Qualitative Assessment of the Inferior Vena Cava: Useful Tool for the Evaluation of Fluid Status in Critically Ill Patients

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Inferior vena cava (IVC) diameter change on limited transthoracic echocardiogram (LTTE) can provide a useful guide of fluid status evaluation in critically ill patients. Institutional review board approval was obtained. Prospective evaluation of hemodynamic status was performed in hypotensive patients via LTTE. Images were obtained using an ultrasound machine without M-mode capability. Qualitative assessment of the IVC was obtained via subxyphoid window. FLAT IVC was defined as diameter less than 2 cm and FAT IVC when the vein was equal or larger than 2 cm. Collapsibility was assessed by observing respiratory variation of the vessel. Lactate was measured before and after therapy was initiated. A follow-up LTTE was obtained after fluid challenge. A total of 108 LTTE were performed. Patients' age ranged from 18 to 89 years with an average of 53. Admission diagnosis was blunt trauma in 66 patients, penetrating trauma in 17, whereas 25 had nontraumatic intra-abdominal emergency. Sixty-nine patients were receiving mechanical ventilation at time of LTTE. Seventy-three patients had a FLAT IVC, and received fluid challenge as therapy. All patients had a change in IVC volume from "FLAT" to "FAT" after the fluid challenge. Seventy-one patients (97%) had resolution of hypotension after the first fluid challenge. Two patients had persistent hypotension and received a second fluid challenge. Follow-up LTTE demonstrated a FAT IVC and lack of collapsibility. Lactate decreased in all 73 patients after therapy guided by LTTE ($P < 0.00001$) Evaluation of the IVC diameter via LTTE offers a rapid, non invasive way to evaluate fluid status in critically ill patients.

ESTIMATION OF VOLUME status in critically ill surgical patients is an ongoing challenge. Inferior vena cava (IVC) diameter is a useful parameter to evaluate fluid status.[1] This parameter has been used by cardiologists to estimate right atrial pressure[2] and by nephrologists to assess fluid status in dialysis patients.[3–6] Additionally, IVC diameter has been shown to be equivalent to central venous pressure in the evaluation of intravascular volume in critically ill surgical patients.[7, 8]

Intensivist-performed transthoracic echocardiogram can also be a useful guide for fluid management in trauma patients.[9] In the absence of a formal echocardiography machine, limited transthoracic echocardiogram (LTTE) has been shown to be useful in guiding therapy in this population.[10] This group has previously published data supporting LTTE as a teachable technique to trauma attendings.[10]

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We hypothesize bedside LTTE is useful for the initial assessment of volume status, and for follow-up of therapy in hypotensive patients. We believe that IVC diameter change on LTTE can provide a real time evaluation of fluid status.

Methods

Institutional review board approval was obtained. Prospective evaluation of hemodynamic status was assessed in hypotensive patients via LTTE by trauma attendings trained in the modality.[10] Hypotension was defined as mean arterial pressure less than 60 mm Hg in more than one sequential reading. Images were obtained using a basic ultrasound machine without M-mode capability (SonoSite S-ICU, SonoSite, Bothell, WA). Attendings performed all windows taught on LTTE, including Parasternal long and short, Apical, and subxyphoid.

IVC diameter was estimated via subxyphoid window (Fig. 1). FLAT IVC was defined as diameter less than 2 cm and FAT IVC as an IVC diameter equal to or greater than 2 cm (Fig. 2). Collapsibility was assessed

by observing respiratory variation of the vessel. A collapsible vessel was indicative of fluid responsiveness. This ultrasound machine did not have any M-mode capabilities, therefore evaluation of the IVC was qualitative not quantitative.

Lactate was measured before and 6 hours after therapy was initiated. A follow-up examination was obtained after fluid challenge to evaluate for change in IVC diameter. Fluid challenge was defined as the administration of 1000 cc of crystalloid solution intravenously.

Results

A total of 112 LTTEs were attempted. In four cases the images were poor in quality making it impossible to perform the test. One hundred and eight patients had adequate images. Age ranged from 18 to 89 with an average of 53 years. Most patients were male (62%). Admission diagnosis was blunt trauma in 66 patients, penetrating trauma in 17, whereas 25 had nontraumatic intra-abdominal emergency surgery. Sixty-nine patients were receiving mechanical ventilation at time of LTTE. Apical windows were obtained in 58 patients, parasternal windows in 95 patients, and subxyphoid windows in 107 patients.

Seventy-three patients had a FLAT IVC, and were considered to be hypovolemic. These patients received fluid challenge as therapy. Fifty-five hypovolemic patients were physically present in the intensive care unit at time of the exam. Fourteen were in the trauma resuscitation unit and four were on the nonmonitored trauma floor at time of LTTE. Forty-three patients had a central venous pressure recorded, four patients had vascular catheter-based assessment of cardiac output monitoring, and one had a pulmonary artery catheter. Twenty-five patients had no other form of hemodynamic monitoring to guide therapy.

Importantly, 100 per cent of the patients had a change in IVC diameter from "FLAT" to "FAT" after a fluid challenge. Seventy-one patients (97%) had resolution of hypotension after the first fluid challenge. Two patients had persistent hypotension and received a second fluid challenge. Follow-up LTTE examination after the second fluid challenge demonstrated a lack of IVC collapsibility in addition to the FAT IVC. Strikingly, lactate decreased in all 73 patients after therapy guided by IVC diameter estimation ($P < 0.00001$).

FIG. 1. Subxyphoid window, getting a longitudinal view of the IVC.

Discussion

This article supports the use of LTTE by trauma attendings for the evaluation of fluid status in critically ill patients. Fluid status evaluation continues to be a challenge in trauma patients. A physical exam is indispensable when treating critically ill patients, but may not be reliable to establish a diagnosis of hypovolemia or fluid overload.[11]

IVC variation is a dynamic parameter. The vessel diameter changes with respiration, reflecting the elasticity of the wall.[12] In mechanically ventilated patients, IVC diameter is maximal at inspiration and minimal on expiration.[13] Respiratory change in IVC diameter is an accurate predictor of fluid responsiveness in ventilated patients irrespective of the positive end-expiratory pressure, plateau pressure, or respiratory system compliance.[14] In the current study most patients were receiving mechanical ventilation at time of LTTE. Regardless of the use of mechanical ventilation, the IVC was found to be FLAT before resuscitation and changed to FAT after fluid resuscitation, suggesting that fluid administration was responsible for the change. In a recent manuscript, Liao et al.[15] found the presence of a FLAT IVC in computerized tomography to be a good indicator of hypovolemia and an accurate

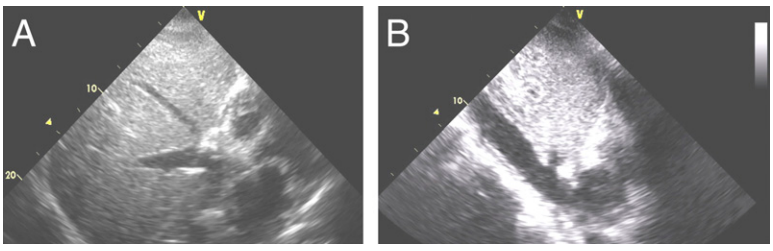

FIG. 2. (*A*) FLAT IVC indicating fluid responsiveness. (*B*) FAT IVC indicating adequate resuscitation.

predictor for prognosis in trauma patients with blunt solid organ injuries.

In this study, attendings were able to estimate IVC diameter and diameter change after fluid bolus without M-mode measurements. Similarly, Fields et al.[16] show that IVC diameter collapsibility evaluation by visual gestalt, without the use of M-mode measurements, has good reliability when evaluating fluid status.

Adequate fluid status estimation in the critical care patient is crucial, because fluid overload can lead to a variety of complications such as pulmonary edema, abdominal hypertension, abdominal compartment syndrome, and increased mortality.[17–19] On the other hand, persistent hypovolemia will result in tissue hypoperfusion and subsequent end organ damage.[20–22] Surgical intensivists have numerous invasive monitoring devices in their armamentarium to assess volume status. These devices have potential morbidities associated with not only insertion, but also with ongoing invasive monitoring.[23–25] Using echocardiography for hemodynamic monitoring presents an attractive alternative, as it eliminates risk related to invasive procedures.[26]

In summary the present manuscript supports the use of LTTE to guide resuscitation in critically ill patients. IVC diameter change and collapsibility are dynamic parameters that change with time and according to therapy. A repeat IVC evaluation is indicated to assess for efficacy of therapy when treating hypovolemia. Evaluation of the IVC diameter via LTTE offers a rapid, noninvasive way to evaluate fluid status in critically ill patients, with minimal risk.

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