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Follow-up of perfusion index and inferior vena cava collapsibility index in fluid therapy in prerenal acute renal failure

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A B S T R A C T

Introduction: Acute renal failure (ARF), which may occur as a result of hypovolemia, is frequently diagnosed in emergency departments. It is essential to determine these patients' volume status and fluid requirement. The aim of this study was to examine the change in the inferior vena cava (IVC) collapsibility index and perfusion index (PI) in order to evaluate fluid deficit, volume status, and response to fluid therapy in patients with prerenal ARF who presented with signs of hypovolemia.
Materials and methods: The study sample included 104 patients diagnosed with prerenal ARF due to hypovolemia in our emergency department. After obtaining informed consent from the patients, intravenous (IV) fluid therapy (20 cc/kg IV infusion of 0.9% sodium chloride solution for 30 min) was initiated. The PI and IVC collapsibility index were measured before and after the treatment.
Results: Of the patients included in this study, 56.7% were women. The mean age was 76.06 years. Of the patients, 46.2% had a history of multiple diseases. Avoidant/restrictive food intake disorder was the most common complaint (28.8%). The mean PI of the patients was 2.20 at admission, which increased to 3.27 after treatment. The mean IVC collapsibility index was 38.39 at admission, which decreased to 29.36 after treatment. There was a significant and negative correlation between the PI and IVC collapsibility index of the patients.
Conclusions: Early diagnosis and treatment of ARF in emergency departments are critical. Serial measurements of the IVC collapsibility index and PI are helpful in monitoring patients' response to fluid therapy.

1. Introduction

Acute kidney injury (AKI) refers to sudden loss of kidney function and is characterized by raised serum creatinine level (an increase of >0.3 mg/dL in creatinine (Cr) within 48 h, a >1.5 fold increase in Cr compared to the baseline), or reduced urine output (≤0.5 mL/kg/h) within 7 days [1,2].

Acute renal failure (ARF) is a common condition associated with increased morbidity and mortality. Although it is reported in the literature that ARF occurs in 3.2%–9.6% of hospitalizations, in-hospital mortality is approximately 20%, and mortality in intensive care patients can reach 50%. It is estimated that approximately 2 million people die from ARF each year [3].

Prerenal ARF is characterized by a decrease in glomerular filtration rate (GFR) due to a decrease in renal perfusion pressure without damage to the renal parenchyma. It resolves after hypoperfusion is corrected [4]. In addition, the volume status of the patient can be evaluated by measuring central venous pressure (CVP) and the inferior vena cava (IVC) collapsibility index using ultrasonography (USG) [4,5]. Hypovolemia is characterized by a decrease in extracellular fluid volume [6,7]. It occurs when fluid intake cannot fully compensate for bodily fluid loss [5]. Effective intravascular isotonic fluid replacement is an appropriate treatment strategy for hypovolemia [7].

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The perfusion index (PI) is the ratio of pulsatile to non-pulsatile blood flow. Peripheral PI (PPI) can be measured continuously and noninvasively using pulse oximetry [8]. PI reflects changes in peripheral vasomotor response. PI can provide insight into systemic and pulmonary blood flow by providing information on patients' intravascular volume, vascular resistance, oxygen delivery, and tissue oxygen utilization. PI provides hemodynamic information by displaying changes in peripheral blood flow, especially in critically ill patients [9].

The IVC diameter is not affected by the body's compensatory vasoconstrictor response to volume loss. Therefore, the IVC diameter is also a good indicator of volume status. The IVC collapsibility index is noninvasive, easy to calculate, and inexpensive; in addition, the index value can be obtained with minimal training. The IVC collapsibility index can be measured with the help of USG [10].

A study in the literature reported that the IVC collapsibility index changes with volume change after fluid therapy [11]. However, the number of studies showing a change in PI after the elimination of fluid deficit is limited. It has been reported that there may be a relationship between postoperative acute renal failure and low PPI [12]. It has been stated in the literature that IVC collapsibility may be useful in identifying patients with ARF who will not respond to fluid therapy, especially in intensive care units (ICU) where the general trend is fluid administration [13]. Furthermore, PI and IVC may provide relative information about the intravascular volume.

The diagnosis of ARF is frequently made in patients who come to the emergency department (ED) with various complaints, and the first place of treatment in ARF is mostly the EDs. Early diagnosis and early initiation of treatment are crucial in these patients. This study aimed to monitor the response to fluid therapy and the change in IVC and PPI to get an idea of the relative intravascular volume in patients presenting to the ED with evidence of hypovolemia and prerenal ARF.

2. Materials and methods

Necessary approval was obtained from the Kayseri City Training and Research Hospital Ethics Committee (Date: 12.11.2020; Decision number: 216). Patients aged >18 years who were admitted to the Emergency Medicine Clinic of Kayseri City Training and Research Hospital between 01.12.2020 and 01.10.2021 on an outpatient basis or by ambulance; those with hypovolemia findings (restlessness, dryness of mucous membranes, oliguria, cold–pale skin, peripheral cyanosis, decreased skin turgor, or prolonged capillary refill time) and prerenal ARF (decrease in urine output, decrease in GFR, increase in BUN and Cr and BUN/Cr > 20, the fractional excretion of sodium (FeNa) < 1% (Formula 1 [14]: FeNa═UNa/PNa ÷ UCr/PCr, where U = urine and P = plasma), urine osmolarity >500 mOsm); and those with spontaneous breathing and a Glasgow Coma Scale (GCS) score of 15 were included in the study. Those with a BUN/Cr ratio >20 were considered prerenal ARF [15]. Prerenal ARF was considered in oliguric patients with a urinary sodium concentration of <20 mEq/L and renal ARF was considered in patients with a urinary sodium concentration of >40 mEq/L [6,15]. Those with urine osmolality <450 mosmol/kg were accepted as renal ARF, and those with >500 mosmol/kg were accepted as prerenal ARF [16].

Written informed consent was obtained from all patients. To increase the intravascular volume, a 20 cc/kg IV infusion of 0.9% NaCl (isotonic saline solution), which is routinely used in the treatment, was administered to the patients for 30 min. The rate of 0.9% NaCl infusion was adjusted such that the infusion was completed in 30 min. The PPI and IVC collapsibility indices were calculated 1 min before the start and 1 min after the completion of the 0.9% NaCl infusion. Notably, the patient's position was maintained during the measurements, and all measurements were performed in the same position. In this single-centered, prospective study, patients' complaints at admission, age, gender, comorbidity, admission, post-treatment vital signs, laboratory values, and changes in PPI and IVC collapsibility index were recorded and the relationship between them was evaluated. Patients aged <18 years, pregnant patients, trauma patients, those with congestive heart failure (CHF), those with chronic kidney failure (CRF), those without spontaneous breathing, unstable patients (GCS score <15, mean arterial pressure <65 mmHg), those in need of emergency dialysis, those with a head deformity that prevented point-of-care USG examination, those with an active infection in the thorax and abdomen, those with a deformity or injury in the finger into which the pulse oximetry probe would be inserted, and those who did not give consent were excluded from the study. Considering the number of previous admissions to the ED with prerenal ARF and hypovolemia, 104 patients were included in the study. OpenEpi program [17] was used to calculate the sample size and the calculated confidence level is 95%—accordingly, the minimal number of patients = 97, Z-test = 97–104, T-test = 97–104. A total of 120 patients were initially included, but 16 were excluded owing to CHF, CRF, and unstable conditions. The study was completed with 104 patients.

Using the MASIMO RAD 57 C pulse oximeter device, the PPI measurement was performed twice (before and after the treatment) in the supine position while the patient was lying on the stretcher by attaching the probe to the second finger of the patient's right hand after the patient's head was at 45° with respect to his body. The device function is based on the laws of physics in which the thickness of the material and the power of the light are inversely proportional (Lambert's Law) and the density of the material and the power of the light are inversely proportional (Beer's Law). This method is based on the absorption of two light sources, with wavelengths of 660 and 940 nm, in the cutaneous vascular bed at the distal end of the index finger. As tissues, such as connective tissue, bone, and venous blood, absorb light, pulse oximetry differentiates the pulsatile component of arterial blood from the non-pulsatile component of venous, capillary, and other tissues [9]. Furthermore, because the device uses two wavelengths, it calculates the arterial oxygen saturation based on the pulsatile component after excluding the non-pulsatile component. First, as changes in peripheral vasomotor tone change the signal of the pulsatile component, this ratio also changes. PI is calculated according to the following formula [18]:

$$\textbf{Formula 2}: \mathbf{PI} = \frac{\textbf{Variable light absorption due to pulsatile arterial blood flow}}{\textbf{Constant light absorption due to nonpulsatile blood flow}} \times \mathbf{100}$$

A low-frequency (3.5–5 MHz) convex probe is used to view IVC using USG. It is evaluated in the subxiphoid region. The IVC diameter should be measured at the end of the inspirium, at the end of the expirium, and perpendicular to the long axis of the IVC. It is recommended to observe IVC throughout the respiratory cycle. However, it is important to consider that M-mode sonography may also give inaccurate measurements because of the displacement of IVC relative to the probe during inspiration [19]. IVC collapsibility index is determined as the percentage of the difference between the expirium Vena Cava Inferior Diameter (eVMID) and the inspirium Vena Cava Inferior Diameter (iVMID) divided by the eVMID [20]. Using a PHILIPS ClearVue 550 ultrasound device and a phase sliced 29 Hz C5-2 probe, the IVC collapsibility index was measured while the patient was in the supine position at 45°. The subxiphoid region was measured twice, with the convex probe pointing to the right axilla. The IVC diameter was measured using point-of-care USG (POCUS) perpendicular to the long axis of the IVC at the end of the inspirium and expirium by M-mode sonography, with an image taken 1 cm distal to the site where the hepatic vein and IVC joined in the sagittal section. The IVC diameter was measured over a single respiratory cycle, and the average of maximum and minimum IVC values was obtained. By measuring the IVC diameters at inspirium and expirium, the IVC collapsibility index was calculated using the following formula [20]: [Formula 3: (eVMID) − (iVMID)/eVMID].

2.1. Statistical analysis

The IBM SPSS 25.0 package program was used for statistical analysis. Before the analysis, the data set was examined for outliers and missing values, and the preliminary analysis was completed. Descriptive statistics (demographic characteristics and vital signs of the participants) were presented as frequency and percentage, mean, standard deviation, and minimum–maximum values. The assumptions of the appropriate analysis methods were tested before the analyses. The conformity of the data to normal distribution was evaluated using Kolmogorov–Smirnov and Shapiro–Wilk tests, skewness and kurtosis values, histograms, QQ plots, and PP plots. Independent sample *t*-test was used to compare variables between two independent groups, and paired sample *t*-test was used to compare the changes in repeated measurements. Spearman's rho correlation was used to determine the relationships between continuous variables. Chi-square analysis was used to compare categorical variables. $P < .05$ was accepted as statistically significant in all analyses. In terms of sensitivity to smaller error probabilities, $P \leq .01$ and $P \leq .001$ significance levels were also considered, and P values were reported as they were.

3. Results

Of the 104 participants, 56.7% were female and 46.2% had a history of multiple diseases. The most common complaint at admission was avoidant/restrictive food intake disorder (ARFID) (28.8%), followed by shortness of breath (26.9%). According to the National Early Warning Score (NEWS), 88.5% (n = 92) of the patients were in the moderate-risk group and 74% had a urine output of <400 mL/day (Table 1). All patients were monitored throughout the study, and their vital findings were recorded before and after treatment. Overall, 12.5% of patients were hypotensive, and in 50% of patients, pulse was ≥90 beat/min. Furthermore, an

Table 1
Descriptive characteristics of participants.

Categorical Variables	*N*	%
Gender		
Female	59	56.7
Male	45	43.3
Total	104	100
History		
No Disease History	9	8.7
Diabetes	3	2.9
Hypertension	13	12.5
Cancer	3	2.9
Coronary Artery Disease	8	7.7
Neurological Diseases (CVD, Alzheimer's)	8	7.7
Other	12	11.5
Multiple Diseases	48	46.2
Total	104	100
Complaints At the Time of Admission		
Avoidant/Restrictive Food Intake Disorder	30	28.8
Gastroenteritis	13	12.5
Shortness of Breath	28	26.9
Neurological Problems	6	5.8
Other	27	26
Total	104	100
NEWS Score		
Moderate Risk	92	88.5
High Risk	12	11.5
Total	104	100
Urinary Output		
<100 mL/h	27	26
<400 mL/h	77	74
Total	104	100

CVD: Cerebrovascular disease.

improvement was observed in vital findings after treatment (Table 2). It was determined that the mean PPI at admission was 2.20 and increased to 3.27 after treatment, whereas the mean IVC collapsibility index was 38.39% at admission and decreased to 29.36% after treatment (Table 3). No significant difference was observed between the patients in terms of their age. A statistically significant difference was observed between the admission and post-treatment measurements of both the PPI and IVC collapsibility index values of the participants. After treatment, the mean PPI increased, whereas the mean IVC collapsibility index decreased (Table 3). In terms of age and gender, no significant difference was found between the admission PPI, post-treatment PPI, admission IVC, post-treatment IVC, serum sodium level, serum potassium level, and serum chlorine level measurements of the participants. A significant difference was found between male and female patients only in terms of urine osmolality. Male patients had higher urine osmolarity than female patients (Table 4). A positive and significant correlation was found between the admission and post-treatment PPI values; patients with high PPI at admission had high PPI values after treatment, and vice versa. Another important relationship was the correlation between the PPI and IVC collapsibility index. A significant and negative correlation was found between the admission PPI and admission IVC collapsibility index and between the post-treatment PPI and post-treatment IVC collapsibility index. In other words, patients with high PPI at both measurements had a low IVC collapsibility index, whereas patients with low PPI had a high IVC collapsibility index. In summary, a significant inverse correlation was found between the PPI and IVC collapsibility index. There was also a significant and negative correlation between the admission PPI and NEWS score (Table 5).

4. Discussion

According to the National Institute for Health and Care Excellence (NICE) 2016 adult IV fluid therapy guidelines, a systolic blood pressure (SBP) of ≤100 mmHg, a heart rate of >90 beats/min, a capillary refill time of >2 s, cold periphery, a respiratory rate of >20/min, and a NEWS score of ≥5 indicate fluid deficit. According to these findings, patients in need of fluid should be given 20 cc/kg of 0.9% IV sodium chloride (NaCl) solution for 30 min. The goal is to increase the hourly urine output to ≥0.5 mL/kg [21]. Water intake is usually reduced in patients who develop prerenal ARF, and fluid loss occurs from the gastrointestinal tract, such as nausea, vomiting, and diarrhea. Dryness of mucous membranes, jugular vein engorgement, peripheral edema, bruit in lung auscultation, and turgor pressure can all be used to determine a patient's volume status [4,5]. Determining volume status and IV fluid therapy is critical in reducing the risk of kidney disease progression. Several studies have shown correlations between IVC collapsibility index evaluation using USG with CVP and invasive cardiac pressure measurement using right heart catheterization. Together, USG and urinary markers can provide an objective assessment of volume status, which is a risk factor for the progression of kidney damage [22]. A previous study found a relationship between the IVC collapsibility index, volume status, and CVP in spontaneously breathing patients [23]. In another study, an IVC collapsibility index of ≥50% was shown to be strongly associated with hypovolemia and low CVP in critically ill, spontaneously breathing patients [24]. More importantly, USG assessment of IVC collapse can quickly identify patients with ARF who do not respond to IV fluid therapy [25]. Although a patient with a high IVC collapsibility index (50%–70%) is likely to be hypovolemic, the probability of a patient being euvolemic or hypervolemic is high if the IVC collapsibility index is low (<20%) [10]. In the present study, after identifying the patients in need of fluid, the PPI and IVC collapsibility index were evaluated together before and after the IV saline treatment to evaluate the patient's volume status and response to volume increase. The findings on the change in the IVC collapsibility index with treatment were consistent with the literature. PI values have been reported to be between 0.02 and 20, with a PI of <1.4 indicating hypoperfusion in critically ill patients [8]. The data obtained in the present study showed a positive and

Table 2
Descriptive statistics summarizing repeated measurements of categorical variables.

Categorical Variables		On admission (n = 104)		After treatment (n = 104)	
		N	%	*N*	%
Blood Pressure					
≤90 mmHg		13	12.5	4	3.8
90–110 mmHg		40	38.5	33	31.7
≥110 mmHg		51	49	67	64.4
Total		104	100	104	100
Pulse					
≤50 beats/min		–	–	–	–
50–90 beats/min		52	50	62	59.6
≥90 beats/min		52	50	42	40.4
Total		104	100	104	100
Saturation					
≤91% (without O2)		49	47.1	78	75
>91% (without O2)		55	52.9	26	25
Total		104	100	104	100
Body Temperature					
<36.1 °C		33	31.7	4	3.8
≤36.1 °C, −38 °C ≤		59	56.7	97	93.3
>38 °C		12	11.5	3	2.9
Total		104	100	104	100
Respiratory rate	Admission	2.20	1.88	0.11	10.00
	After Treatment	3.27	2.43	0.28	11.00

Table 3
Descriptive statistics summarizing single and repeated measurements of continuous variables.

Continuous Variables		Mean	SD	Min.	Max.
Age		76.06	11.43	41	99
Perfusion Index	Admission	2.20	1.88	0.11	10.00
	After Treatment	3.27	2.43	0.28	11.00
IVC Collapsibility Index (%)	Admission	38.39	10.47	12.41	59.72
	After Treatment	29.36	9.36	11.22	48.80
BUN (mg/dL)		55.22	24.58	22.00	157.00
Creatinine (mg/dL)		1.84	0.77	0.99	4.36
BUN/Creatinine		30.69	9.30	20.09	75.00
FeNA (%)		0.45	0.24	0.10	0.90
Urine Osmolality (mOsm/kg)		704.23	166.51	520.00	1360.00
Serum Sodium (mmol/L)		138.91	9.92	112.00	183.00
Serum Potassium (mmol/L)		4.59	0.75	2.50	6.40
Serum Chlorine (mmol/L)		102.43	11.47	71.00	147.00

IVC: inferior vena cava, BUN: blood urea nitrogen, FeNa: fraction of the filtered sodium.

Table 4
Comparison of continuous variables by gender.

Measurement	Gender	N	Mean	SD	Min.	Maks.	*T*	*P*
Age	Female	59	77.81	11.52	41	97	1814	.073
	Male	45	73.76	11.02	44	99		
Perfusion Index at Admission (%)	Female	59	2.06	1.76	0.26	7.6	−0.883	.379
	Male	45	2.39	2.03	0.11	10		
Posttreatment Perfusion Index	Female	59	3.04	2.07	0.32	9.9	−1117	.266
	Male	45	3.57	2.82	0.28	11		
IVC Collapsibility Index at Admission (%)	Female	59	37.25	10.58	12.41	59.72	−1285	.202
	Male	45	39.90	10.23	20.98	57.14		
Posttreatment IVC Collapsibility Index (%)	Female	59	27.95	8.92	11.22	48.80	−1767	.080
	Male	45	31.20	9.71	12.86	48.60		
Urine Osmolality (mOsm/kg)	Female	59	673.90	132.63	520	1040	−2165	.033*
	Male	45	744.00	197.14	520	1360		
Serum Sodium (mmol/L)	Female	59	138.5	10.98	112	180	0.043	.966
	Male	45	138.87	8.45	126	183		
Serum Potassium (mmol/L)	Female	59	4.54	0.75	2.5	6.4	−0.750	.455
	Male	45	4.65	0.74	3.4	6.4		
Serum Chlorine (mmol/L)	Female	59	103.01	12.63	71	146	0.589	.557
	Male	45	101.67	9.83	82	147		

IVC: inferior vena cava. Note: * = $P \leq .05$; ** = $P \leq .01$; *** = $P \leq .001$.

Table 5
Correlation analysis results for continuous variables.

	Age		1		2		3		4	
	r	*P*	r	*P*	r	*P*	r	*P*	r	*P*
1. Perfusion Index at Admission (%)	−0.09	0.37								
2. Posttreatment Perfusion Index (%)	−0.13	0.19	0.707***	0.000						
3. IVC Collapsibility Index at Admission (%)	0.00	0.99	−0.299***	0.000	−0.14	0.15				
4. Posttreatment IVC Collapsibility Index (%)	−0.04	0.65	−0.16	0.11	−0.215*	0.03	0.648***	0.000		
5. NEWS	−0.07	0.50	−0.207**	0.03	−0.14	0.17	0.12	0.24	0.01	0.95

IVC: inferior vena cava. r: correlation ratio.
Note: * = $P \leq .05$; ** = $P \leq .01$; *** = $P \leq .001$.

significant relationship between admission and post-treatment PPI measurements, i.e., patients with high PPI at admission also had high PPI values after treatment, and vice versa. PPI has been used in fluid response tests in some previous studies. The passive leg raise test, which is now accepted in clinical practice, is an easy and reliable method for predicting fluid responsiveness [8,26]. In a previous study, changes in PI were found to be a reliable way to evaluate the hemodynamic effects of the passive leg raise test, and it was thus concluded that PI could be used as a noninvasive method to evaluate preload. In critically ill patients, a 9% increase in PI after the passive leg raise test was found to be predictive of fluid response [27]. In the present study, the PPI values of the patients were evaluated before and after treatment. The present study aimed to compare the IVC collapsibility index and PI in terms of fluid response before and after IV saline treatment. A statistically significant difference was found between the pretreatment and post-treatment measurements of both PPI and IVC collapsibility index values. Although PPI significantly increased after treatment, a significant decrease was observed in the IVC collapsibility index. A statistically significant inverse correlation was found between the PPI and IVC collapsibility index. The results of the present study support the decision to perform fluid therapy; furthermore, by the findings of the relevant literature, the intended outcomes were achieved in the present study.

The mean age of the patients included in the present study was 76.06 ± 11.43 (41–99) years. Of the patients, 56.7% were female and 43.3% were male. When the patient's medical histories were reviewed, it was discovered that ARF was most commonly diagnosed in patients with multiple diseases (46.2%), followed by patients with hypertension (12.5%). The most common complaint of patients who presented to the emergency room after being diagnosed with ARF was ARFID (28.8%), followed by shortness of breath (26.9%). Although 12.5% of patients applied with a complaint of gastroenteritis, 5.8% applied because of neurological problems. When other studies were reviewed, it was found that comorbid conditions were associated with ARF susceptibility [27].

NEWS is a score based on the patient's current measurements of respiratory rate, oxygen saturation, oxygen support requirement, body temperature, heart rate, SBP, and state of consciousness. A high NEWS score indicates greater disease severity and a higher risk of adverse outcomes [28]. A study reported that the general condition of patients with NEWS = 0 was less likely to deteriorate, whereas the condition of patients with higher scores was more likely to deteriorate [29]. According to the NEWS score calculated based on vital findings, 88.5% of patients in the present study were at moderate risk, whereas 12.5% were at high risk. The present study also observed a significant and negative correlation between the PPI and NEWS score measured at admission. The high NEWS score of patients with a high probability of deterioration and low PI values is consistent with the literature. This finding can be interpreted as tissue perfusion deteriorates as the general condition of the patients deteriorates. The severity of the disease and possible adverse outcomes can be predicted by calculating the NEWS score in patients with suspected ARF in the EDs.

The presence of oliguria (urine output of <400 mL per day or <20 mL per hour) or anuria (<100 mL/day) may be one of the first indicators of ARF [30]. Hippocrates had previously described the importance of urine output. In the second century AD, Galen recognized its importance for describing kidney function [31]. Oliguria caused by prerenal causes usually resolves with normal renal perfusion [30]. Of the 104 patients included in the study, 74% were oliguric (<400 mL/day), and 26% were anuric. However, because the length of stay in the emergency room was short, there is a need for further studies to follow up on patients after longer fluid therapy.

This study has some limitations. First, it was conducted in a single center, and the sample size was relatively small. Further studies conducted with a larger number of patients can provide stronger scientific results on the IVC collapsibility index and the PPI related to fluid requirements; in addition, studies with a longer follow-up period can monitor urinary output over a longer period. Second, homogeneity could not be achieved in the male and female groups. Many factors can affect IVC pulsatility, such as respiratory variability, measurement errors due to IVC movement, operator-dependent measurements, etc. Similarly, PI can vary due to factors such as pulmonary and tissue oxygenation, ambient and skin temperature, etc. These factors should be additionally taken into consideration in future studies. Longer follow-up periods can also provide different results in terms of change in both IVC collapsibility index and PI. Notably, the strength of this study is that both IVC and PPI were monitored in response to fluid therapy in patients diagnosed with prerenal ARF. Another strength of the study is that, as a new idea, it was demonstrated that it would be helpful to monitor the change in IVC collapse index and PPI together to get an idea about the intravascular volume and evaluate the response to fluid therapy in patients presenting to the ED with hypovolemia and prerenal ARF findings.

In conclusion, initiating IV fluid therapy in ED is a crucial step in the treatment of patients, especially in cases of hypovolemia and subsequent prerenal ARF. We think that it would be beneficial to use PPI and VCI collapsibility index together, as well as clinical findings in monitoring the response to IV fluid therapy in patients with hypovolemia and related prerenal ARF in ED. In this regard, prospective observational studies to be conducted with more patients in the future may support our findings.

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Ethical statement

The study was approved by the Kayseri City Hospital Ethics Committee with the date and number 12.11.2020/206.

Author contribution statement

Nihal Koc Güdük: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Taner Sahin: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Data availability statement

Data will be made available on request.

Additional information

No additional information is available for this paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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