

CORRELATION BETWEEN CENTRAL VENOUS PRESSURE AND INFERIOR VENA CAVA DISTENSIBILITY INDEX FOR ASSESSMENT OF VOLUME STATUS IN CRITICALLY ILL CHILDREN

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ABSTRACT

Background: Fluid management is a critical component for the management of critically ill children. This condition requires an examination to assess intravascular volume. Assessment of central venous pressure (CVP) is often used in critically ill children. Still, it is an invasive procedure that is prone to various complications, while measurement of the inferior vena cava distensibility index (IVC-DI) with ultrasound is a non-invasive procedure that can also be used to assess volume status in critically ill children.

Objective: To determine the correlation between central venous pressure and inferior vena cava distensibility index to assess volume status in critically ill children.

Methods: Analytic cross-sectional study was carried out in PICU RSUP H. Adam Malik Medan from December 2021 until January 2022. Samples were patients aged from 1 month to 18 years hospitalized in PICU with a central vein catheter installed and mechanical ventilation. Exclusion criteria were defined as patients with heart failure, hemothorax, pneumothorax, and hemopneumothorax. This study was conducted by examining central venous pressure (CVP). Then, the USG doppler was used simultaneously to assess the inferior vena cava distensibility index (IVC-DI). The correlation between central venous pressure and inferior vena cava distensibility index was assessed using the Spearman Correlation test or Kruskal Wallis test.

Results: CVP and IVC-DI values had a strong correlation in negative correlation and the result was statistically significant ($r = -0,623$, $p = 0,003$). Meanwhile, a significant correlation positive was found between CVP and volume status ($r = 0,940$, $p = <0,001$) but it had negative correlation with IVC-DI ($r = -0,573$, $p = 0,008$).

Conclusion: There was a negative correlation between central venous pressure and inferior vena cava distensibility index for assessing volume status in critically ill children.

Keywords: central venous pressure, inferior vena cava distensibility index, volume status, critically ill children

BACKGROUND

Fluid therapy is an essential for critically ill patients. Estimating the proper amount of fluid needed is very important due to obvious outcome from negative and positive fluid balance.¹ Critically ill pediatric patients in the Pediatric Intensive Care Unit (PICU) often have critical and urgent medical problems.² Some experts use invasive hemodynamic monitoring as an adjunct to planning fluid management. Central venous pressure (CVP) is the most commonly used variable, and more than 90% of anesthesiologists use CVP to guide fluid management.³

Despite the limitations of CVP as a marker of intravascular volume status, low CVP can generally be relied to support a positive response to fluid loading.⁴ However, measurement of CVP requires an invasive central venous catheter which is difficult to install and associated with complications.⁵ one study said 69% of patients admitted to the PICU used a central venous catheter.⁶

Inferior Vena Cava (IVC) is a retroperitoneal structure that located longitudinally to the spinal column and lies to the right of the abdominal aorta. The IVC lies posterior to the liver and empties into the right atrium. The hepatic vein drains into the IVC just caudally from the right atrium.⁷ Ultrasound measurement of IVC diameter (IVC-USG) is reported to be a method that can reflect fluid status. Changes in intrathoracic pressure during the respiratory cycle affect venous return (VR) and central venous diameter such as IVC so that they can reflect intravascular fluid status. Variations in IVC diameter following the respiratory cycle can be described in two indices, namely IVC collapsibility index (IVC-CI) and IVC distensibility index (IVC-DI). IVC-CI is calculated by dividing the difference between the maximum IVC diameter at the end of expiration and the minimum IVC diameter at the end of inspiration by the maximum IVC diameter at the end of expiration in spontaneously breathing patients.⁸

Several previous studies were conducted on adult critically ill patients regarding the relationship between CVP and IVC-DI in assessing patient volume status, but the data in children were still limited. Hence, the researcher was interested in assessing the correlation of central venous pressure with the value of the inferior vena cava distensibility index to assess the volume status of critically ill patients.

The purpose of this study is to determine the correlation of central venous pressure with the value of the inferior vena cava distensibility index to assess volume status in critically ill patients admitted to the PICU of H. Adam Malik Hospital Medan.

METHODS

This study is an analytical observational study with a cross-sectional design to determine the correlation between central venous pressure and inferior vena cava distensibility index to assess volume status in critically ill patients. The study was conducted from December 2021 to January 2022 at the Pediatric Intensive Care Unit (PICU) H. Adam Malik Hospital, Medan. Samples were patients aged one month to 18 years treated in the PICU with a central venous catheter and mechanical ventilation. Exclusion criteria were patients with cardiac abnormalities and who had a hemothorax, pneumothorax, or hemopneumothorax. The study was carried out by measuring central venous pressure (CVP), then an inferior vena cava distensibility index (IVC-DI) was assessed using Doppler ultrasound at the same time. Then, the correlation between central venous pressure and inferior vena cava distensibility index was assessed using the Spearman Correlation or Kruskal Wallis test. This study has been approved by the Research Ethics Committee of the University of North Sumatra No: 1329/KEP/USU/2021.

RESULTS

This study conducted 20 children with critically ill patients, with most of the critical child subjects being male that is 12 children (60%). The mean age of the subjects was 86.5 months, with the youngest child being one month old and the oldest being 108 months (17 years). The subjects' average body weight and height were 24.32 kg and 106.45 cm, respectively.

The mean pulse rate was 125.9 beats/minute. The mean systolic blood pressure was 99.5 mmHg, and the average diastolic blood pressure was 57.3 mmHg. Most central venous catheter placement locations were left subclavian, amounting to 10 persons (50%). The most mechanical ventilator mode was PCV installed in 15 children (75%). Furthermore, the characteristics of the research subjects can be seen in table 1.

Table 1. Characteristics of Research Subjects

Subject Characteristics	n = 20	p
Gender, n (%)		
Male	12 (60)	
Female	8 (40)	
Age, month		
Average (SD)	86.5 (79.64)	0.030
Weight, kg		
Average (SD)	24.32 (20.76)	0.056
Height, cm		
Average (SD)	106.45 (45.51)	0.072
Pulse Frequency, x/m		
Average (SD)	125.9 (23.09)	0.200
Systolic Blood Pressure, mmHg		
Average (SD)	99.5 (19.38)	0.200
Diastolic Blood Pressure, mmHg		
Average (SD)	57.3 (14.61)	0.200
Location, n (%)		
Jka	1 (5)	
Ska	9 (45)	
Ski	10 (50)	
Mode, n (%)		
CPAP	1 (5)	
PCV	15 (75)	
PSIMV	2 (10)	
Spontaneous	2 (10)	

Table 2 shows central venous pressure (CVP) examination results and the value of the inferior vena cava distensibility index (IVC-DI). The average CVP in research subjects was 9.15 cmH₂O, with the lowest value was 6 cmH₂O and the highest CVP value was 12.8 cmH₂O. Most of the critical pediatric patients, amounting to 9 persons (45%), had normal volume value, 6 persons (30%) hypovolume, and 5 persons (25%) hypervolume.

The study subjects' inferior vena cava distensibility index values showed an average of 40.49%, with the lowest of 16.6% and the highest of 83.9%. Eight critically ill pediatric patients (40%) showed an increased IVC-DI value, while a decreased IVC-DI was found in 8 patients, and 4 patients (20%) had normal IVC-DI values.

Table 2. CVP and IVC-DI Examination Results

Subject Characteristics	n = 20	p
CVP		
Average (SD)	9.15 (2.52)	0.033
Hypovolume, n (%)	6 (30)	
Normovolume, n (%)	9 (45)	
Hypervolume, n (%)	5 (25)	
ICV-DI		
Average (SD)	40.49 (19.57)	0.046
Decreased, n (%)	8 (40)	
Normal, n (%)	4 (20)	
Increased, n(%)	8 (40)	

The Spearman correlation test showed a significant correlation between CVP and the Inferior Vena Cava Distensibility Index ($p = 0.003$). The correlation value obtained was -0.623. The negative sign means that CVP is negatively correlated with the Inferior Vena Cava Distensibility Index value, which means that the greater the CVP value, the smaller the Inferior Vena Cava Distensibility Index value with a strong correlation. The results of the CVP correlation analysis and the value of the Inferior Vena Cava Distensibility Index can be seen in table 3 and figure 1.

Table 3. Correlation of Central Venous Pressure (CVP) with Inferior Vena Cava Distensibility Index Values

	Inferior Vena Cava Distensibility Index	
	p	r
CVP	0.003*	-0.623

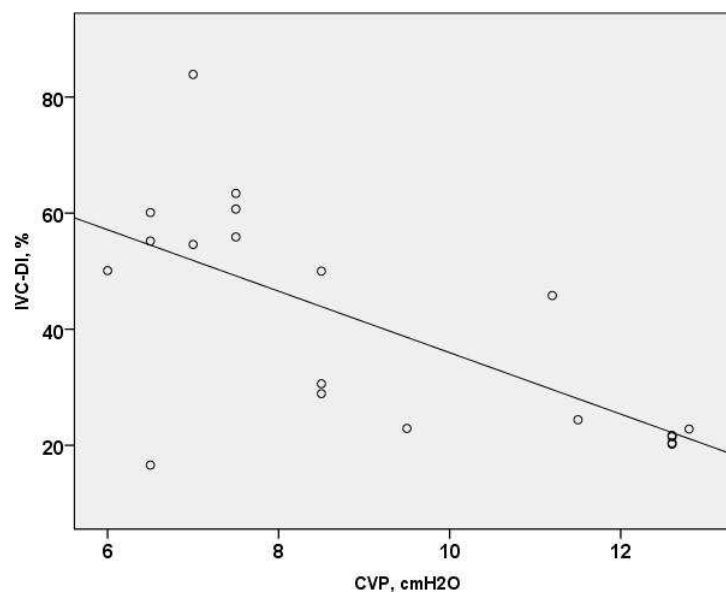


Figure 4.1 Scatterplot Graph of CVP Correlation with IVC-DI value

Table 4 presents the analysis results of the relationship between CVP and the value of the Inferior Vena Cava Distensibility Index by categorizing the two variables. Of the 6 critical pediatric patients with hypovolume central venous pressure, 5 children (83.3%) had increased Inferior Vena Cava Distensibility Index values. Meanwhile, all 5 critical children with hypervolume central venous pressure showed a decreased Inferior Vena Cava Distensibility Index value. The use of the Kruskal Wallis test showed a significant relationship between central venous pressure and the value of the Inferior Vena Cava Distensibility Index.

Table 4. Correlation of Central Venous Pressure (CVP) with Inferior Vena Cava Distensibility Index Values

	Inferior Vena Cava Distensibility Index			p
	Decrease	Normal	Increase	
Hypovolume	1 (16.7)	0	5 (83.3)	0.010*
Normovolume	2 (22.2)	4 (44.4)	3 (33.3)	
Hypervolume	5 (100)	0	0	

Using the Spearman correlation test, table 5 shows a significant correlation between CVP and volume status ($p < 0.001$). The correlation value obtained was 0.940. A positive sign means that CVP was positively correlated with volume status, which means that the greater the CVP value, the volume status will increase with a very strong correlation level ($r\text{-value} > 0.8 - 1$).

Meanwhile, there was also a significant correlation between IVC-DI and volume status ($p = 0.008$) with a correlation value of -0.573. Therefore, a negative sign means that IVC-DI was negatively correlated with volume status, which means that the greater the value of IVC-DI, the volume status will increase with a moderate level of correlation ($r\text{-value} > 0.4 - 0.6$).

Table 5. Correlation of CVP and IVC-DI to Volume Status

	Volume Status	
	r	p
CVP	0.940	<0.001
IVC-DI	-0.573	0.008

DISCUSSION

The characteristic data in this study showed that most of the critical child subjects were male (60%), the mean age of the subjects was 86.5 months, the average body weight and height of the subjects were 24.32 kg and 106.45 cm, respectively, but gender and age did not significantly affect the measurement of central venous pressure (CVP) and IVC diameter. Studies on healthy children also did not discuss the relationship between sex and age in these cases.⁹ Research

conducted by Taneja et al. concluded that there were no correlation between IVC diameter and various somatic parameters such as weight, height, and body surface area in children in India.¹⁰

The hemodynamic data of the study subjects such as pulse rate, systolic, and diastolic blood pressure were found with a mean of 125.9 times/minute, 99.5 mmHg, and 57.3 mmHg, respectively. Research conducted by Vaish et al. and El-Nawawy et al. showed that in 50 pediatric patients with shock, the hemodynamic variables improved with fluid resuscitation and showed an increase in CVP and a decrease in the IVC diameter index in these patients.^{11,12} In this study, the average CVP of the subjects was 9.15 cmH₂O, and the average IVC-DI value of the subjects was 40.49%.

Using a ventilator will affect the diameter of the IVC, where positive pressure ventilation can increase pleural pressure and right atrial pressure by reducing venous return to the heart and increasing intrathoracic pressure during inspiration. The IVC diameter widens during inspiration and contracts during expiration in an intubated patient.^{2,11} In a meta-analysis study by Si et al., the accuracy of IVC diameter was investigated as a predictor of fluid responsiveness in mechanically ventilated patients when tidal volume 8 ml/kg and PEEP 5 cmH₂O.⁸ In this study, the IVC diameter was not assessed for responsiveness to fluids.

Measurement of IVC diameter with ultrasound is significant in assessing intravascular fluid status and response to fluid administration. Ultrasonography plays a role in determining the patient's intravascular volume status with the advantages of non-invasive procedures, not requiring a long time and lower operating costs than CVP. The approach to intravascular fluid volume status (in this case, preload) can also be assessed using bedside ultrasonography (USG) by evaluating the diameter of the SVC and the diameter of the IVC.¹³

Hemodynamic monitoring aims to assess the patient's body fluid status and assess the patient's cardiac function. One of the parameters used is central venous pressure (CVP) which can assess blood pressure in the superior vena cava and right atrium of the heart.¹⁴ The relationship between CVP and IVC-DI values occurs because of the tendency for blood vessels to stretch and contract according to the ability of these blood vessels to comply. Compliance is the magnitude of the change in volume for each change in pressure that occurs, so that in a blood vessel, the greater the compliance, the greater the collapsibility and distensibility.¹⁵ This study found a negative correlation value of -0.623, which means that the greater the CVP value, the lower the inferior vena cava distensibility index value with a strong correlation level. The similar results were found in the study of Frisianto et al., where they found a very strong correlation between CVP and IVC-DI values ($r = -0.820$, $p < 0.05$).¹⁶ CVP values and variations in IVC diameter are influenced by intrathoracic pressure due to the spontaneous respiration process, or the positive pressure given by the ventilator will affect the IVC value.¹⁷

Changes in IVC parameters are due to the interaction between intra- and extra-luminal pressure, namely due to the interaction between intra-thoracic and intra-abdominal pressures. IVC collapsibility may occurred due to decreased of right atrial pressure or CVP, increased intra-abdominal pressure, or a combination of both. Several factors affect IVC, including factors that

affect intraluminal pressure include right ventricular compliance where right ventricular diastolic dysfunction inhibits venous return and results in increased pressure causing greater IVC distention despite the low intravascular volume, the tricuspid disease that can increase right atrial pressure, right atrial obstruction where obstruction to distal blood flow may occur within the heart or in the lungs, diversion of vascular flow in which most of the blood from the lower extremities returns to the right atrium via the IVC, while a small portion returns via the azygos venous system.^{18,19}

In addition, there are also extraluminal factors in the form of intrathoracic pressure such as tension pneumothorax resulting in increased intrathoracic pressure and preventing venous return, spontaneous ventilation where IVC parameters change during spontaneous ventilation, increased respiratory effort in critically ill patients due to pressure from underlying cardiopulmonary pathology, such as asthma or chronic obstructive pulmonary disease, metabolic acidosis or systemic inflammatory response syndrome will result in false IVC measurements.¹⁵ Intrapericardial pressure due to pericardial tamponade by fluid or extrinsic compression can cause atrial collapse and impede venous return. Increased intra-abdominal pressure can reduce IVC, as in ascites or edema of other intra-abdominal organs.²⁰

This study is the first study that assessed the correlation of central venous pressure and inferior vena cava distensibility index in assessing volume status in critically ill children. This study is a non-invasive study in assessing hemodynamic status in critically ill children without the need for invasive procedures that have more complications. This study has several limitations, including the need for special skills to assess the inferior vena cava diameter using ultrasound.

CONCLUSION

Based on the results of the research and discussion described previously, it can be concluded from this study that there was a strong negative correlation between CVP and IVC-DI. CVP was positively correlated with volume status, while the inferior vena cava distensibility index was negatively correlated with volume status. The average CVP in research subjects was 9.15 cmH₂O with the lowest value was 6 cmH₂O, and the highest CVP value was 12.8 cmH₂O, while the mean value of the inferior vena cava distensibility index in research subjects showed an average value of 40.49%, with the lowest value was 16.6%, and the highest was 83.9%.

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