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Original Article

Correlation Between Transhepatic and Subcostal Inferior Vena Cava Views to Assess Inferior Vena Cava Variation: A Pilot Study

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Objectives: To assess the feasibility and reliability of transthoracic echocardiography to measure inferior vena cava (IVC) diameter variation using a transhepatic view.
Design: Prospective cohort study.
Setting: Single-center hospital.
Patients: Forty consecutive patients undergoing elective cardiac surgery.
Interventions: Bedside transthoracic echocardiography.
Measurements and Main Results: Correlation between the two views was measured using Pearson R, while agreement was measured using the intraclass correlation coefficient (ICC). In a nested sub-study of 16 randomly selected participants, all images were re-rated by the same rater, who was blinded to the original measurement results, and by a second blinded operator. Correlation between the subcostal and transhepatic views was moderate when assessing maximum (R 0.46; 95% confidence interval [CI], 0.18-0.68), and minimum (R 0.55; CI, 0.29-0.74) IVC diameter. Correlation when measuring IVC diameter variation was higher (R 0.70; CI, 0.49-0.83). Agreement between the two views for IVC diameter variation measurement was substantial (ICC 0.73; CI, 0.49-0.85). Intra-rater reliability was excellent (ICC 0.95-0.99).
Conclusions: Agreement between subcostal and transhepatic views was substantial for the assessment of IVC diameter variation; however, the magnitude of agreement was less than anticipated. Further research is needed to determine if the transhepatic view can be used reliably in the assessment of fluid responsiveness.

Key Words: echocardiography; vena cava; volume; postoperative care; resuscitation; cardiac surgery

INTRAVASCULAR VOLUME STATUS assessment is an essential component in perioperative care; it is very challenging and still relies mostly on subjective judgment. In fact, clinical judgment and static measurements, such as central venous pressure or pulmonary artery occlusion pressure, remain the most commonly used techniques in the acute care setting. The latter are invasive and have well-known limitations.[1–6]

Dynamic indices rely on the changing physiology of heart–lung interactions to determine if a patient will benefit from increased preload, which is proven more adequate to determine fluid responsiveness (> 20% increase in stroke volume in response to volume administration).[7]

Several dynamic indices have been studied including arterial pulse-pressure variation and change in aortic velocities on transesophageal Doppler or transesophageal echocardiography[8]; however, most of these methods are invasive and not validated in spontaneously breathing patients.[9]

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Despite its limitations,[10] transthoracic echocardiographic evaluation of the respiratory variation of the diameter of the inferior vena cava (IVC) is a simple measure to assess volume status at the bedside. Moderate evidence reported that it was consistently lower in hypovolemia when compared with euvolemia.[11]

The IVC is a distensible extrathoracic blood vessel, in which diameter and flow vary with respiration.[12] In spontaneously breathing patients, IVC diameter decreases during inspiration due to increased venous return while the flow increases. The opposite is observed during expiration. In mechanically ventilated patients**,** the flow and diameter changes are reversed.

The relationship between the transmural pressure and volume of the IVC is nonlinear, with a steep slope at low distension and a plateau at full volume.[13,14] By assessing IVC diameter, lower pressure can be detected more sensitively than normal or elevated pressures.

The IVC enters the right atrium almost immediately after crossing the diaphragm. The IVC intramural pressure closely approximates the right atrial (RA) pressure. On inspiration, the decrease in intrathoracic pressure is transmitted to the right atrium; this generates an increased IVC-to-RA pressure gradient, causing an increased venous drainage and resulting in a decreased IVC diameter. In case of hypovolemia, the effect of decreased intrathoracic pressure on the IVC pressures is more pronounced and results in a larger diameter change.[15,16]

The long axis of the IVC can be visualized using transthoracic echocardiography in the standard subcostal (SC) IVC view. This view is easy to obtain even with basic echocardiography training.[15–18] However, it is not feasible in a series of conditions such as post-laparotomy, after cardiac surgery with mediastinal tubes in place, severely obese patients, and a full stomach. A potential alternative is the non-standard transhepatic (TH) IVC view.[19]

This view provides a long-axis cut of the IVC from the anterior axillary line at the level of the diaphragm. It has not been validated in the assessment of IVC diameter variability to determine volume status in spontaneously breathing patients.

The authors conducted a single-center prospective cohort study to assess the feasibility and reliability of IVC diameter measurements using the TH IVC view, and compared them with the standard SC IVC view in hemodynamically stable spontaneously breathing patients.

Methods

Following research ethics board approval, the authors conducted a single-center prospective cohort study in adult patients (≥ 19 years) scheduled to undergo coronary artery bypass graft surgery at the Toronto General Hospital (Toronto, ON, Canada). Exclusion criteria included the inability to tolerate supine positioning for the ultrasound examination, as well as the history of conditions likely to abnormally increase IVC diameter, such as heart failure, chronic kidney disease, portal hypertension, or pregnancy. Chronic kidney disease was defined as an estimated glomerular filtration rate less than 60 mL/min/1.73 m^2 for more than 3 months, with or without other signs of kidney damage.[20]

Following informed consent, participants underwent a limited preoperative echocardiographic examination in the preoperative holding area by a single experienced operator (J.M.) with level II-equivalent training in transthoracic echocardiography[21] and advanced perioperative transesophageal training.[22]

The following data were recorded in each participant immediately prior to the examination: diagnosis, planned surgery, sex, age, weight (kg), height (cm), American Society of Anesthesiologists physical status classification, blood pressure (systolic and diastolic), heart rate, and oxygen saturation (Table 1). Participants then underwent a baseline limited echocardiogram examination to exclude any pathology that may have caused an abnormal increase in IVC diameter such as impaired right ventricular (RV) function, moderate or severe tricuspid regurgitation (TR), and portal hypertension. Impaired RV function was defined as an RV systolic fractional area change below 35%.[23] The fractional area change was obtained by tracing the RV endocardium both in systole and diastole from the annulus, along the free wall to the apex, and then back to the annulus, along the interventricular septum.[24]

To evaluate the degree of TR, the authors used color-flow Doppler in the parasternal RV inflow view, the parasternal short-axis view, the apical four-chamber view, and the subcostal four-chamber view.[25,26] The degree of TR was defined as moderate when the jet area was 5-10 cm^2, and severe if it exceeded 10 cm^2. If further assessment was needed, the vena contracta width was measured, with TR being considered severe if the width exceeded 0.7 cm.[27] Portal hypertension was defined as a hepatic venous pressure gradient of more than 5 mmHg.[28]

After the baseline assessment, all subjects underwent a standardized echocardiographic evaluation of the IVC using the S5-1 phased-array probe, with a CX50 portable ultrasound system (Philips Inc, Andover, MA). Both SC IVC and TH IVC views were acquired during the patient's normal spontaneous breathing. For the SC IVC view, the transducer was placed in a subxiphoid area and rotated to display the long-axis view of

Table 1
Patients' Characteristics and Baseline Hemodynamics

Patients' Characteristics	Mean ± SD
Age (y)	65.3 ± 8.4
Weight (kg)	87.0 ± 16.6
Height (cm)	171.5 ± 10.1
Body mass index (kg/m^2)	29.6 ± 5.3
Systolic blood pressure (mmHg)	132.7 ± 20.9
Diastolic blood pressure (mmHg)	75.7 ± 11.9
Heart Rate (bpm)	63.8 ± 9.0
SpO_2 (%)	97.0 ± 1.3

Abbreviations: SD, standard deviation; SpO_2, oxygen saturation.