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ORIGINAL ARTICLE

Internal jugular vein collapsibility index associated with hypovolemia in the intensive care unit patients

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Abstract

Objective To evaluate the correlation between the internal jugular vein (IJV) collapsibility index and hypovolemia in intensive care unit (ICU) patients, using point of care ultrasound imaging.

Methods A prospective observational study was conducted in an urban tertiary care teaching hospital, in the surgical ICU. Intensivist point-of-care sonographers performed IJV ultrasound on 31 ICU patients who were diagnosed to be hypovolemic or euvolemic by their treating ICU physicians.

Results Hypovolemic ICU patients (16 of 31) were 50% male and 75% white with a mean age of 63 (±19) years. The variables measured between the hypovolemic and euvolemic ICU patients were the mean arterial pressure, heart rate, respiratory rate, central venous pressure (CVP). Their correlation with hypovolemia was significant ($p < 0.05$). The ROC curve analysis found the IJV collapsibility index ≥39% correlated best with hypovolemic ICU patient with a sensitivity of 87.5% and specificity 100%. The area under ROC curve for IJV collapsibility index was 0.938, with no significant difference to CVP with the area under ROC curve of 0.87 ($p = 0.467$).

Conclusion IJV collapsibility index can be identified by intensivist point-of-care sonographers in the hypovolemic and euvolemic ICU patients. The presence of IJV collapsibility index greater than 39% may be associated with hypovolemia in ICU patients.

Keywords Ultrasound · Internal jugular vein · Collapsibility · Index · Hypovolemia

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Background

Assessment of intravascular volume status and hypovolemia can be challenging at times, especially when relying on physical examination and physiologic data in ICU patients [1, 2, 4]. Bedside echocardiography can estimate central venous pressure (CVP) based on evaluation of the inferior vena cava (IVC) distention and respiratory variation [4, 6]. This can sometimes be limited by equipment availability, ultrasound expertise and the inability to view the IVC [4, 6]. The current standard for measuring the right-sided filling pressures and CVP requires an invasive central venous catheter, which can delay intravascular resuscitation and be associated with possible iatrogenic complications [7].

Point of care ultrasound imaging technique of the IJV has been proposed for the evaluation of the CVP [3, 5]. Lipton [5] describes estimating CVP by identifying the ultrasound pattern of the jugular venous pulsation. Keller et al. [1] discussed the correlation of IJV aspect ratio (height/width) to estimate a CVP of 8 mmHg in spontaneously breathing patients. The measurement of end-expiratory IJV diameter in spontaneously breathing supine patient has shown high correlation with CVP [2]. In this study, we evaluated ICU patients who were euvolemic, hypovolemic, spontaneously breathing or on mechanical ventilation and with or without vasopressor support.

We hypothesize that point of care ultrasound imaging of IJV collapsibility index would be associated and correlate with hypovolemia in ICU patients.

Methods

This prospective, observational study was performed in the surgical ICU of an urban tertiary care teaching hospital. The study was approved by the Institutional Review Boards of Henry Ford Hospital and informed consent was obtained from all persons or their next of kin prior to their inclusion in the study. Convenience samples of 31 patients were included in the study. Recruitment was based on the presenting symptoms that led the treating ICU physicians to decide if the patient's volume status was hypovolemic or euvolemic. This diagnosis and criteria used for volume assessment was based on objective data and the clinical assessment by the treating ICU physician, as heart rate, blood pressure, respiratory rate, as well as invasive monitoring with CVP measurements. The diagnosis and assessment of the treating ICU physician was considered the reference. All enrolled patients had their right or left IJV scanned and measured by one of two intensivist point-of-care sonographers experienced in point-of-care ultrasound. The intensivist point-of-care sonographers were not involved in the medical management of these ICU patients, but were not blinded to the volume status of the patients studied. Inclusion criteria included age of 18 years or older, admission to the surgical ICU and volume assessment determined as hypovolemia or euvolemia by the treating ICU physician. Exclusion criteria were inability to image IJV secondary to a cervical collar, surgical dressing or inability for the patient to be properly positioned. The IJV with a central venous catheter was not examined rather the opposite side was evaluated if no contraindications. No patients were excluded once enrolled and measurements were completed.

Ultrasound measurements were done using a linear transducer 7–10 MHz of the GE LOGIQ e (Wauwatosa, WI), or a linear transducer 14 MHz of the Zonare One Ultra convertible system (Silicon Valley, CA). The IJV was measured using the B mode and/or the M mode. The prescribed measurement technique (Table 1) was followed to determine the IJV anterior–posterior (AP) diameter during a respiratory cycle (Fig. 1). The IJV collapsibility index was calculated as IJV maximal AP diameter during expiration minus IJV maximal AP diameter during inspiration divided by the maximal AP diameter during expiration (Table 1). This relation was reversed in mechanically ventilated patients.

Statistical analysis

Primary data analysis used included Chi-squared analysis for binary variables and nonparametric Mann–Whitney test for continuous variables. p value < 0.05 was considered statistically significant. Logistic regression model adjusted for the association of the predicted variables in hypovolemia. ROC curve was done for those variables with statistically significant association with hypovolemia.

Results

We evaluated 31 patients admitted to the surgical ICU. Their baseline characteristics are listed in Table 2. Six patients or 19% were on mechanical ventilation and positive end-expiratory pressure (PEEP), five in the hypovolemic group (31%) and one in the euvolemic group (7%). The indications and settings for mechanical ventilation were determined by the treating ICU physician. Four

Table 1 Protocol for measurement of internal jugular venous (IJV) collapsibility index

1. Position patient at 30° head elevation, as standard of care for mechanically ventilated patients, ensuring overall comfort
2. Rotate the head slightly <30° to expose right or left IJV
3. Place transducer transversely across the patient neck, the area lateral to the level of the cricoid cartilage
4. IJV vessel identification was done by identifying 2 vessels lateral to the trachea and IJV is identified by compressibility, color flow or pulse wave Doppler
5. Applying minimum pressure, enough to obtain adequate ultrasound image of the right/left IJV
6. Rotate the transducer clockwise or counter-clockwise to obtain the most circular cross-sectional image of the IJV
7. Store the image of the patient's complete respiratory cycle
8. Measure the AP diameter during maximum and minimum distention during a respiratory cycle. On occasion, M mode was used to determine max and min AP diameter
9. Calculate IJV collapsibility index = [(Max diameter − Min diameter)/(Max diameter)] × 100%

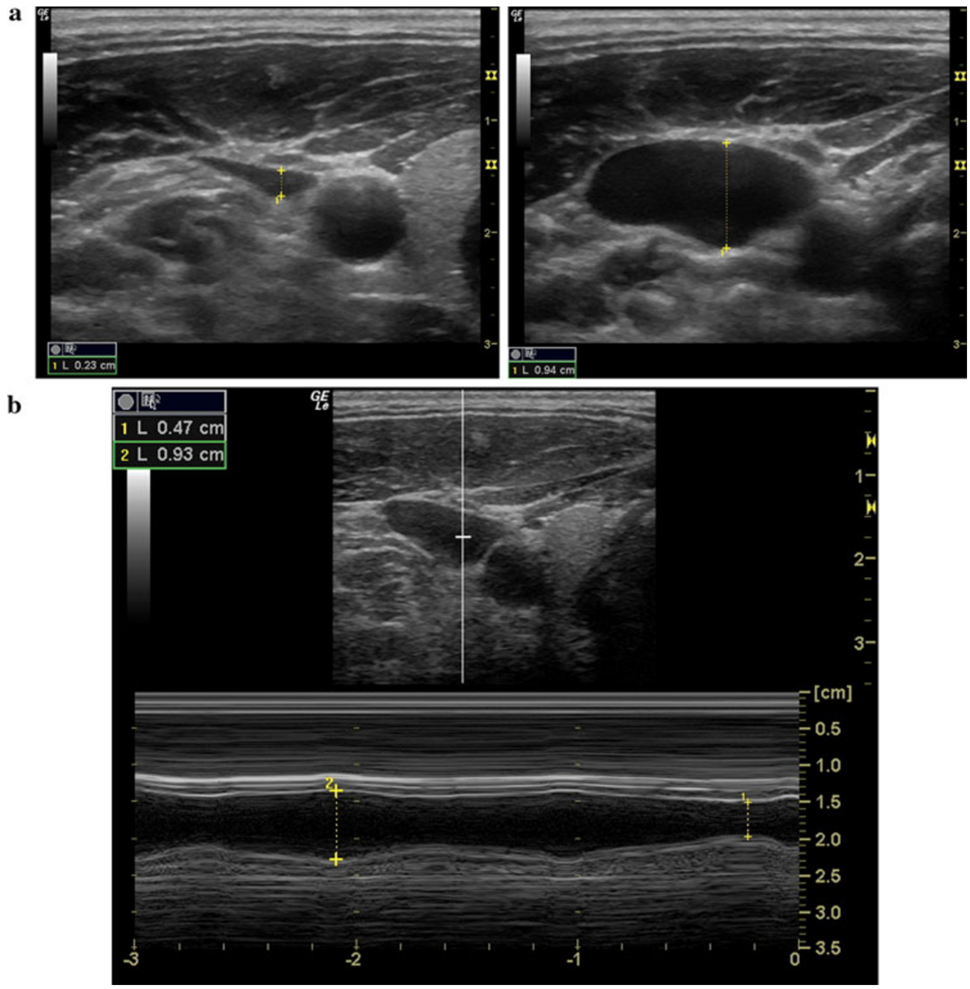

Fig. 1 **a**, **b** Ultrasound images of the internal jugular vein during respiratory cycle in B mode and M mode. **a** IJV collapsibility during respiratory cycle with minimum AP diameter (*right*) maximum AP diameter (*left*) measured in B mode. **b** IJV collapsibility during respiratory cycle with maximum and minimum AP diameter measured in M mode

patients or 13% of patients were on vasopressor support (two for each group). Sixteen patients (52%) were hypovolemic patients with a mean age of 63 (±19) years and weight of 77.7 (±17.5) kg. Fifteen patients or 48% were euvolemic patients, with a mean age of 59 years (±13) and weight of 82.1 kg (±21.8).

The hypovolemic patients were 50% male and 75% white. The baseline physiologic variables of the hypovolemic group were as follows: mean blood pressure 77 (±32) mmHg, heart rate 99 (±19) beats per minute, and respiratory rate 23 (±7) breaths per minute, and temperature 37.3°C (±0.8). Significant variables between the hypovolemic and euvolemic patients were the mean arterial pressure, heart rate, respiratory rate, CVP, and IJV collapsibility index (Table 2).

The logistic regression model for variables associated with hypovolemia showed that the following variables: heart rate, respiratory rate, systolic blood pressure, mean arterial pressure, CVP, and IJV collapsibility index were all significant ($p < 0.05$) (Table 3). The diagnosis of hypovolemia was established by the treating ICU physician and the logistic regression model was used to correlate the results. The ROC curve analysis found the best sensitivity of 87.5% and specificity of 100%, when IJV collapsibility index was ≥39%. In comparing the area under the ROC curve (AUC) for the IJV collapsibility index was 0.938 with no significant difference to the CVP AUC of 0.87 ($p = 0.467$) (Fig. 2).

Subset analysis of the five mechanically ventilated hypovolemic patients showed a mean IJV collapsibility index of 52.9% compared to the one euvolemic mechanically ventilated patient with an IJV collapsibility index of 21% ($p = 0.31$). All mechanically ventilated patients were on PEEP.

Discussion

Point-of-care ultrasound can identify the IJV collapsibility index, which can aid in determining the volume status in ICU patients. The IJV collapsibility index can be applied to most ICU patients including those with mechanical ventilation on PEEP or vasopressor support, which were not included in previous studies [1, 2].

Table 2 Baseline characteristics of euvolemic and hypovolemic patients

Variables	Hypovolemic ($n = 16$)	Euvolemic ($n = 15$)	*p* Value
Age (years)	62.6 (±19)	59.1 (±12.9)	0.406
Weight (kg)	77.7 (±17.5)	82.1 (±21.8)	0.707
Sex (male)	50%	53%	0.853
Race (white)	75%	60%	0.916
Temp (°C)	37.3 (±0.8)	36.8 (±0.3)	0.274
Heart rate (beats/min)	99 (±19)	84 (12)	0.03*
Resp rate (breaths/min)	23 (±7)	17 (±4)	0.019*
SBP (mmHg)	110 (±23)	133 (±23)	0.011*
DBP (mmHg)	61 (±15)	65 (±11)	0.268
MAP (mmHg)	77 (16)	88 (±13)	0.044*
Mechanical ventilation with PEEP	31%	7%	0.172
Vasopressor support	13%	13%	0.945
CVP (mmHg)	6 (±4.0)	13.1(±5.3)	0.001*
IJV collapsibility index	59.5%	23%	0.001*

Patient characteristics of demographics and hemodynamic variables upon enrollment

Proportions are presented as percentages (number of patients)

Values are mean ± SD or proportions presented as percentages

Non parametric Mann–Whitney test for continuous variables and Chi-squared test for binary variables

SBP systolic blood pressure, *DBP* diastolic blood pressure, *MAP* mean arterial pressure, *PEEP* positive end-expiratory pressure, *CVP* central venous pressure, *IJV* internal jugular vein

*$p < 0.05$ compared to Euvolemic Group

Table 3 Variables associated with hypovolemic patients

	OR (95% CI)	*p* Value
Heart rate (beats/min)	1.06 (1.01–1.12)	0.025
Resp. rate (breaths/min)	1.23 (1.03–1.47)	0.023
SBP (mmHg)	0.96 (0.92–0.99)	0.019
MAP (mmHg)	0.95 (0.90–1.00)	0.044
CVP (mmHg)	0.67 (0.47–0.95)	0.025
IJV Collapsibility Index	1.15 (1.05–1.27)	0.004

Logistic regression analysis of those statistically significant predictors for hypovolemia

Resp. rate respiratory rate, *SBP* systolic blood pressure, *MAP* mean arterial pressure, *CVP* central venous pressure, *IJV* internal jugular venous

On daily clinical rounds, intensivists depend on multiple adjunct physiologic and invasive monitoring parameters to aid in determining the volume status of the ICU patient. IJV collapsibility index can be used as an adjunct to physiologic parameter such as higher heart rate, higher respiratory rate, and lower systolic blood pressure and lower CVP found in hypovolemic patients.

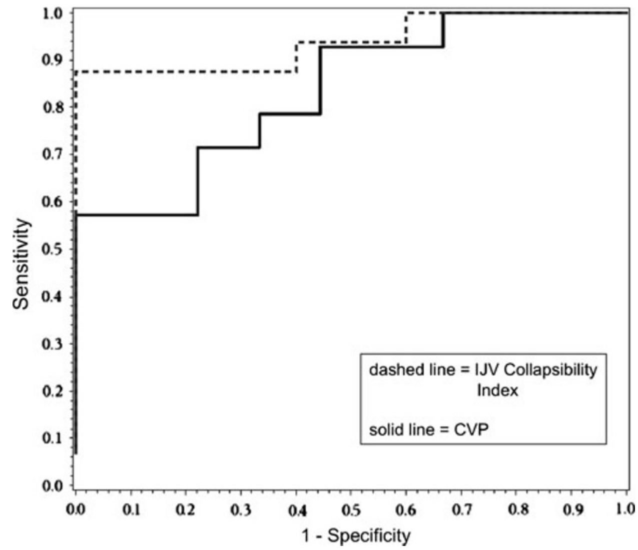

Fig. 2 ROC curves for IJV collapsibility index and CVP associated with hypovolemia. *Dashed line* indicates area under the curve for IJV collapsibility index of 0.93. *Solid line* indicates area under the curve for CVP of 0.87. $p = 0.467$

The measurement process of IJV collapsibility index can be readily accessible, feasible, reproducible, and found to be equivalent in both right and left IJV and in males and females. The training involved requires being able to perform point-of-care ultrasound examination and identify the IJV, then the limited technical expertise of measuring the AP diameter during maximal and minimal distention and calculating the collapsibility index.

Our study was designed to determine the correlation between clinical volume status and IJV collapsibility index. This study was not designed to replace invasive monitoring in ICU patients, rather to determine if the IJV collapsibility index is a promising adjunct to our current objective parameters including invasive CVP monitoring, given the limitation and time required in obtaining central venous access.

The study had some limitations. It was an observational analysis done at a single institution. There was potential selection bias on the limited convenient sample enrolled. All patients enrolled had no recent formal echocardiography prior to identify tricuspid stenosis or regurgitation or any other cardiac disorder that may lead to a falsely elevated central venous pressures. There was no gold standard technique to determine if the patient was hypovolemic or euvolemic as a pulmonary artery catheter, to measure pressures and cardiac output. Instead the volume status was determined by the treating ICU physician, using subjective and objective data including CVP, blood pressure, heart rate, urine output, radiographs in determining the ICU patient to be euvolemic or hypovolemic. Another limitation, the intensivist point-of-care sonographers performing the study were not blinded to the volume status of the patient, which can lead to bias in measurements.

Whether the presence of mechanical ventilation, PEEP, and patient effort of respiration has any effect on the IJV collapsibility index is unknown, but the mean results showed the same trend in IJV collapsibility index in mechanically ventilated patients compared to those who were spontaneously breathing.

Larger studies are needed to verify these results. Future studies may also consider a more standardized method for volume assessment to be used as a gold standard, in addition to the clinical assessment of the treating ICU physician. As an adjunct to invasive CVP monitoring, future studies will be needed to determine the utility of the IJV collapsibility index in the setting of early aggressive fluid resuscitation.

Conclusion

IJV collapsibility index can be identified via point-of-care ultrasound in the hypovolemic and euvolemic ICU patients. The presence of IJV collapsibility index greater than 39% may be associated with hypovolemic ICU patients with or without mechanical ventilation.

Conflict of interest None.

References

1. Keller AS, Melamed R, Malinchoc M et al (2009) Diagnostic accuracy of a simple ultrasound measurement to estimate central venous pressure in spontaneously breathing, critically ill patients. J Hosp Med 4:350–355
2. Donahue SP, Wood JP, Patel BM et al (2009) Correlation of sonographic measurements of the internal jugular vein with central venous pressure. Am J Emerg Med 27:851–855
3. Armstrong PJ, Sutherland R, Scott DH et al (1994) The effect of position and different manoeuvres on internal jugular vein diameter size. Acta Anaesthesiol Scand 38:229–231
4. Baumann UA, Marquis C, Stoupis C et al (2005) Estimation of central venous pressure by ultrasound. Resuscitation 64:193–199
5. Lipton B (2000) Estimation of central venous pressure by ultrasound of the internal jugular vein. Am J Emerg Med 18:432–434
6. Minutiello L (1993) Non-invasive evaluation of central venous pressure derived from respiratory variations in the diameter of the inferior vena cava]. Minerva Cardioangiol 41:433–437
7. Taylor RW, Palagiri AV (2007) Central venous catherization. Crit Care Med 35(5):1390–1396