ORIGINAL ARTICLE

Correlation of Internal Jugular Vein and Inferior Vena Cava Collapsibility Index with Direct Central Venous Pressure Measurement in Critically-ill Patients: An Observational Study

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Abstract

Background and aims: Prompt assessments and quick replacement of intravascular fluid are critical steps to resuscitate hypovolemic patients. Intravascular volume assessment by direct central venous pressure (CVP) measurement is an invasive, time-consuming, and labor-intensive procedure. Nowadays, bedside ultrasound-guided volume assessment of the internal jugular vein (IJV) or inferior vena cava (IVC) is commonly employed as a proxy for direct CVP.

Therefore, we examined the strength of association between CVP and collapsibility index (CI) of the IJV and IVC for evaluating the volume status of critically ill patients.

Methods: Bedside USG-guided A–P diameter and cross-sectional area of the right IJV and IVC were measured, and their corresponding collapsibility indices were deduced. The results of the IJV and IVC indices were correlated with CVP.

Results: About 60 out of 70 enrolled patients were analyzed. The baseline clinical parameters of patients are shown in Table 1. For CSA and AP diameter, the correlations between CVP and IJV-CI at 0° were $r = -0.107$ ($p = 0.001$) and $r = -0.092$ ($p = 0.001$). Correlations between CVP and IJV-CI at 30° for CSA and diameter, however, were ($r = -0.109$, $p = 0.001$) and ($r = -0.117$, $p = 0.001$), respectively. Table 2 depicts the correlation between CVP and IVC-CI $r = -0.503$, $p = 0.001$ for CSA and $r = -0.452$, $p = 0.001$ for diameter.

Conclusion: The IVC and IJV collapsibility indices can be used in place of invasive CVP monitoring to assess fluid status in critically ill patients.

Keywords: Central venous pressure, Critically ill patients, Inferior vena cava collapsibility index, Internal jugular vein, Volume status.

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Highlights

Intravascular volume assessment by direct measurement of central venous pressure (CVP) is invasive, labor-intensive and time-consuming. Bedside ultrasound-guided assessments of the inferior vena cava (IVC) or internal jugular vein (IJV) indices are simple, repeatable, and need little training.

The IVC and IJV collapsibility indices have good correlations with invasive CVP.

Introduction

Prompt assessments of intravascular fluid status are essential but critical clinical skills for an intensivist to effectively and quickly resuscitate critically ill and polytrauma patients with hypovolemia. It has been demonstrated that early goal-directed fluid therapy in septic shock lowers fatalities and improves outcomes.[1]

Likewise, prompt volume assessment and resuscitation are essential steps to prevent fatalities in trauma patients.[2] Clinical assessment of intravascular volume in sick patients is often misleading and not reliable.[3] Central venous canulation for CVP measurement takes crucial time to establish the volume status of sick patients. Central venous canulation also carries the risks of immediate, early, and late complications.[4] Nowadays, bedside ultrasound has become an invaluable tool in the critical care unit for determining the hypovolemic state for managing the patients in shock.

Ultrasound-guided measurement of IVC parameters has been evaluated for assessment of intravascular volume by various researchers with diverse and contradictory outcomes.[5–7] In 10–15% of cases, IVC measurements by ultrasound are not possible. Such conditions are right-sided heart diseases, raised abdominal pressure disrupting IVC caliber, and morbid obesity.[8–10]

Bedside ultrasound-guided IJV measurements are now become a routine clinical practice. Using point-of-care ultrasonography (POCUS), Killu et al. evaluated volume status in sick patients by measuring the IJV-CI (diameter) with an 87.5% sensitivity and a 100% specificity.[11] Akilli et al. examined IJV parameters using point-of-care ultrasonography to detect volume status in healthy blood donors.[12]

Nonetheless, very few studies have examined the relationship between direct CVP and ultrasound-guided assessments of the IJV and IVC caliber in determining volume status in sick patients.

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Therefore, we here examined the strength of the association between direct CVP and ultrasound–guided measurement of IVC and IJV collapsibility index for intravascular volume assessment in critically ill patients.

Materials and Methods

With the Institute Ethical Committee approval (1984/IEC/IGIMS/2020) and CTRI registration (CTRI/2022/10/046566), the prospective observational study was carried out between October 2022 and April 2023.

Before procedures, written and informed consent was obtained from concerned relatives of critically ill patients. The data was recorded for educational and research purposes. The study procedures followed the guidelines of the World Medical Association and adhered to the principles of the Helsinki Declaration, 2013.

Critically ill patients ≥18 years of age, and in whom central venous catheter insertion was required were included in the study. Patients on ventilator support, history of neck or thoracic surgery or radiation therapy, severe tricuspid regurgitation, pulmonary hypertension, past or active deep vein thrombosis in the upper extremities, severe respiratory distress and morbidly obese patients were excluded from the study.

Either the IJV or subclavian vein was catheterized to record the CVP with the help of a transducer leveled with the phlebostatic axis at the mid-axillary line.

An intensivist trained in bedside ultrasonography recorded the right IJV maximum and minimum anteroposterior (AP diameter), and cross-sectional area (CSA) at 0° supine and 30° head up position and their corresponding collapsibility index (CI) was calculated by using the formula given as:

Collapsibility index (CI) = Maximum diameter, or CSA minus minimum diameter, or CSA/maximum diameter, or CSA × 100%.

Likewise, the maximum and minimum AP diameters and cross-sectional area of IVC were measured, at the subxiphoid area, and their corresponding CI was deduced. Patient baseline clinical characteristics, CVP, IJV, and IVC parameters were all part of the data collection. All measurements and data were entered in data collection sheets for statistical analysis.

Statistical Analysis

All of the patients' demographic and other clinical variables were compiled using descriptive statistics. Categorical and continuous variables were represented as frequency (percentage) and mean ± SD. The IJV and IVC diameters were measured using bedside ultrasound and compared to the CVP. The rank correlation coefficients (CI) of Pearson and Spearman were used to analyze the relationship between CVP and the collapsibility index of IJV and IVC. Fisher's exact tests or Chi-square tests were used for qualitative variables. The quantitative data for two independent groups (CVP ≤ 10 and CVP > 10) were calculated by unpaired *t*-test. A two-sided *p*-value of 0.05 was regarded as statistically significant. The Statistical Package for the Social Sciences 26.0 (SPSS Inc, Chicago, IL, USA) was used to analyze all data.

Results

About 60 out of 70 patients enrolled were analyzed .10 patients were excluded as depicted in Figure 1. The patient's baseline clinical characteristics were comparable as shown in Table 1 and were found to be statistically insignificant ($p > 0.05$). The mean CVP was 9.33 mm Hg.

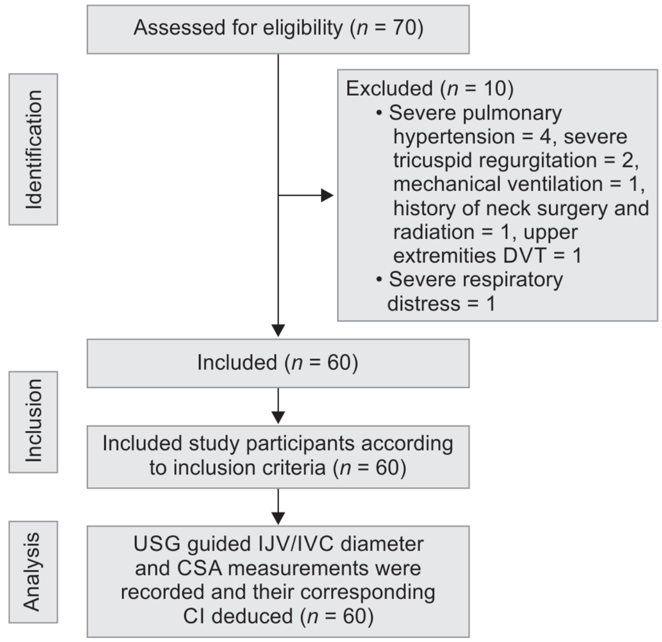

Fig. 1: Strobe flowchart

CI, collapsibility index; CSA, cross-sectional area; CVP, central venous pressure; IJV, internal jugular vein; IVC, inferior vena cava; USG, ultrasonography

Table 1: Comparison of the baseline parameters between two groups of CVP

	CVP ≤ 10 (n = 41) Mean ± SD	*CVP > 10 (n = 19) Mean ± SD*	*p-value*
Age (years)	51.21 ± 10.32	50.89 ± 12.65	0.940
Sex, Male/Female	27/14	10/9	0.318
BMI (kg/m^2)	23.14 ± 1.35	23.27 ± 2.05	0.823
MAP	84.90 ± 15.64	91.26 ± 5.10	0.09
HR	92.90 ± 17.21	100.63 ± 5.99	0.06

BMI, body mass index; CVP, central venous pressure; HR, heart rate; MAP, mean arterial pressure

At 0° supine position, the correlation between CVP and collapsibility index of right IJV was [$r = -0.107$ ($p = 0.001$)] for CSA. For the AP diameter of the right IJV, it was [$r = -0.092$ ($p = 0.001$)] (Table 2 and Figures 2 and 3). However, at 30° head-up position, the relation between CVP and IJV-CI was [$r = -0.109$ ($p = 0.001$)] and [$r = -0.117$, ($p = 0.001$)] for CSA and AP diameter of right IJV respectively. For CSA of IVC, the CI with CVP was [$r = -0.503$ ($p = 0.001$)] while it was [$r = -0.452$, ($p = 0.001$)] for AP diameter of IVC as shown in Table 2 and Figures 4 to 7.

Inferior vena cava and right IJV diameter and cross-sectional area were compared with direct CVP between two groups (CVP ≤ 10 and CVP ≥ 10) as shown in Table 3. Admission diagnoses were shown in Table 4 where 16.2% of patients required vasopressor support.

Discussion

The findings of our study revealed a strong negative relation between direct CVP and the CI of both IJV and IVC obtained by

Table 2: Collapsibility index of IJV and IVC between two groups of CVP

Clinical parameters	*CVP ≤ 10 (n = 41) Mean ± SD*	*CVP > 10 (n = 19) Mean ± SD*	*p-value*	*Pearson's "r" correlation*
IJV AP diameter C.I. (Supine)	29.01 ± 16.14	10.98 ± 2.43	<0.001	–0.092
IJV CSA C.I. (Supine)	46.95 ± 21.02	16.11 ± 4.31	<0.001	–0.107
IJV AP diameter C.I. (30°)	31.83 ± 18.76	11.74 ± 2.41	<0.001	–0.117
IJV CSA C.I. (30°)	50.14 ± 22.75	22.00 ± 4.36	<0.001	–0.109
IVC AP diameter C.I. (Supine)	64.60 ± 14.45	7.76 ± 1.78	<0.001	–0.452
IVC CSA C.I. (Supine)	85.36 ± 12.05	14.84 ± 3.23	<0.001	–0.503

AP, antero-posterior; C.I, collapsibility index; CSA, cross-sectional area; CVP, central venous pressure; IJV, internal jugular vein; IVC, inferior vena cava

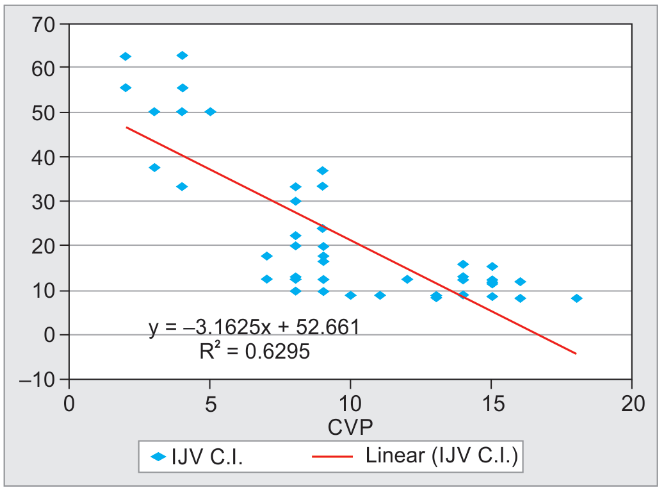

Fig. 2: Comparison of CVP vs IJV AP diameter C.I. (Supine)

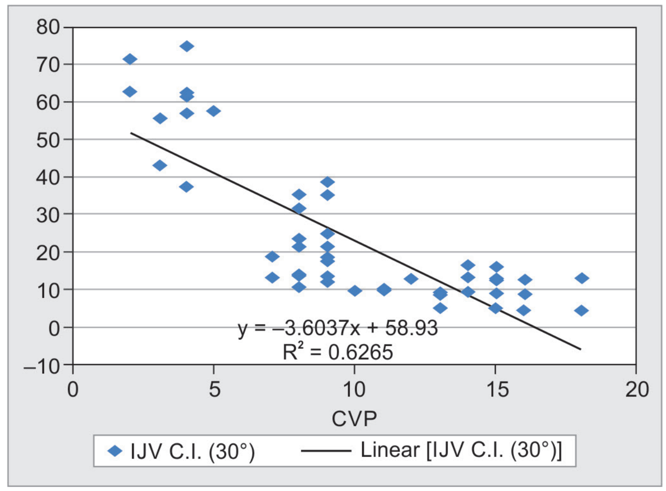

Fig. 4: Comparison of CVP vs IJV AP diameter C.I. (30°)

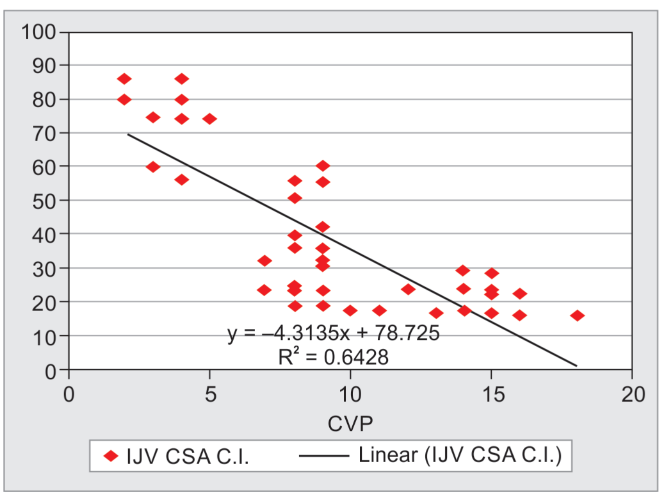

Fig. 3: Comparison of CVP vs IJV CSA C.I. (Supine)

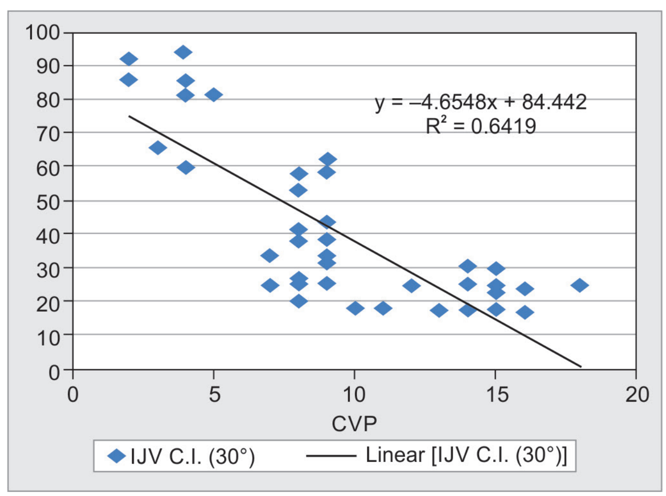

Fig. 5: Comparison of CVP vs IJV CSA C.I. (30°)

bedside ultrasonography for assessing the volume status of sick patients. However, a strong correlation was observed between CVP and IVC-CI.

In a similar study, Jassim et al.[13] demonstrated a mean value of IVC collapsibility index [37.10 (±19.86)] for CVP ≤ 10 mm Hg. At the 30° body position for CVP ≤10, the mean value of collapsibility index concerning cross-sectional area and AP diameter of right IJV were 40.78 (±20.75) and 26.97 (±16.45) respectively whereas at 0° supine position the mean value of collapsibility index concerning cross-sectional area and AP diameter of right IJV were 26.4 ± 16.45 and 20.00 ± 16.58 respectively.

The CI between direct CVP and IVC was [r = –0.503 (p = 0.001)] in our finding, which was similar to Jassim et al. [r = –0.540 (p = 0.001)].

The CI between direct CVP and IJV at the supine position was [r = –0.107 (p = 0.001)] for cross-sectional area and [r = –0.092, (p = 0.001)] for diameter, whereas the corresponding values in Jassim et al. finding were [–0.484 (p = 0.0001)] and [–0.416 (p = 0.001)] respectively.

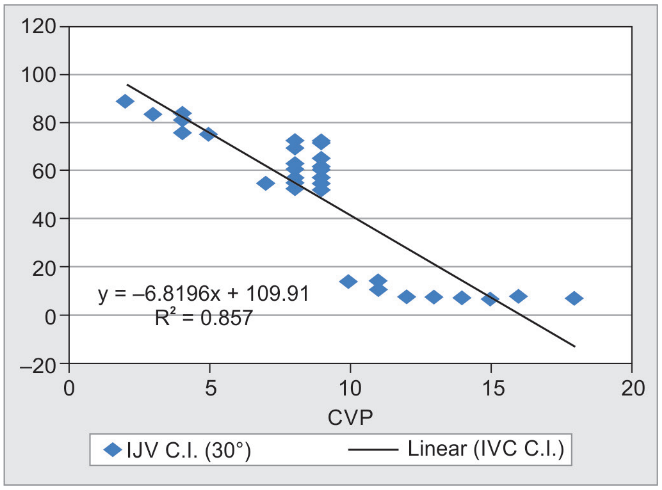

Fig. 6: Comparison of CVP vs IVC AP diameter C.I. (Supine)

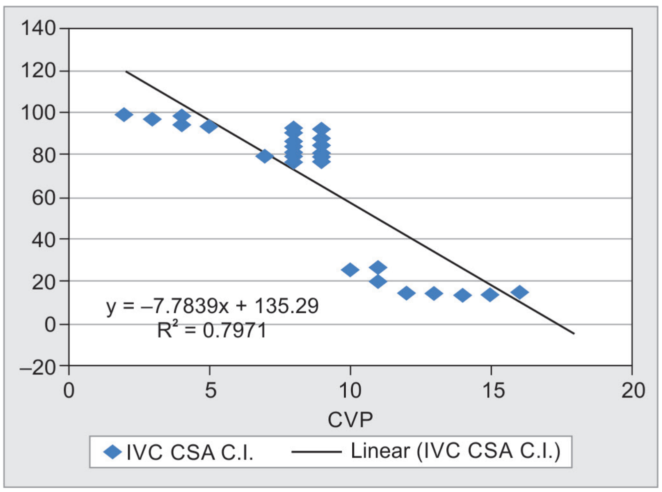

Fig. 7: Comparison of CVP vs IVC CSA C.I. (Supine)

The relation between direct CVP and IJV-CI at the 30° position, were [$r = -0.109$ ($p = 0.001$)] and [$r = -0.117$ ($p = 0.001$)] for the cross-sectional area and AP diameter respectively whereas the corresponding values were [$r = -0.583$ ($p = 0.0001$)] and [$r = -0.559$ ($p = 0.0001$)] respectively in Jassim et al. study.

Ciozda et al. in a systematic review found fair correlations between direct CVP and IVC collapsibility index, though there were differences in IVC measurement timing concerning the respiratory cycle.[14]

Another study by AlaviMoghaddam et al.[15] found a moderate correlation between IVC-CI and direct CVP ($r = 0.54$), which was similar to our findings. However, their CI for minimum and maximum IVC diameter was not statistically significant [$r = 0.60$ ($p = 0.6$) and $r = 0.44$ ($p = 0.14$)]. However, in our study, the CI *for maximum* IVC diameter and minimum IVC diameter were statistically significant [($r = 0.424$, $p = 0.001$)].

At 30° body position, the correlation between IJV and CVP for the minimum CSA ($r = 0.131$, $p = 0.001$) and the maximum CSA of IJV ($r = 0.048$, $p = 0.001$) was statistically significant. Also, the correlation between direct CVP and IJV for the minimum diameter ($r = 0.128$, $p = 0.001$) and the maximum diameter ($r = 0.065$, $p = 0.001$) was statistically significant in our study.

Donahue et al.[16] measured CSA of the IJV at endexpiration and endinspiration at 35° body position and its relation with direct CVP was $r = 0.67$ and $r = 0.41$, respectively. Similarly, a correlation for endexpiratory and endinspiratory IJV diameter with CVP was $r = 0.63$ and $r = 0.44$. However, in our study, the correlation between minimum CSA of right IJV and CVP at the supine position was significant ($r = 0.187$, $p = 0.001$).

Another similar study by Avcil et al.[17] observed a significant correlation between the cross-sectional area of the IJV and the CVP [$r = 0.495$ ($p < 0.001$)] but the timing of the respiratory phase was not defined.

Donahue et al. observed no difference in the CI ($r = 0.69$) both at end-expiratory and end-inspiratory IJV diameter with CVP while in our study there was a statistically significant and higher association with the IJV minimum AP diameter ($r = 0.175$, $p = 0.001$). However,

Table 3: Diameter and cross-sectional area of IJV and IVC between two groups of CVP

Clinical parameters	*CVP ≤ 10 (n = 41) Mean ± SD*	*CVP > 10 (n = 19) Mean ± SD*	*p-value*	*Pearson's "r" correlation*
IJV maximum (Supine)	1.43 ± 0.511	2.37 ± 0.127	<0.001	–0.064
IJV maximum (Supine)	1.18 ± 0.503	2.11 ± 0.089	<0.001	–0.175
IJV AP diameter (Supine)	1.38 ± 0.483	2.24 ± 0.104	<0.001	–0.116
IJV CSA maximum (Supine)	2.15 ± 1.06	4.46 ± 0.477	<0.001	–0.048
IJV CSA minimum (Supine)	1.30 ± 0.822	3.52 ± 0.300	<0.001	–0.187
IJV CSA (Supine)	1.69 ± 0.930	3.97 ± 0.373	<0.001	–0.110
IJV maximum (30°)	1.48 ± 0.472	2.27 ± 0.127	<0.001	–0.065
IJV minimum (30°)	1.08 ± 0.501	2.01 ± 0.087	<0.001	–0.128
IJV AP diameter (30°)	1.28 ± 0.481	2.13 ± 0.117	<0.001	0.003
IJV CSA maximum (30°)	1.90 ± 0.984	4.09 ± 0.459	<0.001	–0.048
IJV CSA minimum (30°)	1.11 ± 0.738	3.18 ± 0.275	<0.001	–0.131
IJV CSA (30°)	1.47 ± 0.846	3.58 ± 0.394	<0.001	0.013
IVC maximum (Supine)	1.85 ± 0.587	2.78 ± 0.132	<0.001	–0.264
IVC minimum (Supine)	0.726 ± 0.444	2.57 ± 0.140	<0.001	–0.424
IVC AP diameter (Supine)	1.29 ± 0.498	2.68 ± 0.134	<0.001	–0.343

(Contd...)

Table 3: *(Contd...)*

Clinical parameters	*CVP ≤ 10 (n = 41) Mean ± SD*	*CVP > 10 (n = 19) Mean ± SD*	*p-value*	*Pearson's "r" correlation*
IVC CSA maximum (Supine)	2.97 ± 1.50	6.12 ± 0.581	<0.001	−0.272
IVC CSA minimum (Supine)	0.566 ± 0.762	5.22 ± 0.570	<0.001	−0.440
IVC CSA (Supine)	1.51 ± 1.01	5.66 ± 0.569	<0.001	−0.358

AP, antero-posterior; C.I., correlation coefficient; CSA, cross-sectional area; CVP, central venous pressure; IJV, internal jugular vein; IVC, inferior vena cava

Table 4: Diagnosis on admission

Diagnosis	*Numbers*
Acute pancreatitis	8
COPD	8
Asthma	2
Septic shock	9
Lobar pneumonia	3
Acute kidney injury/CKD	12
MI	7
Burn	1
Liver cirrhosis	6
SIADH	1
Cerebral infarct	2
Diabetic keto acidosis	1

the correlation between the maximum and minimum AP diameter of IJV with direct CVP was [$r = 0.53$, ($p < 0.001$)] and [0.54, ($p < 0.001$)] respectively in our study.

Limitation

The primary drawbacks of our study are the small sample size and the exclusion of patients undergoing surgery or trauma, as well as those on mechanical ventilation. Only critically ill, non-surgical, and non-traumatic subjects were among our patients. Nonetheless, we believe that trauma patients in the emergency department could benefit from our findings. A study is warranted to determine whether patients on mechanical ventilation would get comparable results.

Conclusion

Bedside ultrasonographic measurements of the collapsibility indices of the IVC and IJV are a valuable non-invasive method for determining indirect CVP and evaluating the intravascular volume status of critically ill patients. In patients where IVCs are inaccessible, IJV parameters could provide useful information regarding volume status.

Ethical Approval

CTRI Registration: CTRI/2022/10/046566.
Institutional Ethics Committee (IEC) No. 1984/IEC/IGIMS/2020.

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