Sonographic measurement of Inferior Vena Cava diameters and its usefulness during resuscitation of patients with trauma

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Abstract :

Introduction: Hemorrhagic shock is the leading etiology in most cases of trauma and can be rapidly fatal. Thus adequate fluid resuscitation is required to improve the outcome of patients. CVP is usually used to guide resuscitation. Point-of-care sonography in emergency medicine provides non-invasive assessment of intravascular volume status. Measurement of inferior vena cava does not require special preparation as it can be done along with FAST examination. **Materials & Methods :** This observational study was conducted on patients with history of trauma presenting to Emergency Department. The patients were divided into two groups: a hypotension group with hypotension on presentation and a normotensive group with normal blood pressure. The diameters of IVC both during inspiration (IVCi) and expiration (IVCe) were measured by M-mode ultrasound using a 3-5 MHz Phased Array Transducer. **Results:** Both IVCe and IVCi were significantly smaller in hypotension group as compared to normotension group of patients, while collapsibility index was increased in hypotensive group. The mean IVCe diameter was 7.8 mm in hypotension group. There was positive correlation of IVC parameters to blood pressure, and shock index. Post-resuscitation there was increase in diameters of IVC, decrease in collapsibility of IVC, and significant improvement in the vital parameters. **Conclusion:** The study showed that the measurement of IVC diameter can be used as a reliable tool to guide resuscitation in trauma patients and can help to predict significant hypovolemia, in patients having normal blood pressure.

Key words : Diabetes, Management

Introduction :

Shock is characterized by the widespread failure of the circulatory system to oxygenate and nourish the body adequately. Although the trauma patient is susceptible to shock from many different etiologies, hemorrhagic shock is the leading etiology in most cases and can be rapidly fatal.[1] These deaths usually occur within the first six hours and are often preventable. In the emergency department (ED), initial physical examination findings, hemoglobin levels and hematocrit values are not sufficient in the detection of hemorrhagic shock. Biochemical markers such as arterial lactate and base deficit have been used as surrogate markers for significant hemorrhagic shock, both of which are sensitive indicators of hypo perfusion.[2]

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.[1] Pulmonary artery and central venous pressure catheters, which provide physiologic data such as cardiac output and right atrial pressure are time-consuming, invasive and carry considerable risks.[3]

Intravenous fluid is often the initial treatment in hypotensive patients, aggressive volume resuscitation may be detrimental in some patients and in certain types of shock.The use of point-of-care sonography grows in critical care and

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emergency medicine, non-invasive assessment of intravascular volume status is increasingly being used to guide therapy of the critically ill.[4]

It was found that in patients with spontaneous respiration there was a significant relationship between IVC (inferior vena cava) diameters measured by bedside ultrasonography at the end of expiratory and inspiratory phases and measured CVP (central venous pressure) values at the same phases. Thus IVC diameter measurement can be used for the determination of intravascular volume status.[5]

Aims and Objectives:

- To measure the diameter of IVC and its respiratory variation (collapsibility index), in all spontaneously breathing trauma patients.
- To compare the diameter of IVC and collapsibility index in patients with hypotension (systolic blood pressure equal or less than 90 mmHg) and in patients without hypotension (normotension).
- To see for fluid responsiveness in patients receiving resuscitation.
- To compare the IVC diameters and collapsibility index in pre and post resuscitation group of patients.

Materials and Methods :

This observational study was conducted on patients with history of trauma (road traffic accident, fall down, assault and others) coming to Emergency Department in a tertiary care centre between the period of May 2017 - April 2018.

ATLS (Advanced Trauma Life Support) protocol was followed, and the patients were divided into two groups: a shock group who were hypotensive (SBP $\leqslant$ 90 mmHg) and a control group who were without hypotension. One litre of crystalloid was used as a bolus during the resuscitation of the patient. The diameters of IVC both during inspiration (IVCi) and expiration (IVCe) were measured by M-mode ultrasound (Sonosite-Micromaxx machine) using a 3-5 MHz Phased Array Transducer. Measurements were made before and after resuscitation. The ultrasound examination was performed by the emergency physician.

All examinations were performed in supine position with the ultrasound transducer placed over the sub-xiphoid location. Saggital sections of the IVC behind the liver were imaged and the maximal diameter of the IVCe and the minimal diameter of the IVCi was measured in M mode ultrasound. The collapsibility index was taken as IVCe – IVCi/IVCe. To measure the IVC diameter, electronic callipers keys of the keyboard sonogram device were used at right angles to the axis of the vascular system (inner to inner diameter) on the screen.

Demographic details of patients and details of mechanism of injuries were recorded. The Glasgow Coma Scale (GCS) scores were recorded. Recorded patient information and baseline characteristics from case record were coded and entered in a Microsoft Excel worksheet. Data was analyzed using appropriate statistical tests. IRB approval was taken.

Exclusion criteria :

- Patients younger than 18 years were excluded.
- Patients with or requiring positive pressure ventilation were excluded.
- Patients presenting with ionotropic support were excluded.
- Patients who developed cardiopulmonary arrest in the emergency department and patients who were not suitable for ultrasound visualization of IVC due to technical problems (severe obesity, severe gas distension, stab

wound at the epigastrium or other problems that prohibit optimal visualization of IVC) were excluded from the study.

- Patients with a newly diagnosed or known history of cor-pulmonale, tricuspid valve regurgitation, and congestive heart failure were excluded.
- Trauma patients with an eventual diagnosis of cardiac tamponade and/or tension pneumothorax were excluded from analysis.

Observation and Results :

Total 103 patients were included after applying exclusion criteria. Out of 103 patients, 91 patients received resuscitation and 12 patients did not received resuscitation as they were with minor injuries. Of those 91 patients, 24 patients presented to ER (Emergency Room) with hypotension (hypotension group) and 67 patients presented without hypotension (normotension group).

Mean age of patients with hypotension (24 patients) was 38.37 years and mean age of patients with normotension (67 patients) was 38.28 years. Mean age of all patient was 38.49 ± 14.10 year, with majority in between age group of 20 - 30 years. Majority of patients were male (70%).

It was observed that road traffic accident was the most common cause for trauma (59%), followed by fall down, assault injuries, machine injury, railway injuries and injury after fall of a wall.Most common observed injury was isolated head injury (n=56), followed by head injury associated with other injuries, long bone injuries, abdominal injuries, thoracic injuries, pelvic and spinal injuries.Long bone injuries were found in 40 patients, abdominal injuries were found in 15 patients, thoracic injuries were found in 11 patients, pelvic injuries were found in 8 patients and 3 patients had spinal injuries. FAST scan was positive in 13 patients of abdominal trauma and EFAST scan was positive in 9 patients.

Comparison of means of vital parameters, shock index (SI) and IVC measurements of all patients before and after resuscitation were as shown in table 1, table 2, and table 3.

As shown in table 3, there was higher change in MAP among patients presenting with hypotension as compared to those without hypotension after resuscitation.

The inferior vena cava collapsibility index was positively co-related to shock index (SI) with value of r value of 0.455 and r^2 value of 0.207.

As shown in Fig 1, IVCe was positively correlated with systolic blood pressure with value of r value of 0.604 and r^2 value of 0.365.

As shown in Fig 2, IVCi was positively correlated with systolic blood pressure with value of r value of 0.484 and r^2 value of 0.235.

Mortality was seen in 19 patients (18.44%). It was observed in our study that, as the shock index (SI) increased, patient's prognosis worsened but was not statistically significant (P=0.14). Mean SI of discharged patients on presentation was 1.047 ± 0.43 as compared to SI of patients who died 1.25 ± 0.53.

Disposition of patient was done according to clinical severity and was individualized.

Discussion :

In our study, the most common age group affected was 20-30 years. The mean age of patients in hypotension group (38.37 years) and patients in normotension group (38.28), were comparable to Nguyen et al[6] (38 and 39 years respectively) and Matsumoto et al[7] (41 years).

It was observed that, male patients (70%) had more trauma which was comparable to other studies done by Yang Li et al[8] (83%), Airapetian et al[9] (51%). This might be because of higher outdoor

Table 1 : Comparisons of means of all patients

Parameters	All patients (91) before resuscitation Mean ± SD (CI)	All patients (91) after resuscitation Mean ± SD (CI)	No resuscitation group (12) Mean ± SD (CI)
Heart rate beats/min	108.5 ± 21.63 (104.01-113.04)	95.89 ± 14.48 (92.86-98.91)	82 ± 10.26 (75.47-88.52)
SBP mmHg	107.75 ± 22.02 (103.16-112.35)	121.49 ± 15.20 (118.32-124.67)	138.16 ± 21.19 (124.7-151.63)
DBP mmHg	69.60 ± 17.77 (65.89-73.31)	79.95 ± 9.10 (78.05-81.85)	86.16 ± 9.47 (80.14-92.18)
MAP (65-110) mmHg	82.32 ± 18.76 (78-86.24)	93.80 ± 10.22 (91.66-95.93)	103.5 ± 12.65 (95.46-111.54)
Shock Index (0.5-0.7) HR/SBP	1.089 ± 0.46 (0.99-1.18)	0.80 ± 0.19 (0.76-0.84)	0.60 ± 0.10 (0.53-0.67)
Mod. Shock Index (0.7-1.3) HR/MAP	1.461 ± 0.70 (1.31-1.69)	1.04 ± 0.24 (0.99-1.095)	0.80 ± 0.31 (0.71-0.88)
IVCe (mm)	10.04 ± 2.88 (10.38-11.54)	13.08 ± 2.64 (12.54-13.56)	16.63 ± 4.34 (13.88-19.39)
IVCi (mm)	5.24 ± 2.4 (4.74-5.74)	7.41 ± 2.41 (6.9-7.91)	11.60 ± 3.68 (9.25-13.94)
Collapsibility Index (IVCe-IVCi/IVCe) (%)	53.89 ± 12.4 (51.29-56.49)	44.23 ± 9.76 (42.19-46.27)	30.54 ± 7.19 (25.97-35.11)

Table 2: Comparisons of means of patients

Parameters	Hypotension group before resuscitation (24) Mean ± SD (CI)	Hypotension group after resuscitation (24) Mean ± SD (CI)	Normotensive group before resuscitation (67) Mean ± SD (CI)	Normotensive group after resuscitation (67) Mean ± SD (CI)
Heart rate beats/min	130± 14.71 (123.45-135.88)	107.83± 14.10 (101.88-113.79)	101.49± 18.25 (97.03-105.95)	91.61± 12.10 (88.65-94.56)
SBP mmHg	78.95± 10.97 (74.30-83.50)	104.75± 8.90 (100.99-108.51)	118.08± 14.13 (114.57-121.61)	127.49± 12.21 (124.51-130.57)
DBP mmHg	45.79± 11.79 (40.81-50.77)	71.5± 10.55 (67.04-75.95)	78.13± 10.11 (75.66-80.60)	82.98± 6.23 (81.46-84.50)
MAP (65-110) mmHg	56.84± 10.73 (52.31-61.38)	82.58± 9.15 (78.71-86.44)	91.45± 10.92 (88.78-94.12)	97.82± 7.15 (96.07-99.56)
Shock Index (0.5-0.7) HR/SBP	1.69± 0.44 (1.5-1.88)	1.04± 0.16 (0.97-1.11)	0.87± 0.19 (0.83-0.92)	0.72± 0.11 (0.69-0.75)
Mod. Shock Index (0.7-1.3) HR/MAP	2.39± 0.72 (2.08-2.69)	1.32± 0.26 (1.21-1.43)	1.13± 0.26 (1.06-1.19)	0.94± 0.14 (0.9-0.97)
IVCe (mm)	7.87± 1.42 (7.27-8.47)	10.86± 1.45 (10.25-11.48)	12.03± 2.45 (11.14-12.63)	13.88± 2.52 (13.27-14.50)
IVCi (mm)	3.07± 1.37 (2.49-3.65)	5.50± 1.61 (4.82-6.19)	6.01± 2.21 (5.48-6.55)	8.09± 2.29 (7.53-8.65)
Collapsibility Index (IVCe-IVCi/IVCe) (%)	62.13± 12.65 (56.78-67.47)	50.03± 10.02 (45.80-54.26)	50.94± 11.08 (48.24-53.64)	42.15± 8.04 (39.99-44.31)

P value was <0.05 for all parameters as calculated using unpaired t test.

Table 3 : Comparison of change in MAP after resuscitation and its significance

Parameters	Mean of MAP before resuscitation	Mean of MAP after resuscitation	Change in Mean of MAP	P value
Patient with Hypotension	56.84	82.58	25.74	<0.001
Patient without Hypotension	91.45	97.82	6.37	

Fig 1: Correlation of IVCe of patients receiving resuscitation (n=91) to SBP

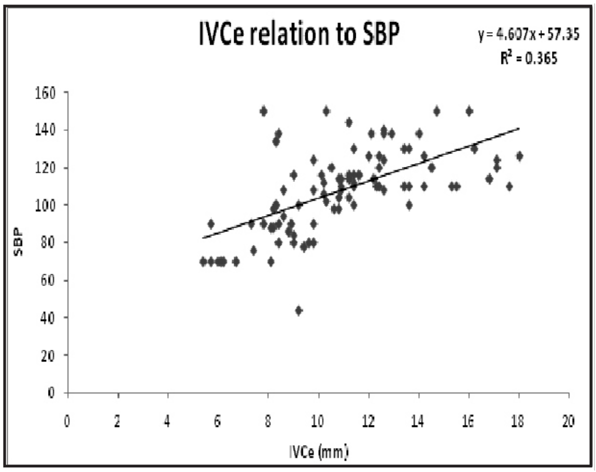
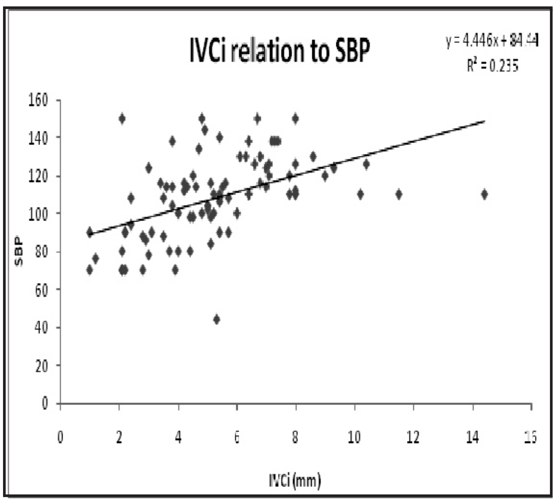


Fig 2: Correlation of IVCiof patients receiving resuscitation (n=91) to SBP



activities and high risk taking behaviour of males.

In our study, no significant differences were found between the age and sex in two groups studied.

In all studied groups of patients, road traffic accident, fall down and assault injuries were the common mechanisms of injury.

In our study, road traffic accident was observed to be the major cause of trauma, which was comparable to Yang Li et al[8], but in the study done by Nguyen et al[6], penetrating injuries (gunshot and stab) were the major cause of trauma.

In our study, the mean heart rate of all patients was 108.5 beats/min which was higher than study done by Radomski et al[10], 88.6 beats/min.

In our study, mean systolic blood pressure of all patients was 107.75 mmHg, which was higher as compared to study done by Radomski et al (97.1 mmHg).[10]

Both IVCe and IVCi were significantly smaller in hypotension group patients, a finding that correlates to Yanagawa et al.[11] The maximum IVCe diameter in the hypotension group was 9.8 mm in our study. In a study by Ando et al[12], in hemodialysis patients the IVCe diameter below which hypotension would occur was 8±3 mm. Yanagawa et al[11] found that IVCe diameter of below 9 mm was associated with shock in trauma patients.

Statistical analysis and comparison were as shown in table 4.

In our study, correlation analysis showed positive correlation of IVCe diameter with systolic blood pressure, diastolic blood pressure, mean blood pressure, shock index and modified shock index.

As shown in Fig 1, in our study IVCe was positively correlated to the systolic blood pressure, with rvalue of 0.604 and r^2 value of 0.365.

As shown in Fig 3, in the study done by Sefidbakht et al, correlation analysis of IVCe with blood pressure showing positive correlation with r^2 value of 0.529.

As shown in Fig 2, in our study diameter of inferior vena cava during inspiration was positively related to systolic blood pressure as shown in the above figure with value of r value of 0.485 and r^2 value of 0.235.

As shown in fig 4, in the study done by Sefidbakht et al, correlation analysis of IVCi with Blood pressure showed positive correlation with r^2 value of 0.544.

In our study, post-resuscitation, there was decrease in collapsibility of IVC, increase in diameters of IVCe and IVCi with significant improvement in the vital parameters.

In Yanagawa et al[(11)] prospective study, IVC diameter in the shock group (n=13) trauma patients was measured during expiration. The IVC diameter increased significantly, in comparison to admission values and those after five days of treatment. Only AP IVC diameter in expiration was evaluated. The AP IVC diameter in the shock group was significantly lower than in the control group at admission. Lyon et al.[(13)] found a significant difference between IVC diameters during inspiration and expiration in 31 healthy blood donors before and after giving blood.

According to the study done by Henry et al[(14)], a Caval Index (collapsibility index) of greater than or equal fifty percent (CI % ⩾ 50%) was predictive of greater fluid responsiveness to initial bolus of 500ml to 2000ml than a Caval Index of less than fifty percent (CI % <50%).

Previous literature suggests that, a change in mean blood pressure of greater or equal to 10 mmHg was considered clinically significant, where as a change of 5 mmHg was considered not clinically significant.[(15-17)]

Both groups in our study had collapsibility indexes of ⩾ 20% which was higher in the shock group, mostly due to volume depletion and more strenuous cardiac activity.

Minutiello et al,[(18)] revealed that a collapsibility index of ⩾20% was associated with the absence of cardiac disease. However, most trauma patients were young and unlikely to have heart disease. Measuring the collapsibility index can also be very helpful in diagnosing patients with heart disease.

The normal shock index, defined as heart rate divided by systolic blood pressure, ranges from 0.5 and 0.72 in adults.[(19)] An increase in shock index occurs with progressive loss in circulation blood volume (CBV) and a shock index >1 was an indicator of blood loss and high mortality.[(19,20)] It was observed in our study that, as the shock index (SI) increased, patient's prognosis worsened but was not statistically significant (P=0.14).

Kevin et al,[(21)] in their study found correlation between shock index of >0.9 and mortality.

Soon YK et al,[(22)] in their study found that as shock index, modified shock index increased, there was increased mortality. They even found better correlation by age specific shock index.

Conclusion :

Since hypotension in the emergency department has been shown to be an independent predictor of in-hospital mortality, early identification, stratification and intervention will be essential to improve outcomes. Tachycardia only suggested

Table 4 : Statistical comparison of patients with hypotension (n=24) on presentation to Civil hospital before resuscitation

Variable		HR beats /min before resuscitation	HR beats /min after resuscitation	SBP mmHg before resuscitation	SBP mmHg after resuscitation	IVCe (mm) before resuscitation	IVCe (mm) After resuscitation	IVCi (mm) before resuscitation	IVCi (mm) After resuscitation
Our Study	Hypotension	130	107.83	78.95	104.75	7.87	10.86	3.07	5.50
	Normotension	101.49	91.61	118.08	127.49	12.03	13.88	7.09	8.09
Yanagawa et al[11]	Hypotension	104.3	103.3	77.1	105.9	6.1	6.5	-	-
	Normotension	113	107.5	78	113.5	6.9	6.5	-	-
Sefidbakht et al[1]	Hypotension	95.4	-	77.7	-	5.6	-	4.0	-
	Normotension	91.6	-	114.7	-	11.9	-	9.6	-

acute blood loss, and heart rate can vary widely according to different internal and external stimulus. Central venous pressure has its own limitation of invasiveness, time consumption and risk of bleeding.

Measurement of IVC diameter, therefore, can be a very useful way to evaluate the patient's hemodynamic status. This was easily performed and was well suited in trauma patients because it could be performed in supine position and required no patient cooperation.

The results of our study suggested, that IVC diameter was smaller in those patients with hypotension on presentation as compared to those with normotension.Patients with >50% collapsibility of IVC required aggressive resuscitation as compared to those with <50% collapsibility.IVC was >50% collapsible in many patients who presented without hypotension suggesting blood loss despite normal blood pressure. IVC collapsibility reduced post resuscitation in both group of patients.

The use of bedside ultrasound may be a very useful tool for rapidly stratifying the patients requiring immediate resuscitation, may even predict significant hypovolemia in patients who still have normal blood pressure due to sympathetic over activity, monitor ongoing blood loss and also it can be used to assess fluid responsiveness. IVC diameter evaluation can be done soon after FAST and EFAST scan. It can be done without any special preparation or any invasive procedures and with an added advantage of preventing over or under resuscitation.

Fig 3 : Correlation of IVCe diameter with blood pressure of Sefidbakht et al

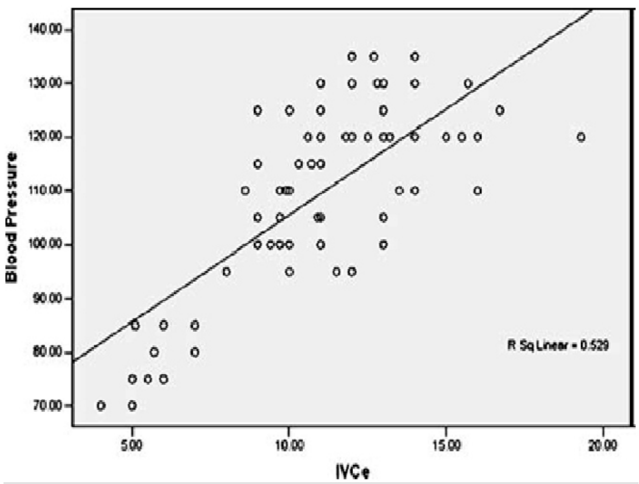
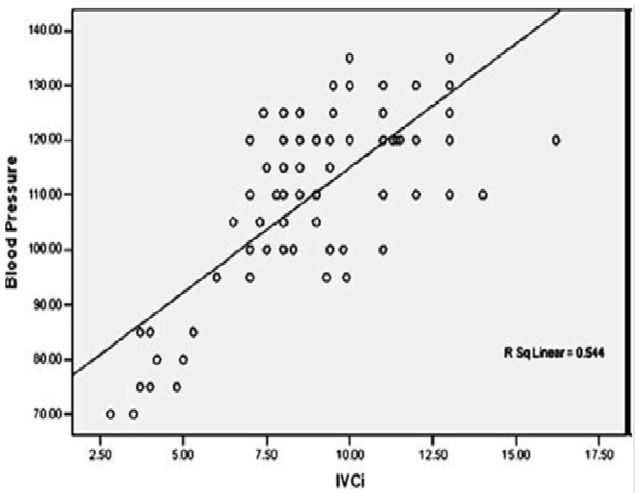


Fig 4 : Correlation of IVCi diameter with blood pressure of Sefidbakht et al



Limitations :

Limitation to our study was of small sample size and single centre study.Another potential limitation of IVC diameter measurement may be in patients with elevated intra-abdominal pressure because narrowing of the upper abdominal IVC unrelated to circulating blood volume can occur.In the current study, the data for children were not investigated.

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