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Validity of shock index, modified shock index, central venous pressure, and inferior vena cava collapsibility index in evaluation of intravascular volume among hypovolemic Egyptian patients

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ABSTRACT

Background: Assessment of intravascular volume is an important component in care of hypovolemia. Physical examination is inaccurate tools in the assessment of intravascular volume, leading to the need for more objective method and accuracy tool.

Aims: The prediction of validation of shock index (SI), modified SI (MSI), central venous pressure (CVP), and inferior vena cava collapsibility index (IVC-CI) in assessment of intravascular volume.

Methods: This study was conducted as cross-sectional, observational study on 150 Egyptians patients attending to the emergency room with hypovolemia state (systolic blood pressure < 90 mmHg, heart rate > 100 beat/minutes, and capillary refill > 2 seconds, and clinical signs with symptoms suggestive any types of shocks) and all patients enter resuscitation room once they arrive to emergency room (ER). With applied resuscitation guideline methods, all the life-threatening conditions of all participants can be treated.

Results: The studied patients revealed negative correlation between the CVP value and (SI and MSI), but positive correlation with IVC-CI value. In addition, the mean CVP was 3.2 ± 2.2 but the mean IVC-CI was $74.9\% \pm 10.5\%$. MSI has 100% sensitivity and 98% specificity, CVP has 100% sensitivity and specificity, and IVC-CI has 100% sensitivity and specificity in diagnosis of hypovolemia when > 1.3, ≤ 8 cmH$_2$O, and ≥ 50%, respectively.

Conclusions: Assessment of intravascular volume is an important diagnostic tools and management of hypovolemic patients with determining collapsibility (>50%) of the IVC by bedside ultrasonography in conjunction with common clinical marker predictors, e.g., SI, MSI, and CVP.

Introduction

Central venous pressure (CVP) considered invasive hemodynamic monitoring and a useful guide for an early resuscitative response with the help to reducing the morbidity and mortality rates in Emergency Department (ED) cases with hypovolemia. CVP less than 8 cmH$_2$O is an indicator for intravenous fluid therapy. However, invasive hemodynamic monitoring may induce side effects (arterial puncture, infection, venous thrombosis, and so on), also may lose a time and some practical limitations to used invasive methods for monitoring CVP in the ED, such as the need for special monitoring tools and supportive resources [1].

The ABCDE approach for resuscitation patients includes **A**irway patency, **B**reathing controlling, optimized the **C**irculatory status, assessed Oxygen **D**elivery for the tissues, and achieved **E**nd points for the resuscitation [2].

The shock index (SI) is calculated by heart rate (HR) divided on systolic blood pressure (SBP). It is a physiological score that can be guided in the pre-hospital and initial emergency care to

determine the severity of the trauma, and to detect an early hemorrhagic shock [3].

The modified SI (MSI) is calculated by HR divided on mean arterial pressure (MAP = [(DBP×2) + SBP]/3) has been proposed to evaluate the stability of the patients and has a better predictor of mortality than the SI alone. The SBP is replaced by MAP in the equation, so as to include the influence of diastolic BP (DBP), MSI > 1.3 indicates a hypovolemic status and is a stronger predictor of ED patient mortality compared to the pulse rate and BP alone [4].

Ultrasound has increased role in ED rapidly because it is safe, non-invasive, rapid, and considered as the bedside test. Bedside ultrasound is one of the emergency clinical assessments today but not formula radiological investigation and focused on to evaluate a clinical question. The inferior vena cava (IVC) carries deoxygenated blood into the right atrium of the heart. A large vein of the size and shape of the IVC is correlated to the CVP and circulating blood volume, IVC can be assessed by ultrasound which is non-invasive tools to measure the volume status. The IVC is compliant vessel whose size changes with intravascular pressure. Consequently, IVC collapses with inspiration because the blood pumped to RT atrium due to the negative pressure created by chest expansion [5].

The IVC diameter (IVCD) changes depending on the phase of respiration. During inspiration, the negative pressure is developed in the thorax, causing the IVC to drain into the right atrium, and decrease its diameter. The measure of this is called the IVC collapsibility index (IVC-CI) given by (IVCD in expiration—IVCD in inspiration)/IVCD in expiration [5].

Potential value of IVC collapsibility index (IVC-CI) is increasing in investigating as non-invasive tool of intravascular volume assessment. The hemodynamic evaluation modality by point of care ultrasound based on its non-invasive character, low cost, easy reproducibility, greater availability, and portability [6].*The study aims of* the prediction of validation of SI, MSI, CVP, and IVC-CI in assessment of intravascular volume at the ED of Suez Canal University Hospital (SCUH) for improving the management process in hypovolemic status.

Methodology

Type of the study

This study was cross-sectional, observational study on patients attended to the ED with hypovolemia state for 1 year of the study, and all patients enter resuscitation room once they arrive to emergency room (ER).

Site of the study

The work carried in the ED of SCUH and patients presented with clinical signs (SBP < 90 mmHg, HR > 100 beat/minutes, and capillary refill > 2 seconds) and symptoms suggestive any types of shock patients who require fluid resuscitation and center venous catheterization with applied resuscitation guideline methods and treat all the life-threatening conditions if present to all participants.

Patients: inclusion criteria

1. Age: 16–70 years old
2. Both genders
3. Patients with functioning central venous catheter
4. Spontaneously breathing patients

Exclusion criteria

1. Age below 16 and above 70 years
2. Non-functioning central venous catheter
3. Pregnancy
4. Pericardial effusion and tamponade
5. Mechanically ventilated patients

Sample size

Sample size was estimated using a predetermined area under the curve for prediction of mortality among hypovolemic patients = 0.844 [7]. The sample size calculated for power of the study of 90% and α error of 0.05. An estimated drop out of 10% added. A series of equations used to estimate sample size using area under the curve (AUC). Computer-based software has been used to calculate the required sample size. The least required sample size is 150 patients.

Patients and methods

The following data obtained:

- Demographic: age, gender, and thorough history.
- Primary evaluation by ABCDE, which means Airway maintenance, Breathing and ventilation, Circulation, Disability and neurological status, and Exposure and environment control, respectively.
- Selected patients whose SBP < 90 mmHg, HR > 100 beat/minutes, and capillary refill >2 seconds and clinical signs with symptoms suggestive any types of shocks.

- Determination of patient's SI from HR divided by SBP and MSI by HR divided by MAP.
- Laboratory: as complete blood count, arterial blood gases, blood typing, cross matching, and serum creatinine.
- Radiology: after ABCDE, all patients were subjected to full history and secondary survey and research associate professor of radiology was evaluated for intravascular volume status by performed bedside ultrasonography using ultrasound machine with convex (3.5–5 MHz) transducer to measure the IVCDs, both end-inspiratory (IVCi) and end-expiratory (IVCe) measured by two-dimensional bedside ultrasonography by M-mode in the subxiphoid area. The IVC collapsibility indices (IVC-CIs) were calculated by the equation: $([(IVCe – IVCi)/IVCe] \times 100)\%$.
- Central venous catheter: insertion and evaluation of CVP by a research associate professor of the emergency medicine.
- The IVC-CI compared with the CVP values.

Data analysis and management

Data collection

The researcher himself collected data.

Statistical analysis of data: statistical analysis

Data were studied, tabulated, and statistically analyzed using Statistical Package for Social Science (SPSS) with *P*-value considered significant if $P < 0.05$.

In the statistical comparison between the different groups, the significance of difference tested using one of the following tests:

- Student's *t*-test: used to compare between mean of two groups of numerical (parametric) data.
- Inter-group comparison of categorical data was performed by using chi-square test (χ_2-value).

A *P*-value < 0.05 was considered statistically significant in all analysis.

Ethical consideration

1. Approval of authority.
2. Agreement of participant without obligation.
3. Confidentiality of data.
4. Explanation of our study to the participants. An informed consent was taken from each patient or from his relatives if comatose before taking any data or doing any intervention.
5. Explanation of the aim in a simple manner to understood by the common people.
6. Right of the patient to refuse involving in the research and he will have his usual treatment.
7. Right of the participant to withdraw from the study at any time without giving any reason.
8. All participants announced the results of the study.
9. Right of patient to have a copy from the informed consent.
10. Signature or fingerprints of the patient or his relatives.
11. The researcher phone number and all possible communicating methods identified to the participant.
12. Inform the patient about the outcome of the research.

Results

This study was prospective carried out on 150 cases which needed CVP in their evaluation at ED, Suez Canal University. They were hypovolemic patients. The anteroposterior diameter of IVC measured in IVCi and IVCe by ultrasonography M-mode in the subxiphoid area. The collapsibility is the difference between the diameters of IVCe and IVCi, and CI calculated by the equation $([(IVCe – IVCi)/IVCe] \times 100)\%$ and measure for all patients SI, MSI, CVP, and IVC-CI.

Demographic characteristics of the studied populations

Age

In this study, the mean age (±SD for the study group 42.38 ± 12.903 and the mean age of the studied patients was comparable without any statistically significant differences ($p = 0.74$). The mean age of the total population was 50.14 ± 16.799 years with the age ranged from 18 to 88 years. In total, the frequency of males was 60%, while the frequency of females was 40% (Table 1).

Body mass index (BMI)

Regarding the mean BMI (±SD) was 31.46 ± 4.69 in the study group as in Table 1.

We found respiratory rate (RR), HR, SBP, DBP, MAP, SI, MSI, and Glasgow coma scale (GCS), mean ± SD as shown in Table 2.

Respiratory rate (RR)

For RR in the study group, the mean (±SD) was 28.40 ± 7.589 with highly statistically significance as clinical predictors for the hypovolemic state as given in Table 2.

Heart rate (HR)

For HR in the study group, the mean (±SD) was 107.6 ± 7.9 with statistical significance as clinical predictors for the hypovolemic state as given in Table 2.

Systolic blood pressure (SBP)

In our study on SBP , the mean (±SD) was 74 ± 16.5 with statistical significance as clinical predictors for hypovolemic state as given in Table 2.

Diastolic blood pressure (DBP)

In the study groups on DBP, the mean (±SD) was 44 ± 15.6 with statistical significance as clinical predictors for hypovolemic state as given in Table 2.

Mean arterial pressure (MAP)

In our study group on MAP, the mean (±SD) was 53.9 ± 15.9 with statistical significance as clinical predictors for the hypovolemic state as given in Table 2.

Glasgow coma scale (GCS)

In our study on GCS, the mean (±SD) was 13.120 ± 2.5285 with statistical significance as clinical predictors for the hypovolemic state as given in Table 2.

Stock index (SI)

In our study, the mean and ±SD of SI in the study group were 1.5 ± 0.4 with statistical significance and P-value ≤ 0.001, as clinical predictors for the hypovolemic state as given in Table 2.

Modified shock index (MSI)

In our study, the mean and ±SD of MSI in the study group were 2.2 ± 0.9 with a statistical significance and P-value ≤ 0.001, as clinical predictors for the hypovolemic state as given in Table 2.

In the study group where 40% patients presented with diabetes mellites (DM), about 30% of patients had hypertension (HTN), 22% of patients had history of ischaemia heart disease (IHD), 26% of patients had history of cerebrovascular stroke, and 24% of patients had liver disease (Table 3).

In our study, there is negative correlation between CVP value and (SI and MSI) (Table 4).

In our study, there is a positive correlation between IVC-CI value and (SI and MSI) (Table 5).

1. **Regarding IVCe**: The mean (±SD) IVCe diameter in the study group was 1.6 ± 0.3 (Table 6).
2. **Regarding IVCi**: The average diameter of IVCi in the study group was 0.4 ± 0.2 cm; P ≤ 0.001 (Table 6).
3. **Regarding CVP**: The mean CVP (±SD) in the study group was 3.2 ± 2.2 (Table 6).
4. **Regarding IVC-CI**: The mean IVC-CI in the study group was 74.9 ± 10.5 % (Table 6).

In the present study, the CVP shows the negative correlation with the IVC-CI with P-value ≤ 0.001 as shown in Figure 1.

1. In our study, SI has 100% specificity and sensitivity in diagnosis of hypovolemia when > 0.7.
2. In the present study, MSI has 100% sensitivity and 98% positive predictive value (PPV) in diagnosis of hypovolemia when > 1.3.
3. In our study, CVP has 100% specificity and sensitivity in diagnosis of hypovolemia when ≤ 8 cmH2O.
4. In the present study, IVC-CI has 100% specificity and sensitivity in diagnosis of hypovolemia when ≥ 50%.

Discussion

The conducted study is a prospective, observational study enrolled 150 adult patients undergoing central venous catheterization at ED, SCUH.

The identification of the hypovolemic state is essentially in critically ill cases because resuscitation of hypovolemia—adequately and early with time—has an effect on the prognosis and the delayed fluid therapy received lead to bad outcomes. Recently, inadequate fluid resuscitation was the commonest errors in died hospital patients. Insufficient fluid therapy resuscitation remains a significant issue, especially in critical cases [8].

In this study, HR in the study group was higher 107.6 ± 7.9 with statistical significance and P-value ≤ 0.001.

Table 1. Demographic characteristics of the studied populations: (number = 150 patients).

		Study group
		Mean ± SD
Age		50.14 ± 16.799
BMI		30.06 ± 5.33
Gender	Female	60 (40%)
	Male	90 (60%)

Table 2. Clinical predictors for hypovolemia of the studied patients.

	Study group	Test of significance
	Mean ± SD	
RR	28.40 ± 7.589	t = 4.3, P ≤ 0.001
HR	107.6 ± 7.9	t = 18.02, P ≤ 0.001
SBP	74 ± 16.5	t = 18.5, P ≤ 0.001
DBP	44 ± 15.6	t = 14.2, P ≤ 0.001
MAP	53.9 ± 15.9	t = 15.8, P ≤ 0.001
GCS	13.1 ± 2.5	t = 5.26, P ≤ 0.001
SI	1.5 ± 0.4	t = 15.2, P ≤ 0.001
MSI	2.2 ± 0.9	t = 11.5, P ≤ 0.001

t of student t-test, P ≤ 0.05 statistically significant.

Table 3. Past medical history of the study group patients: past medical history of patients in the study group.

	Study (n = 150)
DM	60 (40%)
HTN	45 (30%)
IHD	33 (22%)
Cerebrovascular stroke	39 (26%)
Liver disease	36 (24%)

Table 4. Nonparametric Correlations of CVP with SI and MSI in the study group.

Correlations of CVP with SI and MSI			CVP (cmH2O)
Spearman's rho	SI	Correlation coefficient	−0.876**
		Sig. (2-tailed)	0.000
		N	100
	MSI	Correlation Coefficient	−0.870**
		Sig. (2-tailed)	0.000
		N	100

**Correlation is significant at the 0.01 level (2-tailed).

Table 5. Nonparametric Correlations of IVC-CI with SI and MSI in the study group.

Correlations of IVC-CI with SI and MSI			IVC-CI (%)
Spearman's rho	SI	Correlation coefficient	0.816**
		Sig. (2-tailed)	0.000
		N	100
	MSI	Correlation coefficient	0.826**
		Sig. (2-tailed)	0.000
		N	100

**Correlation is significant at the 0.01 level (2-tailed).

Table 6. Relations between IVCDs and CVP in the study group.

Parameter	Study group		Significance test
	Mean ± SD	Median (Min–Max)	
IVCe	1.6 ± 0.3	1.6 (1–3)	*t =1.4, P = 0.2
IVCi	0.4 ± 0.2	0.45 (0–1)	**Z = 8.4, P ≤ 0.001
CVP	3.2 ± 2.2	3 (0–7)	**Z= 8.7, P ≤ 0.001
IVC-CI	74.9 ± 10.5	73 (52–94)	*t = 25.8, P ≤ 0.001

*t of Student's t-test, **Z of Mann–Whitney test

According to Nette et al. (2006), they found that HR affected by both external factors (fever and anxiety) and positive inotropes s not good indication of hypovolemic shock [9].

In this study, BP and MAP were significantly lower with statistical significance and P-value < 0.001 and can predict low-volume states in hypovolemic patients in context of medical scenarios.

Contrary, Zengin et al. (2013) reported that clinical assessment revealed pulse, BP, and initial lab results are one of the indicators used to assess the intravascular volume status and are inaccurate because they are affected by various clinical situations. These indicators may be physiological as the initial compensatory mechanisms of the body. This may lead to delays in the early detection of hypovolemia. For instance, in patients, the body and BP would compensate a 20% loss of total body fluids still within normal range whereas this amount of loss may be induced multiple-organ failure [10]. While Yamanoğlu et al. (2014) also revealed that BP

misguidance predictors of circulatory shock especially at class II and I traumatic hypovolemic shock patients [11].

In this study, patients with history of cerebrovascular diseases were 26% of the study patients as they presented with dehydration.

This agreement with Rowat et al. (2011) who conducted a study to reveal the frequency of risk factors and associations' dehydration with prognosis at hospital improved after stroke and presented that of 2,591 patients registered, and (62%) were dehydrated at some stages during their treatment and admission. Some risk-precipitated factors for dehydration included female, older age, total anterior circulation syndrome, and received diuretics (all P < 0.001). Dehydrated patients increased incidence of dead or dependent at hospital discharge than those without [12].

In our study, the number and percentage of patients with history of liver disease were 24% of the study patients.
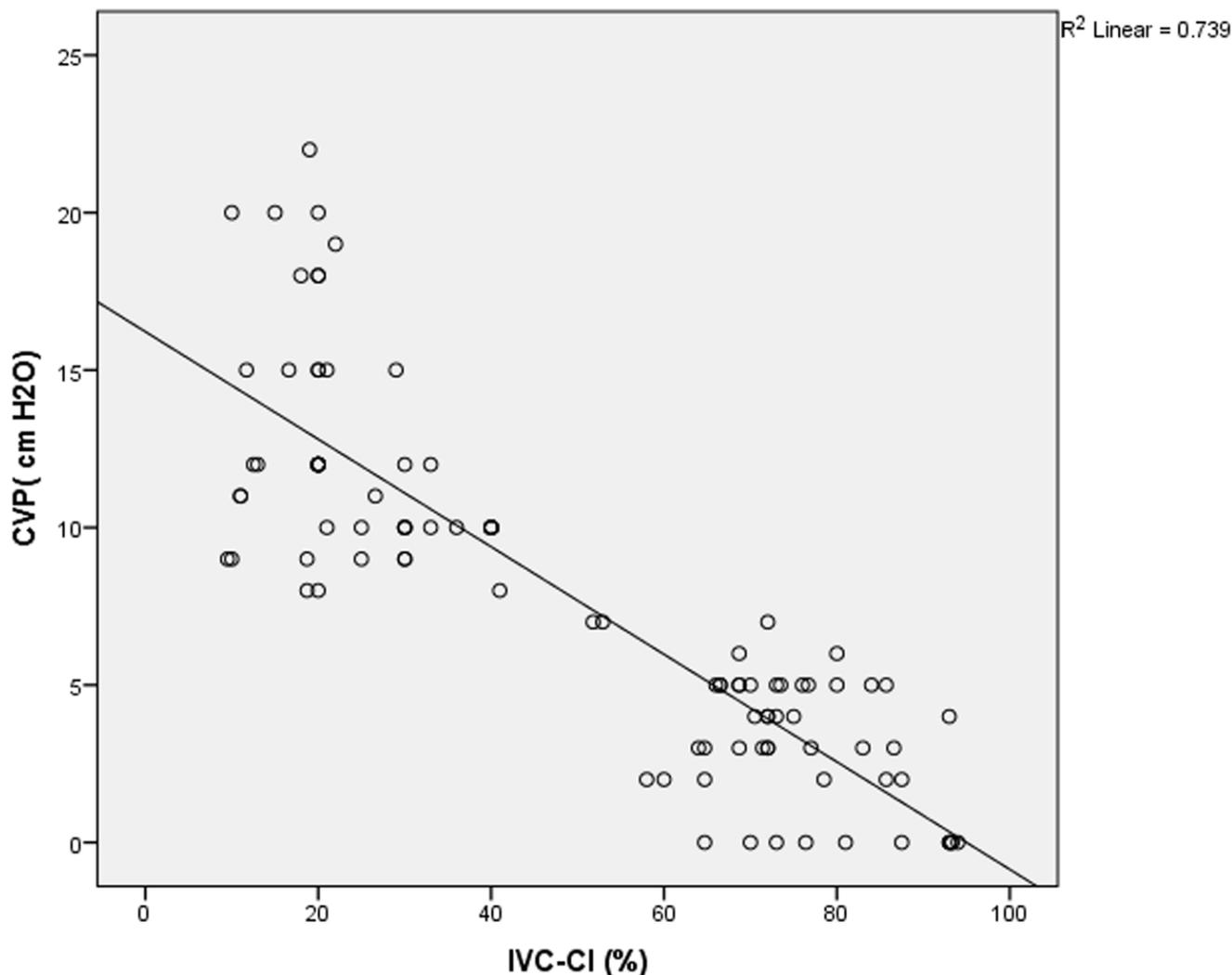
Figure 1. Scatter plot diagram showing correlation between CVP and IVC-CI.

In this study, the mean CVP (±SD) in our study was lower in the study patients (3.2 ± 2.2) which was statistically significance (P-value ≤ 0.0001) and the mean of IVC-CI in our study significantly higher in the study patients (74.9 ± 10.5%) with statistical significance (P-value ≤ 0.001).

In our study, there are negative relations between CVP value and (SI and MSI) with r = −0.876 and P-value ≤ 0.001 and r = −0.870 and P-value ≤ 0.001, respectively.In this study, there is a positive correlation between IVC-CI and (SI and MSI) with r = 0.816 and P-value ≤ 0.001 and r = 0.826 and P-value ≤ 0.001, respectively.

In this study, CVP shows significant correlation with the IVC-CI with r = −0.843 and P-value ≤ 0.001, we revealed an inverse relationship between CVP and IVC-CI.

This result is in accordance with that observed in study performed by Stawicki et al., as they found that

measurements of IVC-CI by intensivists performed bedside ultrasonography can provide a useful guide to non-invasive volume status assessment in the surgical intensive care unit patients. CVP appears to best correlate with IVC-CI in the setting of low (≤20%) and high (≥60%) collapsibility ranges [6].

In our study, the mean (±SD) IVCe in the study patients was 1.6 ± 0.3 which shows no statistical significance while the average diameters of IVCi in the study patients at arrival were significantly smaller (0.4 ± 0.2 cm) with P-value ≤0.001.

Thanakitcharu et al. (2013) found that during inspiratory and expiratory phases of IVCD, there was a significant difference between IVCi diameter and CVP, but insignificant correlations in IVCe diameter. Similarly, in hemodialysis patients, IVCD measured by nephrologists for estimation of the intravascular volume status and considered more accurate for a dry weight. Also in critically ill

patients, anesthesiologists, cardiologists, and intensivists for assessment the body volume status have done the same technique [13].

It is known that in the respiratory cycle there is IVCD variation. However, some authors measured both IVCi and IVCe, and use them as collapsibility or caval index. Nagdev et al. (2010) found that during a respiratory cycle, 50% collapse of the IVCD was strongly significant with a low CVP [1].

Similarly, Farkas and Anawati (2015) agreed that measuring the IVC size at end-expiration just proximal to the junction of the IVC and hepatic veins correlates with CVP. Respirophasic variation in the IVCD (>50% with forced inspiration, or lesser degrees with passive ventilation) suggests a low CVP [14].

According to Muller et al. (2012) in spontaneous breathing patients, respiratory IVCD variation is commonly used because it has good relations to CVP even if CVP is poorly predicted for fluid response. Respiratory IVCD variation corresponds to fluid removal with chronic dialysis in nephrology outpatients or during continuous hemofiltration in spontaneously breathing intensive care unit (ICU) patients with acute heart failure [15].

In this study, IVC-CI shows 100% specificity and sensitivity in diagnostic hypovolemic status when ≥50%.

Kent et al. support the same result as they concluded that IVCDs Measurements and calculation of the IVC-CI found to be reliable markers of both clinical response to volume resuscitation and intravascular volume status. Hypovolemic patients more likely to be diagnosed when IVC-CI >50%. However, when it is <20%, the patient may be either hypervolemia or euvolemia [16].

Also Zengin et al. (2013) found that the IVC considered a major vein; highly collapsibility vein, and its diameter correlate with right atrium of the heart. However, its diameter not affected by the body's vasoconstrictor compensatory mechanisms to fluids loss, so IVC reflects volume status more accurate than other parameters, which based on the vascular system, such as BP, pulse rate, and others [10].

Although Juhl-Olsen et al. (2013) found that baseline IVC-CI and IVCe did not correlate with the relative decrease in cardiac output induced by blood donation, and baseline measurements did not reflect the following hemodynamic response. In addition, a lack of correlation with the decrease in cardiac output also found for the changes in IVC-CI and IVCe caused by blood loss. The sensitivity of dynamic IVC measures for detecting early blood loss was around 80%. They support the use

of ultrasonography for assessment of patients with suspected hemorrhage as it has moderate sensitivity [17].

As reported by Schefold et al., transabdominal ultrasonography IVCD in mechanically septic ventilated patients considered a non-invasive approach to assess the volume status. Especially in sitting of invasive hemodynamic monitoring is unavailable, such as in early resuscitation phase, bedside ultrasonography IVC measures in addition to other methods such as echocardiography. With good training, the use of IVC sonography will be a faster, more goal-directed optimization of volume status, and easy to determined patients with clinical response to volume resuscitation and avoid volume expansion. In addition, this approach not required extensive training or more experiences [18].

Diseases that may influence the IVCDs,s e.g., patients with high pulmonary artery pressures, overt, right ventricular dysfunction, pulmonic, or tricuspid valve disease, and any diseases with increased intra-abdominal pressures, e.g., patients with moderate to massive amount of ascites or morbid obesity [13].

In our study, these patients excluded as obtaining image or IVCDs were difficult and inaccurate.

Intravascular volume status assessment is essential indicators for the management and diagnosis of ED cases.

The bedside ultrasonography evaluation of IVC-CI may be a useful bedside method for the ER physicians.

The physician may be able to obtain a bedside assessment of intravascular volume by the IVC-CI assessment during normal respiration (>46.4%). In conjunction with common clinical markers, bedside ultrasonography of the IVC may be a useful adjunct in the evaluation of the ED patients.

Limitations of the Study

Although we used a larger sample size than that used by Elbaih et al. [19], the sample size was still small and the study could not be blinded which might have introduced some bias into the results. In addition, the accuracy of bedside ultrasonography in measured IVC-CI in shock patients could not be precisely detected from history and diagnosis, which is based on clinical manifestations.

In the case of unstable shock patients, there were contraindications to transport these patients for more investigations, e.g., Pan-CT unless to finished resuscitations so little studied were done for

measurement IVC-CI in shocks patients so this considered some limitations.

In addition, the measurement of IVC-CI depended mainly on individual physicians who experience variations, but in our study, all investigations were carried out on them.

Conclusion

Intravascular volume status assessment is an important parameter for the diagnosis and management of ED patients.

We believe that bedside evaluation of the IVC may be a useful tool for the ER physicians.

The physician may be able to obtain a bedside assessment of intravascular volume by IVC-CI assessment during normal respiration (>50%). In conjunction with common clinical markers, e.g., SI, MSI, and CVP in assessment among hypovolemic Egyptian patients are considered useful adjunct tools in the evaluation of the ED patients.

Recommendations

- Bedside ultrasound should become available and more integrated in clinical practice of emergency medicine and ER physicians.
- Proper training to emergency physicians to use ultrasound in rapid assessment and diagnosis of critical patients by determining the ability to measure caval index.
- Further integration of IVC-CI with clinical markers predictors, e.g., SI, MSI, and CVP for evaluation, early diagnosis, and treatment to improve the management process with hypovolemic state patients.
- Further research in that era.

Summary

Determination of intravascular volume status can sometimes be challenging in the ED patient. Recent research indicates that invasive hemodynamic monitoring of CVP is a useful guide in directing early resuscitation. CVP considered invasive procedure with possible complications.

The aim of this study is to compare IVCi, IVCe, and the caval index (CI) with non-invasive study with CVP, SI, and MSI in patients with hypovolemia.

In this study, the mean age (±SD) for the study group was 50.14 ± 16.799 and for the control group was 42.38 ± 12.903.

SBP in the study group was lower than the control group; the mean (±SD) was 74 ± 16.5 and 122.4

± 8.2, respectively, with statistical significance. DBP in the study group was lower than the control group; the mean (±SD) was 44 ± 15.6 and 79.2 ± 8.04, respectively, with statistical significance.

The mean and ±SD of SI in the study group were lower than the control group 0.6 ± 0.08 and 1.5 ± 0.4, respectively, with statistical significance and P-value ≤ 0.001. The mean and ±SD of MSI in the study group were lower than the control group 0.8 ± 0.1 and 2.2 ± 0.9, respectively, with statistical significance and P-value ≤ 0.001.

There was negative correlation between CVP value and (SI and MSI), while there is a positive correlation between IVC-CI value and (SI and MSI).

CVP shows significant correlation with the IVC-CI with $r = -0.843$ and P-value ≤ 0.001; we noted an inverse relationship between IVC-CI and CVP.

IVC-CI shows 100% sensitivity and specificity in diagnosis of hypovolemia when ≥ 50% also CVP shows 100% sensitivity and specificity in diagnosis of hypovolemia when <8 cmH$_2$O

Bedside ultrasonography evaluation of the IVC could be a non-invasive marker of low volume status for the emergency physician, thereby aiding the clinician in fluid management early in the course of resuscitation before more invasive measurements are undertaken.

References

[1] Nagdev AD, Merchant RC, Tirado-Gonzalez A, Sisson CA, Murphy MC. Emergency department bedside ultrasonographic measurement of the caval index for noninvasive determination of low central venous pressure. Ann Emerg Med 2010; 55(3):290–5.

[2] Nicks B, Gaillard J. Approach to shock. In J. Tintinalli (ed). Tintinalli's emergency medicine a comprehensive study guide, McGraw-Hill Education, New York, pp 63–9, 2016.

[3] Montoya KF, Charry JD, Calle-Toro JS, Núñez LR, Poveda G. Shock index as a mortality predictor in patients with acute polytrauma. J Acute Dis 2015; 4(3):202–4.

[4] Rau CS, Wu SC, Kuo SC, Pao-Jen K, Shiun-Yuan H, Chen YC, et al. Prediction of massive transfusion in trauma patients with shock index, modified shock index, and age shock index. Int J Environ Res Public Health 2016; 13(7):683.

[5] Lyon ML, Verma N. Ultrasound guided volume assessment using inferior vena cava diameter. Open Emerg Med J 2010; 3(1):22–4.

[6] Stawicki SP, Braslow BM, Panebianco NL, Kirkpatrick JN, Gracias VH, Hayden GE, et al. Intensivist use of hand-carried ultrasonography to measure IVC collapsibility in estimating intravascular volume

status: correlations with CVP. J Am Coll Surg 2009; 209(1):55–61.

[7] Bradley AP, Longstaff ID. Sample size estimation using the receiver operating characteristic curve, Pattern Recognition Journal 2004; 47(12): 1175–86.

[8] Bárdossy G, Halász G, Gondos T. The diagnosis of hypovolemia using advanced statistical methods. Comput Biol Med 2011; 41(11):1022–32.

[9] Nette RW, Ie EH, Vletter WB, Krams R, Weimar W, Zietse R. Norepinephrine-induced vasoconstriction results in decreased blood volume in dialysis patients. Nephrol Dial Transplant 2006; 21(5):1305–11.

[10] Zengin S, Al B, Genc S, Yildirim C, Ercan S, Dogan M, et al. Role of inferior vena cava and right ventricular diameter in assessment of volume status: a comparative study: ultrasound and hypovolemia. Am J Emerg Med 2013; 31(5):763–7.

[11] Yamanoğlu NGÇ, Yamanoğlu A, Parlak İ, Pınar P, Tosun A, Erkuran B, et al. The role of inferior vena cava diameter in volume status monitoring; the best sonographic measurement method. Am J Emerg Med 2015; 33(3):433–8.

[12] Rowat A, Graham C, Dennis M. Dehydration in hospital-admitted stroke patients detection, frequency, and association. J Stroke 2012; 43(3):857–9.

[13] Thanakitcharu P, Charoenwut M, Siriwiwatanakul N. Inferior vena cava diameter and collapsibility index: a practical non-invasive evaluation of intravascular fluid volume in critically-ill patients. J Med Assoc Thai 2013; 96(Suppl 3):S14–S22.

[14] Farkas JD, Anawati MK. Bedside ultrasonography evaluation of shock. Hosp Med Clin 2015; 4(2):135–49.

[15] Muller L, Bobbia X, Toumi M, Louart G, Molinari N, Ragonnet B, et al. Respiratory variations of inferior vena cava diameter to predict fluid responsiveness in spontaneously breathing patients with acute circulatory failure: need for a cautious use. Crit Care 2012; 16(5):1.

[16] Kent A, Bahner DP, Boulger CT, Eiferman DS, Adkins EJ, Evans DC, et al. Sonographic evaluation of intravascular volume status in the surgical intensive care unit: a prospective comparison of subclavian vein and inferior vena cava collapsibility index. J Surg Res 2013; 184(1):561–6.

[17] Juhl-Olsen P, Vistisen ST, Christiansen LK, Rasmussen LA, Frederiksen CA, Sloth E. Ultrasound of the inferior vena cava does not predict hemodynamic response to early hemorrhage. J Emerg Med 2013; 45(4):592–7.

[18] Schefold JC, Storm C, Bercker S, Pschowski R, Oppert M, Krüger A, et al. Inferior vena cava diameter correlates with invasive hemodynamic measures in mechanically ventilated intensive care unit patients with sepsis. J Emerg Med 2010; 38(5):632–7.

[19] Elbaih AH, Ismail MT, Abd Elgwad EE, Hassan F, Helmy A. Detection of medical errors in management of traumatic hypovolemic shocked adult patients presented to Emergency Department in Suez Canal University Hospital, Ismailia, Egypt. Int Surg J 2016; 3(2):882–6; doi:10.18203/2349-2902.isj20161162