glycemic control. Additionally,

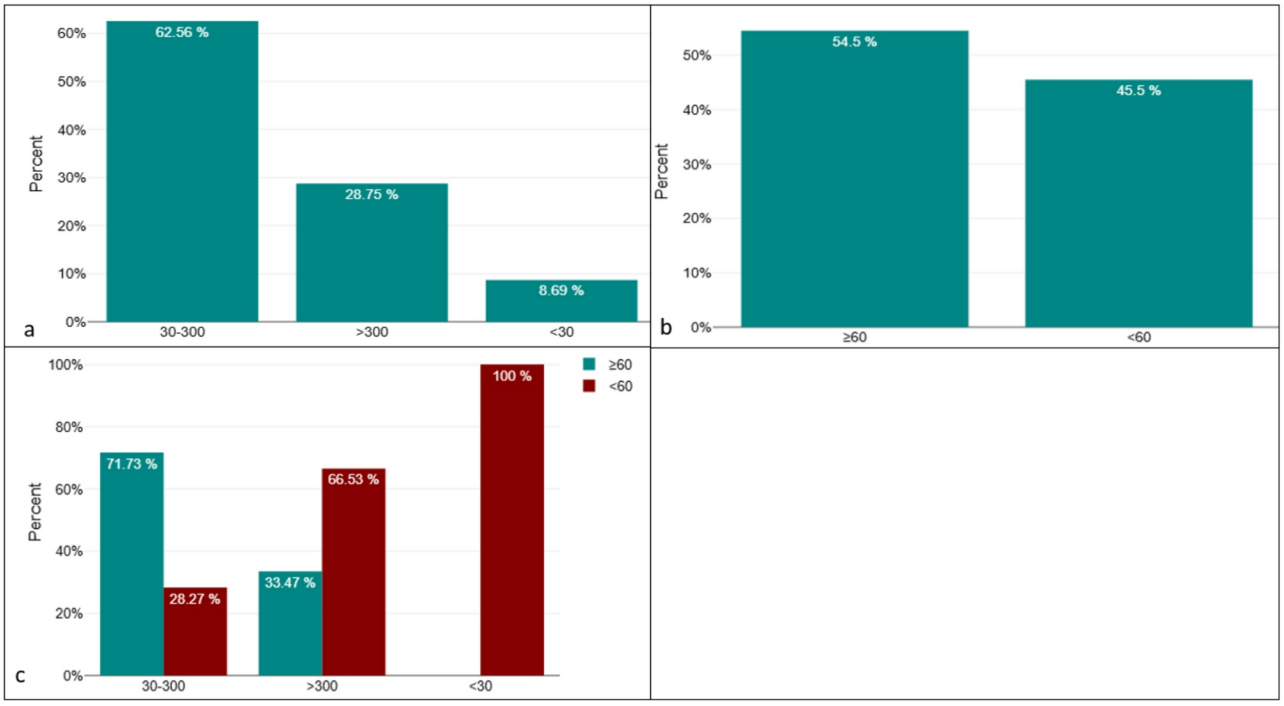

Fig. 2 Categories of CKD in T2DM patients. (**a**) Albuminuria categories, showing the percentage of CKD patients with microalbuminuria (UACR 30–300 mg/g), macroalbuminuria (UACR > 300 mg/g), and normoalbuminuria (UACR < 30 mg/g). (**b**) eGFR categories, showing the percentage of CKD patients with eGFR ≥ 60 ml/min/1.73 m^2 and eGFR < 60 ml/min/1.73 m^2. (**c**) eGFR within albuminuria categories, showing the percentage of patients with eGFR ≥ 60 ml/min/1.73 m^2 (teal) and eGFR < 60 ml/min/1.73 m^2 (maroon) within each albuminuria category: microalbuminuria (UACR 30–300 mg/g), macroalbuminuria (UACR > 300 mg/g), and normoalbuminuria (UACR < 30 mg/g)

Table 2 Binary and multinomial logistic regression results for eGFR < 60 ml/min/1.73 m^2 and UACR categories > 300 mg/g

eGFR < 60 ml/min/1.73m^2	**Coefficient B**	**Standard error**	***p***	**Odds ratio**	**95% confidence interval**
Constant	-2.117	0.398	< 0.001	0.12	0.055–0.262
Age ≥ 60 years (Ref. <60 years)	0.905	0.079	< 0.001	2.472	2.115–2.888
Gender (Ref. Female)	0.197	0.081	0.015	1.218	1.039–1.427
T2DM with duration > 10 years (Ref.) < 5 years)	0.825	0.129	< 0.001	2.282	1.773–2.938
T2DM with duration 5–10 years (Ref. ><5 years)	0.262	0.138	0.057	1.3	0.992–1.703
Non-vegetarian diet	-0.03	0.088	0.734	0.97	0.816–1.154
HbA1c (%)	0.038	0.019	0.046	1.039	1.001–1.079
BMI (kg/m^2)	-0.012	0.009	0.162	0.988	0.97–1.005
Tobacco use (Yes). [Ref. No)	0.157	0.095	0.099	1.17	0.971–1.41
SBP	0.005	0.002	0.003	1.005	1.002–1.009
UACR > 300 mg/g)	**Coefficient B**	**Standard error**	**p**	**Odds ratio**	**95% confidence interval**
Constant	-2.836	0.396	< 0.001	0.059	0.027–0.128
Age ≥ 60 years (Ref. <60 years)	0.297	0.086	0.001	1.346	1.138–1.591
Gender Female (Ref. Male)	0.148	0.087	0.088	1.16	0.978–1.375
T2DM with duration > 10 years (Ref. <5 years)	0.01	0.129	0.938	1.01	0.784–1.301
T2DM with duration 5–10 years (Ref. <5 years)	-0.393	0.14	0.005	0.675	0.513–0.889
Non-vegetarian: Yes (Ref. No)	0.672	0.104	< 0.001	1.959	1.598–2.402
HbA1c ≥ 7% (Ref. <7%)	0.283	0.087	0.001	1.327	1.118–1.575
BMI (kg/m^2)	-0.017	0.01	0.08	0.983	0.964–1.002
Tobacco use: Yes (Ref. No)	0.356	0.098	< 0.001	1.428	1.178–1.732
SBP (mm of Hg)	0.01	0.002	< 0.001	1.01	1.006–1.014

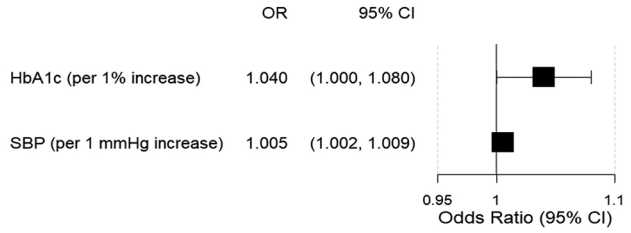

Fig. 3 Forest plot showing odds ratios (ORs) and 95% confidence intervals (CIs) for eGFR < 60 ml/min/1.73 m^2 associated with HbA1c (per 1% increase) and SBP (per 1 mmHg increase) from binary logistic regression

for each mmHg increase in SBP, the odds of macroalbuminuria increased by 1%. Except for neuropathy, all comorbidities were significantly associated with macroalbuminuria. Microalbuminuria was significantly associated only with the duration of T2DM and showed no correlation with comorbidities.

In patients with advanced chronic kidney disease (CKD) (eGFR < 60 ml/min/1.73 m^2 and UACR > 30 mg/g), significant associations were identified with age ≥ 60 years, female gender, type 2 diabetes mellitus (T2DM) duration > 10 years, tobacco use, HbA1c, and systolic blood pressure (SBP).

In contrast to earlier studies from India, the CITE study showed a significant association between glycemic control and CKD, with each 1% increase in HbA1c linked to a 4% higher odds of eGFR < 60 ml/min/1.73 m^2 (OR: 1.04, 95% CI 1.00–1.08, $P = 0.046$). Prior Indian studies, such as those by Tewari et al. (Ref 9), reported no clear link between HbA1c and CKD, possibly due to differences in study design, patient populations, or diagnostic criteria. For instance, earlier studies often relied on a single eGFR measurement or varied in their CKD definitions, whereas the CITE study adhered to ADA/KDOQI guidelines, requiring persistent eGFR < 60 ml/min/1.73 m^2 or UACR > 30 mg/g over three months, confirmed by multiple measurements. Additionally, the CITE study's multi-centric design and larger sample size ($n = 3,325$) may have provided greater statistical power to detect this association. Differences in HbA1c measurement methods or glycemic control patterns in the study populations (e.g., the CITE cohort's median HbA1c of 7.7% with 60.72% having T2DM duration > 10 years) could also contribute to this discrepancy, highlighting the need for standardized protocols in future research.

Study limitations

This study has several limitations. The cross-sectional design inherently limits the ability to establish causality between identified factors (e.g., HbA1c, SBP, tobacco use) and CKD, and unmeasured confounders, such as genetic predispositions or socioeconomic factors, may also influence the observed associations. To avoid confounding in regression models, multicollinear variables (e.g., diastolic blood pressure, hypertension status) were excluded, and multiple comparisons were not adjusted (e.g., Bonferroni method), potentially underestimating confounding effects and increasing the risk of false positives, respectively. Stratified analyses to confirm robustness or explore regional variations (using dummy variables for zones like East, West, South) were not feasible due to sample size constraints, though these could provide insights into geographical differences in future studies. Missing data for some clinical parameters (e.g., lipid profile) limited the scope of secondary analyses, though this did not affect the primary CKD findings. Additionally, LDL cholesterol, which does not require fasting, could not be included due to inconsistent availability in patient records and logistical challenges in standardizing measurements across the 28 participating centers.

The study population predominantly had T2DM duration > 10 years, so findings may not generalize to earlier disease stages, and while duration was categorized into three groups (< 5, 5–10, > 10 years), finer categorizations (e.g., 10–15 years) could better capture risk variations. Finally, we did not analyze the impact of medications (e.g., RAAS inhibitors) on CKD risk in subgroups, an area for future research to optimize treatment strategies.

Table 3 Regression results for comorbidities associated with eGFR < 60 mL/min/1.73 m^2 and uacr > 300 mg/g

eGFR < 60 ml/min/1.73m².	**Coefficient B**	**Standard error**	***p***	**Odds ratio**	**95% confidence interval**
Constant	-0.467	0.044	< 0.001	0.627	0.575–0.683
ASCVD: Yes (Ref. No)	0.469	0.093	< 0.001	1.599	1.332–1.92
HF: Yes (Ref. No)	1.357	0.202	< 0.001	3.883	2.615–5.765
DPN: Yes (Ref. No)	0.204	0.093	0.029	1.226	1.021–1.473
Retinopathy: Yes (Ref. No)	0.772	0.118	< 0.001	2.164	1.718–2.726
UACR > 300 mg/g	**Coefficient B**	**Standard error**	**p**	**Odds Ratio**	**95% confidence interval**
Constant	-1.121	0.049	< 0.001	0.326	0.296–0.359
ASCVD: Yes (Ref. No)	0.243	0.099	0.014	1.275	1.051–1.547
HF: Yes. (Ref. No)	0.629	0.169	< 0.001	1.875	1.345–2.614
DPN: Yes. (Ref. No)	0.138	0.099	0.161	1.148	0.946–1.394
Retinopathy: Yes. (Ref. No)	0.762	0.115	< 0.001	2.143	1.71–2.686

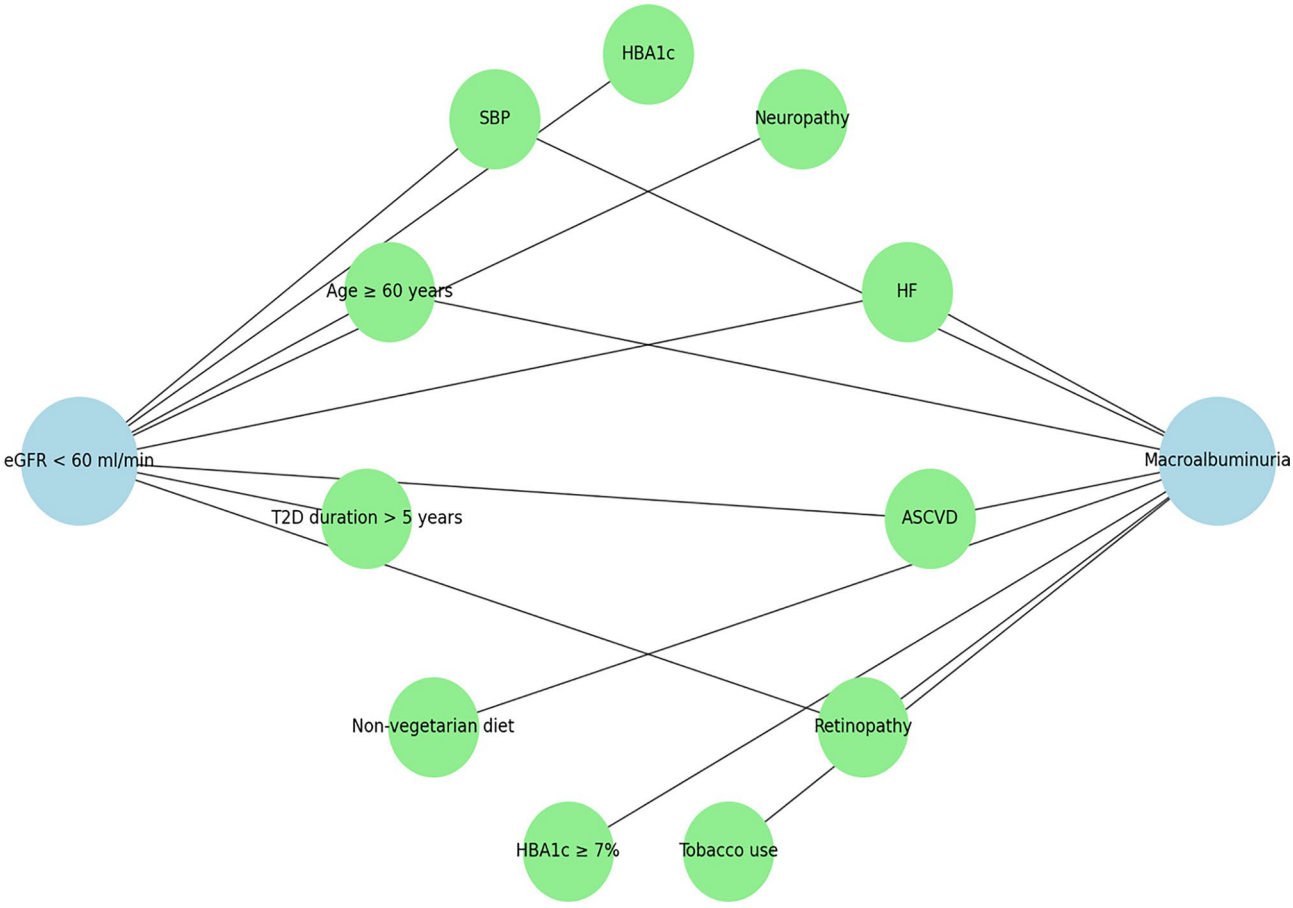

Fig. 4 Significant clinical, laboratory, and variables associated with eGFR < 60 mL/min/1.73 m^2 or UACR > 300 mg/g. Atherosclerotic Cardiovascular Disease (ASCVD), Systolic Blood pressure (SBP), and Heart Failure (HF)

Strengths of the study

This is the first well-designed, multi-centric, cross-sectional study from India. Data were collected prospectively following ADA/KDOQI guidelines for CKD definition. Unlike previous studies, which often relied on eGFR alone or a single creatinine and UACR sample, the CITE study adhered to the recommended protocols for CKD diagnosis. Data were collected from multiple regions across the country, enabling the generalisability of the findings. This is the largest cohort of T2DM and CKD patients analysed for prevalence and risk attributes, with a statistical power 0.90.

Conclusion

The nationwide CITE study found a 32% prevalence of CKD in T2DM patients. Factors associated with CKD included age ≥ 60 years, longer T2DM duration, elevated SBP, higher HbA1c, tobacco use, non-vegetarian diet, and comorbidities (heart failure, atherosclerotic cardiovascular disease, retinopathy, and neuropathy). These associations, particularly with macroalbuminuria, highlight potential targets for intervention. Prospective longitudinal studies are essential to confirm these findings, explore causality, and understand CKD progression in T2DM.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12882-025-04164-6.

Supplementary Material 1

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Author contributions
S.G. and B.S. conceptualised the study. S.T. and S.G. performed the statistical analysis. All authors reviewed the manuscript.

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Data availability
Upon reasonable request, the corresponding author can provide all data related to the preparation of this manuscript. All the raw data are in the excel format and can be emailed on request. Similarly, the Ethics committe approval letter is sn a PDF format and can also be emailed upon recieving a request.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Park Clinic Ethics Committee, Kolkata, India (Approval Code: PCE/2023/12/01) on December 23, 2023. Written informed consent was obtained from all participants using a standardized consent form.

Consent for publication

Consent for publication was not required as no individual participant data are presented in this manuscript, per the Park Clinic Ethics Committee waiver.

Study registration

The CITE study protocol was registered at Open Science Framework (OSF) Registries. DOI https://doi.org/10.17605/OSF.IO/BRF6U).

Competing interests

The authors declare no competing interests.

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