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Evaluation of Fluid Therapy by Point-of-Care Ultrasound in Hyperglycemic Emergencies

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SD, BB and UMK designed the study, wrote the protocol and wrote the first draft of the manuscript. Author RG performed the statistical analysis. Authors BB, MD and SD managed the analyses of the study. Authors BC and BB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Diabetic ketoacidosis (DKA) and Hyperosmolar hyperglycemic state (HHS) are among the cases where total body fluid deficit is high. Although it is known that dehydration is one of the main determinants of mortality and morbidity, it is difficult to determine and follow up fluid treatment in patients with multiple comorbidities. Measurement of the respiratory variability of the vena cava inferior diameter and vena cava inferior / aortic diameter measurement can be performed easily and quickly at the bedside and have a high objectivity compared to physical examination. In this study, we evaluated the follow-up of fluid therapy by POCUS with vena cava inferior diameter and vena cava inferior diameter / abdominal aortic diameter ratio in patients presenting with hyperglycemic emergencies (DKA, HHS, severe hyperglycemia).
Methodology: 56 patients diagnosed with severe hyperglycemia, DKA and HHS according to the American Diabetes Association (ADA) diagnostic criteria were included in the study. Vital signs,

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laboratory tests(venous blood gas analysis, complete urinalysis, osmolarity, fingertip blood glucose level), fluid volume and bedside ultrasonographic measurements [vena cava inferior inspiration and expiration (iVCI and eVCI) diameter,vena cava inferior colapsiability index (VCI index), abdominal aorta diameter and ratio of vena cava inferior to abdominal aorta diameter (VCI/Ao)] were recorded.
Results: Of the 56 patients, 21.4% were diagnosed with DKA 8.9%, HHS and 69.6% with severe hyperglycemia. There was a significant difference in osmolarity and although pH values were not statistically significant, it tended to improve with the amount of fluid given. There was a significant difference in iVCI, VCI index and VCI/Ao.
Conclusion: We believe that planning and monitoring fluid treatment with bedside ultrasonographic VCI diameter and VCI/Ao ratio measurements will reduce the undesirable complications, the intensity of emergency services, long waiting time and follow-up periods and will contribute to patient benefit and emergency departments.

Keywords: Diabetes; hyperglycemia; hyperosmolar; ketoacidosis; POCUS; vena cava inferior.

1. INTRODUCTION

Diabetes Mellitus (DM) is among the major medical problems due to the increase in incidence worldwide [1]. Diabetic ketoacidosis (DKA) and Hyperosmolar hyperglycemic state (HHS) are two major metabolic complications seen in patients with both type 1 and 2 DM [2]. These two decompensated diabetic complications are important causes of mortality and morbidity among DM patients despite well-developed diagnostic criteria and treatment protocols [2]. Still, if severe hyperglycemia is uncontrolled, it may lead to DKA or HHS in the short term and increase the rate of recurrent admissions and hospitalization due to hyperglycemia [3]. The total body fluid deficit is known to be high in hyperglycemic emergencies [4]. Therefore, the first treatment is to close the fluid gap and ensure adequate urine output [2].

Evaluation of intravascular volume status is vital in critically ill patients. Although dehydration is known to be one of the main determinants of mortality and morbidity, it may sometimes be challenging to diagnose and treat [5]. In order to avoid adverse consequences of excessive fluid overload, especially in patients with multiple co-morbidities such as congestive heart failure and chronic renal failure, the volume status should be determined before treatment and monitored during the treatment process [6].

In recent years, many methods used to determine the volume status have been compared and the tendency towards calculations that can be evaluated by point-of-care ultrasound (POCUS), which can compete with invasive methods, has increased. The measurement of respiratory variability in inferior vena cava diameter and the measurement of the inferior vena cava diameter/aorta diameter ratio which draw the attention with their easy and rapid application at the bedside, stand out as a method with high objectivity compared to physical examination [7]. In this study, we evaluated the follow-up of fluid therapy with inferior vena cava diameter and inferior vena cava diameter/abdominal aorta diameter ratio using POCUS in patients admitted to the emergency department with hyperglycemic emergencies (DKA, HHS, severe hyperglycemia).

2. MATERIALS AND METHODS

This prospective study was conducted in an emergency department of a training and research hospital with the approval of the ethics committee between 01.01.2018-01.01.2019. The study protocol was planned in accordance with the Declaration of Helsinki. Patients aged 18 years and older, patients diagnosed or newly diagnosed with diabetes according to the American Diabetes Association (ADA) diagnostic criteria who were diagnosed with severe hyperglycemia [Patients presenting with symptoms such as weakness, polydipsia, polyuria, dry mouth secondary to hyperglycemia to emergency room in whom diabetic ketoacidosis and hyperosmolar hyperglycemic state were not observed and fingertip blood sugar level was measured to be “HIGH” at the time of admission]], diabetic ketoacidosis, and hyperosmolar hyperglycemic state were included in the study. Additional treatments to the fluid treatment of the patients in the study were administered per the treatment recommended by the ADA.

“HIGH” blood glucose level was considered as 380 mg/dl which is the limit of measurement of

fingertip blood glucose meter device (FreeStyle Optium Neo H, Abbott®) and blood glucose test sticks (FreeStyle Optium Neo H, Abbott®).

Demographic data of the patients included in the study, vital signs at admission to the emergency department (0 h), at Hours 1, 2, 3 and 4, laboratory tests (venous blood gas analysis, complete urine analysis, osmolarity, fingertip blood glucose level), the amount of fluid given, and ultrasonographic measurements by POCUS (expiratory inferior vena cava diameter (eVCI), inspiratory inferior vena cava diameter (iVCI), inferior vena cava collapsibility index (VCI index), abdominal aorta diameter and inferior vena cava diameter to abdominal aorta diameter) were recorded.

Ultrasonographic measurements were performed by an ultrasound of "Hitachi Aloka F37" and a 3.5/5 MHz convex probe at the bedside. During the procedure, the patients were in the supine position. The patient position did not change between ultrasonographic measurements. The inferior vena cava diameter was visualized by the liver and heart in the subxiphoid window, and the inferior vena cava and the right atrium were identified. The measurement of the inferior vena cava diameter; joint of inferior vena cava and the right atrium was observed by visualizing the neighborhood of the liver and the heart through the subxiphoid window. Measurements were performed from the image captured in M-mode approximately 2 cm distal from this part (Fig. 1). The inspiratory and expiratory diameters were

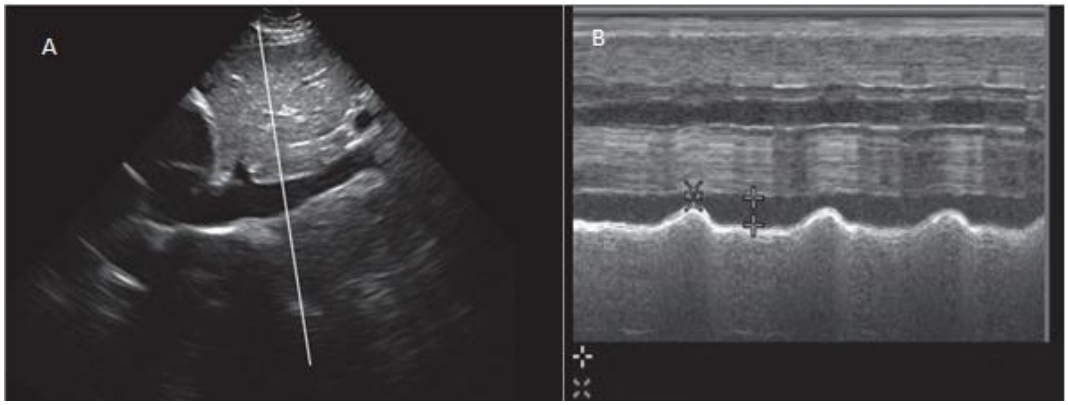

Fig. 1. Measurement of IVC diameter a long-axis view of the IVC. IVC diameter is measured by M-mode on ultrasound 2-3 cm distal from where the hepatic vein joins IVC; B-M-mode demonstration of changes in the diameter of the respiratory cycle

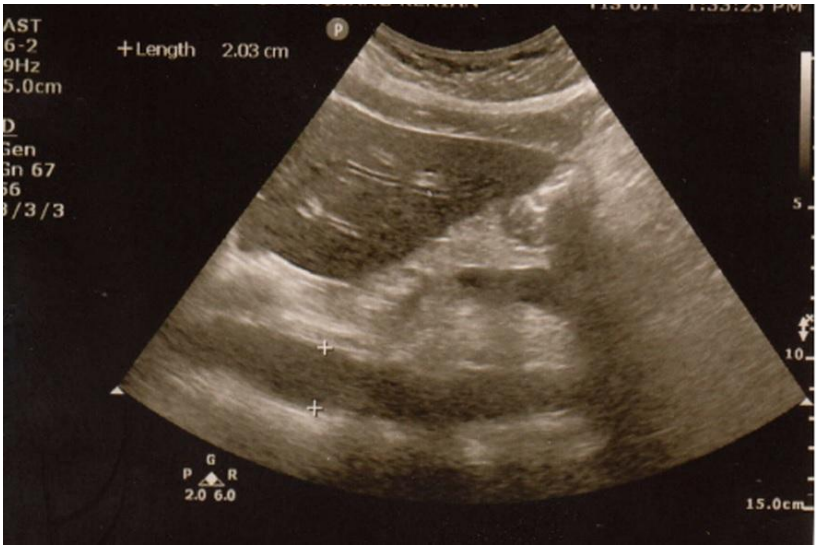

Fig. 2. Ultrasonographic measurement location of abdominal aorta diameter

recorded. Inferior vena cava collapsibility index (VCI index) was calculated. This index was obtained by dividing the difference between expiratory inferior vena cava diameter (eVCI) and inspiratory inferior vena cava (iVCI) diameter by expiratory inferior vena cava diameter. VCI index=(eVCI-iVCI)/eVCI. Abdominal aorta diameter was measured 1 cm above celiac truncus. The ratio of the inferior vena cava diameter to the aorta diameter was calculated and recorded (Fig. 2).

Patients who did not agree to the study and did not give consent, who were under 18 years of age, for whom 1000 cc/hour fluid treatment was contraindicated and who did not meet the diagnostic criteria were excluded from the study.

Data obtained from the study were recorded in SPSS 25.0 (Armonk, NY: IBM Corp.) program. Categorical measurements recorded as numbers and percentages, the suitability of the continuous variables to normal distribution was recorded as median (quartiles) by Shapiro Wilk test. Friedman test was used to compare the values of dependent variables in consecutive time periods. $p < 0.05$ was considered statistically significant.

3. RESULTS

108 patients whose fingertip blood glucose was measured as “HIGH” at the time of hospital admission were included in the study. Of 108 patients, 42 were excluded from the study due to their refusal of treatment, 7 due to withdrawal from the study during treatment and 3 due to developing complications during the treatment (Fig. 3).

Of the 56 patients included in the study, 21.4% (n = 12) were diagnosed with diabetic ketoacidosis, 8.9% with the hyperosmolar hyperglycemic state, and 69.6% with severe hyperglycemia (SH). The median age (quartile) of patients with diabetic ketoacidosis (DKA) was 26.5 (23.2-47.7), the median age (quartile) of patients with the hyperosmolar hyperglycemic state (HHS) was 60.0 (33.0-63.5) and the median age of severe hyperglycemic patients (quartile) was 54.0 (34.0 - 65.0). 66.7% of patients with diabetic ketoacidosis, 40% of patients with hyperosmolar hyperglycemic and 48.7% of severe hyperglycemic patients were female.

In this study, the variations in vital signs depending on the amount of fluid given and the significance levels between these variations are shown in Table 1. Accordingly, while there was no significant variation in systolic blood pressure in patients with DKA and HHS, there was a significant variation in patients with SH ($p = 0.259$, $p = 0.905$, $p = 0.008$, respectively). There was no significant variation in diastolic blood pressure in all patient groups (DKA, HHS, SH) ($p = 0.996$, $p = 0.465$, $p = 0.279$, respectively). There was no significant variation in the pulse of DKA and HHS patients, but there was a significant variation in patients with SH ($p=0.500$, $p=0.728$, $p=0.001$, respectively). There was no significant variation in body temperature in all patient groups ($p = 0.366$, $p = 0.299$, $p = 0.887$, respectively) and there was no significant variation in respiratory rate in all patient groups ($p = 0.213$, $p = 0.293$, $p = 0.245$, respectively). There was no significant variation in saturation levels in all patient groups ($p = 0.728$, $p = 0.425$, $p = 0.140$, respectively).

The variations in venous blood gas parameters, osmolarity, and fingertip blood glucose levels depending on the amount of fluid given in all patient groups by their diagnoses and the level of significance are shown in Table 2. According to this, it was determined that in the venous blood gas analysis, pH values of all groups (DKA, HHS, SH) tended to improve with the amount of fluid given, although not statistically significant ($p=0.810$, $p=0.108$, $p=0.164$, respectively). It was found that there was a significant variation in osmolarity in all patient groups ($p=0.003$, $p=0.001$, $p<0.001$, respectively), there was a significant variation in fingertip blood glucose levels in all patient groups ($p<0.001$, $p=0.002$, $p<0.001$, respectively).

The variations in the ultrasonographic measurements (inspiratory inferior vena cava diameter, expiratory inferior vena cava diameter, inferior vena cava collapsibility index, abdominal aorta diameter, inferior vena cava diameter/aorta diameter ratio) depending on the amount of fluid given in all patient groups by their diagnoses and the level of significance are shown in Table 3. According to this, it was seen that there was a significant variation ($p <0.001$, $p = 0.010$, $p <0.001$, respectively) in the inspiratory inferior vena cava diameter in all patient groups (DKA, HHS, SH), there was a significant variation ($p<0.001$, $p=0.002$, $p<0.001$, respectively) in the expiratory inferior vena cava diameter in all patient groups (DKA, HHS, SH), there was a significant variation ($p=0.037$, $p=0.021$, $p<0.001$, respectively) in the inferior vena cava collapsibility index in all patient groups (DKA, HHS, SH), there was a significant variation

(p=0.001, p=0.007, p<0.001, respectively) in the abdominal aorta diameter in all patient groups (DKA, HHS, SH), there was a significant variation (p<0.001, p=0.005, p<0.001, respectively) in the inferior vena cava diameter/aorta diameter ratio in all patient groups (DKA, HHS, SH).

4. DISCUSSION

DKA, HHS and severe hyperglycemia due to the complications it may cause are called hyperglycemic emergencies. In 2014, the number of patients presenting to emergency rooms with hyperglycemic emergencies was found to be 207 000 [8]. Although the rates vary, it is known that these three conditions may result in mortality [2].

Fluid therapy is the main step in the treatment of hyperglycemic emergencies. It is known that an average of 6 L is needed in DKA and 9 L in HHS [9]. In patients with comorbidities such as congestive heart failure and chronic renal failure, etc., high fluid replacement may cause respiratory problems and cardiac loading findings.

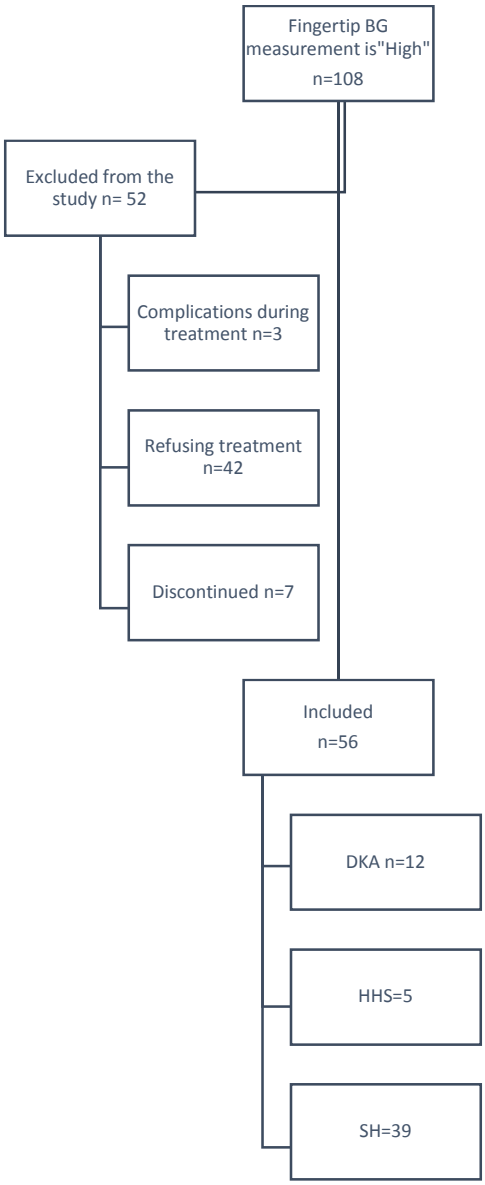

Fig. 3. Study flow chart

Table 1. Demographic characteristics of study groups

	DKA (n=12)	HHS (n=5)	Severe hyperglycemia (n=39)
Age	26.5 (23.2-47.7)	60.0 (33.0-62.5)	54.0 (34.0-65.0)
Gender (Female, %)	66.7	40.0	48.7
SBP			
Hr 0	120.0(102.5-135.5)	136.0 (120.0-153.0)	140.0 (130.0-158.0)
Hr1 (+1000)	130.0(120.0-148.2)	130.0 (115.0-132.5)	130.0 (120.0-150.0)
Hr2 (+2000)	131.0(110.2-140.7)	127.0 (117.5-132.5)	130.0 (120.0-140.0)
Hr3 (+3000)	136.0(110.0-152.5)	130.0 (116.5-131.5)	130.0 (120.0-140.0)
Hr4 (+4000)	130.0 (12.5-146.0)	130.0 (108.0-148.0)	130.0 (119.0-142.0)
p-Value	**0.259**	**0.905**	**0.008***
DBP			
Hr 0	80.0 (70.0-96.0)	90.0 (70.0-98.5)	82.0 (70.0-90.0)
Hr 1(+1000)	81.0 (71.5-90.0)	78.0 (76.0-84.0)	80.0 (75.0-90.0)
Hr 2(+2000)	82.0 (70.2-92.2)	79.0 (68.0-86.0)	80.0 (70.0-90.0)
Hr 3(+3000)	81.5 (72.2-90.0)	76.0 (72.5-82.5)	80.0 (76.0-90.0)
Hr 4(+4000)	84.5 (70.0-90.7)	78.0 (70.0-89.0)	80.0 (70.0-90.0)
p-Value	**0.996**	**0.465**	**0.279**
Pulse			
Hr 0	110.0 (96.5-113.5)	88.0 (67.0-117.5)	90.0 (83.0-98.0)
Hr 1(+1000)	108.0 (95.2-111.7)	95.0 (74.5-114.0)	90.0 (82.0-96.0)
Hr 2(+2000)	106.0 (92.2-123.7)	91.0 (74.0-111.5)	86.0 (80.0-92.0)
Hr 3(+3000)	109.0 (99.2-115.0)	94.0 (75.0-110.0)	89.0 (80.0-92.0)
Hr 4(+4000)	108.5 (94.7-124.7)	85.0 (73.5-109.0)	88.0 (80.0-94.0)
p-Value	**0.500**	**0.728**	**0.001***
Body temperature			
Hr 0	36.5 (36.0-36.7)	36.5 (36.2-36.9)	36.5 (36.3-36.6)
Hr 1(+1000)	36.3 (36.0-36.5)	36.5 (36.0-36.7)	36.5 (36.2-36.6)
Hr 2(+2000)	36.3 (36.2-36.8)	36.4 (36.0-36.7)	36.5 (36.2-36.7)
Hr 3(+3000)	36.6 (36.4-36.8)	36.5 (36.2-36.8)	36.5 (36.1-36.7)
Hr 4(+4000)	36.5 (36.0-36.8)	36.5 (36.3-36.8)	36.5 (36.2-36.6)
p-Value	**0.366**	**0.299**	**0.887**
Respiration			
Hr 0	22.0 (20.0-24.7)	18.0 (17.0-19.0)	20.0 (18.0-22.0)
Hr 1(+1000)	21.0 (20.0-24.7)	16.0 (16.0-20.0)	20.0 (18.0-20.0)
Hr 2(+2000)	22.0 (20.0-24.0)	19.0 (17.0-21.0)	20.0 (18.0-20.0)
Hr 3(+3000)	21.0 (18.2-23.5)	17.0 (16.0-20.5)	20.0 (18.0-20.0)
Hr 4(+4000)	20.5 (18.5-24.0)	20.0 (17.5-21.0)	19.0 (18.0-20.0)
p-Value	**0.213**	**0.293**	**0.245**
Saturation			
Hr 0	98.5 (95.5-99.0)	97.0 (95.5-98.0)	99.0 (96.0-100.0)
Hr 1(+1000)	99.0 (98.0-100.0)	98.0 (93.5-90.0)	99.0 (98.0-100.0)
Hr 2(+2000)	99.0 (98.0-99.0)	95.0 (93.5-98.5)	99.0 (98.0-99.0)
Hr 3(+3000)	98.0 (99.0-96.2)	98.0 (95.5-98.5)	98.0 (97.0-99.0)
Hr 4(+4000)	98.5 (97.0-99.0)	96.0 (94.5-99.0)	99.0 (98.0-100.0)
p Value	**0.728**	**0.425**	**0.140**

**p <0.05 DKA: Diabetic Ketoacidosis HHS: Hyperglycemic hyperosmolar State SBP: Systolic Blood Pressure DBP: Diastolic Blood Pressure*

Hypovolemia and hypovolemic shock resulting from dehydration is a condition that should be diagnosed and treated immediately in emergency departments. In these cases, secondary to volume reduction, diagnosis with more objective measurement techniques than findings on physical examination is the subject of current studies. Central venous pressure (CVP) is a commonly used method for this purpose. However, CVP is an invasive method and may

cause serious complications such as arterial rupture, venous thrombosis, infection, etc. In addition to these difficult and complicated methods for the assessment of volume status, there are currently noninvasive, easily applicable measurements without complications performed by POCUS. Among these measurements, VCI diameter is distinguished by being closely associated with the right heart condition and not being affected by the compensatory vasoconstrictor response of the body [10].

In the meta-analysis of 5 studies by Dipti et al., they noted that IVCex diameter was significantly lower in the hypovolemic state compared to the euvolemic state [6]. In their study, Lyon et al. concluded that serial IVCins and IVCex diameter measurements could be used to monitor ongoing blood loss and evaluate response to treatment [11]. In our study, while IVCins and IVCex diameter measurements and IVC collapsibility index were found to be significantly lower in all patient groups before treatment, serial measurement of them gradually increased and reached normal values every hour during the post-treatment period. Significant variations were also found in IVCins and IVCex diameter measurements and the resulting IVC collapsibility index. We think that there are clinical pictures that cause dehydration in hyperglycemic emergencies and these ultrasonographic measurements may be used to show and follow-up fluid loss, and to display the response to treatment.

The IVC/aorta diameter index is a relatively new calculation which was established as an alternative to the limitations of the IVC measurement and the IVC collapsibility index. The rationale behind this method, in which the aorta is selected as a reference, is the co-development of the aorta and IVC in the embryological period [7]. Aorta diameter might be affected by variables such as age, gender and

Table 2. The venous blood gas analysis (HCO3, pH), osmolarity and blood glucose test of study groups

	DK (n=12)	HHS (n=5)	Severe hyperglycemia (n=39)
pH			
Hr 0	7.08 (7.00-7.24)	7.39 (7.37-7.44)	7.38 (7.35-7.41)
Hr 1(+1000)	7.11 (6.92-7.29)	7.38 (7.37-7.47)	7.38 (7.35-7.42)
Hr 2(+2000)	7.18 (6.92-7.29)	7.42 (7.38-7.46)	7.38 (7.35-7.40)
Hr 3(+3000)	7.13 (6.97-7.33)	7.40 (7.38-7.47)	7.38 (7.35-7.41)
Hr 4(+4000)	7.18 (7.01-7.34)	7.40 (7.39-7.49)	7.37 (7.34-7.40)
p-Value	**0.810**	**0.108**	**0.164**
HCO3			
Hr 0	7.2 (4.3-11.9)	27.9 (24.2-30.7)	26.2 (23.6-27.6)
Hr 1(+1000)	5.7 (3.8-11.9)	27.1 (23.1-29.9)	24.0 (22.0-26.5)
Hr 2(+2000)	7.0 (2.9-12.1)	26.0 (22.5-29.9)	24.0 (22.9-26.0)
Hr 3(+3000)	6.4 (4.2-12.9)	24.3 (22.4-30.1)	23.7 (21.4-26.3)
Hr 4(+4000)	9.0 (3.8-19.3)	24.8 (22.1-29.9)	23.7 (21.9-25.0)
p-Value	**<0.001***	**0.118**	**<0.001***
Osmolarity			
Hr 0	298 (329-290)	324 (320-326)	296 (292-299)
Hr 1(+1000)	295 (286-307)	298 (293-299)	288 (284-294)
Hr 2(+2000)	294 (285-310)	286 (283-288)	285 (281-289)
Hr 3(+3000)	294 (279-302)	283 (275-287)	283 (281-287)
Hr 4(+4000)	290 (277-301)	282 (274-284)	282 (278-285)
p-Value	**0.003***	**0.001***	**<0.001***
Glucose			
Hr 0	586 (397-760)	653 (618-690)	527 (487-580)
Hr 1(+1000)	452 (375-702)	503 (476-564)	410 (369-465)
Hr 2(+2000)	390 (291-598)	410 (294-535)	347 (302-422)
Hr 3(+3000)	324 (265-431)	315 (263-508)	306 (210-367)
Hr 4(+4000)	259 (145-399)	300 (245-437)	250 (179-303)
p-Value	**<0.001***	**0.002***	**<0.001***

Table 3. Ultrasonographic findings of study groups

	DKA (n=12)	HHS (n=5)	Severe hyperglycemia (n=39)
IVCdIns, mm			
Hr 0	4.50 (3.00-6.75)	6.00 (4.00-11.00)	6.00 (3.00-8.00)
Hr 1(+1000)	6.00 (4.25-7.75)	8.00 (5.50-11.50)	7.00 (4.00-9.00)
Hr 2(+2000)	7.00 (6.00-8.75)	9.50 (6.50-12.50)	8.00 (6.00-10.00)
Hr 3(+3000)	8.00 (7.00-10.50)	10.00 (7.50-12.50)	9.00 (7.00-11.00)
Hr 4(+4000)	9.00 (7.25-11.75)	10.00 (9.00-13.00)	10.00 (7.00-12.00)
p-Value	**<0.001***	**0.010**	**<0.001***
IVCdExp, mm			
Hr 0	9.50 (6.00-13.25)	9.00 (9.00-16.00)	11.00 (8.00-12.00)
Hr 1(+1000)	10.50 (9.00-13.50)	10.00 (10.00-18.50)	12.00 (10.00-13.00)
Hr 2(+2000)	11.50(10.00-15.00)	13.00 (10.00-19.50)	13.00 (11.00-14.00)
Hr 3(+3000)	14.50(11.00-16.00)	16.00 (12.00-21.50)	14.00 (12.00-15.00)
Hr 4(+4000)	15.50(13.00-17.00)	18.00 (14.00-21.00)	14.00 (13.00-16.00)
p-Value	**<0.001***	**0.002***	**<0.001***
IVC index, %			
Hr 0	33.3 (21.6-45.0)	30.0 (11.1-44.4)	22.2 (11.1-57.1)
Hr 1(+1000)	47.7 (22.2-54.1)	36.3 (20.0-53.3)	41.6 (23.0-60.0)
Hr 2(+2000)	43.3 (27.5-52.8)	34.7 (12.3-49.5)	35.7 (20.0-53.8)
Hr 3(+3000)	39.2 (23.9-53.4)	37.5 (25.0-50.3)	35.2 (16.6-50.0)
Hr 4(+4000)	39.0 (18.2-46.9)	39.1 (21.4-51.1)	35.7 (20.0-50.0)
p-Value	**0.037**	**0.021**	**<0.001***
Aorta d, mm			
Hr 0	12.00(11.25-13.00)	14.00 (12.50-15.00)	13.00 (12.00-14.00)
Hr 1(+1000)	12.00(11.00-13.00)	15.00 (15.00-17.50)	13.00 (13.00-15.00)
Hr 2(+2000)	13.00(12.00-14.75)	16.00 (15.50-18.05)	14.00 (13.00-15.00)
Hr 3(+3000)	13.50(12.00-14.75)	16.00 (15.50-18.50)	15.00 (14.00-16.00)
Hr 4(+4000)	13.50(13.00-15.75)	16.00 (15.00-19.00)	15.00 (14.00-16.00)
p-Value	**0.001***	**0.007**	**<0.001***
IVCdExp /Aorta d, mm			
Hr 0	0.82 (0.52-0.97)	0.75 (0.64-1.09)	0.83 (0.64-1.00)
Hr 1(+1000)	0.91 (0.71-1.05)	0.66 (0.61-1.17)	0.91 (0.75-1.00)
Hr 2(+2000)	0.91 (0.71-1.13)	0.81 (0.58-1.18)	0.92 (0.83-1.00)
Hr 3(+3000)	0.96 (0.77-1.30)	0.94 (0.70-1.34)	0.93 (0.83-1.07)
Hr 4(+4000)	0.99 (0.86-1.29)	1.00 (0.81-1.36)	0.93 (0.85-1.12)
p-Value	**<0.001***	**0.005**	**<0.001***

VCIdIns: inspiratory inferior vena cava diameter, VCIdExp: expiratory inferior vena cava diameter, Aorta d: Aorta diameter, mm: millimeter

body surface, it also might be affected by fluid status [12,13]. In a study of Durajska et al., they emphasized that the CVP and IVC/Ao index are correlated and that the IVC/Ao index is an easily measurable and reliable method even by users who do not have much USG experience in the field [7]. In a cross-sectional study in hypovolemic and euvolemic patients, Adewumi et al. concluded that the IVC/Ao ratio was sensitive and specific in moderate and severe dehydration [14]. In our study, a significant improvement of IVC/Ao ratio was found in all patient groups compared to other POCUS measurements after standard hydration administration and we can say that this rate can be used more effectively in hyperglycemic emergencies to show and to follow-up the fluid loss and to display the treatment response due to being easily measured and reliable.

Hyperglycemia causes an osmotic diuresis, electrolyte imbalance, high serum osmolarity and metabolic acidosis. Therefore, fluid escape from intracellular to extracellular and secondary dehydration are observed. Ketones formed in the presence of DKA also cause nausea and vomiting, which will increase dehydration. In this context, high serum osmolarity and hypovolemia are thought to be correlated and careful evaluation of plasma osmolarity is very important

in determining the correct fluid treatment [15]. In our study, a significant increase in blood glucose and osmolarity levels was observed at the admission in all three patient groups and levels in hourly serial measurements were gradually normalized in response to standard fluid treatment and this improvement was statistically significant. There was a positive improvement in IVC diameter and IVC/Ao ratio measured by POCUS which correlated with improvement in blood glucose and osmolarity values. As we have seen in both the literature and our study, we believe that POCUS may predict the required fluid deficit in patients with high blood glucose levels in the emergency department and that time loss can be prevented with necessary and adequate treatment.

Despite the similarity in DKA and HHS treatment protocols, these are two conditions in which diagnostic criteria and pathogenesis differ. While pH is less than 7.30 in DKA diagnostic criteria, it is greater than 7.30 in HHS [2]. Severe hyperglycemic conditions are not treated and may cause osmotic diuresis, electrolyte imbalance, high serum osmolarity and metabolic acidosis as time goes on [15]. In such hyperglycemic emergencies, there will be a course of improvement with starting early treatment by preventing deterioration in both pH and bicarbonate levels. In our study, it was observed that the initial pH value (pH: 7.08), which was abnormal especially in the DKA patient group, approached normal values with hourly serial measurements (pH value measured at the last 4^{th} hour: 7.18). Especially in hyperglycemic emergencies, we see that even if only fluid deficit is detected and necessary and adequate treatment is started in the early period, the adverse course of events which may be negative and mortal can be prevented and even it may be moved toward positive processes. In our study, we also believe that starting with the necessary and adequate fluid treatment as indicated in the guidelines by determining fluid deficit by POCUS in patients with high blood glucose can prevent the mortality and morbidity that may occur as a result of late treatment.

5. CONCLUSION

Fluid therapy is a vital step in diseases that cause hypovolemia and alter the patient's hemodynamic status such as hyperglycemic emergencies. There is a need for more objective methods that can be easily applied by physicians working in emergency departments to protect the patient from the complications of incomplete or inappropriate fluid treatment and to avoid unnecessary invasive procedures. The IVC collapsibility index and IVC/Ao index are effective, cheap and easy methods which may be subjective like physical examination and may be used as an alternative to invasive diagnostic methods for hypovolemia such as CVP. We think that planning and monitoring of fluid therapy by IVC diameter and IVC/Ao ratio measurements in busy emergency departments, especially in hyperglycemic emergencies, will contribute to emergency room practice by reducing complications, overcrowdedness of emergency rooms, long waiting and follow-up periods.

6. LIMITATIONS

Limitations in our study are the relatively low number of patients and short follow-up time, failure to investigate the relationship between the IVC collapsibility index and the IVC/Ao diameter and mental status, urine ketone, hourly urine output and serum electrolyte levels and participating as the only center due to having hospitals in the vicinity of our hospital to which such patients apply.

CONSENT

As per international standard or university standard written patient consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

This study is conducted prospectively in patients presented with hypergylcemia in Kanuni Sultan Suleyman Training and Research Hospital, Department of Emergency Medicine between 01.01.2018-01.01.2019 with the approval of Kanuni Sultan Süleyman Training and Research Hospital Ethics Committee.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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