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2017

Comparison of the extent and pattern of cognitive impairment among predialysis, dialysis and transplant patients: a cross sectional study from Australia

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Publication Details

Lambert, K., Mullan, J., Mansfield, K. & Lonergan, M. (2017). Comparison of the extent and pattern of cognitive impairment among predialysis, dialysis and transplant patients: a cross sectional study from Australia. *Nephrology*, 22 899-906.

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Abstract

Aim: The aim of this study was to compare the extent of cognitive impairment and the types of cognitive deficits in an Australian cohort of four patient groups with end stage kidney disease. Characteristics predicting the presence of cognitive impairment were also evaluated.

Methods: Observational cross sectional study of one hundred and fifty five patients with end stage kidney disease recruited from a regional Australian renal unit. Eligible participants included those whose estimated Glomerular Filtration Rate was < 30 ml/min per 1.73m^2 ; were undertaking peritoneal or hemodialysis, or had received a kidney transplant. The Montreal Cognitive Assessment tool was used to screen the study participants for cognitive impairment and evaluate cognitive deficits. Cognitive impairment was defined as a total Montreal Cognitive Assessment tool score $\leq 24/30$.

Results: The extent of cognitive impairment varied between the four groups with end stage kidney disease. Factors predicting the presence of cognitive impairment included undertaking dialysis, age ≥ 65 , male gender, and the presence of diabetes or cerebrovascular disease. Deficits in executive function, attention, language, visuospatial skills, memory and orientation were common amongst the study participants, and these deficits varied according to which end stage kidney disease group the participants were in. Limitations to the study included the cross sectional design and that the presence of confounders like depression were not recorded.

Conclusion: The impact of disparities in the cognitive capabilities identified in this study are likely to be far reaching. Tailoring of education and self management programs to the cognitive deficits of individuals is required.

Disciplines

Medicine and Health Sciences

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Title: A comparison of the extent and pattern of cognitive impairment among predialysis, dialysis and transplant patients: a cross sectional study from Australia.

Short title: Cognitive impairment among predialysis, dialysis and transplant patients

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Keywords: cognitive impairment, dialysis, kidney transplant, predialysis, self management

Introduction

Self management of End Stage Kidney Disease (ESKD) requires patients to evaluate and respond to changes in clinical symptoms (such as blood glucose levels); to manage and adhere to multifaceted medication regimens (such as phosphate binders), and to implement a complex and often contradictory dietary prescription. Unfortunately, self management can be compromised by cognitive impairment (CI) (1, 2).

The evidence suggests that CI is common in people undertaking dialysis (especially hemodialysis), and that dialysis patients differ significantly from normal controls with respect to the prevalence of CI (3-6). For example, it has been estimated that 8.6-19% of the general population have CI (7-11), whereas 28.9% (12) to 80% (13-15) of dialysis patients may have CI. However, the literature is unclear regarding the extent of CI in those with ESKD not undertaking dialysis, and the evidence regarding transplant patients is conflicting (16, 17).

While evidence is consistent that cognitive deficits in orientation, attention and executive function are common in hemodialysis patients (3); the evidence is much less clear about the cognitive deficits in other groups with ESKD (3, 18) . This is an important knowledge gap because CI is well recognised as an independent predictor of mortality in people with ESKD (19, 20), and because it can adversely impact on decision making ability and judgement (21). Correctly identifying those with CI, and understanding the types of cognitive deficits has significant implications for the design and delivery of health information (such as dietary education materials), and self management programs for people with ESKD.

The Montreal Cognitive Assessment Tool (MoCA) has been recommended as an ideal screening tool for CI in people with ESKD (13). This is due to the higher sensitivity and specificity of the MoCA when compared to the Mini Mental State Exam (22). The MoCA assesses a number of cognitive capabilities including executive function, visuospatial skills, attention, language, memory and orientation (23). However, no studies have compared the differences in CI or the types of deficits that may exist between the four common groupings of patients with ESKD: those considered predialysis; and those undertaking a renal replacement therapy such as hemodialysis, peritoneal dialysis or a kidney transplant. Similarly, there have not been any studies published utilising this tool in people with ESKD in the Australian setting

Therefore, the aims of this study were to explore whether CI was present among four common groups of patients with ESKD, and to compare and contrast the nature of any cognitive deficits exhibited by these different groups. In addition, factors potentially predictive of CI, such as age, gender and comorbid disease were also explored.

Subjects and Methods

Invitations to participate in this cross sectional study were sent by mail to all adult patients (≥ 18 years of age) with ESKD ($n=227$) attending the renal unit of a large regional Australian hospital. This included patients with ESKD not undertaking dialysis (ie those with an estimated $GFR < 30 \text{ ml/min/1.73m}^2$) (PRE group); those undertaking peritoneal dialysis (PD group) or hemodialysis (in centre or at home) (HD group); and those who had received a kidney transplant (KT group). Patients with dementia or known CI, as determined by their treating renal physician, were excluded from the study, as were patients with an acute illness in hospital.

The MoCA tool (23) was administered by one of three research dietitians after receiving written informed consent from the participant. Training regarding the administration and scoring of the MoCA was conducted according to the instructions provided by the author of the MoCA and freely available on the website www.mocatest.org. For those with poor vision, the 'blind' version of the MoCA (24) was used. For those undertaking hemodialysis in centre, the MoCA was administered during the second hour of the patient's hemodialysis session within the renal unit. This was intentional and was designed to assess cognitive capabilities at a time when health professionals often provide education to patients receiving hemodialysis. Professional interpreter services were used with the relevant translated version of the MoCA to complete the assessment with patients who could not communicate in English. Scores on the MoCA range from 0 to 30 with a higher score being indicative of better cognition. A cut off value of $\leq 24/30$ was used to indicate the presence of CI (13).

Calculation of the scores for the domains of executive function, visuospatial skills, attention, language, working memory and orientation utilised the method described by the authors of the MoCA (23).

Demographic and clinical information such as age, gender, educational level, comorbid chronic disease burden, dialysis adequacy and duration of renal replacement therapy were obtained from the patient records. Details regarding the presence of chronic disease were limited to the presence of lung disease, coronary artery disease, peripheral vascular disease, diabetes, cerebrovascular disease and cancer. These chronic diseases were chosen because this information is routinely collected for all patients receiving a renal replacement therapy in Australia (i.e. dialysis or a transplant) (25). The definition of comorbidity used in this study was three chronic conditions, because this is considered the norm for people with chronic kidney disease (26). Approval for the study was received from the local human research

ethics committee [removed for blinded peer review] and all participants provided written and verbal consent.

Statistical analysis was performed using SPSS (version 21; SPSS, Chicago, IL, USA). The Shapiro-Wilk Test was used to assess normality. Scores for the MoCA and its subcomponent scores was negatively skewed and were therefore transformed via reflection and log10 prior to analysis. Differences between groups were analysed using the independent samples t-test or one-way analysis of variance with post hoc analysis using the Bonferroni post hoc test for multiple comparisons. Data is reported as mean and 95% confidence interval, and proportions scoring below normative values for normal controls. Categorical variables are expressed as counts and percentages (%) and were evaluated using Pearson's Chi Square test. Spearman's correlation coefficient (rho) was used to determine the relationship between age, dialysis adequacy and duration of renal replacement therapy (RRT) with total MoCA score and sub scores. Logistic regression was used to determine predictors of CI. The dependent variable of CI was dichotomised using a cut off score of $\leq 24/30$ (13). All independent variables with a $p < 0.10$ in univariate analyses or variables known to be associated with CI in the four groups with ESKD (eg PVD (19)) were included in the final model. Statistical significance was set at a p value of 0.05.

Results

A total of 155 individuals agreed to participate in the study (giving an overall response rate of 68.3%). Study participants did not differ from those who declined to participate for age, gender or English speaking status. However, there were significantly more predialysis patients in the group who declined to participate ($p < 0.001$). The median age of the participants was 66 years (Interquartile range, IQR: 55-75), with patients in the transplant

group being significantly younger (58.5 (IQR: 49-66) years) than the other three groups ($p < 0.001$, Table 1). The majority of study participants were males ($n = 92$, 59.4%), had less than 12 years of schooling ($n = 88$, 56.8 %) and were undertaking either hemodialysis ($n = 54$, 35%) or had received a transplant ($n = 52$, 34%) (Table 1). The transplant group had a significantly longer duration of renal replacement therapy compared to the dialysis groups (median duration 8.1 years (IQR: 4.1-14.3), $p < 0.001$). Both the peritoneal and hemodialysis groups were achieving dialysis adequacy as evidenced by their Kt/v values (27, 28). The mean estimated GFR of the predialysis group was 11.9ml/min (sd 4.7) indicating stage 5 chronic kidney disease.

Information regarding comorbid disease burden was not available for 25% ($n = 41$) of the participants including all of the predialysis patients. Half of the participants had more than three comorbidities (Table 2), with almost three quarters of the hemodialysis group ($n = 32$, 71.1%) having more than 3 comorbidities. Moreover, the hemodialysis group had significantly greater proportions of patients with coronary artery disease and peripheral vascular disease than the kidney transplant group. Furthermore, more than one third ($n = 17$, 34.7%) of the kidney transplant group had cancer, and this was significantly higher than all other groups.

Binary logistic regression was undertaken to identify independent predictors of the presence of CI. Independent predictors were found to be: undertaking dialysis (OR 3.09, 95% confidence interval: 1.07-8.94, $p = 0.04$); age ≥ 65 (Odds Ratio [OR] 3.31, 95% confidence interval: 1.14-9.65, $p = 0.03$); male gender (OR 3.09, 95% confidence interval: 1.07-8.89, $p = 0.04$); and the presence of cerebrovascular disease (OR 4.98, 95% confidence interval:

1.27-19.45, $p=0.02$) or diabetes (OR 3.76, 95% confidence interval: 1.10-12.93, $p=0.04$)

(Table 3).

As dialysis was found to be an independent predictor of the presence of CI, the total MoCA scores of the dialysis and non-dialysed patients (predialysis and transplant) were compared (Table 4a). Results indicate that dialysis patients had significantly lower total MoCA scores ($p<0.001$) and CI was more commonly present in this patient group than the non-dialysed group (53.2% vs 18.4%, $p<0.001$). Further analysis of the differences between the four groups indicate that CI was present in all four groups with ESKD (Table 4b). However, disparities were apparent in the extent and severity of CI between these groups. The proportion of participants with a MoCA score ≤ 24 (indicating CI was present) did not differ between the peritoneal and hemodialysis groups (48.0% versus 55.6%, respectively). The hemodialysis group (55.6%) however, had a significantly higher proportion of patients with CI, compared to the predialysis (16.7%) and kidney transplant groups (19.2%). These results are further reflected in the total MoCA scores (Table 4b) highlighting that the hemodialysis group had significantly lower mean MoCA scores than the predialysis and kidney transplant groups.

Analysis of the correlation between age, RRT duration and dialysis adequacy with total MoCA scores and scores for the individual domains within the MoCA are summarised in Table 5. There was a statistically significant negative association between increasing age and total MoCA score, which was also the case for the following MoCA domains; executive function, visuospatial skills, memory and language (Table 5). In addition, RRT duration was weakly associated with attention scores (Spearman's $\rho = -0.20$; $p=0.01$). Dialysis adequacy (as assessed by Kt/V) was not associated with any domain or total MoCA score in either the

hemodialysis or peritoneal dialysis groups. . Further analysis of the relationship between eGFR in the predialysis group and total MoCA score was undertaken. This indicated there was a non-significant relationship between the two variables of eGFR and total MoCA score (n=24; Spearman's rho 0.06, p=0.80).

An examination of the extent and types of cognitive deficits present in the four groups with ESKD is shown in Figure 1. This figure illustrates the proportion of participants achieving MoCA scores below normative values (norms) for normal controls (29). The norms were derived from 90 healthy older community dwelling Canadians with a normal neuropsychological profile and mean age of 72.8 years (23). In this study, deficits in executive function were present in all four groups. More than half of the dialysis patients scored below norms compared to 29.2% of the predialysis and 38.5% of the kidney transplant groups. Deficits in visuospatial skills were apparent in half of the predialysis and 44.4% of the hemodialysis groups and this was significantly greater than in the transplant group (15.4%, $p<0.05$). Deficits in attention were apparent in more than one quarter of the dialysis and transplant groups. Language skills were impaired in all four groups, and to the greatest extent in the peritoneal (60%) and hemodialysis (57.4%) groups. The cognitive domain that was most impaired in all four groups was memory, which affected at least 50% of participants in each of the four groups. Eighty five percent of the hemodialysis group exhibited impairment in this cognitive domain, and this was significantly higher than the predialysis (54.2%) and transplant groups (51.9%, $p<0.05$). Deficits in orientation were uncommon in most groups, except the hemodialysis group where 46.3% of the hemodialysis group scored below norms, and this was significantly more than in all other groups ($p<0.001$).

Discussion

In this cross sectional observational study of four groups of Australian patients with ESKD, we have shown that CI was present in all four groups with ESKD, although disparities were apparent in the types and extent of cognitive deficits. Identified predictors of CI included undertaking dialysis, age ≥ 65 , male gender, and the presence of diabetes or cerebrovascular disease. These predictors were common among the study participants indicating that the findings of this study have important implications for the design and delivery of health information and self management programs for people with ESKD.

Our results regarding the extent of CI are similar to previous studies showing that CI is more common in those undertaking hemodialysis (13, 19, 30-33); in those who are older (12, 14, 19, 34); and that CI was equally common in adequately dialysed peritoneal and haemodialysis patient groups (35). However, our results regarding the extent of CI in those undertaking peritoneal dialysis is higher than almost all previous studies published (12, 14, 36-38). We speculate that the variations from previous studies on the prevalence of CI in peritoneal dialysis are the result of using different assessment tools or applying different study methods when using the MoCA. For example, previous work by Shea et al (12) using the MoCA to screen for CI in those receiving peritoneal dialysis in Hong Kong, utilised a cut off of 21 or 22/ 30 based on previous validation studies in their setting, compared to a cut off $\leq 24/30$ in this study.

There is scarce literature available describing and comparing the cognitive capabilities of predialysis and transplant groups. Our finding, that CI was present in around one in every six predialysis patients (16.7%), and one in every five kidney transplant patients (19.2%), suggests that the prevalence of CI in these groups are not different to that in the general

population (7-11) or previous research in these groups (39-41). However, it remains important to note that a substantial number of predialysis and kidney transplant patients still demonstrated impairments (ie scores below normative values (23)) in the cognitive domains of executive function, visuospatial skills, language and memory, which may in part be related to comorbid disease burden. Further research with larger sample sizes is required in these patient groups to evaluate this hypothesis, as well as to examine the potential impact of impairments in these domains on self management of ESKD.

Successful self management requires a range of skills. These skills include: problem solving; making decisions; finding and using relevant resources; developing a partnership between the patient and health professional; making, taking and sustaining self management actions; and applying and tailoring information obtained to suit the needs of the individual (42). However, all of these components of self management require adequate cognition to be successful (43). In the heart failure context for example, it has been shown that self management programs conducted without consideration given to the self management capacity and cognitive capabilities of participants are likely to be ineffective (44, 45). It is therefore surprising, that there is very little research that directly addresses, or even acknowledges, the potential impact of CI on self management in ESKD. Future efforts should therefore be directed to exploring this aspect in more detail in patients with ESKD.

The most common CI related deficit in this study for each of the four patient groups was memory, and similar to the findings of O'Lone et al (3), where no difference was seen in the extent of memory deficits between the peritoneal and hemodialysis groups. These findings are important because deficits in memory can directly impact on our patient's ability to learn and recall information provided, subsequently affecting their self-management skills of

problem solving, decision making, finding appropriate resources, and sustaining self-management actions. It is also worth noting that MoCA specifically tests working (or short term) memory; and some have suggested that individuals with diminished working memory are probably incapable of adhering to treatment recommendations (even if motivated) due to an inability to retain and retrieve new information (46). Further research into the use of memory aids or cognitive stimulation training (47) and how these impact on self management in ESKD is required.

Deficits in executive function were apparent in all four groups of ESKD participants included in the current study. This is a key finding because diminished executive function could impact on the ability of an individual to successfully self monitor, and to make and sustain appropriate behaviour change in relation to their self management goals (42). Research on the impact of deficits in executive function in ESKD are lacking. However, research in other chronic disease cohorts has demonstrated that deficits in executive function are strongly associated with medication non adherence in older adults (48); poor self management in individuals with diabetes (49) and higher mortality rates in individuals with heart failure (50). Strategies often used to improve adherence, such as motivational interviewing or health coaching are likely to be ineffective in individuals with diminished executive function, because normal cognitive function and ability to control impulsive behaviour is assumed.

Finally, deficits in language and attention, like those reported in this study, would also be expected to compromise the ability to learn and perform self management successfully.

Diminished language skills are believed to be a good indicator of the likelihood that an individual is not able to adequately comprehend and follow advice (46). In this study, impairments in language were experienced by more than 25% of participants in all four

groups. Poor scores on MoCA items relating to language are believed to represent poor retention of auditory information, and in the self management context, may lead to mishearing instructions or hearing only part of the message (51). Individuals with diminished language skills may also have difficulties reading, writing and recalling self-management tasks and goals; as well as undertaking multistep instructions for the same reason. Adequate skills in attention are also an important component of learning how to self manage. Some authors have stated that attention is considered to be the foundation of learning (52). Deficits in attention therefore reduce the ability of the individual to selectively focus on a given task long enough to accomplish a goal. This skill was especially problematic for those in the hemodialysis group, and in around one in every three patients in the peritoneal dialysis and kidney transplant groups. Studies investigating the utility of specific strategies to improve language and attention deficits in individuals with ESKD are warranted.

The clinical implications of our findings are that self management support and patient education, that are specifically tailored to the cognitive capabilities, coexisting comorbid disease burden and health literacy skills (53) of the patient with ESKD, are necessary. We believe that the results of our study also support the proposition that health professionals should routinely screen all people with ESKD for CI, which would help to identify patients at risk of poor treatment adherence. In this study, older males undertaking dialysis, with diabetes and cerebrovascular disease would be a high risk group for CI and we suggest they would be likely to struggle with self management of their ESKD. Further research is required into the timing and feasibility of innovative tailored approaches to patient education and self management in people with ESKD. This is an integral part of providing high quality personalised, patient centred health care (54, 55). This is especially important in nephrology

where patients are complex and exhibit multimorbidity, frailty, CI and other geriatric syndromes (17).

There are several important limitations to this research. Firstly, the cross sectional nature of this study with relatively small patient numbers prevents inferences regarding the potential changes in cognition that may occur when changing between modalities. Unequal numbers between patient groups may have also impacted on our findings. Longitudinal studies with larger sample sizes investigating how cognitive capabilities change over time were not possible in this study but are currently underway by other research groups (56, 57). Secondly, confounders such as the presence of depression was not recorded in this study, and yet it is well known that depression is strongly associated with CI (37). Similarly, the comorbid disease status was not recorded for approximately 25% of participants in this study (including all predialysis patients). The fact that those with known cognitive impairment were excluded from the study may underestimate the prevalence of CI. The lack of normative values for patients with kidney disease may also be a potential limitation. The normative values used in this study have also been used in several previous studies with younger CKD populations and found that the MoCA still showed high sensitivity and specificity in these CKD populations (13, 58). Further, the MoCA has been shown to be age and gender independent (59). We therefore believe that the use of these norms and the results obtained in this study are appropriate. Additional limitations may include failing to account for several other potential confounders such as cardiovascular disease, stroke, anemia and uremic toxins. Further investigation of these potential confounders on cognitive impairment is required. Future work exploring the unexplained, but statistically significant negative relationship between attention and RRT duration is also warranted. The strengths of this study include the nature of the study design and high participant response rate. Finally, even though the results of this study

are from a single centre in one local health district, our participants were similar to ANZDATA Registry 2014 (25) figures for age, gender and number of comorbidities. We also believe this to be the first study that has described the extent of CI and the types of cognitive deficits in those with ESKD in an Australian setting.

In summary, the extent of CI and deficits in executive function, attention, language, visuospatial skills, memory and orientation varied between the four ESKD groups investigated as part of this study. Predictors of CI included older age (≥ 65 years), male gender, undertaking dialysis and diagnosed with diabetes and/or cerebrovascular disease. These findings provide valuable information which can be used to tailor education and self-management interventions to better suit the needs of these different patient groups.

Acknowledgements

The authors declare that the results presented in this paper have not been published previously in whole or part, except in abstract format.

Support: This study was funded by the Australian New Zealand Society of Nephrology.

Financial disclosure: The authors declare that they have no other relevant financial interests.

Contributions: Research idea and study design: KL, ML; Data acquisition: KL; Data analysis/interpretation: KL, ML, JM, KM; Statistical analysis: KL. Each author contributed important intellectual content during manuscript drafting or revision and accepts accountability for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved. KL takes responsibility that this study has been reported honestly, accurately, and transparently and that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant) have been explained.

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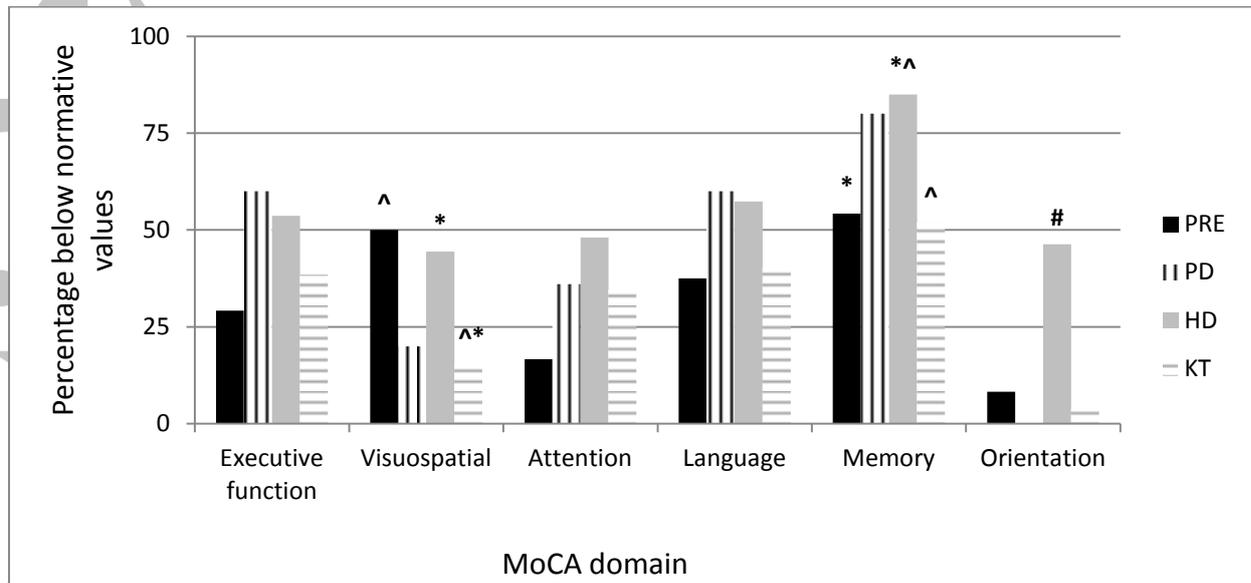
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52.

Figure 1. Proportion of study participants (n=155) with MoCA domain scores below normative values for normal controls



PRE: Predialysis group; PD: Peritoneal Dialysis group; HD: Hemodialysis group; KT: Kidney Transplant recipient group

Values with this superscript (#) are significantly different from all other groups ($p < 0.001$) and (* or ^) significantly different from each other ($p < 0.05$).

Accepted

Table 1: Demographic characteristics of study participants (n=155).

	PRE n=24	PD n=25	HD n=54	KT n=52	Total n=155	P value
Age, years; median (IQR)	70 (63-76)	70 (63-81)	72.0 (58-77)	58.5 (49-66) #	66 (55-75)	<0.001
Male, n (%)	11 (45.8)	13 (52.0)	36 (66.7)	32 (61.5)	92 (59.4)	0.30
<12 years of education, n (%)	13 (54.2)	18 (72.0)	54 (63.0)	23 (44.2)	88 (56.8)	0.09
Renal replacement therapy (years), median (IQR)	N/A	2.5 (1.5-4)	4.25 (2-9)	8.1 (4.1-14.3) #	5.00 (2-9.73)	<0.001
Dialysis adequacy (Kt/v) median (IQR)	N/A	2.30 (1.95-2.74)a	1.50 (1.3-1.7)b	N/A	N/A	N/A
Estimated Glomerular Filtration Rate (ml/min), mean (SD)	11.9 (4.7)	N/A	N/A	58.3 (18.3)	43.1 (26.7)	N/A

PRE: Predialysis group; PD: Peritoneal Dialysis group; HD: Hemodialysis group; KT: Kidney Transplant recipient group

IQR: Interquartile range; N/A: not applicable

Values with this superscript are significantly different from all other groups.

a: Peritoneal dialysis adequacy indicated by Kt/V>1.7 (Reference: 27)

b: Hemodialysis adequacy indicated by Kt/V>1.2 (Reference: 28)

Table 2: Disease burden of study participants (n=114).

	PRE N=24	PD n=20	HD n=45	KT n=49	Total n=114	P value
Lung disease, n (%)	N/A	3 (15.0)	12 (26.7)	8 (16.3)	23 (20.2)	0.38
Coronary Artery Disease, n (%)	N/A	8 (40.0)	27 (60) ^a	13 (26.5) ^a	48 (42.1)	0.004*
Peripheral Vascular Disease, n (%)	N/A	4 (20.0)	26 (57.8) ^a	16 (32.7) ^a	46 (40.4)	0.01*
Diabetes, n (%)	N/A	7 (35.0)	23 (51.1)	14 (28.6)	44 (38.6)	0.08
Cerebrovascular Disease, n (%)	N/A	2 (10.0)	14 (31.1)	8 (16.3)	24 (21.1)	0.09
Cancer, n (%)	N/A	1 (5.0)	9 (20.0)	17 (34.7) [#]	27 (23.7)	0.02*
More than 3 comorbidities, n (%)	N/A	9 (45.0)	32 (71.1) ^a	16 (32.6) ^a	57 (50.0)	<0.0001*

PRE: Predialysis group; PD: Peritoneal Dialysis group; HD: Haemodialysis group; KT: Kidney Transplant recipient group; N/A: not available

Values with this superscript are significantly different from all other groups.

a: values with this superscript are significantly different from each other.

*P value <0.05 indicates statistically significant

Table 3. Logistic regression analyses of factors associated with the presence of cognitive impairment

Factor	Odds Ratio	95% CI	P value
Dialysis	3.09	1.07-8.94	0.04*
Age \geq 65	3.31	1.14-9.65	0.03*
Male gender	3.09	1.07-8.89	0.04*
Cerebrovascular disease	4.98	1.27-19.45	0.02*
Diabetes	3.76	1.10-9.65	0.04*
\geq 3 comorbidities	0.28	0.03-2.48	0.26
< 12 years of education	1.57	0.60-4.13	0.36
Peripheral Vascular Disease	0.36	0.09-1.49	0.16
Coronary Artery Disease	2.73	0.54-13.79	0.22

*indicates statistically significant ($p < 0.05$)

Table 4a. MoCA results of study participants according to those undertaking dialysis vs no dialysis.

	Dialysis (PD and HD group) n=79	Non dialysis (PRE and KT group) n=76	D vs ND P value
Cognitively impaired, Proportion, n, (%)	42 (53.2)	14 (18.4)	<0.001*
Total MoCA score Mean (95% CI)	23.65 (22.67-24.64)	26.86 (26.18-27.55)	<0.001*

Table 4b. MoCA results of study participants according to ESKD group (n=155).

	PRE n=24	PD n=25	HD n=54	KT n=52	Total n=155	P value
Cognitively impaired, Proportion, n, (%)	4 (16.7) ^a	12 (48.0)	30 (55.6) ^{ab}	10 (19.2) ^b	56 (36.1)	<0.001*
Total MoCA score Mean (95% CI)	27.07 (25.55-28.58) ^a	24.80 (23.32-26.28)	23.12 (22.11-24.13) ^{ab}	26.77 (25.74-27.80) ^b	25.23 (24.58-25.88)	<0.001*

PRE: Predialysis group; PD: Peritoneal Dialysis group; HD: Hemodialysis group; KT: Kidney Transplant recipient group

*P value <0.05 denotes statistical significance

a,b: values with this superscript are significantly different from each other.

Table 5. Analysis of the correlation between age, RRT duration and dialysis adequacy with MoCA total and domain scores.

	Age (n=155)	RRT duration (n=154)	Dialysis adequacy (n=69)	
	Spearman's rho (p value)	Spearman's rho (p value)	HD patients (n=52) Spearman's rho (p value)	PD patients (n=17) Spearman's rho (p value)
Total MoCA score	-0.30 (<0.001) *	-0.07 (0.38)	0.11 (0.44)	-0.25 (0.34)
Executive function score	-0.25 (0.002) *	0.07 (0.41)	0.07 (0.64)	-0.13 (0.63)
Visuospatial score	-0.18 (0.03) *	0.05 (0.52)	0.23 (0.11)	-0.06 (0.82)
Memory score	-0.32 (<0.001) *	0.04 (0.66)	0.07 (0.62)	0.02 (0.93)
Attention score	-0.08 (0.34)	-0.20 (0.01) *	-0.05 (0.72)	-0.38 (0.13)
Language score	-0.24 (0.003) *	-0.06 (0.44)	0.006 (0.97)	-0.23 (0.38)
Orientation score	-0.12 (0.13)	-0.04 (0.96)	0.007 (0.96)	N/A

Indicates statistically significant ($p < 0.05$). HD: Hemodialysis; PD: Peritoneal Dialysis.

Dialysis adequacy assessed using Kt/V and represents 96% of all HD patients, 68% of all PD patients, and overall 87% of all dialysis patients in the study N/A: not applicable as all participants scored maximum points and unable to calculate correlation