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Correlation between Ultrasound Measurements of Internal Jugular Venous Diameter and Central Venous Pressure Measurements as a Follow up Tool in Severe Sepsis

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ABSTRACT
Background: Sepsis is one of the primary causes of death among intensive care unit (ICU) patients. Proper and controlled fluid administration is needed in septic patients to overcome generalized vasodilatation and capillary leak that worsen septic patients. **Objective:** Current study aimed to evaluate ultrasonographic measurements of internal jugular vein (IJV) as a predictor for volume status and to define its role in improvement of haemodynamic, urine output and mortality rate among septic patients.
Patients and Methods: Fifty-one adult septic patients were enrolled from ICU of Mansoura University Hospitals who already inserted central venous catheter (CVC) for appropriate indication took part in an observational study. Continuous monitoring of hemodynamic parameters was carried out. Ultrasound guided IJV diameter was assessed when patients were lying down, then central venous pressure (CVP) measurements were taken. Signs of hypovolemia, such as tachycardia, hypotension, and acidosis were assessed clinically.
Results: Data from 51 septic patients who were spontaneously breathing were evaluated. There was significant positive correlation between CVP and both width and height (at admission, 3h or 24 hours following the admission). Systolic blood pressure (SBP) demonstrated statistically significant positive correlation at admission (width and height) and after 24 hours of admission with width. Diastolic blood pressure (DBP) and mean arterial pressure (MAP) demonstrated statistically significant positive correlation at admission (width and height) and after 3 hours of admission with height.
Conclusions: Ultrasonographic measurement of the IJV is a good predictor of fluid response in septic patients.
Keywords: Central venous pressure, Internal jugular vein, Septic shock.

INTRODUCTION
In the intensive care unit (ICU), sepsis is a leading cause of death. The initial priority in treating patients who have developed sepsis is to restore their fluid balance. Nonetheless, the underlying concern is how to appropriately resuscitate each individual patient using fluids. In septic patients, tissue edema could occur by generalized vasodilation and capillary leak, which can be countered with appropriate fluid supply[(1)].

Several different sets of diagnostic criteria and tools are available for determining if a patient has sepsis. These include the systemic inflammatory response syndrome (SIRS) criteria, the Sequential Organ Failure Assessment (SOFA) criteria or quick Sequential Organ Failure Score (qSOFA), the National Early Warning Score (NEWS), and the Modified Early Warning Score (MEWS)[(2)].

Intravenous fluids improve oxygen supply and hemodynamic optimization, which is critical in the treatment of septic patients. It may, however, be ineffective or even hazardous if not closely managed. This stresses the importance of developing a method for determining who will benefit from fluid injection[(3)]. **Wise *et al*.**[(4)] demonstrated the ineffectiveness of central venous pressure, systolic pressure, and other static measures of fluid responsiveness as a predicting outcomes. Therefore, it is crucial, then, to specify non-invasive dynamic techniques for fluid resuscitation prediction[(5)].

The current study aims to evaluate ultrasonographic (US) measurements of the IJV and to define its role in prediction for volume status (primary outcome), improvement of haemodynamic of patient (heart rate, blood pressure and urine output) and decrease of mortality rate (secondary outcome).

PATIENTS AND METHODS
Fifty-one adult patients were enrolled in this prospective, observational clinical study. The patients were admitted in intensive care unit at Mansoura University Hospitals.

Ethical consent:
The study was approved by the Medical Ethics Committee, Faculty of Medicine, Mansoura University (proposal code: MS.18.09.304). First degree relatives of the patients were interviewed and written informed consents were obtained from them for their patients to be a part of our research in ICU. 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.

Inclusion criteria:
Both sexes with age between 18 and 60 years, spontaneously breathing patients with functioning CVC, septic shocked patient, as defined by the criteria, and treated following the guidelines of the Surviving Sepsis Campaign [(6)].

Exclusion criteria:
Pregnant, history of neck radiotherapy, previous or active IJV thrombus, mechanically ventilated patients

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or those with cardiac disease (heart failure, pulmonary hypertension, cor-pulmonale, severe aortic stenosis, AF), and increased intrathoracic pressure (pneumothorax) patients were excluded.

Patients' demographic informations (age, sex, height, and body weight), a complete medical and surgical history, and a comprehensive clinical examination were all used to evaluate all participants in this study. The multichannel monitor was used for routine monitoring procedures. These procedures included a noninvasive arterial blood pressure reading, an electrocardiogram (ECG), and a pulse oximetry reading, and the following data were taken:

- Central venous pressure (CVP) measurements, width and height of IJV by US were measured at (0, 3, 24 hrs).
- Heart rate.
- Non-invasive blood pressure reading.
- Mean arterial pressure.
- Respiratory rate.
- Urine output.
- qSOfA score.
- Glascow coma scale.
- Temperature.

At the time of the study, all patients had invasively monitored CVP through the use of Electronic Pressure Transducer, the patient lies supine, and the transducer zeroed at the mid-thoracic position.

Measurements of Internal Jugular Vein (IJV) by ultrasound:

The patients were placed in a supine posture with their head and legs flat, and a small pillow was used to maintain proper alignment of their head, neck, and trunk. Patients were asked to turn their head to one side (approximately 30 degrees), therefore, in order to expose the internal jugular vein. The ultrasound transducer (Acuson X 150 ultrasound machine, Siemens-using 2 D mode) was placed on the patient's neck in a transverse position over the expected site of the IJV. The transducer is placed perpendicular to the patient's neck, at the level of the cricoid cartilage, which can be identified by gentle compression. To obtain a clear ultrasonic image of IJV, a small pressure transducer was used. Once the internal jugular vein is located, the transducer's position is adjusted so that a circular cross-sectional image is obtained. The patients were instructed to take a few deep breaths normally, then to stop breathing at the normal (tidal volume) end of expiration. After capturing the "best" end-expiration image (in which the internal jugular vein looks most circular), the patient went back to his/her regular breathing pattern.

Anterior-posterior and transverse IJV diameters were measured with the use of the ruler or the cursor feature function. All ultrasound measurements were taken at time of admission (T0), after 3 hours (T3) (after volume expansion by a 30-ml/kg crystalloid infusion), and at (T24) after 24 hours following admission.

Figure (1): An ultrasound probe positioned at the level of the cricoid cartilage in order to locate the internal jugular vein.

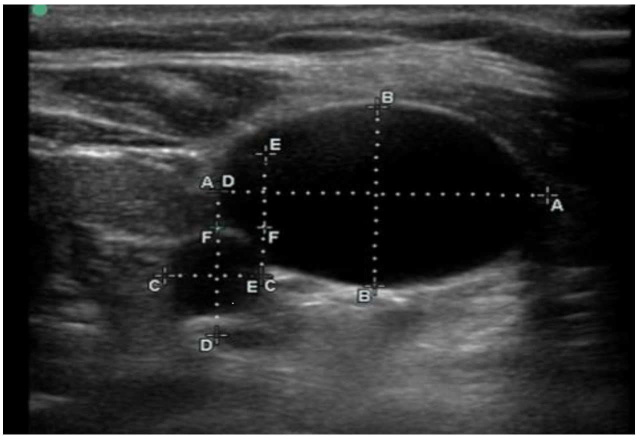

Figure (2): Ultrasound image of IJV and carotid artery.

RESULTS

Table (**1**) demonstrates demographic characteristics, medical history and clinical presentation of studied cases. The mean age was 43.80 ± 13.017 and male to female ratio was 51/49. History of DM, HTN was recorded in 43.1% and 51% respectively. The percentage of qSOFA score, altered GCS and temperature >38.3 were recorded on admission, after 3 and 24 hours.

Table (1): Demographic and clinical data of the studied group (n=51)

All patients (n= 51)		**Mean ± SD**
Age years (mean ± SD)		43.80±13.01
Gender Male n (%)		26 (51.0%)
History of DM n (%)		22 (43.1%)
History of HTN n (%)		26 (51.0%)
qSOFA score median (mean ± SD)	Admission	1.47 ± 0.98
	24 hours	0.90 ± 0.75
Altered GCS n (%)	Admission	27 (52.9%)
	24 hours	15 (29.4%)
Temperature >38.3°C	Admission	31 (60.8%)
	3 hours	17 (33.3%)
	24 hours	18 (35.3%)

Regards to haemodynamic parameters, there were statistical significant improvements of MAP, heart rate (HR), respiratory rate (RR), CVP after 3hours and 24 hours (P<0.05). No significant differences in Anterior-posterior diameter (APD) and transverse diameter (TD) were recorded at follow up periods compared to the admission (P>0.05) with exception of 3 hours following admission being significant in APD only (P=0.03) (Table **2**).

Table (2): Hemodynamic data of the studied patients (n=51)

Parameters		Mean ± SD	P
MAP	Admission	64.31 ± 10.21	-
	3 hours	78.80 ± 12.28	<0.001
	24 hours	81.57 ± 10.46	<0.001
Heart rate	Admission	107.24 ± 18.24	-
	3 hours	103.53 ± 16.03	0.277
	24 hours	98.37 ± 14.71	0.008
Respiratory rate	Admission	22.53 ± 5.29	-
	3 hours	22.13 ± 4.22	0.673
	24 hours	20.76 ± 2.62	0.034
CVP cm H_2O	Admission	6.06 ± 6.88	-
	3 hours	9.10 ± 6.83	0.027
	24 hours	10.00 ± 5.99	0.003
Width of IJV	Admission	12.94 ± 4.04	-
	3 hours	13.07 ± 3.13	0.889
	24 hours	12.73 ± 2.41	0.716
Height of IJV	Admission	8.99 ± 2.92	-
	3 hours	10.17 ± 2.73	0.037
	24 hours	9.35 ± 2.58	0.511

Data is expressed as mean ± standard deviation. P is generated by comparing each reading to the respective basal value. P is significant when < 0.05.

Table (**3**) demonstrates statistically significant positive correlation between CVP and both APD and TD (at admission, 3h or 24 hours following the admission). SBP demonstrated statistically significant positive correlation at admission (APD and TD) and after 24 hours of admission with TD. DBP and MAP demonstrated statistically significant positive correlation at admission (APD and TD) and after 3 hours of admission with APD.

Table (3): Correlation between IJV width and height with CVP, SBP, DBP and MAP measurements

24 hours		Transverse diameter		Anterior-posterior diameter	
		r	P	r	P
CVP	Admission	0.372	0.007	0.331	0.018
	3 hours	0.557	< 0.001	0.489	< 0.001
	24 hours	0.601	< 0.001	0.594	< 0.001
SBP	Admission	0.501	< 0.001	0.345	0.013
	3 hours	0.042	0.770	-0.060	0.676
	24 hours	0.280	0.047	0.035	0.805
DBP	Admission	0.601	< 0.001	0.364	0.009
	3 hours	-0.119	0.407	0.305	0.029
	24 hours	0.186	0.191	0.047	0.745
MAP	Admission	0.579	< 0.001	0.342	0.014
	3 hours	-0.117	0.415	-0.311	0.027
	24 hours	0.177	0.214	-0.117	0.413

P is significant when < 0.05.

Table (**4**) demonstrates oliguria at admission, oliguria after 3 hours, oliguria after 24 hours, need for vasopressors and mortality rate were reported in 68.6%, 49%, 39.2% and 49% and 49%, respectively.

Table (4): Oliguria, need for vasopressors and mortality among the studied patients (n=51)

Parameters		Frequency	Percentage
Oliguria	Admission	35	68.6%
	3 hours	25	49.0%
	24 hours	20	39.2%
Need for vasopressors		25	49.0%
Mortality		25	49.0%

DISCUSSION

Fluid resuscitation is recommended to increase cardiac output and tissue hypoperfusion due to the fact that sepsis is associated with a decrease in blood volume. Fluid overload has been linked to increase mortality in septic patients, according to a number of studies[7].

In this way, predicting the success of volume expansion requires a quick, reliable and frequent determination of intravascular volume status[8,9]. In spite of CVP is used to assess fluid status, its value as a method for guiding fluid resuscitation is a matter of debate, do not accurately predict volume responsiveness as well as its invasive technique with iatrogenic complications[10].

US measurements of IJV is a helpful, rapid, and safe method for early fluid resuscitation during the shock course[11]. Even clinicians with less knowledge or experience may take ultrasound measures as precisely as doctors with formal training after only 3 hours of training [12].

Comparing qSOFA scores upon admission and again after one day showed statistically significant differences in the current investigation. In this context **Talmor *et al*.**[13] reported that respiratory rate and shock index (HR/SBP) were independent factors as a prognostic value for patients with suspected infection. Also **Kenzaka *et al.***[14] reported that significant correlations were found between vital signs, especially; blood pressure, respiratory rate, shock index, and the SOFA score for sepsis severity. **Ho and Lan**[15] in a prospective study reported that both in septic and non-septic patients qSOFA demonstrated only moderate predictive potential for mortality.

In the present study there were statistical significant improvements of MAP, HR, respiratory rate (RR), CVP after 3 hours and 24 hours (P<0.05). There were significant positive correlations between CVP and both IJV and anterior-posterior diameter (APD) and transverse diameter (TD) (at admission, 3h or 24 hours following the admission). SBP demonstrated statistically significant positive correlation at admission (IJV APD and TD) and after 24 hours of admission with IJV TD. DBP and MAP demonstrated statistically significant positive correlation at admission (IJV APD and TD) and after 3 hours of admission with IJV APD.

These results are in accordance with the systematic review and meta-analysis by **Parenti *et al*.**[16] that included spontaneously breathing septic patients that AP-IJVD max showed the best correlation with the CVP and all US parameters of IJV had good validity in predicting CVP.

Similarly, **Bano *et al.***[17] found that IJV diameter was significantly correlated with CVP. **Avcil *et al.*** [18] cleared that CVP was estimated directly and compared to US guided IJV (diameter, area, and height) and IVC (diameter and index). Height and transverse diameter of the IJV had moderately correlated with CVP. However, there was a weak correlation between CVP and IVC diameter and index. They discovered that RIJV height and IVC index have better diagnostic performance for estimating high CVP, but IJV area, maximum diameter, and IVC maximum diameter have high sensitivity for estimating low CVP levels.

Sathyasuba *et al.*[19] demonstrated a significant positive correlation between IJV maximum, IJV minimum, and invasive CVP in patients requiring mechanical ventilation after surgery. In their study, **Mucahit *et al.***[20] observed a moderate association between invasive CVP and IJV (max and min), but a weak correlation between invasive CVP and IJV (IVC max, IVC min, and IVC-CI).

Abbasian *et al*. [21] discovered that the IJV cross section had a high correlation with the CVP of their patients. Transverse IJV diameter was significantly associated with CVP, while longitudinal IJV diameter was not.

Against our findings, **Hilbert *et al*.** [22] found a poor correlation between CVP and end-expiratory internal jagular vein diameter in patients on mechanical ventilation measured in the 0 or 30 position. Also, **Raksamani *et al.*** [23] found only a weak relationship between single IJV measures and CVP in intubated patients, which may reflect the influence of mechanical ventilation.

In the current study regarding renal perfusion affection, oliguria was reported at admission, after 3 hours and after 24 hours while they received fluid resuscitation was 68.6%, 49%, and 39.2% respectively. This agrees with **Harrois *et al*.**[24] who reported that improving hemodynamic macrovascular parameters during septic shock resulted in restored, decreased, or even unaffected cortical renal perfusion.

The reported mortality rate was 49% of our cases, since most of patients included in our study were cancer patients, this relatively high percentage can be explained by the fact that sepsis could be a life-threatening condition in people who are already dying from another diseases. When evaluating our hopes for reducing sepsis mortality rates and considering the increasing number of elderly and weak patients admitted to hospital wards and intensive care units, it is crucial to keep this fact in mind. Baseline mortality from sepsis is almost certainly inherent to the disease itself, and it is unrealistic to hope that, despite our best efforts to learn about, diagnose, and treat the condition, fatality rates will go down to zero[25].

CONCLUSION

The US examination of the IJV is a simple bedside test that can be used as a rapid, non-invasive diagnostic and follow up tool to detect volume status (primary outcome). As well as improvement of haemodynamic of the patients; heart rate, blood pressure, urine output, and decrease of mortality rate (secondary outcome) could occurred.

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REFERENCES

1. **Elsaeed A, Nor El-Din B, El Taher W *et al.* (2022):** Internal jugular vein distensibility variation and inferior vena cava collapsibility variation with fluid resuscitation as an indicator for fluid management in spontaneously breathing septic patients. Ain-Shams J Anesthesiology, 14:26:1-7.
2. **Islam M, Nasrin T, Walther B *et al.* (2019):** Prediction of sepsis patients using machine learning approach: A meta-analysis. Computer Methods and Programs in Biomedicine, 170: 1-9.

3. **Cumpstey A, Grocott M, Mythen M *et al.* (2020):** Fluid management and its role in enhanced recovery. In: Perioperative Fluid Management 2020. Springer, Cham, Pp. 339–363. https://link.springer.com/chapter/10.1007/978-3-030-48374-6_15
4. **Wise R, Faurie M, Malbrain M *et al.* (2017):** Strategies for intravenous fluid resuscitation in trauma patients. World J Surgery, 41(5):1170–1183.
5. **Haase D, Patel R (2020):** Ultrasound for Shock Evaluation, Resuscitation, and Critical Care Procedures. Emergency Department Critical Care. Springer International Publishing. Pp. 637-686. https://link.springer.com/chapter/10.1007/978-3-030-28794-8_37
6. **Levy M, Evans L, Rhodes A *et al.* (2018):** The Surviving Sepsis Campaign Bundle: 2018 update. Intens Care Med., 44(6): 925-928.
7. **Acheampong A, Vincent J (2015):** A positive fluid balance is an independent prognostic factor in patients with sepsis. Crit Care, 19(1): 1-7
8. **Dellinger R (2015):** The future of sepsis performance improvement. Crit Care Med., 43(9): 1787-1789.
9. **De Backer D, Vincent J (2018):** Should we measure the central venous pressure to guide fluid management? Ten answers to 10 questions. Crit Care (London, England), 22(1): 43-43
10. **Howthan A, El-Hady M, Mersal N *et al.* (2020):** Peripheral versus central venous catheter complications and pressure among critically ill patients. Internal J Novel Res Healthcare Nursing, 7(3): 82-95
11. **Guevarra K, Greenstein Y (2020):** Ultrasonography in the Critical Care Unit. Current Cardiology Reports, 22(11): 145-145.
12. **Thalhammer C, Siegemund M, Aschwanden M *et al.* (2009):** Non-invasive central venous pressure measurement by compression ultrasound—A step into real life. Resuscitation, 80(10): 1130-1136.
13. **Talmor D, Jones A, Rubinson L *et al.* (2007):** Simple triage scoring system predicting death and the need for critical care resources for use during epidemics. Crit Care Med., 35(5): 1251-1256.
14. **Kenzaka T, Okayama M, Kuroki S *et al.* (2012):** Importance of Vital Signs to the Early Diagnosis and Severity of Sepsis: Association between Vital Signs and Sequential Organ Failure Assessment Score in Patients with Sepsis. Internal Medicine, 51(8): 871-876.
15. **Ho K, Lan N (2017):** Combining quick Sequential Organ Failure Assessment with plasma lactate concentration is comparable to standard Sequential Organ Failure Assessment score in predicting mortality of patients with and without suspected infection. J Crit Care, 38: 1-5.
16. **Parenti N, Scalese M, Palazzi C *et al.* (2019)**: Role of internal jugular vein ultrasound measurements in the assessment of central venous pressure in spontaneously breathing patients: a systematic review. J Acute Med., 9(2): 39-43.
17. **Bano S, Qadeer A, Akhtar A *et al.* (2018):** Measurement of Internal Jugular Vein and Common Carotid Artery Diameter Ratio by Ultrasound to Estimate Central Venous Pressure. Cureus, 10(3): 2277-2277
18. **Avcil M, Kapci M, Dagli B *et al.* (2015):** Comparison of ultrasound-based methods of jugular vein and inferior vena cava for estimating central venous pressure. Internat J Clin Exper Med., 8(7): 10586. https://pubmed.ncbi.nlm.nih.gov/26379848/
19. **Sathyasuba M, Kala B, Muralitharan M (2017):** Prospective Comparative study of Ultrasound Guided Central Venous Pressure Measurement using Jugular Vein and Inferior Vena cava Diameters for Postoperative Patients on Mechanical Ventilation. Madras Medical College, Chennai. Pp. 1-123. Available at: http://repository-tnmgrmu.ac.in/12610/
20. **Mucahit A, Kapci M, Dagli B *et al.* (2015):** Comparison of ultrasound-based methods of jugular vein and inferior vena cava for estimating central venous pressure. Internat J Clin Exper Med., 8(7): 10586-94.
21. **Abbasian A, Feiz H, Afzalimoghaddam M *et al.* (2015):** Measurement of Central Venous Pressure Using Ultrasound in Emergency Department. Iran Red Cres Med J., 17(12): 19403-19403.
22. **Hilbert T, Ellerkmann R, Klaschik S *et al.* (2016):** The Use of Internal Jugular Vein Ultrasonography to Anticipate Low or High Central Venous Pressure During Mechanical Ventilation. J Emerg Med., 50(4): 581-587.
23. **Raksamani K, Udompornmongkol V, Suraseranivongse S *et al.* (2014):** Correlation between cross-sectional area of the internal jugular vein and central venous pressure. Euro J Anaesthesiol., 31(1): 50-51.
24. **Harrois A, Grillot N, Figueiredo S *et al.* (2008):** Acute kidney injury is associated with a decrease in cortical renal perfusion during septic shock. Crit Care, 22(1): 1-9.
25. **Flaatten H, De Lange D, Morandi A *et al*. (2018):** The impact of frailty on ICU and 30-day mortality and the level of care in very elderly patients (≥80 years). Intens Care Med., 43(12): 1820-1828.