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Correlation Between Inferior Vena Cava Diameter and Collapsibility Index with Central Venous Pressure in Assessment of Septic Shock Patients in Emergency Department

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ABSTRACT

Background: For an early resuscitative response, central venous pressure (CVP) monitoring is an invasive hemodynamic assessment & useful guidance. In relation to the CVP and the volume of blood in circulation, inferior vena cava (IVC) is a sizable vein with a certain size and form. Septic shock is defined as sepsis accompanied by hypotension that does not respond to fluid resuscitation.

Aim: Identifying the link between the diameters of IVC, CVP, as well as Inferior Vena Cava Diameter Collapsibility Index (IVCCI), all while assessing the volume status of critically septic shocked individuals to establish a diagnosis of septic shock.

Patient and methods: This prospective observational research involved one hundred individuals who suffered from septic shock & were hospitalized to emergency department at Mansoura University, Mansoura, Egypt. The research was carried out over the course of a single calendar year, beginning on May 20, 2022, and ending on May 20, 2023.

Results: There was a considerable disparity among both groups regarding age, sequential organ failure assessment (SOFA) score, heart rate, platelets count, serum urea and serum creatinine, C-reactive protein, ESR, serum lactate, PH, serum bicarbonate, inferior vena cava diameter collapsibility index (IVCCI), systolic blood pressure (SBP) & diastolic blood pressure (DBP). Besides, there was no statistically significant variance between both groups regarding sex, the change in the CVP, initial SBP, DBP, respiratory rate (RR) and temperature.

Conclusion: The assessment of CVP as well as IVCCI is an excellent prognostic method in sepsis patients.

Keywords: Collapsibility index, IVC, Septic shock, CVP.

INTRODUCTION

Individuals admitted to the Emergency Department (ED) with hypovolemia can benefit from a CVP assessment since it is both an invasive hemodynamic examination & a valuable guide for an early resuscitative response (a CVP less than eight cmH_2O signals the requirement for IV fluid therapy). Invasive hemodynamic monitoring, such as arterial puncture, infection, venous thrombosis, etc., is often used to track central venous pressure (CVP) in the emergency department, but it comes with a number of drawbacks, including the potential for prolonged monitoring times and the need for specialized equipment and personnel [(1)]. In certain cases, such as coagulation problems, infection at the insertion site, and so on, the use of a central venous catheter is forbidden. Infections, inadvertent artery puncture, hematomas, hemothoraxes, pneumothoraxes, air emboli & dysrhythmias are all possible complications of a central venous catheter [(2)].

Maintaining airway patency, regulating breathing, optimizing circulatory status, monitoring oxygen delivery to tissues, and attaining resuscitation end objectives are all part of the ABCDE strategy for resuscitation of patients [(3)].

IVC carries deoxygenated blood to the heart's right atrium. IVC is a large vein with a certain size and shape that is linked to the CVP and the amount of blood in circulation. Ultrasound, a non-invasive tool for evaluating volume status, can be used to measure the IVC [(4)]. Depending on the phase of respiration, the IVC diameter (IVCD) fluctuates. During inspiration, the thorax develops negative pressure, causing the IVC to drain into the right atrium and shrink in diameter. The IVC collapsibility index (IVC-CI) is measured by dividing (IVCD in expiration - IVCD in inspiration) by IVCD in expiration [(5)]. The goal of this research was to find the relation between IVC diameter, CVP & IVC-CI for the purpose of assessing volume status & making a diagnosis of septic shock in critically ill patients.

PATIENT AND METHODS

A total of one hundred patients with septic shock in this prospective observational research were admitted to Mansoura University Emergency Department, Mansoura, Egypt. The duration of the trial started from May 20, 2022 to May 20, 2023. The patients were divided into 2 groups; non-survivors (55) and survivors (45).

Inclusion criteria: Age from 18 to 70 years old, both genders, patients with functioning central venous catheter and cases suffering from septic shock state.

Defining sepsis: All patients of septic shock & sepsis are stated in 3rd International Consensus Definitions for Sepsis & Septic Shock (Sepsis-3) [(6)].

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Exclusion Criteria: Age below 18 and above 70 years, Non-functioning central venous catheter, pregnancy and pericardial effusion and tamponade.
All participants were subjected to detailed medical history, clinical examination and laboratory investigations.

Technique of laboratory analysis: The three samples were taken in rapid succession in no more than fifteen minutes. Standardized blood gas collection procedures were used to collect all blood gas samples, and the samples were then frozen and shipped to a central laboratory for analysis. Arterial punctures or catheter drains were used to collect blood samples. Blood gas levels were measured using the ABL80 FLEX analyzer (Radiometer America, Inc., Westlake, OH) (Figure 1). In addition to measuring pH, pCO_2, pO_2, and pH, we also measured base excess (BE), bicarbonate (HCO_3) & oxyhemoglobin saturation (O_2 saturation) & partial pressure of hydrogen carbonate (pH). Radiological investigations, central line insertion and neurological state assessment.

Figure (1): ABL80 FLEX analyzer.

Assessment of IVC diameter & collapsibility index & CVP:
DP-2200 plus digital ultrasound diagnostic imaging system was utilized for this study (China, Hi-Tech Industrial Park, Keji 12th Road South, Mindray Building, 2017; B, 2B, B + M, and M imaging modes; 256-level grayscale). Ten-inch non-interlaced screen; 2.5~ 10 MHz transducer frequency; one- or two-transducer connectors. Digital beam-forming (DBF) and dynamic receiving focusing (DRF) are two more forms of beam-forming, in addition to Real-time Dynamic Aperture (RDA), Dynamic Frequency Scanning (DFS), and Dynamic Receiving Apodization (DRA). With a transducer that uses a curved array, the scanning angle may be anywhere from 67 to 120 degrees, and the scanning depth can be anywhere from 21.6 millimeters to 248 millimeters. Mortality rate, duration in ICU staying, essential for mechanical ventilation, Number of ventilator-free days and number of days without vasopressor support.

Ethical consideration: The Institutional Review Board (IRB) of Mansoura Faculty of Medicine gave its permission to every facet of this study. Participants' identities & information were kept private and parents or guardians could withdraw their children from the research at any time without repercussions. Also, no further use for the gathered information. All cases (or their families if unconscious) were given a written explanation of the importance of the research & the procedures to be performed prior to their participation. All data were coded and were not used for any other purposes other than this research. All procedures involving human participants in this study have been performed in conformity with the principles outlined in the World Medical Association's Declaration of Helsinki.

Statistical analysis and data interpretation:
Input data was processed by IBM SPSS version 27 statistical software (Armonk, NY: IBM Corp.). Digital & percentage descriptions of qualitative data were provided. Distributional regularity was confirmed using the Kolmogorov-Smirnov test. Minimal & maximum values, average & standard deviation, median and interquartile range (IQR) were utilized to characterize the quantitative data. Evaluation of the outcomes' significance was performed at the five percent level. Receiver operating characteristic (ROC) analysis, the t-test, the Mann–Whitney test, the chi-square test, and the Fisher's exact or Monte Carlo correction test were all used to evaluate the data.

RESULTS

There was statistically significant variance among both groups that were investigated concerning age (p equal 0.015). There was no statically significant variance among the 2 groups concerning sex (p equal 0. 863) (Table 1).

Table (1): Survival-related demographic information for the cases studied

Items	Group one (non-survivors) n= 55	Group two (survivors) n= 45	P value
Age (years)	52.93 ± 8.67	44.13 ± 4.61	**0.015***
sex			
Male	37 (67.3 percent)	31 (68.9 percent)	**0.863**
Women	18 (32.7 percent)	14 (31.1 percent)	

P: probability. Continuous data expressed as mean ± SD. Categorical data are expressed as number (percentage within group).

No major differences were seen in the two groups' baseline SBP, DBP, RR, or temperature. All of APACHE II score, SOFA score and heart rate were statistically significantly greater in non-survivors (p less than 0.001) (Table 2).

Table (2): Examining both research groups' survival rates in relation to general examination items.

	Group one (non-survivors) N equal 55	Group two (survivors) N equal 45	P value
Pulse (B/Min)	121.05 ± 12.36	107.93 ± 9.06	**0.002***
SBP initial (mmHg)	72.0 ± 14.93	75.83 ± 13.94	0.148
DBP initial (mmHg)	44.0 ± 14.17	46.83 ± 13.59	0.266
RR (Cycle/Min)	23 (15-34)	22(14-31)	0.127
Temperature (ºC)	39.09 ± 2.98	38.46 ± 3.23	0.068
APACHE score	22.95 ± 3.23	14.51 ± 2.64	**Less than 0.001***
SOFA score	4.23 ± 2.26	1.95 ± 1.02	**Less than 0.001***

Statistically significant ($p < 0.05$).

Significant rise were seen statistically in platelets count, serum urea & serum creatinine in the non-survivors group compared to the survivors group (Table 3).

Table (3): correlation of laboratory variables with survival rates in both study groups.

	Group one (non-survivors) N= 55	Group two (survivors) N =45	P value
Hb	8.99 ± 1.62	9.61 ± 2.06	**0.055**
Platelets (10^6/ml)	418 (382-452)	259 (145-442)	Less than 0.001*
WBCs (10^6/ml)	19.14 ± 2.98	16.24 ± 2.07	0.142
Urea in Serum (mg/dl)	74.06 ± 13.29	23.66 ± 5.74	Less than 0.001*
Creatinine	1.96 ± 0.65	0.73 ± 0.10	Less
Bilirubin	1.4 (0.7 – 5.5)	1.3 (0.7 –	0.983
ALT (Iu/l)	92 (42 – 366)	75 (35 –	0.07
AST (Iu/l)	73 (45– 400)	66 (29 –	0.237

Regarding C- reactive protein & ESR, the non-survivors had much greater levels than the survivors. However the non-surviving group had marked lower serum K^+ level (Table 4).

Table (4): A comparison of both groups' survival rates based on an investigation of their serum electrolytes & inflammatory markers.

	Group one (non-survivors) n= 55	Group two (survivors) N equal 45	P value
sodium (mEq/L)	132.24 ± 9.02	132.9 ± 11.15	0.144
Potassium (mEq/L)	4.2 ± 1.12	4.9 ± 1.51	0.004*
c-reactive protein	116.70 ± 22.53	49.41 ± 12.62	**Less than 0.001***
ESR (mm/h)	36 (20-76)	13 (10-18)	0.001*

A statistically significant variance among the 2 groups with non-survivors who had greater blood lactate levels, while, they had lower levels of serum bicarbonate and pH (Table 5).

Table (5): Comparison of both research groups' survival rates by analyzing the components of arterial blood gases & serum lactate.

	Group one (non-survivors) n= 55	Group two (survivors) n= 45	P value
PH	7.31 (7.18 – 7.34)	7.35 (7.27 – 7.4)	0.026*
PaO2	88.5 (70-116)	89.5 (69-116)	0.217
PCO2	43.2 (34-52)	42 (35-49)	0.164
bicarbonate (mEq/L)	17.4 ± 2.76	20.87 ± 1.52	0.019*
Lactate in Serum (mmol/L)	7.66 ± 0.86	3.11 ± 0.57	0.001*

There was a significant statistically rise in the IVC-CI, SBP and DBP after fluid resuscitation as compared to their values before fluid resuscitation (p less than 0.001). However, statistically significant decrease in serum lactate after fluid resuscitation as compared to their values before fluid resuscitation (p less than 0.001). The change in the CVP was not statistically significant (Table 6).

Table (6): Survival analysis by group for CVP, IVC expiratory, IVC inspiratory, & IVC CI

	Prior to fluid resuscitation	following fluid resuscitation	Δ change (Change in %)	P-value
CVP	8 (4 – 13)	7 (2 – 21)	- 10.15 : 46.13	0.162
IVC_CI	40 (12 – 92)	72 (18 – 104)	46.1 : 78.6	Less than 0.001*
SBP	74.62 ± 15.81	112.19 ± 7.11	52.3 : 81.1	Less than 0.001*
DBP	45.2 ± 10.06	72.34 ± 5.13	55.3: 84.9	Less than 0.001*
Lactate in Serum	7.38 ± 0.97	3.65 ± 0.84	33.11 : 76.5	Less than 0.001*

DISCUSSION

Statistically significant variation presented in average age among both groups in our research, with the non-survivors had average age of 52.93 ± 8.67 years & the survivors had average age of 44.13 ± 4.61 years (p=0.015). **Kim and his colleagues** [7] reported advanced years in the non-survivor group, seventy eight years (73.8–83), with a man's percentage of 52.8%. This finding is consistent with the findings that we obtained.

With regards to the gender ratio of the participants in the existing investigation, no statistically significant distinction among both groups was found. There were 37 men (67.3%), and 18 women (32.7%), in the group of people who did not survive, and there were thirty one men (68.9%) & fourteen women (31.1%), in the group of people who survived. In line with the findings of the recently published study, **Choi and his associates** [8] revealed that their research did not show any statistically significant variations among the sexes in terms of the distribution of participants (p = 0.796). The male gender made up 61.3 & 66.7% of the survivors and non-survivors, respectively. Survivors were more likely to be male.

In the present investigation, a number of aspects of the first clinical examination carried out by each of the two groups, including the initial SBP, DBP, RR & temperature, did not show significant variations among the two groups. However, the non-survivors had a heart rate that was statistically considerably greater (p < 0.001) than the survivors had. **Jandial *et al.*** [9] found a statistically significant variance among both research groups (survived against non-survived group) with regards to RR as well as GCS upon admission, and our findings corroborate these findings.

A higher APACHE score was reported by the non-survivor group in this research (p < 0.001). In addition, the non-survivors had a greater SOFA score (4.23 ± 2.26 vs 1.95 ± 1.02) than the survivors did (p value <0.001). **Salem *et al.*** [10] found a statistically significant variance among the 2 groups (p equal 0.005), with the APACHE II score greater in non-survivors. There was a statistically significant variance (p=0.005) among both groups, with survivors having lower SOFA score than in non-survivors. Both the APACHE II as well as the Sequential Organ Failure Assessment (SOFA) score, which are calculated on day one, have been shown to be independently associated to sepsis severity and the 28-MR score in current studies. [11, 12, 13].

CRP levels were substantially greater in the present research's non-survivors than in the survivors (116.70 ± 22.53 against 49.41 ± 12.62 mg/dl; p less than 0.0001). This is similar to previous research [14].

Total leucocytic count did not vary significantly among survivors & non-survivors in our study cases (p = 0.242). Although, the leucocytic count was greater in the non-survivors (13.8 vs. 17.1 - p equal 0.211), **Kim *et al.*** [15] detected no significant distinction statistically among both groups.

In our investigation, the non-survivor groups had a greater platelet count than the survivors did. This difference was statistically significant (p < 0.05). The outcomes of **Orak *et al.*** [16] are in line with our own beliefs. The platelet counts of the dead were significantly greater than those of the living (227 vs. 268; p equal 0.008).

Lactate levels were found to be considerably greater in the non-survivor group (p < 0.001). Lactic acid was found to be considerably higher among the research's non-survivors (p equal 0.0009). Survival and non-survival were associated with serum lactate levels of 2.3 and 3.3 mmol/L respectively [17].

In the recent investigation, the non-survivors had significantly greater levels of creatinine than the survivors did (1.96 ± 0.65 mg/dl versus 0.73 ± 0.20 mg/dl, p < 0.001). This corroborates the findings of **Vardon-Bounes *et al.*** [17], as they found that non-survivors had considerably greater levels of creatinine (148 vs. 115 mmol/dl, p < 0.0001) than survivors did.

In this particular study, Analysis of arterial blood gases showed that the PH was much lower in non-survivors group (7.31 vs. 7.35, p equal 0.046). Additionally, the percentage of non-survivors with a healthy PH was much lower. (17.4 ± 2.76 vs 20.87 ± 1.52 respectively) (p equal 0.019). The remainder of the blood gas analysis parameters did not vary among the research groups (p > 0.05). Another research found similar results, showing that the PH level of the non-survivors was 7.28, whereas those of the survivors were 7.35 (p = 0.0022) [17].

The non-survivors in our research had significantly lower serum K^+ levels than the survivors did (4.2 vs. 4.9; p equal 0.001). However, the combined mean of the 2 groups was within reasonable limits. The potassium levels of survivors & non-survivors did not vary significantly (p = 0.759), according to another research [18].

The present research found that CVP was substantially greater among the study's non-survivors than in the survivors [13 (9-21) versus 7 (2-10)] ($P < 0.001$). This agrees with **Mohammed *et al.*** [19] as they involved thirty cases with sepsis. At the last follow up, 23 patients died and 7 cases survived. The average CVP was statistically significantly greater in the non-survivors (13.26 ± 3.99 and 11.86 ± 2.54 respectively).

In the present research, IVC-CI was statistically significantly greater in the survivor group [68 (22 – 98) vs 46 (12 – 104) respectively] (p=0.025). **Mohammed *et al.*** [19] indicated that the IVC-CI was statistically significantly higher in survivor septic patients (57.43± 9 and 46.78±14.96 respectively).

In the recent research, there was no statistically significant change in the CVP before & after fluid resuscitation. A comprehensive study that included 803 individuals found that the variance in baseline CVP between patients who responded to treatment and those who did not was not statistically significant (p equal 0.3) [20].

In this particular research, there was a statistically significant rise in the IVCCI as contrasted with their values before fluid resuscitation ($p< 0.001$).

Yao B *et al.* [21] found IVC/max was not predictive of fluid responsiveness, lending credence to our findings. IVC-CI > 42%, on the other hand, was shown to be predictive of a rise in CO following fluid infusion in cases who were breathing on their own in the ICU.

CONCLUSION

Our results showed that the assessment of CVP & IVCCI was an efficient predictive tool for determining prognosis in sepsis patients. The CI of IVC was demonstrated to be more indicative of fluid responsiveness than CVP.

DECLARATIONS

- **Consent for publication:** All authors agreed to submit the work
- **Availability of data and material:** Available
- **Competing interests:** None
- **Funding:** No fund
- **Conflicts of interest:** No conflicts of interest.

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