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Would the Blood Volume Analyzer Be an Alternative to the Pulmonary Artery Catheter (PAC) in the Management of Critically Ill Patients

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Summary

Recent reports show lack of effectiveness of pulmonary artery catheterization in critically ill medical patients and relatively late-stage surgical patients with organ failure[1]. The results of this study showed that except for the cardiac output, there is no correlation between Pulmonary Capillary Wedge Pressure (PCWP) readings or Blood Volume (BV) results and the other parameters considered in this study (hematocrit, plasma lactate, arterial pH, arterial HCO_3, mixed venous pH, and mixed venous HCO_3). CVP values deviate from this pattern however, because there is a weak correlation between CVP and arterial pH that is marginally statistically significant. BV measurements did not correlate with either PCWP or CVP, a finding that is compatible with other reports from the literature[2, 3].

Introduction

Traditionally, the management of critically ill patients has been based on many clinical and laboratory parameters, as well as values generated by the PAC. The pressure measurements obtained from the PAC do not correlate with volume status[3] and very often, main decisions for fluids and cardiovascular system management are usually based on these measurements. Since the introduction of the PAC in medical practice by Swan and Ganz[4] in 1970, there has been multiple reports in the literature regarding

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its applications[5, 6] as well as the morbidity (20-53%) and mortality (0-4%)[3,6,7,8,9,10,11] related to its use. Blood volume measurements have been available for over 60 years, but are rarely used in acute clinical situations. This is the result of the technical difficulties in rapidly obtaining an accurate BV measurement[12]. The development of radioactive isotopes permitted a significant improvement in the measurement of the red cell compartment. The injection of radioactive iodine-labeled albumin is considered the "gold-standard" method for blood volume measurement[13], and its efficacy has been compared previously with other methods[14].

The purpose of this study is to explore the interrelationships between the main parameters used in critical care, including the values generated by the PAC, and the values obtained using the Blood Volume Analyzer (BVA). Furthermore, we also examined whether blood volume measurements can accurately and safely be used in the assessment and management of critically ill patients.

Patients and Method

The study was performed at Lutheran Medical Center in Brooklyn, New York. After approval of the experimental protocol by the Institutional Review Board, informed consent was obtained from the study patients. Twenty-four ICU patients, 10 men and 14 women aged 42-93 years (median age = 77.5 years) completed the study.

Inclusion criteria were: admission to the Medical or Surgical Intensive Care Unit, Pulmonary artery Catheter insertion and an APACHE severity score of 8-30, mean of 17.875. Exclusion criteria were: pediatric patients, hemodynamically normal or stable patients, pregnancy, and critically ill patients that were managed in an ICU setting without the use of a PAC catheter. The weight (in pounds) and height (in inches) of each of the individuals from the study group was obtained for further calculation of the individual's normal predicted blood volume as a function of the patient's body weight deviation from ideal weight[12, 15].

Blood volume measurement

Blood volume measurements were performed using the Blood Volume Analyzer (BVA-100, Daxor Corporation). It provides a more precise calculation than previously available, of the normal blood volume measurement of a specific individual. Individuals standard deviations were computed for each blood volume measurement and averaged less than 3%. The degree of hypervolemia or hypovolemia was ranked according to the percentage of deviation from the ideal blood volume calculated for that specific patient. The following scale was used: ±8% is considered *normal*,

±9-16% *mild*, ±17-24% *moderate*, ±25-32% *severe*, and >32% *extreme* hypo or hypervolemia.

Results

Twenty-four patients, 10 men and 14 women, aged 42-93 years (median age = 77.5 years) completed the study.

The inverse correlation of Pulmonary Capillary Wedge Pressure (PCWP) with Cardiac Output (CO) was statistically significant (r= -0.43, p= 0.03). However, there was no significant correlation between PCWP and each of the hematocrit, plasma lactate, arterial pH, arterial HCO3, mixed venous pH, and mixed venous HCO3 (r= -28, -0.19, -0.30, -0.18, -0.22, -0.11, p= 0.19, 0.38, 0.16, 0.39, 0.29, 0.62 respectively) [Table-1].

Table-1: Correlation of Pulmonary Capillary Wedge Pressure (PCWP) with various physiologic variables.

X	*Y*	*R*	*P*
PCWP	Hematocrit	-0.28	0.19
=	Plasma lactate	-0.19	0.38
=	Arterial pH	-0.30	0.16
=	Arterial HCO3	-0.18	0.39
=	Mixed venous pH	-0.22	0.30
=	Mixed venous HCO3	-0.11	0.62
=	Cardiac Output	-0.43	0.04

Central Venous Pressure (CVP) correlated significantly with CO (r= -0.37, p= 0.08), arterial pH (r= -0.42, p= 0.04), and arterial HCO3 (r= -0.43, p= 0.04), whereas it did not do so significantly with the hematocrit, plasma lactate, mixed venous pH, or mixed venous HCO3 (r= -0.18, -0.13, -0.26, 0.14, p= 0.4, 0.55, 0.22, 0.50, respectively) [Table-2].

Results for Blood Volume (BV) measurements were similar to that of

Table-2: Correlation of Central Venous Pressure (CVP) with various physiologic variables.

X	*Y*	*R*	*P*
CVP	Hematocrit	-0.18	0.40
=	Plasma lactate	-0.13	0.55
=	Arterial pH	-0.42	0.04
=	Arterial HCO3	-0.43	0.04
=	Mixed venous pH	-0.26	0.22
=	Mixed venous HCO3	0.14	0.50
=	Cardiac Output	-0.37	0.08

PCWP and showed a significant correlation with CO (r= 0.53, p= 0.01), whereas that with all the other parameters were not significant (r= -0.05, -0.31, -0.06, -0.04, 0.34, -0.12, p= 0.83, 0.14, 0.78, 0.86, 0.11, 0.59, respectively) [Table-3].

Table-3: Correlation of Blood Volume with various physiologic variables. Blood volume did not correlate significantly with either PCWP (r=0.09, p=0.67) or CVP (r=0.03, p=0.87) readings.

X	Y	R	P
Blood Volume	Hematocrit	-0.05	0.83
=	Plasma lactate	-0.31	0.14
=	Arterial pH	-0.06	0.78
=	Arterial HCO3	-0.04	0.86
=	Mixed venous pH	0.34	0.11
=	Mixed venous HCO3	-0.12	0.59
=	Cardiac Output	0.53	0.01

Conclusions

This study is unique in that we chose specific physiologic parameters such as plasma lactate and blood gases that provide a good reflection of the overall physiologic status of the patient We look at the clinical and physiologic validity of direct blood volume measurement using I^{131}-tagged albumin in critically ill patients. It demonstrates that the application of this method can be released from the experimental and research fields and be safely and effectively incorporated into the clinical arena. These results also demonstrate that the parameters generated by the BV analysis are comparable with the ones obtained from the PAC. However, other factors such as cost, feasibility and technical expertise will ultimately determine the appropriate setting for using it in such patients. These results open a fascinating door to new studies, where the clinical use of this method can be applied to other groups of patients and diseases.

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