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Bioelectrical Impedance Analysis Is Not Sufficient for Determining Water Deficit in Hypernatremic Patients

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Background: Hypernatremia is associated with poor outcomes in critically ill patients, and an accurate assessment of water volume is important to determine appropriate fluid hydration. Bioelectrical impedance analysis (BIA) is a new, noninvasive, and relatively easy method for measuring hydration status. This study aimed to investigate whether bioelectrical impedance measurements of body water could reduce the frequency of blood sampling for fluid replacement in patients with hypernatremia.

Material/Methods: Fifty-one hospitalized patients were studied with hypernatremia, defined as a serum sodium ≥150 mmol/L determined by laboratory testing. Laboratory and BIA measurements were compared, and water deficiency was calculated with a conventional formula (sodium-corrected Watson formula) and measured by BIA.

Results: The value of the absolute fluid overload (AFO) equivalent to the overhydration (OH) value, determined using BIA, did not accurately represent water deficit in patients with hypernatremia ($r=0.137$, $P=0.347$). Although the total body water (TBW) measured by BIA showed a significant correlation with that determined by the conventional formula ($r=0.861$, $P<0.001$), there was a proportional bias ($r=0.617$, $P<0.001$). The intracellular water (ICW) measured by BIA underestimated the TBW level calculated by the conventional formula by about 14.06±4.0 L in the Bland-Altman analysis.

Conclusions: It is not currently possible to replace blood testing with BIA for assessing volume status in hypernatremic patients. However, ICW value measured by BIA might represent plasma sodium level more accurately than extracellular water (ECW) or TBW value in patients with hypernatremia.

MeSH Keywords: **Body Fluids • Dehydration • Electric Impedance • Hypernatremia**

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Background

Hypernatremia is not uncommon in hospitalized patients and is defined as a rise in the concentration of serum sodium levels above 145 mmol/L. Hypernatremia is commonly caused by water loss, but in rare cases, it can be due to the administration of hypertonic saline or sodium bicarbonate. As the sodium level rises, the osmotic pressure increases and cerebral osmotic receptors are stimulated to induce feelings of thirst and increased water intake [1]. However, patients who present with hypernatremia usually have a severe underlying condition that impairs their ability to respond to thirst cues or may have a physical disability that prevents them from drinking enough water [1]. Hypernatremia is associated with poor outcomes in the affected patients [2,3].

Sufficient water replacement is required to correct the state of hypernatremia. Estimating water deficits, ongoing free water losses, and sodium correction rates are crucial when determining the required levels of fluid replacement in hypernatremia [4]. Frequent blood sampling is required for making these measurements. Bioelectrical impedance analysis (BIA) has been used as a relatively easy, noninvasive, and reproducible tool to measure fluid status [5]. The BIA method is based on measuring the body's impedance of small electric currents. Recently, this method has been widely used to measure the fluid status in hemodialysis patients, and it has been shown to improve outcomes in these cases [6]. In hyponatremic patients, BIA helps determine the differential diagnosis by measuring the fluid status [7]. However, the potential role of BIA in the management of hypernatremia has not been well reported. Alternatives to frequent blood sampling with noninvasive and safe methods in these patients could be transformative as they would prevent the side effects associated with frequent blood sampling, such as bruising, hematoma, injury to nerves or other anatomic structures, vasovagal attacks, and accidental injury and blood exposure to health workers [8]. Primary care units without the capacity to perform frequent blood tests would benefit from alternative approaches to monitoring and treating cases of hypernatremia.

Therefore, this study aimed to investigate whether bioelectrical impedance measurements of body water could reduce the frequency of blood sampling for fluid replacement in patients with hypernatremia.

Material and Methods

Participants

This study included patients who had been admitted to Konyang University Hospital with hypernatremia (≥150 mmol/L) between October 2016 and June 2018. Patients were excluded from the study if they had a unipolar cardiac pacemaker, ascites, or edema, an amputated extremity, who were pregnant, or who could not be weighed. Fifty-one patients were included in the final study cohort after informed consent was given. All protocols used in this study were approved by the Institutional Review Board of Konyang University Hospital (IRB Number: 2016-10-003).

Study protocol

BIA measurements were performed as soon as possible after sampling of about 5 mL of blood and 10 mL of urine for laboratory tests. Laboratory tests included the measurement of plasma osmolality and plasma levels of hemoglobin, hematocrit, sodium blood urea nitrogen (BUN), creatinine, protein, and albumin, and urine osmolatity and urine levels of sodium, potassium, and creatinine. Patients were treated individually according to the physician's opinion after enrollment into the study. The same test was performed after day 3 of enrollment to confirm whether the changes in the water content calculated with each method were correlated. Patient height and body weight were also measured simultaneously on day 1 and day 3 of enrollment. Bedridden patients were weighed using a hoist.

Water deficit calculated by the conventional method

The total body water (TBW) was calculated using the Watson formula [9].

Men: $2.447-(0.09156\times\text{age})+(0.1074\times\text{height})+(0.3362\times\text{weight})$
Women: $-2.097+(0.1069\times\text{height})+(0.2466\times\text{weight})$

In dehydrated patients, the TBW was corrected by calculating the plasma sodium level. The sodium-corrected TBW was calculated using a previously described formula [9]:

$$\begin{array}{c}\text{Normal expected TBW}\\ \text{(calculated with the Watson formula)}\times\dfrac{140}{\text{pNa}}\end{array}$$

The Watson formula for calculating water deficit was as follows [9].

$$\text{TBW by Watson}\times\left(\frac{140}{\text{pNa}}\right)-\text{TBW by Watson}$$

Water deficit analysis using bioelectrical impedance analysis (BIA)

BIA was performed using a body composition monitor (BCM) (Fresenius Medical Care, Bad Homburg, Germany) operated by a well-trained nurse and as previously described [10]. Briefly, electrodes were attached to the forearm and ipsilateral ankle of the patient when in a supine position. The BCM device was the latest bioimpedance spectroscopy (BIS) instrument that measured 50 frequencies over a range from 5–1000 kHz to determine the electrical resistance of the TBW and the extracellular water (ECW). Based on a fluid model using these resistance measurements, the BCM calculated the ECW (liters, L), intracellular water (ICW) (L), TBW (L), the lean tissue index (LTI) (kg/m^2), the lean tissue mass (LTM) (kg), the body mass (kg), the adipose tissue mass (ATM) (kg), and the fat tissue index (FTI) (kg/m^2). All calculations were performed using the BCM software (Fresenius Medical Care, Bad Homburg, Germany). The absolute fluid overload (AFO) was defined as the difference between the patient's expected ECW under normal physiologic conditions and actual ECW. Normohydration is defined as an AFO and overhydration (OH) value between the 10th and 90th percentiles for healthy age-matched and sex-matched individuals from the reference population. These values were 2.1 to 1.1 L, with volumes below and above this range indicating underhydration and overhydration, respectively [11]. Water deficits were estimated using the following formula:

TBW by BCM–TBW calculated by Watson formula

Statistical analysis

Data were analyzed using R version 2.1.5.0 (R Development Core Team). Continuous data were presented as the mean ± standard deviation (SD). Differences between the two groups were compared using Student's t-test. The Bland–Altman test was used to determine the agreement between the quantitative variables in the BCM components and body water levels calculated using the conventional formula. P-values <0.05 were considered to be statistically significant.

Results

Baseline characteristics of the study subjects

The causes of the hospital admissions for the study participants are listed in Table 1. The baseline characteristics of the study participants are presented in Table 2. The current study cohort of 51 hypernatremic patients included 25 men and 26 women, with 26 of these patients admitted to the intensive care unit (ICU). Eighteen patients had diabetes mellitus, 28 patients had hypertension, and two patients had chronic kidney disease. Fourteen patients were treated with furosemide at enrolment, and nine patients were treated with furosemide at day 3 after enrolment. Among the laboratory values, the plasma osmolality and levels of sodium, protein, and albumin were significantly reduced, and the urine level of sodium was significantly increased at day 3 after enrolment when compared with the day of enrolment. None of the body composition monitor (BCM) results showed significant differences between day 1 and day 3.

Table 1. Causes of hospitalization among the hypernatremic study participants.

Disease	Number of patients
Sepsis	23
Hypoxic brain damage	7
Cerebrovascular accident	7
Intracerebral hemorrhage	4
Cardiac arrest	2
Deceased donor	1
Renal failure	4
Seizure	1
Dementia	2

Correlations between levels of water deficit calculated by the conventional formula and levels of overhydration determined by bioelectrical impedance analysis (BIA)

The mean water deficit value calculated by the conventional formula was 1.23±0.42 L. The mean overhydration (OH) value determined by BIA was 1.61±2.95 L. There was no significant correlation between these measurements (r=0.137, P=0.347) (Figure 1).

Correlation between the level of total body water (TBW) measured by the conventional formula and BIA

Correlations between the TBW levels estimated by the conventional formula and by BIA are shown in Figure 2A. A significant correlation was found between these measurements (r=0.861, P<0.001). A Bland-Altman plot showing the differences between the two methods is shown in Figure 2B and showed a proportional bias (r=0.617, P<0.001). There was a tendency for the extent of these differences to be underestimated as the average decreased, and overestimated as the average increased. The proportional bias remained in a percentage difference plot for these data (r=0.517, P<0.001) (Figure 2C).

Correlation between the level of TBW calculated by the conventional formula and level of intracellular water (ICW) determined by BIA

A significant association was found between the TBW calculations using the conventional formula and the ICW measurements by BIA, as shown in Figure 3A (r=0.679, P <0.001). The Bland-Altman plot further showed that the ICW level determined by BIA underestimated the TBW measured by the

Table 2. Baseline characteristics of the 51 study participants.

		Day 1 (mean ±SD)	Day 3 (mean ±SD)	P-value
Plasma	Hb (g/dL)	11.11±1.81	10.48±1.66	0.072
	Hct (%)	34.26±5.82	32.35±5.20	0.281
	Na (mmol/L)	153.84±4.99	148.2±6.85	0.0001
	K (mmol/L)	3.70±0.64	3.716±0.62	0.925
	BUN (mg/dL)	39.87±19.34	35.98±20.43	0.333
	Cr (mg/dL)	1.09±0.63	1.02±0.73	0.611
	Protein (g/dL)	6.03±1.04	5.58±0.73	0.014
	Albumin (g/dL)	2.91±0.66	2.63±0.49	0.018
	Osmolality (mOsm)	329.57±16.73	315.48±17.37	0.000
Urine	Na (mmol/L)	62.20±37.94	78.82±47.26	0.009
	K (mmol/L)	30.36±10.64	32.16±15.22	0.409
	Cr (mg/dL)	61.88±45.36	58.69±51.33	0.637
	Osmolality (mOsm)	574.30±182.31	574.39±171.21	0.997
BCM	TBW (L)	29.81±8.21	31.20±7.47	0.383
	ECW (L)	14.33±4.07	14.52±3.97	0.823
	ICW (L)	16.36±7.57	16.30±4.52	0.955
	ECW/TBW	0.47±0.05	0.45±0.09	0.127
	Fat (kg)	14.33±8.54	13.07±7.48	0.464
	ATM (kg)	19.57±11.79	17.94±10.29	0.504
	LTM (kg)	33.01±12.65	34.07±10.95	0.680
	LTI (kg/m^2)	12.51±4.04	13.16±4.00	0.459
	FTI (kg/m^2)	7.60±4.84	6.94±3.90	0.485
	OH	1.53±2.81	1.72±2.84	0.739

Hb – hemoglobin; Hct – hematocrit; Na – sodium; K – potassium; BUN – blood urea nitrogen; Cr – creatinine; BCM – body composition monitor, TBW – total body water; ECW – extracellular water; ICW – intracellular water; ATM – adipose tissue mass; LTM – lean tissue mass; LTI – lean tissue index; FTI – fat tissue index; OH – overhydration.

conventional formula, with a 14.06±4.0 L fixed constant bias (r=0.32, P=0.84) (Figure 3B). The fixed bias still appeared in the percentage difference plot for these data (r=0.052, P=0.739) (Figure 3C)

Correlation between the level of water deficit measured by the conventional formula and by BIA

The water deficit estimated by the conventional method (TBW by Watson$\times\left(\frac{140}{\text{pNa}}\right)$–TBW by Watson) and by using BIA (TBW by BCM–TBW by Watson) showed no significant association (r=0.06, P=0.07) (Figure 4).

Changes in TBW measured by the conventional formula and BIA on day 1 and day 3 in the study

There was no correlation between the time-dependent changes in TBW measured by the conventional formula and the BIA methods on day 1 and day 3 (r=0.089, P=0.579) (Figure 5A). The change in ICW determined by BIA on day 1 and day 3 also showed no significant association with the change in TBW calculated by the conventional formula (r=0.036, P=0.251) (Figure 5B).

Correlation between the value of the body water compartment measured by the conventional formula and BIA in patients with sepsis

Subgroup analysis was performed to evaluate the efficiency of BIA in patients with sepsis who had hypernatremia. There was

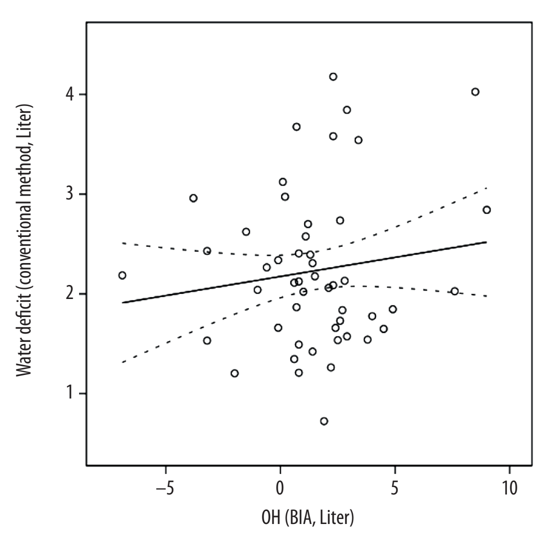

Figure 1. Correlations between the water deficit level calculated by the conventional formula and overhydration level determined by bioelectrical impedance analysis (BIA). Regression analysis of water deficits measured by the conventional formula (x-axis) and overhydration (OH) measured by bioelectrical impedance analysis (BIA) (y-axis). (y=0.038x+2.17, r=0.137, p=0.347).

no correlation between the water deficit value calculated by the conventional formula and the mean OH value determined by BIA (r=0.097, P=0.668) (Figure 6). A significant correlation was found between the TBW levels estimated by the conventional formula and by BIA (r=0.834, P<0.001) (Figure 7A). A Bland-Altman plot showing the agreement between the two methods showed a proportional bias (absolute difference and percentage difference: r=0.617, P<0.001 and r=0.846, P<0.001, respectively) (Figure 7B, 7C). Significant correlations were found between the TBW calculations by the conventional formula and the ICW measurements by BIA, as shown in Figure 8A (r=0.562, P <0.01). A Bland-Altman plot further showed that the ICW level determined by BIA underestimated the TBW measured by the conventional formula, with 11.24±5.2 L fixed constant bias (r=0.321, P=0.159) (Figure 8B). The fixed bias still appeared in the percentage difference plot for these data (r=0.327, P=0.159) (Figure 8C)

Discussion

The findings from this study showed that the overhydration (OH) values determined by bioelectrical impedance analysis (BIA) could not significantly reflect the water deficit levels calculated by a conventional formula in patients with hypernatremia. The total body water (TBW) measured by conventional formula and BIA showed a significant correlation in regression analysis, but there was a proportional bias. The differences between the values calculated by the two methods increased as the average either decreased or increased. The intracellular water (ICW) measured by BIA showed a significant correlation with the TBW calculated with the conventional formula but underestimated this TBW calculation by about 14.06±4.0 L in the Bland-Altman analysis.

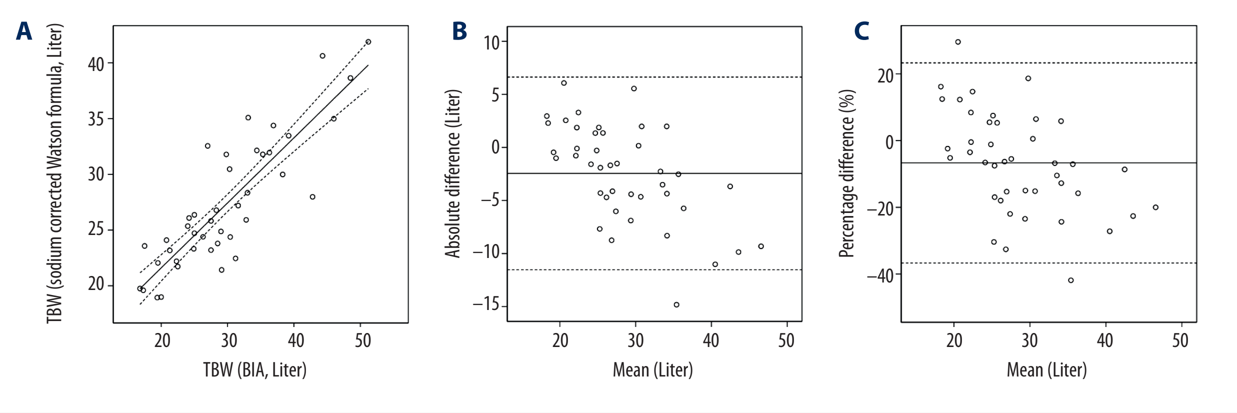

Figure 2. Correlation between the total body water level measured by the conventional formula and bioelectrical impedance analysis (BIA). (**A**) The scatterplot indicating a correlation between the total body water (TBW) level calculated by the conventional formula (x-axis) and measured using bioelectrical impedance analysis (BIA) (y-axis). (y=0.584x+9.936, r=0.861, p<0.000). (**B**) Generalized Bland-Altman plot of the agreement between the TBW values measured by the conventional formula and BIA. The differences between the measurements (y-axis) were plotted against the average of the measurements (x-axis) (r=0.617, p<0.000). (**C**) Differences between the measurements expressed as percentages of the values (y-axis) were plotted against the mean of the two measurements (x-axis). (r=0.517, p<0.000). Dash-dotted lines represent the 95% limits of agreement. The differences between the two measurement methods were regressed using the average values obtained with these two methods (solid line).

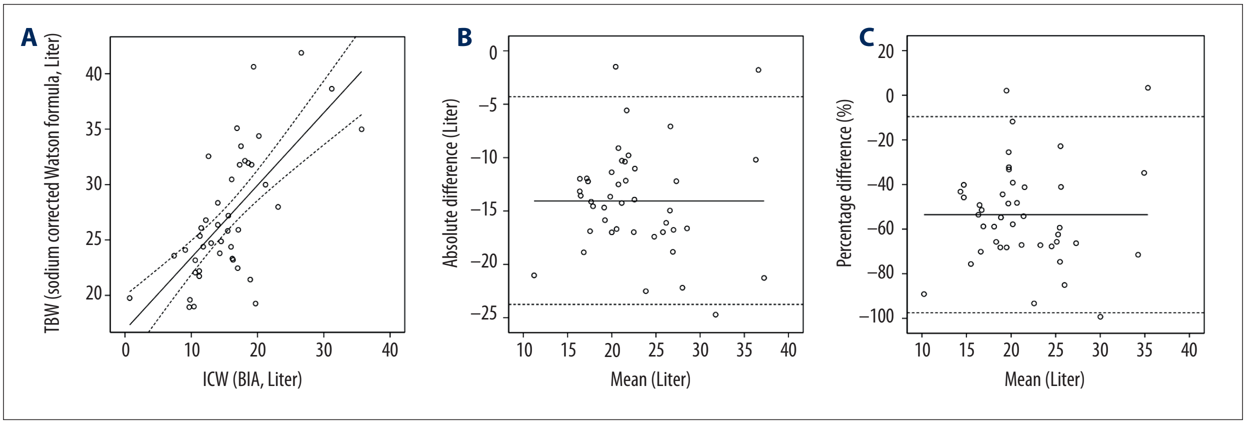

Figure 3. Correlation between the total body water level calculated by the conventional formula and intracellular water level determined by bioelectrical impedance analysis (BIA). (**A**) The scatterplot showing the correlation between the total body water (TBW) level measured by the conventional formula (x-axis) and the intracellular water (ICW) level measured by bioelectrical impedance analysis (BIA) (y-axis) ($y=0.371x+20.999$, $r=0.679$, $p<0.000$). (**B**) The generalized Bland-Altman plot of the agreement between the TBW levels measured by the conventional formula and BIA. Differences between the measurements (y-axis) were plotted against the average of the measurements (x-axis) ($r=0.32$, $p=0.84$). (**C**) Differences between the measurements expressed as percentages of the values (y-axis) were plotted against the mean of the two measurements (x-axis) ($r=0.052$, $P=0.739$) Dash-dotted lines represent the 95% limits of agreement. The differences between the two methods were regressed using the average values obtained with the two methods (solid line).

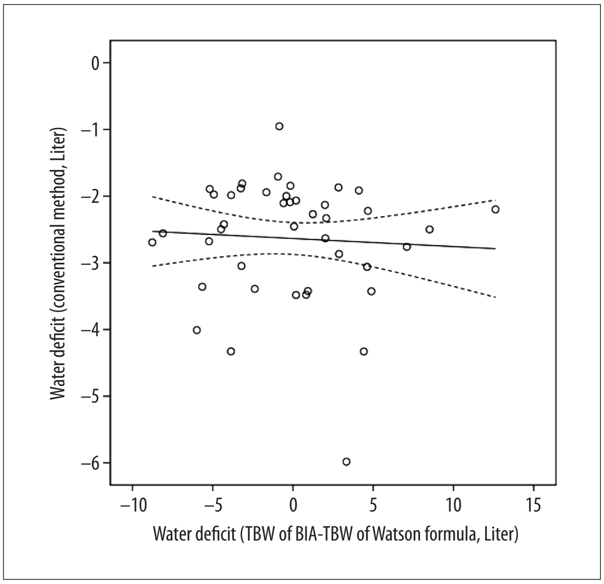

Figure 4. Correlation between the water deficit level measured by the conventional formula and by bioelectrical impedance analysis (BIA). The scatterplot showing the correlation between the water deficit values estimated with a conventional formula (TBW by Watson$\times\left(\frac{140}{pNa}\right)$–TBW by Watson) (x-axis) and using bioelectrical impedance analysis (BIA) (TBW by BCM–TBW by Watson) (y-axis) ($y=-0.295x-0.960$, $r=0.06$, $p=0.7$). Dash-dotted lines represent the 95% limits of agreement. The differences between the two methods were regressed using the average values obtained with the two methods (solid line).

Recently published studies have reported the benefits of measuring the water status using BIA, but few reports have evaluated the utility of this impedance method in determining the dehydration status or the hypernatremia status. To the best our knowledge, this study is the first to evaluate the use of BIA in hypernatremia. O'Brien et al. previously reported that BIA was sufficiently sensitive to detect moderate hypohydration [12]. However, other studies could not accurately determine water content changes using BIA in patients with dehydration [13–15]. Theoretically, the flow of current using BIA may not be sufficient during dehydration due to the decrease in water content, and the resistance determined by BIA will increase [12,15,16]. However, several studies that have assessed the BIA method for water content measurement during dehydration have reported that the resistance value does not always increase, and that TBW measurement by BIA was not consistently accurate [17–19].

A recent study found that BIA more accurately measured changes in body water during dehydration caused by exercise after several hours than immediately after exercise. In this previous study, acute changes in cutaneous blood flow and temperature, as well as in skin electrolyte accumulation after exercise, directly affected the BIA measurement [13]. Another study of dehydration in 27 stroke patients using BIA also reported that this method failed to accurately represent the body water status of the cases studied [14]. Olde Rikkert et al. reported that the BIA showed poor sensitivity (14%) in geriatric patients who were dehydrated and the data did not reflect the observed changes in serum osmolality or osmolarity, and

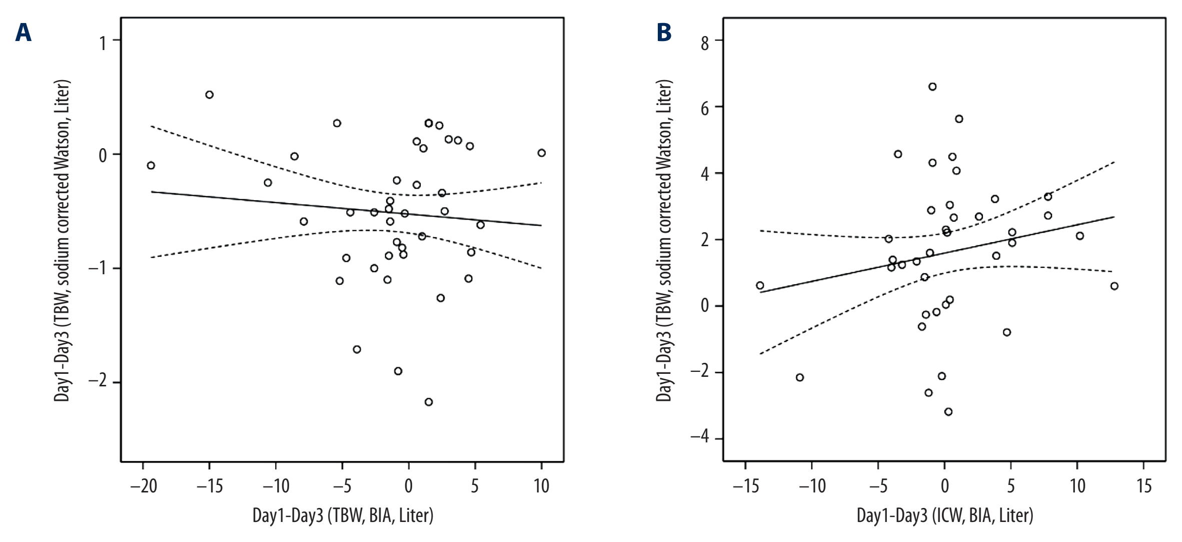

Figure 5. Changes in total body water (TBW) measured by the conventional formula and bioelectrical impedance analysis (BIA) on the first and third days of the study. (**A**) The scatterplot shows the correlation between the changes in total body water (TBW) in the first and third days of the study measured by the conventional formula (x-axis) and bioelectrical impedance analysis (BIA) (y-axis) (y =–0.011x–0.548, r=0.089, p<0.579). (**B**) The scatterplot shows the correlation between the TBW levels measured using the conventional formula (x-axis) and the changes in intracellular water (ICW) determined by BIA (y-axis) on the first and third days (y=0.085x+1.593, r=0.036, p=0.251). Dash-dotted lines represent the 95% limits of agreement. The differences between the two methods were regressed using the average values obtained with two methods (solid line).

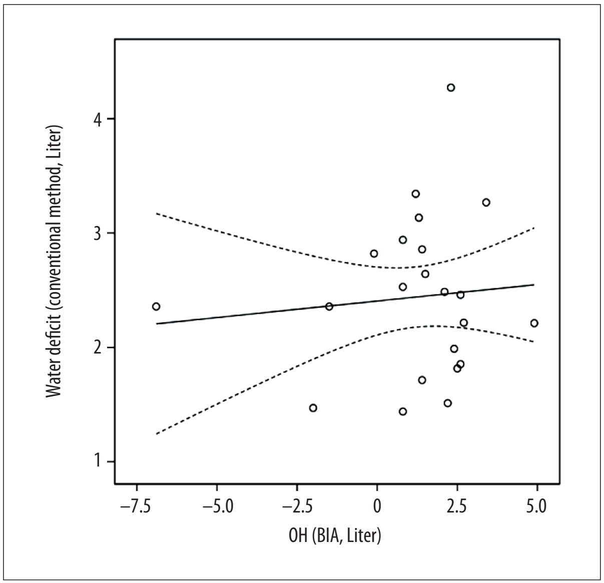

Figure 6. Correlations between the level of water deficit calculated by the conventional formula and the level of overhydration determined by bioelectrical impedance analysis (BIA) in patients with sepsis. Regression analysis of water deficits measured by the conventional formula (x-axis) and overhydration (OH) measured by bioelectrical impedance analysis (BIA) (y-axis). (r=0.097, P=0.668).

could not identify the state of dehydration at the cellular level with sufficient sensitivity [15].

In patients with hypernatremia, alterations to the blood electrolyte concentration or blood volume may impact BIA measurements by directly influencing the electrical conductivity of the body. Hypertonic hypohydration occurs when the loss of water is greater than the loss of solute. In such cases, the plasma osmolality increases and water is redistributed from the intracellular compartment to the extracellular compartment. Therefore, even with the same dehydration state, the TBW value measured at the time of hypertonic hypohydration may be more variable than that measured at the time of isotonic hypohydration.

In this study, the reasons why the body composition monitor (BCM) did not accurately measure the changes in the level of body water are similar to those presented in previous reports. Patients with hypernatremia who participated in this study were almost all severely dehydrated and acutely ill. Acute changes in the body water content in patients with hypernatremia could influence to the ICW/ECW resistivity. Acute alterations in the sodium levels also affect the electrical conductivity measured by BIA. In this study, intracellular fluid (ICF) measured by BIA is more accurately reflected by the changes in the water content than the TBW measured with this method. An explanation for this may be that most of the sodium in the body is distributed in the extracellular water (ECW), so that the electrical current

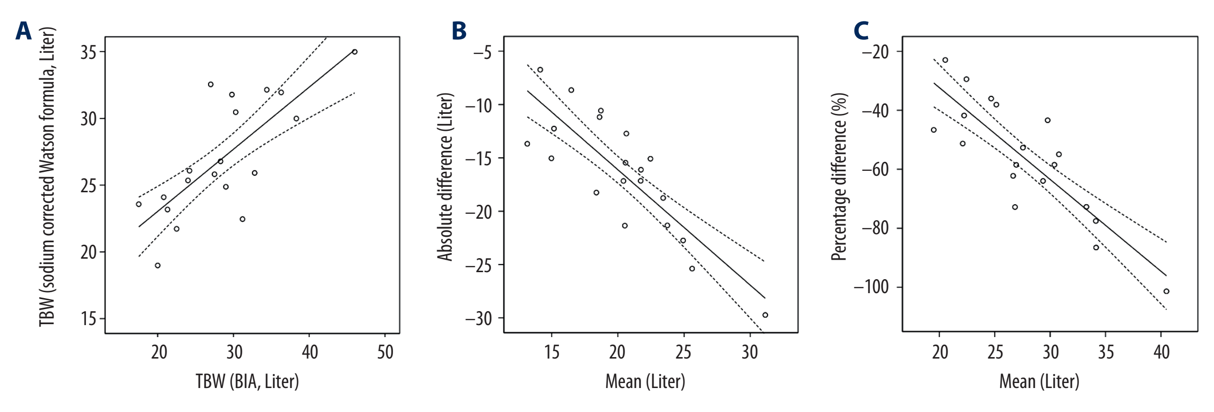

Figure 7. Correlation between the levels of total body water (TBW) measured by the conventional formula and bioelectrical impedance analysis (BIA) in patients with sepsis. (**A**) The scatterplot shows the correlation between the levels of total body water (TBW) calculated by the conventional formula (x-axis) and measured using the bioelectrical impedance analysis (BIA) (y-axis) (r=0.834, P <0.001). (**B**) The generalized Bland-Altman plot of the agreement between the TBW values measured by the conventional formula and BIA. The differences between the measurements (y-axis) were plotted against the average of the measurements (x-axis) (r=0.617, P<0.001). (**C**) The differences between the measurements expressed as percentages of the values (y-axis) were plotted against the mean of the two measurements (x-axis) (r =0.846, P<0.001). Dash-dotted lines represent the 95% limits of agreement. The differences between the two measurement methods were regressed using the average values obtained with these two methods (solid line).

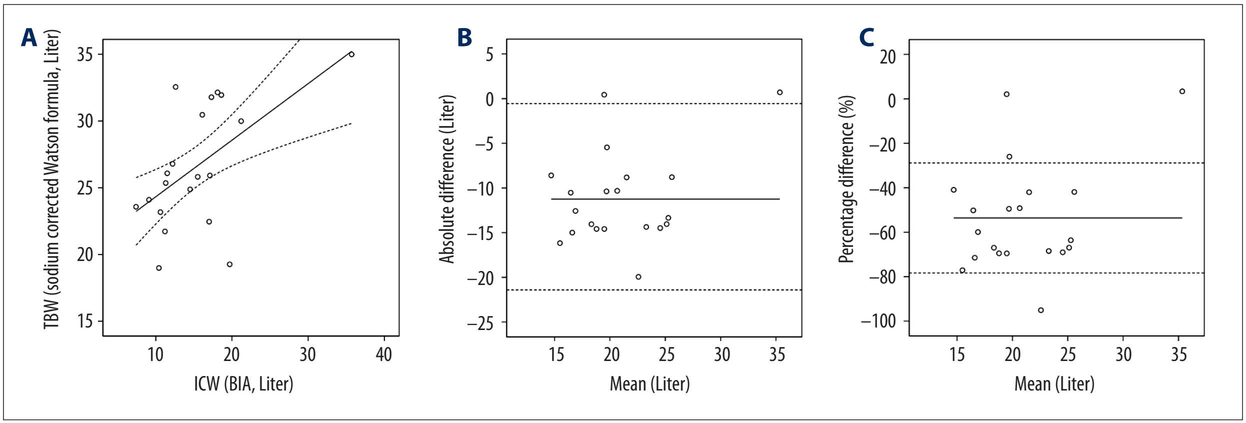

Figure 8. Correlation between the level of total body water (TBW) calculated by the conventional formula and the levels of intracellular water (ICW) determined by bioelectrical impedance analysis (BIA) in patients with sepsis. (**A**) The scatterplot shows the correlation between the level of total body water (TBW) measured by the conventional formula (x-axis) and the level of intracellular water (ICW) measured by bioelectrical impedance analysis (BIA) (y-axis) (r=0.562, P <0.01). (**B**) The generalized Bland-Altman plot of the agreement between the levels of TBW measured by the conventional formula and BIA. Differences between the measurements (y-axis) were plotted against the average of the measurements (x-axis) (r=0.321, P=0.159). (**C**) The differences between the measurements expressed as percentages of the values (y-axis) were plotted against the mean of the two measurements (x-axis) (r=0.327, P=0.159) Dash-dotted lines represent the 95% limits of agreement. The differences between the two methods were regressed using the average values obtained with the two methods (solid line).

that passes through the ECW will be affected more than the ICW in hypernatremia. The TBW level measured by the BCM device was automatically calculated from the ICW and ECW values. Therefore, the TBW measured with the BCM would have been affected by any changes in the ECW.

In this present study, treatment of hypernatremia was individualized according to the physician's judgment. At day 3 after enrollment, the calculated values of water deficiency decreased as the plasma levels of sodium decreased. However, there was no correlation with the values of BIA. A previously published study reported that after infusion of 1L of isotonic saline, the resistance of the BIA immediately fell and showed a significant relationship with ICW [20]. Another study showed that after drinking 466 ml of isotonic saline, and increased plasma volume was found, but this hyperhydration was not detectable with single frequency BIA [21]. Therefore, further studies are needed to determine the accuracy of BIA following hydration.

A previous study reported that systemic inflammation increases vascular permeability and produces changes between the distribution of TBW. Changes in tissue physiology and integrity during sepsis may produce changes in electrical properties [22]. Even though changes of TBW were similar, patients with sepsis and peritonitis have been shown to have higher ECW values compared with patients with traumatic injury [23]. Therefore, we performed a subset analysis of data in 23 patients with sepsis and 28 patients without sepsis, which showed no significant difference. This finding might be explained by the relatively small size of the study population, which could influence the accuracy of the analysis. Even though the patients in our study were not diagnosed with sepsis, they might have had systemic inflammation. Therefore, further larger studies are needed to evaluate the efficacy of BIA in patients with or without inflammation.

This study had several limitations. First, the water deficit formula used in this study was not the gold standard method for measuring the TBW. However, although isotopic dilution methods can measure body water content more accurately, the conventional water deficit formula is more frequently used in clinical practice. Second, the accuracy of the body weights may have been affected as some patients could not stand and had to be weighed using a hoist and scale at the bedside. Third, in this study, we did not examine markers that could predict inflammation, such as C-reactive protein (CRP).

Conclusions

In this study, body water measurements, using bioelectrical impedance analysis (BIA), did not accurately represent the body water content in patients with hypernatremia. Therefore, it is not possible to recommend replacing standard blood testing methods with BIA for the assessment of body water content in hypernatremia. However, the ICW measured by BIA may represent plasma sodium level more accurately than ECW or TBW. BIA has certain limitations, most importantly, the difficulty in validating the method under varied clinical conditions that include abnormal hydration status, and in patients of different age and ethnicity. However, the findings from the present study may form the basis for future developments in the practical use of BIA in specific clinical conditions such as hypernatremia.

Conflict of interest

None.

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