Original article

Correlation of Inferior Vena Cava diameter and IVC Collapsibility Index with Central Venous Pressure (CVP) in critically ill surgical patients

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Abstract

Introduction
Central Venous Pressure is a valuable parameter in the management of critically ill surgical patients in the ICU. Non-invasive methods to extrapolate the volume status of the patient can aid clinicians in expediting proper treatment. The objective of this study is to find a correlation between Inferior Vena cava (IVC) diameter and collapsibility index (CI) with Central venous pressure (CVP) in critically ill surgical patients.

Methods
This cross-sectional study included 60 critically ill patients from September 2020 – 31st February 2021. We recorded the patient's age, sex, heart rate, blood pressure, CVP, volume status, IVC minimum, and maximum diameter. After taking consent and explaining the procedure to the patient, the maximum IVC anteroposterior diameter was noted at the end of inspiration and end of expiration in centimeters. IVC collapsibility index was calculated using the formula ([IVCdmax-IVCdmin]/IVCdmax*100%). Following this, the CVP of the patient was measured.

Results
Among the patients evaluated, 32 were females. The mean age of the participants was 44.90 ± 15.76 years. The mean central venous pressure maintained was 11.10 ± 2.11cm H_2O with an inferior vena cava collapsibility index of 29.69 ± 8.75. There was a negative correlation between CVP and IVC collapsibility index (%), which was statistically significant ($r = -0.701$, $n = 60$, $p < 0.01$). A strong positive correlation between CVP and maximum IVC diameter ($r = 0.712$, $n = 60$, $p < 0.01$) and minimum IVC diameter ($r = 0.796$, $n = 60$, $p < 0.01$) was found.

Conclusion
Inferior Vena Cava diameter and IVC Collapsibility Index can be used as a reliable substitute to central venous pressure to determine the patient's volume status.

Keywords: Central venous Pressure; IVC collapsibility index; IVC diameter.

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Introduction

An accurate assessment of the extracellular volume status is an essential factor in properly diagnosing and managing critically ill patients.[1,2] Although monitoring central venous pressure through the insertion of a central venous catheter is regarded as the gold standard, it is invasive and time-consuming.[3] Moreover, several complications related to central venous catheter insertion include injury to local structures, phlebitis at the insertion site, air embolism, hematoma, arrhythmia, and catheter malposition.[4] A non-invasive and cost-effective method like sonoscopy in ICU can guide the clinician in fluid therapy by determining IVC diameter. Size of IVC changes with respiration and total body fluid.[5] Since the IVC diameter exhibits a variation with the respiratory cycle, several authors have measured both the inspiratory and the expiratory diameters of the IVC and used them to calculate the collapsibility index. Few studies have reported that a 50% collapse of the IVC diameter during a respiratory cycle is associated with a low CVP.[6,7]

Methods

This cross-sectional observational study was carried out in the intensive care unit (ICU) of Kathmandu Medical College Teaching Hospital, Sinamangal, Nepal. A total of 60 participants were enrolled from 1st September 2020 to 31st February 2021. Spontaneously breathing patients ≥18 years old who were admitted to the ICU and who had a central venous catheter inserted (subclavian or internal jugular vein) were included in the study. The exclusion criteria included patients younger than 18 years old, mechanically ventilated patients, patients under CPAP or BiPAP (non-invasive ventilation), patients who were morbidly obese, rendering them unsuitable for bedside sonoscopy to measure IVC, and patients who refused to participate. The sample size was calculated to be 55 using the Cochrane sample size equation, taking the confidence interval of 95%, margin of error at 8%, and the prevalence of septic shock in critically ill patients at 10%8.

Informed consent was taken from all the participants, and ethical approval was obtained from the local ethical committee (Ref:1208202001). The study was done for a total duration of six months. While obtaining the IVC diameter through bedside sonoscopy, the investigators were blinded to CVP measurement.

The bedside sonoscopy of all the patients was performed using a Mindray portable ultrasonography machine model Z6 (Mindray, NJ, USA)© by surgical residents trained in basic bedside sonoscopy. Initially, the patients were kept in the supine position, and the ultrasound gel was applied to the sub-xiphoid region. The IVC was visualized using a curvilinear probe in the subxiphoid location in the longitudinal axis 2cms distal to IVC-hepatic vein junction. IVC diameter at the end of inspiration and end of expiration were measured. The maximum IVC diameter ($IVCd_{max}$) was measured as the maximum anterior-posterior dimension at end-expiration, and the minimum IVC diameter was measured at end-inspiration ($IVCd_{min}$). The IVC collapsibility index was the difference between the maximum and minimum IVC diameters divided by the maximum IVC diameter, expressed as a percentage ($[IVCd_{max} - IVCd_{min}] / IVCd_{max} \times 100\%$). The CVP was measured while the patient was in supine position. The vertical distance between the angle of Louis (manubrium-sternal joint) and the highest level of the meniscus in the CVP catheter at the end of expiration was measured using a ruler. In the end, we added 5cm to the measurement since the right atrium is 5cm below the sternal angle. The patients having CVP between 8–12 cmH_2O were considered euvolemic, patients having CVP>12 cmH_2O were considered hypervolemic, and patients having CVP <8 cm H_20 were considered hypovolemic.[4]

Statistical analysis:

The data were entered and analyzed in SPSS version 21 (IBM, NY, USA). Descriptive statistics were calculated for all qualitative variables. One-way analysis of variance (ANOVA) was used to compare the three groups of patients with different intravascular volume statuses, and Tukey's method was used for posthoc multiple comparisons. Pearson correlation coefficient was used to assess the significance between CVP and IVC collapsibility index (%) and the maximum and minimum IVC diameter. A p-value less than 0.05 was considered to be significant.

Results

A total of 28 (46.66%) males and 32 (53.33%) females were included in the study with a mean age of 44.90±15.76 years. A total of 24 (40%) central venous catheter (CVC) insertion was performed using the subclavian approach, and the rest were performed using the internal jugular approach.

Table 1. Demography of the patients (n=60)

Characterstics	Values
Age of patient (Mean ± Standard Deviation)	44.90 ±15.76
Male participants	28(46.44%)
Subclavian insertion of CVC	24(40%)
Internal jugular insertion of CVC	36(60%)
Euvolemic group	44(73.33%)
Hypervolemic group	16(26.66%)

The mean heart rate was 90.50 ± 12.42 per minute. The mean central venous pressure maintained was 11.10 ± 2.113 cmH_2O with the inferior vena cava collapsibility index of 29.69 ± 8.75. The central venous pressure (CVP) was found to be less than eight cmH_2O in none of the patients, while 44 (73.33%) had CVP between 8–12 cmH_2O and 16 (26.66%) patients had CVP greater than 12 cmH_20. The mean inferior vena cava (IVC) minimum diameter was 1.44 ± 0.36 cm, and the maximum diameter was 2.025 ± 0.31cm.

Table 2. Parameter assessment with volume status

Parameters	Euvolemia (n=44)	Hypervolemia (n=16)	ANOVA (p-value)
Heart rate (per minute)	90.50±10.64	80.87±16.04	0.012
IVC collapsibility index	33.15±6.95	20.17±5.75	0.087
IVC maximum diameter	1.906±0.266	2.35±0.159	0.001
IVC minimum diameter	1.279±0.25	1.881±0.228	0.001

[Hypovolemia CVP<8 cmH_2O, Euvolemia CVP 8-12 cmH_2O, Hypervolemia CVP>12 cmH_2O]

A Pearson correlation was run to determine the relationship between the central venous pressure values and the inferior vena cava collapsibility index (%) and the maximum and minimum inferior vena cava diameter. A negative linear correlation was observed between the central venous pressure (11.10 ± 2.11cmH_2O) and the inferior vena cava collapsibility index (%) (29.69 ± 8.75), which was statistically significant ($r = -0.701$, $p < 0.01$). A strong positive correlation was revealed between the central venous pressure (11.10 ± 2.11cmH_2O) and the maximum inferior vena cava diameter (2.025 ± 0.31 cm) ($r = 0.712$, $p < 0.01$) and the minimum IVC diameter (1.44 ± 0.36 cm) ($r = 0.796$, $p < 0.01$). The correlation is represented in **Figure 1**.

Discussion

In the present study, a prospective cross-sectional study of 60 patients in the intensive care unit, the largest proportion of patients (73.33%) were in a euvolemic state, and the rest (26.66%) were in a hypervolemic state. The study's outcome revealed a positive correlation between Central Venous Pressure (CVP) and IVC diameter. Moreover, the study also compared CVP with IVC-CI, which was found to be inversely related. These results corroborate with findings of other studies like the one done by Stawicki SP et al.[9] They have illustrated that IVC-CI strongly correlates with CVP in the setting of low (≤20%) and high (≥60%) collapsibility ranges. However, Prekker et al[10] showed that a significant correlation between central venous pressure (CVP) and IVC collapsibility index (IVC-CI) was not always seen.

During inspiration, the intrapleural pressure becomes negative, which causes an increase in the venous return to the right side of the heart and a decrease in intraluminal pressure of the IVC. The lumen of the inferior vena cava begins narrowing at the beginning of the inspiration and reaches the narrowest diameter at the end of inspiration. The IVC expands during expiration, Valsalva maneuver, or positive pressure ventilation due to increased intrathoracic pressure. Therefore, inferior vena cava diameter measurement by ultrasonography is a valuable method for predicting central venous pressure.[11-12]

Assessment of intravascular fluid status is essential in the proper diagnosis and management of critically ill patients. There are various methods to monitor the intravascular fluid status in the patient. Among them, sonoscopic measurement of IVC diameter or collapsibility index (CI) and CVP measurement using the central venous catheter is the most commonly used methods.[11] CVP measurement requires invasive central venous catheter placement, which is time-consuming and often trying in urgent situation.[12] However, bedside sonoscopic evaluation of the IVC could provide an immediate measure of volume status at the emergency room or in transit of the patient to an intensive care unit.[13] It is advantageous as it is a safe, non-invasive, and easily performed procedure compared to inserting a central venous catheter. In the past, the IVC diameter evaluation was used by nephrologists in hemodialysis patients to assess intravascular volume status. Subsequently, this technique has been performed by critical care specialists for determining body fluid volume status in critically ill patients.[13-14]

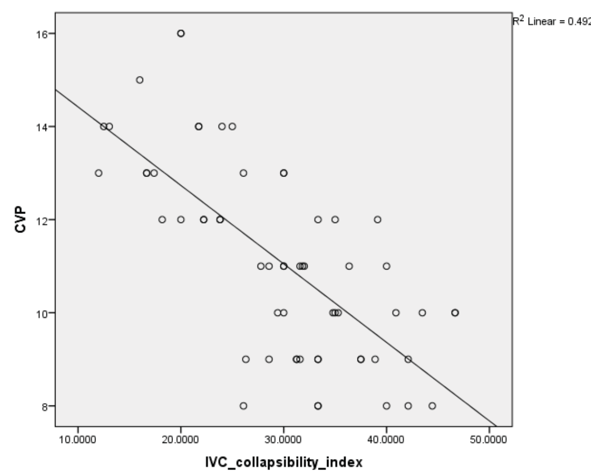

Figure 1. Pearson correlation between CVP and IVC collapsibility index

Our study has a few limitations, such as being performed in a single institute with small sample size. Moreover, the absence of hypovolemic patients in this study may affect the final data. Multiple observers were involved in measuring the IVC diameter using the ultrasound machine, which may have inter-observer variability. Further studies with a large sample size have to be done to externally validate this co-relation.

Conclusion

The study shows a correlation between IVC diameter measured by sonoscopy and the conventional CVP measurement of the patient. Using simple bedside sonoscopy, we can assess the volume status of the patients while avoiding the potential complications of CVP insertion in critically ill patients in ICU. Therefore, we advocate teaching critical care doctors and residents to use sonoscopy to assess the patients' volume status.

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