Clinical Nutrition 38 (2019) 383–388

Contents lists available at ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Original article

Comparison of accuracy between pre-hemodialysis and post-hemodialysis levels of nutritional factors for prediction of mortality in hemodialysis patients

Yoshihiko Kanno [a, *], Eiichiro Kanda [b]

[a] Department of Nephrology, Tokyo Medical University, Japan
[b] Department of Nephrology, Tokyo Kyosai Hospital, Japan

ARTICLE INFO

Article history:
Received 20 September 2017
Accepted 11 December 2017

Keywords:
Hemodialysis
Nutrition
Body mass index
Albumin
Creatinine
Blood urea nitrogen

SUMMARY

Background: The nutritional status of hemodialysis (HD) patients is usually assessed using pre-HD laboratory data. However, it remains unclear whether the most diluted laboratory value is appropriate for assessment. We compared the pre-HD and post-HD laboratory data for their accuracy in predicting mortality.

Methods: Maintenance HD patients (n = 96 700; men, 61.5%) were enrolled. The outcome events were one-year and five-year mortalities. Their laboratory data included body mass index (BMI), and serum albumin, creatinine, and blood urea nitrogen (BUN) levels. Bootstrap resampling was used to compare the accuracy in predicting the mortalities between pre-HD and post-HD levels using area under receiver operating characteristic curves (AUCs) adjusted for baseline characteristics.

Results: The mean age ± standard deviation was 65.7 ± 12.2 years, and the vintage was 8.3 ± 6.7 years. The numbers of patients who died were 6442 (6.7%) in one year and 30 965 (32.0%) in five years. The adjusted AUCs for predicting the one-year and five-year mortalities showed that the pre-HD albumin and creatinine levels and the pre-HD BMI and BUN levels were more accurate than the post-HD levels (each $p < 0.0001$). The pre-HD albumin and creatinine levels showed the highest adjusted AUC for predicting one-year mortality [0.613 (95% CI 0.598, 0.629)] and five-year mortality [0.591 (95% CI 0.586, 0.595)], respectively.

Conclusions: Pre-HD albumin and creatinine levels are more accurate than post-HD levels and other nutritional indices in predicting one-year and five-year mortalities in HD patients.

1. Introduction

The nutritional status of patients receiving hemodialysis (HD) is usually assessed using pre-HD laboratory data [1,2]. Based on this practice, serum albumin level has been reported to predict mortality [3,4]. In fact, most scoring systems evaluating the nutritional status of dialysis patients use pre-HD serum albumin level [5,6]. However, it has been a concern whether the most diluted laboratory value would be appropriate for evaluating nutritional status [7]. Dutton et al. suggested that the prediction of mortality using pre-HD albumin level might be more related to fluid overload than malnutrition. At present, there is a scarcity of small-scale studies (n = 58) comparing pre-HD and post-HD albumin levels as indicators of mortality [8], and there is continuing discussion as to which level is more useful. In Japan, almost all HD patients have been registered to the database of the Japanese Society of Dialysis Therapy (JSDT) since 1968 [1]. Basic data which include body profile, hematologic and biochemistry laboratory, and complications have been collected every end of the year, including additional items according to the theme of the year. In 2008, pre-HD and post-HD laboratory data including serum albumin level were recorded. Using prognosis data after 5 years, we compared the pre-HD and post-HD laboratory data to investigate their accuracy in predicting mortality of HD patients.

2. Methods

2.1. Data

This is a prospective cohort study of maintenance HD patients using the database of the JSDT renal data registry. JSDT has been

* Corresponding author. Department of Nephrology, Tokyo Medical University, 6-7-1 Nishishinjuku, Shinjuku, Tokyo 1600023, Japan. Fax: +81 3 3342 2650.
E-mail address: kannoyh@tokyo-med.ac.jp (Y. Kanno).

https://doi.org/10.1016/j.clnu.2017.12.012

conducting annual surveys of dialysis facilities in Japan since 1968. The 2008–2013 JSDT database was used. This study was approved by the JSDT ethics committee and was exempt from the need for informed consent (JSDT No. 6). The study was performed in accordance with the relevant guidelines of the Declaration of Helsinki, as revised in 2013.

The study subjects were 275 553 patients at the end of 2008. The exclusion criteria were as follows: 1) patients younger than 20 years; 2) patients on hemodiafiltration, hemofiltration, or peritoneal dialysis; 3) patients with missing values or outlier values of laboratory data; 4) patients who had a limb amputated; 5) patients with vintage less than one year. Thus, 96 700 patients were included in the analysis.

The baseline patient data were as follows: 1) age; 2) gender; 3) diabetes mellitus (DM) as a cause of end-stage renal disease (ESRD); 4) history of cardiovascular disease; 5) vintage; 6) serum total cholesterol, phosphorus, and C-reactive protein (CRP) levels; 7) hemoglobin level; 8) KT/V. Pre-HD and post-HD body mass index (BMI), as well as Pre-HD and post-HD albumin, serum creatinine, and blood urea nitrogen (BUN) levels were collected from all the patients. The outcome event was death (i.e., all-cause death and cause-specific death) within one year and five years.

2.2. Statistical analysis

Normally distributed variables were presented as means ± standard deviation (SD); otherwise, the median and interquartile ranges were presented. Highly skewed variables were transformed with the natural logarithm function before their use in models [ln(vintage), ln(CRP)]. A receiver operating characteristic (ROC) curve was used to evaluate the performance of an index to predict all-cause death within one or five years. The area under the ROC curve (AUC) with 95% confidence intervals (CIs) was estimated using the 1000-times bootstrap method. Because ROC is affected by the study population, AUCs were adjusted using generalized linear models with baseline characteristics such as age; gender; DM; cardiovascular disease; ln(vintage); hemoglobin level; serum total cholesterol and phosphorus levels; ln(CRP); KT/V; pre-HD BMI; pre-HD albumin, creatinine, and BUN levels. AUCs were compared between pre-HD and post-HD BMI, serum albumin, creatinine, and BUN levels using the bootstrap method. For the stratification analysis, the subjects were categorized into two groups: DM and non-DM; young (<65 years) and old (≥65 years). In each group, the comparisons of AUCs between pre-HD and post-HD indices were examined using the bootstrap method. Statistical significance was defined as $p < 0.05$. These analyses were conducted using SAS version 9.4 (SAS Inc., NC), STATA version 14 (Stata Corp., TX), and R version 3.3.2 (The R Project for Statistical Computing, Auckland, New Zealand).

3. Results

3.1. Baseline characteristics

The study population consisted of 96 700 patients. The numbers of patients who died in one and five years were 6442 (6.7%) and 30 965 (32.0%), respectively. The mortality rates in one and five years were 18.9 and 21.1/100 000-person days respectively. The baseline characteristics are shown in Table 1.

3.2. Comparison of AUCs between pre-HD and post-HD nutritional indices

Pre-HD and post-HD values of nutritional indices are shown in Table 2. The AUCs of nutritional indices for the prediction of one-year mortality were compared (Table 3, Fig. 1). The adjusted AUCs of the post-HD BMI, pre-HD albumin level, pre-HD creatinine level, and post-HD BUN level were higher than those of the pre-HD BMI, post-HD albumin level, post-HD creatinine level, and pre-HD BUN level, respectively. The Pre-HD albumin level showed the highest adjusted AUC.

The AUCs of nutritional indices for the prediction of five-year mortality were also compared (Table 4). The adjusted AUCs of the post-HD BMI and BUN levels were higher than those of the pre-HD BMI and BUN levels. The AUCs of the pre-HD albumin and creatinine levels were higher than those of the post-HD albumin and creatinine levels. The Pre-HD creatinine level showed the highest adjusted AUC.

Table 1
Baseline characteristics.

N	96 700
Age (years)	65.7 ± 12.2
Men (%)	59 418 (61.5)
Diabetes mellitus as cause of ESRD requiring HD (%)	31 687 (32.8)
Cardiovascular disease (%)	18 425 (19.1)
Vintage (years)	8.3 ± 6.7 6.2 (3.3, 11.1)
Hemoglobin (g/dL)	10.4 ± 1.2
Total cholesterol (mg/dL)	153.7 ± 34.6
Phosphorus (mg/dL)	5.3 ± 1.4
C-reactive protein (mg/dL)	0.5 ± 1.4 0.11 (0.05, 0.34)
KT/V	1.41 ± 0.28
Overhydration (kg)	2.4 ± 1.1

Table 2
Pre-HD and post-HD values of nutritional indices.

Pre-HD BMI (kg/m^2)	22.1 ± 3.5
Post-HD BMI (kg/m^2)	21.2 ± 3.4
Pre-HD albumin level (g/dL)	3.7 ± 0.4
Post-HD albumin level (g/dL)	4.1 ± 0.6
Pre-HD creatinine level (mg/dL)	10.7 ± 2.8
Post-HD creatinine level (mg/dL)	4.1 ± 1.4
Pre-HD BUN level (mg/dL)	64.9 ± 15.6
Post-HD BUN level (mg/dL)	20.6 ± 7.0

Abbreviations: HD, hemodialysis; BMI, body mass index; BUN, blood urea nitrogen.

Table 3
Accuracy of prediction of one-year mortality.

A			
	Pre-HD BMI	Post-HD BMI	*p*-value
Crude AUC	0.635 (0.627, 0.642)	0.631 (0.623, 0.638)	0.0001
Adjusted AUC	0.600 (0.593, 0.608)	0.602 (0.594, 0.610)	0.0001
B			
	Pre-HD albumin level	Post-HD albumin level	*p*-value
Crude AUC	0.730 (0.717, 0.742)	0.735 (0.722, 0.748)	0.287
Adjusted AUC	0.613 (0.598, 0.629)	0.581 (0.566, 0.597)	0.0001
C			
	Pre-HD creatinine level	Post-HD creatinine level	*p*-value
Crude AUC	0.720 (0.712, 0.727)	0.649 (0.642, 0.656)	0.0001
Adjusted AUC	0.606 (0.597, 0.615)	0.579 (0.572, 0.587)	0.0001
D			
	Pre-HD BUN level	Post-HD BUN level	*p*-value
Crude AUC	0.591 (0.583, 0.598)	0.526 (0.518, 0.533)	0.0001
Adjusted AUC	0.512 (0.504, 0.519)	0.519 (0.511, 0.527)	0.0001

AUCs were adjusted for baseline characteristics.
Abbreviations: AUC, area under receiver operating characteristic curve; HD, hemodialysis; BMI, body mass index; BUN, blood urea nitrogen.

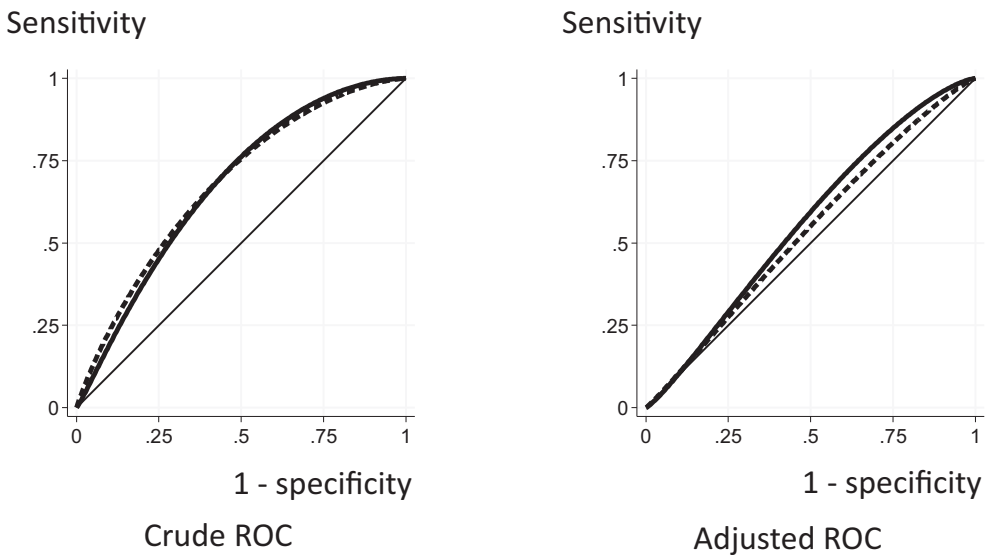

Fig. 1. Receiver operating characteristic curves of serum albumin level for prediction of one-year and five-year mortalities. Area under receiver operating characteristic curve was adjusted for baseline characteristics. Abbreviations: ROC, receiver operating characteristic curve.

Table 4
Accuracy of prediction of five-year mortality.

A			
	Pre-HD BMI	Post-HD BMI	*p*-value
Crude AUC	0.585 (0.581, 0.589)	0.583 (0.579, 0.587)	0.0001
Adjusted AUC	0.553 (0.549, 0.557)	0.557 (0.552, 0.561)	0.0001
B			
	Pre-HD albumin level	Post-HD albumin level	*p*-value
Crude AUC	0.673 (0.666, 0.680)	0.679 (0.671, 0.686)	0.062
Adjusted AUC	0.562 (0.553, 0.570)	0.535 (0.526, 0.544)	0.0001
C			
	Pre-HD creatinine level	Post-HD creatinine level	*p*-value
Crude AUC	0.695 (0.692, 0.699)	0.631 (0.627, 0.635)	0.0001
Adjusted AUC	0.591 (0.586, 0.595)	0.560 (0.556, 0.565)	0.0001
D			
	Pre-HD BUN level	Post-HD BUN level	*p*-value
Crude AUC	0.581 (0.577, 0.585)	0.530 (0.526, 0.534)	0.0001
Adjusted AUC	0.500 (0.495, 0.504)	0.510 (0.506, 0.515)	0.0001

AUCs were adjusted for baseline characteristics.
Abbreviations: AUC, area under receiver operating characteristic curve; HD, hemodialysis; BMI, body mass index; BUN, blood urea nitrogen.

3.3. Stratification analysis

In the non-DM and DM groups, the AUCs of nutritional indices for the prediction of one-year mortality were compared (Table 5). In both groups, the adjusted AUCs of the post-HD BMI, pre-HD albumin level, pre-HD creatinine level, and post-HD BUN level were higher than those of the pre-HD BMI, post-HD albumin level, post-HD creatinine level, and pre-HD BUN level, respectively. The adjusted AUC of the pre-HD albumin level for the prediction of one-year mortality was higher than those of the other indices in both groups. Moreover, in the non-DM and DM groups, the comparison of AUCs for the prediction of five-year mortality showed similar trends (Table 6). The adjusted AUC of the pre-HD creatinine level for the prediction of five-year mortality was higher than those of the other indices in both groups.

In the young and old groups, the adjusted AUCs of the post-HD BMI and BUN levels for the prediction of one-year and five-year mortalities were higher than those of the pre-HD BMI and BUN levels; the adjusted AUCs of the pre-HD albumin and creatinine levels were higher than those of the post-HD albumin and creatinine levels (Tables 7 and 8). The adjusted AUC of the pre-HD albumin level for the prediction of one-year mortality was higher than those of the other indices in both groups, and the adjusted AUC of the pre-HD creatinine level for the prediction of five-year mortality was higher than those of the other indices in both groups.

Table 5
Accuracy of prediction of one-year mortality in non-DM and DM groups.

A				
		Pre-HD BMI	Post-HD BMI	*p*-value
Non-DM	Crude AUC	0.646 (0.637, 0.655)	0.641 (0.631, 0.650)	0.0001
	Adjusted AUC	0.606 (0.596, 0.615)	0.607 (0.598, 0.617)	0.0001
DM	Crude AUC	0.640 (0.628, 0.652)	0.638 (0.626, 0.650)	0.0059
	Adjusted AUC	0.590 (0.578, 0.602)	0.593 (0.580, 0.605)	0.0013
B				
		Pre-HD albumin level	Post-HD albumin level	*p*-value
Non-DM	Crude AUC	0.747 (0.731, 0.763)	0.754 (0.737, 0.770)	0.288
	Adjusted AUC	0.623 (0.603, 0.643)	0.588 (0.564, 0.605)	0.0001
DM	Crude AUC	0.704 (0.683, 0.724)	0.702 (0.681, 0.723)	0.857
	Adjusted AUC	0.600 (0.575, 0.624)	0.577 (0.552, 0.601)	0.021
C				
		Pre-HD creatinine level	Post-HD creatinine level	*p*-value
Non-DM	Crude AUC	0.743 (0.733, 0.753)	0.667 (0.657, 0.676)	0.0001
	Adjusted AUC	0.616 (0.605, 0.627)	0.589 (0.580, 0.599)	0.0001
DM	Crude AUC	0.668 (0.654, 0.681)	0.618 (0.607, 0.630)	0.0001
	Adjusted AUC	0.598 (0.583, 0.614)	0.570 (0.558, 0.581)	0.0001
D				
		Pre-HD BUN level	Post-HD BUN level	*p*-value
Non-DM	Crude AUC	0.604 (0.594, 0.614)	0.532 (0.522, 0.542)	0.0001
	Adjusted AUC	0.506 (0.496, 0.516)	0.513 (0.503, 0.524)	0.00051
DM	Crude AUC	0.560 (0.548, 0.572)	0.522 (0.510, 0.534)	0.0001
	Adjusted AUC	0.523 (0.510, 0.535)	0.531 (0.518, 0.543)	0.00038

AUCs were adjusted for baseline characteristics.
Abbreviations: AUC, area under receiver operating characteristic curve; HD, hemodialysis; DM, diabetes mellitus; BMI, body mass index; BUN, blood urea nitrogen.

Table 6
Accuracy of prediction of one-year mortality in non-DM and DM groups.

A				
		Pre-HD BMI	Post-HD BMI	*p*-value
Non-DM	Crude AUC	0.598 (0.593, 0.603)	0.595 (0.590, 0.600)	0.0001
	Adjusted AUC	0.557 (0.552, 0.563)	0.561 (0.556, 0.567)	0.0001
DM	Crude AUC	0.601 (0.595, 0.608)	0.600 (0.594, 0.606)	0.0006
	Adjusted AUC	0.545 (0.538, 0.552)	0.549 (0.542, 0.556)	0.0001
B				
		Pre-HD albumin level	Post-HD albumin level	*p*-value
Non-DM	Crude AUC	0.687 (0.678, 0.696)	0.695 (0.686, 0.704)	0.035
	Adjusted AUC	0.566 (0.554, 0.577)	0.533 (0.522, 0.545)	0.0001
DM	Crude AUC	0.651 (0.640, 0.663)	0.645 (0.633, 0.657)	0.197
	Adjusted AUC	0.557 (0.543, 0.571)	0.539 (0.525, 0.553)	0.0042
C				
		Pre-HD creatinine level	Post-HD creatinine level	*p*-value
Non-DM	Crude AUC	0.716 (0.711, 0.721)	0.654 (0.641, 0.650)	0.0001
	Adjusted AUC	0.604 (0.598, 0.610)	0.571 (0.565, 0.576)	0.0001
DM	Crude AUC	0.637 (0.630, 0.643)	0.603 (0.596, 0.609)	0.0001
	Adjusted AUC	0.573 (0.566, 0.580)	0.547 (0.540, 0.554)	0.0001
D				
		Pre-HD BUN level	Post-HD BUN level	*p*-value
Non-DM	Crude AUC	0.591 (0.586, 0.596)	0.537 (0.532, 0.542)	0.0001
	Adjusted AUC	0.495 (0.490, 0.501)	0.506 (0.501, 0.512)	0.0001
DM	Crude AUC	0.549 (0.542, 0.555)	0.530 (0.524, 0.537)	0.0001
	Adjusted AUC	0.509 (0.502, 0.516)	0.519 (0.512, 0.526)	0.0001

AUCs were adjusted for baseline characteristics.
Abbreviations: AUC, area under receiver operating characteristic curve; HD, hemodialysis; DM, diabetes mellitus; BMI, body mass index; BUN, blood urea nitrogen.

Table 7
Accuracy of prediction of one-year mortality in young and old groups.

A				
		Pre-HD BMI	Post-HD BMI	*p*-value
Young	Crude AUC	0.568 (0.551, 0.585)	0.569 (0.552, 0.586)	0.15
	Adjusted AUC	0.584 (0.567, 0.601)	0.589 (0.571, 0.606)	1E-04
Old	Crude AUC	0.636 (0.628, 0.644)	0.632 (0.624, 0.640)	1E-04
	Adjusted AUC	0.595 (0.586, 0.604)	0.596 (0.587, 0.604)	0.25
B				
		Pre-HD albumin level	Post-HD albumin level	*p*-value
Young	Crude AUC	0.722 (0.694, 0.750)	0.729 (0.700, 0.759)	0.537
	Adjusted AUC	0.638 (0.606, 0.671)	0.600 (0.566, 0.634)	0.01
Old	Crude AUC	0.696 (0.681, 0.711)	0.698 (0.682, 0.713)	0.72
	Adjusted AUC	0.601 (0.583, 0.618)	0.581 (0.563, 0.599)	0.0055
C				
		Pre-HD creatinine level	Post-HD creatinine level	*p*-value
Young	Crude AUC	0.694 (0.679, 0.709)	0.599 (0.583, 0.616)	0.0001
	Adjusted AUC	0.639 (0.624, 0.655)	0.595 (0.580, 0.611)	0.0001
Old	Crude AUC	0.674 (0.665, 0.684)	0.612 (0.64, 0.621)	0.0001
	Adjusted AUC	0.597 (0.586, 0.608)	0.578 (0.569, 0.587)	0.0001
D				
		Pre-HD BUN level	Post-HD BUN level	*p*-value
Young	Crude AUC	0.585 (0.568, 0.601)	0.501 (0.484, 0.517)	0.0001
	Adjusted AUC	0.503 (0.486, 0.520)	0.520 (0.503, 0.537)	0.0001
Old	Crude AUC	0.566 (0.557, 0.574)	0.508 (0.500, 0.517)	0.0001
	Adjusted AUC	0.516 (0.507, 0.525)	0.519 (0.510, 0.528)	0.084

AUCs were adjusted for baseline characteristics.
Abbreviations: AUC, area under receiver operating characteristic curve; HD, hemodialysis; Young, less than 65 years; Old, 65 years or more; DM, diabetes mellitus; BMI, body mass index; BUN, blood urea nitrogen.

4. Discussion

This study showed that the pre-HD albumin level was more accurate than the post-HD albumin level for predicting the one-year and five-year mortalities in HD patients, and that the pre-HD albumin level was more accurate than the other indices for predicting one-year mortality in a large number of Japanese HD patients. These results are reasonable because pre-HD albumin level has been considered as the most valuable index of nutritional status and a predictor of mortality from malnutrition in HD patients [9]. Moreover, serum albumin level also predicts the mortality in peritoneal dialysis [10] and kidney transplantation [11] patients, and in patients with other statuses [12,13].

Serum albumin level is determined by several other factors: plasma volume expansion, albumin redistribution, exogenous loss, increased fractional catabolic rate, and decreased synthesis. Decreased albumin synthesis is primarily responsible for hypoalbuminemia in HD patients [14]. Thus, it has been used as an indicator of nutritional and inflammation status, and its variants (e.g., prealbumin), which are considered as dominant nutritional factors, have also been proven to predict the prognosis of dialysis patients [15]. Previous studies support the present study showing that the highest AUC for the prediction of one-year mortality was the pre-HD albumin level. On the other hand, there are some studies which showed that the post-HD albumin level was a better index of mortality in HD patients [7,16]. The authors of these studies suggested that the pre-HD albumin level was affected by dilution from fluid volume overload during measurement involving the heaviest body weight. The post-HD albumin level that is extracted from the diluted solution would be more likely suitable than the pre-HD albumin level for evaluating nutritional status alone. However, as a predictor of mortality or cardiovascular event, pre-HD albumin level might be more sensitive because both malnutrition and fluid overload are risks factors for death. Unfortunately, the pre-HD albumin level did not predict the five-year mortality as accurately as we expected. We considered this result because five years is a very long time for any incident from various causes to occur except malnutrition in geriatric HD patients. This is similar to other QOL measurements which most recent evaluation methods predict more accurately [17]. In a previous study [18], pre-HD creatinine level showed a higher accuracy in predicting all-cause death within one or five years. As the serum creatinine and albumin levels have been considered to indicate diet protein intake [19] and predict mortality in the present study, the importance of management of the patients' nutritional status and dietary intake is suggested.

In contrast, the post-HD BMI and BUN levels showed a higher accuracy than the pre-HD BMI and BUN levels in predicting all-cause death within one or five years. These two indices are affected by their removal on dialysis session and residual renal function. In particular, serum BUN level is effected by dialysis dose [20], gastrointestinal bleeding, and other factors except nutrition, thus it would not be considered as an item concerning malnutrition. Although JSDT guidelines for deciding the dry weight exist [21], this depends on each facility and might have an effect on BMI. The results from the stratification analysis based on DM as a cause of ESRD and old age showed similar trends, confirming our suggestion.

Several limitations are considered in the present study. *Firstly*, we collected these data from the JSDT registry data system which has more than 4000 facilities. Although the HD protocol is standard in Japan, optional conditions concerning dialysis dose, membrane selection, dry weight, and dietary restriction vary by region or facility. In particular, the rate of using a high-performance membrane which might allow leakage of albumin [22] may affect the present results. *Secondly*, urine volume was not considered because it was not included in the registry items. As the urine of patients receiving

Table 8
Accuracy of prediction of five-year mortality in young and old groups.

A				
		Pre-HD BMI	Post-HD BMI	*p*-value
Young	Crude AUC	0.537 (0.529, 0.545)	0.538 (0.531, 0.546)	0.00023
	Adjusted AUC	0.552 (0.544, 0.560)	0.556 (0.548, 0.564)	0.0001
Old	Crude AUC	0.582 (0.577, 0.586)	0.581 (0.576, 0.585)	0.00063
	Adjusted AUC	0.550 (0.545, 0.555)	0.553 (0.548, 0.558)	0.0001
B				
		Pre-HD albumin level	Post-HD albumin level	*p*-value
Young	Crude AUC	0.642 (0.628, 0.656)	0.652 (0.638, 0.666)	0.1
	Adjusted AUC	0.573 (0.557, 0.589)	0.545 (0.529, 0.561)	0.00025
Old	Crude AUC	0.633 (0.624, 0.642)	0.631 (0.622, 0.641)	0.7
	Adjusted AUC	0.553 (0.543, 0.564)	0.535 (0.524, 0.545)	0.00011
C				
		Pre-HD creatinine level	Post-HD creatinine level	*p*-value
Young	Crude AUC	0.658 (0.651, 0.665)	0.579 (0.571, 0.586)	0.0001
	Adjusted AUC	0.615 (0.608, 0.622)	0.577 (0.570, 0.585)	0.0001
Old	Crude AUC	0.637 (0.632, 0.642)	0.582 (0.577, 0.587)	0.0001
	Adjusted AUC	0.579 (0.573, 0.584)	0.554 (0.549, 0.560)	0.0001
D				
		Pre-HD BUN level	Post-HD BUN level	*p*-value
Young	Crude AUC	0.561 (0.554, 0.569)	0.500 (0.492, 0.507)	0.0001
	Adjusted AUC	0.504 (0.496, 0.512)	0.517 (0.509, 0.525)	0.0001
Old	Crude AUC	0.555 (0.550, 0.560)	0.509 (0.504, 0.514)	0.0001
	Adjusted AUC	0.501 (0.496, 0.507)	0.509 (0.504, 0.514)	0.0001

AUCs were adjusted for baseline characteristics.
Abbreviations: AUC, area under receiver operating characteristic curve; HD, hemodialysis; Young, less than 65 years; Old, 65 or more years; DM, diabetes mellitus; BMI, body mass index; BUN, blood urea nitrogen.

dialysis contains a large amount of albumin [23], if available, correction using urinary albumin excretion might make this analysis more suitable. *Thirdly*, the items we selected as nutritional factors might be affected by various factors other than nutrition. For this limitation, several scoring systems that combine plural numbers of items such as GNRI [24] and SI [5] have been established and suggested to obtain better prediction. Takahashi et al. combined serum albumin, CRP, and BMI at the start of HD therapy to individually stratify the risk of ten years mortality in ESRD patients [6]. Several scoring systems are presently available, but they require complicated calculations. This may cause difficulties in regularly evaluating the nutritional status of patients using these complicated scoring systems in our clinical scene. Therefore, the usefulness of simple measurement involving albumin, total cholesterol, and other items which are measured regularly to carry out screening is recognized. After the screening by simple measurement, proper evaluation using a scoring system, easily available prealbumin, or normalized protein catabolic rate [19] would be recommended to patients with malnutrition.

In conclusion, our study showed that pre-HD albumin level is more accurate than post-HD albumin level in predicting one-year and five-year mortalities in HD patients. Moreover, pre-HD albumin level is more accurate than other indices in predicting one-year mortality.

Conflict of interest

The authors have no disclosures to make related to this study.

Authors' contributions

Y.K. mainly planned this study and wrote the manuscript. E.K. carried out statistical analysis and suggested discussion point.

Financial support

None.

Acknowledgement

We thank Dr. Edward Barroga for reviewing and editing the manuscript. The data reported here have been provided by the Japanese Society for Dialysis Therapy (JSDT). The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy or interpretation of the JSDT.

References

[1] Allon M, Depner TA, Radeva M, Bailey J, Beddhu S, Butterly D, et al. Impact of dialysis dose and membrane on infection-related hospitalization and death: results of the HEMO study. J Am Soc Nephrol 2003;14:1863–70.
[2] Chertow GM, Goldstein-Fuchs DJ, Lazarus JM, Kaysen GA. Prealbumin, mortality, and cause-specific hospitalization in hemodialysis patients. Kidney Int 2005;68:2794–800.
[3] Dutton J, Campbell H, Tanner J, Richards N. Pre-dialysis serum albumin is a poor indicator of nutritional status in stable chronic haemodialysis patients. EDTNA/ERCA J 1999;25:36–7 (English ed).
[4] Eriguchi R, Obi Y, Streja E, Tortorici AR, Rhee CM, Soohoo M, et al. Longitudinal associations among renal urea clearance–corrected normalized protein catabolic rate, serum albumin, and mortality in patients on hemodialysis. Clin J Am Soc Nephrol 2017;12(7):1109–17.
[5] Kanda E, Bieber BA, Pisoni RL, Robinson BM, Fuller DS. Importance of simultaneous evaluation of multiple risk factors for hemodialysis patients' mortality and development of a novel index: dialysis outcomes and practice patterns study. PloS One 2015;10:e0128652.
[6] Kaysen GA, Chertow GM, Adhikarla R, Young B, Ronco C, Levin NW. Inflammation and dietary protein intake exert competing effects on serum albumin and creatinine in hemodialysis patients. Kidney Int 2001;60:333–40.
[7] Kubrusly M, Oliveira CM, Santos DC, Mota RS, Pereira ML. A comparative analysis of pre- and post-dialysis albumin as indicators of nutritional and morbi-mortality risks in haemodialysis patients. Jornal brasileiro de nefrologia: 'orgao oficial de Sociedades Brasileira e Latino-Americana de Nefrologia 2012;34:27–35.
[8] Llop JM, Munoz C, Badia MB, Virgili N, Tubau M, Ramon JM, et al. Serum albumin as indicator of clinical evolution in patients on parenteral nutrition. Multivariate study. Clin Nutr (Edinburgh, Scotland) 2001;20:77–81.
[9] Lopes AA, Bragg-Gresham JL, Elder SJ, Ginsberg N, Goodkin DA, Pifer T, et al. Independent and joint associations of nutritional status indicators with mortality risk among chronic hemodialysis patients in the Dialysis Outcomes and Practice Patterns Study (DOPPS). J Renal Nutr: Offic J Counc Rens Nutr Natl Kidney Found 2010;20:224–34.
[10] Goldwasser P, Feldman JG, Barth RH. Serum prealbumin is higher in peritoneal dialysis than in hemodialysis: a meta-analysis. Kidney Int 2002;62(1):276–81.
[11] Masakane I, Nakai S, Ogata S, Kimata N, Hanafusa N, Hamano T, et al. Annual dialysis data report 2014, JSDT Renal Data Registry (JRDR). Ren Replacement Ther 2017;3:18.
[12] Hannan JL, Radwany SM, Albanese T. In-hospital mortality in patients older than 60 years with very low albumin levels. J Pain Symptom Manag 2012;43(3):631–7.
[13] Molnar MZ, Kovesdy CP, Bunnapradist S, Streja E, Mehrotra R, Krishnan M, et al. Associations of pretransplant serum albumin with post-transplant outcomes in kidney transplant recipients. Am J Transplant: Offic J Am Soc Transplant Am Soc Transpl Surg 2011;11:1006–15.
[14] Yeun JY, Kaysen GA. Factors influencing serum albumin in dialysis patients. Am J Kidney Dis 1998;32(6 Suppl 4):S118–25.
[15] Nakai S, Suzuki K, Masakane I, Wada A, Itami N, Ogata S, et al. Overview of regular dialysis treatment in Japan (as of 31 December 2008). Ther Apher Dial: Offic Peer-Reviewed J Int Soc Apher Jpn Soc Apher Jpn Soc Dial Ther 2010;14:505–40.
[16] Wapensky T, Alexander SR, Sarwal M. Postdialysis albumin: a better nutrition marker in pediatric hemodialysis patients? J Renal Nutr 2004;14(1):45–51.
[17] Perl J, Karaboyas A, Morgenstern H, Sen A, Rayner HC, Vanholder RC, et al. Association between changes in quality of life and mortality in hemodialysis patients: results from the DOPPS. Nephrol Dial Transplant 2017;32:521–7.
[18] Phelan PJ, O'Kelly P, Walshe JJ, Conlon PJ. The importance of serum albumin and phosphorous as predictors of mortality in ESRD patients. Ren Fail 2008;30:423–9.
[19] Shiotsu Y, Mori Y, Nishimura M, Hatta T, Imada N, Maki N, et al. Prognostic utility of plasma S100A12 levels to establish a novel scoring system for predicting mortality in maintenance hemodialysis patients: a two-year prospective observational study in Japan. BMC Nephrol 2013;14:16.

[20] Spiegel DM, Raggi P, Smits G, Block GA. Factors associated with mortality in patients new to haemodialysis. Nephrol Dial Transplant: Official Publ Eur Dial Transpl Assoc Eur Ren Assoc 2007;22:3568–72.
[21] Takahashi R, Ito Y, Takahashi H, Ishii H, Kasuga H, Mizuno M, et al. Combined values of serum albumin, C-reactive protein and body mass index at dialysis initiation accurately predicts long-term mortality. Am J Nephrol 2012;36:136–43.
[22] Watanabe Y, Kawanishi H, Suzuki K, Nakai S, Tsuchida K, Tabei K, et al. Japanese society for dialysis therapy clinical guideline for "Maintenance Hemodialysis: Hemodialysis Prescriptions". Ther Apher Dial 2015;19:67–92.
[23] Goldwasser P, Kaldas AI, Barth RH. Rise in serum albumin and creatinine in the first half year on hemodialysis. Kidney Int 1999;56(6):2260–8.
[24] Yamada K, Furuya R, Takita T, Maruyama Y, Yamaguchi Y, Ohkawa S, et al. Simplified nutritional screening tools for patients on maintenance hemodialysis. Am J Clin Nutr 2008;87:106–13.