Role of inferior vena cava ultrasound in diagnosis of shock in patients with trauma

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Background
Hemorrhage is responsible for more than 35% of prehospital deaths. Hemorrhagic shock is the leading etiology in most cases.
Objective
The aim was to assess the reliability of inferior vena cave (IVC) sonographic parameters in diagnosis and evaluation of shock in patients with trauma.
Patients and methods
This diagnostic cross-sectional study was conducted on 45 traumatized patients with evident clinical picture of shock. Traumatized patients aged 18 years and older of both sexes were included. Patients who developed cardiopulmonary arrest or with stab wound around the epigastrium were excluded.
Results
The mean age was 36.6±13.8 years. There was a statistically significance between vital signs before and after resuscitation ($P<0.001$). Mean IVC diameter at inspiration and expiration after resuscitation was significantly higher than those before resuscitation. Moreover, mean IVC index before resuscitation was significantly higher than that after resuscitation ($P>0.01$).
Conclusion
Sonographic IVC parameters are feasible, easy, and noninvasive measures to assess hypovolemia in shocked patients.

Keywords:
inferior vena cava ultrasound, shock, patients with trauma

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Introduction

Traumatic injury is defined as damage to the body caused by exchange with environmental energy that is over body resilience, can results from road traffic accident, interpersonal violence, falls, and sports-related accident [1]. After traumatic injury, hemorrhage is responsible for more than 35% of prehospital deaths and more than 40% of deaths within the first 24 h [2]. Shock is a clinical condition that can arise from multiple etiologies; however, in all cases, it is characterized by the widespread failure of the circulatory system to oxygenate and nourish the body adequately [3].

Hemorrhagic shock can be rapidly fatal. Sonography has proved to be a suitable method to detect bleeding sources in patients with trauma referred to as focused assessment with sonography for trauma (FAST) [4,5]. Sonography was used effectively as a primary screening procedure at the entry to a hospital in mass casualty patients with trauma, with an average of 4 min for each patient [6]. However, the standard examination for trauma, the FAST, does not give any information about the hemodynamic status, amount of blood lost, ongoing blood loss, or response to resuscitation.

The rationale of the study was to explore the role of sonographic measurement of inferior vena cava in assessment of the hemodynamic status and evaluating the effectiveness of resuscitation in patients with traumatic hemorrhagic shock.

Objective

The aim was to assess the reliability of inferior vena cave (IVC) sonographic parameters in diagnosis and evaluation of shock in patients with trauma.

Patients and methods

Type of study

This was a diagnostic cross-sectional study.

Study site

The study was conducted in the Emergency Department, Suez Canal University Hospital, Egypt, in the period from January 2017 to February 2018.

Study population

All patients with trauma with evident clinical picture of shock were included.

Inclusion criteria

The following were the inclusion criteria:

(1) Traumatized patients due to road traffic accidents (RTA).
(2) Blunt abdominal trauma, sliding on stairs, or fall from height.
(3) Aged 18 years and older.
(4) Both sexes.
(5) Clinical picture of hemorrhagic shock.

Exclusion criteria

The following were the exclusion criteria:

(1) Patients who developed cardiopulmonary arrest.
(2) Stab wound at the epigastrium or nearby.

Sample type

The sampling was sequential till completion of the sample size.

Ethical considerations

This research was approved by the Faculty of Medicine Ethics Research Committee on February 2017.

Methodology

Data was collected in a preorganized data sheet (questionnaire) by the researcher from patients fulfilling the inclusion and exclusion criteria. Patients were clinically assessed and managed by ABCDE protocol. The following data were collected:

Full history

(1) Patient's file number.
(2) Patient's personal data: age, sex, occupation, and residence.
(3) Date of admission.
(4) Timing of injury and timing of admission.
(5) Mechanism and type of injury.
(6) Associated comorbidity, for example, common endocrinal, cardiovascular, or previous disability.

Clinical examination

Clinical evaluation of the patients was carried out on arrival to the Emergency Medicine Department regarding initial assessment through ABCDE approach.

Laboratory investigations

(1) Complete blood count, blood typing, and cross-match.
(2) Coagulation profile.
(3) Serum creatinine.
(4) Arterial blood gasses.

Radiographic investigation

(1) FAST.
(2) Radiography (limbs–chest–pelvis), computed tomography (CT) chest, CT brain, and CT abdomen with contrast when indicated.
(3) Inferior vena cava ultrasound:
    (a) All patients were followed up for 6 h after arrival to the emergency room.
    (b) IVC parameters were checked by ultrasound twice, upon arrival and 2 h after regain of blood pressure 90/60 or higher, and heart rate reduced to normal.

Technique of IVC ultrasonographic examination

(1) All sonographic studies were done by a senior radiologist resident together with the emergency resident:
    (a) The ultrasound device used in this study was Siemens Acuson×300 (Siemens, Egypt), and the probe used was the low-frequency curvilinear transducer.
(2) Patients were studied in the supine position.
(3) The maximum anteroposterior diameter of IVC was measured ultrasonographically at site 2 cm away from right atrium in both inspiration (i) and expiration, and (e) by M-mode in subxyphoid area.
    (a) The difference between the diameters of IVC_e and IVC_i was regarded as collapsibility.
    (b) Collapsibility index was measured as $IVC_e–IVC_i/IVC_e$.
    (c) IVC collapsibility was correlated to clinical state and laboratory findings of this patient.

Ethical considerations

The date of Ethics Research Committee approval was February 2017.

Results

Table 1 shows vital signs (respiratory rate, blood pressure, pulse, and temperature) and laboratory tests (hemoglobin and pH). All variables returned to normal values after resuscitation. Moreover, there was a statistically significance between these variables before and after resuscitation (<0.001), except for hemoglobin level, which did not significantly change after resuscitation.

Table 2 shows different IVC measures before and after resuscitation. Mean IVC diameter at inspiration after

Table 1 Comparison between clinical and laboratory parameters before and after resuscitation of 45 traumatized patients

Variables	Resuscitation [*n* (%)]		*P* value
	Before	After	
Respiratory rate (min)	21.28 (1.99)	15.74 (1.43)	<0.001
Systolic blood pressure (mm/Hg)	82 (9.44)	101.56 (9.52)	<0.001
Diastolic Blood pressure (mm/Hg)	51.33 (9.23)	62.44 (6.45)	<0.001
Pulse (min)	117.27 (9.24)	88.93 (7.97)	<0.001
Core temperature (°C)	36.53 (0.48)	36.86 (0.25)	<0.001
Hemoglobin (g/l)	11.64 (2.4)	11.93 (1.9)	0.005
pH	7.31 (0.07)	7.37 (0.05)	<0.001

n=45. Statistical significance at *P*<0.0. **P* values are based on paired *t*-test.

Table 2 Comparison of inferior vena cava measures before and after resuscitation of 45 traumatized patients

Variables	Resuscitation [*n* (%)]		*P* value
	Before	After	
IVC diameter at inspiration (mm)	5 (1.31)	12.84 (2.1)	>0.01*
IVC diameter at expiration (mm)	8.13 (1.67)	15.64 (2.4)	>0.01*
IVC index	38.6 (9.6)	17.67 (3.4)	>0.01*

IVC, inferior vena cave. Statistical significance at *P*<0.05. **P* values are based on paired *t*-test.

Table 3 Correlation analysis between inferior vena cava diameter during inspiration before resuscitation and different clinical and laboratory parameters of 45 traumatized patients

Variables	IVC diameter at inspiration (IVC_i)	
	Correlation coefficient (*r*)	*P* value
Systolic blood pressure	0.5	0.02*
Diastolic blood pressure	0.46	0.002*
Pulse	−0.5	0.01*
pH	0.47	0.01*
Hemoglobin	0.25	0.09

IVC, inferior vena cave. Statistical significance at *P*<0.05. **P* values are based on Pearson's correlation test as appropriate.

Table 4 Correlation analysis between inferior vena cava diameter during expiration before resuscitation and different clinical and laboratory parameters of 45 traumatized patients

Variables	IVC diameter at expiration (IVC_e)	
	Correlation coefficient (*r*)	*P* value
Systolic blood pressure	0.44	> 0.01*
Diastolic blood pressure	0.52	<0.01*
pulse	−0.32	0.03*
pH	0.49	>0.01*
Hemoglobin	0.26	0.07

IVC, inferior vena cave. Statistical significance at *P*<0.05. **P* values are based on Spearman correlation test as appropriate.

resuscitation was significantly higher than that before resuscitation. Regarding IVC diameter at expiration, mean IVC diameter at expiration after resuscitation was also significantly higher than that before resuscitation. Finally, we found that mean IVC index before resuscitation was significantly higher than that after resuscitation.

Table 3 shows that there was a positive moderate significant correlation between IVC_i and both systolic and diastolic blood pressures, whereas there was a negative moderate significant correlation between IVC_i and pulse. There was a moderate statistically significant correlation between IVC_i and pH. On the contrary, there was a weak insignificant correlation between IVC_i and hemoglobin level.

Table 4 shows that there was a positive moderate significant correlation between IVC_e and both systolic and diastolic blood pressures, whereas there was a negative weak significant correlation between IVC_e and pulse. There was a moderate statistically significant correlation between IVC_e and pH. On the contrary, there was a weak insignificant correlation between IVC_e and hemoglobin level.

Table 5 Correlation analysis between inferior vena cava index before resuscitation and different clinical and laboratory parameters of 45 traumatized patients

Variables	IVC index	
	Correlation coefficient (*r*)	*P* value
Systolic blood pressure	−0.30	0.06
Diastolic blood pressure	−0.10	0.51
Pulse	0.45	0.002*
pH	−0.15	0.33
Hemoglobin	0.07	0.62

IVC, inferior vena cave. Statistical significance at *P*<0.05. **P* values are based on Spearman correlation test as appropriate.

Table 5 shows that there was a positive moderate significant correlation between IVC index and pulse. Otherwise, there was no other significant correlation between IVC index and any other clinical or laboratory variable.

Table 6 Correlation analysis between inferior vena cava index after resuscitation and different clinical and laboratory parameters of 45 traumatized patients

Variables	IVC index	
	Correlation coefficient (*r*)	*P* value
Systolic blood pressure	−0.342	0.022*
Diastolic blood pressure	−0.273	0.07
Pulse	0.037	0.81
pH	−0.198	0.192
Hemoglobin	0.109	0.475

IVC, inferior vena cave. Statistical significance at $P<0.05$. *P values are based on Pearson's correlation test as appropriate.

Table 6 shows statistically significant correlation between IVC index after resuscitation and those different variables ($P>0.05$). The only exception is the negative weak correlation between IVC index and systolic blood pressure ($r=-0.342$, $P=0.022$).

Discussion

Patients with trauma are susceptible to shock from many different etiologies; nevertheless, hemorrhagic shock is the leading etiology in most cases and can be rapidly fatal. Sonography has proved to be a suitable method to detect bleeding sources in patients with trauma. Our study proved that sonographic measurement of the IVC parameters [IVC diameter during inspiration (IVC_i) and expiration (IVC_e), and collapsibility index] could be a reliable method to assess the hemodynamic status of the shocked patients.

IVC measures are dependent upon the respiratory phases; IVC collapses during inspiration and inflates during expiration, similarly, IVC diameter correlates positively with the intravascular volume [7,8]. In a normal healthy person who breathes spontaneously during inspiration, there is a negative intrathoracic pressure. This pressure increases the venous return which allow the high flow to exert less intraluminal pressure leading to decrease in IVC diameter. On the contrary, IVC diameter increases in response to the ascending intraluminal pressure during expiration. The same applies in hypovolemic cases, thus these cyclic respiratory changes facilitate the predictability of fluid responsiveness [7,9,10].

Our study supports the presence of such normal respiratory cyclic changes during spontaneous breathing in shocked patients, as evident by the lesser IVC diameter during inspiration than during expiration (5 vs 8.13 mm before resuscitation and 12.84 vs 15.64 mm after resuscitation).

During shock and subsequent hypovolemia, all of the following parameters dropped: IVC_i and IVC_e. Mean values of IVC diameter during inspiration and during expiration and IVC index were statistically significant different before and after resuscitation (>0.01). We found that both IVC_i and IVC_e diameters were half their values before resuscitation; in contrast, IVC index was high. Sefidbakht and colleagues agrees with us, as they found that both IVC_e and IVC_i were lower than the standard level 9 mm on arrival to ER (5.6±0.8 and 4.0±0.7 mm), in contrast to control group (11.9±2.2 and 9.6±2.0 mm). Similarly, findings of Yanagawa and colleagues are in agreement with our claims that there is an increase in IVC_e diameter after resuscitation from 7.7 to 13.5 mm, $P=0.001$ [11].

Regarding the relationship between IVC parameters and clinical picture of shocked patients, we found that before resuscitation both IVC_e and IVC_i were significantly correlated with vital signs. For instance, there was a positive correlation with BP and negative correlation with heart rate. Findings of Zengin *et al.* [12] are in agreement with us, as they found similar positive correlation between BP and IVC diameters, and negative correlation between the IVC diameters and pulse in patients with hypovolemia. The same results were reported by Akilli *et al.* [13], who also found that there is a negative correlation between IVC diameters and heart rate, yet insignificant correlation with BP.

In contrast, Yanagawa *et al.* [14] found that 20% of shocked patients developed delayed hypotension despite their initial stable vital signs on arrival. So blood pressure alone cannot always be an indicator of blood loss, whereas pulse can be.

On the contrary, collapsibility index, before resuscitation, only was significantly correlated with heart rate. It is well known that caval index reflects the volume status. Index of 50% or greater indicates low volume and vice versa [15]. In our study, the mean collapsibility index on admission was approximately 39%, and this agrees with Muller *et al.* [9] who considered collapsibility index inconclusive to mirror volume status. Correspondingly, IVC index had week insignificant correlation with blood pressure. This is consistent with Silk de Valk *et al.* [16] who found that blood pressure was unrepresentative of IVC index variations before and after fluid replacement. This is attributed to stability of blood pressure during early and mild to moderate hypovolemia during which compensatory mechanisms sustain vital signs well. So, BP could only be reliable on noncompensatory conditions when prolonged or extreme hypovolemia develops [17].

Along with deteriorated vital signs, metabolic acidosis as well stems from prolonged hypotension and subsequent tissue hypoperfusion. So IVC diameters, but not the caval index, correlate positively with PH, as shown by our findings. Akilli *et al*. [13] augmented our findings as they found a positive correlation between IVC diameters and HCO_3 level and negative correlation with lactate levels among shocked patients confirming the presence of acidosis.

Hemoglobin was insignificantly correlated to IVC diameters, which may be because there was no severe shock to the extent leading to drop in hemoglobin level. Similar studies found no correlation between Hb level, Hct, and IVC measurements, which gives precedence to IVC indices as a more reliable marker of early blood loss than Hb [13,18].After resuscitation, none of the vital signs or laboratory findings were correlated with any of IVC parameters. The only exception was the SBP which had negative weak significant correlation with IVC index. This is may be attributed to the fact that vital signs and laboratory results are not reliable to indicate volume status but IVC is. It is also possible that vital signs are not reliable except in severe shock statuses. In Akilli *et al*. [13] study, similar discrepancy occurred, as all vital signs and laboratory findings were correlated with IVC parameters in the shock group, whereas no correlation was found among the control group.

These discrepancies suggest that vital signs cannot always be reliable markers of hypovolemia and further indicators should be added to augment the clinical decisions in critical care. Here comes the role of sonographic measurement of IVC as a feasible, easy and noninvasive technique to assess hypovolemia in shocked patients. IVC parameters reflect the presence of shock better than clinical picture and laboratory investigations.

Conclusion

Sonographic IVC parameters are feasible, easy and noninvasive measures to assess hypovolemia in shocked patients and reflect the presence of shock simultaneously with clinical picture and laboratory investigations.

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Conflicts of interest

There are no conflicts of interest.

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