AUCTORES
Globalize your Research

International Journal of Clinical Case Reports and Reviews
Keita Sugai *

Open Access

Research Article

The Changes in Cholinesterase During Overhydration in Hemodialysis Patients

Keita Sugai [1]*, Chihiro Sakurai [2], Akari Fujita [2], Yuika Akai [2], Etsuko Shitara [2], Junji Uchino [3], Takehiko Sakai [4], Motoyuki Masai [5], Kohji Shirai [5]

[1]Department of Nutrition, Mihama Katori Clinic, Seijinkai Medical Corporation, Chiba, Japan.

[2]Department of Nutrition, Mihama Hospital, Seijinkai Medical Corporation, Chiba, Japan.

[3]Department of Clinical Engineering, Mihama Hospital, Seijinkai Medical Corporation, Chiba, Japan.

[4]Dialysis Department, Mihama Katori Clinic, Seijinkai Medical Corporation, Chiba, Japan.

[5]Dialysis Department, Mihama Hospital, Seijinkai Medical Corporation, Chiba, Japan.

***Corresponding Author:** Keita Sugai, Department of Nutrition, Mihama Katori Clinic, Seijinkai Medical Corporation, Chiba, Japan 2-9-3 Tamatsukuri, Katori City, Chiba Prefecture, Japan.

Received Date: July 16, 2025 | **Accepted Date:** July 23, 2025 | **Published Date:** July 29, 2025

Citation: Keita Sugai, Chihiro Sakurai, Akari Fujita, Yuika Akai, Etsuko Shitara, et al., (2025), The Changes in Cholinesterase During Overhydration in Hemodialysis Patients, *International Journal of Clinical Case Reports and Reviews*, 28(5); **DOI:10.31579/2690-4861/921**

Abstract:

Background/Aim: Overhydration is a serious complication of maintenance hemodialysis patients. Various predictive factors of overhydration have been mentioned, but the role of nutritional condition has not been fully established. We have encountered several cases whose nutritional indices, especially serum cholinesterase (ChE) and serum albumin (Alb), declined one to two months before the onset of overhydration.

Then, among cases suffering from overhydration, two groups were divided according to the changes of ChE during before and after 3 months from overhydration attack and were certified the features of both groups concerning cardiothoracic ratio (CTR) and blood pressure as well as body weight changes.

Subjects: The subjects were 20 patients suffering from overhydration during maintenance hemodialysis and were hospitalized.

Methods: Monthly changes of ChE, Alb, post-dialysis weight, CTR, and blood pressure for 3 months before and after overhydration.

Results: Among the 20 patients, 14 had a decrease in ChE values during overhydration, and 6 did not. The ChE-decreased groups tended to have lower BMI, Alb, and ChE than the non-ChE-decreased groups. In the ChE-decreased groups, CTR tended to increase, and ChE and Alb decreased significantly from two months before the onset of overhydration and further increase in CTR ($P=0.026$) and further decreases in ChE ($P<0.001$) and Alb ($P=0.005$) were observed at overhydration attack.

Conclusions: In patients with overhydration, there were two types; one is ChE-decreased groups (70%), and the other is non-ChE-decreased groups (30%). Both groups increased CTR and NT-proBNP at overhydration. The former decreased Alb, but latter did not. These results suggested that a decrease in food intake might be the main risk of overhydration and decrease in ChE might be sensitive warning signs for overhydration.

Key words: maintenance hemodialysis; overhydration; serum cholinesterase; dry weight

Abbreviations

HD: Hemodialysis

ChE : Serum cholinesterase

Alb : Serum albumin

CTR : Cardiothoracic ratio

DW : Dry weight

NT-proBNP: N-terminal fragment of human brain natriuretic peptide precursor

1.Introduction

Overhydration is one of the serious complications frequently encountered during hemodialysis treatment. In addition to severe subjective symptoms such as chest discomfort and shortness of breath in the acute phase, overhydration itself is also known to have a poor prognosis. Therefore, overhydration should be avoided [1].

Usually, enhanced cardiothoracic ratio (CTR), high blood pressure, and subjective symptoms such as dyspnea and discomfort were paid attention to find overhydration. However, CTR can fluctuate if insufficient air is inhaled during X-ray imaging, especially in elderly patients, and high blood pressure is not always observed before overhydration. Then it is not easy to find signs and symptoms predicting overhydration.

In recent years, it has been reported that human brain natriuretic peptide (BNP) and N-terminal fragment of BNP precursor (NT-proBNP) are useful indicators for congestive heart failure even in hemodialysis patients [2]. And it might be expected to be a good marker for predicting overhydration [2]. In addition, monitoring of body water volume using bioelectrical impedance method [3] and Fluid indices calculated from the distribution balance of urea and uric acid are also expected to be useful [4], but a comprehensive clinical evaluation is necessary, as one alone is not necessarily sufficient. As for nutritional factors, overeating and excessive water intake are generally thought to be the main cause of overhydration [1].

Whereas, we have often encountered cases whose nutritional factors such as serum cholinesterase (ChE) and serum albumin (Alb) were decreased at the onset of overhydration. Alb is well known as an indicator of protein in the body [5], ChE is generally considered to be an indicator of liver function. And ChE shows high values in patients with fatty liver, obesity, nephrotic syndrome, and hyperthyroidism, and low values in patients with malignant tumors, liver cirrhosis, and organophosphate drug poisoning [6]. As for the relationship with nutritional condition, it is reported that ChE correlates with energy intake in healthy young men [7].

Recently, ChE has been reported to be a prognostic indicator for patients with heart failure and after surgery, but little has been reported about its significance in hemodialysis patients [8,9,10,11].

However, ChE reflects the increase in protein synthesis and lipid metabolism accompanying the influx of energy components into the liver and therefore can also be an indicator of food intake.[6] We also believe that ChE may be an indicator of dry weight (DW) adjustment by predicting weight gain or loss in dialysis patients.

Furthermore, we hypothesize that overhydration accompanied by a decrease in ChE is not due to overeating or drinking, but rather that overhydration is due to the DW setting not keeping up with the patient's actual weight loss.

In this study, we aimed to observe changes in various factors, mainly ChE, in dialysis patients who had experienced overhydration, to clarify the relationship between the occurrence of overhydration and ChE, and to examine whether ChE can be used as an adjustment indicator for the setting of DW.

2. Materials and Methods

2.1. Subjects

The subjects were all 20 cases who were taking maintenance hemodialysis therapy and suffered from overhydration. They were all hospitalized at Mihama Hospital between September 1, 2020. and August 31, 2022. The diagnosis of overhydration was based on the increased CTR, the presence of pleural effusion and symptoms of respiratory distress. Additionally, Pleural effusion occurring at the time of the initiation of emergency dialysis in patients with conservative renal failure and pleural effusion associated with malignant tumors and acute heart disease were excluded from this study.

The clinical background of all subjects at the time of admission is shown in Table 1. The clinical background (median [IQR]) was age 80.5 [72.5-82.25] years old, years of dialysis was 5.8 [3.7-10.2] years, and BMI 21.17 [18.42-23.35] kg/m^2.

At the time of admission, patient's DW was set to be 53.75 [43.5-63.63] kg, whereas the patient's weight after the last dialysis just before overhydration was 55.9 [44.9-63.95] kg. After removal water during hospitalization, the patient's body weight was 51.1 [40.23-60.75] kg. All patients recovered and discharged after improvement of signs and symptoms.

Among patients suffering from overhydration, there were ChE decreasing patients and ChE increasing patients. Then, those patients were separated shown as follows. Patients 1 to 14 were cases whose ChE decreased at overhydration attack, compared to 3 months before. Patients 15 to 20 were cases whose ChE increased or did not change at overhydration attack, comparing 3 months before.

2.2. Study Design and Data Collection

The changes of ChE, Alb, CTR, post-dialysis weight, and intradialytic systolic blood pressure (start, median, and end values) were investigated monthly from 3 months before to 3 months after overhydration attack. NT-proBNP were measured at before 3 months, just overhydration attack and after 3 months.

Regarding the timing of data collection, blood test data were pre-dialysis test values on the regular blood draw day two days after dialysis and on the blood draw day at the time of overhydration hospitalization, post-dialysis weight was the value on the same day, and CTR was the value for the same month. The systolic blood pressure during dialysis was calculated as the average of three dialysis sessions during the regular blood sampling week each month and the average of three dialysis sessions immediately before overhydration and was used as the representative value for each individual.

In addition, post-dialysis weight and blood pressure were also collected immediately overhydration treatment was corrected.

The study design was observational, and all data were retrospectively collected using medical records.

2.3. Statical Analysis

BellCurve® for Excel ver4.01 (Social Survey Research Information Co., Ltd., Tokyo, Japan) was used as statistical software, and the Wilcoxon signed rank test was used to compare data from three months prior to the overhydration with data from each subsequent month.

In addition, Spearman's rank correlation coefficient was calculated to examine the correlation between the decrease in ChE (U/L) from 3 months before overhydration to the time of onset of overhydration and the amount of weight loss from 3 months before overhydration after correction of overhydration.

The significance level was set at less than 0.05 in all cases.

3. Results

3.1. Comparison of clinical backgrounds between ChE-decreased groups and non-ChE-decreased groups

Table 1 showed the background of 20 cases who suffered from overhydration. The means of various clinical features at overhydration were shown in the bottom. Actually, among those 20 cases, there were two groups: one is ChE-decreased groups (No. 1-14 cases, 70%), and the other is non-ChE-decreased groups (No. 15-20 cases, 30%). The main features of two groups were shown in Table 2. The changes of each factor between 3months before and just at overhydration were shown.

Cases	Sex	Age	Years of dialysis	Primary Disease of dialysis	Dry weight (kg)	Weight after the last dialysis just before overhydration(kg)	BMI (kg/m^2)	Weight adjusted for inpatient treatment(kg)	CTR (%)	Alb (g/dL)	BUN (mg/dL)	Cre (mg/dL)	ChE (U/L)	NT-proBNP (pg/mL)	EF (%)
A-1	F	87	1.3	Unclear	38.0	37.4	15.2	36.6	60.4	2.9	50.3	5.53	150	36100	89.4
A-2	F	88	2.7	Diabetic nephropathy	46.0	46.6	21.8	40.9	54.9	3.3	73.9	6.19	170	337000	42.6
A-3	F	73	23.1	Chronic nephritic syndrome	38.5	38.6	15.4	38.0	55.7	3.1	74.7	4.53	152	134000	39.0
A-4	M	82	5.9	Diabetic nephropathy	61.5	60.8	23.2	56.6	52.7	3.7	24.9	5.13	147	54300	48.0
A-5	F	81	11.6	Diabetic nephropathy	52.0	56.7	23.9	50.7	66.8	3.3	50.4	3.62	166	109000	34.4
A-6	M	54	0.4	Diabetic nephropathy	63.5	63.6	21.5	60.0	46.1	3.3	60.5	11.67	193	10200	55.4
A-7	F	71	6.6	Preeclampsia	47.0	47.2	21.3	45.6	61.7	3.7	49.0	6.46	251	22600	60.8
A-8	M	83	9.6	Diabetic nephropathy	39.0	39.0	15.0	38.2	44.4	2.6	29.7	6.05	120	36700	51.5
A-9	M	69	10.5	Diabetic nephropathy	66.0	65.3	20.6	63.0	53.2	3.4	24.6	5.94	149	31000	33.0
A-10	M	82	4.9	Diabetic nephropathy	55.5	55.1	17.7	51.5	63.8	3.8	40.6	5.39	252	87800	21.0
A-11	M	77	5.7	Diabetic nephropathy	75.0	77.3	27.1	74.0	47.6	3.4	57.2	12.30	181	4300	48.8
A-12	M	96	0.6	Nephrosclerosis	47.0	47.6	18.7	43.0	48.7	2.5	48.9	4.73	146	61900	43.5
A-13	M	82	4.3	Polycystic kidney disease	57.5	57.8	21.5	53.1	47.7	2.4	26.7	4.35	141	34200	57.8
A-14	M	80	10.1	Diabetic nephropathy	45.0	46.9	20.0	45.6	52.6	3.7	51.4	8.85	234	34600	53.6
B-1	M	54	9.0	Diabetic nephropathy	95.5	96.3	30.0	94.0	45.5	3.9	49.7	14.57	356	777	60.7
B-2	M	79	22.6	Diabetic nephropathy	64.0	65.0	25.1	63.3	64.0	3.6	58.2	8.46	83	66400	35.2
B-3	M	77	5.3	Diabetic nephropathy	74.0	74.4	25.3	72.0	53.5	3.8	52.8	8.09	253	56900	26.7
B-4	M	82	2.9	Diabetic nephropathy	59.5	59.6	21.0	57.0	47.5	3.6	51.7	8.75	181	28600	62.1
B-5	F	71	3.9	Diabetic nephropathy	38.5	39.8	19.5	37.0	55.4	3.0	54.0	6.77	225	38200	49.3
B-6	F	83	22.8	Chronic nephritic syndrome	33.0	33.0	17.6	32.5	58.1	2.5	55.8	4.53	161	15100	63.8
median [IQR]	M/F＝13/7	80.5 [72.5-82.25]	5.8 [3.7-10.2]	Diabetic nephropathy/Others ＝14/6	53.75 [43.5-63.63]	55.9 [44.9-63.95]	21.17 [18.42-23.35]	51.1 [40.23-60.75]	53.35 [47.68-58.68]	3.35 [2.98-3.7]	50.9 [43.83-56.15]	6.12 [5.03-8.53]	168 [148.5-227.25]	37450 [30400-71750]	49.05 [38.05-58.53]

Table 1: Clinical background of the subjects at the time of admission.

	All cases			[A] ChE-decreased groups			[B] non-ChE-decreased groups		
n	20			14			6		
Sex(M/F)	13/7			9/5			4/2		
Age	80.5 [72.5-82.25]			81.5 [74-82.75]			78 [72.5-81.25]		
Years of dialysis	5.8 [3.7-10.2]			5.79 [3.06-9.96]			7.17 [4.27-19.19]		
Primary disease of dialysis (Diabetic nephropathy / Others)	14/6			9/5			5/1		
EF (%)	49.05 [38.05-58.53]			48.4 [39.9-54.95]			55 [38.73-61.75]		
	3M before	Overhydration at onset	p-value	3M before	Overhydration at onset	p-value	3M before	Overhydration at onset	p-value
ChE(U/L)	194.5 [168-247.75]	168 [148.5-227.25]	0.033	205.5 [171.5-249.25]	159 [147.5-190]	<0.001	185.5 [127.75-209.5]	203 [166-246]	0.028
NT-proBNP(pg/mL)	30000 [8755-37800]	37450 [30400-71750]	<0.001	30000 [8225-38200]	36400 [31800-81325]	0.002	25900 [11900-32625]	47550 [31000-64025]	0.028
Alb(g/dL)	3.6 [3.3-3.725]	3.35 [2.975-3.7]	0.011	3.6 [3.325-3.378]	3.3 [2.95-3.625]	0.005	3.5 [3.175-3.6]	3.6 [3.15-3.75]	0.285
Post-dialysis weight(kg)	58.3 [44.85-64.75]	55.4 [44.4-64.1]	0.016	52.3 [46.03-62.95]	51.35 [46.68-60.05]	0.048	62.4 [46.28-72.53]	62.3 [44.75-72.05]	0.208
CTR (%)	51.2 [47.55-57.5]	53.35 [47.68-59.8]	0.022	50 [47.28-56.48]	52.95 [47.95-59.23]	0.026	53.9 [48.75-58.23]	54.45 [49-58.55]	0.529

(median [IQR])

Comparisons were made using the Wilcoxon signed rank test, with the significance level set at less than 0.05.

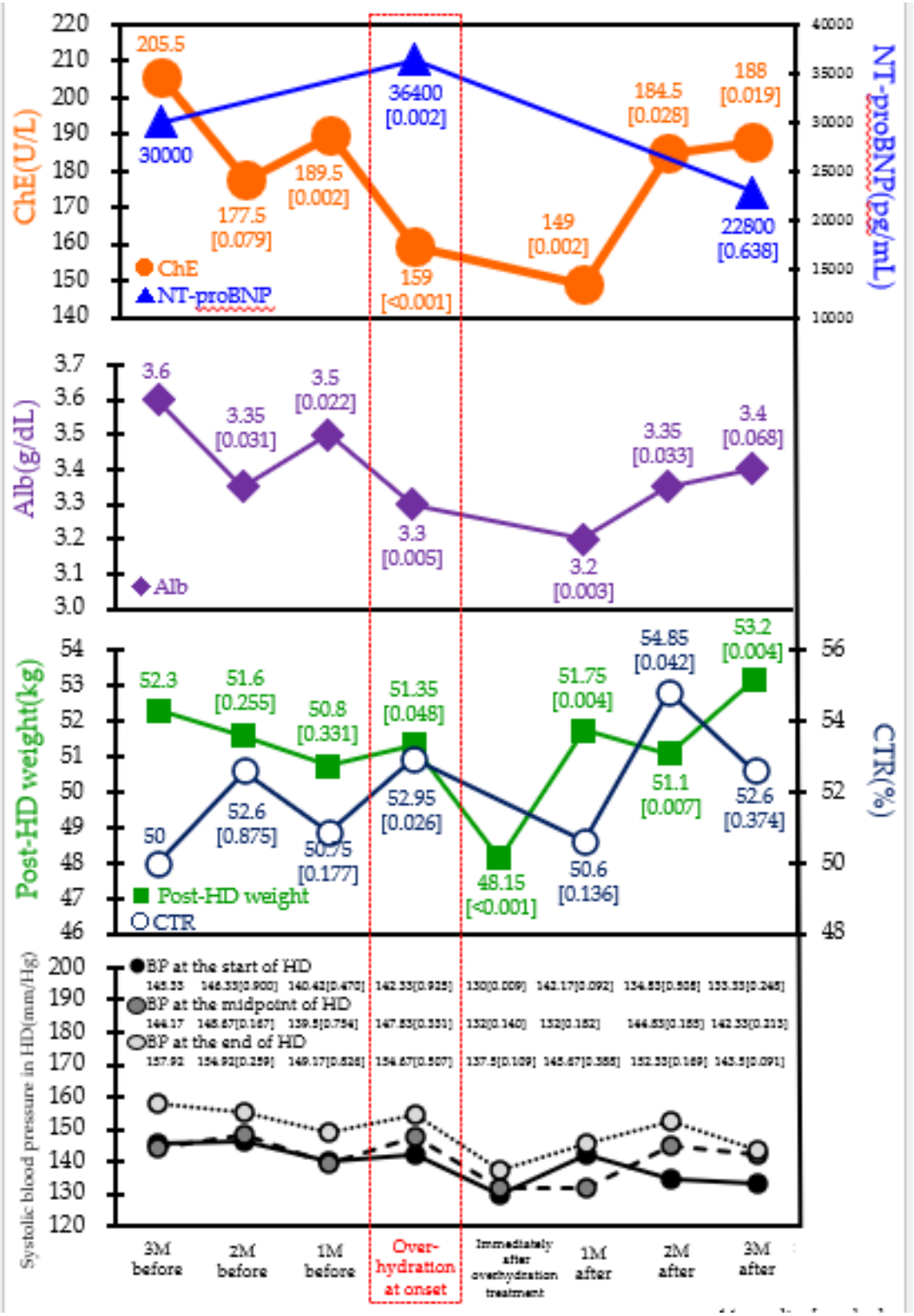
Table 2: Changes in indicators 3 months before and at the time of overhydration.

Usually, overhydration is thought to be due to over-drinking water or eating too much, and insufficient water removal during hemodialysis. Actually, No. 14-20 cases in Table2 showed a not change in body weight at overhydration, accompanying with increased CTR, in addition to an increase in ChE and Alb. The increases in the last two factors are usually due to the result of over drinking and or overeating. Whereas, No. 1-14 cases showed a decrease in body weight, ChE, and Alb, which means that 70% of cases suffered from overhydration were associated with a decrease in food intake.

From these results, the mechanism by which overhydration occurred might be different in both groups. Those two groups were different. Then we analyzed the features of the two groups separately as follows.

3.2. Changes in ChE, Alb, NT-proBNP, CTR, post-dialysis weight, and intradialytic systolic blood pressure (start, median, and end values) 3 months before and after the onset of overhydration in the ChE-decreased groups

The trends (median [p-value]) of ChE, Alb, NT-proBNP, CTR, post-dialysis weight, and intradialytic systolic blood pressure (start value, median value, and end value) in the ChE-decreased groups 3 months before overhydration, 2 months before overhydration, 1 month before overhydration, at the time of overhydration onset, 1 month after overhydration, 2 months after overhydration, and 3 months after overhydration are shown in Figure 1. Numbers in the text and figures indicate median values and p-value compared with baseline 3 months before overhydration.



n=14, median[p-value] Using the Wilcoxon signed rank test, the data from three months prior to the overhydration was used as the base period, and comparisons were made with each subsequent month. The significance level was set at a risk level of less than 0.05.

Figure 1: Changes in various factors before and after the onset of overhydration in the ChE-decreased groups.

3.2.1. Changes in pre-dialysis serum ChE values

Pre-dialysis serum ChE value (U/L) decreased from 205.5 three months before the overhydration to 177.5 [0.079] the following month, and continued to decrease thereafter, further decreasing to 159 [<0.001] at the time of the onset of overhydration. One month after the overhydration, the value remained at 149 [0.002], but then rose again, reaching 188 [0.019] three months after the overhydration.

3.2.2. Changes in pre-dialysis serum Alb values

Pre-dialysis serum Alb value (g/dL) was 3.6 three months before overhydration and decreased significantly to 3.35 [0.031] the following month, and at the time of the onset of overhydration, it had decreased to 3.3 [0.005]. It then dropped to 3.2 [0.003] one month after the overhydration. Three months after overhydration, it had risen to 3.4 [0.068].

3.2.3. Changes in pre-dialysis NT-proBNP values

Pre-dialysis NT-proBNP (pg/mL) values were shown for the values within 3 months before the overhydration, the values at the time of the onset of the overhydration, and the values within 3 months after the overhydration. The value of 30,000 before overhydration significantly increased to 36,400 [0.002] at the time of the onset of overhydration and showed a tendency to decrease to 22,800 [0.638] after overhydration treatment.

3.2.4. Changes in CTR

The CTR (%) tended to increase from 50 three months before overhydration to 52.6 [0.875] the following month, and at the time of the onset of overhydration, there was a significant increase to 52.95 [0.026]. After overhydration, the weight was corrected, and the index fell to 50.6 [0.136] but then rose to 54.85 [0.042].

3.2.5. Changes in post-dialysis weight

Post-dialysis weight (kg) tended to decrease from 52.3 three months before the onset of overhydration to 51.6 [0.255] the following month, and at the time of the onset of overhydration it had significantly decreased to 51.35 [0.048], and ChE and Alb values had also decreased, while NT-proBNP and CTR had increased. Post-dialysis weight after overhydration treatment was temporarily corrected to 48.15 [<0.001], then rose again and remained almost flat, but ChE and Alb values rose again, and NT-proBNP and CTR values decreased.

3.2.6. Changes in intradialytic systolic blood pressure

Intradialytic systolic blood pressure (mm/Hg) 3 months before the overhydration was 145.33 at the start of dialysis, 144.17 in the middle, and 157.92 at the end. There was a tendency for the end to be higher than the start, and this tendency was observed throughout the entire period, but there was no significant change compared to 3 months before the overhydration. Immediately after overhydration treatment, a decrease was observed in all areas, with a significant decrease of 130 [0.009] in the start blood pressure.

3.3. Changes in ChE, Alb, NT-proBNP, CTR, post-dialysis weight, and intradialytic systolic blood pressure (start, median, and end values) 3 months before and after the onset of overhydration in the non-ChE-decreased groups

The trends (median [p-value]) of ChE, Alb, NT-proBNP, CTR, post-dialysis weight, and intradialytic systolic blood pressure (start value, median value, and end value) in the non-ChE-decreased groups 3 months before overhydration, 2 months before overhydration, 1 month before overhydration, at the time of overhydration onset, 1 month after overhydration, 2 months after overhydration, and 3 months after overhydration are shown in Figure 2. Numbers in the text and figures indicate median values and p-value compared with baseline 3 months before overhydration.

3.3.1. Changes in pre-dialysis serum ChE values

Pre-dialysis serum ChE value (U/L) was 185.5 three months before the overhydration and decreased to 171 [0.465] the following month, a non-significant decrease, and continued to decrease thereafter, but at the time of the onset of overhydration, there was a significant increase to 203 [0.028]. One month after the overhydration, the value dropped to 150.5 [0.753], but then increased slightly, reaching 160 [0.686] three months after the overhydration.

3.3.2. Changes in pre-dialysis serum Alb values

The pre-dialysis serum Alb value (g/dL) was 3.5 3 months before the onset of overhydration but had increased to 3.6 [0.285] at the time of the onset of overhydration. The value then showed a decreasing trend to 3.4 [0.500] one month after the overhydration but increased to 3.55 [0.893] three months after the overhydration.

3.3.3. Changes in pre-dialysis NT-proBNP values

Pre-dialysis NT-proBNP (pg/mL) values were shown for the values within 3 months before the overhydration, the values at the time of the onset of the overhydration, and the values within 3 months after the overhydration. The value of 25,900 before the overhydration significantly increased to 47,550 [0.028] at the time of the onset of overhydration and showed a tendency to decrease to 30,850 [0.249] after overhydration treatment.

3.3.4. Changes in CTR

The CTR (%) showed an increasing trend, increasing from 53.9 three months before the overhydration to 54.45 [0.529] at the time of the onset of overhydration. After the overhydration, the dry weight was corrected and dropped to 51.1 [0.345], but three months after the overhydration it rose to 53.3 [0.345].

3.3.5. Changes in post-dialysis weight

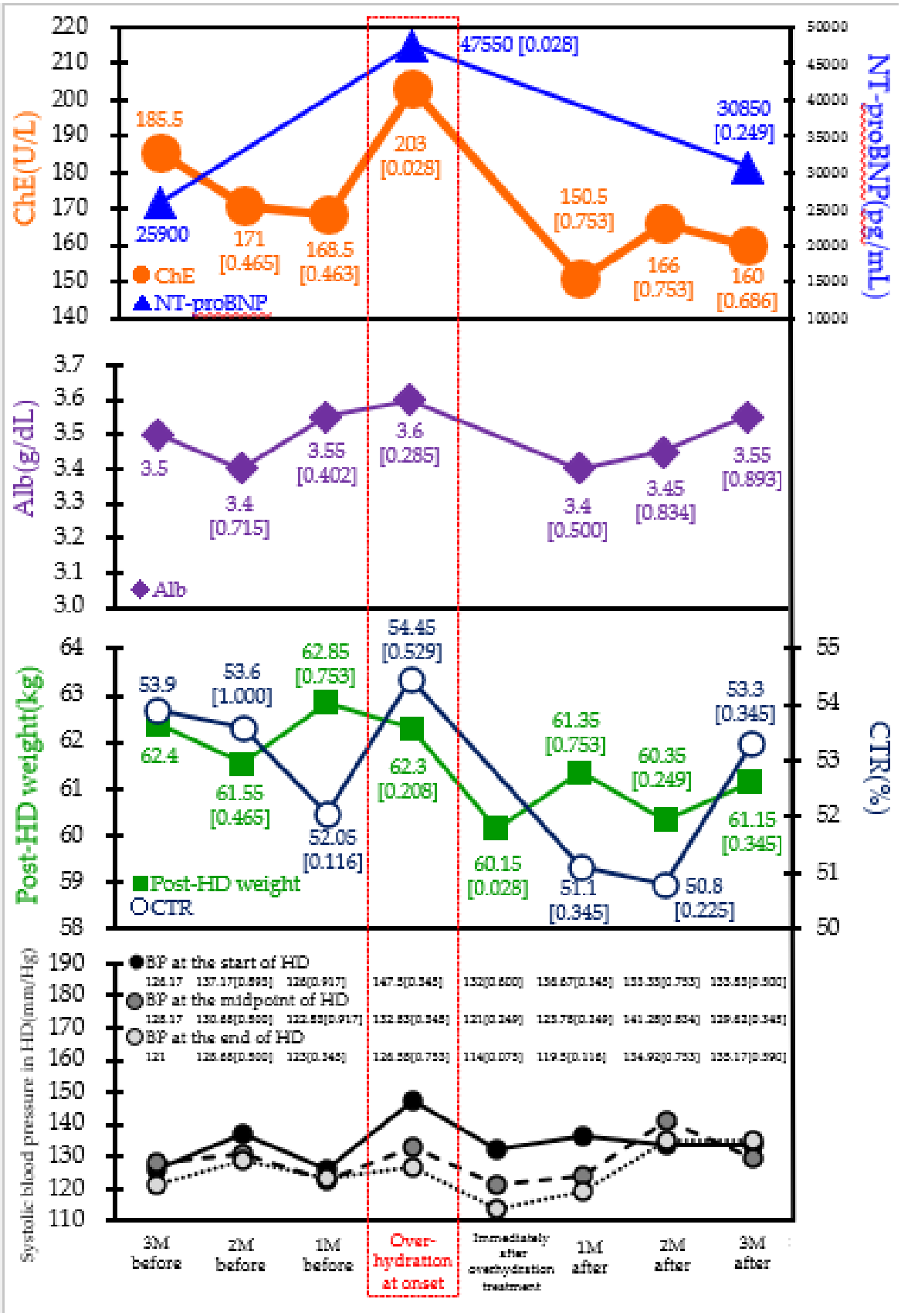
Post-dialysis body weight (kg) was 62.4 kg 3 months before the overhydration and remained almost unchanged at 62.3 [0.208] at the time of the onset of overhydration. After overhydration treatment, a non-significant downward trend was observed.

3.3.6. Changes in intradialytic systolic blood pressure

Intradialytic systolic blood pressure (mm/Hg) 3 months before overhydration was 126.17 at the start of dialysis, 128.17 at the middle, and 121 at the end, showing a tendency for it to be higher at the middle than at the start. No significant changes were observed in any period compared to three months prior to overhydration. At the time of the onset of overhydration, there was a tendency for the values to increase, although not significantly, from 147.5 [0.345] at the start, to 132.83 [0.345] at the middle, to 126.58 [0.753] at the end, which was particularly noticeable at the start.

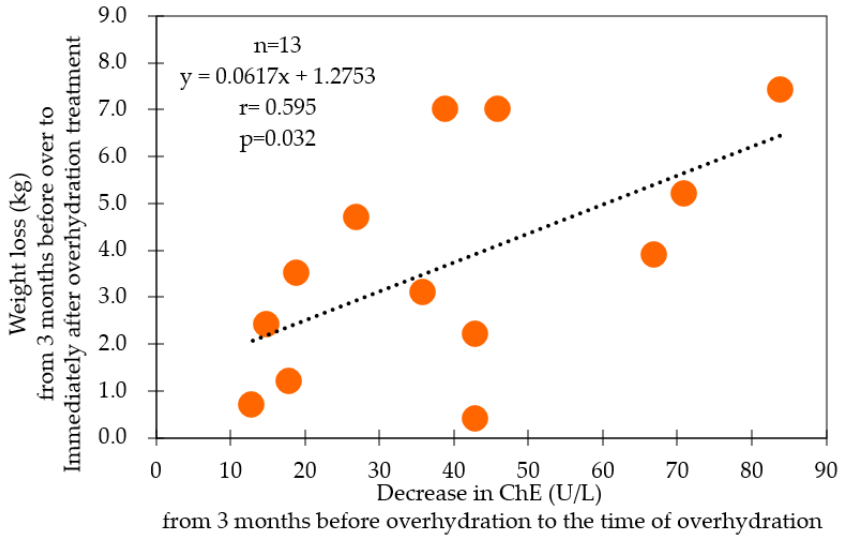
3.4. Correlation between the amount of ChE reduction and the amount of weight loss during 3 months just before overhydration attack in ChE-decreased groups.

The correlation between the amount of ChE reduction and the amount of weight loss during 3 months just before overhydration attack in ChE-decreased groups in 13 cases is shown in Figure 3. Decreased in ChE (U/L) from 3 months before overhydration to the time of overhydration onset and the amount of weight loss from 3 months before overhydration after overhydration were corrected, and found a positive correlation ($r=0.595$, $p=0.032$).



n=6, median[p-value] Using the Wilcoxon signed rank test, the data from three months prior to the overhydration was used as the base period, and comparisons were made with each subsequent month. The significance level was set at a risk level of less than 0.05

Figure 2: Changes in various factors before and after the onset of overhydration in the non-ChE-decreased groups.



Correlation was calculated using Spearman's rank correlation coefficient, with the significance level set at less than 0.05. One patient was excluded from the analysis because his weight loss was a statistical outlier.

Figure 3: Correlation between the amount of ChE reduction and the amount of weight loss during 3 months just before overhydration attack in ChE-decreased groups.

4. Discussion

We observed the changes in weight, blood pressure, CTR, NT-proBNP, as well as ChE and Alb in 20 dialysis patients who were hospitalized for treatment of overhydration. The observation period was three months before and after hospitalization for treatment of overhydration. We found ChE-decreased groups (70%) and non-ChE-decreased groups (30%). In the ChE-decreased groups, ChE showed a tendency to decrease from 2 months before overhydration compared to 3 months before overhydration and was further decreased at the time of the onset of overhydration.

Compared to the ChE-decreased groups, the non-ChE-decreased groups had relatively good nutritional conditions and cardiac function indices such as Alb, ChE, BMI, and EF. And at the time of the onset of overhydration, CTR and NT-proBNP were elevated while ChE was also elevated, suggesting that the increase in body fluids due to overeating and increased fluid intake caused of overhydration. In other words, they were relatively in good nutritional condition.

On the other hand, the ChE-decreased groups had relatively poor nutritional status and cardiac function, and in such cases, ChE and Alb decreased further, and a significant decrease was observed at the time of the onset of overhydration.

ChE is generally considered an indicator of liver function, but it is also considered an indicator of nutritional intake status [7]. This is also confirmed by the correlation between ChE changes and boby weight-changes at show in figure 3. From the above, it is suggested that continuous measurement and observation of ChE in hemodialysis patients, might be useful in predicting overhydration caused by a decrease in food intake. Then, in the cases whose ChE began to decrease, nutritional intervention and adjust DW (figure 4) might be needed to prevent overhydration.

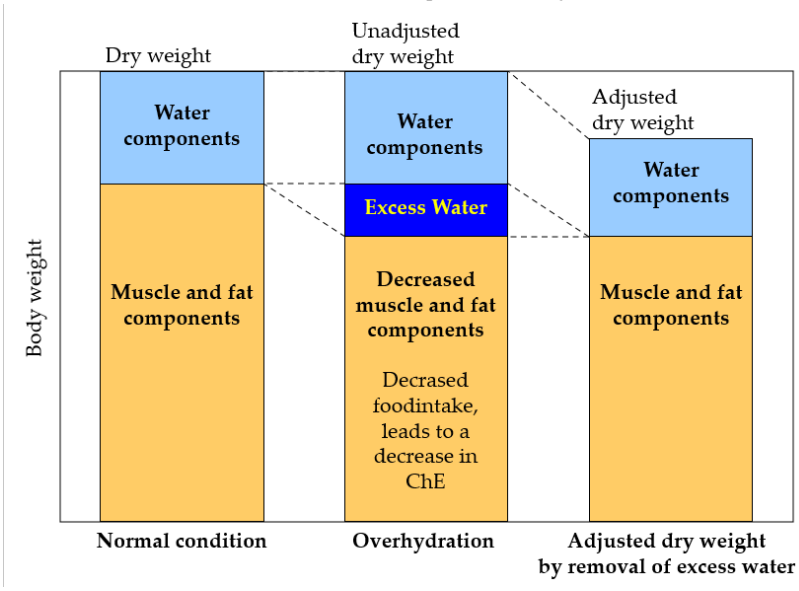


Figure 4: Schematic of net weight loss and dry weight adjustment.

Alb showed almost the same trends as ChE, but the changes in ChE appeared to be more sensitive markers for nutritional conditions. Because, ChE has a short half-life of approximately 10 days and a large molecular weight of 340,000, making it unlikely to leak through the dialysis membrane. This makes it useful as a nutritional indicator for predicting and evaluating weight changes in dialysis patients [6]. Alb has a relatively long half-life of 15 to 20 days and a molecular weight of 66,000. Therefore, it is possible that Alb leaks from dialyzers, which have high waste removal capabilities, and that its levels fluctuate due to the effects of dialysis itself [5,12].

Limitations:

Single-center study and the number of cases was small, a study with a larger number, of cases is needed.

5. Conclusions

When hemodialysis patients developed overhydration, ChE had been decreasing for the two months prior in 70% cases in addition to an increase in CTR and NT-proBNP. These results suggest that watching ChE decrease may be useful to predict overhydration caused by actual weight loss and in adjusting DW for hemodialysis patients. To prevent overhydration, it might be important to intensify fluid removal by considering a decrease of ChE in addition to an increase in CTR and NT-proBNP.

Author Contributions:

K.S. (Keita Sugai) and K.S. (Kohji Shirai) contributed to the study design, and K.S. (Keita Sugai), C.S., A.F., and Y.A. contributed to data collection and interpretation. K.S. (Keita Sugai) performed the analyses, K.S. (Kohji Shirai) supervised the study, and K.S. (Keita Sugai) drafted the initial manuscript. E.S., J.U., T.S., and M.M. contributed to the analysis and critical revision of the manuscript. All authors have read and agreed to the published manuscript.

Funding:

This study received no external funding.

Institutional Review Board Statement:

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of Mihama Hospital, Seijinkai Medical Corporation (approval code number:22-003; 23 January 2023).

Informed Consent Statement:

Only routine medical care data was obtained and anonymized to prevent identification of individuals, and then a retrospective analysis was performed.

Acknowledgments:

We would like to thank our colleagues Keiko Miyamoto, Natsuko Hiroki, Manami Nihei, Honoka Wada, Izuki Mizuguchi, Rina Ogihara, and Mio Ishida (Department of Nutrition, Mihama Hospital, Seijinkai Medical Corporation) for their great help in utilizing the theory presented in this paper and in publishing it.

Conflicts of Interest: The authors declare no conflict of interest.

References:

1. General incorporated association The Japanese Society for Dialysis Therapy [Maintenance hemodialysis guidelines: hemodialysis prescriptions.] Iji ketsueki touseki gaidorain: Ketsueki touseki syohou(in Japanese). *Toseki kaisi.* **2013**, *46*, 587-632
2. Tsutaya,C.; Tsushima,M.; Terayama,Y.; Yamaya,K.; Saitou,H.; Funyuu,T. [Measurement of N-terminal pro-B-type natriuretic peptide (NT-proBNP) in hemodialysis patients-Examination by electrocardiogram-] Ketsueki touseki kanja no NT-proBNP sokutei no yuuyousei – shindenzu syoken kara no kentou – (in Japanese). *Toseki kaisi.* **2010**, *43*, 633-640
3. Sasaki,N.; Ueno,K.; Shiraishi,T.; Yoshimura,A.; Kuno M; Takeda,S; Saitou,T; Andou,Y.; Kusano,E. [The optimal ratio of extracellular water to total body water (ECW/TBW) determined by bioelectrical impedance analysis (BIA) for setting dry weight in hemodialysis patients.] Seitai denki inpiidansu (BIA) hou ni yoru DW settei kijun – kouseido taiseibun bunseki souchi (InbodyS20) ni yoru fusyu chi (ECW/TBW) deno kentou – (in Japanese). *Toseki kaisi*. **2008**, *41*, 723-730
4. Aoki.T.; Nakai.S.; Uchino.J.; Shibata.K.; Shinzato.T.; Masakane.I.; Toma.S.; Fukui.H.; Matsuoka.T.; Kato.S.; Ookawara.S.; Ito.T. Comparison of Body Fluid Volumes Determined by Kinetic Modeling and by Bioimpedance Spectroscopy. *Blood Purif.* **2022**, *51(10)*, 866-874
5. Totsuka,M.; Okumura,N.; Urayama,O.; Matsushita,M.; Yamauchi,K.; Ookawa,R. [*Clinical Laboratory Science, Clinical Chemistry and Laboratory Science*, 3rd ed.] *Rinsyou kensa gaku kouza rinsyou kagaku kensa gaku* dai 3 pan (in Japanese). ; Ishiyaku Publishers,Inc.; Tokyo, Japan, **2010**; 159-161
6. Nakamura,S. [Cholinesterase] Korinesuteraze(in Japanese). *Nipponrinsyo.* **1995**, *53*, 292-295
7. Imaki,M.; Miyoshi,T.; Yoshimura,T.; Tamura,T.; Hori,Y.; Tomiya,T.; Nakamura,T.; Tanada,M.; Kitakouji,M.; Itou,S. [Relationships between serum cholinesterase activity and energy intake and food intake pattern.] Kessei korinesuterase kasseichi to sessyu netsuryou oyobi syokumotsu sessyu patan tono kanrensei ni tuite(in Japanese). *Japanese journal of health and human ecology*. **1986**, *52*, 190-195
8. Seo,M.; Yamada,T.; Tamaki,S.; Morita,M.; Furukawa,Y.; Iwasaki,Y.; Kawasaki,M.; Kikuchi,A.; Kawai,T.; Abe,M.; Nakamura,J.; Yamamoto,K.; Kayama,K.; Kawahira,M.; Tanabe,K.; Kimura,T.; Ueda,K.; Sakamoto, D.; Sakata,Y.; Fukunami,M. Prognostic significance of serum cholinesterase in patients with acute decompensated heart failure: a prospective comparative study with other nutritional indices. *Am. J. Clin. Nutr.* **2019**, *110*, 330-339.
9. Sato,T.; Yamauchi,H.; Suzuki,S.; Yoshihisa,A.; Yamaki,T.; Sugimoto,K.; Kunii,H.; Nakazato,K.; Suzuki,H.; Saitoh,S.; Takeishi,Y. Serum cholinesterase is an important prognostic factor in chronic heart failure. *Heart Vessels.* **2015**, *30*, 204-10
10. Kazama,Y.; Ishikawa,F.; Yamabe,S.; Matsushima,S.; Kaneko,M.; Mishima,A.; Shimizu,R.; Kuwahara,M.; Higuchi,A.; Kanno,K. [Success of nutrition support team intervention and its association with poor prognostic factors at

our hospital.] Touin no NST kainyuu no seika oyobi yogo furyou inshi tono kanren(in Japanese). *JJSMN*. **2020**, *54*, 206-210

11. Katou,A.; Kanda,E.; Seto,Y.; Odamaki,M,; Yoshida,T.; Yabe,H.; Nagai,M.; Inaba,M.; Nagasawa,Y.; Sakamoto,K.; Kanno Y.; Nakamoto H. [Malnutrition in patients receiving hemodialysis.] Mansei iji touseki kanja ni okeru teieiyou no hyouka hou(in Japanese). *Toseki kaisi.* **2019**, *52*, 319-325
12. Kawanishi,H.; Mineshima,M; Tomo,T; Minakuchi,J. [Functional Classification of Blood Purifiers (Hollow Fiber Type) 2013.] Ketsueki jouka ki (chyuukuu shi gata) no kinou bunrui 2013(in Japanese). *Toseki kaisi.* **2013**, *46*, 501-506

DOI:10.31579/2690-4861/921