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Central Venous Pressure versus Internal Jugular Vein or Inferior Vena Cava Collapsibility Indices to Predict Fluid Status in Critically Ill Patients

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ABSTRACT
Background: The assessment of the volume status in critically ill paediatric patients in intensive care units is vitally important for fluid therapy management. The most commonly used parameter for detecting volume status is still central venous pressure (CVP). However, in recent years, various kinds of methods and devices are being used for volume assessment in intensive care units to minimize the many complications of invasive central venous catheter insertion.
Objective: This study aimed to use internal jugular vein (IJV) or inferior vena cava collapsibility indices (CI) by ultrasonography as a first-line approach for the bedside non-invasive assessment of central venous pressure/fluid status in critical ill intensive care unit patients.
Patients and Methods: This study was carried out on 67 patients of both sex who were admitted to the Surgical Intensive Care Units of Anesthesia Department, Faculty of Medicine, Zagazig University Hospitals during the period from January 2021 to January 2022.
Results: There were a statistical significance decrease in all CI among cases had CVP >10 mmHg compared to cases had CVP ≤10. CI of IJV at 0 degree at cut off >21.4 had sensitivity 88.4%, specificity 79.2% and accuracy 85.1% in prediction of CVP ≤ 10 while at 30 degree at cut off 20.7 had sensitivity 90.7%, specificity 83.3% and accuracy 88.1% in prediction of CVP ≤ 10 mmHg. Finally, CI of IVC at cut off >31.75 had sensitivity 74.4%, specificity 70.8% and accuracy 73.1% in prediction of CVP ≤ 10 mmHg among the studied cases.
Conclusions: Ultrasonographic measurement of venous parameters of IJV provides a useful non-invasive tool for assessment of intravascular volume status in critically ill patients.
Keywords: Internal jugular vein, Inferior vena cava, Collapsibility index, Central venous pressure.

INTRODUCTION

A demanding and difficult responsibility for intensivists and emergency physicians is hemodynamic monitoring and quick evaluation of intravascular fluid status for the early, rapid, and successful resuscitation of hypovolemia in critically sick ICU patients. In patients with severe sepsis and septic shock, early goal-directed treatment for achieving an ideal fluid state has been proven to lower morbidity and death [(1)]. Cornerstones of treatment to stabilise hemodynamics in critically unwell patients are fluid resuscitation and the introduction of vasoactive medications. Yet it might be difficult to select the best resuscitation technique. A poor overinfusion might be harmful because, for instance pulmonary edema can worsen the patient's health. However, in cases of volume depletion, inotropic support and vasopressors will be ineffective and cause ventricular arrhythmia. As a result, it is critical to develop methodologies for assessing the patient's intravascular volume condition [(2)]. Blood pressure or heart rate are not accurate indicators of low volume status in the early stages of shock. In the early stages of hemorrhagic shock, considerable blood loss is still possible even in the absence of tachycardia or hypotension. Using only the clinical examination and vital signs might be dangerous and waste valuable time during resuscitation [(3)].

The gold standard for measuring CVP involves inserting a central venous catheter, which is invasive, time-consuming, and labor-intensive. Additionally, it has its own risks and difficulties and is not practicable in pre-hospital settings or in an urgent resuscitation scenario [(4)]. Due to the high compliance of central venous veins, many non-invasive methods of CVP assessment employing portable ultrasonography as an alternative approach to invasive CVP monitoring have been proposed [(3)]. The CVP was indirectly measured using several IJV characteristics. In ordinary clinical practice, the height of jugular venous pulsation has been employed as an indirect measure of central venous and right atrial pressure, albeit with low sensitivity. Physical examination was only 50% accurate in assessing right atrial pressure in 50% of individuals [(5)].

The inferior vena cava (IVC) collapsibility index (CI) has been examined as an indirect measure of CVP to determine the volume status of critically sick patients, with diverse and contradictory results [(5)]. The CI is computed by taking measurements during inhalation and exhalation (the difference in IVC or IJV diameter during inhalation and exhalation divided by IVC or IJV diameter during exhalation) [(6)].

In the present study, we aimed to use internal jugular vein or inferior vena cava collapsibility indices by ultrasonography as a first-line approach for the bedside non-invasive assessment of central venous pressure/fluid status in critically ill intensive care unit patients.

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PATIENTS AND METHODS

This study was carried out on 67 patients of both sex who were admitted to the Surgical Intensive Care Units of Anesthesia Department, Faculty of Medicine, Zagazig University Hospitals during the period from January 2021 to January 2022.

Inclusion criteria: Patient or relative consent, age from 21-60 years old, both sexes (males and females), body mass index less than 35 Kg/M^2, and critically ill ICU patient with CVP catheter already been inserted for clinical indication.

Exclusion criteria: Patients on mechanical ventilation, patients with history of radiotherapy or surgery to the neck or chest, patients with severe tricuspid regurge, pulmonary hypertension, arrhythmia, patients with previous or active upper extremity deep venous thrombosis, pregnant women, patients with high intra-abdominal pressure (for fallacies due to compression of IVC) patients with COPD, patients with organ failure, and patients on vasopressors.

Withdrawal criteria: Patient has the right to withdraw from the study at any time without any negative consequence on his/her medical or surgical treatment plan.

All patients included in the study were subjected on admission to the following:

- Complete history taking from the patient and the relatives.
- Complete physical examination including arterial blood pressure with mean arterial blood pressure (MABP) calculation and heart rate (HR).
- Electrocardiogram (ECG) and those with any cardiac arrhythmias were excluded.
- Sequential organ failure assessment (SOFA) score was calculated initially for all patients on admission [(7)].
- CVP was measured using a central venous catheter (CVC) inserted into subclavian vein, and a transducer. CVP was recorded at the midaxillary line where the manometer arm was leveled with the phlebostatic axis, this is where the fourth intercostal space and midaxillary line cross each other, allowing the measurement to be as close to the right atrium as possible

Management:

1. The study measurements were done by intensivists who are trained on critical care ultrasound and had an experience in using bedside ultrasound.
2. The investigators were blinded for the invasively measured CVP.
3. Full echocardiographic examination was done to all patients.

Measurement of:

- Patient characteristic data (Name, age, sex and body mass index).
- Hemodynamic variables (HR, SBP, DBP and MABP) taken before assessment of CVP and CI.
- SOFA score in critically ill patients (disease score).
- CVP (mmHg) using a central venous catheter (CVC) inserted into subclavian vein.
- The CI calculated by ultrasonography on right IJV with the patients initially lying supine at 0° and later head end elevated at 30°.
- The CI calculated by ultrasonography on IVC with the patients lying in supine position.
- IVC CI measured during normal quiet breathing of the patients

Ethical consent:

An approval of the study was obtained from Zagazig University Academic and Ethical Committee. Every patient signed an informed written consent for acceptance of participation in the study. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistic analysis:

The collected data were coded, processed and analyzed using the SPSS (Statistical Package for Social Sciences) version 22 for Windows® (IBM SPSS Inc., Chicago, IL, USA). Data were tested for normal distribution using the Shapiro Walk test. Qualitative data were represented as frequencies and relative percentages. Chi square test (χ^2) to calculate difference between two or more groups of qualitative variables. Quantitative data were expressed as mean ± SD (Standard deviation). Independent samples t-test was used to compare between two independent groups of normally distributed variables (parametric data). P value ≤ 0.05 was considered significant.

RESULTS

Table (1) showed that the mean age of the studied cases was 42.3 years and 65.7% of them were male. Also, there were no statistical significance differences between cases that had CVP ≤10 and cases that had CVP >10 mmHg in age or sex distribution. The mean BMI among the studied cases was 28.58 Kg/m^2. There were no statistical significance differences between cases that had CVP ≤10 and cases that had CVP >10 in BMI.

Table (1): Demographic data of the studied cases

Variable		Total (n=67)		CVP ≤10 (n=43)		CVP >10 (n=24)		t	P
Age: (years)	Mean ± SD Range	42.3 ± 14.51 19-60		45.81 ± 14.82 19-60		47.17 ± 14.22 24-60		0.36	0.72 NS
BMI: (kg/m^2)	Mean ± SD Range	28.58 ± 4.11 21-34.1		28.27 ± 4.06 21.3-34.1		29.15 ± 4.23 21-33		0.84	0.40 NS
Variable		**No**	**%**	**No**	**%**	**No**	**%**	**2 χ**	**P**
Sex:	Male Female	44 23	65.7 34.3	28 15	65.1 34.9	16 8	66.7 33.3	0.02	0.90 NS

SD: Standard deviation t: Independent t test χ^2: Chi square test NS: Non significant (P>0.05)

Table (2) showed that mean HR among the studied cases was 95.81 beat /min also mean SBP, DBP and MABP were 116.75, 67.52 and 78.18 mmHg respectively. Also, there were a statistical significance increase in SBP, DBP and MABP among cases that had CVP >10 mmHg than cases that had CVP ≤10. The mean Sofa score among the studied cases was 2.76 and mean CVP was 7.54 mmHg. There were no statistical significance differences between the studied cases in Sofa score but there was a statistical significance increase in CVP among cases that had CVP >10 compared to cases that had CVP ≤ 10.

Table (2): HR & blood pressure, sofa and CVP among the studied cases

Variable		Total (n=67)	CVP ≤10 (n=43)	CVP >10 (n=24)	t	P
HR: (beat/min)	Mean ± SD	95.81±14.27	97.65±9.97	92.5±19.62	1.43	0.16 NS
SBP: (mmHg)	Mean ± SD	116.75±15.33	110.74±14.62	127.5±9.81	**5.01**	**<0.001 ****
DBP: (mmHg)	Mean ± SD	67.52±13.89	62.23±12.34 48-91	77±11.36	**4.83**	**<0.001 ****
MABP: (mmHg)	Mean ± SD	78.18±9.15	75.49±9.15	83±7.03	**3.49**	**<0.001 ****
Sofa:	Mean ± SD	2.76±0.53	2.91±0.99	2.5±0.51	1.61	0.11 NS
CVP: (mmHg)	Mean ± SD	7.54±1.61	5.51±1.33	11.17±1.09	11.18	**<0.001 ****

Table (3) showed that mean collapsibility index of IJV at 0 ^{0}, IJV at 30 ^{0} and IVC were 40.62, 42.75 and 47.01% respectively. Also, there were a statistical significance decrease in all CI among cases that had CVP >10 compared to cases that had CVP ≤10.

Table (3): Collapsibility index among the studied cases

Variable		Total (n=67)	CVP ≤10 (n=43)	CVP >10 (n=24)	t	P
CI of IJV at 0^0:	Mean ± SD Range	40.62±8.9 19.6-61.3	48.20±9.92 20.2-61.3	26.29±4.49 19.6-55.5	**8.35**	**<0.001 ****
CI of IJV at 30^0:	Mean ± SD Range	42.75±10.13 15.5-81.8	54.1±12.61 28.3-81.8	22.42±5.53 15.5-31	**8.47**	**<0.001 ****
CI of IVC:	Mean ± SD Range	47.01±8.82 30.3-69.2	49.54±7.62 33.2-69.2	42.48±9.16 30.3-56.6	**3.38**	**0.003* S**

SD: Standard deviation t: Independent t test NS: Non significant (P>0.05) *: Significant (P<0.05) **: highly significant (P<0.001)

Table (4) showed that CI of IJV at 0 degree had –ve significant correlation with SBP, DBP, MABP and CVP among the studied cases also it had +ve significant correlation with CI of IJV at 30 degree and of IVC.

Table (4): Correlation between CI of IJV at 0 degree and different studied parameters among the studied cases

Variable	IJV at 0 (n=67)	
	r	P
Age: (years)	0.15	0.22 NS
BMI: (Kg/m^2)	0.05	0.68 NS
Heart Rate: (beat/min)	0.06	0.61 NS
SBP: (mmHg)	**-0.60**	**<0.001****
DBP:(mmHg)	**-0.63**	**<0.001****
MABP: (mmHg)	**-0.51**	**<0.001****
Sofa:	0.18	0.16 NS
CVP:	**-0.80**	**<0.001****
CI for IJV at 30^o	**0.81**	**<0.001****
CI for IVC:	**0.35**	**0.004***

Table (5) showed that CI of IJV at 30 degrees had –ve significant correlation with SBP, DBP, MABP and CVP among the studied cases also it had +ve significant correlation with CI of IVF.

Table (5): Correlation between CI of IJV at 30 degree and different studied parameters among the studied cases

Variable	IJV at 30 (n=67)	
	r	P
Age: (years)	0.12	0.32 NS
BMI: (Kg/m^2)	-0.09	0.49 NS
Heart Rate: (beat/min)	0.06	0.61 NS
SBP: (mmHg)	**-0.65**	**<0.001****
DBP:(mmHg)	**-0.59**	**<0.001****
MABP: (mmHg)	**-0.59**	**<0.001****
Cofa:	0.13	0.30 NS
CVP:	-0.90	**<0.001****
CI for IVC:	**0.24**	**0.04***

Table (6) showed that CI of IVC had –ve significant correlation with DBP and CVP among the studied cases.

Table (6): Correlation between CI of IVC and different studied parameters among the studied cases

Variable	IVC (n=67)	
	r	P
Age: (years)	0.15	0.21 NS
BMI: (Kg/m^2)	-0.07	0.56 NS
Heart Rate: (beat/min)	0.02	0.88 NS
SBP: (mmHg)	-0.11	0.34 NS
DBP:(mmHg)	**-0.33**	**0.006***
MABP: (mmHg)	0.01	0.93 NS
Sofa:	0.03	0.84 NS
CVP:	**-0.29**	**0.01***

Table (7) showed that CI of IJV at 0 degree at cut off >21.4 had sensitivity of 88.4%, specificity of 79.2% and accuracy of 85.1% in prediction of CVP ≤ 10 while at 30 degree at cut off 20.7, CI of IJV had sensitivity of 90.7%, specificity of 83.3% and accuracy of 88.1% in prediction of CVP ≤ 10 mmHg. Finally, CI of IVC at cut off >31.75 had sensitivity of 74.4%, specificity of 70.8% and accuracy of 73.1% in prediction of CVP ≤ 10 mmHg among the studied cases.

Table (7): Validity of CI of IJV & IVC in prediction of CVP ≤ 10 among the studied cases:

CI	Cut off %	AUC (95% CI)	P	Sensitivity	Specificity	PPV	NPV	Accuracy
IJV at 00	**>21.4**	0.89 (0.80-0.98)	**<0.001 ****	**88.4%**	**79.2%**	**88.4%**	**79.2%**	**85.1%**
IJV at 300	**>20.7**	0.94 (0.89-0.99)	**<0.001 ****	**90.7%**	**83.3%**	**90.7%**	**83.3%**	**88.1%**
IVC:	**>31.75**	**0.71 (0.56-0.86)**	**0.004***	**74.4%**	**70.8%**	**82.1%**	**60.7%**	**73.1%**

AUC: Area under curve CI: Confidence interval PPV: +ve predicted value NPV: -ve predicted value
**: Highly significant (P<0.001)

DISCUSSION

Our results demonstrated that a total of 83 cases were enrolled, out of which 9 were excluded (4 pulmonary HP, 3 sever TR and 2 other), leaving a final cohort of 74 for analysis. In 7 cases IVC can't be visualized as; (4 had obesity and 3 had abdominal gases). The studied cases were classified according to CVP into two groups that were compared to each other in demographic data, which revealed that the mean age of all studied cases was 42.3 years and 65.7% of them were male. Also, there were no statistical significance differences between cases that had CVP ≤10 and cases that had CVP >10 in age or sex distribution. The mean BMI among the studied cases was 28.58 Kg/m^2, and there were no statistical significance differences between cases that had CVP ≤10 and cases that had CVP >10 in BMI. In agreement with our study, **ElHossieny *et al.*** **[8]** reported that 62 patients (72.1%) were men. Mean age was 36.8 years. The main cause of ICU admission was polytrauma (n=49, 57%). Also, **Jassim *et al.*** **[9]** reported that the mean age was 54.34 ± 16.61 years (range =20–81 years), 81% were males with no significant difference regarding age and gender. **Dodhy** **[10]**, found that among 126 patients, 42.9% were females and 57.1% were males. Average age of the patients was 42 years with minimum of 22 years and maximum of 58 years [18].

The hemodynamic data revealed that mean HR among the studied cases was 95.81 beat /min also mean SBP, DBP and MABP were 116.75, 67.52 and 78.18 mmHg respectively. Also, there were a statistical significance increase in SBP, DBP and MABP among cases that had CVP >10 (SBP (127.5), DBP (77), and MABP (83)), and cases that had CVP ≤10 (SBP (110.74), DBP (62.23), and MABP (75.49)). In agreement with our study, **ElHossieny *et al.*** **[8]** found in his results that the mean systolic blood pressure was 115.14 mmHg, diastolic blood pressure was 71.24, and MABP was 85.87 mmHg. In contrary to our study, **Kadhim *et al.*** **[11]** found that systolic was 123.5, diastolic was 77.2 and MAP was 96.3 mmHg.

In the current study, the mean sofa score among the studied cases was 2.76 and mean CVP was 7.54 mmHg. There were no statistical significance differences between the studied cases in sofa score but there was a statistical significance increase in CVP among cases that had CVP >10 (11.17) compared to cases that had CVP ≤ 10 (5.51 mmHg). In **Jassim *et al.*** **[9]** study, the mean CVP was 9.88 mmHg (range = 1–25). **ElHossieny *et al.*** **[8]** study noticed in his results that the mean CVP was 7.5 mmHg.

The current study found that mean collapsibility index of IJV at 0◦, IJV at 30◦ and IVC were 40.62, 42.75 and 47.01% respectively. Also, there were a statistical significance decrease in all CI among cases that had CVP >10 (IJV at 0◦ (26.29), IJV at 30◦ (22.42), and IVC (42.48)), compared to cases that had CVP ≤10 (IJV at 0◦ (48.20), IJV at 30◦ (54.1), and IVC (49.54)). This comes in agreement with **Jassim *et al.*** **[9]** who found that there was a statistical significant difference between both groups regarding IJV at 30◦ and IVC while there was no significance regarding IJV at 0◦.

The correlation between CI of IJV at 0 degree and different studied parameters among the studied cases demonstrated that CI of IJV at 0 degree had –ve significant correlation with SBP (-0.60), DBP (-0.63), MABP (-0.51) and CVP (0.80) among the studied cases, but it had +ve significant correlation with CI of IJV at 30 degree (0.81) and of IVF (0.35). The correlation between CI of IJV at 30 degree and different studied parameters among the studied cases demonstrated that CI of IJV at 30 degrees had –ve significant correlation with SBP (-0.65), DBP (-0.59), MABP (-0.59) and CVP (-0.90) among the studied cases, but it had +ve significant correlation with CI of IVF (0.24). Also, the correlation between CI of IVC and different studied parameters among the studied cases revealed that CI of IVC had –ve significant correlation with DBP (-0.33) and CVP (-0.29) among the studied cases. **Jassim *et al.*** **[9]** found that the correlations between CVP and IJV-CI at 0° were r=−0.484 (P=0.0001). However, the highest significant correlation was found between CVP and IJV-CI at 30° (r=–0.583, P=0.0001). Similarly, IVC- CI also showed a significant correlation with CVP (r=–0.540, P=0.0001). Also, another study done by **Wiwatworapan *et al.*** **[12]** on critically ill medical patients reported that the measurement of the IVC diameter has a good correlation with CVP. Moreover, **ElHossieny *et al.*** [8] reported that determination of correlation coefficient IVC-CI was shown to be significantly correlated with CVP value (r=−85, PË 0.001 at 95% confidence interval), while it disagrees with our study correlated with mean arterial blood pressure and as compared to CVP. In 2016 a study done by **Garg *et al.*** [13] confirmed that IVC-CI is significantly negatively correlated with CVP, and either method can be used in fluid management. **Akilli *et al.*** [14] measured the IJV-diameter, area, and collapsibility index as an indicator of hemorrhagic shock in healthy blood donors and found that measurement of IJV is reliable indicators of class I hemorrhagic shock. However, they have not correlated their results with invasively measured CVP.

Our study showed that IJV sonography imaging was easy to obtain in all patients, whereas IVC imaging was not possible in some patients due to various reasons, of which abdominal gas shadow and obesity, which were the predominant cause. This finding validates the results of past trials, which also showed similar limitations in obtaining the images of IVC [15-17].

We demonstrated in case of Validity of CI of IJV & IVC in prediction of CVP ≤ 10 mmHg among the studied cases that CI of IJV at 0 degree at cut off >21.4% had sensitivity of 88.4%, specificity of 79.2% and accuracy of 85.1% in prediction of CVP ≤ 10 mmHg, while at 30 degree at cut off >20.7%, they had sensitivity of 90.7%, specificity of 83.3% and accuracy of 88.1% in prediction of CVP ≤ 10 mmHg. Finally CI of IVC at cut off >31.75% had sensitivity of 74.4%, specificity of 70.8% and accuracy of 73.1% in prediction of CVP ≤ 10 mmHg among the studied cases. **Jassim *et al.***[9] demonstrated that the most suitable cut-off value determined for collapsibility index for IJV CSA at 0 degree was >14.1% with AUC =0.792 with sensitivity, specificity, and PPV ranging 73%–82% in predicting CVP ≤10. A cutoff value >19% was found to be an optimum for collapsibility index for IJV at 30° with AUC =0.851, with sensitivity, specificity, and PPV ranging 73%–83% in accurately predicting CVP ≤10. **ElHossieny *et al.*** [8] reported that IVC-CI cutoff value of 29% discriminates between CVP values less than 10 cmH_2O and values more than or equal to 10 cmH_2O with high sensitivity (88.6%) and specificity (80.4%). Similar study by **Muller and his colleagues** [15] reported that IVC-CI after 500 cc fluid resuscitation showed best cutoff value of 40% with AUC 0.77 (p0.08) with sensitivity, specificity, PPV and NPV of 70%, 80%, 72% and 83% respectively. Clinicians can rapidly evaluate a critically ill patient with the use of bedside USG without waiting for the advanced imaging [16, 17].

CONCLUSION

Ultrasonographic measurement of venous parameters of IJV provides a useful non-invasive tool for assessment of intravascular volume status in critically ill patients.

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