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Evaluation of the Role of Inferior Vena Cava/Aortic Index Sonography in Assessment of Intravascular Volume Status in Resuscitation of Major Blunt Trauma Patients in Emergency Department

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ABSTRACT

Introduction: In order to prevent unnecessary deaths and severe morbidity in these patients, it is crucial to evaluate the hemodynamic status of polytrauma patients as well as to screen for continued bleeding and evaluate the effectiveness of resuscitation.

Aim of this study: To assess inferior vena cava (IVC) /aortic index importance in assessment of intravascular volume status and in prediction of early blood transfusion in trauma patients.

Patients and methods: This study was conducted as a prospective cohort study. The major blunt trauma patients were divided into two groups. Patients group had signs of shock such as decreased blood pressure<90/60 mmHg or a more than 30% decrease from the baseline systolic pressure, heart rate >100 b/m, cold clammy skin, capillary refill >2 sec *Control group:* had normal blood pressure (≥90/60 mmHg) and normal heart rate, no other signs of shock.

Results: There were 31 patients (51.7%) required blood transfusion after 24-hour. The mean 24-hour blood transfusion was 1556.3 ± 1081.9. IVC/aortic index 0 at presentation in case group, mean ± SD was 0.60 ± 0.12, while in control group mean ± SD was 0.98 ± 0.08 (p-value < 0.001). IVC/aortic index 1 in case group, mean ± SD was 0.70 ± 0.12, while in control group mean ± SD was 0.94 ± 0.09 (p-value < 0.001).

Conclusion: The IVC/aorta diameter index can be used as a parameter for detecting volume status and early blood transfusion in polytrauma patients.

Keywords: Hypovolemic, Shock, Ultrasound, Blood transfusion.

INTRODUCTION

Trauma is characterized as a tissue harm that happens relatively quickly as a result of an accident or violent act. Trauma triggers the immune system, the hypothalamic-pituitary-adrenal axis, and the metabolic processes that restore homeostasis [(1)].

The WHO estimates that road traffic crashes claim the lives of 1.35 million people annually, mostly children and young adults between the ages of five and 29. In the absence of intervention, traffic accidents are expected to increase and rank eighth among all causes of mortality by 2030. Approximately 12,000 people in Egypt lose their lives in car accidents each year [(2)]. Hemorrhagic shock is divided into four classifications according to the Advanced Trauma Life Support (ATLS) system. The only blood classes with a drop in blood pressure that necessitates more than 30% of the total blood volume are III and IV. Therefore, blood pressure can be maintained at normal levels even while the loss is significant enough to cause multiple organ failure [(3)].

In order to prevent unnecessary deaths and severe morbidity in these patients, it is crucial to evaluate the hemodynamic status of polytrauma patients as well as to screen for continued bleeding and evaluate the effectiveness of resuscitation. Numerous factors are useful in identifying individuals who may have hypovolemia. Physical exam results, hematocrit levels, and biochemical markers are not specific signs and are not trustworthy because they could be discovered to be normal as the body's compensating mechanisms kick in, delaying the identification of volume loss [(4)]. Central venous pressure (CVP) is widely used to assess volume status. However, its effectiveness in determining volume response has been questioned recently. Chest wall compliance, ventilator settings, and right-sided heart failure can all affect how accurate CVP is as a measure of volume status[(5)] and because it is an intrusive operation, the traumatized patient runs the risk of developing numerous problems during or after the procedure, including arterial puncture, venous thrombosis, infection, and pneumothorax [(6)].

A favorable response to fluids is defined as changes of more than 10-15% in either cardiac output (CO) or stroke volume (SV). This suggests that measuring blood flow is necessary in addition to blood pressure monitoring. As long as there is a positive response (SV maximization), additional fluids can be administered under controlled conditions if SV or CO rise. Since only one fluid challenge is equal to an excess of fluids, this method prevents fluid overload [(7)].

Volume status can be assessed using either static or dynamic approaches. The initial indices that were created to aid in forecasting volume responsiveness were static measures of pressure and volume. These measurements consist of the central venous and pulmonary artery occlusion pressures (PAOP), along with surrogates acquired via echocardiography. The measurements are taken at a specific condition or time and are assumed to represent preload. Lower values

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indicate a position on the slope of the Frank-Starling curve, suggesting a higher probability of being in a volume responsive state [8].

The dynamic parameters are determined by the fluctuating cardiac output (CO) without the administration of fluids in order to predict the clinical response. A significant number of these techniques rely on the interplay between the lungs and the heart. Respiratory-induced changes in transpulmonary pressure result in variations in cardiac output, which can be evaluated using any of the following techniques: Systemic venous (SV) variation, pulse pressure variation, variations in the diameter of the superior vena cava (SVC), and variations in the diameter of the inferior vena cava (IVC) [9].

The sonographic evaluation of the diameter of the inferior vena cava (IVC) is a noninvasive and cost-effective method that is becoming increasingly valuable in determining the volume status of critically ill patients and anticipating their fluid needs [10].

In this context, we propose the utilization of the inferior vena cava to abdominal aortic (IVC:AA) diameter index as a novel tool in the emergency department (ED) for evaluating fluid status during the initial phase of resuscitation and determining the necessity for early blood transfusion in patients with traumatic hypovolemia.

PATIENTS AND METHODS

Study type: This study was conducted as a prospective cohort study.

Patients' recruitment: The major blunt trauma patients (having a significant injury to two or more ISS (Injury Severity Score) body regions or an ISS greater than 15) [11], were recruited from the Emergency Department, Suez Canal University Hospital, Ismailia and this study was carried out for one year (from February 2022 to February 2023). Shocked patients were managed in our ED Resuscitation Room and the length of stay was determined according to patient condition and resuscitation efforts.

Study Population:

A. Patients group: Sixty of both genders aged 18-60 years old. Major blunt trauma patients with signs of shock such as decreased blood pressure<90/60 mmHg or a reduction of almost 30% from the initial systolic pressure, heart rate >100 b/m, cold, clammy skin, capillary refill >2 sec and (shock index above 0.9) [12].

B. Control group: Sixty of both genders aged 18-60 years old major blunt trauma patients with normal blood pressure (≥90/60 mmHg) and average heart rate, no other signs of shock (normal capillary refill, warm skin) and (shock index ≤ 0.9).

Inclusion criteria

Major blunt traumatic patients who came to ER Suez Canal Hospital were admitted after stabilization to the Inpatient ward or ICU.

Exclusion criteria

Participants were excluded from the study if they exhibited any of the following characteristics:

- Age below 18 and more than 60.
- Cardiopulmonary resuscitation on arrival.
- Transferred from another hospital.
- Traumatic brain injury or cervical spine injury alone.
- The patient who had sustained severe damage to the lower chest and upper abdomen wall, resulting in the presence of subcutaneous emphysema.
- Morbid obesity.
- Contraindicating fluid challenges, such as cardiac insufficiency and Renal failure.
- Tricuspid regurge, right-sided heart disease, obstructive lung disease, and portal hypertension.
- Mechanically ventilated patients as in positive pressure ventilation, respiratory changes in IVCD become reversed.
- Pregnant women.

Statistical plan

Based on the equation provided[13], the projected sample size for each group was 60 participants.

$$n = \left[\frac{Z_{\alpha/2} + Z_{\beta}}{\frac{1}{2}\log\frac{1+r}{1-r}}\right]^2 + 3$$

n = required sample size.

Zα/2 = 1.96 (The critical value that divides the central 95% of the Z distribution from the 5% in the tail).

Zβ = 0.84 (The critical value that separates the lower 20% of the Z distribution from the upper 80%) r = correlation

So, n= 54 subjects per group, 10 % (~ 6) were add to compensate for non-responders, and the sample size was 60 subjects in each group.

Data management:

The data were gathered and categorized, and then inputted into a spreadsheet using Microsoft Excel for Windows Office 2010. The collected data were analyzed using SPSS version 22.0.0.0. Quantitative data were represented as the mean value plus or minus the standard deviation (SD), range, median, and interquartile range (IQR), whereas qualitative data were represented as numerical values and percentages (%). The significance of the difference for quantitative variables was tested using the Student t-test, while the significance of the difference for qualitative factors was tested using the Chi-Square test. Sensitivity, specificity, accuracy, positive predictive value, and negative predictive value were computed. A probability value (p-value) less than 0.05 was deemed statistically significant.

Ethics consideration

- **The study protocol received approval from the Research Ethics Committee of the Faculty of Medicine at Suez Canal University prior to commencing the fieldwork.**
- **Prior to collecting any data or conducting any investigations, all participants provided written informed consent.**
- **The Helsinki Declaration was followed throughout the study's conduct.**

Socio-demographic data:

• Patient's identification number.
• Patient demographic information: Age and Gender.
· Trauma data: Time, mechanism of injury, anatomical site, associated injuries, clinical presentation, and event.
· Present illness history: Onset, course, duration of the symptoms, and history of previous investigations.
 Allergy, drug history, last meal, past history.

Clinical examination:

1. Essential physiological measurements: heart rate, arterial pressure, breathing rate, body temperature, and oxygen saturation, pain severity on visual analog scale if conscious patient.
2. The initial evaluation of ABCDE (airway and cervical spine management, breathing, circulation, central nervous system dysfunction, and exposure) was performed and Glasgow coma scale was measured.
3. Trauma sheet data; ISS: site of injury, such as the head, neck, chest, abdominal, back, pelvic, and extremities
4. Assessment of the condition the patients' stability, or lack thereof, would define the necessary investigations and course of action.

Investigations: included:

1. The laboratory tests include a complete blood count, blood typing and cross match, and a coagulation profile, which measures platelet count, prothrombin time (PT), partial thromboplastin time (PTT), international normalized ratio of prothrombin time (INR), and base excess (BE). Serum lactate, arterial blood gases, the quantity of red blood cells (RBCs), fresh frozen plasma (FFP), and platelet transfusions administered within the initial 24 hours following the injury were documented.
2. Radiographic investigations were recorded.

Protocol

In the first hour of resuscitation, the patients (unstable shocked) were given 1 liter of crystalloid solution for fluid resuscitation (according to recent ATLS guidelines). If the patient was still unstable after 1 liter of fluid or had ongoing blood loss, O-negative blood transfusion was administered and type-specific blood was ordered and the trauma team activated massive transfusion protocol according to recent ATLS Guidelines even if normal hemoglobin.[19]

The evaluations were performed by emergency and radiologist specialists on arrival. The tests were conducted with the ultrasound transducer positioned subxiphoidally while the patient was in a supine position and engaged in silent passive respiration. A portable ultrasound machine was used for this purpose (Butterfly iQ/iQ+™) made in USA or Phillips HD11EXm made in Netherland.

An ultrasound probe with a frequency range of 3.5-7.5 MHz was used to capture images of the inferior vena cava (IVC) located behind the liver in a sagittal plane. The diameter of the inferior vena cava (IVC) was measured approximately 2 cm away from the junction with the hepatic vein and 2 cm away from the entrance of the right atrium (RA). This measurement was taken at a location where both the front and back walls of the IVC were visible and running parallel to each other.

Images were stored through at least two respiratory cycles. The (Diameter inferior vena cava at maximum of expiration) (DIVC max) and diameter inferior vena cava at minimum of inspiration (DIVC min) were measured. IVC dimensions were obtained by measuring the vein lumen during a regular breathing cycle from one interior wall to the opposite interior wall. Inferior vena cava collapsibility (IVCCI) was calculated using the following formula: IVCCI = (dIVC expiration – dIVC inspiration) / dIVC expiration × 100. The abdominal aorta diameter was also measured in a similar manner during systole, 5 to 10 mm above the celiac trunk, from one interior wall to the opposite interior wall.

IVC/aortic index sonography was assessed in both groups:

 On arrival (before resuscitation)
 After 60 minutes of initial resuscitation
 and after 24 hours of admission

Fate at Emergency Room: Fate of the patient was recorded whether:

 had surgical intervention.
 Admitted to inpatient under observation.
Admitted to the intensive care unit.
 Died.

RESULTS

The mean age in our study showed a statistically significant difference between the two groups (case and control) as it was higher in the control group. There were statistically significant differences in cases group when compared with control group regarding chest, extremity, face and abdomen affection. No statistically significant difference was found between studied groups regarding gender, and head and neck affection as in table (1).

Table (1): Comparisons of demographic data and Injury Severity Score between studied groups.

		Cases (N = 60)		Control (N = 60)		Stat. test	P-value
Age (years)	**Mean ± SD**	32.4 ± 12.4		39.01 ± 13.5		**T = 2.7**	**0.006 S**
	Min - Max	18 - 56		18 - 60			
	Median (IQR)	32 (21 - 44)		37 (27.75 - 55)			
Gender	**Male**	47	78.3%	51	85%	X^2 = 0.89	0.345 NS
	Female	13	21.7%	9	15%		
ISS	**Mean ± SD**	33.8 ± 8.4		22.8 ± 5.4		**T = 8.5**	**< 0.001 S**
	Min - Max	25 - 57		17 - 32			
	Median (IQR)	33 (27 - 36)		22 (18 - 25)			
Anatomical site	**Head and neck**	6	10%	11	18.3%	1.71	0.191 NS
	Face	6	10%	32	53.3%	**26.03**	**< 0.001 S**
	Chest	44	73.3%	28	46.7%	**8.89**	**0.003 S**
	Abdomen	55	91.6%	34	56.7%	**33.1**	**< 0.001 S**
	Extremity	57	95%	50	83.3%	**4.2**	**0.04 S**

ISS (Injury Severity Score), interquartile range (IQR). T: Independent sample T test. X^2: Chi-square test. S: S: Significant. NS: Non-significant.

Our study showed that cases (shocked) group had higher respiratory rate, heart rate, shock index, mean arterial blood pressure (on arrival, after 1 hour, and after 24 hours of resuscitation) compared to the control group as shown in table (2).

Table (2): Comparisons of vital signs between studied groups.

		Cases (N = 60)	Control (N = 60)	T	P-value
RR 0	**Mean ± SD**	21.7 ± 3.8	14.3 ± 1.5	**14**	**< 0.001 S**
RR 1	**Mean ± SD**	19.6 ± 3.8	14.3 ± 1.3	**10.2**	**< 0.001 S**
RR 24	**Mean ± SD**	18.1 ± 4.7	14.2 ± 1.0	**6.1**	**< 0.001 S**
MAP 0	**Mean ± SD**	59.2 ± 5.9	87.2 ± 7.3	**23.1**	**< 0.001 S**
MAP 1	**Mean ± SD**	66.3 ± 5.9	87.2 ± 7.3	**17.3**	**< 0.001 S**
MAP 24	**Mean ± SD**	73.9 ± 14.6	91.2 ± 4.7	**8.7**	**< 0.001 S**
H.R 0	**Mean ± SD**	130.8 ± 14.6	76.6 ± 7.8	**20.6**	**< 0.001 S**
H.R 1	**Mean ± SD**	120.3 ± 16.3	75.6 ± 7.7	**14.5**	**< 0.001 S**
H.R 24	**Mean ± SD**	95.3 ± 20.7	64.2 ± 5.8	**4.01**	**< 0.001 S**
Shock index 0	**Mean ± SD**	1.75 ± 0.33	0.64 ± 0.08	**22.7**	**< 0.001 S**
Shock index 1	**Mean ± SD**	1.39 ± 0.44	0.71 ± 0.03	**11.2**	**< 0.001 S**
Shock index 24	**Mean ± SD**	0.99 ± 0.22	0.70 ± 0.06	**9.8**	**< 0.001 S**

R.R (Respiratory rate), MAP (Mean arterial blood pressure), H.R (Heart Rate), 0 (on arrival), 1 (after 1 hour), 24 (after 24 hours of 1st hour of resuscitation), S: Significant, T: Independent sample T test.

Regarding hemoglobin in case (shocked) group, mean ± SD was 11.6 ± 1.6 while mean ± SD in control group was 12.6 ± 0.8, hematocrit mean ± SD in case (shocked) group was 33.2 ± 3.5 while mean ± SD in control group was 38.1 ± 3.0, base deficit mean ± SD in case (shocked) group was -15.3 ± 7.6 while in control group mean ± SD was -1.0 ± 1.4, lactate mean ± SD in case (shocked) group was 3.4 ± 1.9 while mean ± SD in control group was 1.3 ± 0.6 (p value < 0.001) and pH (on arrival) in case (shocked) mean ± SD was 7.3 ± 0.05 while mean ± SD in control group was7.4 ± 0.04 (p value < 0.001)

Table (3) shows that IVC Diameter, maximum IVC diameter, and minimum IVC diameter, and IVC/aortic index, at presentation, after 1 and 24 hours were significantly higher in control group compared to case group. While IVCCI at presentation and after 1 hour was significantly higher in case group than in control group.

Table (3): Comparisons of IVC Sonography data between studied groups.

		Cases (N = 60)	Control (N = 60)	P-value
IVCD 0	**Mean ± SD**	8.5 ± 2.3	16.6 ± 2.6	**< 0.001 S**
	Min – Max	4 - 12	13.4 - 19	
IVCD 1	**Mean ± SD**	10.1 ± 2.5	15.6 ± 2.2	**< 0.001 S**
	Min – Max	6 - 15.3	13 - 19.5	
IVCD 24	**Mean ± SD**	13.0 ± 3.0	16.8 ± 2.6	**< 0.001 S**
	Min – Max	10 - 17.5	15 - 21.5	
DIVC Max 0	**Mean ± SD**	10.1 ± 2.6	18.3 ± 2.4	**< 0.001 S**
	Min – Max	5 - 15	15.8 - 21.9	
DIVC Max 1	**Mean ± SD**	11.9 ± 2.1	17.7 ± 2.2	**< 0.001 S**
	Min – Max	8.5 - 16	16 - 22	
DIVC Max 24	**Mean ± SD**	14.4 ± 3.4	19.2 ± 2.2	**< 0.001 S**
	Min – Max	11 - 20	17 - 23	
DIVC Min 0	**Mean ± SD**	6.2 ± 2.0	14.4 ± 3.3	**< 0.001 S**
	Min – Max	2.5 - 9	11 - 19.3	
DIVC Min 1	**Mean ± SD**	8.2 ± 2.3	13.8 ± 2.2	**< 0.001 S**
	Min – Max	5 - 12.5	11 - 17	
DIVC Min 24	**Mean ± SD**	11.3 ± 2.7	15.4 ± 2.8	**< 0.001 S**
	Min – Max	0 - 16	13 - 20	
IVCCI 0	**Mean ± SD**	39.4 ± 9.8	21.9 ± 9.9	**< 0.001 S**
	Min – Max	18.1 - 50	4.5 - 31.5	
IVCCI 1	**Mean ± SD**	35.4 ± 9.8	22.1 ± 6.1	**< 0.001 S**
	Min – Max	15.3 - 55	14.1 - 31.5	
IVCCI 24	**Mean ± SD**	20.4 ± 6.2	20.2 ± 6.8	0.867 NS
	Min – Max	11.6- 28.5	13 - 31.6	
IVC/aortic index 0	**Mean ± SD**	0.60 ± 0.12	0.98 ± 0.08	**< 0.001 S**
	Min – Max	0.3 - 0.75	0.9 - 1.1	
IVC/aortic index 1	**Mean ± SD**	0.70 ± 0.12	0.94 ± 0.09	**< 0.001 S**
	Min – Max	0.5 - 0.9	0.88 - 1.1	
IVC/aortic index 24	**Mean ± SD**	0.84 ± 0.21	1.01 ± 0.06	**< 0.001 S**
	Min – Max	0.5 - 1.1	0.95 - 1.1	

T: Independent sample T test, S: Significant, IVCD (Inferior Vena Cava Diameter), DIVC Max (Diameter Inferior Vena Cava at Maximum of expiration), DIVC Min (Diameter Inferior Vena Cava at Minimum of inspiration) and IVCCI (Inferior Vena Cava Collapsibility Index) 0 (on arrival), 1 (after 1 hour), 24 (after 24 hours of 1st hour of resuscitation).

All studied patients of cases (shocked) group required fluid at the 1st hour of resuscitation (1000) ml. There were 44 patients (73.3%) required blood transfusion at the 1st hour of resuscitation (still hypotensive not responding to initial crystalloid given according to recent ATLS guidelines). There were 31 patients (51.7%) required blood transfusion after 24 hours. The mean 24-hour blood transfusion was 1556.3 ± 1081.9. There were 28 patients (46.7%) required fluid > 2400 ml after 24-hour. Also, there were significant statistical difference between studied groups (shocked mean ± SD 2810 ± 909.3 and non-shocked group mean ± SD was 1595 ± 494.8) (p-value < 0.001) as regard to total fluid requirement after 24 hours of the first hour of resuscitation). **IVC/aortic index (on arrival)** could be used to discriminate between two study group patients at a cutoff level of 0.46, with 100% sensitivity, 80% specificity, 83.3% PPV and 100% NPV **(AUC = 0.9 and p-value < 0.001)**. **IVC/aortic index (1 hour)** could be used to discriminate between two study group patients at a cutoff level of 0.69, with 100% sensitivity, 100% specificity, 100% PPV and 100% NPV **(AUC = 1.0 and p-value < 0.001)**.

Table (4) shows statistically significant difference (p-value < 0.001) between studied groups (Cases and control) regarding fate at ER.

Table (4): Comparisons of fate at ER between studied groups.

		Cases (N = 60)		Control (N = 60)		Stat. test	P-value
Fate at ER	**ICU admission**	20	33.3%	0	0%	**X^2 = 36.5**	**< 0.001 S**
	OR for laparotomy	3	5%	0	0%		
	Ward admission	37	61.7%	60	100%		
	Died	2	3.3%	0	0%		

X^2: Chi-square test, S: Significant.

In our study, we found that IVCci0 at a cutoff point >38.5 had a sensitivity of 80.0% and specificity of 85.71% with area under curve (AUC) 0.971 and a good 95% CI (0.938 – 1.0), which means that IVCci of 38.6% or more can indicate fluid responsiveness. We also found that IVCci 1 hour (after fluid resuscitation) at cutoff point >28.6 had a sensitivity of 80.0% and specificity of 75% with AUC of 0.886 and good 95% CI (0.803 – 0.968), which means that IVCci of 28.5% or less can indicate fluid unresponsiveness after 1st hour of resuscitation.

There was no statistically significant correlation between 1st hour blood transfusion and IVC (on arrival DIVC Max, DIVC Min, IVCCI) and there was statistically significant difference between patients with 1st hour blood transfusion when compared with patients who didn't receive 1st hour blood transfusion regarding IVC/aortic (on arrival).

DISCUSSION

The assessment of hemodynamic status in polytrauma patients is an important idea behind the primary survey of trauma patients.

Elbaih and Housseini in 2018 investigated the cause of instability in polytrauma patients that can be attributed to the use of RUSH (Rapid Ultrasound in Shock) technique and hypotension protocol for early detection of different types of shock. This study included a total of one hundred polytrauma patients. There were 75 males (75%) and 25 females (25%). The mean age was (27.5 ± 17.8) years in polytrauma patients [(14)], which agrees with our study.

Cholo *et al.* [(15)] aimed to analyze the burden of trauma to the society as they investigated a total of 1,073 incidents of motorcycle crash injuries, which were recorded among male patients across all age groups in all categories of hospital attendees (P<.001) with mean age± SD 29.6 ±12.19 years, which also agrees with our study. **Asim *et al.*** in 2023 investigated out of the 1645 trauma patients brought to the hospital, it was discovered that 24.5% of them had a high shock index (SI). The average age was 39.2 ± 15.2 years, with the majority being males (91%). Patients exhibiting high systemic inflammation (SI) were of a younger age and experienced more serious injuries [(16)], which agrees with our study.

Hatton *et al.* [(17)] investigated the association of occult hypoperfusion and outcome in trauma, they included a total of 3,126 trauma patients, elderly were (808) patient. Rates of shock (33% and 31%) were similar in young and elderly patients, which doesn't agree with our study.

Also WHO reported in 2018 that the most prevalent age group engaged in accidents ranged from 5 to 29 years [(18)].

The high incidence of accidents among adults aged 20 to 40 can be attributed to their engagement in productive activities that require frequent and rapid movement between locations. This increased mobility may predispose them to road traffic accidents (RTAs) or crashes. Additionally, the involvement of alcohol or the abuse of psychoactive substances or drugs while driving further contributes to this phenomenon. Young adults who experience polytrauma suffer from severe injuries that impose a significant economic cost on both the country and their families.

Mean Injury Severity Score (ISS) in our study was 33.8±8.4 in unstable hypovolemic patients while in the control was 22.8±5.4 and there is a highly statistically significant difference between both groups (p-value < 0.001).

Our study showed that according to the anatomical site of injury between studied groups there were no statistically significant differences regarding head and neck **(p-value = 0.191)**, there were statistically significant differences between both groups regarding chest affection, extremity, and abdomen (p-values **0.003, 0.004, and < 0.001 respectively)**

Jávor *et al.* in 2021 agrees with our study as they investigated 156 patients who were hypovolemic shocked patients , 84 patients (53.9%) had thorax affection and 75 patient (48.1%) had extremities affection, their ISS had a median of 29 with IQR (20-34) [(19)].

Kim *et al.* in 2019 had investigated a total of 628 trauma patients and divided them into survivors and non-survival group. ISS showed a significant statistical difference between both groups (p<0.001) as in the survival group the mean± SD was (12.44±11.20) and the non-survival group had a mean of 28.15 with a standard deviation of 14.01. The location of the injury was strongly correlated with death in relation to the chest (p<0.001) and extremity (p=0.021) [(20)]. Which also agrees with our study.

Khajehpour and Behzadnia's study found no statistically significant distinction in systolic blood pressure and respiratory rate between two trauma groups: the hemorrhagic shock group (n=36) and the non-hemorrhagic shock group (n=39). However, these findings contradict our own investigation. Statistically significant disparities were observed between the two groups in terms of clinical measures such as shock index and injury severity score, as well as laboratory parameters including lactate level (P<0.05) [(21)], which is consistent with our research findings**.**

Also, **Shah *et al.'s*** [(22)] study was conducted to assess the safety of polygeline (a type of colloid) within 6 hours after administration in patients who presented with hypovolemia caused by accident trauma in the emergency department. The delivery of polygeline resulted in a significant improvement in all vital measures (blood pressure, pulse, and respiratory rate) at both 1 hour and 6 hours (p<0.001). The mean blood lactate levels exhibited a statistically significant alteration from the initial measurement (p<0.05) at both the 1-hour and 6-hour time points, which aligns with the findings of our study.

We found a significant difference (P-value <0.01) between patients with hypovolemic shock, the maximum inferior vena cava (IVCmax) was shown to be consistently low, with a mean value of 10.1±2.6, and non-shocked patients, where the IVCmax was found to be higher, with a mean value of 18.3±2.4.

Elbaih *et al.'s* [23] study revealed a high level of diagnostic reliability for each form of shock in polytrauma patients, with an overall accuracy rate of 95.2%. The measurement of the inferior vena cava (IVC) was a component of the rapid ultrasound in shock (RUSH) assessment.

In our study, we found that IVCci0 at cutoff point >38.5 had sensitivity of 80.0% and specificity of 85.71% with AUC of 0.971 and good 95% CI (0.938 – 1.0), which means that IVCci of 38.6% or more can indicate fluid responsiveness and to discriminate between depleted and non-depleted patients. We also found that IVCci 1 hour after the administration of fluid to restore bodily fluids, when the threshold was set at a value greater than 28.6, the sensitivity was found to be 80.0% and the specificity was still to be 71.43% with AUC of 0.886 and good 95% CI (0.803 – 0.968), which means that IVCci of 28.5% or less can indicate fluid unresponsiveness.

Monira *et al.* [24] also agrees with our study. They did research on several types of shock in connection to both central venous pressure and inferior vena cava. Out of the 44 patients with hypovolemic shock, 23 (52.3%) were responders and 21 (36.2%) were non-responders. There was a substantial difference in the maximum inferior vena cava (IVC) diameter between responders and non-responders at time 0 and 30. This indicates that measuring the IVC max diameter can be used to diagnose hypovolemia (p value <0.05, 0.003).

They also found out that IVCci0 (at baseline) at cutoff point 40 had sensitivity of 100% and specificity of 90.5% with AUC of 0.976 and good 95% CI (0.92-1.03), which means that IVCci of 40% or more can indicate fluid responsiveness. IVCci0 (at baseline) at cutoff point 40 has sensitivity of 100% and specificity of 90.5% with AUC of 0.976 and good 95% CI (0.92-1.03), which means that IVCci of 40% or more can indicate fluid responsiveness. These results demonstrate that IVC respiratory variations can predict fluid responsiveness in hypovolemic shock patients and detect which patient will benefit most [25].

Chong *et al.'s* [26] study in 2023 included a total of 31 delivery of a baby at the end of the normal duration of pregnancy. Women who gave birth vaginally and experienced a postpartum hemorrhage had an estimated blood loss of ≥500 mL. The diameters of the inferior vena cava at the end of expiration (IVCe) and at the end of inspiration (IVCi) were measured. The intravascular volume expansion (IVCe) in the intravascular compartment of the circulatory system increased considerably at T4 (when postpartum hemorrhage reached 500 mL) by 31.1 ± 13.7%, compared to T3 (the third stage of labor), which had an increase of 27.7 ± 14.0% (P = 0.005). Following the prompt administration of a balanced saline infusion after postpartum hemorrhage (T5), immediately after receiving 500 mL of balanced crystalloid infusion therapy, there was a notable drop in the IVC-CI compared to T4 (P = 0.005), with a mean reduction of 25.8 ± 12.1%. Simultaneous measurement of IVC diameters did not result in any notable alterations in HR or MAP. The value of P was greater than 0.05. The results indicate that changes in intravascular volume status (IVC) are more effective than blood pressure and heart rate in identifying decreased blood volume in patients with postpartum hemorrhage.

On the other side a meta-analysis in **2017** was done by **Long *et al.*** [27]. The study showed that the respiratory changes in the diameter of the inferior vena cava (IVC) had limited potential to accurately predict fluid responsiveness, especially in individuals who are breathing on their own. Consideration of the clinical environment is essential when utilizing IVC ultrasonography to inform treatment decisions. Seventeen studies were included in that study. The sensitivity and specificity of an IVC ultrasonography in predicting fluid response were 0.63 and 0.73, respectively.

The same in the study of **Orso *et al.*** [28]. A meta-analysis was performed on 20 trials to assess the caval index. The combined area under the curve, logarithmic diagnostic odds ratio, sensitivity, and specificity were found to be 0.71 and 0.75, respectively. Furthermore, they asserted that using ultrasound to assess the width of the inferior vena cava (IVC) and its respiratory changes does not appear to be a dependable technique for predicting fluid responsiveness.

In the study of **Doucet *et al.*** [10], out of the 196 individuals who were admitted to the hospital and had an intraventricular conduction delay (IVCD) of 12 mm or an intraventricular collapse index (IVCCI) of 50% or less, a total of 144 individuals were included in the study. There was a total of 86 individuals who were repleted and 58 individuals who were not repleted. The nonrepleted individual exhibited a reduced intraventricular conduction delay (IVCD). (6.0 ± 3.7 mm vs. 14.2 ± 4.3 mm, $p < 0.001$) and higher IVCCI (41.7% ± 30.0% vs. 13.2% ± 12.7%, $p < 0.001$) but no significant difference in IJVD (Internal jugular venous diameter) or IJVCCI. Repleted had greater 24FR than nonrepleted (2503 ± 1751 mL vs. 1,243 ± 1,130 mL, $p = 0.003$). Receiver operating characteristic analysis indicates that the IVCDMIN model predicted a 24FR with an area under the curve (AUC) of 0.74 and a 95% confidence interval [CI], 0.64–0.84; $p < 0.001$) as did IVCCI (AUC, 0.75; 95% CI, 0.65–0.85; $p < 0.001$).

Our study showed statistically significant difference between both groups (case and control) **(p-value < 0.001,** < 0.05**).** A study was conducted to investigate the IVC/aortic index at several time points (on arrival, after 1 hour, and after 24 hours from the 1st hour of resuscitation) in a group of polytrauma patients.

The results showed a significant p-value, indicating that the IVC/aortic index is a reliable indicator for detecting volume status in these patients.

Also, our study showed statistically significant difference **(p-value = 0.001) between** patients who received a blood transfusion within the first hour compared to patients who did not receive a blood transfusion within the first hour in terms of their IVC/aortic ratio upon arrival.

Sridhar and Srinivasan [29] furthermore, their study aligns with ours as they examined the efficacy of the inferior vena cava/aorta index (IVC/Ao) in evaluating fluid status by comparing it to the central venous pressure (CVP). The average IVC/aorta index of patients with a central venous pressure (CVP) less than 7 cm H_2O was 0.7 ± 0.09, CVP between 8 to 12 cm H_2O was 1.2 ± 0.12 and CVP more than 13 cm H_2O was 1.6 ± 0.05.

The study of **Luo *et al.*** [30] consisted of 271 patients, with 150 having a shock index of 0.7 or lower, and 121 having a shock index higher than 0.7. The anteroposterior (AP) diameter of the inferior vena cava (IVC) and the ratio of AP IVC to aorta were found to be significantly different across the groups. The study determined the cutoff value for the AP to aorta ratio to be 0.62, which demonstrated both high sensitivity and specificity in predicting the shock index >0.7, demonstrating moderate accuracy (AP to aorta ratio: area under the curve, 0.70; sensitivity, 55%; specificity, 91%).

LIMITATIONS OF THE STUDY

The scope of our study was limited to a single hospital, which may restrict the applicability of our findings to a broader population. The study population was small; therefore, we cannot draw definitive conclusions.

CONCLUSION

Evaluating the hemodynamic condition of polytrauma patients is a crucial aspect of the initial examination of trauma patients. The IVC/aorta diameter index can serve as a criterion for identifying volume status and early blood transfusion in polytrauma patients. These results are valuable for hypovolemic patients.

RECOMMENDATIONS

From the study results we recommend:

- Repeated measurement of IVC, IVC/aortic index ultrasound for hypovolemic unstable patients and continuous monitoring to the fluid responsiveness
- Ultrasound devices should be available in each emergency department.
- All emergency physicians should have point-of-care ultrasound as a part of their training course.

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