Relationship Between Serum Total Carbon Dioxide Concentration and Bicarbonate Concentration in Patients Undergoing Peritoneal Dialysis

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Abstract

Background

Few studies have assessed the relationship between serum total carbon dioxide (CO2) and bicarbonate ion (HCO3−) concentration in patients undergoing peritoneal dialysis. We determined the agreement between serum total CO2 and HCO3− concentration and the diagnostic accuracy of serum total CO2 for the prediction of low (HCO3−<24 mEq/L) and high (HCO3−≥24 mEq/L) bicarbonate concentrations in patients on peritoneal dialysis.

Methods

We collected 245 samples of venous blood from 51 patients on peritoneal dialysis. Independent factors that correlated with the HCO3− concentration were analyzed using multiple linear regression analysis. The diagnostic accuracy of serum total CO2 was evaluated by receiver operating characteristic (ROC) curve analysis and a 2×2 table. Agreement between serum total CO2 and HCO3− concentration was assessed by Bland-Altman analysis.

Results

Serum total CO2 was independently correlated with HCO3− concentration (β = 0.354, p < 0.001). The area under the curve of serum total CO2 for the identification of low and high bicarbonate concentrations was 0.909. The diagnostic accuracy of serum total CO2 for the prediction of low and high bicarbonate concentrations was: sensitivity, 91.5%; specificity, 74.7%; positive predictive value, 53.5%; negative predictive value, 96.5%; and accuracy, 78.8%. Bland-Altman analysis showed a moderate agreement between serum total CO2 and HCO3− concentration.

Conclusion

Serum total CO2 correlated closely with the HCO3− concentration in patients undergoing peritoneal dialysis. Serum total CO2 might be useful for predicting low and high bicarbonate in peritoneal dialysis patients.

Introduction

Metabolic acidosis is a commonly observed complication in patients with chronic kidney disease (CKD), including those undergoing peritoneal dialysis, and is associated with bone mineral loss, protein-energy wasting, insulin resistance, and higher mortality risk [1–4]. It also contributes to a rapid decline in residual renal function [5]. Therefore, early detection and accurate diagnosis of metabolic acidosis is important to preserve residual renal function and improve prognosis in patients undergoing peritoneal dialysis.

In Japan, blood-gas analyzers are available in most hospitals. Therefore, bicarbonate ion (HCO3−) measured using arterial/venous blood gas samples has been widely used for the assessment of metabolic acidosis in peritoneal dialysis patients [6]. A lower HCO3− concentration has been reported to be associated with...
increased mortality in patients undergoing peritoneal dialysis [7]. Because the \( \text{HCO}_3^- \) concentration is an important predictor of mortality, a specific device measurement and syringe are necessary, in addition to the blood samples used for blood-gas analyses [8].

The serum total carbon dioxide (\( \text{CO}_2 \)) concentration represents the total amount of carbon dioxide in the serum. It can be readily measured, along with creatinine, urea, and electrolytes, using a biochemical analyzer in clinical settings [9]. Furthermore, serum total \( \text{CO}_2 \) has been shown to be correlated strongly with the \( \text{HCO}_3^- \) concentration in both patients with CKD not undergoing renal replacement therapy [10] and patients undergoing hemodialysis [11]. However, few studies have investigated the relationship between serum total \( \text{CO}_2 \) and the \( \text{HCO}_3^- \) concentration in patients undergoing peritoneal dialysis. We analyzed the relationship between serum total \( \text{CO}_2 \) and the \( \text{HCO}_3^- \) concentration in peritoneal dialysis patients.

**Materials And Methods**

**Ethics approval**

The study was approved by the ethics committee of Saitama Medical Center, Jichi Medical University (S17-052), and was conducted according to the principles contained within the Declaration of Helsinki. The requirement of informed consent was waived and an opt-out method was used because of the retrospective design of the study.

**Participants**

Inclusion criteria were: (i) age >20 years; (ii) CKD stage G5D; (iii) regular peritoneal dialysis; (iv) simultaneous measurement of serum total \( \text{CO}_2 \)and \( \text{HCO}_3^- \) concentrations. Exclusion criteria were: (i) hemodialysis and (ii) renal transplantation.

**Study design**

This was a single-center, retrospective, cross-sectional study. We analyzed the patient data obtained from medical records from the Division of Nephrology, Saitama Medical Center, between April 2017 and March 2019. The laboratory data of blood tests and venous blood-gas tests obtained simultaneously were used for analyses. The relationship between serum total \( \text{CO}_2 \) and the \( \text{HCO}_3^- \) concentration was analyzed using Pearson’s correlation coefficient. Independent factors correlated with the \( \text{HCO}_3^- \) concentration were analyzed using multiple linear regression analysis. The diagnostic accuracy of serum total \( \text{CO}_2 \) for low and high bicarbonate was analyzed using receiver operating characteristic (ROC) curve analysis and a 2×2 table. The correlation between serum total \( \text{CO}_2 \) and \( \text{HCO}_3^- \) concentration was analyzed using Bland-Altman analysis.

**Laboratory methods**

Blood and urinary parameters were determined by the Department of Clinical Laboratory, Saitama Medical Center. Samples of venous blood were collected in EDTA-containing tubes from the antecubital vein in all patients and centrifuged within 15 minutes to obtain serum. Serum total \( \text{CO}_2 \) was measured within 15 minutes after centrifugation using an automated biochemical analyzer (ICA-BM6070; JEOL, Tokyo, Japan), as were biochemical parameters (hemoglobin, total protein, blood urea nitrogen, serum creatinine, sodium, potassium, chloride, calcium, phosphate, magnesium, and glucose). Serum total \( \text{CO}_2 \) was determined by an enzymatic method using a commercial kit (Toyobo, Osaka, Japan) in an automated biochemical analyzer. Total weekly urea clearance (\( \text{Kt/V} \)) was measured by calculating the sum of the residual renal and peritoneal clearances of urea and converting this to a weekly value [12]. Residual renal urea clearance was determined using 24-hour urine urea divided by plasma urea concentration. Total body water volume was estimated from height, weight, age, and gender using Watson’s formula [13].

Samples of venous blood for gas analyses were collected in a heparinized blood-gas syringe from the brachial vein simultaneously with samples for other blood tests and analyzed within 10 minutes to obtain values for \( \text{pH} \) and the partial pressure of carbon dioxide (\( \text{pCO}_2 \)). The \( \text{pH} \) and \( \text{pCO}_2 \) of blood were measured using a blood-gas analyzer (Rapidlab-1265; Siemens Healthcare Diagnostics, Tarrytown, New York). The \( \text{HCO}_3^- \) concentration was calculated from measured \( \text{pH} \) and \( \text{pCO}_2 \) using the Henderson-Hasselbalch equation [14]:

\[
\text{pH} = 6.1 + \log(\text{HCO}_3^- / \text{pCO}_2 \times 0.03).
\]

**Statistics**

Statistical analyses were performed using JMP v11 (SAS Institute, Cary, North Carolina). Continuous variables were expressed as mean ± standard deviation when they were normally distributed and as median.
and interquartile range when non-normally distributed. Categorical variables were expressed as numbers and percentages. The peritoneal dialysis duration was not normally distributed; therefore, this variable was transformed using a natural logarithm. The relationships between two variables were evaluated using Pearson’s correlation coefficient. Linear regression analysis was used to identify parameters that independently correlated with HCO₃⁻ concentration. The parameters that significantly correlated with HCO₃⁻ concentration in simple linear regression analyses were included in subsequent multiple linear regression analysis. The diagnostic accuracy of serum total CO₂ was determined using ROC curve analysis and a 2×2 table. The area under the curve (AUC), sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were calculated for the identification of low (HCO₃⁻ <24 mEq/L) and high (HCO₃⁻ >24 mEq/L) bicarbonate concentrations. The cut-off value for HCO₃⁻ was set at 24 mEq/L based on a previous study [15]. Agreement between serum total CO₂ and HCO₃⁻ concentration was assessed using the Bland-Altman method. P < 0.05 was considered to represent statistical significance.

Results

Patient characteristics

Patients’ characteristics and medications are shown in Table 1. A total of 245 blood samples from 51 patients (35 males and 16 females, mean age 62.3 ± 13.6 years, mean peritoneal dialysis duration 27.5 ± 29.6 months) were obtained. Forty-one patients (80.4%) were on continuous ambulatory peritoneal dialysis (CAPD), 33 patients (64.7%) on automated peritoneal dialysis (APD), and 23 patients (45.1%) on a combination of CAPD and APD. The mean total weekly Kt/V was 1.68 ± 0.39. Thirty-three percent of the patients had diabetes mellitus. The proportions of the patients receiving each medication were: corticosteroid, 5.9%; β-blocker, 43.1%; renin-angiotensin system inhibitor, 72.5%; aldosterone receptor antagonist, 7.8%; loop diuretic, 64.7%; thiazide diuretic, 39.2%; tolvaptan, 29.4%; potassium binder, 0.0%; phosphate binder, 82.4%; vitamin D analog, 54.9%; calcimimetic, 21.6%; and sodium bicarbonate 0.0%. Calcium concentrations of each peritoneal dialysis solution were as follows: icodextrin solution, 1.75 mmol/L; lactate-buffered solution, 1.25 mmol/L; and bicarbonate-buffered solution 1.25 mmol/L.
| Patient characteristic | Value |
|------------------------|-------|
| Number of patients     | 51    |
| Number of samples      | 245   |
| Age (year)             | 62.3 ± 13.6 |
| Gender male (number, %)| 35 (68.6) |
| Body mass index (kg/m²)| 22.7 ± 3.6 |
| Peritoneal dialysis duration (month) | 18.2 [9.8-33.7] |
| Peritoneal dialysis modality |  |
| - CAPD (number, %)     | 41 (80.4) |
| - APD (number, %)      | 33 (64.7) |
| - CAPD and APD (number, %) | 23 (45.1) |
| Peritoneal dialysis solution |  |
| - Icodextrin solution (number, %) | 28 (54.9) |
| - Lactate-buffered solution (number, %) | 14 (27.5) |
| - Bicarbonate-buffered solution (number, %) | 37 (72.5) |
| Diabetes mellitus (number, %) | 17 (33.3) |
| Corticosteroid (number, %) | 2 (3.9) |
| β-blocker (number, %) | 22 (43.1) |
| Renin–angiotensin system inhibitor (number, %) | 37 (72.5) |
| Aldosterone receptor antagonist (number, %) | 4 (7.8) |
| Loop diuretic (number, %) | 33 (64.7) |
| Thiazide diuretic (number, %) | 20 (39.2) |
| Tolvaptan (number, %) | 15 (29.4) |
| Potassium binder (number, %) | 0 (0.0) |
| Phosphate binder (number, %) | 42 (82.4) |
| Vitamin D analogue (number, %) | 28 (54.9) |
| Calcimimetic (number, %) | 11 (21.6) |
| Sodium bicarbonate (number, %) | 0 (0.0) |
| 4-hour dialysate/plasma creatinine | 0.65 ± 0.11 |
| Total weekly Kt/V | 1.68 ± 0.39 |
| Renal weekly Kt/V | 0.69 ± 0.43 |
| Peritoneal weekly Kt/V | 1.00 ± 0.30 |

**TABLE 1: Patient characteristics and medication**

Abbreviations: APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; Kt/V, urea clearance. Values are shown as mean ± standard deviation, median [interquartile range], or number (%).

**Relationship between serum total CO₂ and HCO₃⁻ concentration**

Figure 1 shows the correlation between serum total CO₂ and HCO₃⁻ concentration. Serum total CO₂ was correlated with HCO₃⁻ concentration significantly and closely (r = 0.80; p < 0.001).
Factors correlated with HCO$_3^-$ concentration

Simple linear regression analyses showed that HCO$_3^-$ concentration was significantly negatively correlated with gender male, body mass index, serum albumin, blood urea nitrogen, creatinine, uric acid, sodium, potassium, chloride, phosphate, and magnesium, and with the use of a bicarbonate-buffered solution, phosphate binder, and vitamin D analog. HCO$_3^-$ concentration was also significantly positively correlated with diabetes mellitus, four-hour dialysate/plasma creatinine, total weekly Kt/V, peritoneal weekly Kt/V, total calcium, and serum total CO$_2$, and with the use of CAPD, CAPD and APD, icodextrin solution, lactate-buffered solution, loop diuretic, thiazide diuretic, and tolvaptan. Multiple linear regression analysis was performed using the variables that showed significant correlations with HCO$_3^-$ concentration in simple linear regression analyses (Table 2). This analysis revealed that total weekly Kt/V (standard coefficient [$\beta$ = 0.119, $p = 0.027$]), serum albumin ($\beta$ = -0.171, $p = 0.007$), blood urea nitrogen ($\beta$ = -0.138, $p = 0.011$), sodium ($\beta$ = 0.352, $p < 0.001$), chloride ($\beta$ = -0.629, $p < 0.001$), total calcium ($\beta$ = 0.204, $p < 0.001$), phosphate ($\beta$ = -0.155, $p = 0.006$), and serum total CO$_2$ ($\beta$ = 0.354, $p < 0.001$) were independently correlated with HCO$_3^-$ concentration.

| Parameter                              | Simple linear regression analysis | Multivariate linear regression analysis |
|----------------------------------------|-----------------------------------|----------------------------------------|
|                                        | Standard coefficient | $P$ value   | Standard coefficient | $P$ value   |
| Age (year)                             | 0.083                | 0.20        |                         |             |
| Gender male (yes vs. no)               | -0.235               | <0.001      | 0.084                   | 0.09        |
| Body mass index (kg/m$^2$)             | -0.194               | 0.002       | -0.006                  | 0.91        |
| Log-peritoneal dialysis duration (month)| 0.018                | 0.78        |                         |             |
| CAPD (yes vs. no)                      | 0.353                | <0.001      | 0.007                   | 0.91        |
| APD (yes vs. no)                       | -0.114               | 0.08        |                         |             |
| CAPD and APD (yes vs. no)              | 0.189                | 0.003       | 0.087                   | 0.11        |
| Parameter                                                                 | β   | p-Value   | β   | p-Value   | β   | p-Value   |
|--------------------------------------------------------------------------|-----|-----------|-----|-----------|-----|-----------|
| Icodextrin solution (yes vs. no)                                         | 0.242 | <0.001   | -0.122 | 0.06     |
| Lactate-buffered solution (yes vs. no)                                   | 0.242 | <0.001   | 0.002  | 0.97     |
| Bicarbonate-buffered solution (yes vs. no)                               | -0.242 | <0.001   | 0.000  | ---      |
| Diabetes mellitus (yes vs. no)                                           | 0.214 | <0.001   | 0.072  | 0.15     |
| Corticosteroid (yes vs. no)                                              | 0.112 | 0.08     |       |          |
| β-blocker (yes vs. no)                                                   | 0.058 | 0.37     |       |          |
| Renin-angiotensin system inhibitor (yes vs. no)                          | 0.012 | 0.85     |       |          |
| Aldosterone receptor antagonist (yes vs. no)                             | 0.013 | 0.84     |       |          |
| Loop diuretic (yes vs. no)                                               | 0.289 | <0.001   | 0.052  | 0.43     |
| Thiazide diuretic (yes vs. no)                                           | 0.256 | <0.001   | 0.016  | 0.76     |
| Tolvaptan (yes vs. no)                                                   | 0.165 | 0.010    | -0.070 | 0.22     |
| Potassium binder (yes vs. no)                                            | 0.000 | ---      |       |          |
| Phosphate binder (yes vs. no)                                            | -0.131 | 0.041   | 0.040  | 0.46     |
| Vitamin D analog (yes vs. no)                                            | -0.173 | 0.007   | 0.049  | 0.22     |
| Calcimimetic (yes vs. no)                                                | 0.075 | 0.24     |       |          |
| Four-hour dialysate/plasma creatinine                                    | 0.293 | <0.001   | 0.008  | 0.88     |
| Total weekly Kt/V                                                        | 0.138 | 0.031    | 0.119  | 0.027    |
| Renal weekly Kt/V                                                        | -0.031 | 0.63   |       |          |
| Peritoneal weekly Kt/V                                                   | 0.160 | 0.012    | -0.092 | 0.05     |
| Total protein (g/dL)                                                     | -0.112 | 0.08   |       |          |
| Serum albumin (g/dL)                                                     | -0.206 | 0.001   | -0.171 | 0.007    |
| Hemoglobin (g/dL)                                                        | -0.040 | 0.54   |       |          |
| Blood urea nitrogen (mg/dL)                                              | -0.481 | <0.001   | -0.138 | 0.011    |
| Creatinine (mg/dL)                                                       | -0.134 | 0.037   | -0.014 | 0.83     |
| Uric acid (mg/dL)                                                        | -0.295 | <0.001   | -0.016 | 0.71     |
| Sodium (mEq/L)                                                           | -0.185 | 0.004   | 0.352  | <0.001   |
| Potassium (mEq/L)                                                        | -0.301 | <0.001   | 0.025  | 0.66     |
| Chloride (mEq/L)                                                         | -0.550 | <0.001   | -0.629 | <0.001   |
| Total calcium (mg/dL)                                                    | 0.283 | <0.001   | 0.204  | <0.001   |
| Phosphate (mg/dL)                                                        | -0.514 | <0.001   | -0.155 | 0.006    |
| Magnesium (mg/dL)                                                        | -0.180 | 0.005   | -0.014 | 0.76     |
| Blood glucose (mg/dL)                                                    | 0.094 | 0.14     |       |          |
| Serum total CO₂ (mmol/L)                                                 | 0.805 | <0.001   | 0.354  | <0.001   |

**TABLE 2: Simple and multiple linear regression analyses of the parameters correlating with HCO₃⁻ concentration**

Abbreviations: APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; CO₂: carbon dioxide; HCO₃⁻, bicarbonate ion; Kt/V, urea clearance; Log, logarithm

Diagnostic accuracy of serum total CO₂ for the prediction of low and
high bicarbonate concentrations

The ROC curve of serum total CO$_2$ for detecting low (HCO$_3^-$ < 24 mEq/L) and high (HCO$_3^-$ ≥ 24 mEq/L) bicarbonate concentrations is shown in Figure 2. The AUC was 0.909, and the optimal cut-off value was 23.7 mmol/L. The 2×2 tables, stratified according to serum total CO$_2$ and HCO$_3^-$ concentration for low and high bicarbonate, are shown in Table 3. The diagnostic accuracy measures of serum total CO$_2$ for the prediction of low and high bicarbonate concentrations were as follows: sensitivity (91.5%), specificity (74.7%), positive predictive value (53.5%), negative predictive value (96.5%), accuracy (78.8%), pre-test probability (24.1%), positive post-test probability (53.5%), and negative post-test probability (3.5%).

FIGURE 2: ROC curve of serum total CO2 for detecting low bicarbonate (HCO3− <24 mEq/L) and high bicarbonate (HCO3− ≥24 mEq/L) concentrations

AUC: area under the curve; CO2: carbon dioxide; HCO3−: bicarbonate ion; ROC: receiver operating characteristic
TABLE 3: 2×2 table stratified according to serum total CO2 and HCO3− concentration for low and high bicarbonate

Abbreviations: CO2, carbon dioxide; HCO3−, bicarbonate ion

| Serum total CO2 | Low serum total CO2 (Serum total CO2 <24 mmol/L) | High serum total CO2 (Serum total CO2 ≥24 mmol/L) | Total |
|----------------|-----------------------------------------------|-----------------------------------------------|-------|
| Low bicarbonate (HCO3− <24 mEq/L) | 54 | 47 | 101 |
| High bicarbonate (HCO3− ≥24 mEq/L) | 5 | 139 | 144 |
| Total | 59 | 186 | 245 |

Correlation between serum total CO2 and HCO3− concentration

Bland-Altman analysis showed moderate agreement between serum total CO2 and HCO3− concentration. The mean difference was -1.64 ± 3.66, and 95.1% of the points were included within the limits of agreement (the mean difference between the two methods ± 2 standard deviation [95% confidence interval]) (Figure 3).

FIGURE 3: Bland-Altman plot comparing serum total CO2 and HCO3− concentration

CO2: carbon dioxide; HCO3−: bicarbonate ion; SD: standard deviation

Discussion

In the present study, we investigated the relationship between serum total CO2 and HCO3− concentration in
peritoneal dialysis patients and found that serum total CO₂ closely correlated with HCO₃⁻ concentration. We also found that serum total CO₂ has high diagnostic accuracy for predicting low bicarbonate and high bicarbonate in peritoneal dialysis patients.

Serum total CO₂ is a total concentration of all forms of CO₂ in a serum sample, including HCO₃⁻, carbonate, and dissolved CO₂. Serum total CO₂ value is known to be approximately equivalent to HCO₃⁻ concentration because most of CO₂ exists as HCO₃⁻ in blood [9]. In fact, serum total CO₂ has been reported to have a close correlation with HCO₃⁻ concentration in both pre-dialysis CKD patients [10] and hemodialysis patients [11]. However, a discrepancy between serum total CO₂ and HCO₃⁻ concentration is sometimes observed, and temperature and acidity [16] are considered one of the causes of discrepancy in patients without renal impairment [17]. In the present study, serum albumin, calcium, chloride, sodium, phosphate, blood urea nitrogen, and total weekly Kt/V in addition to serum CO₂ were independently correlated with HCO₃⁻ concentration in serum.

Serum albumin represents the nutritional status of patients and is reportedly associated with dietary protein intake in peritoneal dialysis patients [18]. Protein intake is associated with metabolic acidosis because amino acids into which dietary proteins are broken down release hydrogen ions [19]. Increased serum albumin was reported to be associated with metabolic acidosis in pre-dialysis CKD patients [20]. The weak acidity of albumin has also been considered as the cause of this phenomenon [21]. These findings are consistent with our result, showing a negative correlation between serum albumin and HCO₃⁻ concentration.

It has been reported that HCO₃⁻ was positively correlated with calcium concentration in hemodialysis patients [22]. In the present study, HCO₃⁻ concentration was positively correlated with calcium concentration in peritoneal dialysis patients. These findings suggest that serum HCO₃⁻ concentration might be positively correlated with calcium concentration in patients with end-stage renal disease. There were differences in calcium concentrations among peritoneal dialysis solutions used in the present study. The possibility remains that these differences might affect the results of our study.

HCO₃⁻ concentration has been shown to decrease along with an increase in chloride concentration through following equilibrium with HCl and NaHCO₃: H⁺ + Cl⁻ + Na⁺ + HCO₃⁻ = Na⁺ + Cl⁻ + H₂CO₃ [23]. In the present study, chloride concentration was negatively correlated with HCO₃⁻ concentration, which is consistent with the findings of previous reports [10-11].

A cross-sectional study of peritoneal dialysis patients reported that sodium concentration was lower in patients with HCO₃⁻ < 22 mEq/L than in patients with 22 ≤ HCO₃⁻ < 28 mEq/L [24]. In the present study, sodium concentration was positively correlated with HCO₃⁻ concentration. These results suggest that sodium concentration is positively associated with HCO₃⁻ concentration in peritoneal dialysis patients.

Phosphate and blood urea nitrogen were shown to be associated with daily protein intake in patients with end-stage renal disease [25]. Protein intake is negatively associated with bicarbonate, as the amino acids into which dietary proteins are broken down release hydrogen ions [19]. Phosphate and blood urea nitrogen were reported to be negatively correlated with bicarbonate in peritoneal dialysis patients [24], which is consistent with the findings of our study.

Currently available peritoneal dialysis fluids contain alkaline anions of 35–40 mmol/L as lactate or and bicarbonate [6]. The influx of alkaline anions from the peritoneal dialysis fluid into the blood occurs during peritoneal dialysis because the alkaline anion concentration in serum is usually lower than that in peritoneal dialysis fluid [24]. A previous study reported that dialysis adequacy assessed by daily Kt/V was positively correlated with serum bicarbonate level [20]. In the present study, the total weekly Kt/V was positively correlated with HCO₃⁻ concentration. These results suggest that peritoneal dialysis dose-dependently increases serum HCO₃⁻ concentration caused by the influx of bicarbonate from the peritoneal dialysis fluid into the blood.

In the present study, serum total CO₂ was closely correlated with HCO₃⁻ concentration and showed high accuracy for the differentiation of low or high bicarbonate concentrations. Therefore, serum CO₂ may be a good predictor of bicarbonate concentration and useful to predict whether this is low or high. However, the correlation between serum total CO₂ and HCO₃⁻ concentration in the present study (β = 0.325) was weaker as compared with that of hemodialysis patients (β = 0.858) [11]. The number of clinical parameters
correlated with $\text{HCO}_3^-$ concentration was greater in the present study than in the previous one [11] (eight vs three), which might explain the lower correlation between serum total CO$_2$ and $\text{HCO}_3^-$ in this study. The correlation between serum total CO$_2$ and $\text{HCO}_3^-$ concentration might be attenuated in peritoneal dialysis patients. Further studies are necessary to confirm the close correlation between serum total CO$_2$ and $\text{HCO}_3^-$ concentration and the usefulness of serum total CO$_2$ for the diagnosis of low or high bicarbonate concentrations in peritoneal dialysis patients.

The measurement of serum total CO$_2$ has two advantages as compared with blood-gas analyses. First, the cost of a blood gas-syringe can be saved and the amount of blood required will be reduced using serum total CO$_2$ instead of a blood-gas test. Second, serum total CO$_2$ can be used to predict low bicarbonate and high bicarbonate without the use of a blood-gas analyzer. Therefore, the measurement of serum total CO$_2$ could reduce some of the burden on peritoneal dialysis patients and laboratory staff.

Our study had four limitations. First, it was a retrospective, observational study; therefore, selection bias could not be completely eliminated. Second, the study was performed at a single center, which limits the external validity of the results. Third, the study cohort was small, which restricts the generalizability of our findings. Fourth, we used venous blood samples for the analyses. The results might have been different if arterial blood samples had been used. Therefore, further prospective, large-scale, multicenter studies are necessary to confirm our findings.

Conclusions

Serum total CO$_2$ correlated closely with $\text{HCO}_3^-$ concentration in peritoneal dialysis patients. Serum total CO$_2$ might be useful for predicting low and high bicarbonate in peritoneal dialysis patients.

Additional Information

Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. Ethics committee of Saitama Medical Center, Jichi Medical University issued approval S17-052. Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue. Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors declare that no financial support was received from any organization for the submitted work. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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