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Measurement of Blood Volume at Bedside: New Era in Critical Care Medicine

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Abstract

Accurate assessment of volume status of the critically care ill patients in the intensive care unit is a challenging task facing intensivits each day. Since direct measurement of blood volume at bedside has not been readily accessible and practical in the past, clinicians have used clinical surrogates instead. It has been shown that the accuracy of these clinical data in estimating of patients' volume status is less than 50%. To overcome these limitations several methods have been developed to measure blood volume by using tracer dilution technique, but there are many problems with these techniques and most of them are complicated, time consuming, unreliable, and not readily available for clinical use. A semi-automated instrument approved by US food and Drug Administration is currently available that can measure blood volume in less than 90 min with a 98% accuracy. In two small studies, this technology has been shown to influence treatment decisions in 20% to 35% of patients. More studies are necessary to further define the role of bedside volume analysis in critical care medicine.

Accurate assessment of volume status of the critically care ill patients in the intensive care unit is a challenging task facing intensivits each day. Failure to correct the volume deficit in patients with shock is known to significantly increase the morbidity and mortality in these patients [1] . On the other hand, fluid overload may cause worsening pulmonary edema, worsening hypoxemia, and deleterious effect in patients with acute respiratory distress syndrome [2] . Assessment of volume status becomes even more complicated when caring for patients with congestive heart failure, pulmonary arterial hypertension, renal failure, and cirrhosis.

Since direct measurement of blood volume at bedside has not been readily accessible and practical in the past, clinicians have used clinical surrogates instead. The clinical data that have been utilized to estimate the patients' blood volume are as follows: 1. History, 2. Physical examination (skin mottling, pulmonary crackles, and peripheral edema) 3.Urine output, 3. Sodium concentration, 4. Measurement of ongoing fluid loss in ICU like chest tube or abdominal drain output, 5. Fluid balance in the last 24 hours, 6. Presence of pulmonary congestion on chest x-ray, 7. Spot urinary sodium concentration [3] . It has been shown that the accuracy of these clinical data in estimating of patients' volume status is less than 50% [3] , [4] , [5] . Monitoring of routine hemodynamic variables also has little value to differentiate hypovolemic and non-hypovolemic patients [6] , [7] . Urine output and spot urinary sodium concentration may vary due to conditions commonly seen in critically ill patients like hyperglycemia, renal failure, diuretic agents, post-obstructive diuresis, and nephrogenic diabetes insipidius. Since there are too many confiding factors, urinary output and spot urinary sodium concentration are not useful in estimation of volume status in critically ill patients [3] , [8] . The hemoglobin concentration also has no value in

determining the blood volume for two major limitations, 1. In rapid severe bleeding, drop in hemoglobin values is a late finding, and 2. Hemoglobin concentration becomes uninterruptible after infusion of packed red cells or large volume of fluids.

Monitoring of central venous pressure (CVP) and pulmonary arterial occlusion pressure (PAOP) has been used commonly in critically ill patients to assess the patients' volume status. Because CVP varies considerably in critically ill patients, due to heart-lung interaction especially in mechanically ventilated patients, CVP has no significant clinical value in these patients. PAOP also has been shown to fail to predict ventricular filling pressure, blood volume, and response to volume infusion [3] , [9] , [10] . Measurement of CVP and PAOP is invasive and requires central venous catheter access that carries risks of pneumothorax, infection, and bleeding.

Because of above-mentioned limitations, several methods have been developed to measure blood volume by using tracer dilution technique. The tracer should be inert, safe, and remains within intravascular compartment. Tracers for blood volume measurement that have been used include 1.I^{125}Radio-labeled albumin, 2. Synthetic colloids (Hetastarch, dextran-70), 3.Small molecules that bind to plasma proteins (Evan's blue dye, indo-cyanine green), 4. Red cell labeling (chromium-51, carbon monoxide). There are many problems with these techniques and most of them are complicated, time consuming, unreliable, and not readily available for clinical use [11] .

A semi-automated instrument (BVA-100, Dexor Corporation) approved by US food and Drug Administration (FDA) is currently available that can measure blood volume in less than 90 min with a 98% accuracy. The blood volume is measured after intravenous injection of 10 to 25 μ Ci of iodine-131-labeled albumin [12] . Information provided by blood volume analyzer is shown in table 1.

Table 1: Information provided by blood volume analyzer

Total blood volume (ml)	Ideal Blood Volume (ml)	Deviation from ideal (ml and %)
Total Red Cell Volume (ml)	Ideal Red Cell Volume (ml)	Deviation from ideal (ml and %)
Total Plasma Volume (ml)	Ideal Plasma Volume (ml)	Deviation from ideal (ml and %)
Normalized Hematocrit (Hematocrit corrected for volume status)		
Slope (Rate of albumin transudation, measure of capillary permeability)		

Two studies have evaluated the value of bedside blood volume analyzer. Yamauchi et al showed that although there was a statically significant correlation between PAOP and blood volume, blood volume information resulted in different treatment in 21% of the time [13] . In another retrospective study of 40 surgical patients, Biuk-Aghai et al demonstrated that treatment change occurred in 36% cases with addition of blood volume information. The treatment changes included less fluid infusion, less diuretic use, and packed blood transfusion [14] . Although these results are interesting, further studies are necessary to document the impact of bedside blood volume analyzer on major outcomes like mortality, ICU stay, ventilator free days, and hospital stay. Bedside blood volume analyzer provides the researchers and clinicians with and effective and practical tool that enable them to answer important questions in critical care medicine by performing new studies that were not easily possible in the past.

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