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Original Research Article

SONOGRAPHIC ASSESSMENT OF INFERIOR VENA CAVA COLLAPSIBILITY INDEX DURING RESUSCITATION AND ITS CORRELATION WITH CLINICAL PARAMETERS IN TRAUMA PATIENTS

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ABSTRACT

Background: Traumatic hypovolemic shock is a life-threatening emergency requiring rapid & timely resuscitation. Accurate bedside assessment of intravascular volume status remains challenging. The Modified Shock Index (MSI) and the Inferior Vena Cava Collapsibility Index (IVCCI) are non-invasive parameters that may aid early detection and monitoring of hypovolemia. The aim is to evaluate changes in inferior vena cava (IVC) diameter and collapsibility index before and after fluid resuscitation in patients with traumatic haemorrhagic shock and to determine the correlation between IVCCI and clinical parameters, including MSI. **Materials and Methods:** A prospective observational study was conducted among 44 spontaneously breathing adult trauma patients presenting with systolic blood pressure <90 mmHg and classified as Class III or IV hemorrhagic shock. Serial assessments of vital parameters, MSI and IVC diameters were performed using point-of-care ultrasound. Measurements were obtained at five time points from arrival to 6 hours following resuscitation with intravenous balanced crystalloids and blood products (T0–T4). The IVCCI was calculated, and its correlation with clinical parameters was analysed. **Results:** Post-resuscitation, significant improvements were observed in vital parameters systolic and diastolic blood pressure, mean arterial pressure, heart rate, respiratory rate and MSI ($p < 0.0001$). IVC diameters increased progressively, while IVCCI decreased significantly, indicating improved intravascular volume status. On arrival, Inferior Vena Cava Diameter at Inspiration (IVCi) and IVCCI showed significant correlation with heart rate. At 6 hours, both demonstrated strong correlations with blood pressure, mean arterial pressure, heart rate, and MSI. **Conclusion:** MSI and IVCCI are reliable non-invasive markers for assessing and monitoring traumatic hypovolemic shock.

INTRODUCTION

Traumatic haemorrhage remains a major cause of preventable mortality among trauma patients presenting to emergency departments worldwide, primarily due to hypovolemic shock and delayed recognition of circulatory compromise.[1,2] Early identification of intravascular volume depletion is therefore crucial for timely resuscitation and improved outcomes.[3] Conventional vital signs such as blood pressure and heart rate may remain normal during the early stages of shock, limiting their reliability in trauma assessment.[4] The Shock Index and its derivative, the Modified Shock Index (MSI), have been proposed as simple bedside indicators of hemodynamic instability and predictors of mortality.[5] Point-of-care ultrasound evaluation of the inferior vena cava (IVC), particularly the IVC collapsibility index (IVCCI), has emerged as a non-invasive tool for estimating volume status and guiding fluid resuscitation in critically ill and trauma patients.[6,7]

MATERIALS AND METHODS

Study Design and Setting: This prospective observational study was conducted in the Emergency Department of a tertiary care teaching hospital. The study aimed to evaluate the usefulness of The Inferior Vena Cava Collapsibility Index (IVCCI) measured using point-of-care ultrasound for assessing intravascular volume status during resuscitation in trauma patients presenting with hypovolemic shock. The sample size was calculated as 44 patients based on previously published data on the inferior vena cava index in trauma patients.[8]

Adult trauma patients presenting to the emergency department with features suggestive of hypovolemic shock were screened for eligibility during the study period. We included spontaneously breathing trauma patients (road traffic accidents, assault, fall from height, animal attacks, and fall of heavy objects) with systolic blood pressure <90 mmHg, corresponding to Class III or Class IV hemorrhagic shock. We excluded patients in pediatric age group, pregnant patients, patients requiring mechanical ventilation or inotropic support at presentation, patients in cardiopulmonary arrest, patients in whom adequate IVC visualization was not possible due to severe obesity, excessive bowel gas, epigastric injury, or subcutaneous emphysema, patients with newly diagnosed or known cor pulmonale, tricuspid regurgitation, or congestive heart failure and patients diagnosed with obstructive, neurogenic, cardiogenic, or distributive shock.

All patients were managed according to the Advanced Trauma Life Support (ATLS) protocol. Initial resuscitation included administration of 1 L of Ringer's lactate and blood products, as clinically indicated, during the resuscitation phase.

Ultrasound assessment of the inferior vena cava was performed at the bedside using a Mindray UMT-200 ultrasound system equipped with low-frequency Curvilinear probe (2.5–5 MHz). Measurements were obtained with the patient in the supine position using M-mode imaging through the subxiphoid window, approximately 2 cm distal to the right atrium. The following measurements were recorded: IVC diameter during inspiration (IVCi) and IVC diameter during expiration (IVCe). The inferior vena cava collapsibility index (IVCCI) was calculated using the formula: IVCCI= (IVCe−IVCi)/IVCe.

IVC measurements were obtained at five predefined time points: T0 – On arrival, T1 – 1 hour after resuscitation, T2 – 2 hours after resuscitation, T3 – 4 hours after resuscitation, T4 – 6 hours after resuscitation. At each time point, the following clinical parameters were recorded: Heart rate (HR), Systolic blood pressure (SBP), Diastolic blood pressure (DBP), and Respiratory rate (RR) and Mean arterial pressure (MAP). The Modified Shock Index (MSI) was calculated for each measurement using the formula Heart Rate/Mean Arterial Pressure. The primary outcome was to evaluate the changes in IVC diameters and IVCCI following resuscitation. Secondary outcomes included assessing the correlation between IVCCI and clinical parameters, particularly MSI, during the course of resuscitation.

All ultrasound examinations were performed by trained emergency physicians experienced in point-of-care ultrasound and familiar with standardized techniques for IVC assessment. The study protocol was reviewed and approved by the Institutional Ethics Committee of the hospital. Written informed consent was obtained from patients or their legally authorized representatives prior to enrolment in the study.

Data were entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS) software. Categorical variables were expressed as frequencies and percentages. Continuous variables were presented as mean ± standard deviation. The Pearson correlation coefficient was used to assess the linear relationship between IVC parameters and clinical variables. Receiver operating characteristic (ROC) curve analysis was used to determine sensitivity, specificity, and optimal cut-off values. Chi-square tests were used to compare categorical variables. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 44 patients presenting with traumatic hemorrhagic shock were included in the study. The mean age of the study population was 42.95 years. The majority of patients belonged to the >50-year age group (38.64%), followed by 20–29 years (20.45%) and 30–39 years (20.45%). Patients aged 40–50 years constituted 18.18%, while 2.27% were younger than 20 years.

Male patients predominated in the study population. Thirty-two patients (72.73%) were males, while 12 patients (27.27%) were females, with a male-to-female ratio of 2.67:1. Significant improvements were observed in all hemodynamic parameters following resuscitation. The mean systolic blood pressure (SBP) increased progressively from 71.72 ± 11.98 mmHg at arrival (T0) to 89.04 mmHg at 1 hour, 100.18 mmHg at 2 hours, 107.45 mmHg at 4 hours, and 114.90 mmHg at 6 hours, showing a statistically significant improvement ($p < 0.0001$). Similarly, the mean diastolic blood pressure (DBP) increased from 39.50 ± 6.75 mmHg at arrival to 50.09 mmHg, 60.68 mmHg, 65.13 mmHg, and 67.54 mmHg at 1, 2, 4, and 6 hours, respectively ($p < 0.0001$).

In contrast, heart rate (HR) showed a progressive reduction during resuscitation. The mean HR decreased from 119.31 ± 7.90 beats/min at arrival to 110.02, 100.02, 92.09, and 85.68 beats/min at 1, 2, 4, and 6 hours, respectively ($p < 0.0001$). The mean

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respiratory rate (RR) also decreased significantly from 22.68 ± 2.35 breaths/min at arrival to 18.15, 15.84, 14.84, and 14.90 breaths/min at subsequent time intervals ($p < 0.0001$).

The mean arterial pressure (MAP) showed a progressive increase from 50.23 ± 7.60 mmHg at arrival to 63.26, 73.84, 79.24, and 83.33 mmHg at 1, 2, 4, and 6 hours, respectively ($p < 0.0001$). The Modified Shock Index (MSI) decreased significantly following resuscitation. The mean MSI decreased from 2.44 ± 0.49 at arrival to 1.76 at 1 hour, 1.36 at 2 hours, 1.16 at 4 hours, and 1.03 at 6 hours, demonstrating a statistically significant trend ($p < 0.0001$).

Significant changes were observed in the sonographic measurements of the inferior vena cava following resuscitation. The IVC diameter during inspiration (IVCi) increased progressively from 5.12 ± 0.58 mm at arrival to 6.36 mm at 1 hour, 7.58 mm at 2 hours, 8.75 mm at 4 hours, and 9.93 mm at 6 hours ($p < 0.0001$). Similarly, the IVC diameter during expiration (IVCe) increased from 11.06 ± 0.50 mm at arrival to 12.39 mm, 13.81 mm, 14.81 mm, and 16.04 mm at 1, 2, 4, and 6 hours, respectively ($p < 0.0001$).

In contrast, the IVC collapsibility index (IVCCI) showed a progressive decrease following resuscitation. The mean IVCCI decreased from 53.85% ± 3.71 at arrival to 48.70% at 1 hour, 45.12% at 2 hours, 40.92% at 4 hours, and 38.10% at 6 hours ($p < 0.0001$). On arrival, IVC diameter during inspiration (IVCi) showed a statistically significant correlation with heart rate ($p = 0.048$). Similarly, IVC collapsibility index at arrival demonstrated a significant correlation with heart rate ($p = 0.032$).

At 6 hours following resuscitation, IVCi showed significant correlations with systolic blood pressure ($p = 0.0018$), diastolic blood pressure ($p = 0.0164$), mean arterial pressure ($p = 0.0216$), heart rate ($p = 0.0329$), and modified shock index ($p = 0.0492$). IVC diameter during expiration at 6 hours also demonstrated significant correlations with systolic blood pressure ($p = 0.0162$), diastolic blood pressure ($p = 0.0262$), mean arterial pressure ($p = 0.0051$), respiratory rate ($p = 0.0135$), and modified shock index ($p = 0.05$). Furthermore, IVC collapsibility index at 6 hours showed significant correlations with systolic blood pressure ($p = 0.0183$), diastolic blood pressure ($p = 0.0038$), mean arterial pressure ($p = 0.0206$), heart rate ($p = 0.006$), and modified shock index ($p = 0.0198$).

Table 1: Comparative Statistics of Vital Parameters:

Parameter	Time	Mean	SD	IQR	p value
Systolic Blood Pressure	T0	71.727	11.989	17	<0.0001
	T1	89.045	9.336	16	
	T2	100.182	7.228	14	
	T3	107.455	7.463	10	
	T4	114.909	7.300	10	
Diastolic Blood Pressure	T0	39.500	6.753	6	<0.0001
	T1	50.091	7.370	1.5	
	T2	60.682	5.770	0	
	T3	65.136	5.019	10	
	T4	67.545	5.419	6	
Heart Rate	T0	119.318	7.906	14	<0.0001
	T1	110.023	6.136	10	
	T2	100.023	5.959	8.25	
	T3	92.091	4.836	6.5	
	T4	85.682	3.893	7.25	
Respiratory Rate	T0	22.682	2.350	3	<0.0001
	T1	18.159	2.332	4	
	T2	15.841	1.033	1	
	T3	14.841	0.680	1	
	T4	14.909	0.640	0.25	
Mean Arterial Pressure	T0	50.238	7.600	9.5025	<0.0001
	T1	63.262	7.024	6.66	
	T2	73.846	5.367	6.66	
	T3	79.240	3.713	3.34	
	T4	83.330	3.850	6.66	

Table 2: Comparative Statistics of Modified Shock Index and IVC measurements and indices:

Parameter	Time	Mean	SD	IQR	p value
Modified Shock Index	T0	2.444	0.491	0.6225	<0.0001
	T1	1.763	0.268	0.31	
	T2	1.365	0.161	0.225964	
	T3	1.165	0.079	0.124538	
	T4	1.032	0.068	0.093916	
IVC Diameter (Inspiration)	T0	5.128	0.580	0.9725	<0.0001
	T1	6.367	0.540	0.975	
	T2	7.582	0.504	0.895	
	T3	8.752	0.479	0.67	

	T4	9.933	0.456	0.6425	
IVC Diameter (Expiration)	T0	11.065	0.500	0.7975	<0.0001
	T1	12.398	0.531	0.92	
	T2	13.813	0.505	0.6525	
	T3	14.812	0.428	0.525	
	T4	16.045	0.359	0.525	
IVC Collapsibility Index	T0	53.855	3.712	4.9375	<0.0001
	T1	48.706	2.818	3.766699	
	T2	45.126	2.828	3.859046	
	T3	40.925	2.474	3.145179	
	T4	38.101	2.242	2.685593	

Table 3: Correlation between parameters at T0:

Variable At T0	IVC Diameter Inspiration		IVC Diameter Expiration		IVCCI	
	R	P	R	P	R	P
Systolic Blood Pressure	0.8321	0.6924	0.7854	0.6169	-0.79	0.6239
Diastolic Blood Pressure	0.3989	0.1591	0.3507	0.123	-0.4031	0.1625
Heart Rate	-0.22	0.0483	-0.285	0.0815	0.1792	0.0321
Respiratory Rate	-0.533	0.2845	-0.554	0.3067	0.4709	0.2217
Mean Arterial Pressure	0.6741	0.4544	0.621	0.3856	-0.6544	0.4282
Modified Shock Index	-0.638	0.4065	-0.6	0.3601	0.6248	0.3904

Table 4: Correlation between parameters at T4:

Variable At T4	IVC Diameter Inspiration		IVC Diameter Expiration		IVCCI	
	R	P	R	P	R	P
Systolic Blood Pressure	0.0419	0.0018	-0.127	0.0162	-0.135	0.0183
Diastolic Blood Pressure	0.1281	0.0164	0.162	0.0262	-0.062	0.0038
Heart Rate	0.1468	0.0216	0.0717	0.0051	-0.143	0.0206
Respiratory Rate	-0.1815	0.0329	-0.251	0.063	0.0775	0.006
Mean Arterial Pressure	-0.335	0.1124	-0.116	0.0135	0.3537	0.1251
Modified Shock Index	-0.2219	0.0492	-0.232	0.0539	0.1406	0.0198

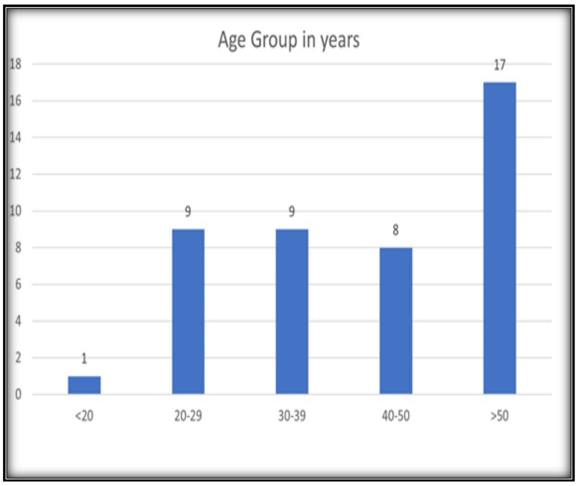

Figure 1: Age Distribution of Study Population:

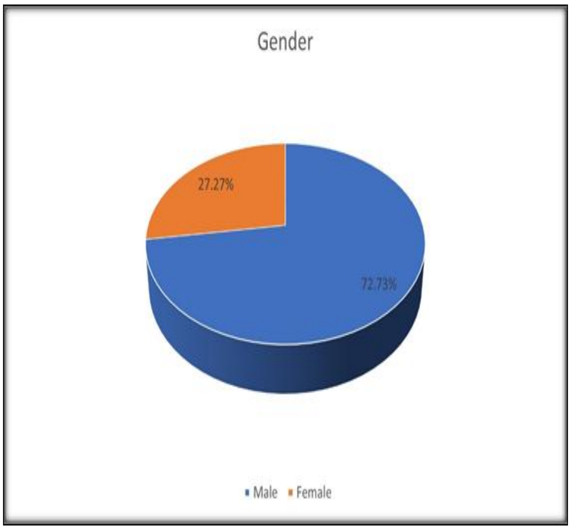

Figure 2: Gender Distribution of Population:

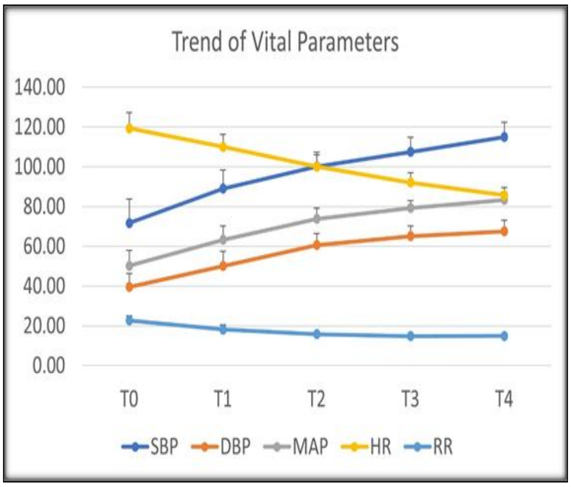

Figure 3: Trend of Vital Parameters.

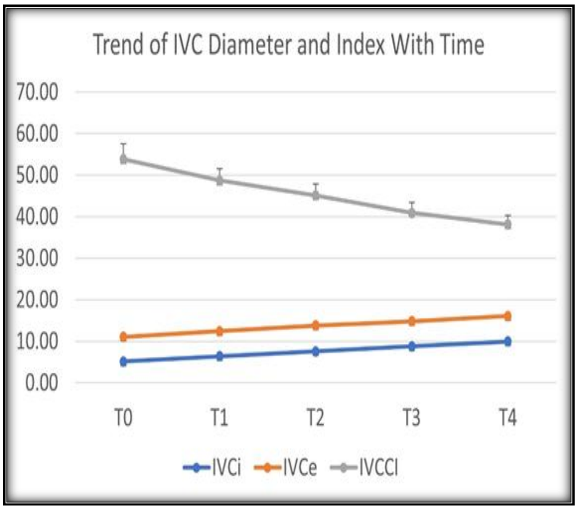

Figure 4: Trend of IVC Diameter and Index with Time.

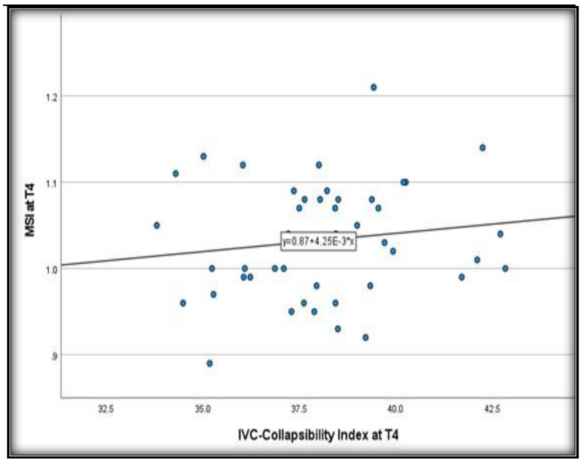

Figure 5: Correlation between IVC Collapsibility index at T4 and Modified Shock Index at T4

DISCUSSION

Traumatic haemorrhage continues to be one of the leading causes of preventable mortality among trauma patients worldwide, particularly during the early phase following injury when hypovolemic shock develops rapidly if not promptly recognized and treated.[1] Early identification of intravascular volume depletion is therefore essential for initiating timely resuscitation and preventing end-organ hypoperfusion.[9] However, conventional vital signs such as blood pressure and heart rate may remain relatively preserved during the early stages of hemorrhagic shock due to compensatory mechanisms, thereby limiting their sensitivity as early indicators of significant blood loss.[10]

In the present study, the mean age of patients was 42.95 years, with a predominance of male patients (72.73%). This demographic pattern is consistent with the epidemiology of trauma worldwide, where young and middle-aged males represent the majority of victims due to increased exposure to high-risk activities such as road traffic accidents and occupational hazards.[11]

Our study demonstrated significant improvement in hemodynamic parameters following resuscitation. Systolic blood pressure, diastolic blood pressure, and mean arterial pressure showed progressive increases from arrival to six hours after resuscitation, while heart rate and respiratory rate showed significant reductions. These findings are consistent with the physiological response to adequate fluid resuscitation in hemorrhagic shock, where restoration of circulating volume improves cardiac output and tissue perfusion.[12] Similar improvements in vital parameters following resuscitation have been reported in trauma resuscitation studies evaluating fluid responsiveness and early hemodynamic stabilization.[13]

The Modified Shock Index (MSI) in our study showed a significant reduction from 2.44 at presentation to 1.03 at six hours following resuscitation. The shock index and its derivatives have been widely investigated as simple bedside tools for assessing hemodynamic instability and predicting mortality in trauma patients.[14] Studies have demonstrated that elevated shock index values are associated with increased risk of severe haemorrhage, need for massive transfusion, and higher mortality rates.[15] Berger et al. demonstrated that the Modified Shock Index, which incorporates mean arterial pressure, may provide improved predictive ability for adverse outcomes compared to the traditional shock index.[16]

In addition to clinical parameters, this study evaluated sonographic measurements of the inferior vena cava as indicators of intravascular volume status. We observed a progressive increase in both inspiratory and expiratory IVC diameters during the course of resuscitation. These findings support the concept that IVC diameter reflects venous return and right atrial pressure, both of which increase as circulating volume is restored during fluid resuscitation.[17]

Conversely, the IVC collapsibility index showed a progressive decline during the resuscitation period. The collapsibility index represents the degree of respiratory variation in IVC diameter and is widely considered an indirect indicator of intravascular volume status in spontaneously breathing

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patients.[18] In hypovolemic states, the IVC becomes small and highly collapsible due to reduced venous return, resulting in higher collapsibility indices. As intravascular volume increases following fluid resuscitation, the IVC diameter enlarges and respiratory variation decreases, leading to lower collapsibility indices.[19]

These findings are consistent with previous studies evaluating the role of ultrasound assessment of the inferior vena cava in shock states. Nagdev et al. demonstrated that bedside measurement of the caval index could be used to estimate central venous pressure and identify patients with low intravascular volume in the emergency department.[20] Similarly, Feissel et al. reported that respiratory variations in IVC diameter can guide fluid therapy in critically ill patients by predicting fluid responsiveness.[21] Muller et al. also emphasized that respiratory variation of IVC diameter can be used as a marker of fluid responsiveness in patients with acute circulatory failure.[22]

Another important observation in our study was the significant correlation between IVC measurements and clinical parameters at six hours following resuscitation. IVCi and IVCe demonstrated significant correlations with systolic blood pressure, diastolic blood pressure, mean arterial pressure, respiratory rate, and Modified Shock Index. These findings support the hypothesis that IVC measurements reflect systemic hemodynamic status and can serve as a dynamic indicator of volume responsiveness during resuscitation.[23]

Previous studies have also demonstrated correlations between IVC parameters and invasive hemodynamic measurements. Studies comparing IVC diameter with central venous pressure have reported strong correlations, suggesting that ultrasound assessment of the IVC may serve as a non-invasive alternative for evaluating intravascular volume status.[24] In trauma settings, ultrasound-based evaluation of IVC diameter has been shown to correlate with the presence of hypovolemia and severity of shock.[25]

The integration of point-of-care ultrasound into emergency and trauma care has expanded significantly in recent years. Ultrasound assessment of the inferior vena cava can be performed rapidly at the bedside and provides real-time information about a patient's hemodynamic status without the need for invasive monitoring. In trauma patients undergoing resuscitation, serial IVC measurements may provide valuable information regarding response to fluid therapy and adequacy of resuscitation.[26]

The findings of our study further support the growing body of evidence suggesting that ultrasound-derived IVC parameters can complement clinical assessment during the management of hemorrhagic shock. The significant correlations observed between IVC measurements and hemodynamic parameters suggest that IVC collapsibility index may serve as a useful adjunct for monitoring fluid responsiveness and guiding resuscitation in spontaneously breathing trauma patients.[27]

Nevertheless, several limitations should be considered. The study sample size was relatively small and was conducted at a single centre, which may limit the generalizability of the findings. In addition, ultrasound measurements are operator-dependent and may be affected by patient-related factors such as obesity, bowel gas, or abdominal injuries that limit acoustic windows. Future multicentre studies with larger sample sizes may help further clarify the role of IVC ultrasound in trauma resuscitation protocols.

Overall, the present study demonstrates that serial measurements of IVC diameters and collapsibility index correlate well with clinical parameters during resuscitation of trauma patients with hemorrhagic shock. These findings support the use of bedside ultrasound evaluation of the inferior vena cava as a valuable non-invasive tool for assessing intravascular volume status and monitoring response to resuscitation in emergency settings.

CONCLUSION

Ultrasonographic evaluation of the inferior vena cava (IVC), especially through the collapsibility index (IVCCI), has been widely used as a non-invasive indicator of intravascular volume and fluid responsiveness in critically ill patients. In this study, sequential IVC measurements were found to reflect hemodynamic recovery during resuscitation in trauma patients experiencing haemorrhagic shock. Additionally, IVCCI demonstrated meaningful associations with key clinical parameters, including the Modified Shock Index. These observations highlight the potential role of IVCCI as a convenient bedside tool for real-time assessment of resuscitation progress and for assisting fluid management decisions in spontaneously breathing trauma patients.

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