Inferior Vena Cava Collapsibility Index versus Central Venous Pressure for Assessment of Intravascular Volume Status in Injured Traumatized Patients

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ABSTRACT

Background: Intravascular volume status assessment is one of the most challenging tasks for clinicians in intensive care unit so fluid therapy is considered as cornerstone in improving the outcome of the injured traumatic patients. Assessment of intravascular volume state is achieved by multiple methods; non-invasively (such as arterial blood pressure (ABP), heart rate (HR), and urine output (UOP)) and invasively as using central venous catheter (CVC).
Objective: The aim was to assess inferior vena cava (IVC) collapsibility index by using ultrasound and to assess central venous pressure through central venous catheter inserted in internal jugular vein to predict intravascular volume status in injured traumatic patients.
Patients and Methods: This cohort prospective study was conducted at Zagazig University Hospitals. It included 36 polytraumatic patients who were admitted in Surgical and Emergent Intensive Care Unit. Male patients represented 55.6% and female patients represented 44.4% of them. Age ranged from 21 to 60 years with mean 35.33 years old, mean BMI was 29.03 kg/m^2 and the severity of trauma varies from moderate to severe (AIS grade 2-4).
Results: The results showed that the mean of IVC collapsibility index gradually decreased in the second day of assessment to 30-38% and decreased more in the third day to 25-35 %. The mean CVP gradually increased in the second day to 4-9 mmH$_2$O and it increased more in the third day to 6-12 mmH$_2$O. This study showed that there was statistically significant inverse correlation between IVC collapsibility index and CVP.
Conclusion: IVC collapsibility index has a strong statistically significant inverse correlation with central venous pressure, which is more accurate at low central venous pressure values.
Keywords: Central venous pressure, Inferior vena cava collapsibility index, Injured traumatized patients, Intravascular volume status.

INTRODUCTION

Trauma is considered as a common cause of death worldwide as it may be associated with blood loss due to traumatic vascular or traumatic organ injury, which may lead to hypovolemic shock (hemorrhage after trauma is responsible for more than 35% of pre-hospital deaths and more than 40% of deaths within the first 24 h) [(1)]**.** In case of severe blood loss, compensatory mechanisms fail to maintain adequate peripheral circulation and lead to severe hypotension, hypoperfusion, multi-organ system failure and death [(2)]**.**

Assessment of hemodynamics can be achieved through invasive and non-invasive methods; invasive methods such as invasive arterial blood pressure and invasive central venous pressure through central venous catheter inserted in jugular vein but their reliability are reduced due to the invasive nature of the procedure and linked complication risks [(3)].

Non-invasive methods include non-invasive arterial blood pressure (ABP), heart rate (HR), and urine output (UOP) monitoring which are more applicable and sensitive without risk of complications [(4)]. IVC collapsibility index is considered as an indirect method to assess central venous pressure by using ultrasound for assessment intravascular fluid status [(5)].

Ultrasonography has an important role in injured traumatic patients, it used to detect volume status, which can affect the patient's condition. Ultrasonography has a lot of advantages such as it is accurate, non-invasive and can be performed by non-radiologist [(6)]**.**

The aim of this study was to assess inferior vena cava collapsibility index by using ultrasound and to assess central venous pressure through central venous catheter inserted in internal jugular vein to predict intravascular volume status in injured traumatic patients. The aim was also to compare in between the inferior vena cava collapsibility index and central venous pressure measurement in predicting the intravascular volume status and to monitoring the effect of optimization of intravascular volume status on the outcome of injured traumatized patients.

PATIENTS AND METHODS

This Cohort prospective study was conducted at Zagazig University Hospitals. In the present study, 36 polytraumatic patients were included. They were admitted in Surgical and Emergent Intensive Care Unit.

Inclusion criteria:

Patient or relative acceptance. Age: 21-65 years old. Both sexes. Patient: traumatized patients in Surgical Intensive Care Unit. Body mass index <35 kg\m^2. Severity of trauma: moderate to severe according to AIS (abbreviated injury score) AIS code (2-4), and type of trauma: polytrauma.

Exclusion criteria:

Pregnant women. Patient with severe tricuspid regurge and pulmonary hypertension. Patient with increase of intra-abdominal pressure (For fallacies due to IVC compression). Patient with chronic obstructive

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pulmonary disease (COPD). Patient with organ failure. Patient on high dose of vasopressors. Patient on mechanical ventilation, and presence of abdominal bandage due to abdominal operations, which can prevent accurate measurement of IVC collapsibility index by ultrasound.

Parameters included in this study:

In this study, measurements were done by intensivist who is trained in critical care ultrasound. Monitoring of intravascular volume status was achieved through measurement of central venous pressure (CVP) through central venous catheter (CVC), which was inserted in internal jugular vein for clinical indications, mean arterial blood pressure (MAP), heart rate (HR) and urine output (UOP) and these data were collected every 12 hours for 3 day. CVP was measured by determining the height of jugular venous pulsation when patient in supine position.

CVP measurement with water manometers:

Before CVP measurement, water manometers was zeroed on the scale with the level of the right atrium. After zeroing, the chamber was almostly filled with fluid (saline or dextrose) by turning the flow tap to allow the fluid to flow through the measuring chamber, while closing flow to the patient. The tap was turned off so the fluid flow was stopped, and the chamber was opened to the patient. The fluid level started to fall down by the effect of gravity until reached to certain level. This level represented that the resistance from the patient's CVP matched the pressure of gravity. Respiratory movement can change pressure slightly (about 1 cm) and it was the cause of the oscillating pattern of the fluid fall.

CVP was measured at level of the mid-axilla and patient lied in a supine position to reflect right atrial pressure. Normal range of CVP is 7-14 cm H_2O. Lower than 7 was considered hypovolemia and resuscitation by fluid was needed. Also IVC collapsibility index (IVC CI) was measured to assess intravascular volume status. IVC collapsibility index was measured through ultrasound device. Siemens Acuson×300 phased array probe for IVC imaging (1-5) was used.

All the measurements were done on IVC in patients in supine position, The probe was placed in the sub-xiphoid region to detect the diameter of IVC at site 2 cm away from right atrium during inspiration and expiration, the marker of the probe was directed cranially and had angle with the skin about 45°, then gently pressed and slide to the patient's right few centimeters. The measuring diameters included IVC diameter during inspiration (IVCi) (the minimum diameter) and expiration (IVCe) (the maximum diameter).

In spontaneous breathing, collapsibility index (CI) was measured as difference between IVCe, IVCi divided by IVCe CI = IVCe – IVCi /IVCe x100.

IVC collapsibility indices were measured by using ultrasound every 12 hours for 3 days.

Data collection:

From each patient, the following data were collected:

Patient characteristics. Type of trauma: polytrauma. Severity of trauma: moderate to severe (AIS code 2-4). Hemodynamics variables: MAP (mean arterial blood pressure), HR and UOP every 12 hours for 3 days. The collapsibility index done on IVC with the patient in supine position every 12 hours for 3days. Measuring CVP through CVC inserted in jugular vein every 12 hours for 3days.

Ethical consent:

An approval of the study was obtained from Zagazig University Academic and Ethical Committee. Every patient signed an informed written consent for acceptance of participation in the study. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis

Data analysis was performed using the software SPSS (Statistical Package for the Social Sciences) version 20. Quantitative variables were described using their means and standard deviations, and range and were compared by repeated measure ANOVA. Categorical variables were described using their absolute and relative frequencies. For ordinal binary data, Kolmogorov-Smirnov (distribution-type) and Levene (homogeneity of variances) tests were used to verify assumptions for use in parametric tests. Pearson correlation coefficient was used to assess strength and direction of relation between two quantitative data. ROC curve was used to determine best cutoff point and other diagnostic indices. The level of statistical significance was set at $P<0.05$. Highly significant difference was present if $P\leq0.001$

RESULTS

This study included 36 patients presented with polytrauma. Male represented 55.6% of them. Age ranged from 21 to 60 years **(Table 1).**

Table (1): Demographic data of the studied patients

	N=36 (%)
Gender:	
Male No. (%) Female No. (%)	20 (55.6 %) 16 (44.4 %)
Age (year):	
Mean ± SD Range	35.33 ± 11.35 21 – 60
BMI (kg/m²)	
Mean ± SD Range	29.03 ± 3.63 23 – 35
Type of trauma:	
Polytrauma	36 (100 %)

This table shows that mean IVC collapsibility index statistically significantly decreased over time (**Table 2)**.

Table (2): inferior vena cava collapsibility index of the studied patients over time

IVC	Mean ± SD	Range
1st day	37.86 ± 1.91	33 – 43
2nd day	34.03 ± 1.84	30 – 38
3rd day	29.44 ± 2.83	25 – 35
P	<0.001**	

: Statistically highly significant

Table (3) shows the mean of HR, MAP, UOP, IVC, and CVP in 3 days.

Table (3): The mean and standard deviations of studied parameters over 3 days

Parameters	First day	Second day	Third day
HR	112.31 ± 12.1	100.86 ± 11.36	91.17 ± 9.71
MAP	75.42 ± 7.64	83.67 ± 7.31	91.11 ± 6.55
UOP	461.39 ± 58.71	580.56 ± 71.99	711.11 ± 87.11
IVC	37.86 ± 1.91	34.03 ± 1.84	29.44 ± 2.83
CVP	4.44 ± 0.84	6.75 ± 1.13	9.39 ± 1.61

There was statistically significant negative correlation between IVC collapsibility index and each of MAP, CVP and urine output on the corresponding point of time. There was significant positive correlation between IVC collapsibility index and heart rate on the corresponding point of time **(Table 4)**.

Table (4): Correlation between inferior vena cava collapsibility index on the first day and the studied parameters

Parameters on 1st day	IVC collapsibility index 1st day	
	R	**P**
MAP	-0.457	0.005*
Heart rate	0.721	<0.001**
CVP	-0.775	<0.001**
UOP	-0.547	<0.001**

***: Statistically significant. **: Statistically highly significant**

There was statistically significant negative correlation between IVC collapsibility index and each of CVP and urine output on the corresponding point of time. There was significant positive correlation between IVC collapsibility index and heart rate on the corresponding point of time **(Table 5)**.

Table (5): Correlation between inferior vena cava collapsibility index on the second day and the studied parameters

Parameters on 2nd day	IVC collapsibility index 2nd day	
	R	P
MAP	-0.275	0.105
Heart rate	0.468	0.004*
CVP	-0.864	<0.001**
UOP	-0.534	<0.001**

***: Statistically significant. **: Statistically highly significant**

There was statistically significant negative correlation between IVC collapsibility index and each of CVP and urine output on the corresponding point of time. There was significant positive correlation between IVC collapsibility index and heart rate on the corresponding point of time **(Table 6)**.

Table (6): Correlation between inferior vena cava collapsibility index on the third day and the studied parameters

Parameters on 3rd day	IVC collapsibility index on 3rd day	
	R	P
MAP	-0.318	0.059
Heart rate	0.477	0.003*
CVP	-0.923	<0.001**
UOP	-0.449	0.006*

***: Statistically significant. **: Statistically highly significant**

The best cutoff of IVC in diagnosis of low CVP was ≥28.5% (**Table 7**).

Table (7): Performance of IVC collapsibility index on third day at 9 pm in prediction of low CVP 9<10 cmH_2O)

Cutoff	AUC	Sensitivity	Specificity	PPV	NPV	Accuracy	P
≥28.5%	0.998	100%	94.7%	94.4%	100%	97.2%	<0.001**

DISCUSSION

In the present study, the mean of IVC collapsibility index in the first day was 37.86 with the range of 33-43%, it gradually decreased in the second and more in the third to 29.44 with the range of 25-35 %. The mean CVP in the first day was 4.44 with the range of 3-6 mmH_2O, it gradually increased in the second and more in third day to 9.39 with the range of 6-12 mmH_2O. The mean ABP in the first day was 75.42 with the range of 60-90 mmHg, it gradually increased in the second and more in the third to 91.11 with the range of 70-105 mmHg. The mean HR was 112.31with the range of 90- 131 beat/minute in the first day, it gradually decreased in the second and more in the third day to 91.17 with the range of 75-110 beat/minute. The mean UOP in the first day was 461.39 with the range of 350-580 ml, it gradually increased in the second and more in the third day to 711.11 with the range of 550 - 900 ml.

In the present study, there was statistically significant negative correlation between IVC collapsibility index and CVP over 3 days of measurement; r was -0.775, -0.864, and -0,923 in the first, second, and third day respectively.

The best cutoff of IVC in diagnosis of low CVP is ≥28.5% with area under curve 0.998, sensitivity 100%, specificity 94.7%, positive predictive value (PPV) 94.4%, negative predictive value (NPV) 100% and accuracy 97.2%.

In the present study, there was statistically significant positive correlation between IVC collapsibility index and heart rate on the corresponding point of time; r =0.721, 0.468, and 0.477 in the first, second, and third day respectively.

In the present study, there was statistically significant negative correlation between IVC collapsibility index and each of MAP in first day only; r= -0,457.

In the present study, there was statistically significant negative correlation between IVC collapsibility index and urine output on the corresponding point of time; r= -0.547, -0.534, and -0.449 in the first, second, and third day respectively.

A study was conducted by **Wiryana *et al.*** [7] over 70 patients. The age range was from 18 to 64 years and body mass index was within normal value. The percentage of male patients was 65.7% and the rest was female patients. The median CVP was 11 cmH_2O with the range 6-18 cmH_2O, the median of maximum IVC diameter was 1.67 mm with the range 1.50 -2.50 mm and the median of IVC collapsibility index was 29.6% with the range from 4.32-69.28%. They found a very strong significant negative correlation between CVP and inferior vena cava collapsibility index (*r=-0.854; p <0.001*). These results agree with the results of the present study.

Karacabey *et al.* [8]**,** conducted a study over 83 patients between June 2012 and October 2012, and the male patients were 48. The mean age was 73.6±11.2 years. The range of systolic blood pressure was (60–220 mmHg) and the mean was (117.6±37.7 mmHg) .The range of diastolic pressure was (30– 140 mmHg) and the mean was (70.5±24.3 mmHg). The range of heart rate was (50–170 beat per minute) and the mean was (102.3±25.8 beat per minute). They found a negative correlation of IVC collapsibility measurements with CVP measurements (r=-0.68, p<0.01)[9]**.** These results agree with the results of the present study.

A study was conducted by **Shalaby *et al.*** [9] over 50 adult patients. The range of age was 30- 60 years. They found a significant negative correlation between IVC collapsibility index and CVP measurement (r = -0.788, p <0.001). Many researchers have documented that there is a good correlation between CVP and the respiratory variability of IVC in spontaneously breathing patients [7-10]. This study agrees with the results of the present study.

A study was conducted by **Ilyas *et al.*** [10]**,** over 100 patients. The male patients represented (68%) and the female patients represent (32%). The mean age of patients was 50.4 ± 19.3 years. The mean of IVC collapsibility index was (30.68 ± 10.93) and the mean CVP was (10.38 ± 4.14 cmH_2O). The mean ABP was (82.6 ± 21.1 mmHg) and the mean HR was (95.2 ± 21.1 beat/minute). The mean IVC minimum diameter was (1.17 ± 0.27 cm) and IVC maximum diameter was (1.75 ± 0.27 cm). They found a strong negative correlation between the CVP and IVC collapsibility and it was statistically significant (r = -0.827, p < 0.0005) and they also found a strong positive correlation between the CVP and the maximum diameter of IVC (r = 0.371, n = 100, p < 0.0005)**.** These results agree with the results of the present study.

CONCLUSION

The conclusion of this study is that IVC collapsibility index has a strong statistically significant inverse correlation with central venous pressure, which is more accurate at low central venous pressure values.

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