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Correlation Between Ultrasound Guided Internal Jugular Vein Collapsibility Index Vs Inferior Vena Cava Collapsibility Index for Assessment of Volume Status in Patients with Sepsis

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Abstract:

Background: Assessment of intravascular volume status continues to be one of the biggest challenges in the management of critical care.

Aim: To evaluate the efficacy of internal jugular vein (IJV)-collapsibility index in prediction of fluid responsiveness and assessment of volume status in correlation with inferior vena cava (IVC)-collapsibility index and invasively monitored central venous pressure (CVP) in ICU sepsis patients.

Patients and methods: This Prospective observational study was conducted on 30 patients who admitted to the ICU with central venous catheter at Intensive care unit in Suez Canal University hospitals from January 2021 to November 2022.

Results: There was a significant decrease in Internal Jugular Vein Collapsibility Index (IJC-CI) and CVP after fluid resuscitationp value <0.001, with a mean decrease of 46.50 compared to 48.80. A negative correlation was found between IVC-CI and IJV-CI p= 0.017, 0.040. The inferior vena cava collapsibility index was found to be the most effective in predicting fluid responsiveness in dehydrated patients, with a sensitivity of 84.62% and specificity of 76.47%. Central venous pressure and internal jugular vein collapsibility index were not significantly effective.

Conclusion: The inferior vena cava collapsibility index is the most effective predictor of fluid responsiveness in dehydrated patients, with a sensitivity of 84.62% and specificity of 76.47%, despite a negative correlation between IVC-CI and CVP.

Keywords: Ultrasound Guided Internal Jugular Vein Collapsibility Index, Inferior Vena Cava Collapsibility Index, Volume Status, Sepsis.

1. Introduction

Assessment of intravascular volume status continues to be one of the biggest challenges in the management of critical care. Limitations of invasive hemodynamic monitoring are increasingly apparent(1). Body volume status can be assessed by several methods, like central venous pressure (CVP), inferior vena cava (IVC) or left internal jugular vein (IJV) collapsibility, pulmonary artery occlusion pressure (PAOP), left ventricular end diastolic area, and trans-pulmonary thermo dilution index (2).

Fluid management in intensive care plays a vital role in the outcome of the patient. Hypovolemia with inappropriate use of vasopressors to maintain the blood pressure reduces the organ perfusion leading to ischemia. On the other hand fluid overload causes cellular swelling and congestion of lungs thereby increasing morbidity and mortality (3).

Sepsis is associated with decreased effective blood volume, and fluid resuscitation is usually recommended to increase cardiac output and improve tissue hypoperfusion(4). However, studies have shown a relationship between positive fluid balance and mortality in patients with sepsis (5). Therefore, rapid, accurate, and reproducible assessment of intravascular volume status is crucial in order to predict the efficacy of volume expansion (6).

Early goal-directed therapy for reaching an optimal fluid status has been shown to reduce morbidity and mortality in patients with severe sepsis and septic shock (7,8). The role of clinical examination in assessing the intravascular volume status of critically ill patients has been found to be unreliable and lacking in accuracy and precision (9,10).

This study aimed to evaluate the efficacy of internal jugular vein (IJV)- collapsibility index in prediction of fluid responsiveness and assessment of volume status in correlation with inferior vena cava (IVC)-collapsibility index and invasively monitored central venous pressure (CVP) in ICU sepsis patients.

Patients and methods

This Prospective observational study was conducted on 30 patients who admitted to the ICU with central venous catheter at Intensive care unit in Suez Canal University hospitals from January 2021 to November 2022.

Inclusion criteria: Patients older than 18 years of age admitted to ICU from January 2021 to January 2023, Sex: both sex males and females, Septic patients who met clinical indications for IV fluid bolus and who have a CVP catheter that are already inserted for clinical indications, ICU patients who have sepsis as defined by qSOFA score 2 or more and ICU patients who have septic shock

Exclusion criteria: The patients who were on mechanical ventilation, Patients who have a history of radiotherapy or surgery to the neck or chest, Patients with pulmonary hypertension, valve regurgitation abnormality, Patients with previous or active jugular venous or upper extremity deep venous thrombosis, Pregnant women or increased intra-abdominal pressure and younger than 18.

Sample size

The sample size was calculated using the following formula:

$$n = \left[\frac{Z_{\alpha/2} + Z_{\beta}}{\frac{1}{2} \log \frac{1+r}{1-r}} \right]^2 + 3 \quad (11)$$

Where:

n = sample size

$Z\alpha/2$ = 2.576 (The critical value that divides the central 99% of the Z distribution from the 1% in the tail)

$Z\beta$ = 1.64 (The critical value that separates the lower 10% of the Z distribution from the upper 90%)

r = correlation coefficient = 0.976

So, by calculation, the sample size is equal to 31 subjects after the addition of a drop-out proportion of 20%.

The study was performed in 4 sequential stages

Baseline parameters were recorded with the patient in semirecumbent position (T0). Then a fluid challenge 7ml per kg for 10 min.Second measurement immediately after fluid challenge test (T1). Third measurement was performed 3 hours after fluid challenge test (T2). Fourth measurement 6 hours after challenge (T3).

Recordings and Measurements:

CVP measurement cm H2O

A transducer was used to measure central venous pressure (CVP) in a patient, fixed at the patient's phlebostatic axis. The transducer was connected to a monitor, and the CVP waveform was displayed on the monitor. If CVP was less than 10 cm H2O or signs of hypovolemia were observed, a passive leg raising test was performed. If PLR caused an increase of CVP of <5 cm H2O, a fluid bolus was given. If PLR caused a high increase of CVP of >5 cm H2O, further fluid infusion was considered unsafe. A patient was considered a fluid responder if the mean arterial pressure increased by at least 20% compared to pre-fluid challenge.

IJV measurement

All the measurements was done on Right IJV with the patients initially lying supine at 0° .With the patients in supine position, the USG transducer was placed on the right side of the neck in the transverse plane over RIJV 2 cm above the sternoclavicular joint. The IJV was identified by the color flow Doppler and compressibility. Care was taken not to compress or obliterate the vein by applying minimal pressure(12). When the whole circumference of the vein is visible the measurements was done. The maximum, minimum AP diameters, and cross-sectional area was estimated and, from this, corresponding CI was derived (Maximum diameter or cross-sectional area (CSA)–minimum diameter or CSA/maximum diameter or CSA)×100%.

IVC measurements

Maximum IVC diameter at end expiration (IVCdmax): cm. To measure the IVC diameter, a curvilinear probe of Sonosite turbo ultrasound machine was placed longitudinally in the sub xiphoid region with the probe marker to the patient's head, to visualize the confluence of the hepatic veins draining the IVC. We may need to move the probe 1-2 cm to the patient's right and then tilt it slightly towards the heart. The internal anterior posterior [AP] diameter of the IVC just caudal to the confluence of the hepatic veins in the longitudinal plane was measured (13). Minimum IVC diameter at end inspiration (IVCdmin): cm. The IVC collapsibility index (IVC CI):%. The difference between the maximum and minimum IVC diameters divided by the maximum IVC diameter, expressed as a percentage ([IVCdmax – IVCdmin] / IVCdmax × 100%) (14).

Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). Qualitative data were described using number and percent. The Shapiro-Wilk test was used to verify the normality of distribution. Quantitative data were described using range (minimum and maximum), mean, standard deviation, median and interquartile range (IQR). The significance of the obtained results was judged at the 5% level.The used tests were ANOVA with repeated measures and Pearson coefficient.

Results

Table 1 shows that a total of 30 patients were included in our study 83.3% (n=25) were males and 16.7% (n=5) were females, their age ranges from 47-63 with mean ± SD 56.60 ± 5.08.

Table 2 shows there was a significant increase in central venous pressure throughout different time periods in our study. (p value<0.001*). which represents a static measure after fluid resuscitation. Mean CVP increased significantly from 5.60(± 4.34) at baseline to 7.53 (± 3.69) 6 hours after fluid resuscitation.

Table 3 shows there was a significant decrease in inferior vena cava collapsibility index throughout different time periods in our study after fluid resuscitation p=0.005

Table 3 shows there was a significant decrease in inferior vena cava collapsibility index throughout different time periods in our study after fluid resuscitation p=0.005.

Table 4 shows that there was a significant decrease in Internal jugular vein collapsibility index throughout different time periods in our study after fluid resuscitation p value <0.001. The mean(± SD)decrease of IJV-CI just after fluid resuscitation was 46.07(± 8.30),and 46.17 ± 7.98 after three hours of fluid resuscitation both values were statistically significant p value

<0.001*There was a significant decrease in IJC-CI after 6 hours of fluid resuscitation with a mean (± SD) 46.50 (± 7.93)when compared to baseline mean (± SD) measurement 48.80 (± 8.58).

Table 5 shows that a negative significant correlation was found between both (IVC-CI) (IJV-CI) and CVP p= 0.017, 0.040 respectively.

Table 6 shows a negative significant correlation also was found between both (IVC-CI) (IJV-CI) and CVP p= 0.005, 0.001 respectively.

Table 7 shows that the inferior vena cava collapsibility index was found to be the most effective in predicting fluid responsiveness in dehydrated patients, with a sensitivity of 84.62% and specificity of 76.47%. Central venous pressure and internal jugular vein collapsibility index were not significantly effective.

Table 1: Distribution of the studied cases according to demographic data (n = 30)

	No.	%
Sex		
Males	25	83.3
Females	5	16.7
Age (years)		
Min. – Max.	47.0 – 63.0	
Mean ± SD.	56.60 ± 5.08	
Median (IQR)	57.0 (54.0 – 61.0)	

IQR: Inter quartile range SD: Standard deviation Data are presented as mean ± SD, median, range or number

Table 2: Mean changes in central venous pressure (CVP) throughout the different studied periods:

CVP	Baseline(T0)	T1	T2	T3	F	p
Min. – Max.	0.0 – 16.0	2.0 – 15.0	2.0 – 14.0	3.0 – 15.0	24.245*	<0.001*
Mean ± SD.	5.60 ± 4.34	7.0 ± 3.95	7.0 ± 3.64	7.53 ± 3.69		
Median (IQR)	6.0 (2.0 – 8.0)	7.0 (3.0 – 9.0)	6.0 (4.0 – 11.0)	6.0 (5.0 – 11.0)		

p0		<0.001*	<0.001*	<0.001*	
Sig. bet. Periods		p1<0.001*,p2=1.000,p3=0.219			

IQR: Inter quartile range, SD: Standard deviation,F: F test (ANOVA) with repeated measures, CVP:central venous pressureT0: baseline measurement, T1:just after fluid resuscitation, T2:three hours after fluid resucuitation, T3:6 hours after fluid resuscitation . p: p value for comparing between the different studied periods p0: p value for comparing between Baseline and each other periods p1: p value for comparing between T1 and T2 p2: p value for comparing between T1 and T3 p3: p value for comparing between T2 and T3 Statistically significant at p ≤ 0.05 *

Table 3: Mean changes in inferior vena cava collapsibility index (IVC-CI) during the studied periods:

IVC-CI	Baseline(T0)	T1	T2	T3	F	p
Min. – Max.	25.0 – 58.0	21.0 – 55.0	21.0 – 55.0	22.0 – 62.0	4.566*	0.005*
Mean ± SD.	43.63 ± 9.73	41.03 ± 9.35	41.63 ± 9.07	41.87 ± 9.70		
Median (IQR)	42.50(38.0 – 55.0)	39.50(38.0 – 51.0)	41.50(39.0 – 50.0)	41.0(38.0 – 51.0)		
p0		0.026*	0.022*	0.048*		
Sig. bet. Periods		p1=0.844,p2=0.432,p3=0.0.134				

IQR: Inter quartile range SD: Standard deviation F: F test (ANOVA) with repeated measures, IVC-CI: inferior vena cava collapsibility index T0: baseline measurement, T1:just after fluid resuscitation, T2:three hours after fluid resucuitation, T3:6 hours after fluid resuscitation .

Table 4: Mean changes in Internal jugular vein collapsibility index (IJV- CI) during the studied periods

IJV-CI	Baseline(T0)	T1	T2	T3	F	p
Min. – Max.	35.0 – 62.0	30.0 – 58.0	31.0 – 59.0	31.0 – 60.0	31.016*	<0.001*
Mean ± SD.	48.80 ± 8.58	46.07 ± 8.30	46.17 ± 7.98	46.50 ± 7.93		
Median (IQR)	52.0(42.0 – 57.0)	47.0(40.0 – 54.0)	48.50(40.0 – 54.0)	48.0(39.0 – 53.0)		
p0		<0.001*	<0.001*	<0.001*		
Sig. bet. Periods		p1<0.001*,p2=1.000,p3=1.000				

Table 5: Correlation between CVP with IVC-CI and IJV-CI (n= 30) just after fluid resuscitation (T1)

	CVP	
	r	p
IVC-CI	-0.433	0.017*
IJV-CI	-0.378	0.040*

r: Pearson coefficient ,CVP:central venous pressure, IVC-CI:inferior vena cava collapsibility index,IJV- CI:internal jugular vein collapsibility index. *: Statistically significant at p ≤ 0.05

Table 6: Correlation between central venous pressure (CVP) with inferior vena cava collapsibility index (IVC-CI) and internal jugular vein collapsibility index (IJV-CI) at three hours and 6 hours after fluid resuscitation.

	CVP	
	r	p
IVC-CI	-0.295	0.005*
IJV-CI	-0.338	0.001*

r: Pearson coefficient ,CVP:central venous pressure ,IVC-CI:inferior vena cava collapsibility index,IJV-CI: internal jugular vein collapsibility index (IJV-CI) *: Statistically significant at p ≤ 0.05.

Table 7: Validity (AUC, sensitivity, specificity) for CVP, IVC-CI, and IJV-CI, to predict responsiveness

Baseline	AUC	p	95% C.I	Cut off	Sensitivity	Specificity	PPV	NPV
CVP	0.572	0.503	0.361 – 0.784	≤6	69.23	47.06	50.0	66.7
IVC-CI	0.821	0.003*	0.651 – 0.991	>41	84.62	76.47	73.3	86.7
IJV-CI	0.613	0.295	0.401 – 0.825	>47	61.54	52.94	50.0	64.3

AUC: Area Under a Curve p value: Probability value. CI: Confidence Intervals, CVP:central venous pressure, IVC-CI: inferior vena cava collapsibility index .IJV- CI:internal jugular vein collapsibility index NPV: Negative predictive value PPV: Positive predictive value *: Statistically significant at p ≤ 0.05

Discussion

Ultrasound has become one of the cornerstones of modern ICU. It can be used in daily ICU practice to measure the different dynamic predictors of fluid responsiveness, such as inferior vena cava collapsibility index (variation of IVC diameter with respiration) and internal jugular vein collapsibility index to differentiate between fluid responders and nonresponders (15).

Any pressure or volume change in the intrathoracic systemic venous system is reflected in the extrathoracic system, such as the inferior vena cava and the internal jugular vein (16).

Individuals who were able to maintain a stable blood pressure after fluid resuscitation had a significant diameter increase in end-expiratory IVC, whereas those who remained hemodynamically unstable did not have a change in IVC diameter with resuscitation. The authors concluded that changes in IVC diameter in response to fluid resuscitation is a better indicator of adequate fluid resuscitation than vital signs.

A prospective double-blind observational study by Worapratya and his Colleagues in was conducted in the emergency room of a tertiary care center on shocked patients. The IVC-CI was calculated. The correlation of CVP and the IVC-CI were calculated by Pearson's coefficient among the 30 patients. This study concluded that the IVC-CI measured by bedside ultrasound in the emergency room had a good correlation with CVP, a result that resonates with our study results (17).

Also the current study was in agreement with another study was carried in Al-Azhar University by Shalaby and his colleagues in to evaluate the correlation between Central Venous Pressure (CVP) measurement and ultrasound measurements of the Inferior Vena Cava diameter, and Collapsibility Index (IVC-CI), aiming to evaluate the ultrasound as a noninvasive tool in assessment of intravascular volume status and fluid responsiveness in critically ill intensive care unit patients. 50patients aged 30-60 years were involved in this single blinded correlational study. A significant negative correlation between CVP and IVC CI ($r=-0.788$, $p<0.001$) showed that Inferior Vena Cava Collapsibility Index (IVC CI) had the most favorable performance in predicting CVP (18).

Preau, Sebastien also investigated whether the collapsibility index of the inferior vena cava recorded during a deep standardized inspiration predicts fluid responsiveness in 90 nonintubated patients and found that The collapsibility index of the inferior vena cava during a deep standardized inspiration is a simple, noninvasive bedside predictor of fluid responsiveness in nonintubated patients with sepsis-related acute circulatory failure (19).

Shaobing Dai a, Jianjun Shen demonstrated that SCV-CI proved to be the independent predictor for fluid responsiveness and SCV-CI could predict fluid responsiveness in spontaneously breathing parturients, with an AUROC curve of 0.757, which may be because that the diameter of subclavian vein is less affected by spontaneous breathing (19). Their data clarified that ultrasound- derived SCV-CI could be the measure of intravascular volume status and has a certain guiding role in perioperative fluid therapy in spontaneously breathing parturients.

Abdelwahab et al. discovered a significant relationship be- tween CVP and sonographic IVC measurements (IVC diameter and caval index) in spontaneously breathing patients. Although a statistically sig nificant correlation was found between IVC measurements (IVC diameter and caval index) and CVP in spontaneously breathing and mechanically ventilated patients ($p < 0.001$), regression coefficients were higher in spontaneously breathing ($r = 0.74$ for IVC diameter and − 0.76 for caval index) than mechanically ventilated patients ($r = 0.4$ for IVC diameter and − 0.47 for caval index)(20). Nazemi et al. also revealed that caval index > 50% has a sensitivity of 94% and a specificity of 97% in predicting low CVP (8 mmHg) (21).

In the same context, Ma et al. confirmed our results stating that IJV is a strong predictor for fluid responsiveness with AUC 0.88, 95% CI 0.78–0.94, sensitivity of 91.2%, and specificity of 82.8% at cutoff value > 12.99%. They collected hemodynamic data from 70 mechanically ventilated post-cardiac surgery patients. Patients were classified as responders when stroke volume increased by > 15% after passive leg raise and intravenous infusion of 500 ml of Gelofusine. Their cutoff value differs from ours presumably because of mechanical ventilation usage and different calculation equations (22).

Among different respiratory phases of IVC diameter and the IVC collapsibility index, the authors found that there was a significant correlation between CVP and IVC-CI, iIVCD, and mean IVCD, but not eIVCD. Only the IVCCI and iIVCD were, respectively, best inversely correlated or correlated with the CVP. This understanding of the change in IVC diameter and collapsibility index will provide a good clinical adjustment in fluid therapy in critically-ill patients. As a consequence, fluid challenge should be avoided in patients with an increase in IVC diameter (23).

Nagdev, et al. reported that CI > 50% had a strong association with a lower CVP < 8 mmHg (24). Brennen, et al. documented that the combination of both collapsibility indices (CI) and IVC diameter measurements may assist in improved ultrasonographic evaluations of the IVC with clinically important categories of right atrial pressure (e.g. 0–10 mmHg); however, the limitation of the study was the exclusion of ventilated patients and poor statistical significance that limits the applicability of this approach to our investigation of predominately critically ill patients (25).

If the tidal volume is less than 8 ml/kg, it may cause smaller variations in intrathoracic blood volume and pressure, and IVC variation will be smaller. Therefore, these two factors can influence the IVC accuracy in predicting fluid responsiveness (26).

Conclusion

we concluded that inferior vena cava collapsibility index was found to be the most effective in predicting fluid responsiveness in dehydrated patients, with a sensitivity of 84.62% and specificity of 76.47%. Central venous pressure and internal jugular vein collapsibility index were not significantly effective. Also , there was negative significant correlation between both (IVC-CI) (IJV-CI) and CVP.

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