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Original Research Article

Association Between Chronic Kidney Disease and Cerebral Small Vessel Disease: A Radiological Study from a Tertiary Care Centre in North India

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Abstract

Background: *Chronic kidney disease (CKD) is a systemic microvascular disease with rapidly rising prevalence[1–3]. Latest studies and emerging data suggest a strong relationship between CKD and cerebral small vessel disease (CSVD), which is a major contributor of cognitive impairment and stroke [5,6,8,11,18,19,25,30]. However, data from Indian population remains limited[3,21,29].*

Objectives: *To determine the occurrence of cerebral small vessel disease in patients with chronic kidney disease and to identify various risk factors contributing to development of cerebral small vessel disease.*

Methods: *This hospital-based observational study included patients with diagnosed CKD patients of grade 3 and 4 according to KDIGO (Kidney Disease Improving Global Outcomes) criteria, aged 18 to 50 years attending a tertiary care centre in North India. All participants underwent detailed clinical evaluation, laboratory investigations including renal parameters, and magnetic resonance imaging (MRI) of the brain. CSVD markers—white matter hyperintensities (WMH), lacunes, cerebral microbleeds, and enlarged perivascular spaces—were assessed using standardized MRI criteria. Statistical analysis was performed to evaluate associations between CKD severity and CSVD burden.*

Results: *A significant proportion of CKD patients were demonstrated to have markers of CSVD on neuroimaging[18–21,25,26,37,39,40]. The prevalence and severity of CSVD markers increased with declining estimated glomerular filtration rate (eGFR), increasing age and in patients with other comorbidities like hypertension and diabetes mellitus [14,18,19,22,25,30,45]. These were considered to be significant clinical and biochemical risk factors for the development of CSVD in CKD patients [11,13,16,22,27,30].*

Conclusion: *CKD and CSVD are strongly associated thus supporting the concept of shared kidney–brain microvascular axis [5,11,17,22,27,28,30,44]. Early intervention to reduce the risk factors and early identification of CSVD in CKD patients may help in reducing the risk of vascular manifestation like stroke and cognitive impairment through planned preventive strategies [10,17,18,25,32,54,62].*

Keywords: *Chronic kidney disease, cerebral small vessel disease, MRI brain, white matter hyperintensities, kidney–brain axis*

Introduction

Chronic kidney disease (CKD) is a growing public health concern characterised by progressive decline in kidney function and is one of the leading cause of morbidity and mortality according to the Global Burden of Disease study[2,4]. CKD has a disproportionate burden in low- and middle-income countries of south east Asia including India [2,3,29]. CKD is known to cause multisystem complications, particularly cardiovascular and cerebrovascular diseases[4,11,14].

Cerebral small vessel disease (CSVD) is a spectrum of pathalogical processes affecting the small vessels of brain including small arteries, arterioles, capillaries, and venules[6,7]. It predisposes to stroke, vascular cognitive impairment, and dementia[10,17,62]. On neuroimaging, markers of CSVD are- white matter hyperintesities (WMH), lacunes, cerebral microbleeds (CMBs), enlarged perivascular spaces, and brain atrophy[8,9,23,51,56].

The concept of "kidney-brain axis" states that the kidney and brain being low resistance end organs, having similar microvascular architecture, are prone to develop systemic vascular injury[5,11,22,28]. CKD and CSVD have common pathophysiologically mechanism like endothelial dysfunction, chronic inflammation, oxidative stress, and vascular stiffness along with common risk factors like hypertension, increasing age and diabetes mellitus [13,14,15,16,22,27,45]. Despite of growing literature linking CKD with CSVD, there is scarcity of data from Indian sub-continent[21,29]. Given the rising prevelance of CKD in Indian population and it's probable neurological sequelae, this study aims to evaluate the association between CKD and CSVD in Indian cohort using standardised neurological markers [3,9,21].

Materials and Methods

Study Design and Setting:

The study was a hospital-based observational study conducted at a tertiary care centre in North India.

Study Population

Patients aged ≥18 years with a diagnosis of chronic kidney disease (as per KDIGO criteria) were included. Patients with known neurodegenerative disorders, history of stroke, intracranial tumors, or traumatic brain injury were excluded.

Clinical and Laboratory Evaluation:

Demographic data, duration of CKD, blood pressure, and comorbidities were recorded. Laboratory investigations included serum creatinine, urea, hemoglobin, and urine albumin. Estimated glomerular filtration rate (eGFR) was calculated using standard equations.

MRI Brain Protocol:

All participants underwent MRI brain using standard sequences including T1-weighted, T2-weighted, FLAIR, DWI, and susceptibility-weighted imaging (SWI). CSVD markers were assessed according to STRIVE criteria.

Statistical Analysis:

Data were analyzed using appropriate statistical software. Continuous variables were expressed as mean ± SD, while categorical variables were expressed as percentages. Associations between CKD parameters and CSVD markers were evaluated using correlation and regression analysis. A p-value <0.05 was considered statistically significant.

Results

A total of 140 patients with chronic kidney disease (CKD) were studied. Cerebral small vessel disease (CSVD) was detected on MRI in 81 patients (57.9%), while 59 patients (42.1%) showed no evidence of CSVD.

Among CSVD-positive patients, white matter hyperintensities (WMH) were the most frequent MRI finding, followed by lacunes and cerebral microbleeds. CSVD burden increased progressively with worsening renal function and increasing CKD stage.

Patients with CSVD had lower estimated glomerular filtration rate (eGFR) as compared to those without CSVD, supporting the "kidney- brain axis" hypothesis.

Hypertension was found to be strongly associated with CSVD. Out of the 81 patients having CSVD on neuroimaging, 77 (95.1%) were hypertensive, compared with 14 (23.7%) in the non-CSVD group (OR = 61.8, $p < 0.001$). Diabetes mellitus was present in 28 CSVD patients (34.6%) and 7 non-CSVD patients (11.9%), making it a strong risk factor (OR = 3.93, $p < 0.05$).

A pronounced synergistic effect was observed in patient having combined vascular risk factors (diabetes and hypertension). All 24 patients (100%) having both hypertension and diabetes had CSVD on their neuroimaging, whereas none of the both were found in the CSVD-absent group. Among patients with only one risk factor, CSVD was present in 57 of 78 patients (73.1%), while none of the 38 patients without either risk factor had CSVD.

Overall, hypertension and diabetes were identified as strong risk factors for CSVD with hypertension being the strongest predictor of neurological sequelae in CKD patients.

Table 1: Prevalence of CSVD in CKD Patients

Parameter	Total CKD Patients (n = 140)	Frequency (n)	Percentage (%)
Patients with CSVD	140	81	57.9
Patients without CSVD	140	59	42.1

Table 2: Distribution of Hypertension and Diabetes in CSVD and Non-CSVD Groups

Group	Total Patients	HTN only (n)	DM only (n)	Both HTN + DM (n)	Neither HTN nor DM (n)
CSVD present	81	53	4	24	0
CSVD absent	59	14	7	0	38
Total	140	67	11	24	38

Table 3: Association Between Hypertension and CSVD

Hypertension Status	CSVD Present (n)	CSVD Absent (n)	Total (n)	Percentage with CSVD (%)
Hypertensive	77	14	91	84.6
Non-hypertensive	4	45	49	8.2
Total	81	59	140	—

Table 4: Association Between Diabetes Mellitus and CSVD

Diabetes Status	CSVD Present (n)	CSVD Absent (n)	Total (n)	Percentage with CSVD (%)
Diabetic	28	7	35	80.0
Non-diabetic	53	52	105	50.5
Total	81	59	140	—
Odds Ratio (OR)	3.93			$p < 0.05$

Discussion

This observational study demonstrates a strong association between CKD and CSVD in line with modern literature and emerging data in context of Indian population[11,18–21,25,30,39,40]. The findings are consistent and supports the existing evidence of CKD being a systemic microvascular disorder affecting multiple organs simultaneously rather than just kidney dysfunction [5,11,14,17,22,27,28,44].

Limitations

The study was hospital-based and may not reflect the general population of India adequately. Longitudinal follow-ups were not done, limiting causal inference.

Conclusion

Chronic kidney disease is significantly associated with cerebral small vessel disease, reinforcing the concept of a kidney–brain microvascular axis and CKD being a systemic microvascular disease affecting multiple organs[5,11,17,22,27,28,30,44]. Neuroimaging based detection of CSVD can aid in early risk stratification and implementation of preventive strategies to reduce neurological morbidities in CKD patient thus improving the outcomes and quality of living in these patients [9,10,18,25,32,40,62].

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