A COMPARISON OF PULSE PRESSURE VARIATION AND BLOOD VOLUME MEASUREMENT

Shirley Domingo, Mihae Yu, Marc Osborne, Sharon Moran, Kevin Pei, Kurt Edwards, Sharon Takiguchi, Fedor Lurie, Danny Takanishi
University of Hawaii, Department of Surgery and Critical Care and The Queen's Medical Center

Introduction

The assessment of intravascular volume status in critically ill patients continues to challenge clinicians. It is an important aspect that determines whether or not patients will benefit from volume expansion. Administering fluids is the first line of therapy in shock to augment and improve patient hemodynamics.

Pulse pressure variation is a hemodynamic parameter that may be used to guide volume infusion. Aortic pulse pressure (systolic-diastolic pressure) is directly proportional to left ventricular (LV) stroke volume and inversely related to aortic compliance (5). Therefore, the respiratory changes in LV stroke volume have been shown to be reflected by changes in peripheral pulse pressure during the respiratory cycle (4).

A systematic review by Michard et al concluded that dynamic measures of preload responsiveness (*ie*, systolic pressure variation (SPV), pulse pressure variation (PPV), inspiratory decrease in central venous pressure (CVP), and respiratory changes in aortic blood velocity) were superior to static preload parameters (*ie* central venous pressure (CVP), pulmonary artery occlusion pressure (PAOP), and left ventricular end diastolic area (LVEDA) when used to guide fluid management (1). Of these parameters, PPV was a good predictor of fluid responsiveness, with a value of 13% having the highest sensitivity and specificity in predicting an increase in cardiac output (CO) in response to fluid administration in a group of septic patients (2).

It is unclear whether cardiac responsiveness to fluids has a relationship to circulating blood volume.

Introduction

Blood volume (BV) can be measured utilizing a radioactive-labeled iodine technique. Blood volume analysis provides information on intravascular, circulating volume and its component volumes (plasma volume + red cell volume). Assessment of intravascular blood volume in critically ill patient may be useful to guide clinicians in administering fluid therapy.

This study describes the relationship between pulse pressure variation (a surrogate endpoint of cardiac fluid responsiveness) and BV (a measurement of intravascular volume).

Methods

Patients were enrolled into the study with the following admission criteria: sepsis or septic shock, surgical patients requiring pressor support, and patients with ARDS. Exclusion criteria included pregnancy, head injury with GCS < 12, age < 18, and non-survivable conditions. Critically ill surgical patients had simultaneous measurements of blood volume using radioactive labeled iodine, with recordation of arterial pressure and respiratory waves.

Methods

Pulse Pressure Variation

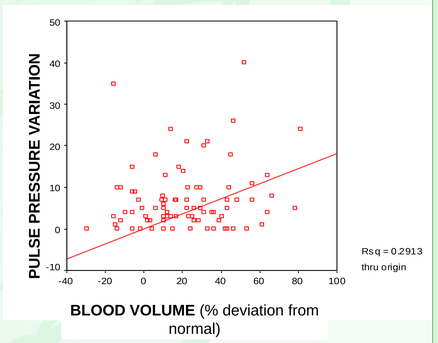
Systolic and diastolic arterial pressures were measured on a beat-to-beat basis and pulse pressure (PP) was calculated as the difference between systolic and diastolic pressure (SBP-DBP). Maximal and minimal values for pulse pressure (PPmax and PPmin, respectively) were measured over a single respiratory cycle. Pulse pressure variation was calculated as previously described (2): PPV(%)={(PPmax-PPmin)/(PPMax+PPmin)/2}x 100. Values during irregular heart rate and spontaneous respirations were deleted.

Blood Volume = (plasma volume (PV) + red cell volume (RBCV)

PV was measured using the BVA-100 (Daxor, NY, NY). After obtaining a baseline sample of 5 mL of blood, 1 mL of I-131 labeled albumin was injected over 1 minute. After 12 minutes to allow complete mixing, 5 blood samples were collected at 6 minute intervals and extrapolated to time 0 to account for albumin extravasation from the intravascular space. Simultaneous Hct (RBCV/RBCV + PV) measurement allowed calculation of RBCV, with BV being RBCV + PV. PV, RBCV, and BV results are reported as a percentage deviation from the patients normal. Predicted normal values were derived from a formula based on patient height, weight, and %deviation from ideal weight (6). For these critically ill patients with vascular volume expansion, hypovolemia was defined as any value less than 0% deviation from ideal blood volume.

Results

29 surgical patients contributed 84 data points. Demographics were: age 60+14 years, 12 Female 17:male, APACHE II score 25+3, septic shock (n=16), severe sepsis (n=7), ARDS (n=16). The correlation coefficient between PPV and BV was r=0.54, and R2=0.29. In 69 instances when PPV was <13%, 14 of 69 BV measurements demonstrated hypovolemia. In 15 instances when PPV was >13%, 13 of 15 BV measurements demonstrated hypervolemia. In 57 of 84 times, the information from PPV and BV values was congruent.



Conclusions

There was no relationship between PPV and blood volume. Although PPV has been shown to be an accurate indicator of fluid responsiveness in mechanically vented patients with acute circulatory failure related to sepsis, PPV may not reflect true intravascular status. In 69 instances when PPV was <13%, 14 of 69 BV measurements demonstrated hypovolemia. These situations are designated fluid non-responders by PPV and yet are hypovolemic by blood volume measurement.

In 15 instances with PPV>13%, 13 of 15 instances demonstrated high BV and would have received fluids if PPV was used to guide fluid therapy. Fluid management in the critically ill surgical patient continues to be complex. While there is no ideal method of assessing intravascular volume status, clinicians must use caution when extrapolating surrogate markers such as hemodynamic parameters to determine intravascular blood volume status.

References

1 Michard F, Teboul JL. *Predicting Fluid Responsiveness in ICU Patients: A Critical Analysis of the Evidence*. Chest 2002. 121: 2000-2008
2 Michard F, Boussat S, Chemla D, et al. *Relation between Respiratory Changes in Arterial Pulse Pressure and Fluid Responsiveness in Septic Patients with Acute Circulatory Failure*. Am J Respir Crit Care Med 2000. 162:134-138
3 Kramer A, Zygun D, Hawes H, et al. *Pulse Pressure Variation Predicts Fluid Responsiveness Following Coronary Bypass Surgery*. Chest 2004. 126:1563-1568
4 Jardin F, Farcot P, Gueret J, et al. *Cyclic changes in arterial pulse during respiratory support*. Circulation 68:266-274
5 Berne R, Levy M. Physiology. 4th ed. Mosby, St. Louis, MO. 415-428
6 Feldschuh J, Enson Y. Prediction of the Normal Blood Volume. Circulation 1977;56:605