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Original Research Article

Respiratory variation of inferior vena cava diameter and central venous pressure in ventilated and non-ventilated children in fluid refractory septic shock: an observational study

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ABSTRACT

Background: Ultrasound guided fluid assessment in management of septic shock has come up as an adjunct to the current gold standard Central Venous Pressure monitoring. This study was designed to observe the respiro-phasic variation of IVC diameter (RV-IVCD) in invasively mechanically ventilated and spontaneously breathing paediatric patients of fluid refractory septic shock.
Methods: This was a prospective observational study done at Paediatric intensive Care Unit (PICU) in Paediatric ward of Jawaharlal Nehru Medical College and Hospital (JNMCH) from February 2016 to June 2017. 107 consecutive patients between 1 year to 16 years age who were in shock despite 40ml/kg of fluid administration were included. Inferior Vena Cava (IVC) diameters were measured at end-expiration and end inspiration and the IVC collapsibility index was calculated. Simultaneously Central Venous Pressure (CVP) was recorded. Both values were obtained in ventilated and non-ventilated patients. Data was analysed to determine to look for the profile of RV-IVCD and CVP in ventilated and non-ventilated cases.
Results: Out of 107 patients, 91 were on invasive mechanical ventilation and 16 patients were spontaneously breathing. There was a strong negative correlation between central venous pressure (CVP) and inferior vena cava collapsibility (RV-IVCD) in both spontaneously breathing (-0.810) and mechanically ventilated patients (-0.700). Negative correlation was significant in both study groups in CVP <8 mmHg and only in spontaneously breathing patients in CVP 8-12 mmHg range. IVC collapsibility showed a decreasing trend with rising CVP in both spontaneously breathing and mechanically ventilated patients.
Conclusion: Ultrasonography guided IVCCI appears to be a valuable index in assessing fluid status in both spontaneously breathing and mechanically ventilated septic shock patients. However, more data is required from the paediatric population so as to define it as standard of practice.

Keywords: Central venous pressure, Fluid status, Inferior vena cava collapsibility index, Mechanically ventilated, shock, Spontaneously breathing, Ultrasonography

INTRODUCTION

Fluid assessment is an important aspect in the management of septic shock. Apart from the clinical assessment of fluid responsiveness, central venous pressure monitoring is the current standard of practice for the accurate measurement of the preload and for the assessing the requirement of fluid boluses and the response to fluid administration. However, CVP monitoring is an invasive procedure and is associated

with complications like pneumothorax, hemothorax, arterial puncture and failure of catheter insertion.[1]

In recent times, ultrasound has emerged as a bedside non-invasive modality of assessment of intravascular status by measuring inferior vena cava diameter.[2] Several studies have been done to study the IVC diameter and its correlation with the CVP in fluid assessment of shock.[3] However, most of the studies have been done in the adult patients.[4-6] So, this observational study was designed to study the Respiratory Variation in the IVC Diameter (RV-IVCD) in septic shock patients of the paediatric age group, and their correlation with the CVP, in both spontaneously breathing and in patients on invasive mechanical ventilation.

METHODS

This study was done at Paediatric intensive Care Unit (PICU) in Paediatric ward of Jawaharlal Nehru Medical College and Hospital (JNMCH) from February 2016 to June 2017. The clearance was taken from Institutional Ethics Committee of JNMCH. This was a prospective observational study. During the study period, consent was taken from parents of all consecutive paediatric septic shock patients from 1 year to 14 years age who were being admitted to PICU.

Central line placement was done in the internal jugular vein according to the standardised protocol, and central venous pressure was transduced via the seven parameter (Nihon Kohden). The bedside echocardiography was done by the pediatric critical care specialist on a GE vivid model. The ultrasonography images were obtained in supine position of the patient with ultrasound probe in subxiphoid position visualising IVC in a longitudinal plane. The IVC-RA (Right atrium) junction and the hepatic vein were visualised and IVC diameters were measured 2 cm distal to the hepatic vein-IVC junction. M mode was used to capture the images.

In both spontaneously breathing and ventilated patients, the IVC diameter was measured at end-expiration and end inspiration. The IVC collapsibility index was calculated by subtracting the minimum diameter of IVC (Dmin) from the maximum diameter of IVC (Dmax) divided by the maximum diameter expressed as a percentage.

$$\text{RV} - \text{IVCD} = \frac{(\text{Dmax} - \text{Dmin})}{\text{Dmax}} \times 100$$

Baseline clinical variables were noted. The CVP, IVC diameters were measured.

The data was entered and analysed on the latest SPSS version 21. Descriptive statistics were calculated for both qualitative variables. Pearson correlation coefficient was used to assess the significance between CVP and RV-IVCD(%). A p-value <0.05 was considered as significant.

RESULTS

A total of 107 patients were recruited in the study out of which 91 were on invasive mechanical ventilation and 16 patients were spontaneously breathing. The mean age of the patients was 7 year 6 months.

Table 1: Baseline parameters.

Parameter	
Age (years)	7.6 (±4.153)
Gender	
Males(n=49)	46%
Females(n=58)	54%

Table 2: Clinical parameters.

Mean heart rate(beats/min)	**150(±25)**	
Mean respiratory rate/minute (before intubation)	37(±10)	
Mean Oxygen Saturation(%)	97%(±2.110)	
Type of breathing	Intubated	85%
	Non-intubated	15%
BP (MAP) (mm of Hg)	Age 1-5	52.79(±11.829)
	Age 6-10	61.66(±15.857)
	Age 11-14	62.23(±12.402)
CFT	<3 sec	19.5%
	>3 sec	80.5%
Clinical fluid status	Hypovolemic	51%
	Euvolemic	38%
	Hypervolemic	11%
Type of shock	septic shock (primary diagnosis)	93%
	septic shock (secondary to other diseases)	7%

Majority of the patients (85%) were intubated, and saturation was maintained in all patients According to clinical fluid status maximum patients (51%) were in hypovolemic state and had septic shock (93%). All mechanically ventilated patients were sedated and paralyzed.

In all cases CVP was measured. In 66.4% cases, CVP was <8mmHg, in 13.1% cases CVP was from ≥8 to 11mmHg, and in rest 20.6% cases CVP was above ≥12mmHg. Inverse correlation between CVP and IVCCI was observed in both spontaneously breathing and mechanically ventilated patients. (Figure 1, Table 3).

There was trend of decreasing IVC collapsibility with rising CVP in both spontaneously breathing and mechanically ventilated patients with negative correlation

being significant in both study groups in CVP <8 mmHg and only in spontaneously breathing patients in CVP 8-12 mmHg range (Figure 2, Table 4). Only 1 case was there in non-intubated group with CVP ≥ 12mmHg.

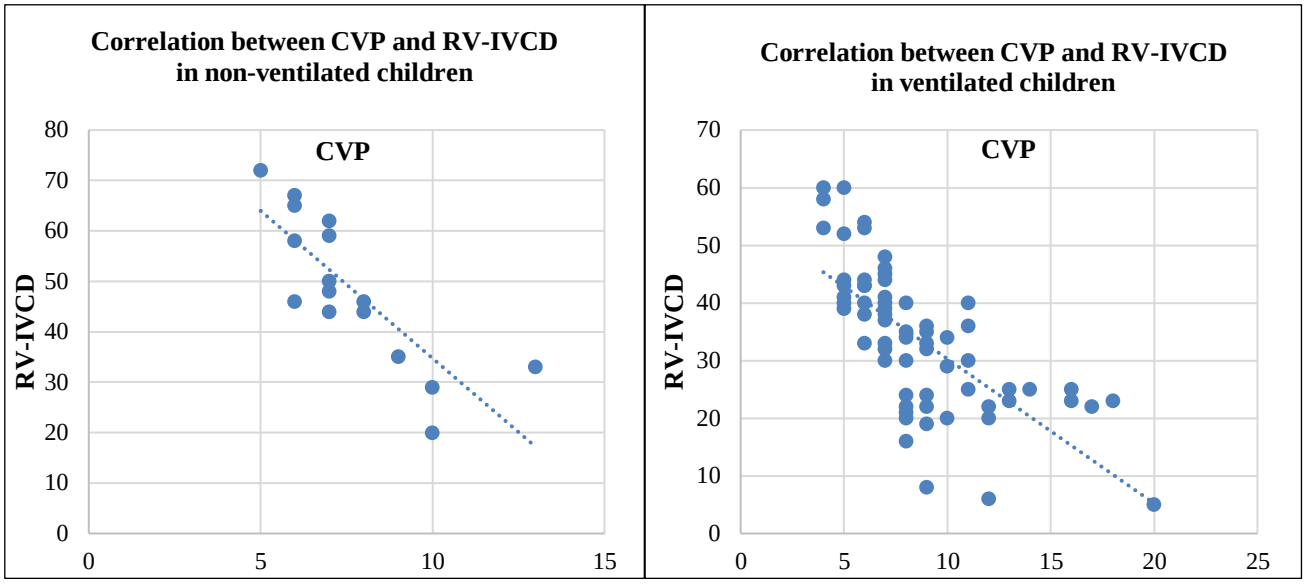

Figure 1: The correlation of RV-IVCD (Y-axis) at different CVP values (X-axis) in mechanically ventilated and spontaneously breathing patients.

Table 3: Correlation of IVCI and CVP in intubated and non-intubated patients.

	IVCCI (%)	CVP(mm of Hg)	Correlation
Intubated (N=91)	36.21(±13.91)	8.263(±3.16)	-0.7004
Non-Intubated (N=16)	53.19(±12.95)	7.5(±1.93)	-0.810

Table 4: CVP range wise correlation between CVP and RV-IVCD.

	CVP	RV-IVCD	Correlation	P
CVP <8mmHg				
All (N=56)	6.07(±0.959)	46.127(±12.119)	-0.524	<0.01
Intubated(N=46)	6(±1)	42.432(±10.298)	-0.516	P <0.01
Non Intubated (N=10)	6.4(±0.663)	57(±8.832)	-0.631	P<0.05
CVP 8-12mmHg				
All (N=40)	8.945(±0.998)	33.96(±12.309)	-0.098	0.44
Intubated (N=35)	8.997(±1.015)	29.272(±7.480)	0.058	0.74
Non Intubated(N=5)	8.6(±0.8)	36.66(±9.48)	-0.978	<0.01
CVP >12mmHg				
All (N=11)	14.667(±2.56)	23.115(±15.091)	-0.526	0.07
Intubated(n=10)	14.818(±2.662)	21.25(±12.787)	-0.514	0.08

DISCUSSION

In this study, it was found that the RV-IVCD had a negative correlation with CVP, with IVC collapsibility decreasing with the rising CVP values. The correlation was significant in both intubated and spontaneously breathing patients in lower CVP values of <8mmHg, while with >8mmHg CVP values, although, there was inverse correlation in RV-IVCD and CVP, however, it was significant only in the spontaneously breathing group of patients.

Several studies have been done in the past studying the RV-IVCD and its correlation with CVP. However, most of the studies have been done in adult patients and there is lack of comprehensive data in the pediatric population. A recent study compared RV-IVCD with CVP in pediatric mechanically ventilated patients of septic shock

in age group 1-12 years, and found that RV-IVCD index was 45.5% sensitive and 91.7% specific with positive predictive value of 71.4 and negative predictive value of 78.6 to predict CVP <8mmHg, concluding IVC non-invasive indices as a useful guide in fluid assessment especially in lower CVP range.[7]

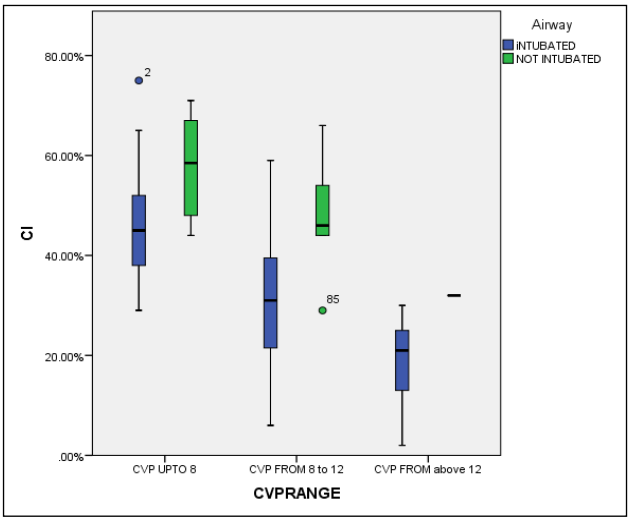

Figure 2: The trend of RV-IVCD across different CVP ranges in mechanically ventilated and spontaneously breathing patients.

Paediatric patients with cardiovascular disease with the aim to find the effectiveness of IVC diameters variability in assessing high CVP by studying the correlation between CVP and RV-IVCD. The study population included paediatric patients who underwent cardiac catheterization. The study revealed that the maximum and minimum diameters of IVC correlated well with CVP in spontaneously breathing patients than mechanically ventilated patients. RV-IVCD also significantly correlated with CVP in spontaneously breathing patients.[8] This study showed results similar to our study however the profile of patients was different with most patients in septic shock in our study as compared to cardiac patients in this study.

A systematic research article published in 2016 analysed twenty one studies done in adults regarding IVC and CVP correlation and found that most studies demonstrated moderate strength correlations between measurements of IVC diameter and collapsibility and CVP. However, findings were inconsistent among mechanically ventilated patients, except in the absence of positive end-expiratory pressure.[3] Another on comparative evaluation of CVP and IVC changes to assess fluid responsiveness in mechanically ventilated septic shock patients found inverse correlation was found between the measured CVP and RV-IVCD.[9] If noninvasive USG guided IVC diameters and RV-IVCD were helpful to assess intravascular volume status in 83 adult intubated critical patients. This study also noted negative correlation between CVP and IVC.[10]

The CVP is the current standard of practice by intensivists and anesthetists regarding fluid assessment in management of shock patients. However, CVP is an invasive procedure which is time-taking, and is associated with complications like pneumothorax, hemothorax, arterial puncture and bleeding and a failure to place central venous line. Therefore, ultrasonography is the emerging modality in the fluid assessment and management of shock. It is less invasive, quick to perform and not associated with any potential complications. There are few limitations like supine posture and less reliability in conditions of raised intra-abdominal pressure however can be performed without any additional expertise over CVP placement as an intensivist can perform both invasive line placement as well as bedside echocardiography.

CONCLUSION

Ultrasonography guided IVCCI is a valuable modality for fluid assessment in both spontaneously breathing and mechanically ventilated patients. There is strong negative correlation between central venous pressure (CVP) and inferior vena cava collapsibility (RV-IVCD) in both group of patients which seems to be more significant in lower CVP ranges. Indexing IVC collapsibility is non-invasive, less time consuming and is not associated with any complications which makes it more appealing. However, we need to have more data in paediatric population to define it as standard of practice for volume assessment.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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