Correlating IVC Measurements with Intravascular Volume Changes at Three Distinct Measurement Sites

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Abstract

Bedside ultrasound of the inferior vena cava (IVC) has grown to be an important tool in the assessment and management of critically ill patients. This study endeavors to examine which location along the IVC is most highly correlated with changes in intravascular volume status. We compared the following three sites:
(1) the diaphragmatic juncture (DJ)
(2) two centimeters caudal to the hepatic vein juncture (2HVJ) or
(3) left renal vein juncture (LRVJ).

Data was collected in this prospective observational study on patients in the adult emergency department who were treated with intravenous fluids (IVF). IVC measurements were recorded at each site during standard inspiratory and expiratory cycles, and again with the patient actively sniffing using rapid forced inspiration. IVF was then administered and the same six measurements were repeated after completion of fluid bolus. The difference in caval index (dCI) was calculated for all six data sets and correlated with the mL/kg of IVF administered.

There was a statistically significant correlation between mL/kg of IVFs administered and dCI at all three sites (DJ: r = 0.354, p=0.0002; 2HVJ: r = 0.334, p=0.0003; LRVJ: r = 0.192, p= 0.03). The greatest correlation between amount of fluids administered and dCI was observed at the diaphragmatic juncture. Our data suggests that every mL/kg of IVFs administered should change the dCI by 0.86-1.00%. This anticipated change in IVC diameter can be used to gauge a patient's response to intravascular volume repletion during fluid resuscitation.

Introduction

There are currently a variety of methods available for assessing a patient's intravascular volume status such as the use of pulmonary artery catheters or central venous pressure monitors. Many of these methods require invasive procedures that place the patient at risk for complications such as hemorrhage and infection. Physical exam findings such as skin turgor, mucous membrane appearance, and capillary refill have been shown to be very subjective and are limited by the interpretation of the practitioner. The idea of using bedside ultrasound to evaluate the IVC and its relationship to intravascular volume status has been met with great enthusiasm. The application is portable, non-invasive, and the results have been shown to be highly reliable in various patient populations. Practitioners have found that the IVC can be easily visualized via bedside ultrasound, and measurements of the IVC correlate directly with pressures and readings obtained from more invasive monitoring devices.

The IVC is a highly compliant vessel, whose size varies with changes in total body water and the respiratory cycle. During inspiration, negative intrapleural pressure develops, which results in increased venous return to the heart, causing a decrease in intraluminal pressure and subsequently the diameter of the IVC. The difference in diameter at inspiration (IVC_i) and expiration (IVC_e) is referred to the collapsibility index (also known as the caval index, CI) and is defined as:

$$\frac{IVCe - IVCi}{IVCe}$$

The CI has been shown to be higher in patients with shock..

There are typically three common sites of measurement along the IVC: (1) at the diaphragmatic junction (DJ), (2) two centimeters distal to the hepatic vein inlet (2HVJ), and (3) at the left renal vein junction (LRVJ). While other studies have proposed which site is the best to measure the CI, none have established which location along the IVC is most accurate for measuring the changes before and after fluid resuscitation. In the first portion of our study, we attempt to identify which of the three sites is the most accurate, dynamic, and reproducible spot for determining intravascular volume status. We then evaluated whether changes in IVC diameter can be predicted based on patient weight and amount of fluid administered.

Figure 1. The phased array ultrasound probe is placed in the midaxillary line for a long-axis view of the IVC.
(Photo by sonospot.wordpress.com)

Table 2: Mean difference in IVC collapse (dCI) at each site and its correlation to intravenous fluid (IVF) administered (mL/kg). The greatest correlation between mL/kg of fluid administered and change in caval index was seen at the diaphragmatic junction.

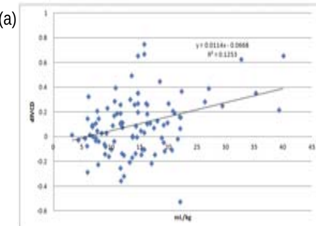
	Mean difference in IVC collapse (dCI) in cm	Correlation between mL/kg IVF and dCI
DJ	0.97	0.354
2HVJ	1.15	0.334
LRVJ	0.8	0.192

Results

A total of 117 patients were recruited for enrollment in the study based on the inclusion and exclusion criteria. All six measurements were successfully obtained in 100 of the 117 enrolled patients.

Figure 3. dIVC vs. mL/kg at the Diaphragmatic Juncture (DJ).

(a)



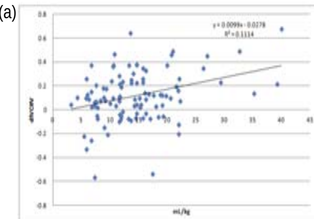
3(a). This graph depicts the mL/kg with the corresponding change in caval index for each patient. r=0.354

(b)

3(b). This figure diagrams the location of the diaphragmatic site of the IVC

Figure 4. dIVC vs. mL/kg at the Hepatic Vein Junction (2HVJ).

(a)



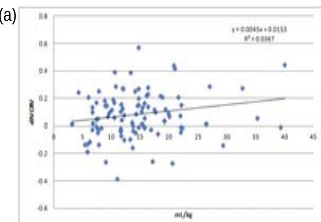
4(a). This graph depicts the mL/kg with the corresponding change in caval index for each patient. r=0.334

(b)

4(b). This figure diagrams the location of 2 cm caudal to the hepatic vein juncture along the IVC

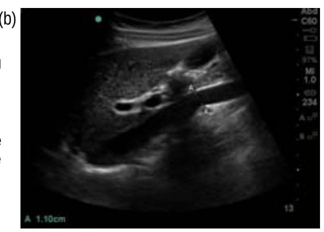
Figure 5. dIVC vs. mL/kg at the Left Renal Vein Junction (LRVJ).

(a)



5(a). This graph depicts the mL/kg with the corresponding change in caval index for each patient. r=0.192

(b)



5(b). This figure diagrams the location of renal vein juncture measured along the IVC

Methods

This was a prospective, observational study where bedside ultrasound was used to obtain serial IVC diameter measurements in emergency department (ED) patients. It was conducted at a Level 1 trauma center with an annual ED census of approx. 65,000 patients. Eligible patients included those older than 16 years and receiving IVF as part of their treatment plan based on clinical diagnosis. Patients were excluded if they were unable to give consent, under positive-pressure ventilation, a trauma patient, or pregnant greater than 20 weeks of gestational age.

EM residents, ultrasound fellows and attending physicians were trained on performing bedside IVC measurements. Patients were placed in the supine position. Using a phased array transducer on a SonoSite M-Turbro (Bothell, WA), the IVC and aorta were identified in the transverse plane in the subxiphoid window. Once the IVC was identified in the transverse plane, the probe was rotated 90 degrees so that a long-axis view of the IVC was obtained. Measurements of the IVC were obtained in the long-axis view along the anterior to mid-axillary line on the right side of the patient, using the liver as an acoustic window.

Initial measurements of the IVC diameter were taken at the DJ, 2HVJ, and LRVJ during the patient's standard inspiratory and expiratory cycle at baseline. Then, all three measurements were repeated with the patient actively sniffing to decrease intrapleural pressures. Intravenous fluids (IVFs) were then administered per the individual treatment plans and the same six measurements were taken after the fluid bolus was completed. The difference in caval index (dCI) was calculated for all six data sets. The Pearson correlation coefficient (r) with the mL/kg of IV fluids administered was then calculated for the dCI at each individual location.

Discussion and Conclusions

Our study demonstrated that the greatest correlation between the amount of intravenous fluids administered and the dCI was seen at the diaphragmatic junction (DJ) and that this site is where the largest change in diameter can be appreciated on ultrasound during intravascular volume resuscitation. Our data also suggests that for every mL/kg of IVFs administered, the dCI should change in a predictable way, increasing by 0.86-1.00%. This anticipated change in IVC diameter can be used to gauge a patient's response to intravascular volume repletion.

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