Internal Jugular Vein and Inferior Vena Cava Collapsibility indices as a Predictor of Fluid Responsiveness in Intensive Care Unit patients

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ABSTRACT

The assessment of the volume status in ICU patients is vitally important for fluid therapy management. The most commonly used parameter for detecting volume status is still central venous pressure (CVP); however, in recent years, various kinds of methods and devices are being used for volume assessment in intensive care units.

Objective: to assess the role of IJV and IVC-CI in prediction of fluid responsiveness in ICU patients

Conclusion: The IJV collapsibility index, especially at 30° head end elevation, can be used as a first-line approach for the bedside non-invasive assessment of CVP/fluid status in ICU patients. IVC-CI can be used either as an adjunct or in conditions where IJV assessment is not possible.

Keywords: internal jugular vein, inferior vena cava, collapsibility index, central venous pressure.

Introduction:

Hemodynamic parameters that can predict fluid responsiveness can be grouped generally as static or dynamic indicators. Classically, static indicators are parameters of ventricular preload such as central venous pressure (CVP), pulmonary capillary wedge pressure (PCWP), or left ventricular end-diastolic volume or area (LVEDA) obtained using transesophageal echocardiography (TEE). All of these parameters have been shown to be of minimal value aspredictors of fluid responsiveness **(1)**.

For example, data from PCWP, which estimates LVEDA, may be misleading because several variables affect ventricular compliance, such as myocardial ischemia, vasopressor use, afterload reduction, and ventricular interaction. CVP has is a poor predictor of fluid responsiveness; in a systematic review, the likelihood that CVP could predict fluid responsiveness accurately was only 56% **(2).**

Safety also may be an issue with some modalities: CVP, for example, carries the concern of central line infection. Moreover, echocardiographic parameters such as LVEDA are inaccurate predictors of fluid responsiveness and require technical skills and training. This does not mean that such parameters should not be monitored in the anesthesiology or ICU practice, but rather that they should not be used to assess fluid responsiveness **(3).**

IVC U.S Assessment:

To image the IVC, the probe is placed in the subxiphoid region 1-2cms to the right of the midline, with the marker dot pointing towards the sternal notch with the probe marker oriented laterally to identify the right ventricle and right atrium. As the probe is progressively aimed toward the spine, the convergence of the IVC with the right atrium will be seen. The IVC should be followed inferiorly, specifically looking for the junction of the hepatic veins with the IVC. (**4).**

The IVC can also be evaluated in the long-axis plane. For this view, the probe is turned from a 4-chamber subxiphoid to a 2- chamber subxiphoid orientation, with the probe now in a longitudinal orientation (**5).**

Although this view allows visualization of the IVC throughout the length of the hepatic segment, the diameter of the IVC may be underestimated in the long axis because of an error known as the cylinder tangent effect. This effect occurs when the ultrasound beam travels through the vessel longitudinally in an off-centered plane. This can be avoided by angling the probe laterally and medially until the greatest dimension is obtained. The diameter of the IVC should be measured perpendicular to the long axis of the IVC at end-expiration and end-inspiration. The finding of a small-diameter IVC (<1cm) with large inspiratory collapse (high caval index) and Low CVP correlates with low volume states. This phenomenon may be observed in hypovolemic and distributive states (**6).**

Conversely, a large IVC diameter (>2cm) and abnormally high CVP with minimal collapse (low caval index) suggests a high volume state such as cardiogenic or obstructive shock. Movement of the diaphragm, especially during forceful inspiration or sniffing, may displace the IVC from the plane, making it difficult to obtain comparative measurements at the same location. In the short axis, the probe may need to be angled inferiorly during inspiration to locate the site measured at expiration. In the long axis, displacement of the IVC may require angling inferiorly and/or laterally (to avoid tangential measurement). In either orientation, it is recommended to observe the changes of the IVC through more than one respiratory cycle. Sometimes the IVC is near completely collapsed and may be difficult to visualize (virtual IVC). Such a situation in a mechanically ventilated or spontaneously breathing patient always indicates severe hypovolemic state in the absence of raised intra- abdominal pressure. The IVC diameter is an indicator of volume status and not volume responsiveness, these two are not the same. (**7).**

M-mode sonography of the IVC can be used to graphically document the absolute size and dynamic changes in the caliber of the vessel during the patient"s respiratory cycle in both short and long axes. It should be noted, however, that Mmodesonography may introduce inaccurate measurements due to the displacement of the IVC against the probe during inspiration. Movement of the IVC out of the plane of the M-mode cursor may appear as vessel collapse on the M-mode tracing. It is therefore recommended that M-mode sonography be used after adequately visualizing IVC variability in the B-mode to avoid inaccurate assessment of vessel size and collapse. If the patient is spontaneously breathing, ask him to take a short quick inspiratory effort ("a sniff") during the M-mode recording. If the patient is mechanically ventilated, record the M-mode through 3 or 4 respiratory cycles, then freeze the M-mode image and using calipers, measure the maximum and minimum diameter of the IVC tracing. (**6).**

In spontaneously breathing patients, the normal IVC respiratory variation is about 40%. In many prospective study, point-of-care sonography evaluating cardiac contractility and IVC collapsibility in patients with suspected sepsis was shown to increase physician trust and altered more than 50% of management plans. Inadequate dilatation of the IVC after a fluid challenge was more sensitive than blood pressure for identification of hypovolemia in trauma patients (**8)**.

It may be more useful to watch changes in vessel size and collapsibility over time in response to an intervention rather than depending on a single finding. Studies have shown a decrease in the IVC diameter and increased collapsibility after blood loss and fluid removal during hemodialysis. In hypotensive emergency patients, volume resuscitation was associated with increases in the IVC diameter and less inspiratory collapsibility **(9)**.

As a single blood pressure measurement is an independent indicator of the hemodynamic status of a patient, sonography of the IVC should be repeated after interventions or changes in clinical scenario. Monitoring of the IVC diameter during resuscitation is an emerging area of research, and further studies are necessary to determine the exact values to interpret IVC size and its changes (**10)**.

A dynamic evaluation of IVC changes with respiration may correlate better with the intravascular volume status than a single static measurement of the vessel diameter. Add, IVC flatness on CT scan is not an accurate indicator of volume status in hemodynamically stable trauma patients (**11)**.

Artifacts during U.S examination:

Care should be taken to maintain adequate visualization of the IVC throughout the respiratory cycle because the probe and IVC may be displaced by diaphragmatic and abdominal wall movements. Overestimation of intravascular volume may occur in conditions that impede flow to the right heart, including valvular abnormalities, pulmonary hypertension, and heart failure. Caval physiological manner is hindered by conditions that restrict the physiologic variability of the IVC such as any conditions causing elevated intraabdominal pressure. So interpretation of these

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measurable characteristics of the IVC should be done in context with exact understanding the patient‟s clinical scenario and adjunctive data. (**6).**

Drawbacks of U.S use:

Unfortunately every modality has its disadvantages. Drawbacks of ultrasonography can be related to the patient, the operator as it is operator dependent, or the ultrasound machine. Also it is inaccurate in morbid obese patients as the depth penetration of ultrasound is limited specially in portable systems, making it difficult to image deep structures. Furthermore, it will be extremely difficult to visualize intraabdominal structures in case when there is ileus or subcutaneous surgical emphysema. Add to that, ultrasound cannot differentiate between blood, urine, bile, ascites or post resuscitation intraperitoneal exudates accurately **(12).**

The operator should be familiar with the ultrasound machine, the type of transducers used, how to improve ultrasound gain and how to control its outcome. The operator should be especially knowledgeable of the sonographic artifacts that can mislead interpretation. Awareness of these artifacts and limitations may help in the diagnosis even. For example, sonography of the adult brain is very limited. This means that in terms of trauma diagnosis involving concussions, sonography will not work. A high level of skill and experience is needed to acquire good-quality images and make accurate diagnoses, which is one of the skills that an emergency team must acquire. Since most emergency medicine teams are small and suffer high turnover, remaining qualified personnel can be difficult. Drawbacks of caval ultrasonography are that The IVC should be followed to the junction with the right atrium to avoid misidentification with the aorta. As a single long-axis view may be inaccurate, it is recommended to assess the IVC in both short and long axes. Inferior vena cava identification should be made at or near the confluence with the hepatic veins. Measurements elsewhere may not give accurate data about intravascular volume. Despite the clear advantages of critical sonography, there was initial resistance and reluctance to use ultrasound by nonradiologists. As more experience and knowledge in this area is being gained, more critical care physicians are using it. The value of ultrasound will be optimized only after full understanding its limitations and pitfalls **(13).**

Internal Jugular Vein Dispensability as a Dynamic Measurement of Fluid Responsiveness

Increasing cardiac output by volume expansion is a cornerstone treatment of critically ill patients with sepsis presumed to have tissue hypoperfusion. Fluid resuscitation is performed because it is assumed that the heart is operating of the steep ascending portion of the Frank-Starling curve (preload-responsive). However, fluid resuscitation in the non-preload-responsive patient may be deleterious if it promotes cor pulmonale, pulmonary edema, or peripheral edema **(14).**

Several studies have emphasized the reduced clinical value of static hemodynamic parameters, such as central venous pressure (CVP) and pulmonary artery occluding pressure, as compared with dynamic parameters in predicting fluid responsiveness **(15).**

Many clinical examples, from tricuspid regurgitation to heart failure, from right heart failure to both hypo and hypervolemia illustrate that any time pressure and volume change within the intra thoracic systemic venous compartment a change also occurs in extrathoracic veins, such as in the intra-abdominal IVC or extrathoracic internal jugular vein (IJV) **(16).**

Therefore it is useful to have reliable predictors of volume responsiveness such as dynamic indicators. Similarly, ultrasound evaluation of respiratory variations of both superior and inferior vena cava diameter accurately reflects volume responsiveness. Specifically, both the superior vena cava (SVC) collapsibility index and the inferior vena cava (IVC) distensibility index **(17).**

IVC imaging can be problematic in the obese and those with ascites, and SVC imaging, though more accurate requires transesophageal echocardiography, limiting its application. Furthermore, measurement of IVC may fail to predict fluid responsiveness in some conditions like following cardiac surgery by virtue of methodological problems such as difficult subcostal caval imaging due to midline chest drainage tubes **(18).**

It's obvious that the internal jugular vein (IJV) is much more technically accessible for sonographic visualization than the IVC. More over recently, Guarracino et al. published promising results regarding the predictive value of IJV distensibility for fluid responsiveness in septic mechanically ventilated patients **(19).**

Also, Broilo et al. reinforce the idea that the respiratory variation in the internal jugular vein diameter (ΔDRIJ) is correlated with the respiratory variation in the inferior vena cava diameter (ΔDIVC), suggesting that the internal jugular distensibility may be an easy, noninvasive alternative to evaluate fluid responsiveness in mechanically ventilated patients (**20).**

Ma and others (21) evaluate the efficacy of using internal jugular vein variability (IJVV) as an index of fluid responsiveness in mechanically ventilated patients after cardiac surgery. Hemodynamic data coupled with ultrasound evaluation of IJVV and inferior vena cava variability (IVCV) were collected and calculated at baseline, after a passive leg raising (PLR) test and after a 500-ml fuid challenge. They reported that Ultrasound-derived IJVV is an accurate, easily acquired noninvasive parameter of fuid responsiveness in mechanically ventilated postoperative cardiac surgery patients, with a performance similar to that of IVCV**.**

Because internal jugular vein imaging does not require transesophageal echocardiography and is technically more simple than visualizing the IVC, this technique seems to be a simple and promising bedside method for the evaluation of fluid responsiveness **(22).**

Conclusion:

The IJV collapsibility index, especially at 30° head end elevation, can be used as a first-line approach for the bedside non-invasive assessment of CVP/fluid status in ICU patients. IVC-CI can be used either as an adjunct or in conditions where IJV assessment is not possible.

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