Correlation between Inferior Vena Cava Diameter and Central Venous Pressure in Critically Ill Patients

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Background: *The inferior vena cava (IVC) diameter is often used to estimate central venous pressure (CVP); however, the correlation and the cutoff of IVC compared with CVP have not yet been described in a Thai-population.*
Material and Method: *A cross-sectional study evaluated the critically ill patients in the medical intensive care unit who had a central venous catheter inserted. The correlation between CVP and IVC diameter measured by a 2-dimensional, long-axis subxiphoid view at the end-expiratory phase with bedside ultrasonography were evaluated.*
Results: *Forty-seven patients with a mean age of 60 $\pm$ 16 years (range, 18 to 91) were studied. Correlation (r) between end-expiration IVC diameter and CVP was 0.75 (95% CI 0.59-0.85; $p < 0.0001$). An IVC diameter of $\leq$ 10 mm predicted CVP of 10 cmH_2O (sensitivity 77% and specificity 91%) and IVC diameter of $\geq$ 15 mm predicted CVP of 15 cmH_2O (sensitivity 90% and specificity 89%).*
Conclusion: *The present study indicate that the measurement of the IVC diameter has a good correlation with CVP in Thai-population and useful for assessment of the volume status. The measurement of the IVC by ultrasonography may be an important additional evaluation of critically ill patients.*

Keywords: *Inferior vena cava, Central venous pressure, Ultrasonography*

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The accuracy of volume status assessment is important for patients with a critical illness such as septic shock, congestive heart failure, acute renal failure, and acute blood loss. For example, Rivers et al demonstrated that the measurement of central venous pressure (CVP) as an early hemodynamic assessment provides a significant by better outcome in patients with severe sepsis and septic shock(1).

Examination of the jugular venous pulse (JVP) to estimate CVP is a commonly performed bedside technique. CVP refers to the mean vena caval or right atrial pressure (RAP), which is equivalent to right ventricle end diastolic pressure in the absence of tricuspid stenosis. Detection of an elevated JVP in patients with left-sided heart failure predicts an elevated pulmonary capillary wedge pressure, without severe pulmonary disease, which indicates a poor prognosis(2).

However, the accurate JVP measurement is often difficult to accurately obtain because of patient body habitus or poor examiner technique. Although JVP is easily visualized, clinicians measure JVP with moderate inter-observer agreement(3). Moreover, there was no good correlation between the assessment of JVP and CVP(4).

Measurement of CVP by invasive techniques either internal jugular vein or subclavian vein catheterization has been reported complications such as pneumothorax, air embolism, arterial puncture, or injury of great vessels and catheter associated infection(5,6). As such, there is a need for a reliable noninvasive technique for determination of CVP.

2-dimensional and M-mode ultrasonography has been shown to be useful for noninvasive estimation of CVP from measuring the diameter of the inferior vena cava (IVC) and the change in diameter with respiration. Several studies demonstrated fair to excellent correlation between CVP and a variety of IVC parameters(7-13). Many studies used IVC diameter of more than 10 to 20 mm as cutoff points for high CVP. However, only one study in a Thai population has evaluated IVC diameter for an estimation of CVP in hypovolemia patients(7). To the authors' knowledge, was no study has shown the correlation and cutoff

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point between CVP and IVC diameter in critically ill Thai patients.

Material and Method

The present study was approved by the Institutional Review Board of Maharat Nakhon Ratchasima Hospital. The present study included patients who had an internal jugular venous catheter, admitted in medical intensive care units (ICU) and respiratory care units (RCU), Department of Medicine, Maharat Nakhon Ratchasima hospital, between May and August 2008. Exclusion criteria were patients with superior vena cava (SVC) or IVC obstruction, massive ascites, morbid obesity, pregnancy and abdominal skin infection. Patient demographics including age, sex, present illness, underlying disease, vital signs, and indication of central catheter placement were recorded.

CVP was measured via an internal jugular venous catheter using fluid column technique in the supine position. The end-expiratory CVP was measured from the lowest point, phlebostatic axis (fourth intercostal space intersect with midway between xiphoid and back) to the highest fluid level in cmH_2O scale (1 $cmH_2O \sim 0.74$ mmHg) during regular respiration. Several measurements of the CVP were taken on each subject and averaged for the final value.

Then the patients underwent a bedside ultrasonographic examination (HS-2000, Honda Electronics, Aichi, Japan) focused on the IVC. The IVC was assessed with the patient in the supine position with 2-dimentional subxiphoid long axis. Measurements were taken immediately after CVP was recorded. The end-expiratory IVC diameter was measured 2 cm distal from the IVC-right atrium junction. Distances between IVC walls were measured in millimeters. Calipers were placed just inside both the near field and far field walls. A single physician was designated to take the measurements in all patients. The reader was blinded to the CVP before measuring the IVC diameter.

The primary outcome was the correlation between CVP and IVC diameter. Data are presented as mean $\pm$ SD and percentage. Pearson correlation coefficients and linear regression were used for data analysis. The present study was designed to recruit 36 patients to detect 0.6 of primary outcome (two-sided alpha level of 0.05, power of 99%) Statistical significance was set as $p < 0.05$. ROC curves were generated using data obtained from the derivation group to determine optimal cutoffs for prediction of CVP. The sensitivity and specificity were computed in the test group of patients in the usual fashion, using MedCalc statistical software.

Results

Demographic data of the patients are summarized in Table 1. Forty-seven patients participated, including 27 (57%) men with the mean age of 60 $\pm$ 16 years (range 18 to 91 years). Indications for internal jugular venous catheterization were hemodynamic monitoring (60%), temporary pacemaker or pulmonary catheter insertion (25%), lack of peripheral line (9%), parenteral nutrition (4%), and rapid venous access (2%). Of the patients, 68% were on mechanical ventilation with average PEEP 4 cmH_2O.

The mean CVP was 14.6 $\pm$ 7.6 cmH_2O (range 3 to 37). The average end-expiratory diameter of IVC was 13.8 $\pm$ 4.8 mm. Fig. 1 shows the relationship between end-expiratory diameter of IVC and CVP in linear regression line. The correlation coefficient (r) was 0.75 (95% CI 0.59-0.85; $p < 0.0001$).

At various diameters of IVC, the sensitivity and specificity for CVP < 10 cmH_2O and > 15 cmH_2O were determined. The optimal end-expiratory diameter of IVC was 15 mm for predict CVP > 15 cmH_2O with sensitivity of 90% and specificity of 89%. Fig. 2 shows

Table 1. Demographic data (n = 47)

Age (years)	60 $\pm$ 16
Sex (male/female, %male)	27/20 (57)
Indication of catheterization (n [%])	
Hemodynamic monitoring	28 (60)
Temporary pacemaker or PA catheter insertion	12 (25)
Lack of peripheral line	4 (9)
Parenteral nutrition	2 (4)
Rapid venous access	1 (2)
Systolic blood pressure (mmHg)	110 $\pm$ 25
Diastolic blood pressure (mmHg)	64 $\pm$ 16
Heart rate (bpm)	90 $\pm$ 30
Respiratory rate (per minute)	21 $\pm$ 5
Mechanical Ventilator (n [%])	32 (68)
PEEP (cmH_2O)	4 $\pm$ 2
Current illness (n)	
Pneumonia	12
Septic abortion	2
Sepsis	10
Acute myocardial infarction	5
Bradyarrhythmia	7
Congestive heart failure	2
Diabetic ketoacidosis	3
Other	10

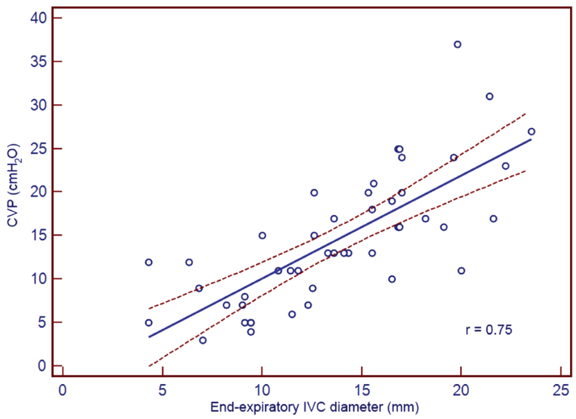

Fig. 1 Regression line of CVP and end-expiratory IVC diameter. Correlation coefficient (r) = 0.75 (95% CI 0.59-0.85; $p < 0.0001$)

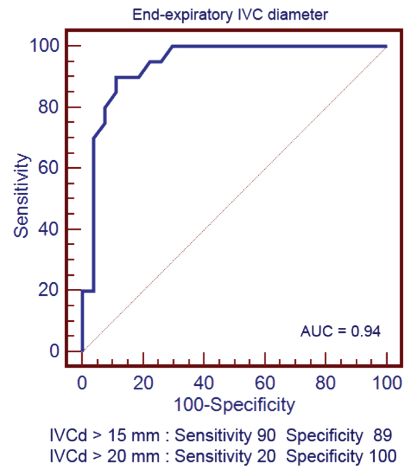

Fig. 2 ROC for predict CVP > 15 cmH_2O. AUC = 0.94

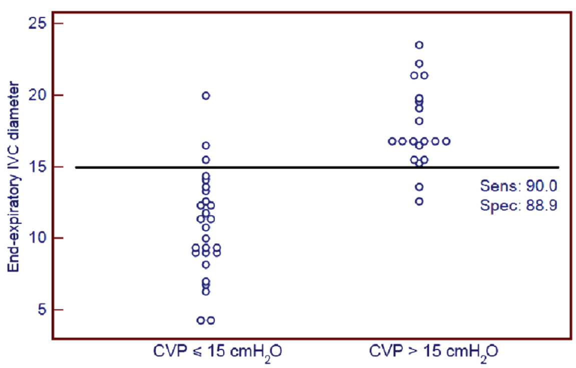

Fig. 3 Dot diagram for predict CVP > 15 cmH_2O

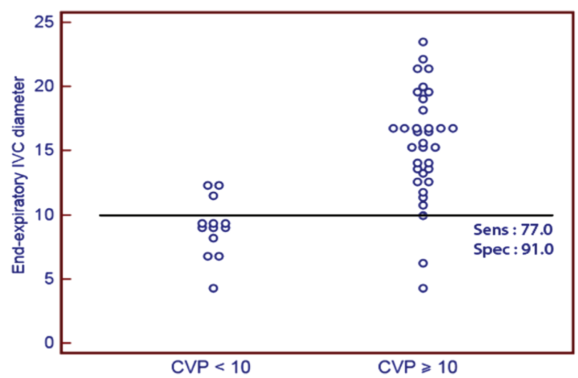

Fig. 4 Dot diagram for predict CVP < 10 cmH_2O

the area under the receiver operating characteristic (ROC) curve of IVC diameter > 15 mm. Fig. 3 demonstrates dot diagram for predict CVP > 15 cmH_2O. Fig. 4 shows prediction of CVP < 10 cmH_2O, the optimal end-expiratory diameter of IVC was 10 mm with sensitivity of 77% and specificity of 91%.

Discussion

Multiple studies have demonstrated fair to excellent correlation between CVP and a variety of IVC parameters. Kircher BJ et al[8] found the correlation between IVC end-expiratory and CVP was 0.41. In mechanically ventilated patients, Karim Bendjelid et al[9] found the correlation was 0.81. There is a paucity of data that evaluates the correlation in a Thai population. In hypovolemic patients, Attainsee et al[7] demonstrated a good correlation between IVC diameter and low CVP.

The present study also demonstrated a good correlation between the end-expiratory diameter of IVC and CVP (r = 0.75), regardless of the CVP level, range from 3 to 37 cmH_2O.

In previous studies, there have been many methods to identify IVC diameter such as long axis view, short axis view, and M-mode. The reasons for using long axis view in the present study were because it is easy to perform without extensive experience and all of these methods have an excellent correlation[10].

In addition to classifying CVP in a binary fashion, it is clinically helpful to assign CVP into a range. Mintz et al[11] found CVP $\geq$ 10 mmHg correlated with IVC end-diastolic diameter $\geq$ 10 mm/m^2. In critically ill patients, Jue et al[12] found CVP $\leq$ 10 mmHg correlated with IVC end- expiratory diameter $\leq$ 12 mm with sensitivity of 25% and specificity of 100%.

Brennan et al[13] used IVC end- expiratory diameter cutoff of 20 mm to predicting CVP > 10 mmHg (~13.6 cmH_2O), reported sensitivity of 73% and specificity of 85%. Moreno et al[10] used IVC end-expiratory diameter cutoff of 23 mm to predicting CVP > 7 mmHg (~9.5 cmH_2O), reported sensitivity of 40% and specificity of 97%. However, in the present study, the optimal IVC end- expiratory diameter cutoff to predicting CVP > 15 mmH_2O was 15 mm. If the cutoff was changed to 20 mm, the lower sensitivity (20%) and higher specificity (100%) was reported. The optimal IVC end- expiratory diameter cutoff to predicting CVP < 10 mmH_2O was 10 mm. The present study showed the optimal cutoff IVC diameter was lower than previous reports. The results were different, probably, because of the small body build in the Thai-population.

Limitation

The present study had several potential limitations. First, the population in the present study was calculated from the primary endpoint, the number might be too small to conclude the true sensitivity and specificity. Second, ultrasonographic imagine is an operator dependent technique, this study did not demonstrate the inter-observer variation. Third, the present study aimed to simplify the way to measure CVP. The IVC diameter is easy to measure, so the IVC respiratory index did was included in the present study. The benefit of additional classification using responses to respiration may be useful which need further study.

Conclusion

The present study demonstrated a good correlation between the end-expiratory diameter of IVC and CVP (r = 0.75). The IVC size cutoff with optimum predictive use for CVP above or below 10 cmH_2O was 10 mm and for predictive use for CVP above or below 15 cmH_2O was 15 mm. The ultrasonographic assessment is a simple technique even without extensive experience and may provide a benefit for estimating the volume status in critically ill patients.

Potential conflicts of interest

None.

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ความสัมพันธ์ระหว่างเส้นผ่านศูนย์กลางของหลอดเลือดดำอินฟีเรียร์เวนาคาวาโดยการตรวจคลื่นสะท้อนเสียงกับแรงดันในหลอดเลือดดำใหญ่ในหออภิบาลผู้ป่วยหนัก

วีรพันธ์ วิวัฒน์วรพันธ์, นุชภา รัตนจรัสโรจน์, บัญชา สุขอนันต์ชัย

ภูมิหลัง: *การประเมิน CVP สามารถทำได้โดยการวัดขนาดของ IVC diameter จาก bedside ultrasonography อย่างไรก็ตามยังไม่มีข้อมูลของความสัมพันธ์ และจุดตัดระหว่าง CVP และ IVC diameter ในประชากรไทย*

วัตถุประสงค์: *เพื่อศึกษาความสัมพันธ์ระหว่าง central venous pressure (CVP) และ inferior vena cava (IVC) diameter ด้วยวิธี non invasive technique โดยการใช้ bedside ultrasonography*

ชนิดของการศึกษา: *การศึกษาเชิงวิเคราะห์, Cross sectional study*

วัสดุและวิธีการ: *ศึกษาผู้ป่วยหนักในหออภิบาลอายุรกรรมที่ใส่ internal jugular venous catheter เพื่อหาความสัมพันธ์ระหว่าง CVP วัดโดยวิธี fluid column และ IVC diameter ด้วย subxyphoid ultrasound 2 เซนติเมตรใต้ต่อ right atrium ในขณะหายใจออก*

ผลการศึกษา: *ผู้ป่วยทั้งหมดจำนวน 47 คน อายุเฉลี่ย 60 ± 16 ปี ค่าความสัมพันธ์ (correlation; r) ระหว่าง end-expiratory IVC และ CVP เท่ากับ 0.75 โดยการวินิจฉัย CVP > 15 cmH_2O ใช้จุดตัด IVC > 15 mm ได้ sensitivity และ specificity ที่ 90 และ 89 ตามลำดับ ส่วนการวินิจฉัย CVP < 10 cmH_2O ใช้จุดตัด IVC < 10 mm ได้ sensitivity และ specificity ที่ 77 และ 91 ตามลำดับ*

สรุป: *จากการศึกษานี้พบว่าการวัดขนาด IVC diameter มีความสัมพันธ์ที่ดีกับค่า CVP ในประชากรไทย ดังนั้นการวัดขนาด IVC diameter โดย bedside ultrasonography สามารถให้ข้อมูลเพิ่มเติมในผู้ป่วยหนักในหออภิบาลได้ด้วย*