Alternative Methods to Central Venous Pressure for Assessing Volume Status in Critically Ill Patients

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Introduction: Early goal-directed therapy increases survival in persons with sepsis but requires placement of a central line. We evaluate alternative methods to measuring central venous pressure (CVP) to assess volume status, including peripheral venous pressure (PVP) and stroke volume variation (SVV), which may facilitate nurse-driven resuscitation protocols.

Methods: Patients were enrolled in the emergency department or ICU of an academic medical center. Measurements of CVP, PVP, SVV, shoulder and elbow position, and dichotomous variables Awake, Movement, and Vented were measured and recorded 7 times during a 1-hour period. Regression analysis was used to predict CVP from PVP and/or SVV, shoulder/elbow position, and dichotomous variables.

Results: Twenty patients were enrolled, of which 20 had PVP measurements and 11 also had SVV measurements. Multiple regression analysis demonstrated significant predictive relationships for CVP using PVP (CVP = 6.7701 + 0.2312 × PVP − 0.1288 × Shoulder + 12.127 × Movement − 4.4805 × Neck line), SVV (CVP = 14.578 − 0.3951 × SVV + 18.113 × Movement), and SVV and PVP (CVP = 4.2997 − 1.1675 × SVV + 0.3866 × PVP + 18.246 × Awake + 0.1467 × Shoulder = 0.4525 × Elbow + 15.472 × Foot line + 10.202 × Arm line).

Discussion: PVP and SVV are moderately good predictors of CVP. Combining PVP and SVV and adding variables related to body position, movement, ventilation, and sleep/wake state further improves the predictive value of the model. The models illustrate the importance of standardizing patient position, minimizing movement, and placing intravenous lines proximally in the upper extremity or neck.

Key words: Central venous pressure; Volume status; Hemodynamics; Stroke volume variation

Early Goal-Directed Therapy (EGDT) has been shown to improve survival in persons with severe sepsis and septic shock.[1-24] However, despite a significant survival benefit from EGDT, barriers exist to compliance with the protocol. One major obstacle is the requirement for central line placement to allow measurement of central venous pressure (CVP) and central venous oxygen saturation (Scv_{O_2}) monitoring.[4,6,10,12,25,26]

Jones and Kline[27] propose that simplified protocols with less invasive monitoring may facilitate compliance.

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TABLE 1
Patient demographics

Patient age, sex	Location	HD	Diagnosis	IV site	Shoulder (degrees)	Elbow (degrees)	Awake	Movement	VPDIFF (mm Hg)	SVV (%)	Vented
69 M	ED	1	Sepsis	L AC	0	0	Y	N	3.1	_	_
49 F	SICU	1	Sepsis	L FA	0	0	N	N	4.1	_	_
58 F	SICU	59	Metastatic CA/ESLD	L foot	0	10	N	N	5.6	_	_
48 F	ED	1	Severe Sepsis	L EJ	0	0	Y	N	7.1	_	_
64 F	MICU	1	Sepsis	R AC	0	0	N	N	0.4	_	_
81 M	MICU	1	Sepsis	R FA	0	0	Y	N	3.4	_	_
72 M	CCU	2	Severe Sepsis	R AC	0	50	N	N	2.3	_	_
22 M	SICU	2	Splenic rupture	L FA	0	20	Y	N	16.1	_	_
63 M	SICU	4	TBI	L wrist	30	30	N	N	20.4	6.9	Y
36 M	SICU	2	Kidney/panc transplant	R foot	0	25	Y	N	16	19.1	N
80 M	MICU	2	Septic shock	R FA	0	0	Y	N	14	31.4	N
76 F	SICU	2	Trauma	R hand	0	0	N	N	9.6	11	Y
43 M	CCU	11	Aortic valve replacement	L AC	30	0	Y	Y	16.3	21.6	N
72 M	SICU	2	Bladder ca	R hand	0	0	Y	Y	26	8.7	N
71 M	SICU	2	Bladder ca	R thumb	25	45	Y	N	36.3	7.6	N
58 F	SICU	2	Pancreatic Transplant	R wrist	30	30	Y	N	18.9	13.7	N
67 M	SICU	12	Metastatic Ca	L FA	30	0	N	N	8.1	31.6	N
69 M	MICU	2	Septic shock	R FA	15	0	N	N	-0.1	5.4	Y
69 M	MICU	2	Urosepsis	L AC	30	15	Y	N	3.9	_	_
19 F	PICU	1	Acute viral illness	EJ	0	0	5/7	2/7	2.9	10.0	N

AC, Antecubital; *CA,* cancer; *CCU,* cardiac care unit; *EJ,* external jugular; *ESLD,* end-stage liver disease; *F,* female; *FA,* forearm; *HD,* hospital day; *IV,* intravenous; *L,* left; *M,* male; *MICU,* medical ICU; *Panc,* pancreas; *PICU, p*ediatric ICU; *R,* right; *SICU,* surgical ICU; *SVV,* stroke volume variation; *TBI,* traumatic brain injury; *VPDIFF,* mean difference between central venous pressure and peripheral venous pressure.

Lin et al[10] describe a goal-directed resuscitation protocol that excludes CVP measurement and demonstrates improved survival compared with control subjects, but the intervention arm of this study still has a higher mortality rate than the control group of the original EGDT study.[1] Less invasive alternatives to CVP for assessing intravascular volume status have been described, including peripheral venous pressure (PVP),[28-31] ultrasound of the inferior vena cava[32-34] or internal jugular vein,[35] and measurement of stroke volume variation (SVV) in patients undergoing mechanical ventilation.[36-38] These measures have been studied primarily in anesthetized patients during surgery; their utility for monitoring critically ill patients in the emergency department or ICU remains largely unknown.

The primary aim of this study was to examine alternative methods to CVP to assess volume status in critically ill patients.

Methods

The 18-month study was conducted in the emergency department and adult ICU in 2 hospitals in a major university hospital system from April 2009 to October 2010. This study was approved by the Human Subjects Protection Program.

Inclusion criteria were that the patients were 18 years or older who had existing central, peripheral, and arterial lines, or for whom such lines were being placed as part of their routine clinical care. Exclusion criteria were