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Correlation of central venous pressure with venous blood gas analysis parameters; a diagnostic study

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ABSTRACT

Objective: This study was conducted to assess the correlation between central venous pressure (CVP) and venous blood gas (VBG) analysis parameters, to facilitate management of severe sepsis and septic shock in emergency department.

Material and methods: This diagnostic study was conducted from January 2014 until June 2015 in three major educational medical centers, Tehran, Iran. For patients selected with diagnosis of septic shock, peripheral blood sample was taken for testing the VBG parameters and the anion gap (AG) was calculated. All the mentioned parameters were measured again after infusion of 500 cc of normal saline 0.9% in about 1 h.

Results: Totally, 93 patients with septic shock were enrolled, 63 male and 30 female. The mean age was 72.53 ± 13.03 and the mean Shock Index (SI) before fluid therapy was 0.79 ± 0.30. AG and pH showed significant negative correlations with CVP, While HCO3 showed a significant positive correlation with CVP. These relations can be affected by the treatment modalities used in shock management such as fluid therapy, mechanical ventilation and vasopressor treatment.

Conclusion: It is likely that there is a significant statistical correlation between VBG parameters and AG with CVP, but further research is needed before implementation of the results of this study.

1. Introduction

Shock is a true emergency medical condition, defined as inadequate blood perfusion to the body's tissues. This situation causes an imbalance between oxygen demand and supply, and leads to serious damage.[1] Therefore, it definitely needs prompt diagnosis and management, and serial assessments.[2] There are some major categories for better understanding and proper approach to shock including distributive, cardiogenic, hypovolemic, obstructive, and combined.[3,4] To emphasize the importance of this topic, it should be mentioned that shock usually needs treatment before finding out the exact underlying cause. Septic shock, which is a subgroup of the distributive category, is considered as a common cause of emergency department (ED) visits all around the world.[5] This type of shock needs adequate fluid therapy alongside antibiotic and probably corticosteroid administration. Assessment of the severity of circulatory fluid depletion in these patients, and reassessment of the situation during treatment is crucial and needs a ruler for better performance. Central venous pressure (CVP), along with some other parameters, has been used in this regards in ED. To measure the CVP, an invasive procedure should be performed to insert a central venous catheter (CVC). This procedure needs special preparation, including proper equipment, knowing the coagulation profile of the patient, and an expert physician. It is clear that these properties cannot be prepared in all EDs. If other less-invasive and routine parameters can estimate CVP, management of septic shock

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will be facilitated. Venous blood gas (VBG) analysis provides some parameters that are useful in this regard.[2] Detailed explanation pathophysiologically connection between tissue hypoxia, hypoperfusion and acidosis with CVP might help for better understanding the aspect. It is obvious that tissue hypoxia resulted from hypoperfusion happens in early stages of septic shock. The anticipated result should be acidosis that could be finding out by VBG analysis parameters.[5,6] CVP measures the perfusion, so it is conceivable to be a correlation between CVP and VBG analysis parameters. This study was conducted to assess the correlation between CVP and VBG analysis parameters to facilitate septic shock management in ED.

2. Material and methods

2.1. Study design

This diagnostic study was conducted from January 2014 until June 2015 in three major educational medical centers, Tehran, Iran.

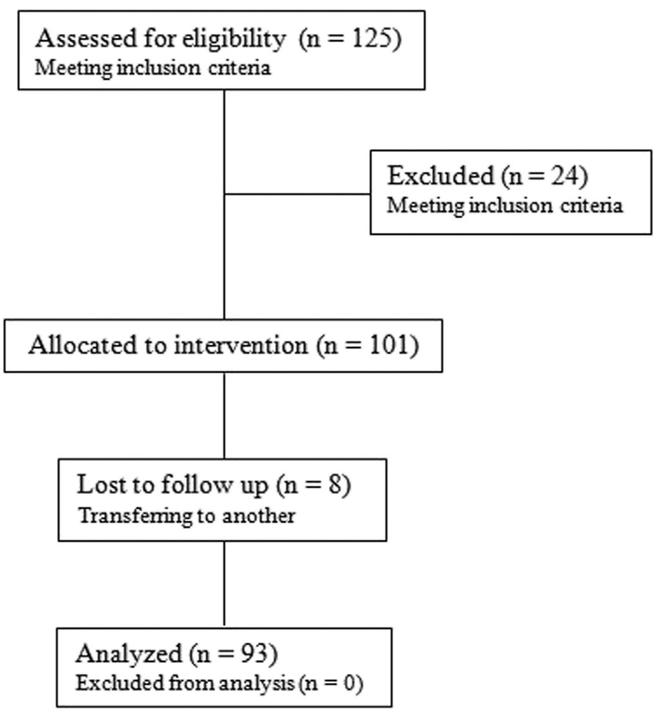

Fig. 1. Patient flow diagram.

2.2. Population and intervention

All patients with diagnosis of severe sepsis were enrolled in the study.[5] Those with known history of heart failure and/or renal failure were excluded. Following initial resuscitation of 20 cc/kg of crystalloid solutions, if the patient was still hypotensive and/or had serum level lactate of more than 4 mmol/l, central venous line was inserted in the internal jugular vein and those with initial CVP more than 8 cmH2O were excluded from the study[7] and those with CVP less than 8 cmH2O considered as eligible cases. For selected patients, peripheral blood sample was taken for testing VBG (measurement of pH, base excess (BE), and HCO3), sodium (Na) and chloride (Cl), and also the anion gap (AG) was calculated. These data along with demographic data were registered in a prepared checklist. Fluid challenge test [8,9] with infusion of 500 cc of normal saline 0.9% in about 1 h was performed and those with more than 3 cmH2O raise in CVP were excluded. All mentioned parameters were measured again for remained patient. Fig. 1 showed the patient flow diagram in this study.

2.3. Statistical analysis

SPSS version 21 with McNamara and kappa tests, statistical analysis was performed. Descriptive baseline variables are mentioned as mean ± standard deviation. For all comparative analysis p-value and r was calculated. P-value ≤ 0.05 was considered significant. For better understanding the comparisons bivariate and multivariate analysis were also conducted and related results are showed with tables and graphs.

2.4. Ethical issues

The study protocol was approved by the ethical committee of Shahid Beheshti University of Medical Sciences. The authors adhered to the Helsinki ethical principles throughout this research.

3. Results

Totally, 93 patients with a diagnosis of septic shock were enrolled in this study. The mean age was 72.53 ± 13.03 and 63 cases (67.7%) were male. The mean Shock Index was 0.79 ± 0.30 before fluid administration and 0.82 ± 0.74 after (normal range = 0.5–0.7). Table 1 shows the baseline characteristics of the sample patients including vital signs, VBG parameters, AG, and CVP before and after fluid administration and their changes in details.

Bivariate analysis Pearson correlation tests revealed that pH and AG had significant negative correlation (r = −0.21 and −0.18 respectively; %95 CI) with CVP, while HCO3 had significant positive correlation (r = 0.35; %95 CI) with CVP (P value < 0.05), as shown in

Table 1
Vital signs, VBG parameters, SI, AG, and CVP before and after fluid administration as well as their changes.

Variable	Before fluid administration	After fluid administration	The changes (Δ)
SBP	117.99 ± 30.00	120.76 ± 28.78	1.81 ± 15.76
DBP	67.28 ± 18.96	72.25 ± 17.94	5.04 ± 16.76
MAP	85.26 ± 22.04	89.34 ± 21.27	3.81 ± 15.90
PR	87.06 ± 19.19	84.22 ± 19.44	−1.36 ± 14.81
SI	0.79 ± 0.30	0.82 ± 0.74	−0.02 ± 0.17
pH	7.35 ± 0.10	7.34 ± 0.14	0.00 ± 0.14
HCO3	24.36 ± 6.76	25.87 ± 24.45	−0.47 ± 5.64
BE	0.25 ± 8.26	1.73 ± 7.99	1.19 ± 7.51
AG	11.71 ± 9.25	13.85 ± 9.38	2.19 ± 8.61
CVP	6.90 ± 5.07	8.41 ± 4.54	2.34 ± 3.74

SBP: systolic blood pressure; DBP: diastolic blood pressure; MAP: mean arterial pressure; PR: pulse rate; SI: shock index; BE: base excess; AG: anion gap; CVP: central venous pressure.

Table 2 and Fig. 2(A) and (B)-(C).

Multivariate analysis showed that among patients under mechanical ventilation, pH and AG showed significant negative correlation (r = −0.19 and −0.22 respectively; %95 CI) with CVP, but HCO3 showed a significant positive correlation (r = 0.36; %95 CI) with CVP (P value < 0.05). Whereas in patients without mechanical ventilation, only pH had a significant negative correlation (r = −0.36; %95 CI) with CVP, as shown in Table 3.

It also showed that among patients treated by vasopressor drugs, pH had a significant negative correlation (r = −0.40; %95 CI), but HCO3 showed a significant positive relationship (r = 0.47; %95 CI) with CVP (P < 0.05). On the other hand, among patients without vasopressor treatment, AG had a significant negative correlation (r = −0.35; %95 CI), while HCO3 showed a positive correlation (r = 0.33; %95 CI) with CVP, as shown in Table 4.

The effect of fluid therapy on the relationship between VBG parameters and AG with CVP was also assessed. PH (P = 0.51; r = 0.07), HCO3 (P = 0.70; r = 0.04), BE (P = 0.31; r = 0.11) and the CVP had not significant correlation. Only the change in AG before

Table 2
Correlation of VBG parameters and AG with CVP (%95 CI).

Variable	CVP	
	P	R
pH	0.003	−0.21
HCO3	<0.001	0.35
Base excess	0.15	0.07
Anion gap	0.04	−0.18

CVP: central venous pressure.

Table 3
Relation of venous blood gas parameters and AG with CVP according to of mechanical ventilation (%95 CI).

Variable	Patients CVP on mechanical ventilation		Patients CVP with spontaneous breathing	
	P	r	P	r
pH	0.003	−0.19	0.049	−0.36
HCO3	<0.001	0.36	0.30	0.19
Base excess	0.15	0.09	0.81	−0.04
Anion gap	0.04	−0.22	0.07	0.33

CVP: central venous pressure.

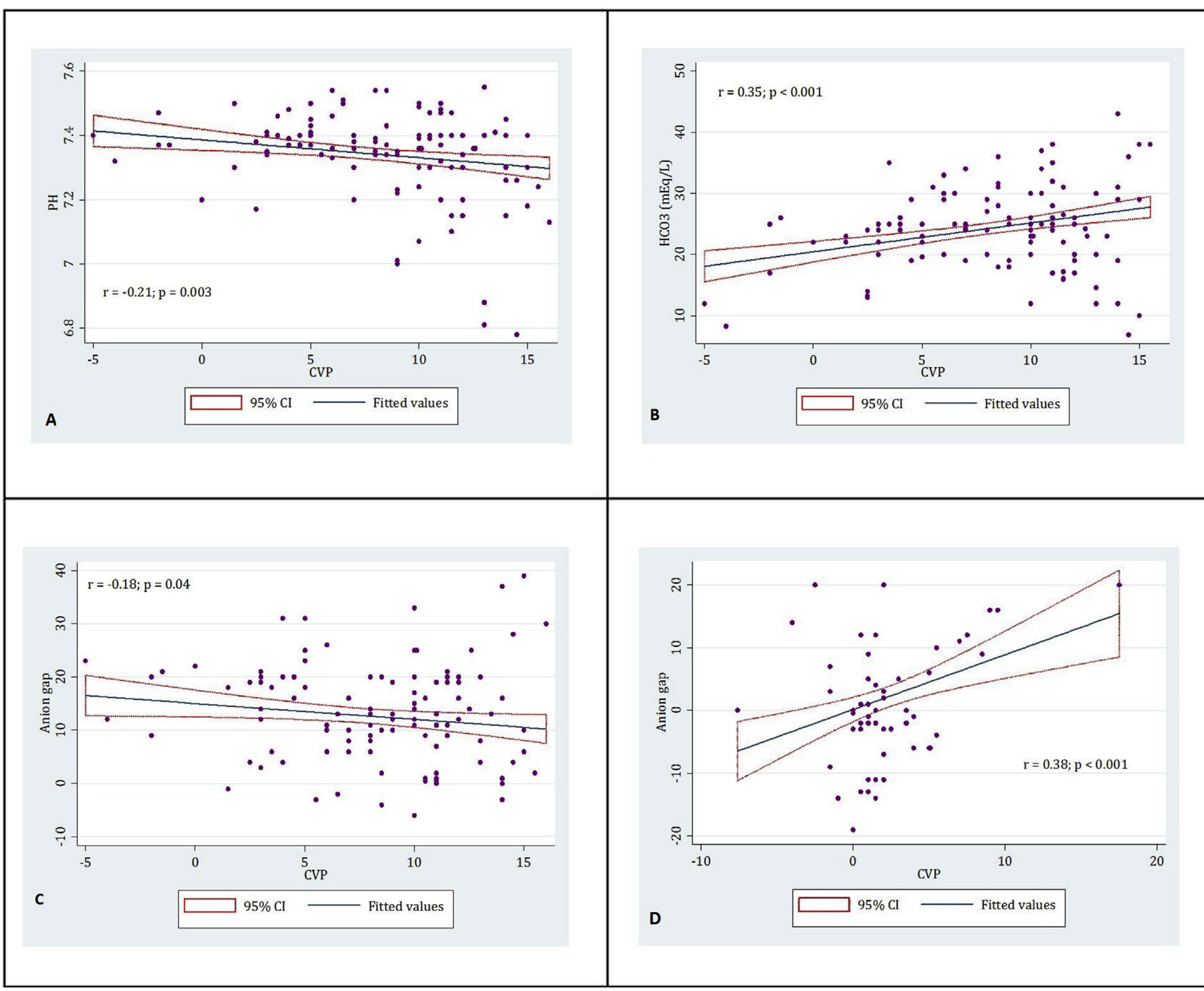

Fig. 2. Correlation of pH with CVP (A); Correlation of HCO3 with CVP (B); Correlation of AG with CVP (C); Correlation of ΔAG with CVP (D).

Table 4
Relation of venous blood gas parameters and AG with CVP according to vasopressor administration (%95 CI).

Variable	Patients CVP on vasopressor		Patients CVP without vasopressor	
	P	r	P	r
pH	0.003	−0.40	0.94	−0.006
HCO3	0.001	0.47	<0.001	0.33
Base excess	0.39	0.05	0.20	0.11
Anion gap	0.29	−0.11	<0.001	−0.35

CVP: central venous pressure.

and after fluid therapy (Δ AG) had a significant positive correlation ($r = 0.38$; %95 CI) with CVP ($P < 0.05$), as shown Fig. 2 (D).

4. Discussion

Early goal directed therapy (EGDT) is still considered in dealing with septic shock in ED, but recent studies put some doubt on its usefulness in practice.[10,11]Therefore several studies are ongoing to modifying each step. In this study we point to perform a basic study to challenge the possibility of replacing the CVP with less invasive parameters.[12,13] Based on our findings, there was a significant statistical correlation between some of the VBG parameters including pH and HCO3 and also AG with CVP.

Both low and high intravascular volumes are important variables affecting hemodynamic instability that can be associated with poor outcomes; hence, rapid and proper correction of both states through fluid therapy is a cornerstone in shock management. Therefore, fluid therapy needs a reliable, available, and fast measurement tool for estimating the intravascular volume. Despite the wide use of CVP as a tool to guide fluid therapy, there are still some negative points in this regard.[14] Use of CVP implies insertion of a central venous line, which requires specialized health institutions and highly trained personnel, and can be associated with significant morbidities. CVC causes more than 90% of catheter related infections in hospitalized patients.[15] Thrombosis of internal jugular and subclavian veins occur in 33–67% of patients if the catheter is used for more than 7 days.[16] Several studies have doubted the efficacy of CVP as a consistent measure in monitoring shock patients due to persistence of elevated shock index even after normalization of this parameter.[17] In a study by Kumar et al., CVP & pulmonary artery occlusion pressure (PAOP) failed to prove a significant correlation with stroke volume and end diastolic volume.[18] Also, the use of CVP in evaluating shocked patients can be impaired by multiple confounding factors such as right ventricular dysfunction and valvular heart diseases.[8] Other studies have concluded the superiority of dynamic circulatory markers such as variation in cardiac output, heart rate, and stroke volume, over static measures like CVP and PAOP due to their accurate reflection of intravascular volume.[19,20]

Current study assessed the effect of fluid therapy on VBG, CVP and vital signs through biphasic measurement of these variables before and after first fluid administration following insertion of central venous line. This enhances our understanding of the effect of such therapeutic intervention on different monitoring parameters. The findings of our study are sort of consistent with the results of a study performed by Kaplan et al. on traumatic patients, showing that the initial measurement of pH, BD, and AG at the ED could predict survival in patients with major vascular injury.[21] They also correlate with the results of a pilot diagnostic study by Baratloo et al. which concluded that the correlation between CVP and VBG parameters such as pH, anion gap and bicarbonate can be used to develop a non-invasive tool for monitoring patients with septic shock.[2] Considering the findings of current study and also pathophysiology of septic shock, it could be recommended to pay more attention to such easily available paraclinic findings for shock management in ED. Specially BE and HCO3 that directly affected by metabolic acidosis as a result of shock may be more reasonable.

Considering the disadvantages of CVP and the doubt of its efficacy, some studies were conducted to find non-invasive or less invasive parameters that can significantly correlate with CVP. A study by Creuter et al. indicated that patients with septic shock showed lower O2 saturation compared to normal controls.[22] The correlation between O2 saturation with hemodynamic and metabolic parameters can serve as a tool to predict the outcome of shock.[23,24] In the same way, several lines of evidence investigated the correlation between base deficit (BD) and shock index and suggested BD measurements to predict hemorrhage and multi organ failure.[25–28]

In this study, we tested the possibility of VBG parameters as monitoring tools by investigating the correlation between these measures and CVP. The correlation was proven statistically, but further research is needed to make this correlation clinically practical. At our study CVP and VBG analysis are given comparatively and the authors believe that researches with larger study population may result to derivation of a mathematical equation so could estimated the CVP based on VBG analysis parameters. If so, it could be used at clinic practice. Even base excess that did not show significant statistical correlation with CVP in current study, could be consider as a valuable parameter for evaluating the process and efficacy of fluid therapy. We strongly believe that assessing the amount of base excess changes (Δ BE) would be more useful in this regards.

5. Limitations

We did not correlate our study variables to clinical parameters like length of ICU stay, incidence of organ dysfunction and mortality rate. Although we performed biphasic measurement of our variables before and after fluid administration, we did not conduct follow up measurements to evaluate the correlation of these variables with different stages of shock. Moreover, the presence of some confounding variables such as mechanical ventilation and vasopressor administration might have affected our study results. Further studies are recommended to address these limitations.

6. Conclusion

It is likely that there is a significant statistical correlation between some of the VBG parameters and CVP, but further research is needed before implementation of the results of this study.

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Conflict of interest

All authors declare that there is no conflict of interest in this study.

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