Original Article

Diagnostic Accuracy of Internal Jugular Vein Collapsibility Index For The Diagnosis of Hypovolemia In Intensive Care Unit Patients

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Abstract

Objective: To determine the diagnostic accuracy of the internal jugular vein collapsibility index for the diagnosis of hypovolaemia in intensive care unit patients using central venous pressure as the gold standard.

Method: This cross-sectional validation study was conducted at the Department of Anesthesiology, Benazir Bhutto Hospital. IJV-CI was calculated as the percentage reduction in vein diameter from expiration to inspiration in the supine, 30° head-up position. Hypovolemia was defined as a CVP of < 8 mmHg.

Results: Of the 150 participants, 46.7% (n=70) were hypovolemic according to the CVP criteria. IJV-CI had a sensitivity of 52.9%, specificity of 85.0%, positive predictive value (PPV) of 75.5%, negative predictive value (NPV) of 67.3%, and accuracy of 70.0%. The mean IJV-CI was higher in hypovolemic patients than in non-hypovolemic patients (40.8% vs. 29.1%; $p < 0.001$). The Area Under the Curve (AUC) was 0.783.

Conclusion: IJV-CI is a useful noninvasive tool for detecting hypovolaemia in ICU patients, demonstrating good overall discriminative power.

Keywords: Hypovolemia; Central Venous Pressure; Jugular Veins; Ultrasonography; Intensive Care Units; Sensitivity and Specificity; Hemodynamics.

Introduction

The internal jugular vein collapsibility index (JVCI) is a diagnostic tool that uses ultrasound to assess hypovolemia.[1] Hypovolaemia is a state of decreased intravascular volume, which reduces venous return and central venous pressure. By evaluating the collapsibility index of the internal jugular vein, we can gain insights into the patient's fluid status.[2-4]

Hypovolaemia decreases the diameter of the internal jugular vein and increases collapsibility on ultrasound. These sonographic findings are markers of reduced intravascular volume. Similarly, euvolemia or hypervolemia (where fluid levels are within normal or elevated ranges) in the internal jugular vein shows greater dilation and reduced collapsibility.[5]

It should be emphasised that although the internal jugular vein collapsibility index found by ultrasound can support the diagnosis of hypovolaemia, it is usually used in combination with thorough clinical evaluations that include vital signs, laboratory results, physical examination findings, and the patient's medical history.

Ultimately, diagnosing hypovolaemia requires a comprehensive assessment that incorporates a variety of diagnostic techniques and wise clinical judgement by medical specialists.[5,6]

A study by Killu et al. 6 showed that the prevalence of hypovolaemia in intensive care unit (ICU) patients was 31%. When compared to the gold standard for measuring Central Venous Pressure (CVP), they found a sensitivity of 87% and a specificity of 100% for the Internal Jugular Vein collapsibility index in detecting hypovolaemia in ICU patients.

Contributions:
MZ AZ - Conception, Design
MZ TZ WA KA HS - Acquisition, Analysis, Interpretation
MZ TZ WA KA HS - Drafting
AZ MZ TZ WA KA HS - Critical Review

All authors approved the final version to be published & agreed to be accountable for all aspects of the work.

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Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Materials And Methods

The Department of Anaesthesiology and Intensive Care at Benazir Bhutto Hospital in Rawalpindi, a tertiary care facility connected to Rawalpindi Medical University, was the site of this validation study after receiving approval from the College of Physicians and Surgeons Pakistan (CPSP/REU/ANS-2023-126-3183) and Rawalpindi Medical University ethics committee (reference number: 401/IREF/RMU/2025). Using central venous pressure (CVP) measurement as the gold standard, this study aimed to ascertain the diagnostic accuracy of the Internal Jugular Vein Collapsibility Index (IJV-CI) for identifying hypovolaemia in intensive care unit (ICU) patients.

The reporting of this observational study of diagnostic accuracy was conducted in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines. A sample size of 150 patients was calculated based on a reported hypovolaemia prevalence of 31%, expected sensitivity of 87%, specificity of 100%, precision of 10%, and 95% confidence level [6]. Participants were recruited through non-probability consecutive sampling. Adults aged 18–75 years admitted to the Intensive Care Unit (ICU) with clinical suspicion of hypovolaemia and signs of haemodynamic instability (tachycardia, hypotension, altered mental status, oliguria, or elevated lactate levels) were included. Patients who were pregnant, had cardiac tamponade, had structural or pathological abnormalities of the internal jugular vein, had contraindications to ultrasound, had severe respiratory distress, had undergone recent neck surgery or trauma, had limited life expectancy, had do-not-resuscitate (DNR) status, refused to consent, had extreme clinical instability, or were undergoing active fluid resuscitation at the time of assessment were excluded.

After obtaining informed consent, the demographic data were recorded, and an ultrasound examination of the internal jugular vein was performed using a portable ultrasound machine with a high-frequency linear probe. To prevent measurement bias, the sonographers performing the internal jugular vein ultrasound were blinded to the simultaneous CVP measurements. All collected data points were complete; therefore, no specific handling of missing data was required. The patients were positioned supine, and their heads were elevated at 30 °. The vein was imaged in a transverse or longitudinal view to obtain the maximum inspiratory and minimum expiratory diameters, from which the IJV-CI was calculated as the percentage reduction during inspiration. As per the cutoff by Killu et al., 39% was taken as the cutoff for the definition of hypovolaemia [6]. CVP was measured simultaneously using a central venous catheter inserted via the internal jugular vein and connected to a pressure transducer. A value of less than 8 mmHg was considered diagnostic of hypovolaemia.

Data were analysed using SPSS version 22, with means and standard deviations calculated for quantitative variables such as age and BMI, and frequencies and percentages for categorical variables such as sex. A 2×2 contingency table was constructed to determine sensitivity, specificity, positive and negative predictive values, and overall accuracy, with ROC curves generated to evaluate the discriminatory ability of IJV-CI; effect modifiers, including age and BMI, were stratified, and post-stratification diagnostic accuracy was calculated.

Results

A total of 150 patients were included, with a mean age of 47.3 years (SD 15.9, range 18–75) and a mean BMI of 27.1 kg/m² (SD 7.2). Males constituted 61.3% (n=92) and females 38.6% (n=58) of the patients. The mean maximum IJV diameter (D*max*) was 12.9 mm (SD 2.8), and the mean minimum diameter (D*min*) was 8.5 mm (SD 2.7). The average IJV collapsibility index (IJV-CI) across all patients was 34.0% (SD 15.0). The mean central venous pressure (CVP) was 8.3 mmHg (SD 3.1).

Of the 70 patients with hypovolaemia as indicated by CVP, 37 were accurately identified by IJV-CI (true positives), whereas 33 were overlooked (false negatives), according to the corresponding confusion matrix. Twelve patients were mistakenly classified as hypovolemic (false positives), whereas 68 of the 80 patients who were not hypovolemic were correctly identified as such (true negatives).According to this distribution, the 39% cutoff had a higher specificity than sensitivity, indicating that it was more likely to confirm hypovolaemia when it was present than to rule it out when it was not.

The diagnostic performance of the index was modest compared to the gold-standard CVP measurement using the 39% IJV-CI cutoff. With a sensitivity of 52.9% (95% CI: 0.413 to 0.641), the IJV-CI accurately identified more than half of the patients with hypovolaemia (CVP < 8 mmHg). On the other hand, the high specificity (85.0%, 95% CI: 0.756 to 0.912) showed that this cutoff accurately excluded the majority of non-hypovolemic patients. The positive predictive value (PPV) was 75.5% (95% CI: 0.619–0.854). The percentage of all correctly classified cases was 70.0% (95% CI:0.622 to 0.768), with a negative predictive value (NPV) of 67.3% (95% CI: 0.577 to 0.757).

Table 1 shows that 70/150 (46.7%) patients were hypovolemic and 80/150 (53.3%) were non-hypovolemic according to the gold standard (CVP < 8 mmHg). The IJV-CI for the hypovolemic group was significantly higher (40.8 ± 12.1%)

than that for the non-hypovolemic group (29.1 ± 10.6%; $p < 0.001$). As anticipated, CVP was significantly lower in hypovolaemia (6.4 ± 1.1 mmHg) than in non- hypovolaemia (10.1 ± 1.4 mmHg; $p < 0.001$). There were no significant differences in BMI (p = 0.766) or age (p = 0.114) between the groups.

Table 1: Comparison of Hypovolemic versus Non-hypovolemic Patients

Variable	Hypovolemia (n=70)	Non-hypovolemia (n=80)	p-value
IJV-CI (%)	39.8 ± 8.4	29.1 ± 10.6	<0.0001
CVP (mmHg)	6.4 ± 1.1	10.1 ± 1.4	<0.0001
Age (years)	49.6 ± 15.8	45.5 ± 15.9	0.114
BMI (kg/m²)	27.3 ± 7.3	27.0 ± 7.2	0.766

Receiver operating characteristic (ROC) curve analysis was used to evaluate the discriminative power of IJV-CI in more detail. With an area under the ROC curve (AUC) of 0.783, the IJV- CI showed a diagnostic performance that was within the "good" range. This suggests that the IJV-CI correctly ranked hypovolemic and non-hypovolemic patients in almost 78% of cases. The ideal threshold for IJV-CI was determined using the Youden index, which weighs sensitivity and specificity, to be 33.3%, which is marginally less than the traditional 39% cutoff. The sensitivity increased to 82.9% at this optimal threshold, which shows that most of the hypovolemic. Patients were accurately identified. This led to a higher number of false positives, which decreased the specificity to 65%. This is shown in Figure 1.

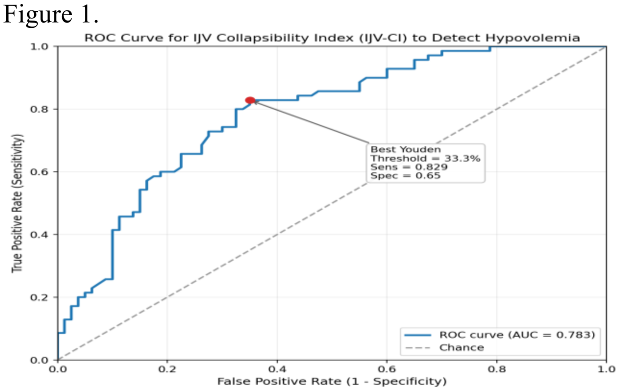

Figure 1: ROC and Youden Index

Subgroup Analysis

A subgroup analysis was performed to determine the performance of IJV-CI's CI in various age and BMI groups. The cutoff value was set at 39%. Analysis by age showed that younger patients had higher diagnostic accuracy. In patients aged ≤40 years (n=50), the IJV-CI had an accuracy, sensitivity, and specificity of 76.0%, 61.9%, and 86.2%, respectively. In contrast, among patients over 40 years of age (n=100), the sensitivity decreased to 49.0%, and the specificity remained constant at 84.3%, leading to a lower overall accuracy of 67.0%. These results indicate that the index performs better in younger patients because of their higher sensitivity (Table 2).

Table 2: Post-stratification of Age Groups

BMI Group	n	TP	TN	FP	FN	Sensitivity	Specificity	PPV	NPV	Accuracy
<25	63	19	28	7	9	0.679	0.8	0.731	0.757	0.746
>=25	87	18	40	5	24	0.429	0.889	0.783	0.625	0.667

Stratification by BMI showed similar results. The IJV-CI had an accuracy of 74.6% in patients with a BMI <25 kg/m² (n=63), with a sensitivity of 67.9% and a specificity of 80.0%. In contrast, for individuals with a BMI of ≥25 kg/m² (n=87), the sensitivity decreased to 42.9%, and the specificity increased to 88.9%, with an accuracy of 66.7%. This implies that while the index maintains high specificity in overweight or obese patients, its sensitivity decreases, resulting in a greater number of false negatives (Table 3).

Table 3: Post-stratification of BMI

BMI Group	n	TP	TN	FP	FN	Sensitivity	Specificity	PPV	NPV	Accuracy
<25	63	19	28	7	9	0.679	0.8	0.731	0.757	0.746
>=25	87	18	40	5	24	0.429	0.889	0.783	0.625	0.667

Discussion

The present study found a modest use of IJV CI, and our findings are different from those of the original study by Killu et al., who reported a higher sensitivity (87.5%) and a specificity of 100%.[6] This difference could be because our patients were different, and our ICU settings were more varied. Our study included a wider mix of ICU patients with varying degrees of hypovolaemia, which we believe is a more realistic picture of everyday clinical practice.

Compared to a large meta-analysis by Wang et al.,[7] our results fall on the lower end of the spectrum. They found that IJV ultrasound had a sensitivity and specificity of 82%. The cutoff of 39% missed cases; therefore, our analysis suggests that an optimal cutoff might be 33.3%. At this lower 33.3% cutoff, sensitivity improved to 82.9%, and we may be able to detect more patients with hypovolaemia. However, the specificity drops to 65.0%, which means we may incorrectly flag more patients who have normal fluid levels. This cutoff is better when the risk of missing hypovolaemia is high and can lead to systemic consequences.

A higher cutoff of 39% is preferred when the judicious use of fluids is prioritised. Although we used CVP as our reference standard, it is known to be a poor predictor of a patient's fluid status. A landmark review by Marik et al.,[8] showed that there is a minimal correlation between CVP and actual blood volume. They also concluded that it cannot reliably predict whether a patient will improve with fluid resuscitation.

We found that both age and body weight influenced its utility. The test performed better in younger patients (≤40 years old). The accuracy dropped from 76.0% to 67.0% in patients over 40 years of age. This could be due to age-related changes in venous stiffness or due to other health conditions in older adults.[9] We observed a similar pattern in body weight. The test was more accurate in patients with a lower BMI (<25 kg/m²). In overweight or obese patients, the sensitivity decreased from 67.9% to 42.9%. This suggests that excess body fat makes it harder to obtain a good ultrasound reading or might change how the vein collapses. This is a crucial point, as obesity is common in the ICU.[10].

Finally, it's important to remember that the IJV-CI is just one tool for assessing fluid status. Other methods like Pulse Pressure Variation (PPV) and Stroke Volume Variation (SVV) are excellent predictors of fluid responsiveness.[11],[12] IJV-CI is the only tool for assessing fluid status. Other methods, such as Pulse Pressure Variation (PPV) and Stroke Volume Variation (SVV), are also excellent predictors of fluid responsiveness. However, these methods require an invasive arterial line.[13]

Despite its limitations, IJV CI is a non-invasive, quick, and readily available alternative that can provide valuable information, especially when its limitations regarding age and BMI are addressed. Despite its drawbacks, IJV-CI is a valuable point-of-care tool. It is quick, repeatable, non-invasive, and does not require any special training beyond the fundamentals of ultrasound. IJV-CI may provide useful additional data for fluid status assessment in situations with limited resources or when central venous catheterisation is not recommended. IJV assessment is more technically feasible than IVC assessment; studies have shown that IJV imaging is successful in all patients, whereas IVC visualisation failure rates range from 10% to 20% .[14]However, our results do not imply that IJV-CI should be used as the only foundation for fluid management decisions or as a substitute for a thorough clinical evaluation. Rather, it should be combined with other clinical parameters, such as vital signs, lactate levels, urine output, physical examination results, and, if available, dynamic fluid responsiveness measures. Clinical context and patient characteristics should be considered when choosing between the 39% and 33% cutoffs.

Clinicians should be particularly cautious when interpreting IJV-CI in older patients and those with an elevated BMI, as the sensitivity is significantly reduced in these populations. In such cases, alternative or complementary methods of volume status assessment should be considered. The integration of IJV-CI with physical examination has been shown to improve diagnostic accuracy; for example, combining IJV ultrasound with physical examination improved the combined specificity to 97% for predicting elevated right atrial pressure.[15-17] Another important point is that the collapsibility of other veins, such as the subclavian or inferior vena cava, can be added as an adjunct to measure the haemodynamic status.[18] The hepatic and portal veins can be assessed, too. [19,20]

This study has a few limitations to take into account. First, we employed CVP as the gold standard, which is not an accurate representation of intravascular volume status and fluid responsiveness. Second, we used consecutive sampling and a single-centre design, which restricts the generalisability of the study. The high prevalence of hypovolaemia in our cohort (46.7%) may have affected our estimates of diagnostic accuracy and limited the application to populations with varying disease prevalence. Lastly, ultrasound measurements are operator-dependent, and, significantly, inter-observer variability was not evaluated in this study. Future studies should address these limitations.

Conclusions

Using the traditional 39% threshold, the Internal Jugular Vein Collapsibility index showed suboptimal sensitivity (52.9%) but good discriminative ability (AUC 0.783) for detecting hypovolaemia in ICU patients. Although it has potential as a non-invasive bedside assessment tool, age and body mass index affect its clinical usefulness; older patients and those with a higher BMI have much lower sensitivity. Instead of being used as a stand-alone diagnostic test, IJV-CI should be interpreted in conjunction with a thorough clinical evaluation. The clinical context and relative risks of false-positive versus false-negative results should be considered when choosing a threshold (39% for higher specificity versus 33% for higher sensitivity).

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