Renal Replacement Therapy

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Long-term body composition changes in patients undergoing hemodialysis: a single-center retrospective study

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Abstract

Background: Patients undergoing dialysis experience substantial decreases in muscle mass and functional muscle weakness. Muscle mass loss in patients undergoing hemodialysis is an independent predictor of survival, so muscle mass maintenance is essential for continued hemodialysis. This study examined longitudinal changes in the body composition of patients undergoing hemodialysis in different dialysis periods.

Methods: We retrospectively analyzed body composition measurements obtained by bioelectrical impedance analysis (BIA) using the same measuring instrument. The dialysis periods were 1–10 years from the start of hemodialysis for group A ($n=25$), 10–20 years for group B ($n=22$), and 20–30 years for group C ($n=9$). The initial and final measurements of each group were compared. Furthermore, the nutritional status based on the inflammation and nutritional indicators obtained during the measurement period of each group was examined.

Results: Muscle mass did not significantly decrease in groups A and B but did decrease in group C ($P<0.05$). In all groups, the extracellular water-to-total body water ratio (ECW/TBW) significantly increased ($P<0.001$). C-reactive protein in groups A and B increased; however, the median initial and final values were < 0.2 mg/dL, and no changes were observed in group C. Furthermore, the median normalized protein catabolic rate was 0.86–1.05 g/kg/day, and there was no difference in the initial or final rates. The mean energy and protein daily intakes were 30–32 kcal/ideal body weight (IBW) kg/day and 1.1 g/IBW kg/day, respectively.

Conclusions: In patients undergoing hemodialysis, even if the muscle mass values are maintained, the possibility of a substantial decrease in muscle mass cannot be ruled out when ECW/TBW increases. Control of inflammation and nutritional intake may help minimize muscle mass loss caused by continued hemodialysis in patients.

Keywords: Patients undergoing hemodialysis, Body composition, Bioelectrical impedance analysis, Nutritional status, Muscle mass

Background

Sarcopenia, defined as a decrease in skeletal muscle mass or physical performance [1], is generally an age-related condition. In 2018, individuals aged ≥ 75 years accounted for 35.4% of patients undergoing hemodialysis in Japan [2]. The prevalence of sarcopenia among patients undergoing hemodialysis ranges from 12.7 to 40.0% [3–8]; sarcopenia can be caused by age-related factors, but secondary sarcopenia can result from pathological conditions specific to chronic kidney disease (CKD), such as inflammation, hypercatabolism, uremia, and malnutrition [9]. Hence, measures to minimize sarcopenia in patients undergoing hemodialysis are important for patients undergoing dialysis at present. In Japan,

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the prevalence of patients undergoing hemodialysis for ≥ 10 years has been increasing [2]. Prolonged dialysis causes various complications that affect physical activity and the continuation of dialysis therapy. In particular, arteriosclerosis can cause cardiovascular disease, which is a major concern in patients undergoing hemodialysis and is associated with muscle loss, chronic inflammation, and nutritional disorders [10, 11].

The International Society of Renal Nutrition and Metabolism proposed the term "protein-energy-wasting," which refers to the loss of muscle mass and adipose tissue or the presence of inflammation as well as malnutrition in patients with CKD [12]. Decreased muscle mass and weight loss are widely used as a nutritional index of patients undergoing hemodialysis [13–16]; therefore, muscle mass measurement is necessary for nutritional status assessments. Furthermore, because muscle mass loss in patients undergoing hemodialysis is an independent predictor of survival [3, 17], maintenance of muscle mass is essential for continued hemodialysis treatment.

Many studies on changes in body composition in patients undergoing hemodialysis have been conducted cross-sectionally [18–20]; however, only a few longitudinal studies observing long-term changes have been conducted. One reason for this is that differences in measured values can depend on the measurement instruments and devices, which makes it difficult to continuously collect body composition data. Therefore, we continued to evaluate body composition with the same model in our daily medical treatment of dialysis patients. Dialysis treatment periods have varied from the start of dialysis to > 30 years of continuous dialysis among patients who received hemodialysis therapy during this period.

The primary study aim was to investigate the longitudinal changes in body composition of patients undergoing hemodialysis over different dialysis periods and analyze the data retrospectively. Second, we simultaneously collected data on nutritional indicators, inflammatory status, and nutritional intake during the body composition assessment and examined these indicators along with changes in muscle mass during the dialysis period.

Methods

Subjects

Body composition measurements using the same measuring instrument were performed from 2000 to 2017. Given that this study was designed to analyze the 11 years of body composition data collected by the same instrument, 63 patients who underwent body composition measurement for 11 of 17 years were selected as target subjects. Of them, seven were excluded because of transfers to other hospitals, difficulty in standing during the measurement because we used a standing-posture bioelectrical impedance analysis (BIA), and the use of a pacemaker that affected the measurement outcomes. Accordingly, body composition measurements from 56 subjects were analyzed, with a focus on dialysis periods. Body composition measurements were performed from 0 to 10 years after the initiation of hemodialysis (group A; initiation of hemodialysis between 2000 and 2007), from 10 to 20 years (group B; between 1990 and 1997), and from 20 to 30 years (group C; 1980 and 1987). The numbers of patients in groups A, B, and C were 25, 22, and 9, respectively. In group A, the data were analyzed from year 1 after the initiation of hemodialysis when the dialysis conditions and clinical data were stable.

Measurement of body composition

Body composition measurements were performed using InBody 3.0™ (InBody Co., Ltd., Seoul, Korea). The device used the direct segmental multifrequency bioimpedance analysis method (DSM-BIA). Body composition measurements were performed after removal from the hemodialysis instrument in all patients. The extracellular water-to-total body water ratio (ECW/TBW) and extracellular water-to-intracellular water ratio (ECW/ICW) were calculated on the basis of ICW, ECW, and TBW.

Laboratory data

Blood urea nitrogen (BUN) ($n = 55$), creatinine (Cr) ($n = 55$), and C-reactive protein (CRP) ($n = 48$) were measured regularly using a standard method, and albumin (Alb) ($n = 51$) was measured using the bromocresol green method. The normalized protein catabolic rate (n-PCR) ($n = 49$) and Kt/V were calculated in the month of body composition measurement [21].

The diet survey was conducted using the 24-h recall method under the direction of a doctor. The daily intake of energy and protein was calculated on the basis of a dietary survey and normalized by ideal body weight according to dietary recommendations for CKD [22]. The dietary survey was administered to 42 subjects during the data collection period.

Statistical analyses

The chi-square test was used to compare categorical data. The Shapiro–Wilk test was used to evaluate the distribution of variables. Normally distributed variables and those without a normal distribution are expressed as the means ± standard deviations and medians (interquartile ranges), respectively. One-way analysis of variance was used for comparisons among the three groups. The paired t test or Wilcoxon signed-rank test was used to assess the difference between the start and end of the data collection period for each group. Percent changes

in muscle mass, ECW/TBW, and ECW/ICW were calculated by the least squares method, and the association between each index and the number of measurement years was examined using partial regression coefficients. In addition, differences between groups for each change were analyzed using a linear mixed model. Statistical analyses were performed using Bell Curve for Excel (version 3.23; Social Survey Research Information Co., Ltd., Tokyo, Japan).

Results

Study subjects

The patient characteristics are presented in Table 1. The mean dry weight (DW) and body weight (BW) values were similar in all groups. Significant differences between groups were observed for n-PCR ($P<0.05$).

Body composition measurement

The initial and final measurement values of each group were compared (Table 2). Muscle mass remained unchanged in groups A and B but decreased significantly in group C ($P<0.05$). The ECW was unchanged in all groups, whereas the ICW decreased significantly in all groups ($P<0.01$). The TBW was significantly decreased in group C only ($P<0.05$). The ECW/TBW and ECW/ICW increased significantly in all groups ($P<0.001$).

Muscle mass values, ECW/TBW, and ECW/ICW

Changes in muscle mass values were examined in each group. The muscle mass change rate values per year were −0.054 kg/y (−0.08%), −0.079 kg/y (−0.16%), and −0.160 kg/y (−0.38%) in groups A, B, and C, respectively. The association between the number of measurement years and muscle mass values was significant in groups B and C (Fig. 1). The relationship between dialysis duration and ECW/TBW or ECW/ICW is shown in Figs. 2 and 3, respectively. The association between the number of measurement years and ECW/TBW as well as ECW/ICW was significant in all groups. According to the results of a linear mixed model analysis, the changes

Table 1 Patient characteristics

Number of subjects	Group A 25	Group B 22	Group C 9	*P* value
Dialysis duration, y	1	10	20	
Male/Female	19/6	12/10	7/2	0.419
DM/Non-DM	2/23	1/21	1/8	0.998
Age, y	52.7 ± 9.7	52.2 ± 7.8	55.2 ± 9.8	0.688
Height, m	1.69 (1.55–1.72)	1.60 (1.54–1.68)	1.60 (1.54–1.70)	0.335
BMI, kg/m^2	22.7 ± 2.4	21.5 ± 2.8	22.5 ± 1.9	0.254
DW, kg	61.5 ± 11.2	55.0 ± 10.6	58.7 ± 8.3	0.120
BW, kg	61.4 ± 11.1	54.8 ± 10.5	58.7 ± 8.5	0.107
Fat mass, kg	12.7 ± 3.7	11.7 ± 4.5	13.1 ± 3.3	0.579
Muscle mass, kg	46.0 ± 9.4	40.9 ± 8.4	43.0 ± 7.4	0.143
LBM, kg	48.8 ± 9.9	43.1 ± 8.9	45.6 ± 7.8	0.122
BCM, kg	30.2 ± 6.2	26.4 ± 4.7	28.1 ± 4.8	0.060
ECW, L	11.1 ± 2.3	9.9 ± 2.2	10.5 ± 1.9	0.198
ICW, L	18.0 ± 3.7	15.8 ± 3.2	16.6 ± 2.8	0.100
TBW, L	29.0 ± 6.0	25.7 ± 5.3	27.2 ± 4.7	0.132
ECW/TBW	0.381 ± 0.010	0.383 ± 0.015	0.387 ± 0.012	0.411
ECW/ICW	0.615 ± 0.027	0.621 ± 0.040	0.633 ± 0.031	0.388
BUN, mg/dL	69 ± 17	70 ± 11	78 ± 7	0.229
Cr, mg/dL	11.5 ± 2.0	12.3 ± 1.4	13.0 ± 2.3	0.101
CRP, mg/dL	0.10 (0.00–0.20)	0.00 (0.00–0.10)	0.20 (0.00–0.20)	0.581
Alb, g/dL	3.7 ± 0.3	3.6 ± 0.2	3.6 ± 0.3	0.223
n-PCR, g/kg/day	0.86 (0.73–0.93)	0.90 (0.79–1.01)	1.05 (1.01–1.11)	0.017
Kt/V	1.21 ± 0.25	1.37 ± 0.23	1.29 ± 0.27	0.097

Data are expressed as the number, mean ± standard deviation, or median (interquartile range)

P values were assessed by chi-square test or one-way analysis of variance

DM Diabetes mellitus, *DW* Dry weight, *BW* Body weight, *BMI* Body mass index, *LBM* Lean body mass, *BCM* Body cell mass, *ECW* Extracellular water, *ICW* Intracellular water, *TBW* Total body water, *ECW/TBW* Extracellular water-to-total body water ratio, *BUN* Blood urea nitrogen ($n=55$), *Cr* Creatinine ($n=55$), *CRP* C-reactive protein ($n=48$), *Alb* Albumin (n = 51), *n-PCR* Normalized protein catabolic rate ($n=49$)

Table 2 Change in body composition measurements and laboratory data

Duration, y	Group A			Group B			Group C		
	1	10	*P* value	10	20	*P* value	20	30	*P* value
DW, kg	61.5 ± 11.2	61.5 ± 12.3	0.967	55.0 ± 10.6	53.7 ± 9.5	0.247	58.7 ± 8.3	57.4 ± 9.5	0.391
BW, kg	61.4 ± 11.1	61.7 ± 12.4	0.778	54.8 ± 10.5	54.0 ± 9.6	0.442	58.7 ± 8.5	57.3 ± 9.6	0.386
Fat mass, kg	12.7 ± 3.7	13.5 ± 3.8	0.292	11.7 ± 4.5	11.6 ± 4.2	0.935	13.1 ± 3.3	13.6 ± 4.5	0.638
Muscle mass, kg	46.0 ± 9.4	45.6 ± 9.5	0.383	40.9 ± 8.4	40.0 ± 7.9	0.113	43.0 ± 7.4	41.2 ± 7.1	0.012
LBM, kg	48.8 ± 9.9	48.2 ± 9.9	0.230	43.1 ± 8.9	42.4 ± 8.2	0.245	45.6 ± 7.8	43.7 ± 7.5	0.012
BCM, kg	30.2 ± 6.2	29.6 ± 6.2	0.014	26.4 ± 4.7	25.8 ± 4.9	0.178	28.1 ± 4.8	26.6 ± 4.5	0.004
ECW, L	11.1 ± 2.3	11.4 ± 2.4	0.065	9.9 ± 2.2	10.1 ± 2.2	0.179	10.5 ± 1.9	10.6 ± 2.0	0.584
ICW, L	18.0 ± 3.7	17.5 ± 3.7	0.002	15.8 ± 3.2	15.1 ± 2.8	0.005	16.6 ± 2.8	15.5 ± 2.6	0.002
TBW, L	29.0 ± 6.0	28.8 ± 6.0	0.432	25.7 ± 5.3	25.2 ± 4.9	0.212	27.2 ± 4.7	26.1 ± 4.5	0.016
ECW/TBW	0.381 ± 0.010	0.394 ± 0.016	< 0.001	0.383 ± 0.015	0.399 ± 0.019	< 0.001	0.387 ± 0.012	0.405 ± 0.014	< 0.001
ECW/ICW	0.615 ± 0.027	0.652 ± 0.044	< 0.001	0.621 ± 0.040	0.665 ± 0.054	< 0.001	0.633 ± 0.031	0.683 ± 0.039	< 0.001
BUN, mg/dL	69 ± 17	65 ± 12	0.217	70 ± 11	61 ± 11	0.003	78 ± 7	72 ± 9	0.216
Cr, mg/dL	11.5 ± 2.0	13.0 ± 2.3	< 0.001	12.3 ± 1.4	11.5 ± 2.0	0.027	13.0 ± 2.3	11.7 ± 2.1	0.024
CRP, mg/dL	0.10 (0.00–0.20)	0.08 (0.06–0.37)	0.012	0.00 (0.00–0.10)	0.07 (0.03–0.11)	0.007	0.20 (0.00–0.20)	0.13 (0.05–0.16)	0.051
n-PCR, g/kg/day	0.86 (0.73–0.93)	0.91 (0.75–1.04)	0.178	0.90 (0.79–1.01)	0.94 (0.85–1.01)	0.507	1.05 (1.01–1.11)	0.98 (0.90–1.03)	0.173
Alb, g/dL	3.7 ± 0.3	3.7 ± 0.3	0.703	3.6 ± 0.2	3.7 ± 0.3	0.114	3.6 ± 0.3	3.8 ± 0.3	0.068
Kt/V	1.21 ± 0.25	1.40 ± 0.25	0.217	1.37 ± 0.23	1.52 ± 0.30	0.045	1.29 ± 0.27	1.57 ± 0.31	0.002

Data are expressed as the mean ± standard deviation or median (interquartile range)

P values were assessed by paired t test or Wilcoxon signed-rank test

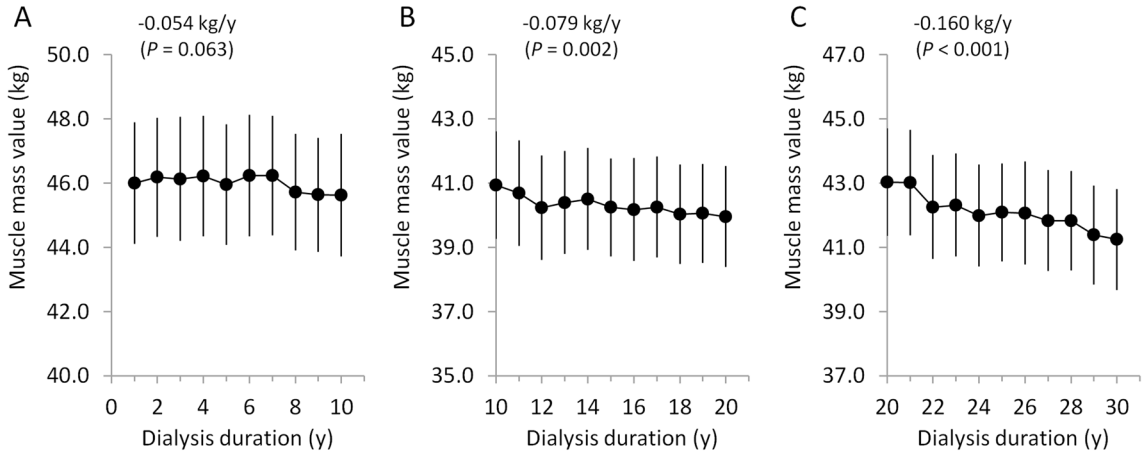

Fig. 1 Changes in muscle mass values in patients undergoing hemodialysis. Dots and error bars represent the mean and standard error. The dialysis period was 1–10 years for group A, 10–20 years for group B, and 20–30 years for group C. The values indicate the percentage change using the least squares method. *P* values were calculated by partial regression coefficients.

in muscle mass, ECW/TBW and ECW/ICW did not show significant differences between groups ($P=0.079$, $P=0.101$, $P=0.103$, respectively).

Laboratory values and food intake

The median initial and final CRP measurements were 0.10 mg/dL and 0.08 mg/dL in group A, 0.00 mg/dL and 0.07 mg/dL in group B, and 0.20 mg/dL and 0.13 mg/dL in group C, respectively. CRP increased significantly in groups A and B ($P<0.05$ and $P<0.01$) but did not significantly change in group C.

No significant changes in Alb or n-PCR were observed between the initial and final measurements in all groups (Table 2).

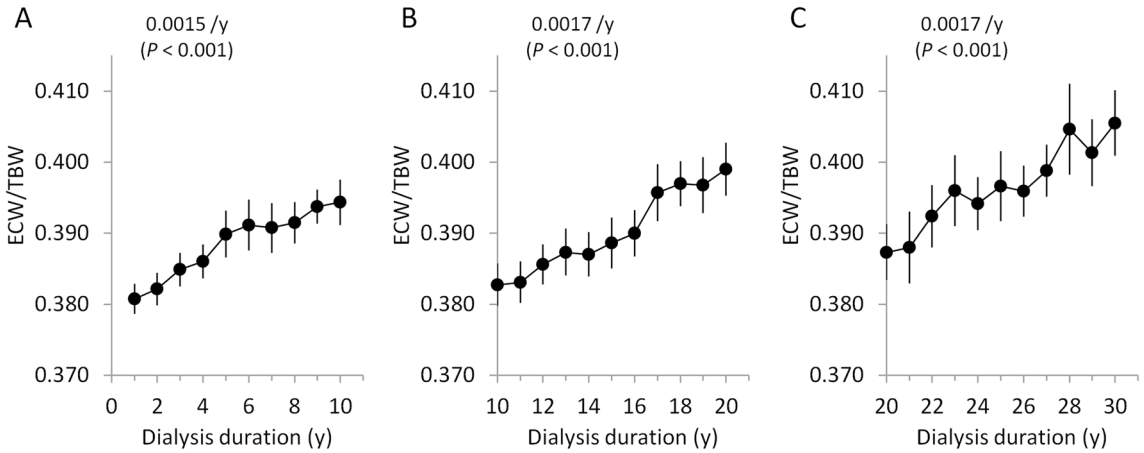

Fig. 2 Changes in ECW/TBW in patients undergoing hemodialysis. Dots and error bars represent the mean and standard error. The dialysis period was 1–10 years for group A, 10–20 years for group B, and 20–30 years for group C. The values indicate the percentage change using the least squares method. *P* values were calculated by partial regression coefficients. ECW/TBW, extracellular water-to-total body water ratio.

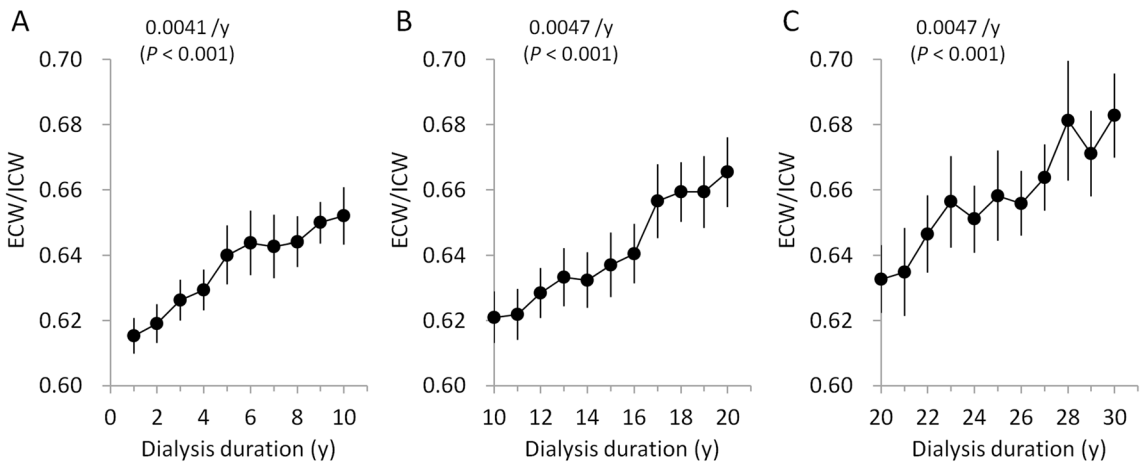

Fig. 3 Changes in ECW/ICW in patients undergoing hemodialysis. Dots and error bars represent the mean and standard error. The dialysis period was 1–10 years for group A, 10–20 years for group B, and 20–30 years for group C. The values indicated the percentage change using the least squares method. *P* values were calculated by partial regression coefficients. ECW/ICW, extracellular water-to-intracellular water ratio.

The mean energy intake of groups A, B, and C ranged from 30 to 32 kcal/IBW kg/day, without a significant difference between the groups. The protein intake was 1.1 g/IBW kg/day in all groups, and no significant difference was observed among the groups (Table 3).

Discussion

In this study, body composition measurements using the same analysis method, DSM-BIA, were performed in patients undergoing hemodialysis. To our knowledge, this is the first study to demonstrate longitudinal changes in the body composition of patients undergoing hemodialysis in different dialysis periods.

Patient characteristics

Among all subjects, the mean age and percentage of patients with DM were 54.0 years and 7.1%, respectively. According to a Japanese statistical survey in 2018, the mean age and DM rate were 68.8 years and 39.0%, respectively [2]. One factor that caused these differences is that patients undergoing hemodialysis in Japan had backgrounds different from those of the patients in 2000, whose mean age and DM rate were 61.2 and 26.0%, respectively [2]. Furthermore, the rate of patients undergoing hemodialysis for primary diseases, such as chronic glomerulonephritis and nephrosclerosis, rather than DM, was high at the study

Table 3 Dietary intake

	Group A	Group B	Group C	*P* value
Energy intake, kcal/day	1744 ± 286	1774 ± 413	1713 ± 220	0.909
Energy intake, kcal/kg/day[1]	31 ± 5	32 ± 7	30 ± 3	0.635
Protein intake, g/day	60.6 ± 10.0	60.0 ± 12.3	61.0 ± 6.2	0.975
Protein intake, g/kg/day[2]	1.1 ± 0.2	1.1 ± 0.2	1.1 ± 0.1	0.960

Data are expressed as the mean ± standard deviation

P values were assessed by one-way analysis of variance

The dialysis period was 1–10 years for group A, 10–20 years for group B, and 20–30 years for group C

Dietary intake ($n = 42$)

[1] Daily energy intake according to ideal body weight

[2] Daily protein intake according to ideal body weight

facility in 2000 when the body composition measurements started.

Changes in DW

All subjects' body composition measurements were performed after hemodialysis, so we could collect data under the same conditions in this study. There were no significant differences in BW or DW between the start and end of the measurement period regardless of the hemodialysis period. Chazot et al. reported that DW reduction in patients undergoing hemodialysis was observed in the 11th year after hemodialysis initiation and became significant from the 16th year onward [23]. These data indicate that the DW of the subjects remained unchanged for a long time.

Muscle mass values and ECW/TBW

The muscle mass values were not significantly reduced in patients with a hemodialysis duration ≤ 20 years. Although the muscle mass values significantly decreased in patients with a hemodialysis duration ≥ 20 years, the mean muscle mass values decreased by < 1% per year. Muscle mass loss in healthy subjects was associated with aging [19, 20] and reportedly decreased by 1–2% per year after the age of 50 years [19, 24]. The ECW/TBW increases with an age-related ICW decrease, regardless of edema status, in both healthy subjects and patients with CKD [18, 25]. On the other hand, the enlargement of the cross-sectional area of muscle fibers in maintenance patients undergoing hemodialysis is partially caused by edema [26]. This result indicates that patients experienced edema even though the muscle mass was apparently maintained.

Because the muscle mass values measured via BIA included water, it was thought that the decrease in the muscle mass values did not necessarily indicate a substantial decrease in muscle mass. ECW/TBW, an indicator of volume status, is important in patients with CKD prone to excess body water. Fluid overload is a predictor of all-cause mortality in patients undergoing hemodialysis [27]. Therefore, careful and continuous observation of not only the muscle mass but also the ECW/TBW ratio in patients undergoing hemodialysis upon assessment of their body compositions is essential.

ECW and ICW

The ECW remained unchanged, and the ICW decreased regardless of the hemodialysis duration. According to Ohashi et al., the ECW and ICW decrease with age in healthy subjects [18]. However, the ECW varies depending on the DW setting in patients undergoing hemodialysis. Therefore, changes in the ECW may be affected by fluid management in patients undergoing hemodialysis. The decrease in the ICW in healthy subjects is mainly considered to be indicative of a decrease in cell volume, which is associated with muscle loss [18]. In this study, the ECW/ICW increased as the hemodialysis duration increased. Our results suggest that the ECW/ICW in patients undergoing hemodialysis increases more than the age-related changes in healthy individuals.

Nutrition and inflammation

CRP did not significantly change in group C but increased in groups A and B; however, the median of the initial and final values was < 0.2 mg/dL. In all groups, n-PCR, an index of protein catabolism that increases with increased inflammation, was unchanged. CRP increases as a result of the production of inflammatory cytokines known to be associated with muscle atrophy. Increased inflammatory cytokines may induce a decrease in food intake by causing loss of appetite [12, 28]. Although these findings are limited, protein catabolism caused by long-term nutritional disorders and inflammation was unlikely to have occurred in the subjects.

The results of the dietary survey showed that energy and protein intake did not differ among the subjects with different hemodialysis durations. The daily energy and protein intakes were within the 30–35 kcal/kg/day and 0.9–1.2 g/kg/day ranges, respectively, which are the dietary standards for patients undergoing hemodialysis in Japan [22]. Hence, the energy and protein intakes of the subjects were similar to the dietary standards. According to the study by Houston et al., healthy elderly individuals with a high protein intake (1.1 g/kg/day) had an approximately 40% smaller decrease in skeletal muscle mass than those with a lower protein intake (0.7 g/kg/day) [29]. Furthermore, energy intake was reduced along with protein intake in patients with CKD who had decreased skeletal muscle mass [30, 31]. The prevalence of patients with

sarcopenia is 40% among patients undergoing hemodialysis [8]. Analysis of the longitudinal changes in the nutritional index, amount of nutrition intake, and inflammatory index, as well as body composition data, suggests that the subjects were well nourished and that especially the patients undergoing long-term dialysis in this study ate adequately. These findings indicate that proper nutrition may have contributed to the maintenance of muscle mass in the study subjects, and dietary reference intakes for patients undergoing hemodialysis in Japan are considered an indicator of good nutritional status in patients undergoing hemodialysis.

Limitations

The backgrounds of the subjects from whom data were collected in this study, especially age distribution and the proportion of patients with underlying diseases, differed from those of current patients undergoing dialysis in Japan [2]. Therefore, care must be taken when comparing the measurements shown with those obtained from other current patients undergoing dialysis because our study measurements may be difficult to generalize to other patient populations. In addition, as of 2017, patients undergoing hemodialysis with a dialysis period of 1–30 years were included in the study. In this regard, attention must be paid to the difference between the dialysis medical treatment each subject received and the current treatment in terms of dialysis equipment and medication.

This study was performed with a small sample at a single facility. The parameters related to inflammation and nutrition could not be collected in all patients during the body composition measurement data collection period. Furthermore, the number of subjects from whom nutritional intake data could be collected was limited. On the other hand, there are few reports on the nutritional intake of Japanese patients undergoing hemodialysis. In the future, larger and more accurate prospective studies will be needed to reach more generally applicable conclusions regarding the association between the maintenance of muscle mass, inflammation, and nutrition in patients undergoing dialysis.

Conclusions

We retrospectively analyzed body composition measurements obtained via BIA from patients undergoing hemodialysis with different dialysis periods. Continuous body composition assessments of patients undergoing hemodialysis therapy may be useful for obtaining information on changes in muscle mass. Even if the muscle mass values are maintained, the possibility of a substantial decrease in muscle mass cannot be ruled out when an increase in ECW/TBW is observed simultaneously. Hence, this change may be an important sign that should not be overlooked for the early detection of sarcopenia. Inflammation and nutritional control may help minimize muscle mass loss caused by continued dialysis therapy in patients.

Abbreviations

CKD: Chronic kidney disease; BIA: Bioelectrical impedance analysis; DSM-BIA: Direct segmental multifrequency bioimpedance analysis; DM: Diabetes mellitus; DW: Dry weight; BW: Body weight; BMI: Body mass index; LBM: Lean body mass; BCM: Body cell mass; ECW: Extracellular water; ICW: Intracellular water; TBW: Total body water; ECW/TBW: Extracellular water-to-total body water ratio; BUN: Blood urea nitrogen; Cr: Creatinine; CRP: C-reactive protein; Alb: Albumin; n-PCR: Normalized protein catabolic rate.

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Author contributions

YS planned the study and analyzed the data. YS and MK drafted the manuscript. TM and EM helped interpret the data. TM and YK helped draft the manuscript. All authors read and approved the final version of the manuscript for submission.

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Availability of data and materials

Not applicable.

Declarations

Ethics approval and consent to participate

This retrospective study was conducted with the approval of the Ethics Committee of Eijinkai Hospital (approval number 1802). Informed consent was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

YK is the associate editor of Renal Replacement Therapy.

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