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ORIGINAL ARTICLE

Study of the Diameter and Collapsibility index of Inferior Vena Cava by Ultrasound in Patients Receiving Mechanical Ventilation Under General Anesthesia

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ABSTRACT

Background: Hypotension is a prevalent complication in patients under general anesthesia since its incidence after general anesthesia induction ranges from 8% to 9%. Due to the circulatory depressive and vasodilatory actions of anesthetic drugs, individuals are especially vulnerable to developing hypotension after the induction of general anesthesia. In addition, hypovolemia due to dehydration and inadequate compensatory responses may already exist in certain patients. The patient's intravascular volume status may predict the likelihood of hypotension following the onset of general anesthesia. Intraoperative hypotension susceptibility has been demonstrated to be affected by a patient's preoperative volume status, which can vary depending on the patient's physical level, comorbidities, and prior treatments such as bowel preparation and fasting. The purpose of this article is to provide comprehensive information on how to measure the internal vena cava (IVC) diameter and determine the IVC collapsibility index and the IVC distensibility index in patients undergoing mechanical ventilation. For patients undergoing general anesthesia and requiring mechanical ventilation, we felt it was crucial to stress the need for a noninvasive, bedside, objective way of determining volume status.

Conclusion: Anesthesiologists routinely use non-invasive ultrasound examination as a helpful tool for assessing patient safety during anesthesia and measuring vital signs such as global left ventricular function, ventricular diameters, pericardial effusion, and inferior vena cava diameter. The greatest diameter of the IVC at the end of expiration during spontaneous respiration (dIVC max) and its collapsibility index (CI) are two ultrasound parameters that have been recommended as quick and noninvasive accurate markers for evaluating volume status.

Keywords: Ultrasound; Inferior Vena Cava Collapsibility Index; Mechanical Ventilation;General Anesthesia.

INTRODUCTION

Hypovolemia lowers the blood volume that the body can use effectively. Systemic blood pressure and tissue perfusion are maintained through increased heart rate, cardiac contractility, and peripheral vasoconstriction in mild hypovolemia. Blood flow to healthy organs is self-regulated, with the brain, heart, and kidneys receiving more perfusion while the skin and splanchnic bed receive less. Activation of the sympathetic nervous system, the renin-angiotensin system, and the antidiuretic hormone system are insufficient to maintain blood pressure in the presence of more severe hypovolemia. Patients with hypertension are more likely to experience complications after cardiac and non-cardiac surgery if they experience intraoperative hypotension, including myocardial infarction, stroke, heart failure, acute kidney injury, a more extended hospital stay, and an increased risk of death within a year. To restore cardiac output, perfusion pressure, and oxygen delivery, the rapid intravenous (IV) administration of fluids to hypovolemic patients is recommended [1].

This article aimed to provide comprehensive information on how to measure the internal vena cava (IVC) diameter and determine the IVC collapsibility index and the IVC distensibility index in patients undergoing mechanical ventilation. For patients undergoing general anesthesia and requiring mechanical ventilation, we felt it was crucial to stress the need for a noninvasive, bedside, objective way of determining volume status.

Especially for patients in shock, it is crucial to detect volume status and plan adequate fluid therapy, inotropic, vasopressor, and indicator treatments. Correct hydration therapy can decrease the severity of multiple organ failure and the likelihood of death. Patients' intravenous fluid status is evaluated by assessing heart rate, central venous pressure (CVP), skin turgor, urine output, and mean arterial pressure. New evidence, however, reveals that people's subjective assessments can moderate the benefits of these elements [1].

The diameter of the inferior vena cava (IVC) can provide insight into volume status and is closely related to the proper functioning of the heart's right side. When there is a shift in right-sided preload, it will be reflected in the IVC diameter [2]. However, there are caveats to using the IVC diameter to forecast preload to the right side of the heart, such as cardiac disorders (severe tricuspid regurgitation, right-side heart failure, and cardiomyopathy) [3].

The pressure inside the Inferior Vena Cava:

Although many veins have valves to ensure that the blood flows forward in one direction toward the heart, IVC does not contain such valves, which makes the blood flow from IVC to the heart dependent on the pressure gradient created by normal respiration. During inspiration, the diaphragm contracts, creating negative pressure inside the thorax to expand the lungs. This pressure gradient pulls the blood from the abdominal IVC into the thoracic IVC, then into the right atrium. The intra-abdominal pressure during inspiration also increases during inspiration due to the down displacement of the diaphragm. During the breathing cycle, the inferior vena cava (IVC) can be seen to go from its most minor diameter during inspiration to its largest diameter during expiration [4].

Dynamic changes of inferior vena cava:

No generally agreed thresholds exist. Diameters of the inferior vena cava (IVC) during inspiration and expiration typically fall within the range of 0 to 14 and 15 to 20 millimeters, respectively, in healthy people. Maximal IVC diameter has been proven more negligible in patients with hypovolemia, even if the absolute IVC size fluctuates wildly among healthy individuals and may not be diagnostic [5].

The ability of the IVC to collapse is a more accurate measure of intravascular volume. The collapsibility index of an IVC is calculated as the ratio of the most minor diameter to the maximum diameter. The maximal diameter, which occurs during expiration, is the denominator here. IVC Expansion/IVC Insufficiency. Patients are more likely to be volume overloaded or depleted if their collapsibility index is closer to 0% or 100%, respectively. Only unventilated patients who are breathing on their own should utilize this index. No attempts have been made to use it as a benchmark for volume sensitivity. It was primarily used to estimate intravascular volume non-invasively and to track fluid loss during ultrafiltration in persons with spontaneous respiration [6].

Patients on mechanical ventilation have decreased venous return because of increased pleural pressure during inspiration. As a result, the IVC dilation during the inspiratory portion of the respiratory cycle is greater than the dilation during the expiratory phase [7].

The proper atrial pressure cannot be reliably predicted from the IVC diameter in a patient on mechanical breathing. If a mechanically ventilated patient with indications of circulatory failure has no respiratory fluctuations in IVC diameter, then volume expansion is unlikely to be beneficial in 90% of cases. The M-mode scan's maximum and minimum diameters derive this variation's value, which is then divided by the scan's average diameter. This is expressed as the IVC collapsibility index (ΔIVC). Keep in mind that the average diameter is being used as the numerator. Patients on mechanical ventilation with a variance of 12 percent or more had a 93 percent positive predictive value for responding to increased intravascular volume (i.e., cardiac output) and a 92 percent negative predictive value. Tidal volume should be at least 8 ml/kg with patients without severe cardiac arrhythmia during the measurements, which should be conducted during required ventilator breaths [8].

Ultrasound Measurement of IVC Collapsibility Index:

With the advent of portable ultrasound machines, the scope of clinical examination was broadened to include answering pressing, crucial concerns. In addition, we now know that when non-radiologists perform point-of-care ultrasound, the focus shifts from anatomical to physiological analysis. The sonographic data should be used within diagnostic algorithms and connected with the clinical picture for making important decisions. There is solid evidence supporting the use of point-of-care ultrasound for the diagnosis and management of shocked patients according to established guidelines. This comprises a thorough evaluation of the heart's ability to contract and measurements of the IVC diameter and pleural, pericardial, and peritoneal fluid. The quality of ultrasound imaging is directly related to the technician's competence. The training time can be much shorter if the operator needs to learn a few specific things [9].

U.S assessment of IVC:

With the probe marker orientated laterally to identify the right ventricle and right atrium, the IVC can be imaged by positioning the probe 1–2 centimeters to the right of the midline. You can see where the IVC meets the right atrium as you move the probe closer and closer to the spine. The inferior vena cava (IVC) should be traced to its connection with the hepatic veins [10] (Figure 1).

Longitudinally, we can assess the IVC as well. The probe is rotated from a 4-chamber to a 2-chamber subxiphoid, and the search is performed in a longitudinal direction for this perspective [11] (Figure 2).

Although the IVC can be seen over the whole hepatic segment in this perspective, the diameter may be underestimated along the long axis due to the cylinder tangent effect. This occurs when the ultrasonic beam crosses the vessel in a plane that is not perpendicular to its longitudinal axis. You can avoid this by angling the probe laterally and medially until you find the largest dimension. End-expiratory and end-inspiratory diameters of the IVC should be taken perpendicular to the IVC's long axis [12].

To determine typical values for IVC properties, including size, collapsibility, and distensibility, more research is required (in mechanically ventilated patients). Assessing IVC collapsibility in a critically ill patient whose caval index is borderline is helpful until then. Furthermore, progress in these parameters can be evaluated by repeating the caval sonography during resuscitation [13].

In patients who can breathe generally on their own, the usual range of IVC respiratory fluctuation is around 40%. Point-of-care sonography assessing cardiac contractility and IVC collapsibility in patients with suspected sepsis has been shown to boost physician trust in several prospective investigations. It resulted in changes to over half of all management strategies [14].

IVC insufficiency following fluid administration was a more sensitive indicator of hypovolemia in trauma patients than blood pressure [15].

Rather than relying on a single discovery, tracking how vessel size and collapsibility change over time in response to an intervention may be more helpful. The loss of blood and fluid during hemodialysis has been found to reduce IVC width and enhance collapsibility. Increased IVC width and decreased inspiratory collapsibility were observed after volume resuscitation in hypotensive emergency patients [16].

Sonography of the IVC should be repeated following interventions or changes in clinical settings, much as a single blood pressure test is an independent sign of a patient's hemodynamic condition. Further research is needed to discover the exact numbers to interpret IVC size and its fluctuations, as monitoring IVC diameter during resuscitation is a relatively new study area. Compared to a static measurement of the vessel's diameter, a dynamic evaluation of IVC changes with respiration may more accurately reflect the intravascular volume status [17].

Image Interpretation and clinical applications:

If the IVC collapses on inspiration, as it usually does during expiration, it signals volume depletion and the need for fluid replacement [18].

Patients who are breathing independently have a maximum IVC diameter during expiration, while those who are ventilated have a maximum IVC diameter during inspiration. The caval index is called the collapsibility index in patients who are breathing independently and the distensibility index in those who require mechanical ventilation [19].

Artifacts when performing U.S. examination:

Because the diaphragm and abdominal wall may shift, displacing the probe and IVC, care must be taken to preserve the proper vision of the IVC during the breathing cycle.

Conditions that restrict blood flow to the right heart, such as valve anomalies, pulmonary hypertension, and heart failure, might cause an overestimation of intravascular volume. Conditions that limit the IVC's physiologic variability, such as high intraabdominal pressure, impair caval function. So, it's essential to evaluate these IVC measurements in the context of the patient's specific clinical situation and supplementary data [12].

Weaknesses of U.S :

There are drawbacks to using any medium. Ultrasound has limitations that may originate from the patient, the operator (because ultrasound is very dependent on the operator), or the ultrasound machine itself. Because of its limited depth penetration, especially in portable systems, ultrasonography is also unreliable in morbidly obese people because it is challenging to examine deep structures. As an added complication, intraabdominal designs will be challenging in patients with ileus or subcutaneous surgical emphysema. Also, ultrasound cannot distinguish between bodily fluids such as blood, urine, bile, ascites, or intraperitoneal exudates after cardiopulmonary resuscitation [20].

The IVC must be traced to its connection with the right atrium to prevent confusion with the aorta. Due to the potential for error in a single long-axis view, it is advised that the IVC be evaluated along both the short and long axes. The inferior vena cava should be identified at or near its junction with the hepatic veins. The intravascular volume may not be accurately measured externally. Despite the apparent benefits of critical sonography, non-radiologists were initially reluctant to utilize ultrasonography. More and more primary care physicians use it as expertise and knowledge in this field grows. Once ultrasound's potential benefits and risks are fully understood, they can only be maximized [21].

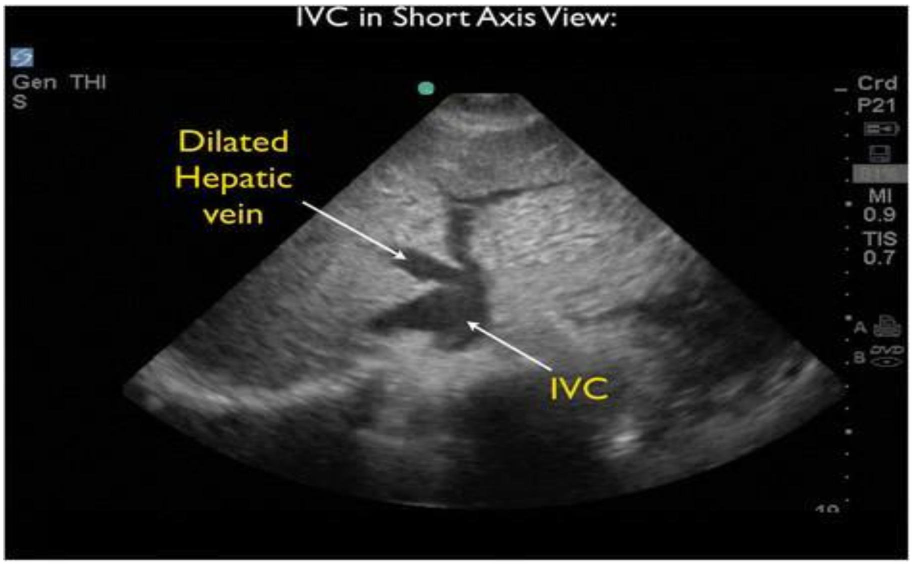

Figure (1): Short-axis view of the IVC

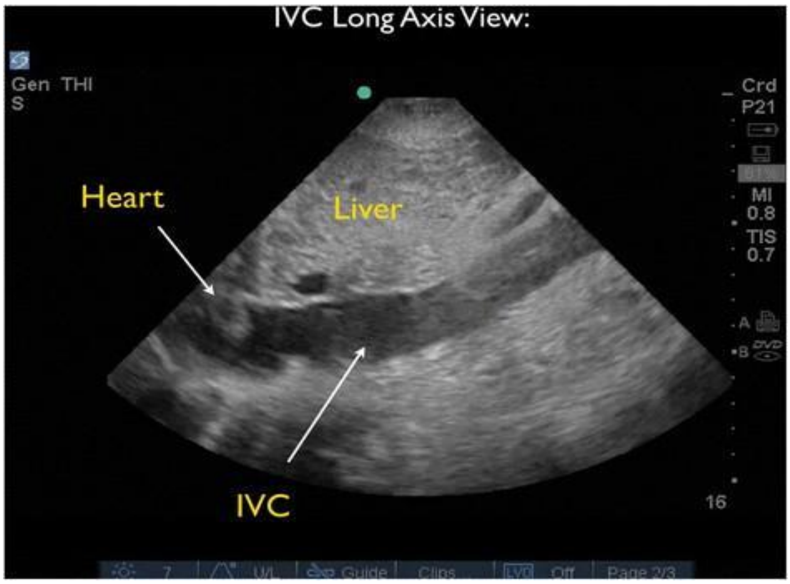

Figure (2): Long-axis view of the IVC

CONCLUSION

Safe anesthetic administration and assessment of vital signs, including global left ventricular function, ventricular diameters, pericardial effusion, and inferior vena cava diameter, can all be aided by non-invasive ultrasound examination, which is routinely used by anesthesiologists. To help prevent hemodynamic instability after induction of general anesthesia in hypertensive patients, it has been suggested that ultrasound measurements of the maximum diameter of the IVC (dIVC max) at the end of expiration during spontaneous respiration and its collapsibility index (CI) could serve as rapid and noninvasive reliable indicators for estimating volume status.

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REFERENCES:

1. **Semler M, Siew E, & Shaw A**. Principles of Fluid Therapy. In Critical Care Nephrology Elsevier,2019,350-3.
2. **Agarwal R, Bouldin JM, Light RP, Garg A**. Inferior vena cava diameter and left atrial diameter measure volume but not dry weight. *Clin J Am Soc Nephrol*. 2011;6(5):1066-72.
3. **Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L,et al.** Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr*. 2015;28(1):1-39. e14.
4. **Muller L, Bobbia X, Toumi M, Louart G, Molinari N, Ragonnet B,et al**. Respiratory variations of inferior vena cava diameter to predict fluid responsiveness in spontaneously breathing patients with acute circulatory failure: need for a cautious use. *Crit Care*. 2012;16(5):R188.
5. **Dipti A, Soucy Z, Surana A, Chandra S**. Role of inferior vena cava diameter in assessment of volume status: a meta-analysis. *Am J Emerg Med*. 2012;30(8):1414-9.e1.
6. **Yildirimturk O, Tayyareci Y, Erdim R, Ozen E, Yurdakul S, Aytekin V,et al.** Assessment of right atrial pressure using echocardiography and correlation with catheterization. *J Clin Ultrasound*. 2011;39(6):337-43.
7. **Brennan JM, Blair JE, Goonewardena S, Ronan A, Shah D, Vasaiwala S, et al**.

Reappraisal of the use of inferior vena cava for estimating right atrial pressure. *J Am Soc Echocardiogr*. 2007;20(7):857-61.

8. **Rudski LG, Lai WW, Afilalo J, Hua L, Handschumacher MD, Chandrasekaran K, et al**. Guidelines for the echocardiographic assessment of the right heart in adults: a report from the American Society of Echocardiography endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography. *J Am Soc Echocardiogr*. 2010;23(7):685-788.
9. **Abu-Zidan F. M, & Hefny A. F**. Point-of-care ultrasound in critically ill patients. Acute Care Surgery Handbook: Volume 1 General Aspects, Non-gastrointestinal and Critical Care Emergencies,2017; 335-60.
10. **Stone MB, Huang JV.** Inferior Vena Cava Assessment: Correlation with CVP and Plethora in Tamponade. *Glob Heart*. 2013;8(4):323-7.
11. **Karasek K, & Leo M.** Ultrasound Guidance of Resuscitation in Shock. Manual of Austere and Prehospital Ultrasound,2021; 181-210.
12. **Seif D, Mailhot T, Perera P, Mandavia D.** Caval sonography in shock: a noninvasive method for evaluating intravascular volume in critically ill patients. *J Ultrasound Med*. 2012;31(12):1885-90.
13. **Lujan Varas J, Martinez Díaz C, Blancas R, Martinez Gonzalez O, Llorente Ruiz B**, Molina Montero R, et al. Inferior vena cava distensibility index predicting fluid responsiveness in ventilated patients. Intensive Care Medicine Experimental, 2015; 3(1), 1-1.
14. **Haydar SA, Moore ET, Higgins GL 3rd, Irish CB, Owens WB, Strout TD.** Effect of bedside ultrasonography on the certainty of physician clinical decisionmaking for septic patients in the emergency department. *Ann Emerg Med*. 2012;60(3):346-58.
15. **Yanagawa Y, Sakamoto T, Okada Y.** Hypovolemic shock evaluated by sonographic measurement of the inferior vena cava during resuscitation in trauma patients. *J Trauma*. 2007;63(6):1245-8.
16. **Lyon M, Blaivas M, Brannam L.** Sonographic measurement of the inferior vena cava as a marker of blood loss. *Am J Emerg Med*. 2005;23(1):45-50.
17. **Krause I, Birk E, Davidovits M, Cleper R, Blieden L, Pinhas L, et al.** Inferior vena cava diameter: a useful method for estimation of fluid status in children on haemodialysis. *Nephrol Dial Transplant*. 2001;16(6):1203-6.
18. **Weekes AJ, Tassone HM, Babcock A, Quirke DP, Norton HJ, Jayarama K, et al**. Comparison of serial qualitative and quantitative assessments of caval index and left ventricular systolic function during early fluid resuscitation of hypotensive emergency department patients. *Acad Emerg Med*. 2011;18(9):912-21.
19. **Jankowich, M., & Gartman, E.** Ultrasound in the intensive care unit. Springer.2014.
20. **Radwan MM, Abu-Zidan FM.** Focussed Assessment Sonograph Trauma (FAST) and CT scan in blunt abdominal trauma: surgeon's perspective. *Afr Health Sci*. 2006;6(3):187-90.
21. Finnerty NM, Panchal AR, Boulger C, Vira A, Bischof JJ, Amick C, et al. Inferior Vena Cava Measurement with Ultrasound: What Is the Best View and Best Mode?. *West J Emerg Med*. 2017;18(3):496-501.

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