Research Square

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Factors associated with intradialytic MoCA scores in chronic hemodialysis patients

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Abstract

Background:

Cognitive impairment is a very common yet underappreciated complication among chronic kidney disease (CKD) patients receiving long-term haemodialysis treatment. Though compromised haemodynamic during the procedure have emerged as contributing factors, the effect of psychological influences like anxiety, as well as behavioural factors like sleep disturbance, remains an understudied issue, particularly in low- and middle-income countries.

Objectives

The aim of this study was to investigate cognitive performance in patients undergoing long-term haemodialysis treatment and its relation to sleep quality, level of anxiety, and haemodynamic parameters related to dialysis.

Methods:

A case-controlled observational study was conducted among patients over 18 years on haemodialysis for at least six months or longer in three tertiary care hospitals. In our study we utilized the Montreal Cognitive Assessment (MoCA) as a tool for evaluating cognitive decline in patients. Additionally, the study measured the quality of sleep quality and anxiety in patients using the Pittsburgh Sleep Quality Index (PSQI) and the Generalized Anxiety Disorder-7 (GAD-7) tool. Finally, demographic, clinical, and haemodynamic variables, including pre-dialysis, intra-dialysis, and post-dialysis blood pressure, are analysed using the chi-square and correlation tests, with a p-value < 0.05 being statistically significant.

Results:

The data showed that cognitive impairment was a major issue among the sample group, as most subjects showed mild to moderate cognitive symptoms (68.9%). The cognitive domains that were most affected were "abstraction" and "delayed recall" **(1.01 ± 0.705), (1.74 ± 1.14)** respectively, while "orientation" was least impaired (**4.20 ± 1.27).** Anxiety and sleep quality were seen to be widely prevalent and associated with the CKD patients (73%) and (59.5%) respectively. Besides sleep quality, anxiety severity was related to systolic blood pressure before, during, and after dialysis. There was a very high positive correlation between anxiety levels and sleep disorder severity, given by a correlation coefficient of $r = 0.543$, $p < 0.001$ indicating co-morbidity in CKD patients. Anxiety scores but not sleep quality was correlated to cognitive MoCA scores ($p < 0.001$).

Conclusion:

In essence, patients subjected to long - term haemodialysis present cognitive, which is characterized by substantial cognitive impairment, mainly in relation to higher order brain functions. Among these, anxiety and quality of sleep show strong association, while anxiety presents substantial association with states of cognitive impairment and haemodynamic instability. As far as the present research is concerned, it Favors a patient assessment model, which is multi-dimensional and incorporates cognitive, psychological, and sleep checkups for haemodialysis patient care.

Introduction

Chronic kidney disease (CKD) is becoming a major health issue worldwide as more patients are advancing to end stage renal disease (ESRD) and need renal replacement therapy for life (1, 2, 3). Worldwide, haemodialysis (HD) is the most frequently used modality and has made major survival improvements (3). Nevertheless, along with its life supporting benefits, long term HD is linked to a wide range of systemic complications that go beyond renal function, including adverse neurological and cognitive effects (4).

The impairment of cognitive functions represents a condition which is increasingly being observed in patients with CKD and those on haemodialysis therapy (5).

Depending on the tools for assessment, as well as the design of the studies undertaken and the nature of the patients included (6, 7), the prevalent rates of patients suffering from cognitive impairment as a result of haemodialysis have been quoted as ranging from one-third to more than half of the population of haemodialysis patients (8). For most haemodialysis patients with cognitive impairment, deficits in their attention abilities, executive functions, memory capabilities, as well as their processing speed, have been observed (9). Besides, it is well documented that cognitive impairment in haemodialysis patients is linked with a higher risk of hospital admissions and death (1, 10).

The causes of cognitive impairment in the population with haemodialysis are multifactorial (11). Other than the usual vascular risk factors, namely hypertension, diabetes, and atherosclerosis, which damage the small blood vessels of the brain (12), other mechanisms unique to CKD like chronic inflammation, oxidative stress, anemia, build-up of uremic toxins, and metabolic derangements significantly contribute to brain malfunction (12,

13). Dialysis also through a series of physiological stressors pose a risk, particularly rapid change of fluid and blood pressure fluctuations that may cause cerebral autoregulation to fail in the setting of haemodialysis (14).

Intradialytic hypotension and haemodynamic instability are common during haemodialysis sessions and may lead to repeated episodes of cerebral hypoperfusion (15). Such repetitive episodes, over time, are considered to result in changes in the structure and function of the brain (15, 16), such as damage to white matter and shrinkage of the hippocampus, ultimately causing a gradual decline in cognitive functions (17). The kidney - brain axis concept has been put forward to highlight the tight relationship between the deterioration of the kidneys and neurological sequelae (17), thus pointing out the vulnerable state of the vascular system and endothelial dysfunction, which are common to and affect both organs thus pointing out the vulnerable state of the vascular system and endothelial dysfunction, which are common to and affect both organs (5, 13, 16)

Patients who undergo haemodialysis are increasingly recognized not only for the roles that physiological factors play in their condition, but also for the psychological and behavioural factors that affect their performance of daily activities (4, 7). A major problem in these patients is sleeping disturbance (7, 17). This is due to several factors which includes Uremia, Restless Leg Syndrome, Pruritus, Altered Circadian Rhythms, Dialysis Schedule. Sleep quality of low quantity is also related to the impairment of attention, memory, and executive functions, which can result in cognitive impairments (1, 9, 10).

For patients needing haemodialysis, they suffer from anxiety which is a neglected problem despite being a common health problem (1, 7). Factors such as a chronic illness problem, being tied to a lifelong treatment process, prognosis concerns, and the restriction of social and work activities often result in severe mental distress (4, 7). Anxiety deteriorates cognitive performance by impairing concentration, decreasing working memory capacity, and altering executive control (1, 9). In addition to that, anxiety and sleep disorders are tightly connected and have a two-way relationship (7, 17). Anxiety causes troubles in sleep initiation as well as sleep maintenance, whereas sleep deprivation may exacerbate anxiety symptoms.

Although there has been an increase in awareness about cognitive impairment, sleep disturbance, and anxiety in haemodialysis populations, most of the studies that exist have looked at these areas separately (6, 9, 10). Very few studies have investigated the combined effects of these disorders on brain function, or their interaction with dialysis related haemodynamic parameters (2, 15). This deficiency is even more distinctive in low- and middle-income countries where socioeconomic factors, access to health care, and dialysis practices may be further complicating neuropsychological outcomes (4).

Given the multidimensionality of brain dysfunction in haemodialysis patients, this requires a multidimensional approach towards assessment (6). Elucidation of inter-relationship among cognitive performance, sleep quality, anxiety level, and haemodynamic instability may lead to early identification of high-risk individuals and also may guide the targeted interventions more effectively (2, 6).

Thus, the present study aims to explore further the effect of long-term haemodialysis on brain function by measuring cognitive abilities and examining the association with sleep quality and anxiety degree as well as haemodynamic factors related to haemodialysis in patients undergoing maintenance haemodialysis.

Methodology

Study Design and Setting

This is a cross-sectional multi-centre study performed in three different locations in Pune, Maharashtra, India. These locations included dialysis units within 3 multi-speciality hospitals. These dialysis units were offering long term haemodialysis to patients suffering from CKD (Stage III-Stage V).

Study Population & Sampling Strategy:

The study population included 148 long term haemodialysis patients suffering from CKD (Stage III-Stage V). Convenience sampling was used to obtain the total of 148 patients (Centre 1: 84 patients; Centre 2: 25 patients; Centre 3: 39 patients). These patients were approached for this study during their routine haemodialysis visits typically lasting 4 hours (consisting of pre-dialysis monitoring and dialysis) with each participant providing informed consent before the study.

The following inclusion criteria were used for selection of patients for this study: 1) Patients on maintenance haemodialysis aged 18 years; 2) Patients on haemodialysis for at least six months; 3) clinically stable patients validated through reports at the time of the study (patients negative for infectious diseases such as HIV, hepatitis B, C, and patients not suffering from any neurological disorders like Dementia or Alzheimer's-Any patients with a known history of major neurodegenerative disorders, previous stroke with residual neurological deficits, severe psychiatric illness, hospitalisation due to acute medical illness within the last four weeks, or significant visual, hearing, or speech impairments that would prevent cognitive testing were excluded from the study) and 4) All participants were able to communicate adequately for the cognitive and psychological assessments.

Data Collection

Data was gathered via patient interviews during dialysis (MoCA was administered 1 hour after initiating dialysis) and examination of medical records for demographic variables such as Age, gender, body weight, comorbid conditions such as hypertension and diabetes mellitus, duration of haemodialysis, and occupation. Similarly, haemodynamic variables such as systolic blood pressure, diastolic blood pressure were recorded at certain intervals such as before treatment (while doing priming), during treatment (1 hour after initiating dialysis), and after treatment (15–30 minutes after dialysis is done) as routine procedures. The pulse rate was recorded during dialysis

Cognitive Assessment

Cognitive assessment was done using the Montreal Cognitive Assessment, MoCA assessing domains such as areas of visuospatial and executive functions, naming, attention, language, abstraction, delayed recall, and orientation. Based on this test, individuals were categorized as having normal cognitive capacity, mild, moderate, or severe cognitive impairment based on specified cut-off values, (0–10 severe, 11–17 mild, 18–26 moderate, and 26–30 considered normal), The level of education is adjusted for by adding one point to the total score for participants with ≤ 12 years of formal education (18).

Sleep Quality Assessment

The Pittsburgh Sleep Quality Index (PSQI) tool is employed for determining the quality of sleep in the patient. The sleep quality tool, i.e. PSQI, is specifically designed for evaluating sleep quality and sleep disturbances for over a month. The range of the global scale is 0-21points with a score of more than 5 reflecting poor sleep quality (19).

Anxiety Assessment

For measuring the level or severity of anxiety, a generalized anxiety disorder 7 questionnaires assessment method was employed. In this regard, GAD 7 includes 7 items which measures the level or severity of anxiety in the last 2 weeks, with a scoring scale ranging from 0 to 21. For measuring the level or severity, standard cut off scores are employed, which include normal (0–4), mild (5–9), moderate (10–14), and severe (15–21). (20)

Haemodynamic Parameters

Blood pressure and pulse measurements taken before dialysis, during dialysis, and after dialysis were used for assessing haemodynamic instability. Systolic and diastolic blood pressure readings were divided into normal or abnormal categories, according to the criteria of standard clinical thresholds, Normal systolic BP (90–130 mmhg), Normal diastolic BP (60–90 mmhg). The changes of these parameters in different dialysis stages were considered as markers of haemodynamic instability; Pulse was considered normal between (70–100 Bpm).

Statistical Analysis

Statistical analyses were carried out with the help of Jamovi (Version 2.6) [Computer Software]. Categorical variables consisted of dichotomous disease states such as diabetes vs non diabetic, hypertension vs non hypertensive, MoCA categories (4 subtypes), Anxiety categories (4 subtypes), and PSQI categories (2 categories)). Categorical variables were presented as counts and percentages. -Continuous variables included Age, weight, Pulse, years of hypertension, years of diabetes, years on dialysis.

Continuous variables were described using mean and standard deviation, median, interquartile range (Q1, Q3), and mode. The test of independence between categorical variables was done by means of the t-test; Kruskal Wallace test, chi square test or Fisher's exact test when appro The test of independence between categorical variables was done by means of the chi square test or Fisher's exact test if the situation required.

Correlation analyses were done to examine the associations between continuous variables. A p value less than 0.05 was considered statistically significant.

Ethical Considerations

Ethical approval

was obtained from the Ethics Committee of the Symbiosis Institute of Health Sciences, Symbiosis International (Deemed) University, Lavale, Pune, under approval number SIU/IEC/1207, prior to study initiation. Written informed consent was obtained from all participants, and confidentiality of patient data was strictly maintained. The study was conducted in accordance with the principles of the Declaration of Helsinki and relevant ethical guidelines and regulations.

Results

Demographic Characteristics

Demographic and clinical patient characteristics is described in Table 1 (N = 148 participants). The average age of the study participants was (54.7 ± 12.6) years with a median of 55.5 years (median). Systolic blood pressure before, during and after dialysis were reported to be (145 ± 18.9) mmHg, (133 ± 18.8) mmHg and (136 ± 17.7) mmHgand diastolic blood pressure were reported to be (98.8 ± 12.9) mmHg, (83 ± 11.8) mmHg and (84.8 ± 11.1) mm Hg respectively. The average pulse rate was (82.5 ± 11.6) beats per minute, and the average body weight was (62 ± 7.35) kg. The average duration for which the patients had hypertension and diabetes was (4.45 ± 3.56) years and (3.60 ± 3.65) years, respectively. The average time of which the patients had been on dialysis was (2.74 ± 1.88) years.

Table 1
Demographic and clinical characteristics of the study participants (N = 148)

Domains	Mean ± SD	Median	Range	(Q1-Q3)	Mode
Age	**54.7 ± 12.6**	**55.5**	**25–77**	**(45-64.5)**	**54**
BD BP systolic	**145 ± 18.9**	**145**	**99–205**	**(131.5–158)**	**142**
BD BP diastolic	**89.8 ± 12.9**	**90**	**45–132**	**(81.5–98)**	**88**
DD BP systolic	**133 ± 18.8**	**132**	**94–193**	**(118–148)**	**132**
DD BP diastolic	**83 ± 11.8**	**82**	**43–125**	**(75–91)**	**79**
AD BP systolic	**136 ± 17.7**	**135**	**100–195**	**(118–150)**	**120**
AD BP diastolic	**84.8 ± 11.1**	**84**	**48–120**	**(76–92)**	**84**
pulse	**82.5 ± 11.6**	**80**	**65–126**	**(74–88)**	**78**
weight	**62 ± 7.35**	**62**	**45–95**	**(58–66)**	**65**
hypertension dur.	**4.45 ± 3.56**	**4**	**0–15**	(2–7)	**0**
Diabetes dur.	**3.60 ± 3.65**	**2.25**	**0–15**	**(0–5)**	**0**
dialysis dur.	**2.74 ± 1.88**	**2**	**0–11**	(1–4)	**1**
(BD BP: before dialysis, blood pressure), (DD BP: during dialysis, blood pressure), (AD BP: after dialysis, blood pressure)					

Table 2
Frequency and percentage distribution of demographic and clinical characteristics of participants:

Variable	Option	Mean ± SD	FREQENCY	%
age	> 45	60.6 ± 7.99	110	74.3
	< 45	37.5 ± 5.75	38	25.7
Sex	Male		80	54.06
	Female		68	45.94
Occupation	white collar		35	23.7
	blue collar		113	76.3
pulse	normal	80 ± 7.81	137	92.6
	abnormal	110 ± 11.2	11	7.4
Weight	low BMI	49 ± 2.76	7	4.7
	Normal	61.3 ± 4.77	124	83.3
	high BMI	74.9 ± 6.01	17	11.5
Hypertension duration	Yes	5.35 ± 3.23	114	77
	No	0	34	23
Diabetes duration	yes	4.99 ± 3.39	98	66.2
	no	0	50	33.8
sleep quality	good	3.67 ± 0.989	60	40.5
	poor	9.38 ± 2.83	88	59.5
anxiety	normal	2.62 ± 1.37	40	27
	abnormal	10.4 ± 3.82	108	73
BD BP systolic	normal	120 ± 8.4	112	75.7
	abnormal	153 ± 18	36	24.3
BD BP diastolic	normal	81 ± 7.57	77	52
	abnormal	99.5 ± 10.2	71	47
DD BP systolic	normal	117 ± 9.24	70	47.3
	abnormal	147 ± 12.3	78	52.7
DD BP diastolic	normal	78 ± 8.16	100	67.6
	abnormal	95.2 ± 12.2	48	32.4
AD BP systolic	normal	119 ± 7.37	56	37.8
	abnormal	147 ± 12.6	92	62.2
AD BP diastolic	normal	79.9 ± 7.05	100	67.6
	abnormal	97.5 ± 9.83	48	32.4
(BD BP: before dialysis, blood pressure), (DD BP: during dialysis, blood pressure), (AD BP: after dialysis, blood pressure)				

Clinical and demographics characteristics segregation by group revealed that majority of the participants were above 45 years of age (74.3%) with a mean age of 60.6 ± 7.99 years (Table 1). Majority of responders were blue-collar employees (76.3%) Males comprised 54.06% of the sample. Descriptive statistics of clinical characteristics revealed that majority (76.3%) of participants had normal pulse (I.e. between 70–100 bpm), had normal BMI (83.3%), with prevalent Hypertension (77%) and Diabetes (66.2%). BP before, during, and after dialysis was measured. Abnormal Systolic BP was found to be 24.3%, 52.7% and 62.2%; while abnormal diastolic BP was found in 47%, 32.4% and 32.4%.

Figure 1 depicts the allocation of severity levels among the participants in the study. Most participants were classified in the moderate and mild group, with 68.9% of patients, only 10.8% were normal.

MoCA screening was done during dialysis, which indicates an important role of haemodialysis in cognitive impairment.

Table 3
Descriptive statistics of MoCA cognitive domain scores:

Domains (Total Score)	Mean ± SD	Median	Range	(Q1-Q3)	Mode
Visuospatial (5)	**2.42 ± 1.56**	**2**	**(0–5)**	**(1–4)**	**2**
Naming (3)	**1.91 ± 0.876**	**2**	**(0–3)**	**(1–3)**	**2**
Attention (6)	**3.19 ± 1.69**	**3**	**(0–6)**	(2–4)	**3**
Language (3)	**1.64 ± 0.849**	**2**	**(0–3)**	(1–2)	**2**
Abstraction (2)	**1.01 ± 0.705**	**1**	**(0–2)**	**(0–1)**	**1**
Delayed recall (5)	**1.74 ± 1.14**	**2**	**(0–4)**	(1–3)	**2**
Orientation (6)	**4.20 ± 1.27**	**4**	(2–6)	(3–5)	**4**

Then we wanted to look into the descriptive of MoCA domains score of the study participants in Table 3. we noticed the most damaged domains were abstraction (1.01 **±** 0.705) out of 2 and delayed recall with an average score of (1.74 ± 1.14) out of 5, on the other hand the safest domain was orientation with a mean score of (4.20 **±** 1.27) out of 6.

Table 4
MoCA Key Cognitive Domains

Normal	**(16)**	**Mild (48)**		**Moderate**	**(54)**	**Severe (30)**		**p value**
visuospatial (5)	**4.35 ± 0.55**	**visuospatial (5)**	**3.40 ± 1.07**	**visuospatial (5)**	**1.87 ± 0.912**	**visuospatial (5)**	**0.6 ± 0.563**	**< 0.001**
naming (3)	**2.88±.05**	**naming (3)**	**2.42 ± 0.539**	**naming (3)**	**1.76 ± 0.671**	**naming (3)**	**0.833 ± 0.513**	**< 0.001**
attention (6)	**5.50 ± 0.516**	**attention** (6)	**4.27 ± 1.14**	**attention** (6)	**2.69 ± 1.02**	**attention** (6)	**1.13 ± 0.776**	**< 0.001**
language (3)	**2.75 ± 0.466**	**language** (3)	**2.13 ± 0.57**	**language** (3)	**1.31 ± 0.639**	**language** (3)	**0.867 ± 0.629**	**< 0.001**
abstraction (2)	**2 ± 0**	**abstraction** (2)	**1.31 ± 0.552**	**abstraction** (2)	**0.907 ± 0.486**	**abstraction** (2)	**0.167 ± 0.379**	**< 0.001**
delayed recall (5)	**3.56 ± 0.629**	**delayed recall** (5)	**2.17 ± 1.01**	**delayed recall** (5)	**1.48 ± 1**	**delayed recall** (5)	**0.633 ± 0.850**	**< 0.001**
orientation (6)	**5.69 ± 0.704**	**orientation** (6)	**4.73 ± 0.917**	**orientation** (6)	**3.96 ± 1.12**	**orientation** (6)	**2.97 ± 0.964**	**< 0.001**

Then we subdivided the MoCA scores based on their categories in Table 4 to take a deeper look. The trend of the average scores gradually decreased in all areas as the cognitive impairment increased in severity. The visuospatial scores decreased from 4.35 ± 0.55 for the normal to 0.6 ± 0.563 for the severe group ($p < 0.001$). similarly, naming scores decreased from 2.88 ± 0.05 to 0.833 ± 0.513 ($p < 0.001$), while attention scores decreased from 5.50 ± 0.516 to 1.13 ± 0.776 ($p < 0.001$).

Language, abstraction, and delayed recall domains showed significant declines across the severity spectrum, $p < 0.0001$ for each. Abstraction had a significant decline from 2 ± 0 in the normal group to 0.167 ± 0.379 in the severe group. Orientation scores also declined from 5.69 ± 0.704 in the normal group to 2.97 ± 0.964 in the severe group, with $p < 0.001$. all differences across domains were found statistically significant.

Table 5
Association Between Sleep, Anxiety and MoCA

	MoCA Categories							
	Normal	**Mild**	**Moderate**	**Severe**	**Total**	**p value**	**Mean ± SD**	**p Value**
Good Sleepers (PSQI < 5)	**8**	**31**	**30**	**16**	**83**		**16.4 ± 6.36**	
						0.458		**0.597**
Poor Sleepers (PSQI > 5)	**8**	**17**	**24**	**14**	**65**		**15.8 ± 6.7**	
Normal Anxiety	**6**	**10**	**7**	**11**	**34**		**15.8 ± 8.05**	
Mild Anxiety	**0**	**18**	**32**	**2**	**52**		**16.3 ± 3.93**	
						< 0.001**		**< 0.001****
Moderate Anxiety	**2**	**13**	**5**	**23**	**43**		**14.8 ± 6.24**	
Severe Anxiety	**8**	**4**	**3**	**4**	**19**		**20.3 ± 8.25**	

Next, we wanted to understand whether anxiety and sleep quality are associated with MoCA. Table 5 shows the allocation of MoCA categories based on sleep quality and levels of anxiety. no statistically significant link was identified between sleep quality and categories of cognitive Impairment (p = 0.458), nor with average MoCA scores (p = 0.597).

Conversely, anxiety levels highlighted a statistically significant association with MoCA categories (p < 0.001) and average MoCA scores (p < 0.001). differences in cognitive performance were noted based on anxiety severity levels, with severe anxiety exhibiting the highest average MoCA scores (20.3 ± 8.25), whereas moderate anxiety displayed a lower average score of (14.8 ± 6.24).

Table 6
Correlation Analysis

Anxiety	**MoCA**	**Anxiety**	**PSQI**
	p value: 0.061	**1**	**p: <0.001****
	r value: 0.154		**r: 0.543**
PSQI	**p: 0.547**	**p: <0.001****	**1**
	r: -0.050	**r: 0.543**	

Next, we tested for correlations between sleep quality, Anxiety, and MoCA scores in Table 6.

A slight positive correlation was found between the MoCA score and anxiety level (r = 0.154), nearing but not achieving statistically significance (p = 0.061).

No notable correlation was observed between MoCA score and sleep quality assessed by PSQI (r= -0.050, p = 0.547), suggesting no linear association between cognitive performance and sleep quality in the study group.

Conversely, a robust positive correlation was found between anxiety levels and PSQI scores (r = 0.543, p < 0.001), indicating that increased anxiety levels correlated with decreased sleep quality.

Table 7
Demographic/Clinical Characteristics Associated with MoCA

		MoCA categories						
Demographics		**Normal (26–30)**	**Mild (18–25)**	**Moderate (11–17)**	**Severe (0–10)**	**p value**	**Mean ± SD**	**p value**
Age	**> 45**	**5**	**19**	**11**	**3**		**15.2 ± 6.54**	
	< 45	**11**	**26**	**46**	**27**	**0.008****	**19.2 ± 5.41**	**< 0.001**
Pulse	**normal**	**8**	**22**	**22**	**12**		**16.1 ± 6.51**	
	abnormal	**8**	**23**	**35**	**18**	**0.654**	**17.6 ± 6.42**	**0.402**
Weight	**low BMI**	**3**	**2**	**3**	**1**		**11.1 ± 6.33**	
	Normal	**8**	**38**	**66**	**6**	**0.679**	**16.8 ± 6**	**0.032***
	high	**5**	**8**	**6**	**2**		**15.1 ± 8.64**	
BP BD S	**normal**	**4**	**7**	**15**	**10**		**15 ± 6.84**	
	abnormal	**12**	**38**	**42**	**20**	**0.344**	**16.6 ± 6.36**	**0.287**
BP BD D	**normal**	**13**	**22**	**29**	**14**		**17.2 ± 6.67**	
	abnormal	**3**	**23**	**28**	**16**	**0.111**	**15 ± 6.14**	**0.022***
BP DD S	**normal**	**10**	**20**	**26**	**14**		**16.8 ± 6.83**	
	abnormal	**6**	**25**	**31**	**16**	**0.637**	**15.6 ± 6.16**	**0.204**
BP DD D	**normal**	**12**	**36**	**41**	**16**		**17 ± 6.34**	
	abnormal	**4**	**9**	**16**	**14**	**0.091**	**14.3 ± 6.54**	**0.014***

(BD BP S: before dialysis, blood pressure, systolic), (DD BP S: during dialysis, blood pressure, systolic), (AD BP S: after dialysis, blood pressure, systolic), (BD BP D: before dialysis, blood pressure, Diastolic), (DD BP D: during dialysis, blood pressure, Diastolic), (AD BP D: after dialysis, blood pressure, Diastolic)

In Table 7 we wanted to find the association between demographic and clinical factors with MoCA domains. Age had a statistically significant association with cognitive impairment ($p = 0.008$), whereas those below 45 had a higher average MoCA score (19.2 ± 5.41) compared to those below 45 (15.2 ± 6.54), ($p < 0.001$). (Table 7)

There was no significant association found for categories of MoCA with pulse, systolic blood pressure (among all phases of dialysis) hypertension, gender, weight and occupation (all $p > 0.005$). nevertheless, significant links were observed with some diastolic blood pressure levels. abnormal before dialysis diastolic blood pressure levels were associated with lower average MoCA score categories (15 ± 6.14 vs 17.2 ± 6.67; $p = 0.022$) (Table 7). during dialysis blood pressure diastolic levels were also significant ($p = 0.014$) (Table 7), and after dialysis diastolic blood pressure levels showed a significant association with cognitive impairment categories ($p = 0.009$) (Table 7), also diabetes duration demonstrated a strong link with MoCA categories, although the association was lower at $p = 0.042$. in comparison to the non-diabetic population, whose average scores was 18.8 ± 5.85 ($p < 0.001$) (Table 7)

		MoCA categories						
Demographics		**Normal (26–30)**	**Mild (18–25)**	**Moderate (11–17)**	**Severe (0–10)**	**p value**	**Mean ± SD**	**p value**
Age	**> 45**	**5**	**19**	**11**	**3**		**15.2 ± 6.54**	
BP AD S	**normal**	**9**	**17**	**21**	**12**		**16.9 ± 7.01**	
	abnormal	**7**	**28**	**36**	**18**	**0.554**	**15.7 ± 6.12**	**0.233**
BP AD D	**normal**	**14**	**37**	**41**	**15**		**17.3 ± 6.32**	
	abnormal	**2**	**8**	**16**	**15**	**0.009****	**13.3 ± 6.11**	**< 0.001****
Hypertension dur.	**yes**	**14**	**36**	**48**	**25**		**16.1 ± 6.51**	
	no	**2**	**9**	**9**	**5**	**0.901**	**16.5 ± 6.53**	**0.76**
Diabetes dur.	**yes**	**9**	**29**	**42**	**27**		**15.2 ± 6.48**	
	no	**7**	**16**	**15**	**3**	**0.042****	**18.8 ± 5.85**	**< 0.001****
Gender	**male**	**7**	**29**	**27**	**17**		**16.2 ± 6.36**	
	female	**9**	**28**	**18**	**13**	**0.651**	**16.1 ± 6.69**	**0.972**
Occupation	**white**	**6**	**13**	**11**	**4**		**18.2 ± 6.06**	
	blue	**10**	**32**	**46**	**26**	**0.186**	**15.6 ± 6.52**	**0.61**

(BD BP S: before dialysis, blood pressure, systolic), (DD BP S: during dialysis, blood pressure, systolic), (AD BP S: after dialysis, blood pressure, systolic), (BD BP D: before dialysis, blood pressure, Diastolic), (DD BP D: during dialysis, blood pressure, Diastolic), (AD BP D: after dialysis, blood pressure, Diastolic)

In Table 7 we wanted to find the association between demographic and clinical factors with MoCA domains. Age had a statistically significant association with cognitive impairment ($p = 0.008$), whereas those below 45 had a higher average MoCA score (19.2 ± 5.41) compared to those below 45 (15.2 ± 6.54), ($p < 0.001$). (Table 7)

There was no significant association found for categories of MoCA with pulse, systolic blood pressure (among all phases of dialysis) hypertension, gender, weight and occupation (all $p > 0.005$). nevertheless, significant links were observed with some diastolic blood pressure levels. abnormal before dialysis diastolic blood pressure levels were associated with lower average MoCA score categories (15 ± 6.14 vs 17.2 ± 6.67; $p = 0.022$) (Table 7). during dialysis blood pressure diastolic levels were also significant ($p = 0.014$) (Table 7), and after dialysis diastolic blood pressure levels showed a significant association with cognitive impairment categories ($p = 0.009$) (Table 7), also diabetes duration demonstrated a strong link with MoCA categories, although the association was lower at $p = 0.042$. in comparison to the non-diabetic population, whose average scores was 18.8 ± 5.85 ($p < 0.001$) (Table 7)

Table 8
Odds ratio Analysis of Factors Associated with Cognitive Impairment

		CI	,95%CI	
	odds ratio	lower	Upper	p value
Age	**1.36**	**0.441**	**4.21**	**0.589**
weight	**0.737**	**0.261**	**2.08**	**0.563**
BD BP D	**0.224***	**0.061**	**0.822**	**0.015**
DD BP D	**0.795**	**0.241**	**2.62**	**0.705**
AD BP D	**0.341**	**0.0739**	**1.57**	**0.15**
Diabetes duration	**0.446**	**0.154**	**1.29**	**0.129**
Anxiety	**2.23**	**0.746**	**6.66**	**0.144**
(BD BP D: before dialysis, blood pressure, Diastolic), (DD BP D: during dialysis, blood pressure, Diastolic), (AD BP D: after dialysis, blood pressure, Diastolic)				
Among all variables included, only before dialysis diastolic blood pressure (BD BP D) showed a statistically significant association with the outcome (OR = 0.224, 95% CI: 0.061–0.822, p = 0.015) (Table 8)				

The odds ratio of (0.224) (Table 8)indicates that patients with abnormal BD BP D had significantly lower odds of being in the normal MoCA group

Table 9
Demographic/clinical Factors Association with Sleep (PSQI)

Demographics		Good sleepers PSQI < 5	Poor sleepers PSQI > 5	p value	Mean ± SD	p value
Age <45		21	17	0.906	6.11 ± 3.56	
>45		62	48		6.19 ± 3.48	0.328
Pulse	Normal	77	60		6.13 ± 3.43	
	Abnormal	6	5	0.915	6.75 ± 4.15	0.61
	Low BMI	5	2		3.80 ± 1.48	
Weight	Normal	53	71		6.17 ± 3.25	0.070*
	High BMI	7	10	< 0.001*	7.71 ± 5.01	
BD BP S	Normal	23	13		5.39 ± 2.73	
	Abnormal	60	52	0.278	6.44 ± 3.67	0.256
BD BP D	Normal	54	23		5.17 ± 2.79	
	Abnormal	29	42	< 0.001*	7.31 ± 3.83	< 0.001
DD BP S	Normal	44	26		5.44 ± 2.76	
	Abnormal	39	39	0.116	6.85 ± 3.92	0.092
DD BP D	Normal	67	38		5.42 ± 2.77	
	Abnormal	16	27	0.003*	8.05 ± 4.30	< 0.001
AD BP S	Normal	37	22		5.47 ± 2.79	
	Abnormal	46	43	0.186	6.65 ± 3.82	0.162
AD BP D	Normal	70	37		5.39 ± 2.78	
	Abnormal	13	28	< 0.001*	8.24 ± 4.24	< 0.001
Hypertension dur	yes	68	55		6.20 ± 3.47	
	No	15	10	0.665	6.03 ± 3.62	0.965
Diabetes dur	yes	55	52		6.6 ± 3.62	
	no	28	13	0.064	5.1 ± 2.82	0.028*
Sex	male	48	32		6.36 ± 3.76	
	female	32	33	0.297	5.97 ± 3.14	0.768

(BD BP S: before dialysis, blood pressure, systolic), (DD BP S: during dialysis, blood pressure, systolic), (AD BP S: after dialysis, blood pressure, systolic), (BD BP D: before dialysis, blood pressure, Diastolic), (DD BP D: during dialysis, blood pressure, Diastolic), (AD BP D: after dialysis, blood pressure, Diastolic)

Demographics		Good sleepers PSQI < 5	Poor sleepers PSQI > 5	p value	Mean ± SD	p value
Age <45		**21**	**17**	**0.906**	**6.11 ± 3.56**	
>45		**62**	**48**		**6.19 ± 3.48**	**0.328**
Occupation	**white**	**22**	**12**		**5.47 ± 3**	
	blue	**61**	**53**	**0.248**	**6.39 ± 3.6**	**0.621**
(BD BP S: before dialysis, blood pressure, systolic), (DD BP S: during dialysis, blood pressure, systolic), (AD BP S: after dialysis, blood pressure, systolic), (BD BP D: before dialysis, blood pressure, Diastolic), (DD BP D: during dialysis, blood pressure, Diastolic), (AD BP D: after dialysis, blood pressure, Diastolic)						

To have a clearer view, in Table 9 we demonstrated the relationship between demographics and clinical parameters and sleep quality (PSQI)

significant results were found with varying levels of diastolic blood pressure; ($p < 0.001$), (p0.003), ($p < 0.003$) respectively (Table 9)

The weight category indicated a significant association with sleep quality ($p < 0.001$), where the results indicated that the quality of sleep of the patients with a high BMI had considerably high PSQI scores on average (7.71 ± 5.01) rising from (3.80 ± 1.48) in the low BMI patients. (Table 9).

Table 10
Demographic and clinical Factors Association with Anxiety

		Anxiety categories						
Demographics		**Normal (0–4)**	**Mild (5–9)**	**Moderate (10–14)**	**Severe (15–21)**	**p value**	**Mean ± SD**	**p value**
Age	**> 45**	**19**	**45**	**31**	**15**		**8.93 ± 4.61**	
	< 45	**15**	**7**	**12**	**4**	**0.015***	**7.76 ± 5.07**	**0.127**
Pulse	**normal**	**31**	**49**	**41**	**16**		**8.59 ± 4.64**	
	abnormal	**3**	**3**	**2**	**3**	**0.437**	**9.08 ± 5.99**	**0.699**
Weight	**low BMI**	**3**	**2**	**1**	**1**		**7 ± 6.24**	
	Normal	**27**	**47**	**35**	**15**		**8.55 ± 4.45**	**0.321**
	high	**4**	**3**	**7**	**3**	**0.035***	**10.2 ± 5.69**	
BP BD S	**normal**	**5**	**14**	**11**	**6**		**8.97 ± 4.95**	
	abnormal	**28**	**38**	**32**	**14**	**0.779**	**8.52 ± 4.70**	**0.616**
BP BD D	**normal**	**22**	**27**	**18**	**10**		**8.28 ± 4.99**	
	abnormal	**12**	**25**	**25**	**9**	**0.24**	**9.01 ± 4.45**	**0.203**
BP DD S	**normal**	**16**	**21**	**21**	**12**		**8.32 ± 4.74**	
	abnormal	**18**	**31**	**22**	**7**	**0.398**	**8.97 ± 5.04**	**0.409**
BP DD D	**normal**	**29**	**38**	**25**	**13**		**8.05 ± 4.89**	
	abnormal	**5**	**14**	**18**	**6**	**0.072**	**10 ± 4.08**	**0.008****
BP AD S	**normal**	**13**	**19**	**17**	**10**		**9 ± 4.98**	
	abnormal	**21**	**33**	**26**	**9**	**0.666**	**8.38 ± 4.59**	**0.455**
BP AD D	**normal**	**28**	**41**	**24**	**14**		**8.09 ± 4.8**	
	abnormal	**6**	**11**	**19**	**5**	**0.034***	**10 ± 4.33**	**0.011****
Hypertension dur.	**yes**	**27**	**47**	**32**	**17**		**8.59 ± 4.66**	
	no	**7**	**5**	**11**	**2**	**0.161**	**8.84 ± 5.22**	**0.784**

(BD BP S: before dialysis, blood pressure, systolic), (DD BP S: during dialysis, blood pressure, systolic), (AD BP S: after dialysis, blood pressure, systolic), (BD BP D: before dialysis, blood pressure, Diastolic), (DD BP D: during dialysis, blood pressure, Diastolic), (AD BP D: after dialysis, blood pressure, Diastolic)

we tested again in Table 10 to find the associations between demographic/clinical factors and anxiety courses. Age unveiled statistical significance concerning the relationship between age and anxiety categories (p = 0.015). more specifically, it was noted that the greater the age is related to a wider distribution in the spectrum of anxiety. But not statistically significant (p = 0.127). (Table 10)

		Anxiety categories						
Demographics		**Normal (0–4)**	**Mild (5–9)**	**Moderate (10–14)**	**Severe (15–21)**	**p value**	**Mean ± SD**	**p value**
Age	**> 45**	**19**	**45**	**31**	**15**		**8.93 ± 4.61**	
Diabetes dur.	**yes**	**18**	**41**	**34**	**14**		**9.05 ± 4.58**	
	no	**16**	**11**	**9**	**5**	**0.037***	**7.54 ± 5.04**	**0.037****
Gender	**male**	**16**	**30**	**26**	**8**		**8.63 ± 4.64**	
	female	**18**	**22**	**17**	**11**	**0.432**	**8.61 ± 4.90**	**0.931**
Occupation	**white**	**10**	**14**	**7**	**3**		**5.59 ± 4.75**	
	blue	**24**	**38**	**36**	**16**	**0.408**	**8.94 ± 4.72**	**0.331**
(BD BP S: before dialysis, blood pressure, systolic), (DD BP S: during dialysis, blood pressure, systolic), (AD BP S: after dialysis, blood pressure, systolic), (BD BP D: before dialysis, blood pressure, Diastolic), (DD BP D: during dialysis, blood pressure, Diastolic), (AD BP D: after dialysis, blood pressure, Diastolic)								
we tested again in Table 10 to find the associations between demographic/clinical factors and anxiety courses. Age unveiled statistical significance concerning the relationship between age and anxiety categories (p = 0.015). more specifically, it was noted that the greater the age is related to a wider distribution in the spectrum of anxiety. But not statistically significant (p = 0.127). (Table 10)								

Higher BMI levels were related to anxiety categories, with higher levels of mean anxiety being recorded in the population with high BMI (10.2 ± 5.69). diabetes had a relation to anxiety categories (p = 0.037), with the population of diabetics having recorded higher average anxiety levels compared to the population of non-diabetics 9.05 ± 4.58 (Table 10).

Additionally, after dialysis diastolic BP reading demonstrated significant association with anxiety levels (p = 0.034), though at relatively higher anxiety scores 10 ± 4.08, p = 0.008. (Table 10)

Table 11
Correlation between demographic/clinical variables and cognitive function (MoCA), anxiety levels, and sleep quality (PSQI)

Demographics	MoCA	Anxiety	PSQI
Age	**p: 0.015****	**p:0.002****	**p: 0.121**
	r: – 0.199	**r: 0.254**	**r: 0.128**
Pulse	**p:0.017****	**p: 0.016****	**p: 0.011****
	r: 0.841	**r: 0.197**	**r: 0.208**
Weight	**p: 0.623**	**p: 0.053**	**p: <0.001****
	r: -0.041	**r: 0.159**	**r: 0.399**
BD BP S	**p: 0.121**	**p: 0.208**	**p: <0.001****
	r: -0.128	**r: 0.104**	**r: 0.316**
BD BP D	**p: 0.811**	**p: 0.509**	**p: <0.001****
	r: -0.020	**r: -0.055**	**r: 0.296**
DD BP S	**p: 0.017****	**p: 0.386**	**p: <0.001****
	r: -0.196	**r: -0.074**	**r: 0.371**
DD BP D	**p: 0.407**	**p: 0.526**	**p: <0.001****
	r: -0.069	**r: 0.053**	**r: 0.284**
AD BP S	**p: 0.028****	**p: 0.489**	**p: <0.001****
	r: -0.181	**r: 0.057**	**r: 0.335**
AD BP D	**p: 0.192**	**p: 0.556**	**p: <0.001****
	r: -0.108	**r: 0.049**	**r: 0.294**
Hypertension duration	**p: 0.004****	**p: 0.968**	**p: 0.095**
	r: -0.236	**r: -0.003**	**r: 0.138**
Diabetes duration	**p: 0.004****	**p: 0.158**	**p: <0.001****
	r: -0.237	**r: 0.117**	**r: 0.369**

(BD BP S: before dialysis, blood pressure, systolic), (DD BP S: during dialysis, blood pressure, systolic), (AD BP S: after dialysis, blood pressure, systolic), (BD BP D: before dialysis, blood pressure, Diastolic), (DD BP D: during dialysis, blood pressure, Diastolic), (AD BP D: after dialysis, blood pressure, Diastolic)

Lastly in Table 11, we wanted to study the relationship among demographic and clinical factors with cognitive function (MoCA), anxiety, and sleep quality (PSQI).

Age exhibited a notable negative correlation with MoCA scores (r=-0.199, p = 0.015), suggesting a decrease in cognitive ability as age increases, whereas it revealed a significant positive correlation with anxiety levels (r = 0.254, p = 0.002). no notable correlation was found between age and PSQI scores.

Pulse rate had a significant correlation with all three outcomes, exhibiting a strong positive relationship with MoCA (r = 0.841, p = 0.017) and weaker yet significant correlation with anxiety and PSQI scores.

Weight showed a notable association with anxiety (p = 0.053) and had a strong correlation with decreased sleep quality (PSQI) (r = 0.339, p < 0.001), but not with MoCA scores.

Blood pressure metrics, especially systolic and diastolic measurements during dialysis (BD, DD, and AD), exhibited stable and significant positive correlations with PSQI scores (p < 0.001), indicating that elevated blood pressure levels are associated with worse sleep quality. multiple systolic blood pressure reading showed notable negative correlations with MoCA scores, suggesting poorer cognitive functioning.

Hypertension and diabetes showed a strong negative correlation with MoCA scores (p = 0.004), suggesting reduced cognitive function in the impacted patients. Diabetes demonstrated a significant positive correlation with PSQI scores (r = 0.369, p < 0.001), whereas anxiety was not notably linked to either condition.

Discussion

The study explored cognitive performance in patients undergoing long-term haemodialysis and examined its association with sleep quality, anxiety levels, and haemodynamic parameters. The findings demonstrate a substantial burden of cognitive impairment in this population and highlight the multifactorial nature of brain dysfunction in haemodialysis patients. (21)

Prevalence and Pattern of Cognitive Impairment

Approximately 89.2% of patients scored below 26 on the MoCA during intradialytic assessment, with only 10.8% (Fig. 1) classified as cognitively normal.

More than two-thirds of the population fell into the mild to moderate impairment categories.

This prevalence is higher than many previously reported studies, which often range between one-third to one-half of haemodialysis patients (21, 22, 23). The higher proportion observed in this study may be explained by intradialytic MoCA testing, which could capture the acute haemodynamic and metabolic stress occurring during dialysis sessions. (24)

Importantly, cognitive decline was not uniform across domains (25). Higher-order functions particularly abstraction and delayed recall (mean **±** SD falling from 2 ± 0 to 0.167 ± 0.379 and 3.56 ± 0.629 to 0.633 ± 0.850, respectively) (Table 4) were the most severely affected, whereas orientation was relatively preserved keeping a mean **±** SD score of 2.97 ± 0.964 in the severe group **(**Table 4**)**

Some demographic factors showed an association with lower MoCA scores such as Age p = 0.008, diabetes duration p = 0.042. (Table 7) (24, 26)

This selective vulnerability suggests a predominantly subcortical or vascular pattern of impairment rather than a diffuse cortical dementia process (26, 27). The marked decline in abstraction and memory functions may reflect dysfunction of frontal-subcortical circuits and hippocampal structures, both highly sensitive to hypoperfusion. (28)

The progressive reduction in domain scores across severity categories reinforces the graded nature of impairment and supports the clinical relevance of MoCA stratification in this population. (25)

Our results showed a higher level of cognitive impairment compared to studies where cognitive evaluation was done before dialysis or in relatively stable conditions. Studies such as Iyasere et al. and Lee et al (29, 30). reported executive and memory impairment in haemodialysis patients; however, cognitive screening was generally performed prior to dialysis sessions, reflecting a more physiologically stable state. In contrast, our intradialytic assessment may have captured the additional burden of acute haemodynamic stress, potentially explaining the higher prevalence and severity of impairment observed in our population.

On the other hand, Lambert et al. (31) conducted cognitive testing during the second hour of haemodialysis, allowing a more direct comparison with intradialytic assessment. Similar to our findings, they reported significantly lower MoCA scores among dialysis patients with a multidomain pattern of impairment, particularly affecting memory and executive functions. However, the overall burden of impairment in our cohort appears clearer.

Haemodynamic Instability and Cognitive Function

A central finding of this study is the strong association between diastolic blood pressure (DBP) after dialysis and cognitive impairment. Abnormal DBP after dialysis was significantly associated with lower MoCA scores (p = 0.009) (Table 7) which indicates that after a long time of being exposed to hypoperfusion episodes the cognitive abilities of a CKD patient will drop significantly. (24, 32)

Most importantly, in the odds ratio model, before-dialysis diastolic BP emerged as the only independent predictor of cognitive impairment (OR = 0.224, 95% CI: 0.061–0.822, p = 0.015) (Table 8) which means that Patients with abnormal pre-dialysis DBP had significantly reduced odds of belonging to the normal cognitive group. (33)

Diastolic blood pressure plays a critical role in maintaining cerebral perfusion during cardiac relaxation. Repeated fluctuations in DBP across dialysis sessions may impair cerebral autoregulation (34). Chronic exposure to intradialytic hypotension can lead to recurrent cerebral hypoperfusion. Over time, such episodes may result in white matter injury and hippocampal atrophy, structures strongly implicated in executive function and memory. (28, 34)

Previous studies in CKD and post-transplant populations have demonstrated persistent cognitive impairment even after improvement in renal function, often without a clear correlation with blood pressure parameters. This suggests that while chronic kidney disease contributes to cognitive vulnerability, our findings highlight that acute diastolic haemodynamic instability during dialysis may exert a more immediate and measurable impact on cognitive performance. (35, 36)

Interestingly, systolic blood pressure did not demonstrate the same strength of association with cognitive categories. This suggests that cerebral perfusion in haemodialysis patients may be more sensitive to diastolic changes than to systolic pressures. These findings support the concept that dialysis-related haemodynamic instability is not a cardiovascular concern but a neurovascular one. (37)

Anxiety and Cognitive Performance

Anxiety was highly prevalent in this cohort, affecting 73% of participants (Table 1)

Anxiety categories showed a significant association with MoCA categories ($p < 0.001$) (Table 5) (23), and significant differences in mean MoCA scores were observed across anxiety severity levels (38), what was surprising that it wasn't declining as expected we observed a little increase from normal to mild (15.8 ± 8.05 to 16.3 ± 3.93) (Table 5) and then it declined to 14.8 ± 6.24 in the moderate group and re-peaked again to 20.3 ± 8.25 in the severe group (Table 5), which supports the hypothesis that severe anxiety levels may improve cognitive levels, but this concept was hypothesised on healthy individuals but not in the CKD cases. (39)

Although the linear correlation between total MoCA scores and anxiety approached but did not reach statistical significance ($r = 0.154$, $p = 0.061$), the categorical analysis clearly demonstrated cognitive differences across anxiety groups, which may be an indicator to a stronger link in different population if more studies were applied.

Anxiety may influence cognition through several mechanisms:

- Reduced attentional capacity
- Working memory overload
- Executive dysfunction
- Increased sympathetic activation leading to vascular instability

Furthermore, anxiety was associated with diastolic BP after dialysis $p = 0.034$, suggesting a physiological pathway linking psychological stress with haemodynamic changes (40). Chronic sympathetic activation may worsen vascular instability during dialysis, potentially amplifying cerebral hypoperfusion. (39)

Anxiety also showed an association with other demographic factors like Age, weight, and diabetes duration ($p = 0.015$, $p = 0.035$, and $p = 0.037$. respectively) (Table 10)

These findings reinforce the importance of considering psychological health when evaluating cognitive performance in haemodialysis patients. (39)

Sleep Quality and Cognitive Function

Sleep disturbance was common, with 59.5% of participants classified as poor sleepers. (Table 1) However, no statistically significant association or correlation was found between sleep quality (PSQI) and MoCA scores.

This finding suggests that although sleep disturbance is prevalent, it may not independently drive cognitive impairment in this population. One explanation may be that vascular damage shows a stronger and more direct effect on cognitive function, overshadowing the independent contribution of sleep. (41)

Nevertheless, sleep quality showed strong associations with haemodynamic variables and anxiety. A robust positive correlation was observed between anxiety and PSQI scores ($r = 0.543$, $p < 0.001$). (42)

This indicates a bidirectional relationship: anxiety may impair sleep, and sleep disruption may exacerbate emotional dysregulation. (42)

Thus, sleep may function more as a mediating factor within a broader psychophysiological network rather than as a primary determinant of cognitive decline. (41)

More importantly, sleep quality showed a very strong association with blood pressure before ($p < 0.001$), during (0.003), and after dialysis ($p < 0.001$), we also noticed a very strong association with weight ($p < 0.001$) (Table 9) (43)

Multidimensional Model of Cognitive Dysfunction in Haemodialysis

The results support a multidimensional explanatory framework:

1. Primary vascular mechanism:

1. Repeated diastolic BP fluctuations - cerebral hypoperfusion - white matter and hippocampal injury - executive and memory deficits. (28, 34)

hippocampus is important because it is responsible for memory formation and delayed recall, while white matter is important because it is responsible for transmitting signals between different brain regions and executive functions and abstraction (27, 28)

3. Psychological amplification:

1. Anxiety - impaired attention and executive efficiency + sympathetic activation -haemodynamic instability. (39, 42)

sympathetic nervous system activation is important because it increases blood pressure fluctuations, increase hemodynamic instability, increases the likelihood of cerebral perfusion. (39)

3. Sleep as a contributing factor:

Closely linked to anxiety and BP changes, but not independently predictive of global cognitive decline. (41, 42, 43)

The pattern of impairment predominantly affecting higher-order cognitive domains aligns with a vascular-subcortical profile rather than a diffuse degenerative process like Alzheimer's. (27, 28, 35)

Clinical Implications

The findings suggest that management of haemodialysis patients should extend beyond biochemical and renal parameters. Routine monitoring should include:

- Stability of diastolic blood pressure (32)
- Screening for anxiety (e.g., GAD-7) (39)
- Assessment of sleep quality (PSQI) (43)
- Periodic cognitive screening (MoCA) (25)

Early identification of haemodynamic instability and psychological distress may allow timely interventions aimed at preserving neurological function. (35)

A multidisciplinary approach involving nephrologists, neurologists, psychologists, and sleep specialists may improve long-term neurological outcomes and overall quality of life. (39)

Recommendations for the clinicians

This study's results lead us to propose several guidelines for how healthcare providers can better take care of patients receiving long-term haemodialysis (HD). Integration of routine cognitive assessment into every patient's HD care will help identify signs of cognitive impairment early among older patients and those at risk (long-duration HD, and/or co-existing diseases e.g., hypertension, diabetes). There should be an ongoing assessment process, in addition to the regular screening originally initiated to assist healthcare professionals provide the best possible care to their haemodialyzed patients; particularly anxiety is prevalent among this patient cohort, and is commonly associated with cognitive impairment, sleep disturbances, and generate complications (i.e., hypotension)/cardiovascular instability during HD. Although there was not a direct link established between sleep quality and any of the measures of global cognitive functioning evaluated in this investigation, there was a significant correlation identified between anxiety/cardiovascular instability and sleep, suggesting that issues relating to sleep should be evaluated and addressed. Finally, all clinicians should emphasize the need for careful monitoring of hemodynamic stability in patients receiving HD prior, during and following their treatment through individual HD prescriptions and appropriate volume management (i.e., buccal space, total body volume).

Limitations

Despite its important findings, this study has several limitations.

First, the cross-sectional design limits causal inference. While significant associations were identified, longitudinal studies are required to determine whether haemodynamic instability and anxiety precede cognitive decline or result from it.

Second, cognitive, sleep, and anxiety assessments relied on screening tools rather than comprehensive neuropsychological or psychiatric evaluation. Although MoCA, PSQI, and GAD-7 are validated instruments, self-reported measures are subject to reporting bias.

Third, neuroimaging was not performed. The absence of MRI data prevents direct correlation between cognitive findings and structural brain changes such as white matter lesions or hippocampal atrophy.

Fourth, blood pressure measurements were recorded at defined intervals rather than continuously, potentially missing transient intradialytic hypotensive episodes that may be clinically significant.

Finally, the findings may not be generalizable to other geographic or socioeconomic settings due to variations in dialysis practices and patient characteristics.

Abbreviations

CKD
Chronic Kidney Disease
MoCA
Montreal Cognitive Assessment
PSQI
Pittsburgh Sleep Quality Index
GAD-7
Generalized Anxiety Disorder 7
ESRD
End Stage Renal Disease
CI
cognitive Impairment
HD
Haemodialysis
BD BP S
Before Dialysis Blood Pressure Systolic
BD BP D
Before Dialysis Blood Pressure Diastolic
DD BP S
During Dialysis Blood Pressure Systolic
DD BP D
During Dialysis Blood Pressure Diastolic
AD BP S
After Dialysis Blood Pressure Systolic
AD BP D
After Dialysis Blood Pressure Diastolic
SBP
Systolic Blood Pressure
DBP
Diastolic Blood Pressure
BMI
Body Mass Index

Declarations

Funding

No funding was received for this study.

• Clinical Trial:

Clinical trial number: not applicable.

• Ethics and Consent to Participate:

Ethical approval was obtained from the Ethics Committee of the Symbiosis Institute of Health Sciences, Symbiosis International (Deemed) University, Lavale, Pune, under approval number SIU/IEC/1207, prior to study initiation. Written informed consent was obtained from all participants, and confidentiality of patient data was strictly maintained. The study was conducted in accordance with the principles of the Declaration of Helsinki and relevant ethical guidelines and regulations.

• Consent to publish declaration:

Not Applicable.

• Availability of Data and Materials:

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contribution

AS: data analysing, drafting and finalizing the manuscriptPK: data collectionDF: data analysing, drafting the manuscriptKD: choosing the idea, data collectionSJ: overall supervising

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Figures

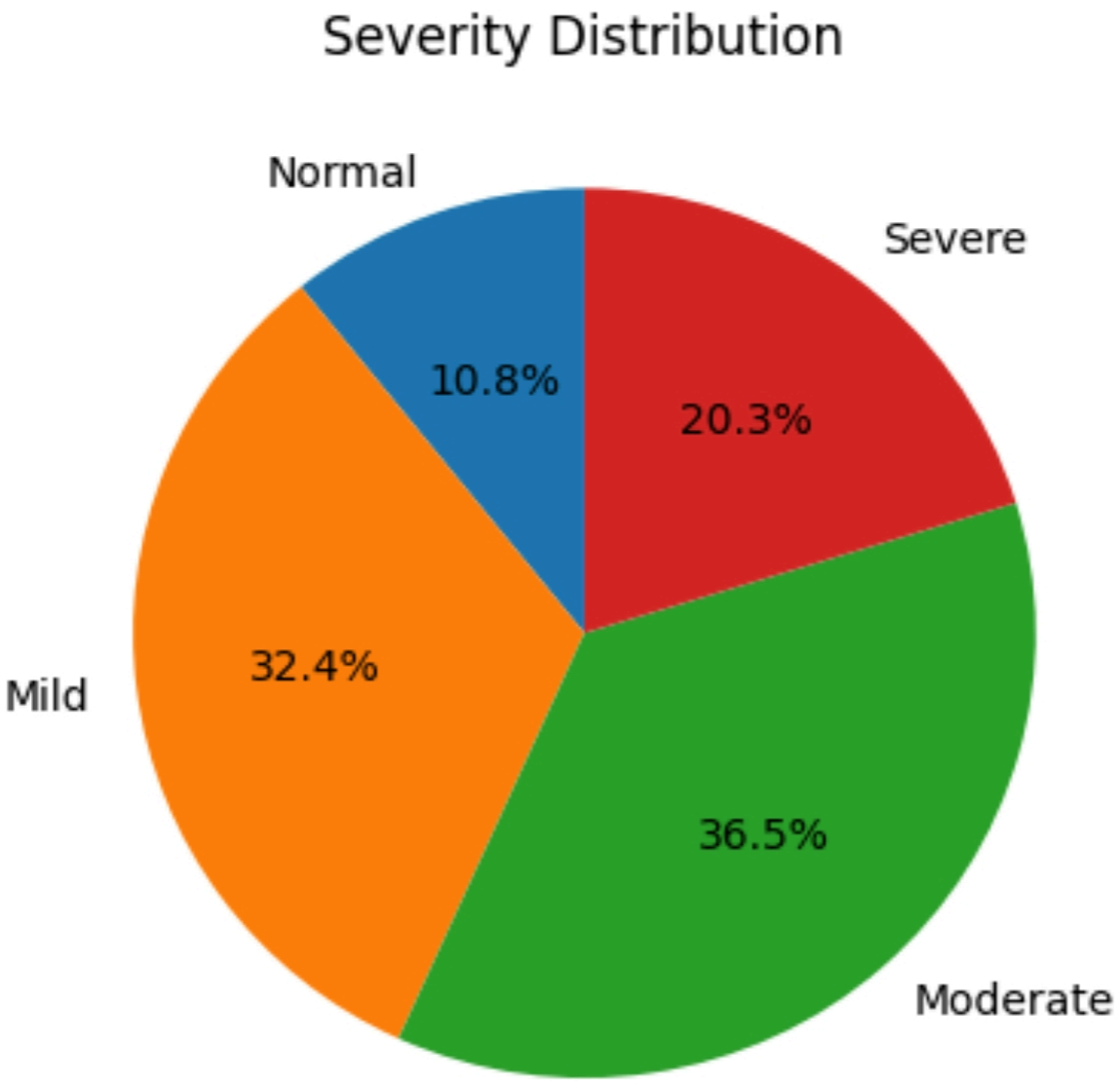


Figure 1

Cognitive status based on MoCA (During Dialysis)