

ICU

MANAGEMENT & PRACTICE



2022

VOLUME 22
ISSUE 5

Imaging the Critically Ill

The Use of Critical Care Ultrasound, *E. Brogi, G. Bozzetti, M. Romani et al.*

The Role of Lung Imaging to Personalise Lung Ventilation in ARDS Patients, *D. Chiumello, E. Tomarchio, S. Coppola*

Imaging the Critically Ill Patient: Echocardiography, *L. Dragoi, G. Douflé*

Point of Care Ultrasound: The Critical Imaging Tool for the Critically Unwell, *C. King, J. Wilkinson, A. Miller, M. Peck*

Rapid Assessment of Fluid Responsiveness and Tolerance With Ultrasound of the Neck Vessels in Critically Ill Patients, *R. Flores-Ramírez, C. Mendiola-Villalobos, O. Pérez-Nieto et al.*

POCUS in Critical Care Physiotherapy: Give Me Sight Beyond Sight, *A. Gómez-González, M. Martínez-Camacho, R. Jones-Baro et al.*

Bedside Point-of-Care Ultrasound Use in the Critically Ill: Historical Perspectives and a Path Forward, *C. Bryant*



Raymundo Flores-Ramírez

Hospital ISSSTEP Puebla
Puebla, México
Unidad de Cuidados Intensivos

rayf_7@hotmail.com

🐦 @rayofr7



Carlos Mendiola-Villalobos

Hospital General San Juan del Río
Querétaro, México
Unidad de Cuidados Intensivos

drCarlosmevi@gmail.com

🐦 @MenVill_Carlos



Orlando R Pérez-Nieto

Hospital General San Juan del Río
Querétaro, México
Unidad de Cuidados Intensivos

orlando_rpn@hotmail.com

🐦 @orlando_rpn



Éder Iván Zamarrón-López

Hospital MAC Tampico
Tamaulipas, México
Unidad de Cuidados Intensivos

ederzamarron@gmail.com

🐦 @ederzamarron



Susana Carbajo-Martínez

Hospital General San Juan del Río
Querétaro, México
Unidad de Cuidados Intensivos

susanacarabajo13@gmail.com

🐦 @215car



Ernesto Deloya-Tomas

Hospital General San Juan del Río
Querétaro, México
Unidad de Cuidados Intensivos

deloyajmr@hotmail.com

🐦 E_DeloyaMD

*All authors are members of Sociedad Mexicana de Medicina Crítica y Emergencias

Rapid Assessment of Fluid Responsiveness and Tolerance With Ultrasound of the Neck Vessels in Critically Ill Patients

Ultrasonographic assessment of the neck vessels in critically ill patients contributes to rapid and non-invasive management of fluids in order to evaluate responsiveness and tolerance, as well as blood volume status.

Introduction

There are multiple ways to evaluate the responsiveness and tolerance to IV fluids, as well as venous congestion, in critically ill patients. For these purposes, some static variables have traditionally been used, such as central venous pressure (CVP) and inferior vena cava diameter (IVCd), up to dynamic variables like pulse pressure variation (PPV), stroke volume variation (SVV), passive leg raising (PLR) combined with continuous measurement of cardiac output (CO) and stroke volume (SV), inferior vena cava variation index (IVCvi) and internal jugular vein variation index (IJVvi), velocity time integral variation (VTIv) of the left ventricle outflow tract (LVOT) and internal carotid artery peak systolic flow variation (ICASFv).

For a long time, placing a central venous catheter to measure CVP or placing a catheter in the pulmonary artery to measure pulmonary artery occlusion pressure were parameters to decide upon the administration of IV fluids in shock patients (Rivers et al. 2001); in present day, CVP is considered a reference point to stop IV resuscitation, in addition to evaluating venous congestion; later, the dynamic variable PPV was widely used to assess fluid responsiveness (Michard et al. 1999; Yang and Du 2014). Both techniques have the disadvantage of requiring an invasive device; furthermore, they imply additional financial costs. In the last decade, point-of-care ultrasound

(POCUS) has been proposed as a non-invasive, low-cost device to evaluate fluid responsiveness and tolerance, such as the assessment of the inferior vena cava (IVC) and transthoracic echography (TTE), which require some degree of expertise; nonetheless, neck vessels are relatively easy to assess with ultrasound, and may provide prompt information for decision-making in critically ill patients, while properly correlating with other methods.

Ultrasonographic Assessment of Neck Vessels to Evaluate Fluid Responsiveness and Tolerance

Positive responsiveness to fluids is defined as an increase in SV of 10 to 15%, and therefore of CO after the administration of an IV fluid challenge, usually 5 to 10% of the estimated blood volume. The neck is an accessible anatomical region in most critically ill patients in Intensive Care Units (ICU), emergency departments (ED) and operating rooms (OR), unlike the ultrasonographic evaluation of the IVC and transthoracic echocardiography which may not be feasible or may be technically difficult to obtain images from, such as in patients with abdominal or chest pain, patients with abdomen or chest surgeries, patients on mechanical ventilation (MV) or on prone position, obese or ascites patients, or patients with chest wall deformities or with a poor anatomic window. Performing an ultrasonographic scan to the internal

jugular vein (IJV) and the common carotid artery (CCA) could be much easier and faster than other methods and may provide valuable information to manage fluid therapy in critically ill patients, particularly in patients with circulatory shock (Table 1).

Evaluation of Fluid Responsiveness With the Internal Jugular Vein

IJV is a superficial vessel that lies beneath the sternocleidomastoid muscle, and it can be easily observed with an ultrasound. Cyclic

changes in the pressure and volume of the intrathoracic systemic venous compartment induced by mechanical ventilation or spontaneous breathing can be transmitted to extrathoracic veins, which makes the evaluation of blood volume possible.

Technique

For this approach, a high-frequency linear transducer (10 MHz) with B and M modes is required. With the head of the patient at 30 to 45°, the transducer is placed

transversely to the trachea at the level of the cricoid cartilage, to subsequently slide laterally to the line that goes along the angle of the mandible until observing the IJV and the CCA, the former being usually more lateral, of greater diameter, oval in shape, collapses on compression, distends with Valsalva manoeuvre, has a continuous flow and has thinner walls compared with the CCA. Once the image of the jugular vein is centered, caution must be taken not to press it with the transducer to avoid

Internal jugular vein variation index (IJVvi)	$IJVvi (\%) = (\text{maximum diameter} - \text{minimum diameter}) / [(\text{maximum diameter} + \text{minimum diameter}) / 2] \times 100$	Cut-off > 12,99%, ↑ CO 15%, sensitivity 91,43 %, specificity 82,86 % and AUC of 0,88 (CI 0,78–0,94).	Ma et al. 2018
Internal jugular vein diameter variation index (IJVdvi)	$IJVdvi = [(\text{maximum diameter} - \text{minimum diameter}) / \text{maximum diameter}] \times 100$	Cut-offs from 9.7% to 28.7% in patients under controlled MV. >11.4% in patients with spontaneous MV (CPAP-PS), sensitivity 83 % and specificity 94 %. >36% in MV without mechanical support (CPAP). >36% with PLR, sensitivity 78 % and specificity 85 %, AUC of 0,872.	Haliloglu et al. 2017 Iizuka et al. 2020
Internal jugular vein (IJV) distensibility index	$[(\text{maximum diameter} - \text{minimum diameter}) / \text{minimum diameter}] \times 100$	Cut-off >18 %, sensitivity 80% and specificity 95%, before fluid challenge (AUC of 0.915).	Guarracino et al. 2014 Broilo et al. 2015
Internal jugular vein diameter ratio (IJVdr)	$IJVdr = \text{IJV diameter during Valsalva} / \text{IJV minimum diameter at end-expiration}$	> 4 is considered normal: normal CVP and may tolerate fluids. <4 considered abnormal. <2 suggests severe congestion.	Simon et al. 2010 Pellicori et al. 2014
Internal jugular vein and common carotid artery diameter ratio	IJV/CCA ratio	IJV/CCA ratio <1.75 predicts CVP < 10mmHg, sensitivity 84.62%, specificity 52.17%, PPV 66% and NPV 75%.	Bano et al. 2018
Internal carotid artery peak systolic flow variation (ICASFv)	$ICASFv = (\text{MaxCDPV} - \text{MinCDPV}) / [(\text{MaxCDPV} + \text{MinCDPV}) / 2] \times 100$	11 to 14% predicts fluids responsiveness in MV, sensitivity and specificity near 86%. ≥13% in spontaneous breathing.	Song et al. 2014 Ibarra-Estrada et al. 2015
Change in carotid flow time (CFTc)	CFTc	≥24,6% CFTc increase with PLR predicts fluid responsiveness, sensitivity 60%, specificity 92%.	Jalil et al. 2018
End-inspiratory and end-expiratory occlusion manoeuvre	$(\text{End-expiratory occlusion} - \text{End-inspiratory occlusion}) / \text{End-inspiratory occlusion} \times 100$	13% cutoff, though there is insufficient evidence.	Jozwiak et al. 2017 Kenny et al. 2020

Table 1. Fluid responsiveness and tolerance predictors in neck vessels

unnecessary manipulation, in order to reduce the risk of a vasovagal reflex; for these purposes, we suggest leaning the operating hand in some bone structure or on the patient's bed. We then switch to M-mode and measure the maximum and minimum IJV diameter.

Internal jugular vein diameter variation index (IJVdvi), which can be calculated with the formula: $(\text{maximum diameter} - \text{minimum diameter}) / [(\text{maximum diameter} + \text{minimum diameter}) / 2] \times 100$, predicts fluid responsiveness capacity in postoperative patients and patients with controlled MV, with sensitivity of 91.43%, specificity of 82.86%, and AUC of 0.88 (CI 0.78–0.94) with a cut-off point of $> 12.99\%$, and shows good correlation with SVV ($r = 0.51$, $p < 0.01$ and AUC 0.88 vs. 0.97, $p = 0.03$) with good agreement between the variability of measurements made by two evaluators (Ma et al. 2018).

IJVdvi measurement can be performed with the formula: $[(\text{maximum diameter} - \text{minimum diameter}) / \text{maximum diameter}] \times 100$. Also known as IJV collapsibility index, it predicts adequate fluid responsiveness with cut-off points from $>9.7\%$ to $>28.7\%$ in patients under controlled MV, $>11.4\%$ in patients on spontaneous mode MV, and $>36\%$ in patients without MV (Haliloglu et al. 2017; Iizuka et al. 2020).

IJVdvi has also been described with the following formula:

$$[(\text{maximum diameter} - \text{minimum diameter}) / \text{minimum diameter}] \times 100$$

Also known as IJV distensibility index, it has a cut-off point of $>18\%$ for prediction of fluid responsiveness in patients with controlled MV and sepsis, with sensitivity of 80% and specificity of 95% for fluid responsiveness prediction (Guarracino et al. 2014).

Note: multiple authors describe internal jugular vein diameter variation as “collapsibility” or “distensibility” according to the phase of the respiratory cycle and MV mode, which may lead to confusion, thus we propose to only name it as internal jugular vein diameter variation index (IJVdvi), whilst taking into consideration the cut-off points referred to in the studies according to the type of patient.

Measurement of the Internal Jugular Vein Diameter Ratio for Assessment of Venous Congestion

It has been determined that a CVP >8 mmHg is associated with greater risk of acute kidney injury, while CVP >10 mmHg has been associated with greater mortality risk. The previously proposed goals of 8–12 mmHg in early resuscitation in patients with sepsis are no longer recommended. One proposal to assess the systemic venous congestion is the IJV diameter ratio (IJVdr), which is the ratio between the maximum IJV diameter during Valsalva manoeuvre and the resting diameter at the end of the expiratory phase. It can be performed in patients without MV, with a low inter-rater error bias. Even in patients with heart failure, a good correlation with NT-proBNP plasma levels has been documented, with a cut-off point of <2 (Simon et al. 2010; Pellicori et al. 2014). Resting IJV diameter is low (0.10–0.15 cm), and it usually increases up to 1 cm during Valsalva manoeuvre; this is similar between patients with and without heart failure. Normal IJVdr is >4 , which identifies patients who have normal CVP and who may be able to tolerate fluids. When IJVdr is <4 , it is considered abnormal, and if it reaches <2 , it is considered a case of severe congestion. IJVdr calculation is performed with the following formula: IJV diameter during Valsalva / IJV minimum diameter at the end of the expiration. Another alternative method to estimate CVP is the measurement of the internal jugular vein and common carotid artery diameter ratio, which is known as the IJV/CCA ratio, with a cut-off point of <1.75 to predict CVP <10 mmHg with sensitivity of 84.62% and specificity of 52.17%, positive predictive value (PPV) of 66% and negative predictive value (NPV) of 75% (Bano et al. 2018). Measurement of anteroposterior IJV diameter (AP-IJVd) measured at 2 cm above the clavicle, also correlates with CVP. An AP-IJVd <7 mm adequately correlates with a CVP <10 mmHg in patients without MV in the supine position ($r = 0.92$) (Donahue et al. 2008).

It is important to mention the limitations that the assessment of the IJV has, which are similar to that of the assessment of the IVC

and the CVP. Any increase in the intrathoracic pressure can generate IJV distensibility and therefore underestimate its variation as occurs in mechanically ventilated patients with high positive end-expiratory pressure (PEEP), tension pneumothorax, severe air trapping, venous outflow obstruction such as venous stenosis, superior vena cava syndrome, cardiac tamponade, severe tricuspid regurgitation, heart failure, low lung compliance, arrhythmias, or jugular vein thrombosis. In the case of patients with spontaneous ventilation with vigorous respiratory effort, modifications in the IJV diameter will be significant and may overestimate its variation.

Evaluation of Fluid Responsiveness With the Internal Carotid Artery

CCA is another superficial, easy-to-access vessel for ultrasonographic assessment. It has been shown that in shock patients, deviation of blood flow is greater in this territory, which confidently reflects the status of systemic resistance and the respiratory variation of SV.

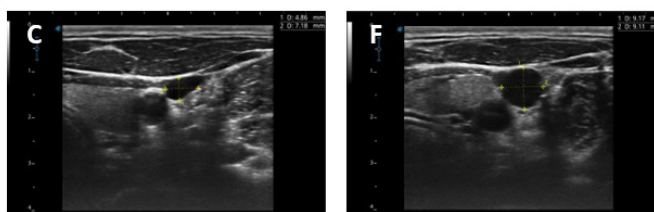
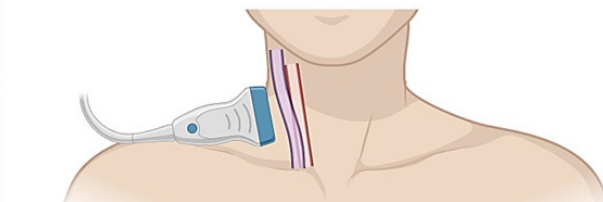
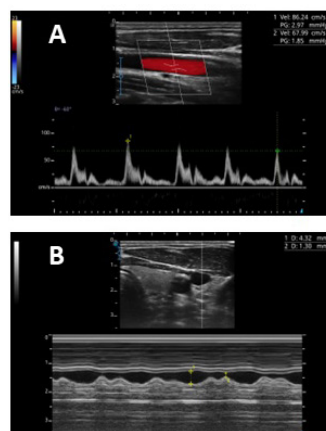
Technique

To perform this evaluation, a linear transducer and pulsed Doppler are required. With the head of the patient at 30° , the transducer is placed in the longitudinal plane of the internal carotid artery with the probe orientation marker towards the patient's head, and pulsed Doppler is applied placing the sample volume at the centre of the vessel lumen with angle correction, observing the trace of the systolic flow spectrum and its variance with the patient's respiratory cycle (**Figure 1**). Preferably, the sampling sweep is increased to more easily observe the peak systolic flow velocity (PSFV); the one with the highest velocity is identified and compared with the one with the lowest velocity by using the following formula:

$$\text{CCApsfv} = (\text{Maximum psfv} - \text{Minimum psfv}) / [(\text{Maximum psfv} + \text{Minimum psfv}) / 2] \times 100$$

Common carotid artery peak systolic flow velocity variation (CCApsfv) with cut-off points of >11 to 14% predicts fluid responsiveness in patients under controlled

Predicts Fluid Responsiveness



Predicts Fluid Unresponsiveness

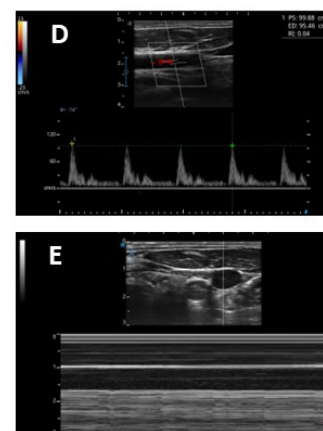


Figure 1. Assessment of fluid responsiveness with ultrasound of the neck vessels.

A: Common carotid artery peak systolic flow velocity variation of 23.6 %. B: M-mode assessment of the anteroposterior diameter of the internal jugular vein with a variability of 69.7%. C: Internal jugular vein in transverse plane with anteroposterior diameter of 4.86 mm. D: Common carotid artery peak systolic flow velocity variation of 4.5 %. E: Lack of variation of the internal jugular vein. F: Internal jugular vein in transverse plane with anteroposterior diameter of 9.17 mm.

MV with an excellent correlation with SVV ($r = 0.84$; $p < 0.001$). In spontaneous ventilation, cut-off points greater or equal to 13% for prediction of fluid responsiveness has been established (Song et al. 2014; Ibarra-Estrada et al. 2015).

Another assessment which is not affected by changes in spontaneous breathing is the measurement of the change in carotid flow time (CFTc), by measuring the maximum velocity; subsequently, passive leg raising is performed for 60 seconds. An increase in CFTc of more than 24.6% is expected in order to consider fluid responsiveness, with sensitivity of 60% and specificity of 92%.

On the other hand, in patients who

are under MV, the end-inspiratory and end-expiratory occlusion manoeuvre can be performed, with a separation of 15 seconds, observing the pattern of change in pulsed Doppler flow velocity of the carotid artery with a cut-off point of 13% for precise fluid responsiveness prediction (Jalil et al. 2018).

The most important limitations of this technique, which can decrease its clinical predictive value, can be recalled with the mnemonics "LIMITS" - L: Low heart rate (HR)/respiratory rate (RR) (for instance, severe bradycardia, high ventilator frequency), I: Irregular heartbeats, M: Mechanical ventilation with low tidal volume or high

total PEEP, I: Increased abdominal pressure, T: Thorax open, and S: Spontaneous breathing (Michard et al. 2015), which is why it is advisable to use at least two assessment techniques of fluid responsiveness to increase certainty in evaluation and clinical judgment (Michard et al. 2015).

Conclusion

Neck vessels ultrasonography is a simple, non-invasive technique that allows for evaluation of fluid responsiveness and tolerance in critically ill patients.

Conflict of Interest

None. ■

References

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):e2277.

Bayraktar M, Kaçmaz M (2022) Correlation of internal jugular vein, common carotid artery, femoral artery and femoral vein diameters with central venous pressure. *Medicine*. 101(43):e31207.

Blehar DJ, Glazier S, Gaspari RJ (2014) Correlation of corrected flow time in the carotid artery with changes in intravascular volume status. *Journal of Critical Care*. 29(4):486-488.

Broilo F, Meregalli A, Friedman G (2015) Right internal jugular vein distensibility appears to be a surrogate marker for inferior vena cava vein distensibility for evaluating fluid responsiveness. *Rev Bras Ter Intensiva*. 27(3):205-211.

Donahue SP, Wood JP, Patel BM, Quinn JV (2009) Correlation of sonographic measurements of the internal jugular vein

with central venous pressure. *Am J Emerg Med*. 27:851-855.

Guarracino F, Ferro B, Forfori F et al. (2014). Jugular vein distensibility predicts fluid responsiveness in septic patients. *Crit Care*. 18(6):647.

Haliloglu M, Bilgili B, Kararmaz A, Cinel I (2017) The value of internal jugular vein collapsibility index in sepsis. *Ulus Travma Acil Cerrahi Derg*. 23:294-300.

For full references, please email editorial@icu-management.org or visit <https://iii.hm/like>

INTENSIVE CARE | EMERGENCY MEDICINE | ANAESTHESIOLOGY

icu-management.org  [@ICU_Management](https://twitter.com/ICU_Management)

ICU

MANAGEMENT & PRACTICE

