Correlation Between IVC Diameter Measurements on Bedside Ultrasound in the ICU and Measurements of Central Venous Pressure Obtained Via Central Venous Catheters

IRB Protocol
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A. Study Purpose and Rationale

The systemic inflammatory response syndrome (SIRS) is defined as two or more of the following: 1. Temperature of less than 36 degrees C or greater than 38 degrees C, 2. Heart rate greater than 90 beats per minute, 3. Respiratory rate greater than 20 breaths per minute or a PaCO2 less than 32 mmHg, 4. White blood count greater than 12,000/μL or less than 4,000/ μL or > 10% bands. SIRS is a non-specific constellation of findings, and can be caused by a number of different underlying pathologies, including but not limited to infection, trauma, pancreatitis, and burns. SIRS in the presence of documented or presumed infection is termed sepsis. Severe sepsis is defined as SIRS in the presence of documented or presumed infection with evidence of organ dysfunction or hypoperfusion. Septic shock is defined as sepsis with systolic blood pressure less than 90 mmHg after adequate fluid challenge.

The pathophysiology of septic shock is characterized by peripheral vasodilation and intravascular volume depletion along with increased metabolic demand, the end result of which is that oxygen demand exceeds oxygen delivery and tissue ischemia occurs, leading to significant morbidity and mortality.

Early goal-directed therapy, in which certain hemodynamic and laboratory parameters are used to guide treatment of septic shock and severe sepsis, has been shown to improve mortality.[1] An important component of early goal directed therapy is ascertaining adequacy of volume resuscitation using measurements of central venous pressure. The current guidelines published by the Society of Critical Care Medicine for the management of severe sepsis and septic shock recommend the use of CVP monitoring to guide fluid resuscitation.[2] Monitoring of central venous pressures requires placement of a central venous catheter, which is associated with certain risks to the patient, including infection, bleeding, and damage to adjacent structures.

Ultrasound has been suggested as a non-invasive means of assessing volume status in septic and other forms of shock.[3] Several parameters have been suggested as measurements of volume status, including left ventricular end-diastolic area on transthoracic echocardiogram (TTE), superior vena cava collapsibility on transesophageal echocardiogram (TEE), and IVC diameter on transthoracic echocardiogram.[3] Left ventricular end-diastolic area on TTE turns out not to be a particularly good predictor of who will respond to fluid challenge.[4-6] Measurements of SVC collapsibility require TEE, which is relatively invasive. Measurements of the IVC, however, can be performed non-invasively using TTE.

In at least one prior study of mechanically ventilated patients, an IVC diameter of less than 12 mm was shown to predict a right atrial pressure of 10 mmHg or less (measured using either central venous catheters or pulmonary artery catheters), though an IVC diameter of greater than 12 mm had no predictive value for right atrial pressure.[7] In that study, an IVC diameter of < 12 mm was a sensitive but not a specific predictor of right atrial pressure less than 10 mmHg.[7] Other studies examining respiratory variation in IVC diameter in mechanically ventilated patients with septic shock have found that greater respiratory variation in IVC diameter correlates with response to fluid challenge.[8-9]

In summary, adequate volume resuscitation has been shown to improve mortality in septic shock and severe sepsis.[1] Studies demonstrating this mortality benefit assessed volume resuscitation using CVP. Several studies suggest that bedside ultrasound measurement of IVC diameter may provide a less invasive means of assessing volume status.

I propose to examine the correlation between IVC diameter as measured via bedside ultrasound by medical housestaff in the medical intensive care unit and measurements of central venous pressure obtained using central venous catheters.

B. Study Design and Study Procedure

The study design is a prospective examination of the correlation between IVC diameter on bedside ultrasound and measurement of central venous pressure (CVP) using central venous catheters placed in either the internal jugular vein or subclavian vein. Subjects will be drawn from the medical intensive care units at CPMC. Please see study subjects section for inclusion and exclusion criteria. Importantly, the primary team caring for each patient must already plan to place a central venous catheter and a monitor for the measurement of CVP. Patients must also be able to provide consent, and can not be mechanically ventilated at the time of central venous catheter placement.

Following catheter placement and prior to measurement of CVP, bedside ultrasound will be used to measure the diameter of the IVC (mm). Images will be recorded by a medical resident uninvolved in the care of the patient and unaware of the clinical history of the patient. Following recording of the IVC diameter, measurement of CVP (mmHg) will be performed. Measurement of CVP will be performed as soon after completion of bedside ultrasound as possible, so as to minimize changes in hemodynamics and volume status between measurement of IVC diameter and CVP.

C. Statistical Analysis

Results for IVC diameter will be expressed as a continuous variable with mean +/- standard deviation. Results for CVP will be categorical, with subjects divided into two groups, those subjects with a CVP less than 8 mmHg (inadequate volume resuscitation) and those with a CVP greater than 8 mmHg (adequate volume resuscitation). The data will be analyzed using the unpaired student's T-test since there are two groups and a continuous variable is being analyzed. The study will be powered at 80% with a $p = 0.05$. Assuming from prior studies an effect size of approximately 3 mm, and a standard deviation of 3 mm, approximately 34 subjects will need to be enrolled in the study.

D. Study Drugs
Not applicable.

E. Medical Device
Central venous catheters will be placed by the primary team caring for the patient as previously planned prior to study entry. Choice of central venous catheter and central venous pressure monitor is at the discretion of the primary team caring for the patient.

F. Study Questionnaires
Not applicable.

G. Study Subjects
Inclusion Criteria:
- Age 18 years or older
- Presence of sepsis (meet ≥ 2 SIRS criteria with documented or presumed infection)
- Presence of shock (systolic blood pressure < 90 mmHg after adequate fluid resuscitation) OR severe sepsis (evidence of end organ damage or arterial lactate ≥ 4 mmol/L)
- Primary team caring for patient planning to place central venous catheter and measure CVP
- Patient able to provide consent

Exclusion Criteria:
- Age less than 18 years
- Contraindication to central venous catheter placement
- Unable to provide consent
- Mechanically ventilated

H. Recruitment of Subjects
Potential subjects will be identified by the primary team in the medical intensive care units at CPMC. Subjects will be approached after the primary team has ascertained that the patient is willing to discuss study participation.

I. Confidentiality of Study Data
All data will be coded using a unique code number for each study subject. Data will be stored in a secure location, accessible only to study investigators.

J. Potential Conflict of Interst
There are no potential conflicts of interest.

K. Location of the Study
The study will be conducted in the medical intensive care unit at CPMC.

L. Potential Risks
Ultrasound measurement of IVC diameter carries minimal risks, including discomfort from pressure applied to obtain ultrasound images and potential allergy to the gel used to lubricate the ultrasound probe.

Central venous catheter placement carries risk, however the decision to place CVC is made by the primary team prior to study enrollment and is not a study intervention per se.

M. Potential Benefits

N. Alternatives
None.

O. Compensation of Subjects
Subjects will not be compensated for participating in this study.

P. Costs to Subjects
There will be no cost to the subjects.

Q. Minors as Research Subjets
Patients under the age of 18 will not be eligible for this study.

R. Radiation and Radioactive Substances
Not applicable.

S. References
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