

Decreased Intracellular to Total Body Water Ratio and Depressive Symptoms in Patients with Maintenance Hemodialysis

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Objective: Depression is a common psychiatric disorder and related to poor outcomes in patients undergoing maintenance hemodialysis (MHD). Previous studies have reported some associations between sarcopenia and depressive symptoms. Recently, intracellular water (ICW) and total body water (TBW) have been found to reflect muscle function and muscle mass. ICW/TBW ratio is a marker of sarcopenia that is simple to assess. However, the relationship between ICW/TBW ratio and depression has not been explored in MHD patients.

Methods: In our cross-sectional and multi-center study, 3300 adult MHD patients were included from June 1, 2021, to August 30, 2021. Depressive symptoms were evaluated using the Beck Depression Inventory-II (BDI-II). TBW and ICW were measured by Body Composition Monitor (BCM). Multivariable logistic regression, stratified analyses, and interactive analyses were conducted to assess the relationship between ICW/TBW ratio and depression.

Results: About 16.5% of the 3300 MHD patients were found to have depressive symptoms. The prevalence of depression increased with decreasing quartiles of ICW/TBW ratios, and decreased ICW/TBW ratio was independently associated with depression after adjusting for potential confounders. Patients in Quartile 1 of ICW/TBW ratios were more likely to have depressive symptoms (odds ratio 1.55, 95% confidence interval 1.07–2.22; $p=0.002$) than those in Quartile 4. History of diabetes and education status had interactive roles in the relationship between depression and ICW/TBW ratios ($p < 0.05$). The association of ICW/TBW ratios and depression existed in patients of both genders and different education levels, but only in non-diabetic patients.

Conclusion: In MHD patients, the decreased ratio of ICW/TBW was independently related to high depression rates.

Keywords: depression, hemodialysis, intracellular water, total body water

Introduction

Psycho-nephrology, which is mainly caused by kidney damages, existed commonly in patients with chronic kidney disease (CKD) and maintenance hemodialysis (MHD).¹ Depressive symptoms are serious psychiatric disorders in MHD patients that cause bad patient outcomes. According to a guideline recommended for dialysis patients, the psychological status of patients, especially the presence of depressive symptoms, should be evaluated at least once every 2 years.² Compared with the general population, patients with every CKD stage have a much higher prevalence of depression,^{3,4} and the prevalence is estimated between 13.1% and 76.3% for patients on dialysis.⁵ Different psychometric scales, different diagnostic threshold values, and different populations might explain this wide range of depression rates.

In the CKD population, depressive symptoms were reported to be related to more hospitalization events, faster deterioration of renal function, and worse quality of life.⁶⁻¹¹ In 2019, a study from Taiwan found that dialysis patients who were previously diagnosed with depression had higher risks of both severe and fatal infections.¹² Many researchers

also reported a significant relationship between depressive symptoms and death in patients with ESRD.^{11,13–16} Due to its adverse outcomes and the difficulty of drug treatment only, depression needs to be carefully observed and its risk factors should be identified. Early detection of patients with high risk of depression and intervention targeting risk factors will help to prevent this mental disease. Early detection of patients at high risk of depression and intervention measures targeting risk factors will help prevent this psychological disorder.

A systematic review showed that sarcopenia is related to depression in the general population.¹⁷ Another cross-sectional study also reported a significant association between this psychological disorder and sarcopenia in elderly HD patients.¹⁸ Furthermore, a recent report suggested that depression could predict one-year sarcopenia in patients with end-stage renal disease (ESRD), though sarcopenia was defined by a simple scale in this study.¹⁹ It is well known that sarcopenia is represented as weakened muscle strength and reduced muscle mass. Intracellular water (ICW), a marker of cell hydration, was reported to reflect muscle mass and function in both elderly individuals and athletes.^{20–23} A proposed explanation for the relationship between muscle quality and ICW is the cell swelling theory,^{24,25} which has in vivo evidence suggesting that cellular swelling stimulates anabolism and glycogen synthesis, whereas ICW depletion promotes catabolic effect and protein degradation. In clinical practice, lower ICW was found to be related to increased risk of memory impairment, frailty, and reduced psychomotor skills.^{20,26,27}

In MHD patients, the water balance in their bodies is obviously disordered due to the complete loss of renal function, which is characterized by a significant decrease in ICW and its proportion in total cell water (TBW). Therefore, the study aims to assess if ICW/TBW ratio in an MHD population is associated with depression, independently of other confounding factors.

Methods

Patients

From June 1, 2021, to August 30, 2022, we conducted a cross-sectional and multicenter study in 20 dialysis centers of tertiary hospitals. Adult patients who received HD for at least 3 months were recruited to this investigation. If participants met one or more criteria, they were excluded: (a) patients with any extremity amputation or those with the implanted stent, cardioverter-defibrillator, or pacemaker; (b) patients with neurological and psychiatric disorders diagnosed prior to beginning dialysis therapy and patients with long-term drug abuse; (c) patients with language incompatibility, visual or auditory disability that affected the accuracy of the questionnaire evaluation; (d) patients who received hospitalization because of severe infection, congestive heart failure, gastrointestinal bleeding, and other reasons at the time of evaluation; (e) individuals with malignant tumor; (f) unwillingness to participate. 3300 HD patients were eventually included in this study.

Body Water and Lean Tissue Mass Measurements

ICW, ECW, total body water (TBW), and lean tissue mass (LTM) were measured approximately 30 min before the HD session using Body Composition Monitor (BCM, Fresenius Medical Care, Bad Homburg, Germany), a portable whole-body bioimpedance spectroscopy device. The accuracy of this device in measuring cellular waters has been proven to be satisfactory.²⁸ Patients were placed in a supine position, with their arms parallel to their trunks. Two disposable electrodes were placed on the dorsal surface of the patient's hand and two on the foot contralateral to the vascular access. TBW, ICW, ECW, and LTM were extracted from the measuring instrument.

Assessment of Depression

Depression was evaluated with the Beck Depression Inventory II (BDI-II), which has been widely verified for depression screening in CKD patients.^{29–31} BDI-II is a 21-item self-report scale and includes somatic, cognitive, and affective observed items. Each item of BDI-II scores on a scale of 0 to 3 and a total score ranges from 0 to 63 with higher scores suggesting more severe symptoms of depression. According to the literature, BDI-II scores greater than or equal to 11 were used to define depression.³² Those with scores of less than 11 were classified as not having depression. Throughout the study, this depression scale was assessed by professionally trained and same medical staff.

Other Data Collection

This study also included other variables such as sociodemographic and disease characteristics, lifestyle behaviors, and laboratory data. As described in our previous study,³³ these variables were acquired from a standardized questionnaire, dialysis run sheets, or electronic medical record system. More than 9 years of schooling education was classified as a high school level. In this study, a history of cardiovascular disease (CVD) was defined as congestive heart failure, arrhythmia, coronary artery disease, and stroke that required hospitalization in the past. Daily urine volume greater than 200mL was considered to have residual renal function.

Statistical Analysis

Categorical data were expressed as numbers and percentages. Continuous data with a skewed distribution were expressed as the medians and interquartile ranges. The differences between non-depressed and depressed groups were compared by the Chi-square tests or Mann–Whitney *U*-test. We further split patients into four groups of Quartile 1, Quartile 2, Quartile 3, and Quartile 4 according to their ICW/TBW ratios. Chi-square tests or Kruskal–Wallis tests were applied to compare the characteristics of the above 4 groups. Odds ratios (ORs) and 95% confidence intervals (CIs) for the association of ICW/TBW ratios with depressive symptoms were calculated by multivariable logistic regression. In multivariate logistic regression models, covariates included were those whose *p* value was less than 0.05 in univariate logistic regression analysis. Prior to logistic regression, the collinearity between covariates was also checked. A subgroup analysis was conducted to determine the stability of the original results. The grouping variables of the subgroup analysis included sex (male or female), education level (≤ 9 or >9 years of schooling education), and the presence of diabetes (yes or no). All analyses were conducted using R software version 4.0.1 and SPSS version 26.0. Statistical significance was determined at $p < 0.05$.

Results

Comparison of Characteristics Between Non-Depressed and Depressed Groups

In our final analysis, data on 3300 patients were used. Table 1 depicts the clinical and sociodemographic characteristics of all participants, non-depressed, and depressed patients. According to the BDI-II scoring criteria used in this study, 543 (16.5%) participants were judged to have depression. Compared to non-depressed participants, depressed patients had

Table 1 Characteristics of the Patients in Depressed and Non-Depressed Groups

Characteristics	Total (n=3300)	Non-Depressed (n=2757)	Depressed (n=543)	<i>p</i> -value
Age (years)	56.0(44.0,66.0)	55.0(44.0,64.0)	60.0(50.0,71.0)	<0.001
Male sex (%)	2048(62.1)	1739(63.1)	309(56.9)	0.007
Educational level (high school) (%)	1003(30.4)	871(31.6)	132(24.3)	0.001
Diabetes (%)	1004(30.4)	792(28.7)	212(39.0)	<0.001
Working (%)	205(6.2)	191(6.9)	14(2.6)	<0.001
Dialysis accompanied (%)	754(22.8)	576(20.9)	178(32.8)	<0.001
More than 30 min to dialysis unit (%)	1293(39.2)	1050(38.1)	243(44.8)	0.004
HDF treatment (%)	2836(85.9)	2379(86.3)	457(84.2)	0.192
HP treatment (%)	2641(80.0)	2212(80.2)	429(79.0)	0.513
Urine volume>200mL/d (%)	730(22.1)	627(22.7)	103(19.0)	0.053
Dialysis vintage (months)	42.0(18.0,75.0)	43.0(19.0,75.0)	38(17.0,74.0)	0.256
History of CVD	1186(35.9)	926(33.6)	260(47.9)	<0.001
BMI (kg/m ²)	22.7(20.5,25.1)	22.8(20.5,25.1)	22.8(20.4,25.0)	0.770
SBP (mmHg)	136.0(124.0,149.0)	136.0(124.0,149.0)	135.0(124.0,150.0)	0.791
DBP (mmHg)	78.0(69.0,87.0)	78.0(70.0,87.0)	76.0(68.0,85.0)	0.001
Hemoglobin (g/L)	110.0(97.0,123.0)	111.0(98.0,123.0)	108.0(92.0,123.0)	0.004

(Continued)

Table 1 (Continued).

Characteristics	Total (n=3300)	Non-Depressed (n=2757)	Depressed (n=543)	p-value
Albumin (g/L)	39.6(37.1,42.2)	39.8(37.3,42.2)	38.8(36.0,41.8)	<0.001
CRP (mg/L)	3.5(1.5,8.9)	3.4(1.5,8.8)	3.9(1.6,9.4)	0.166
BDI scores	4(1,8)	3(1,6)	14(12,18)	<0.001
Body water in men				
ICW (kg)	18.7(16.6,21.1)	18.9(16.8,21.3)	17.8(16.0,20.3)	<0.001
ECW (kg)	15.0(13.5,16.9)	15.0(13.5,16.8)	15.2(13.5,17.3)	0.171
TBW (kg)	33.9(30.5,37.8)	34.0(30.7,37.9)	33.6(29.6,37.6)	0.065
ICW/TBW	0.55(0.53,0.58)	0.56(0.53,0.58)	0.54(0.51,0.57)	<0.001
LTM (Kg)	39.8(34.7,45.8)	40.2(35.1,46.0)	38.1(32.2,43.9)	<0.001
Body water in women				
ICW (kg)	14.8(13.2,16.7)	14.9(13.3,16.7)	14.2(12.7,16.3)	0.002
ECW (kg)	12.2(10.9,13.8)	12.2(10.9,13.8)	12.2(10.9,13.6)	0.731
TBW (kg)	27.1(24.5,30.2)	27.2(24.6,30.3)	26.8(24.1,29.9)	0.066
ICW/TBW	0.55(0.52,0.57)	0.56(0.53,0.58)	0.54(0.51,0.57)	<0.001
LTM (Kg)	30.8(26.3,35.6)	31.1(26.7,35.7)	29.2(25.0,34.4)	0.002

Abbreviations: HDF, hemodiafiltration; HP, hemoperfusion; CVD, cardiovascular disease; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; BID, Beck Depression Inventory; CRP, C-reactive protein; ICW, intracellular water; ECW, extracellular water; TBW, total body water; LTM, lean tissue mass.

a higher proportion of diabetes, a history of CVD, and females; lower educational level and older age; higher BDI scores; lower diastolic blood pressure (DBP), albumin, and hemoglobin; lower LTM, ICW, TBW, and ICW/TBW ratio. Patients in the depressed group also worked less and needed more dialysis companionship (all $p < 0.05$). Other variables such as C-reactive protein (CRP), hemodiafiltration (HDF) treatment, hemoperfusion (HP) treatment, residual renal function, dialysis vintage, and body mass index (BMI) were not different in the two groups ($p > 0.05$).

Characteristics Comparison of Patients Grouped by ICW/TBW Ratio Quartiles

As shown in Table 2, the prevalence of depression increased with decreasing quartiles of ICW/TBW ratio. The depression rates of patients with Quartile 4, Quartile 3, Quartile 2, and Quartile 1 were, respectively, 11.9%, 12.2%, 16.9%, and 26.4% ($p < 0.001$). Patients in the lower ICW/TBW ratio group had older age, more histories of diabetes and CVD. Statistically decreased trends were also observed in LTM, albumin, hemoglobin, serum creatinine, serum uric acid, and DBP with decreasing quartiles of the ICW/TBW ratio. Other variables such as HDF treatment, HP treatment, residual renal function, dialysis vintage, BMI, and CRP were similar across groups of ICW/TBW ratio quartiles ($p > 0.05$).

Association Between ICW/TBW Ratio and Depression

In univariate logistic regression analysis, these parameters including ICW/TBW ratio, age, sex, education, working, the distance from home to the dialysis unit, history of diabetes, history of CVD, diastolic blood pressure, albumin, and hemoglobin were statistically correlated with depression ($p < 0.05$). With the highest quartile as reference, Table 3 shows ORs and 95% CIs in six models for the associations of depression and quartiles of ICW/TBW ratio. The depression risk of patients with Quartile 1 is 1.55 times higher than that of participants with Quartile 4 after adjusting for other above potential confounders. Patients in Quartile 2 and Quartile 3 had similar depression ORs compared with those in Quartile 4 in the fully adjusted model. To estimate whether correlations between ICW/TBW ratio and the depression diagnosed by different cutoff values of BDI scores are different, BDI cutoff scores of ≥ 13 and ≥ 15 instead of BDI scores ≥ 11 were, respectively, used to suggest diagnosis of depression. Though 11.4% and 7.9% instead of 16.5% of participants were diagnosed with depression ($n = 375$ and 261 respectively), the correlation between ICW/TBW ratio and depression has not materially been changed.

Table 2 Characteristics of Study Subjects According to the ICW/TBW Ratio Quartiles

Variables	Quartile 1 (n=641)	Quartile 2 (n=1103)	Quartile 3 (n=927)	Quartile 4 (n=629)	p value
Age (years)	64.0(54.0,72.0)	58.0(49.0,68.0)	52.0(42.0,60.0)	45.0(36.0,56.0)	<0.001
Male sex (%)	413(67.2)	606(54.9)	644(69.5)	367(58.3)	<0.001
High school (%)	211(32.9)	333(30.2)	279(30.1)	180(28.6)	0.403
Diabetes (%)	355(55.4)	378(34.3)	188(20.3)	83(13.2)	<0.001
History of CVD (%)	258(40.2)	421(38.2)	317(34.2)	190(30.2)	<0.001
Dialysis accompanied (%)	238(37.1)	320(29.0)	130(14.0)	66(10.5)	<0.001
HDF treatment (%)	538(83.9)	938(85.0)	807(87.1)	553(87.9)	0.118
HP treatment (%)	488(76.1)	875(79.3)	757(81.7)	521(82.8)	0.011
Working (%)	34(5.3)	61(5.5)	69(7.4)	41(6.5)	0.231
Urine volume>200mL/d (%)	153(23.9)	243(22.0)	204(22.0)	130(20.7)	0.589
Dialysis vintage (months)	40.0(18.0,73.0)	43.0(18.0,79.0)	41.0(18.0,77.0)	43.0(19.3, 71.8)	0.256
BMI (kg/m ²)	23.8(21.4,26.0)	23.0(20.7,25.3)	22.5(20.4,24.7)	21.6(19.8,24.2)	0.770
LTM (Male, Kg)	34.5(29.8,38.6)	38.3(34.3,43.4)	42.3(37.4,48.1)	45.6(41.4,51.4)	<0.001
LTM (Female, Kg)	25.9(22.8,30.0)	29.0(25.6,33.0)	32.0(28.5,35.9)	36.0(32.4,40.8)	<0.001
SBP (mmHg)	139.0(125.0,152.0)	136.0(125.0,151.0)	135.0(123.0,148.0)	133.5(122.0,145.0)	0.791
DBP (mmHg)	75.0(65.0,83.0)	76.0(68.0,86.0)	79.0(71.0,88.0)	79.0(73.0,89.0)	0.001
Hemoglobin (g/L)	108.0(92.0,119.0)	110.0(96.0,122.0)	112.0(99.0,125.0)	113.0(100,124.0)	0.004
WBC (x10 ⁹ /L)	6.1(5.1,7.5)	6.0(4.9,7.3)	6.1(5.0,7.5)	5.9(4.8,7.3)	0.245
PLT (x10 ⁹ /L)	170.0(128.0,215.0)	168.0(131.0,210.0)	172.0(135.0,213.0)	167.0(136.0,210)	0.079
Albumin (g/L)	38.8(36.3,41.4)	39.4(36.8,41.9)	40.0(37.7,42.5)	40.5(38.1,42.9)	<0.001
Serum creatinine (μmol/L)	806(618,981)	892(711,1081)	1022(842,1231)	1095(902,1306)	<0.001
Serum uric acid (μmol/L)	425(355,496)	439(368,509)	464(390,533)	472(398,542)	0.006
iPTH (pg/mL)	255(126,454)	281(138,495)	322(172,629)	380(203,614)	0.073
CRP (mg/L)	3.6(1.7,8.8)	3.8(1.7,9.4)	3.0(1.4,9.0)	3.2(1.4,7.4)	0.166
Depression (%)	169(26.4)	186(16.9)	113(12.2)	75(11.9)	<0.001

Abbreviations: ICW, intracellular water; TBW, total body water; HDF, hemodiafiltration; HP, hemoperfusion; CVD, cardiovascular disease; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; PLT, platelet; iPTH, intact parathyroid hormone; CRP, C-reactive protein; LTM, lean tissue mass.

Table 3 Multivariate-Adjusted Odds Ratio (OR) and 95% Confidence Intervals (CI) for Depression According to the ICW/TBW Ratio Quartiles

Variable	Quartile 1	Quartile 2	Quartile 3	Quartile 4	P value
Model 1	2.65(1.96,3.56)	1.50(1.12,2.00)	1.03(0.75,1.40)	1	<0.001
Model 2	2.01(1.46,2.77)	1.19(0.88,1.61)	0.95(0.70,1.31)	1	<0.001
Model 3	2.06(1.50,2.84)	1.21(0.89,1.64)	0.96(0.70,1.32)	1	<0.001
Model 4	1.94(1.40,2.70)	1.16(0.85,1.57)	0.95(0.69,1.31)	1	<0.001
Model 5	1.61(1.14,2.27)	1.06(0.77,1.46)	0.86(0.61,1.20)	1	<0.001
Model 6	1.55(1.07,2.22)	1.07(0.77,1.49)	0.86(0.61,1.22)	1	0.002

Notes: Model 1, Unadjusted model; Model 2, adjusted for age, sex, and education; Model 3, above + working, the distance from home to the dialysis unit; Model 4, above + history of diabetes, cardiovascular disease; Model 5, above + diastolic blood pressure+ albumin; Model 6, above + hemoglobin.

Subgroup Analyses for the Associations Between Depression and ICW/TBW Ratio

As shown in Figure 1, the stability of associations between depressive symptoms and ICW/TBW ratio was checked by subgroup analyses of multivariable logistic regression (quartile 4 vs quartile 1–3). On the whole, after adjusting for education, sex, age, working, the distance from home to the dialysis unit, history of diabetes, history of CVD, diastolic blood pressure, albumin, and hemoglobin except for the stratified variable, the relationship between depression and ICW/TBW ratio still persisted in four subgroups divided by education status and gender. However, this association only existed in non-diabetic patients but not diabetic patients. Both history of diabetes and education status had interactive roles in the correlation between depression and ICW/TBW ratios ($p < 0.05$).

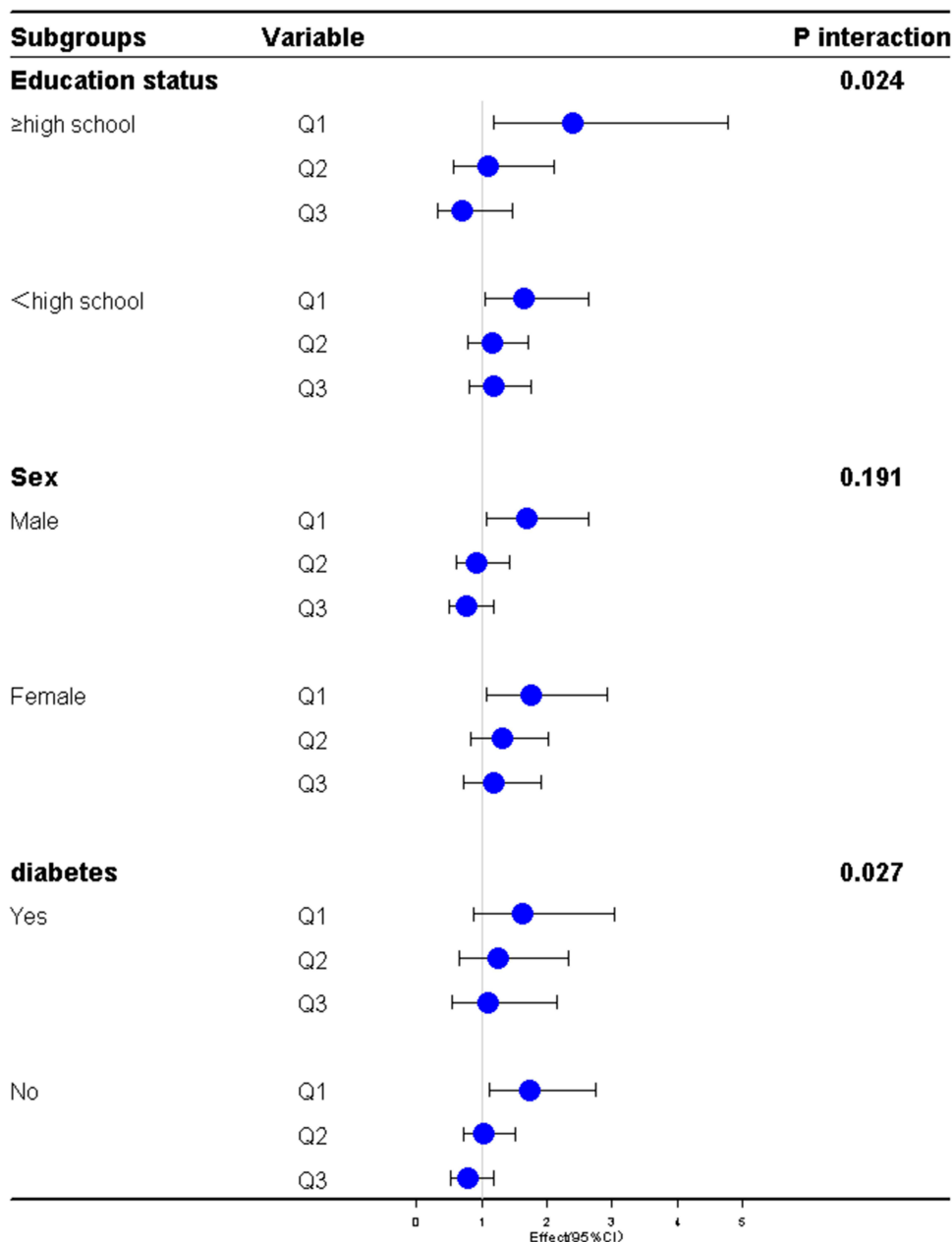


Figure 1 Subgroup analyses of the association between intracellular to total body water ratio and depression stratified by sex, diabetes, and education status. **Notes:** Odds ratios (ORs) were calculated after adjusting for age, sex, education, work, the distance from home to the dialysis unit, history of diabetes, history of cardiovascular disease, diastolic blood pressure, albumin, and hemoglobin if not stratified.

Discussion

Previous reports have shown that the prevalence of depression diagnosed by the BDI-II questionnaire is mostly over 20% in CKD patients.^{34–39} However, in our study, the rate of depression was only 16.5%, even with a lower BDI cutoff. The relatively lower prevalence of depression in our MHD patients was similar to that of other two reports.^{40,41} This lower rate of depression might be mainly caused by two reasons. First one is that patients diagnosed with neurological and psychiatric disorders prior to beginning dialysis therapy and patients with long-term drug abuse were excluded. Second one is that the depression of our participants might have been improved to some extent because they were MHD patients, having obtained disease education in HD centers for a longer time. Consistent with most previous reports, we also found that diabetes, CVD, serum albumin, hemoglobin, gender, and education level were associated with depression, while

CRP was not associated with it.^{38,42–47} In addition, patients with depression had lower pre-dialysis DBP than non-depression patients. Lower DBP was speculated to cause decreased cerebral perfusion and psychiatric disorders.

To our knowledge, this multicenter study is the first to explore the correlation between depression and ICW/TBW ratio in MHD patients. The main finding was that the rates of depression increased with decreasing ICW/TBW ratio. In MHD subjects, the association between ICW/TBW ratio and depression was independent of sex, education, age, work, the distance from home to the dialysis unit, history of diabetes, history of CVD, diastolic blood pressure, albumin, and hemoglobin. Moreover, both history of diabetes and education status had interactive roles in the relationship between depression and ICW/TBW ratios. The association between ICW/TBW ratios and depression existed in patients of both genders and different education levels, but only in non-diabetic patients. In this study, we included patients who had been on MHD for more than 3 months without obvious edema. However, we also admitted that in addition to the small sample size, the reason why there was no correlation between ICW/TBW ratio and depression in diabetic patients might be the effect of diabetic recessive edema on this outcome compared with non-diabetic patients. To assess the stability of the relationships between ICW/TBW ratio and depression, BDI cutoff scores of ≥ 13 and ≥ 15 but not BDI scores ≥ 11 was used to suggest the diagnosis of depression, respectively. The association between ICW/TBW ratio and depression has not materially been changed.

The coexistence of depression and low ICW/TBW ratios might be ascribed to the fact that they share common risk factors such as older age, CVD, diabetes, low blood perfusion, and malnutrition. However, after multivariable adjustment including common risk factors of both depression and ICW depletion, ICW/TBW ratio is still independently associated with depression, which suggests that there might be some unique pathophysiological mechanism between depression and ICW/TBW ratios in MHD patients. Existing evidence for a relationship between depression and sarcopenia^{17–19} in patients undergoing MHD might suggest identifying the capacity of ICW/TBW ratios for depressive symptoms in this population.

For the treatment of depression in HD subjects, short daily HD was reported not to improve self-reported depression compared with conventional HD.⁴⁸ In a meta-analysis, antidepressant use had no advantage or ungradable benefits over placebos.⁴⁹ Moreover, some adverse reactions such as hypotension, headache, and sexual dysfunction had been reported during the antidepressant therapy.⁴⁹ Compared with drug therapy, non-pharmacological therapies such as self-management, cognitive-behavioral therapy (CBT), telephone care, psychological intervention, music, problem-solving, and laughter therapies might have better efficacy and safety.⁵ For patients with depression, exercising may also be a promising therapy.⁵⁰ In addition, both endurance and resistance training during HD were shown to help alleviate depressive symptoms.⁵¹ Early identification of depression and application of non-drug therapy need to be advocated, and multidisciplinary teams to work together to implement appropriate interventions should be required.

Although this study has several strengths such as detailed ascertainment of potential confounders, multicenter representation, subgroup analyses, and a relatively large sample size. The limitations of our analysis should be recognized. Firstly, this observation was based on a cross-sectional design, so we could not deduce the causal relationship between the ICW/TBW ratio and depression. In our follow-up, we will explore whether there is a mutually causal relationship between the two through a cohort study. Secondly, depression was diagnosed by a BDI-II questionnaire rather than a structured clinical interview. However, the gold standards that need judgement from psychological experts, are complex and time-consuming to be used in busy clinical work. The BDI-II scale with a high sensitivity was validated against a gold standard for diagnosing depression and has often been applied to evaluate depression among CKD participants.^{29–31,52–54} Thirdly, ICW, ECW, and TBW were measured using the BCM. Although tracer dilution is the gold standard for evaluating body water, it is unrealistic to use this method to assess cellular hydration state in both clinical research and daily work. BCM has been highly recognized for evaluating fluid overload and body composition among HD participants.^{55,56} Fourthly, although we considered some demographic and laboratory confounders in the adjusted models, there might still be some variables such as marital status and monthly income that remain unadjusted.

In conclusion, decreased ICW/TBW ratio was related to high prevalence of depression in MHD patients. Our findings may suggest that the measurement of cellular waters based on bioimpedance spectroscopy might be a simple and valid means for identifying the occurrence of depression in HD patients.

Data Sharing Statement

The datasets analyzed in this study could be obtained from the first author if the request is reasonable.

Informed Consent and Ethics Approval

Informed consent forms were signed by patients or their legal representatives before participation. This study was performed in compliance with the Declaration of Helsinki. The Ethics Review Committee of Guizhou Provincial People's Hospital approved the protocol, and the approval number was "(Scientific Research) (2019) No. 29".

Acknowledgment

All the patients who participated in the study are appreciated.

Funding

Guizhou Science and Technology Plan Project (QKH [2020] 2201) and Guizhou High-level innovative Talent Project (QKH [2018] 5636-2).

Disclosure

The authors report no conflicts of interest in this work.

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