Is it possible to evaluate the hypernatremia with ultrasonographic vena cava parameters?

The hypernatremia with ultrasonographic vena cava parameters

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Abstract

Aim: In this study, we aimed to evaluate the relationship of inferior vena cava (IVC) respiratory variation with hypernatremia due to fluid response, and to evaluate its applicability in determining SNa levels in these patients.

Material and Methods: Geriatric patients with dehydration and hypernatremia were included in the study. In the inferior vena cava (IVC) measurement, the diameter of the IVC was measured for each patient by different emergency physicians using experienced and trained sonography. This prospective, cross-sectional and observational study was conducted as a double centre study from January to July 2020.

Results: The evaluation was performed on 103 patients. Of the 103 dehydrated patients included in the study, 78 (75.7%) had mild hypernatremia (Serum Sodium (SNa)145-154 mEq/L), and 25 (24.3%) patients had severe hypernatremia (SNa>155 mEq/L). When patients with hypernatremia were divided into two groups as mild and severe, the diagnostic efficiency of the VCI diameter, IVCCI parameters and the ROC curve and AUC, cut-off, sensitivity and specificity were discriminately analyzed to guide the patient's condition in the patient follow-up. For the VCI diameter parameter, the AUC, cut-off, sensitivity and specificity were 0.893 %, 14.7%, 65.2% and 95.2%, respectively. IVCCI AUC, cut-off, sensitivity, and specificity were 0.756, 56.19, 73.9% and 70%, respectively.

Discussion: IVC and IVCCI can be used to identify patients with dehydration-induced hypernatremia and determine disease severity, and moreover, they can be used as a useful tool in the assessment of adequate fluid volume replacement in the follow-up of these patients.

Keywords

Inferior Vena Cava (IVC), IVCCI; Dehydration, Geriatric Patients, Ultrasonography, Hypernatremia

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Introduction

Dehydration is a clinically important health problem in elderly [1]. People over 65, whom we called the geriatric age group in this study, tend to develop hypernatremia due to age-related physiological changes, such as decreased thirst, impaired ability to concentrate urine, and decreased total body water. In the literature, the prevalence of hypernatremia is reported to be 3.7%, especially in the elderly population [2]. Hypernatremia can be grouped in two ways. The serum sodium value, which is called mild hypernatremia and seen in approximately 1-3% of hospitalized patients, is above 145 mmol/L [1,3]. Although severe hypernatremia is seen less frequently, it is defined as Serum Sodium (SNa) being above 155 mmol/L. Mortality rates have increased up to 37%-55%, especially in patients with hypernatremia [4]. It is known that invasive and non-invasive measurements are used in the volume assessment of patients [5,6]. In some studies in the literature, it has been reported that the VCI USG measurement is useful in evaluating the volume status, especially in hypotensive and hypovolemic patients [7]. The importance of USG use in the paediatric age group, especially regarding dehydration, is emphasized [8,9]. However, there is no study evaluating the relationship between vena cava parameters, especially in patients with geriatric hypernatremia, which is the subject of our study.

In this study, we aimed to evaluate the relationship of inferior vena cava (IVC) respiratory variation with hypernatremia due to fluid response, and to evaluate its applicability in determining SNa levels in these patients.

Material and Methods

Study Design

This diagnostic test evaluation was carried out in two centres between 01.01.2020-01.07.2020. This study is a prospective, cross-sectional and observational study, including geriatric patients with signs of dehydration and hypernatremia. The patients were included in the study consecutively between the dates of the study. A healthy control group was also included in the study, provided that it consisted of volunteers. The study was conducted as a double centre study at Yozgat Bozok Üniversitesi Emergency Medicine Clinic and Kanuni Sultan Suleyman Research and Training Hospital Emergency Medicine Clinic. This study was approved by the Ethics Committee of Yozgat Bozok University with the number 2019-10-239. (30.10.2019).

Working Environment and Population

Our target group was geriatric patients with dehydration and hypernatremia. The inclusion criteria are outlined below:

Patient Group

- Patient age above 65
- Physical hydration assessment of patients based on 7 signs of physical dehydration (tachycardia (>100 bpm), low systolic blood pressure (<100 mm Hg), dry mucosa, dry armpits, weak skin turgor, sunken eyes, and long capillary filling time (>2 seconds) was evaluated (13). Patients with these physical characteristics were included in the study.
- An SNa level above 145 mEq/L

Study Protocol

Physical examination findings and laboratory evaluations of the patients included in the study were recorded by a separate emergency medicine specialist. In the inferior vena cava (IVC) measurement, the diameter of the IVC was measured for each patient by different emergency physicians using experienced and trained sonography.

Ultrasound Protocol

The HM70A with Plus ultrasound system (Samsung Medison Co., Ltd, Seoul, Korea) were available at both hospitals and were used to make the necessary measurements during this study. A 1-7 MHz curve probe was used. The IVC diameter was measured between the junction of the hepatic vein-IVC and IVC-right atrium during inspiration. Using a convex probe or sector probe, it was held in the subxiphoid area to show the right armpit, and the entrance of the right atrium and vena cava inferior was found. The IVC diameter was monitored for 30 seconds in M-Mode and the screen was frozen, on which, the diameter of the IVC was measured from the narrowest (IVC min) and widest (IVC max) location. The VCI expands on expiration and narrows on inspiration.

Statistical Analysis

The GPower 3.1 software (Universität Kiel, Kiel, Germany) was used to clarify the adequacy of the sample size in all calculations for this study prior to data collection. Type 1 was determined as 23 persons for every three groups (healthy, control and 2 patient groups) with 0.05 error and an 85% power analysis. We recorded demographic data and basic clinical characteristics of the patients and the healthy group who agreed to participate in the study together with the respiratory variations in the IVC diameter. For statistical analysis, the IBM SPSS Statistics 22 (IBM Inc., Armonk, NY, USA) program was used. When evaluating the data in the study, if it was qualitative, the Chi-Square test was used; and numerical values were expressed as mean ± standard deviation. The Kruskal-Wallis H test was used in statistical evaluations according to the status of the variables that were statistically nonparametric and the correlated variables were categorical (nominal or ordinal) and a numerical independent group. Spearman's rank correlation method was used in nonparametric data for correlations between data. According to the clinical results, the VCI and CI activities in hypernatremia were evaluated with the Receiver-Operating Characteristics Curve (ROC curve). The results were evaluated for a significance level of $p < 0.05$.

Results

Between January 1, 2020 and July 1, 2020, a total of 37,210 patients over the age of 65 applied to the emergency services of the two hospitals. Hypernatremia was found in 107 patients with clinical dehydration. Four patients were excluded from the study because they had previously been diagnosed with diabetes insipidus. Of the 103 dehydrated patients included in the study, 78 (75.7%) had mild hypernatremia (Serum Sodium(SNa): 145-154 mEq/L), and 25 (24.3%) patients had severe hypernatremia (SNa > 155 mEq/L). The lowest measured serum sodium was 146 mmol /L and the highest measured serum sodium was 176 mmol /L. The mean age of the patients was 74.6 years (standard deviation, 9.6), 34 (33.3%) of the patients were female and 69 (66.7%) were male.

Table 1 shows the clinical evaluation of the patients' physical

Table 1. Physical signs of dehydration in patients

Physical signs of dehydration	Hypernatremia groups %(n)	Mild Hypernatremia group %(n)	Severe Hypernatremia group %(n)	P value
Low systolic BP	58.3(61)	48.8(39)	95.5(22)	0.000*
(<100 mm Hg)				
Tachycardia	66(68)	61.7(50)	81.8(18)	0.078
(HR > 100 bpm)				
Dry mucous	82.5(86)	79(64)	95.5(22)	0.111
membrane				
Axillary dryness	44.7(46)	38.3(31)	68.2(15)	0.012*
Poor skin turgor	81.6(84)	80.2(65)	86.4(19)	0.757
Sunken eyes	40.8(42)	37(30)	54.5(12)	0.138
Capillary refill > 2	43.7(45)	33.3(27)	81.8(18)	0.000*

As statistical analysis, the Chi-Square test was used. * sign =p<0.05 was considered significant.

Table 2. Physiological and laboratory parameter values of the groups

	Control Group	Mild Hypernatremia group	Severe Hypernatremia group	P value
Systolic Blood Pressure mmHg	120.3±12.4(95-139)	99.5±10.7(89-111)	91.5±9.1(83-105)	0.000*
Diastolic blood pressure mmHg	56.7±9.7	53.8±7.3	50±4,6	0.065
Pulse	95.9±16.1	102.7±11.4	111.1±12.1	0.011*
MAP mmHg	84.6±9.5	69±4.5	63.8±5.3	0.000*
Shock index	0,6±0,08	1,04± 0,15	1,22±0,18	0.000*
Glucose mg/ dl	96.9±19	97.6±18.8	99.6±19.6	0.227
BUN mg/dL	18.3±12.3	52.9±20.3	80.8±48.2	0.000*
Creatine mg/dL	1,51±0,9	1.6±1.05	2.9±2.2	0.007*
Sodium (Na) mEq/L	138,4±2.1	150±2,6	165±7,6	0.000*
Plasma osmalaity mOsmol/L	288.6±6.8	324.6±8.5	364.6±24.7	0.000*
IVC(mm)	22,6±1,6	18.3±2,1	14,5±1,2	0.000*
IVCCI %	33,3±3,17	53,11±4,6	59.9±5.9	0.000*

As statistical analysis, the Kruskal-Wallis H test was used. * sign =p<0.05 was considered significant.

Table 3. ROC analysis results according to the severity of hypernatremia in patients

Laboratory parameter	Cut-off value	AUC	P value	95% Confidence Interval (Lower Bound- Upper Bound)	Sensitivity %	Specificity %
VCI(mm)	14.7	0.893	0.000	0.804-0.983	65.2	95.2
IVCCI%	56.19	0.756	0.000	0.653-0.859	73.9	70

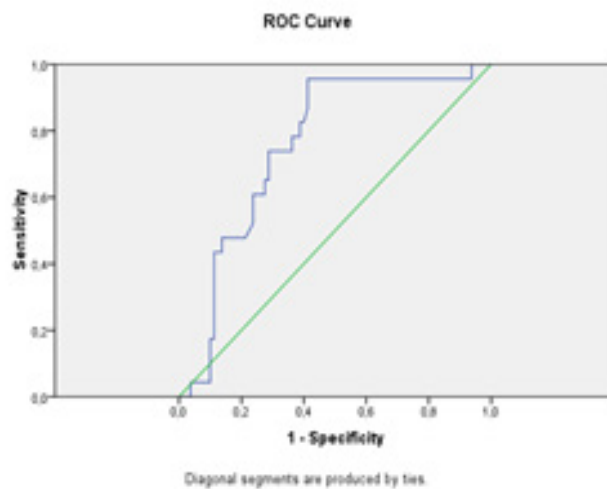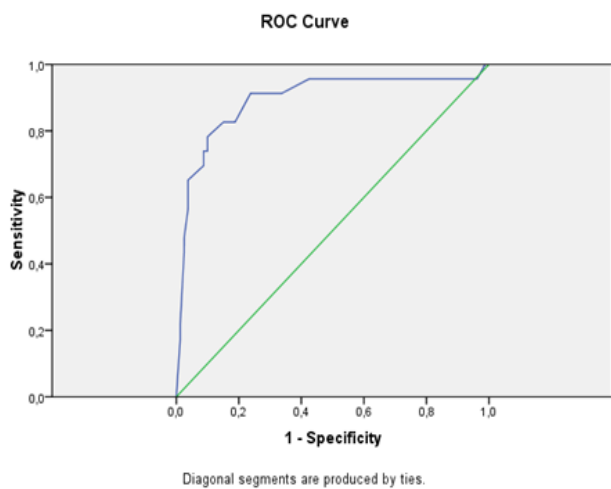IVC: Inferior vena cava, IVCCI: Inferior vena cava collapsibility index.

Figure 1. IVC ROC analysis to determine the severity of hypernatremia

Figure 2. IVCCI ROC analysis to determine the severity of hypernatremia

dehydration symptoms. The clinical evaluation consisted of 7 physical signs of dehydration. Compared to the hypernatremia groups, low systolic blood pressure was found to be lower in severe hypernatremia than in the mild hypernatremia group (< .05). Axillary board and capillary filling findings of more than 2 seconds were found to be higher in the severe hypernatremia group compared to the mild hypernatremia group (< .05).

Within the scope of the research, when vital signs, mean arterial pressure (MAP) and the shock index of the groups were evaluated, the pulse and shock index were significantly higher in the severe hypernatremia group as shown in Table 2 (< .05). Systolic blood pressure and MAP were found to be significantly lower in the severe hypernatremia group compared to the mild hypernatremia and control groups (< .05). When the relationship between physiological parameters and hypernatremia levels was evaluated, there was a high level of correlation with systolic blood pressure in a negative direction and a positive direction with the shock index (<.05).

Laboratory parameters due to dehydration were higher in severe hypernatremia than in the control group and mild hypernatremia, and there was a significant difference between the groups (< .05). However, there was no significant difference between the groups in glucose laboratory parameters (> .05). (Table 2).

When the measured IVC and Inferior vena cava collapsibility index (IVCCI) of the groups were evaluated, the mean IVC in the severe hypernatremia group was 14.5 mm, and this difference was found to be significant as shown in Table 2 (< .05), and it was > 50% in severe and mild hypernatremia. IVCCI between groups was significantly higher in severe hypernatremia (< .05). Evaluating the correlation between sodium levels of the groups, IVCCI and IVC showed a negative high-level relationship between the sodium level and the diameter of the IVC (r: -669; p = 0.000). A moderate positive correlation was found between the vena cava collaboration index (IVCCI) and sodium level (r: 0.407; p: 0.028). When the correlation between MAP, IVCCI and VCI diameter was evaluated, a moderate correlation between VCI and mean arterial pressure was found (r: .626; p = 0.000). However, no positive or negative correlation of mean arterial pressure with IVCCI was found (r: 0.092;p: 0.356).

ROC analysis for IVC and IVCCI parameters

The ROC curve and AUC, cut-off, sensitivity and specificity were analyzed to evaluate the diagnostic efficiency of the VCI diameter and IVCCI parameters in hypernatremia patients compared to those with normal sodium levels. Accordingly, the AUC, cut-off, sensitivity and specificity of IVCCI were 0.908, 50.05%, 78,6% and 96.6%, respectively. For the VCI diameter parameter, the AUC,cut-off, sensitivity and specificity were 0.863%, 19.2%, 77.7% and 86.4%, respectively.

When the patients with hypernatremia were divided into two groups as mild and severe, the diagnostic efficiency of the VCI diameter, IVCCI parameters and the ROC curve and AUC, cut-off, sensitivity and specificity were discriminately analyzed to guide the patient's condition in the patient follow-up. Parameters with AUC <0.6 and P> 0.05, which were not found to be statistically significant, were excluded. For the VCI diameter parameter, the AUC, cut-off, sensitivity and specificity were 0.893 %, 14.7%, 65.2% and 95.2%, respectively. IVCCI AUC, cut-off, sensitivity,

and specificity were 0.756, 56.19, 73.9% and 70%, respectively (Table 3) (Figure 1,2).

Discussion

We investigated the correlation between IVC respiratory variations and hypernatremia values in patients with dehydrated hypernatremia. In addition, we examined whether the IVC diameter and IVCCI parameters of clinicians from the first treatment stage were sufficient to determine the severity of the disease in our patient group. Therefore, we aimed to determine the IVC diameter and IVCCI cut-off values. In this study, cases with IVC over 14.5 mm and a IVCCI above 56.19% were associated with severe hypernatremia.

Hypernatremia due to dehydration in geriatric individuals is a disease associated with significant morbidity and mortality. In addition to investigating the underlying causes of hypernatremia, urgent diagnoses and treatments in particular, reduce the mortality rates of patients [10]. In the studies conducted, an inferior vena cava measurement via an ultrasound, which is used as a predictor of volume status, stands out [11].

When the physical properties of dehydrated patients are evaluated in our study, among the 7 physical dehydration findings, differences were found in systolic blood pressure, axillary dryness and capillary filling, especially in the severe hypernatremia patient group when compared to the other group. Fortes et al. reported that only systolic blood pressure was an auxiliary parameter among the seven findings in their study [12]. However, in our study, there was a prolongation of capillary filling in addition to systolic blood pressure. We think that in the severe hypernatremia group, the fluid deficit is due to the addition of circulatory disorders as it increases.

In the literature, it is emphasized that the shock index (SI), which combines systolic blood pressure and pulse, is a strong predictor, especially in hypovolemia [13]. In previous studies, the shock index has been reported to be significant, especially in diseases with fluid deficit, hypovolemic shock, and trauma patients with bleeding [14]. It was found in our study that as the intravascular fluid deficit increases, the severity of hypernatremia increases and the SI cut-off value above 1.09 can be considered an important parameter for diagnosis in patients with possible severe hypernatremia. The results of our study showed that shock index data correlated moderately with the diameter of the vena cava. Shock index and ultrasonographic methods are repeatable, and when considered non-invasive, they can provide clinical benefit by providing a dynamic information flow in patient management in addition to the physical examination and laboratory findings.

The inferior vena cava (IVC) is a primary vessel that varies with respiration, blood volume, and right heart function. However, it also reflects the fluid status of the patient [15,16]. Studies in the literature report the use of respiratory variation measurements in the inferior vena cava in conditions such as dehydration, sepsis and hypotension [12,17]. In our study, especially in patients with hypernatremia due to dehydration, as the severity of the disease and fluid deficit increased, the diameter of the vena cava decreased. In our study, a high level of correlation was found between VCI diameter and blood sodium level. In severe hypernatremia, the VCI diameter was 14.5 mm and in

mild hypernatremia, it was 18.3 mm. In some studies in the literature, it is reported that VCI, especially with a diameter of less than 2.1 cm, supports the presence of hypovolemia [18,19]. Although the patient group and methodology of these studies are different from our study, our study obtained similar results because hypovolemia occurred in both studies. Hypovolemia is an important clinical entity that often requires rapid diagnosis and treatment in the emergency room. Ultrasonography has an important place in the estimation of intravascular volume in the emergency department. Prediction of sodium balance in patients with ultrasonographic hypovolemia can provide clinicians with a clinical prediction during a patient follow-up.

Due to the widespread use of USG in critically ill patients, the use of IVC and IVCCI instead of CVP, which is a widely used invasive method in the assessment of volume status, is increasing [18]. In the IVCCI measurement evaluated in our study, it was significantly higher in severe hypernatremia and mild hypernatremia compared to the healthy group. In addition, when the correlation with IVCCI hypernatremia was examined, a moderate relationship was found. In a study conducted with septic shock patients in the literature, the correlation between CVP and IVC respiratory variations has been reported, and mortality has high IVCCI and low IVC diameters [8]. Pasquero et al. unlike our study, emphasize that measured VCI and IVCCI are particularly effective in evaluating volume status in patients with hypovolemic hypernatremia [20]. In our study, besides the VCI parameter, the cut-off value of IVCCI is 49.9% in patients with clinical dehydration compared to the normal population, and when the disease severity is evaluated, we think that the presence of IVCCI with more than 56.19% collapsibility will support severe hypernatremia.

Limitations

This study had some limitations. One of these limitations is that it offers a new application in the current disease. There is a lack of VCI measurement in clinical practice in the patient group we worked with. For these reasons, multi-centre studies with larger populations are needed.

Conclusion

Since the insufficient or excessive correction of blood sodium level affects the prognosis of patients with hypernatremia, correct diagnosis and appropriate treatment are very important. IVC and IVCCI can be used to identify patients with dehydration-induced hypernatremia and determine disease severity, and moreover, they can be used as a useful tool in the assessment of adequate fluid volume replacement in the follow-up of these patients. We think that the results of this study will also guide future studies that aim to guide clinical treatment.

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