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Original Article

Overhydration measured by bioimpedance analysis and the survival of patients on maintenance hemodialysis: a single-center study

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Abstract

Background: Bioimpedance analysis (BIA) helps measuring the constituents of the body noninvasively. Prior studies suggest that BIA-guided fluid assessment helps to predict survival in dialysis patients. We aimed to evaluate the clinical usefulness of BIA for predicting the survival rate of hemodialysis patients in Korea.

Methods: We conducted a single-center retrospective study. All patients were diagnosed with end-stage renal disorder and started maintenance hemodialysis between June 2009 and April 2014. BIA was performed within the 1st week from the start of hemodialysis. The patients were classified into 2 groups based on volume status measured by the body composition monitor (BCM; Fresenius): an overhydrated group [OG; overhydration/extracellular water (OH/ECW) >15%] and a nonoverhydrated group (NOG; OH/ECW ≤15%).

Results: A total of 344 patients met the inclusion criteria. Of these, 252 patients (73.3%) were categorized into the OG and 92 patients (26.7%) into the NOG. Age- and sex-matching patients were selected with a rate of 2:1. Finally, 160 overhydrated patients and 80 nonoverhydrated patients were analyzed. Initial levels of hemoglobin and serum albumin were significantly lower in the OG. During follow-up, 43 patients from the OG and 7 patients from the NOG died (median follow-up duration, 24.0 months). The multivariate-adjusted all-cause mortality was significantly increased in the OG (odds ratio, 2.569; $P = 0.033$) and older patients (odds ratio, 1.072/y; $P < 0.001$). No significant difference of all-cause or disease-specific admission rate was observed between the 2 groups.

Conclusion: The ratio of OH/ECW volume measured with body composition monitor is related to the overall survival of end-stage renal disorder patients who started maintenance hemodialysis.

Introduction

Modern medicine has evolved in the direction of developing less-invasive methods for a wide variety of diagnoses and treatments. The bioimpedance analysis (BIA) method has been used as a method to measure the constituents of the human

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body noninvasively. Commercial medical devices using BIA have become popular because of their convenience and safety [1]. It is possible to measure segmental human body composition of water, muscle and fat mass, and even cardiac output using BIA [2–4].

Assessing the precise body water status in patients with renal disorders is very important for their health. It has been reported that chronic fluid overload is present even in the early stages of renal insufficiency [5]. If the volume overload in a patient with chronic renal failure is not controlled, serious problems such as pulmonary edema, cardiac remodeling, and diastolic heart failure can develop [6].

Especially for dialysis patients, an assessment of the dry weight is essential to determine ultrafiltration volume during the dialysis session. It affects both hemodynamic stability and symptoms of the patient, such as muscle cramps, abdominal pain, generalized weakness, dyspnea, edema, hypertension, or hypotension during and after dialysis [7,8]. Clinicians have used predialysis and postdialysis blood pressure (BP), amount of weight gain between dialysis sessions, and subjective symptoms of the patient as an index of volume overload. Recently, an increasing number of dialysis centers have started to use body water measurement devices using BIA.

Prior studies suggest that BIA-guided fluid assessment can help to predict survival rate in dialysis patients. Chazot et al [9] have reported that a hyperhydrated group showed higher all-cause mortality than a nonhyperhydrated group when they were classified according to the ratio of overhydration/extracellular water (OH/ECW) measured with multifrequency whole-body bioimpedance spectroscopy. Fluid overload is thought to be an independent risk factor of all-cause mortality or cardiovascular morbidity in patients with advanced chronic kidney disease (CKD) [10].

According to the report of the Korean Society of Nephrology, the total number of end-stage renal disorder (ESRD) patients was 75,042 and 52,378 patients were undergoing hemodialysis at the end of 2013. The number of new patients undergoing renal replacement therapy was 12,183 which included 9,543 hemodialysis patients in 2013 [11].

To date, there has been no report of survival data for Korean patients according to the volume status measured by the BIA method. We have used the body composition monitor (BCM; Fresenius Medical Care, Bad Homburg, Germany) in a dialysis center since 2009, and the hydration status measured by BCM was correlated well with interdialysis weight gain in our previous cross-sectional study [12]. Because the BCM provides overhydration index and suggested dry weight compared with the reference group, it is easy to understand and apply to the patient at the bedside [1].

The objective of this study was to evaluate the clinical usefulness of hydration status measured by BCM at the initiation of hemodialysis in patients with ESRD for predicting outcomes of dialysis patients. We analyzed the survival and admission rates of each chronic hemodialysis patient, according to hydration status measured by BCM.

Methods

Study design

We conducted a single-center retrospective study of dialysis patients between June 2009 and April 2014. Most data were collected from the electronic medical records of the Chungnam National University Hospital. Information on mortality was obtained from the database of the National Health Insurance Service. We did not give physicians special treatment guidelines depending on hydration status; treatment of each patient was carried out according to the clinical judgment of the attending physician.

Patient selection

All patients were diagnosed with ESRD and started maintenance hemodialysis between June 2009 and April 2014. Maintenance hemodialysis was defined as hemodialysis performed 1–3 times/wk for more than 3 months. BIA was performed within the 1st week from the start of hemodialysis.

Exclusion criteria were as follows: a patient who started dialysis due to acute kidney injury; a patient whose date of dialysis start and death were in the same admission period; and a patient with a history of renal transplantation, a history of peritoneal dialysis longer than 1 month, or active malignancy (all solid organ cancer and hematologic malignancy). Patients were included if the cancer had completely recovered without recurrence for more than 5 years before the start day of dialysis.

Study population

Ultimately, 344 patients met the inclusion criteria. Of these, 252 patients (73.3%) were categorized into the overhydrated group (OG) and 92 patients (26.7%) were assigned to the nonoverhydrated group (NOG). There was a significant difference of mean age between the 2 groups in the preliminary analysis (62.3 years in the OG and 64.4 years in the NOG). Twelve patients who were considered to be dehydrated (OH/ECW $\leq -13\%$) were excluded from our analysis, and age- and sex-matching patients were selected with the rate of 2:1; finally, 160 overhydrated patients and 80 nonoverhydrated patients were analyzed.

Measurements of clinical parameters

Extent of overhydration and dry body weight were assessed with the BCM. The value of initial overhydration measured with BCM was used without modification, if it was measured on the 1st dialysis day. In the case that analysis with BCM was delayed after the 1st dialysis day, the value of initial overhydration was calculated by the difference between initial body weight and dry body weight measured with BCM.

Based on the ratio of overhydration and extracellular water of initial dialysis, the patients were classified into 2 groups: OG (OH/ECW >15%) and NOG (OH/ECW $\leq$15%). The cutoff value of our study (OH/ECW >15%) was selected with reference to the analysis by Chazot et al [9] and Wizemann et al [13].

Baseline patient characteristics analyzed included age at start day of dialysis (years), sex, height (cm), initial body weight (kg), overhydration (L), dry body weight (kg), initial systolic/diastolic BP (mmHg), initial comorbidities (presence of diabetes, hypertension, glomerulonephritis, cardiovascular disorder, or cerebral vascular disorder), and initial laboratory data [hemoglobin, blood urea nitrogen, creatinine (Cr), albumin, total calcium, phosphorus, sodium, potassium, chloride, C-reactive protein, intact parathyroid hormone (PTH), iron, total iron-binding capacity, transferrin saturation, and ferritin].

Cardiovascular disorder was defined as cardiac insufficiency, nonfatal myocardial infarction, angina pectoris, and atrial fibrillation. Cerebrovascular disorder was defined as cerebral infarction/embolism and intracranial hemorrhage.

Outcomes

A primary outcome was overall survival of patients. We also compared short-term survival, long-term survival, overall rate (days and number of events) of all-cause admissions, and disease-specific admission rate (cardiovascular disorder, cerebral vascular disorder, infection, and malignancy) between the 2 groups.

We could have calculated the overall survival rate from the database of the National Health Insurance Service. However, the patients whose follow-up data were lost were excluded from analysis of the admission rate because of the uncertainty of this medical database. Data of the patients who received a kidney transplant during their follow-up period were managed as censored data.

Statistics

Mean values and frequencies of the parameters were compared by the Student's *t*-test and the chi-square test. The level of significance was set to $P < 0.05$. Survival rates, according to the baseline hydration status, were described using the Kaplan–Meier technique. The log-rank (Mantel–Cox) test was used for the Kaplan–Meier graph. Cox proportional hazard models were used to compare survival according to the baseline hydration status, adjusting for demographic data (age and gender), comorbid conditions (diabetes, cardiovascular problems, and cerebral vascular disorders), and other predictors (laboratory data including albumin, hematocrit, intact PTH, predialysis phosphate, predialysis Cr). Estimated relative risks (hazard ratios) and their 95% confidence intervals were calculated with the use of the estimated regression coefficients and their standard errors. All statistical analyses were performed using the SPSS software, version 21 (IBM Corporation, New York, United States).

Results

Baseline characteristics

Average amount of overhydration was 6.6 ± 4.2 L in the OG and 0.7 ± 1.0 L in the NOG. The OG had a lower average dry weight even though the patients of 2 groups had comparable initial body weight (Table 1). Initial levels of hemoglobin and albumin were significantly lower in the OG compared with the NOG (Table 2). The proportion of patients presenting the symptoms of overhydration was higher in the OG: dyspnea related to pulmonary edema or pleural effusion (50.0% in the OG vs. 25.0% in the NOG) and peripheral edema (36.9% in the OG vs. 17.5% in the NOG).

There was no significant difference in the cause of ESRD [diabetic nephropathy (70.0% in the OG vs. 61.3% in the NOG)]. Initial comorbidities also did not exhibit significant differences [cardiovascular disorder (20.1% in the OG vs. 33.8% in the NOG), cerebral vascular disorder (15.6% in the OG vs. 16.9% in the NOG)]. No significant difference was found in initial systolic/diastolic BP, initial blood urea nitrogen, Cr, total calcium, phosphorus, sodium, potassium, chloride, C-reactive protein, intact PTH, iron, total iron-binding capacity, transferrin saturation, or ferritin between the 2 groups (Table 1, 2).

Most of the enrolled patients were transferred to private dialysis centers after stabilization of initial symptoms. Primary symptoms or signs of overhydration were subsided within 2 weeks after the start of dialysis.

Patient survival and risk factors of death

Median follow-up duration was 24.0 months (28.5 months for the OG vs. 19.4 months for the NOG). During the follow-up period, 43 patients (26.9%) from the OG and 7 patients (8.8%) from the NOG died. Patients from the OG had a higher risk for all-cause mortality ($P = 0.023$; Fig. 1).

The most common cause of death was infection (a total of 13 patients, including 6 patients with pneumonia, 3 patients with sepsis, 2 patients with arteriovenous fistular infection, 1 patient with deep neck infection, and 1 patient with septic arthritis).

Table 1. Comparison of clinical characteristics of study participants stratified by volume status

Variables	Overhydrated group ($n = 160$)	Nonoverhydrated group ($n = 80$)	*P*
Demographics			
Sex (male)	98 (61.3)	49 (61.3)	1.000
Age (y)	65.6 ± 12.8	65.7 ± 12.6	0.957
Weight (kg)	62.8 ± 12.0	62.4 ± 11.2	0.782
Overhydration (L)	6.6 ± 4.2	0.7 ± 1.0	<0.001
Dry weight (kg)	56.2 ± 10.7	61.7 ± 10.9	<0.001
Systolic blood pressure (mmHg)	153.8 ± 31.0	146.9 ± 31.9	0.110
Diastolic blood pressure (mmHg)	80.2 ± 17.5	79.1 ± 16.9	0.653
Cause of ESRD			
Diabetic nephropathy	112 (70.0)	49 (61.3)	0.782
Nondiabetic nephropathies (hypertensive nephropathy, glomerulonephritis, etc.)	48 (30.0)	31 (38.7)	0.164
Comorbidities			
Hypertension	114 (71.3)	64 (80.0)	0.130
Cardiovascular disorder	39 (28.1)	27 (33.8)	0.140
Cerebrovascular disorder	24 (15.0)	13 (16.3)	0.850
Symptoms at the start of dialysis			
Dyspnea related to pulmonary edema or pleural effusion	80 (50.0)	20 (25.0)	0.001
Peripheral edema	59 (36.9)	14 (17.5)	<0.000
Anorexia, nausea, vomiting	86 (53.8)	56 (70.0)	0.013

Data are expressed as *n* (%) for categorical variables and mean ± SDs for continuous variables, as appropriate.
ESRD, end-stage renal disorder.

Table 2. Comparison of laboratory parameters of study participants stratified by volume status

Variables	Overhydrated group ($n = 160$)	Nonoverhydrated group ($n = 80$)	P
Hemoglobin (g/dL)	8.6 ± 1.8	9.3 ± 1.6	0.003
Blood urea nitrogen (mg/dL)	94.6 ± 35.9	97.0 ± 34.7	0.627
Creatinine (mg/dL)	9.3 ± 6.2	8.2 ± 3.4	0.061
Albumin (g/dL)	3.2 ± 0.6	3.5 ± 0.7	0.001
Total calcium (mg/dL)	8.6 ± 10.5	7.9 ± 1.5	0.429
Phosphorus (mg/dL)	5.8 ± 2.1	5.8 ± 1.8	0.754
Sodium (mEq/L)	135.3 ± 5.7	134.7 ± 5.0	0.444
Potassium (mEq/L)	5.0 ± 1.0	5.0 ± 0.9	0.986
Chloride (mEq/L)	104.7 ± 10.3	103.2 ± 7.8	0.200
C-reactive protein (mg/dL)	2.3 ± 4.5	2.0 ± 3.8	0.543
Intact parathyroid hormone (pg/mL)	185.8 ± 177.2	168.2 ± 141.4	0.405
Iron (μg/dL)	60.1 ± 38.5	71.7 ± 48.5	0.065
Total iron-binding capacity	208.2 ± 75.2	212.2 ± 85.5	0.722
Transferrin saturation (%)	28.3 ± 19.1	31.7 ± 21.5	0.229
Ferritin (ng/mL)	280.2 ± 244.1	315.8 ± 276.7	0.330

Data are expressed as means ± SDs for continuous variables.

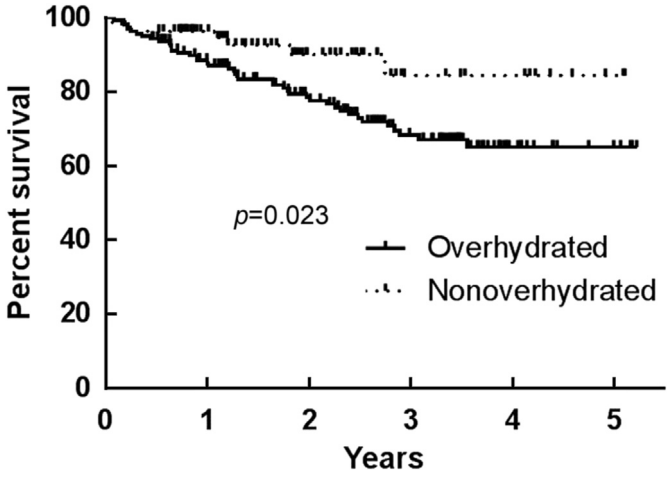

Figure 1. Kaplan-Meier survival curve of two groups for all-cause mortality. Median follow-up duration was 24.0 months. During the follow-up period, 43 patients (26.9%) from the overhydrated group(OG) and 7 patients (8.8%) from the non-overhydrated group(NOG) died. Patients from the OG had a higher risk for all-cause mortality ($P = 0.023$).

The other patients died from cardiovascular disorders (6 patients: 3 patients with heart failure, 2 patients with cardiac arrest, and 1 patient with aortic dissection); malignancy (5 patients: non−small-cell lung cancer, hepatocellular carcinoma, advanced gastric cancer, cervical cancer, and glioblastoma); cerebral vascular disorder (2 patients: acute stroke and intraventricular hemorrhage); or other disorders (4 patients: 2 patients with gastrointestinal bleeding, 1 patient with abdominal aortic thrombosis, and 1 patient with discontinuance of dialysis). We were not able to determine the cause of death of 20 patients (Table 3).

The risk factors of death were analyzed by logistic regression analysis and Cox regression analysis. The presence of overhydration [odds ratio (OR), 2.582] and older age (OR, 1.070/y) showed a significantly higher OR in the analysis of all 3 methods (Tables 4−6).

Overall rate of admissions

Follow-up duration of the OG (20.6 ± 15.8 months) was longer than that of the NOG (16.2 ± 15.2 months). Follow-up duration of admission analysis was shorter than that of survival analysis because only admission data of Chungnam National University Hospital were available, whereas survival data were from the database of the National Health Insurance Service. There was no significant difference in the all-cause admissions rate (days and number of events) or disease-specific admission rate (cardiovascular disorder, infection, malignancy) between the 2 groups (Table 7).

Analysis of the patient groups reclassified according to mortality

The patients were divided into survivors and deaths, and the baseline characteristics were compared with each other. The deaths showed a higher proportion of overhydrated patients (86.0% vs. 62.1%), older age (71.6 ± 11.7 vs. 64.1 ± 12.5 years, $P < 0.001$), lower body weight (59.3 ± 11.3 vs. 63.5 ± 11.7 kg, $P = 0.023$), and lower dry weight (53.7 ± 9.7 vs. 59.1 ± 11.2 kg, $P = 0.001$), and also a lower serum level of albumin (3.1 ± 0.5 vs. 3.3 ± 0.7 g/dL, $P = 0.020$). There was no significant difference in causes of ESRD, comorbidities, all-cause admissions rate, or disease-specific admission rate between the 2 groups.

Discussion

The overhydrated state is known to be an independent risk factor for mortality in ESRD patients under hemodialysis treatment [7]. Excessive volume loading can result in several problems such as arterial hypertension, peripheral edema, dyspnea due to pulmonary edema, left ventricular hypertrophy, diastolic heart failure, or other adverse cardiovascular sequelae [6−8,14]. Those previous findings are consistent with our result

Table 3. Causes of death ($n = 50$)

Causes	Overhydrated group	Nonoverhydrated group
Infection	10	3
Cardiovascular disorder	6	0
Cancer	5	0
Cerebrovascular disorder	2	0
Others	4	0
Unknown	16	4
Total number of patients	43	7

Table 4. Risk factors of death during entire follow-up: univariate logistic regression analysis

Variables	Odds ratio	*P*	95% Confidence interval	
			Low	High
Presence of overhydration	4.768	0.001	1.841	12.351
Age	1.061	0.001	1.026	1.098
Diabetes mellitus	0.636	0.284	0.278	1.454
Hypertension	0.463	0.061	0.207	1.036
Glomerulonephritis	0.742	0.672	0.187	2.951
Cardiovascular disorder	2.134	0.049	1.002	4.545
Cerebral vascular disorder	0.667	0.416	0.252	1.768

Table 5. Risk factors of death during entire follow-up: multivariate logistic regression analysis

Variables	Odds ratio	*P*	95% Confidence interval	
			Low	High
Presence of overhydration	2.569	0.033	1.077	6.126
Age (/y)	1.072	<0.001	1.034	1.106
Cardiovascular disorder	2.569	0.095	0.895	3.960

Table 6. Risk factors of death during entire follow-up: Cox regression analysis

Variables	Hazard ratio	*P*	95% Confidence interval	
			Low	High
Presence of overhydration	2.582	0.020	1.159	5.750
Age (/y)	1.070	<0.001	1.040	1.100

that the presence of overhydration is related to higher mortality of dialysis patients.

Nescolarde et al [15] used a single-frequency bioelectrical impedance vector to volume status to investigate the association between overhydration and mortality in dialysis patients, and Chazot et al [9] used multifrequency bioimpedance spectroscopy, as used in our study. A recent study by Wizemann et al [13] conducted using BCM also showed that overhydration is an important and independent predictor of mortality in chronic dialysis patients, secondary only to the presence of diabetes.

BIA is a method that uses a change in reactance and resistance of the current passing through the body fluid with the solute for measuring the body components and its distribution. Multifrequency BIA can measure extracellular and intracellular water separately. Low-frequency current, which cannot cross the cell membrane, is used to measure extracellular water, and high-frequency current, which can pass through the cell membrane, is used to measure intracellular water [16,17]. Jang et al [18] reported that total body water and intracellular water/extracellular water ratio measurement with multifrequency BIA is a useful tool to estimate adequate ultrafiltration for dialysis patients.

BCM uses various frequencies from 5 to 1,000 kHz to analyze the impedance of the body. It is a reproducible, low-cost, and noninvasive technology to measure body fluid volume status of dialysis patients, as previously reported in several studies [19–22]. Onofriescu et al [23] demonstrated an improvement in all-cause mortality over 2.5 years, arterial stiffness, relative fluid overload, and systolic BP after strict volume control using BIA. We have used BCM in a dialysis center since 2009, and hydration status measured by BCM correlated well with interdialysis weight gain in our previous cross-sectional study [12].

The patients enrolled in the study by Chazot et al [9] were under maintenance hemodialysis, whose median dialysis vintage was more than 3 years. We analyzed patients at the start of dialysis, so that the result could be more helpful to predict the prognosis of dialysis patients earlier in the disease process. There was no significant difference between the absolute value of overhydration between the mortality and survival groups, but OH/ECW measured by the BCM was higher in the mortality group. It emphasized the importance of the ratio of overhydration and extracellular water measured with the BCM, in spite of the short follow-up duration in our study.

The most common cause of death was infection in this study. It is similar to the results of the study by Tsai et al [10]. Tsai et al described the following as the cause: (1) lower cardiovascular morbidity and mortality in Asians compared to Westerners; (2) bowel wall edema due to fluid overload,

Table 7. Comparison of morbidities of study participants stratified by volume status

Admission rates	Overhydrated group ($n = 160$)	Nonoverhydrated group ($n = 80$)	*P*
Follow-up duration (mo)	20.6 ± 15.8	16.2 ± 15.2	0.042
Overall admission			
d/y	13.3 ± 29.8	11.1 ± 28.2	0.584
Number of events/y	1.2 ± 1.6	0.9 ± 1.4	0.185
Hospital days			
d/event	8.0 ± 19.4	6.3 ± 14.7	0.438
Disease-specific admission			
Cardiovascular disorder			
d/y	2.1 ± 7.3	1.0 ± 4.4	0.138
Number of events/y	0.3 ± 0.9	0.2 ± 0.5	0.126
Infection			
d/y	6.1 ± 35.0	4.3 ± 18.7	0.603
Number of events/y	0.3 ± 0.5	0.3 ± 0.7	0.669
Malignancy			
d/y	0.3 ± 2.2	0.1 ± 0.4	0.144
Number of events/y	0.1 ± 0.3	0.0 ± 0.1	0.124
Others			
Number of events/y	1.5 ± 2.2	1.1 ± 1.5	0.098

Data are expressed as mean ± SDs.
d/y, days/year.

resulting in the increase in gut permeability, destroying protective barriers, and admitting overgrowth of pathogenic species; (3) changes in brain natriuretic peptide associated with volume status, related to diminishing the total numbers of monocytes, B cells, and natural killer cells and impairing natural killer cell cytotoxicity.

Cardiovascular disorders should be considered as an important risk factor of mortality, despite our statistically nonsignificant result. Antunes et al [24] demonstrated several parameters reflecting volume overload, such as phase angle and capacitance, help to predict cardiovascular prognosis. The presence of cardiovascular disorder was a risk factor of mortality during the entire follow-up period in our study. It is a possible explanation that the volume overload aggravates cardiovascular disorders as this is known to occur. The results of our study resemble prior studies addressing the relationship of BIA-guided fluid management and improvement in cardiovascular outcomes [25–27].

It is unclear whether the prognosis was improved if dialysis started earlier before the patient became overhydrated. BIA measurements at the 1st week from the start of hemodialysis are unstable and may be associated with residual renal function or timing of the start of renal replacement therapy. Nonetheless, it is clear that BIA is conducive to identification of overhydrated patients with advanced CKD who are not currently on dialysis [28].

The proportion of patients presenting the symptoms of overhydration such as dyspnea or peripheral edema was higher in the OG compared to NOG. Fluid overload is known to be associated with malnutrition and inflammation [29,30]. It is not clear whether malnutrition or inflammation is a cause or consequence of fluid overload so far. Initial levels of hemoglobin and albumin were significantly lower in the OG, but the level of C-reactive protein was not in this study.

Hypoalbuminemia is an important risk factor for increased morbidity and mortality in patients on dialysis. Several different factors contribute to hypoalbuminemia in a patient on chronic dialysis, including malnutrition [14], chronic inflammation [31,32], atherosclerosis [33–35], the concentration of free toxins such as p-cresol [36], and overhydration [37]. These prior studies are in agreement with our results.

Anemia is also associated with increased rates of hospitalization and mortality in patients with CKD [38,39]. The all-cause mortality was lowest in Korean dialysis patients with hemoglobin levels of 10–11 g/dL [40]. The OG of our study had significantly lower serum levels of hemoglobin. Anemia might have contributed to the increase of overall mortality, though the OR was not increased to a statistically significant degree (data not shown). Anemia may be a secondary effect by overhydration rather than malnutrition or decrease in red blood cells.

There was no significant difference of all-cause admission rate or disease-specific admission rate between the 2 groups. Some following details are thought to be the cause. Most of the enrolled patients were transferred to private dialysis centers for maintenance dialysis on 1–2 weeks after the start of dialysis, so admission with mild disorder in other hospitals may have been missed. Some of the patients had prolonged hospitalization periods because of complicated disorders such as infection, and only the major cause of admission was included in the analysis. There is also the possibility that the number of events was too small to establish the statistical significance.

Twelve patients who were considered to be dehydrated (OH/ECW $\leq -13\%$) were excluded from our analysis, and 5 patients were died during 1.83 years of follow-up. The causes of death were as follows: 1 case of myocardial infarct, 1 case of septic shock, 1 case of intracerebral hemorrhage, and 2 unknown cases. Four dead patients had underlying cardiovascular disorders (2 cases of heart failure, 1 case of prior myocardial infarct, and 1 case of atrial fibrillation). There is a possibility that the associated cardiovascular disorders have affected the death of the patients. It might be meaningful work to analyze factors related to dehydration, cardiovascular disorders, and aggravation of CKD or other serious general medical conditions in a larger patient group.

There are several limitations to this study. First, the retrospective study design allows for findings to be subjective to many other variables not analyzed in this study. Second, the patients in the study were enrolled in a single center. Third, this study did not include follow-up measurements of dry weight. Serial follow-up of volume status is more important than single measurement to guide dialysis patients toward normohydration and better BP control [20]. Further evaluation with BCM analysis, such as multicenter prospective trials with periodic measurement or meta-analysis of existing studies, might be helpful.

In conclusion, the volume status measured by BCM is related to overall survival of ESRD patients who started maintenance dialysis. Volume status should be assessed for each patient who is starting dialysis as an easy-to-use predictor of mortality in the clinical environment.

Conflicts of interest

All authors have no conflicts of interest to declare.

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