SIGNA VITAE 2017; 13(SUPPL 1): 56-60

CVP vs. dynamic hemodynamic parameters as preload indicators in hemodynamically unstable patients after major surgery

TAJANA ZAH BOGOVIĆ , ANTONIO BULUM , PERO HRABAČ , MLADEN PERIĆ[1], DINKO TONKOVIĆ[1], DANIELA BANDIĆ PAVLOVIĆ[1], ROBERT BARONICA[4]

University of Zagreb, School of Medicine Šalata 3, 10 000 Zagreb
Department of Anesthesiology, reanimatology and intensive care
University hospital centre Zagreb, Kišpatićeva 12, 10000 Zagreb

Department for Diagnostic and Interventional Radiology,
University Hospital Dubrava

Croatian Institute for Brain Research, Šalata 12, 10000 Zagreb
Department of Anaesthesiology, reanimatology and intensive care
University hospital centre Zagreb, Kišpatićeva 12, 10000 Zagreb

ABSTRACT

Introduction. Adequate circulating blood volume is essential for the good outcome in postoperative patients. Therefore, the primary resuscitation question is how to assess the circulating volume. The aim of this study was to compare the central venous pressure (CVP) and dynamic LIDCO parameters as markers indicating preload in surgical patients.
Materials and Methods. This prospective study included 24 patients hospitalized after major surgery at the surgical intensive care unit of the University hospital Zagreb, Croatia. The patients were mechanically ventilated, without spontaneous breathing attempts and in sinus rhythm. Patients were divided into 2 groups, hemodynamically stable and hemodynamically unstable. The CVP was measured as a static parameter while the stroke volume variation (SVV) and pulse pressure variation (PPV) were measured as the dynamic parameters.
Results. Study groups were comparable in terms of gender, age and body mass index. The difference in the CVP between the hemodynamically stable (13,2±3,74 mmHg) and hemodynamically unstable group of patients (10,1±5,6 mmHg) was statistically insignificant (p=0,144). Differences in SVV (10,2±6,48% in stable compared to 18,8±7,04% in unstable group) and PPV (11,5±6,65% in stable compared to 18±6,32% in unstable group) were both statistically significant with p values of 0,005 and 0,022 respectively.
Conclusion. The study confirmed the inability of CVP to provide valid assessment of the preload as a reason for hemodynamic instability in comparison to dynamic LiDCOTMplus system parameters in mechanically ventilated major surgical patients.

Key Words: Blood Volume, Central Venous Pressure, Stroke Volume, Pulse Pressure

INTRODUCTION

The basic role of the cardiovascular system is to adequately supply the vital organs and peripheral tissues with oxygen and various nutrients that are both often deficient in patients hospitalized at the intensive care unit (ICU). Consequently, hemodynamic instability is common among these patients and what we are really worried about is the accompanying insufficient tissue perfusion (1). In order to prevent that from developing, quick, timely, and adequate medical interventions are required. However, the intervention is not possible without a proper assessment of the regional and peripheral tissue perfusion where adequate hemodynamic monitoring plays a crucial role. Hemodynamic optimization is a cornerstone in the management of critically ill patients and associated with improved outcome in the perioperative and intensive care setting (2,3). In hemodynamic optimization, fluid loading is considered the first step in the resuscitation and therefore the primary question is to assess the preload and whether the patient is volume responsive.
Measuring the central venous pressure (CVP), although being developed more than half a century ago, is still considered the procedure of choice in some intensive care units (ICU) (4). CVP is frequently used to make decisions regarding fluid management. Some clinical guidelines recommend using CVP as the end point of fluid resuscitation (5). Over the last decade there was a significant advancement in the technology of ICU monitoring with the introduction of many devices used for hemodynamic monitoring (6). In this context, newer methods are expected to measure the dynamic parameters, be less invasive, associated with less complications, easier to perform and, most importantly, to improve the clinical outcome of treatment. They all operate by measuring static and dynamic parameters of the cardiovascular system. One of the non-invasive systems for hemodynamic monitoring is the LiDCOTMplus system (LiDCO Ltd., Cambridge, United Kingdom). Apart from transesophageal monitoring, it is currently the first choice in non-invasive cardiac output measuring systems (7). The system uses an indicator dilution method and software analysis to measure the cardiac output and dynamic preload parameters stroke volume variation (SVV) and pulse pressure variation (PPV) of the patient (8). The goal of this study was to compare static (CVP) with dynamic (SVV, PPV) parameters in assessment of the preload.

MATERIALS AND METHODS

In this prospective non-randomized study we included 24 patients after major (abdominal or trauma) surgery. The patients were hospitalized at the surgical intensive care unit of the University hospital Zagreb, Croatia, from January 1st to November 15th 2014. Ethical approval was obtained from the institution's Ethics committee. The study included patients older than 18 years of age, mechanically ventilated (IPPV, Intermittent Positive Pressure Ventilation), without spontaneous breathing attempts, and in sinus cardiac rhythm. The exclusion criteria were history of cardiac arrhythmias, positive end-expiratory pressure (PEEP) >10 cmH2O, right ventricle dysfunction, pregnancy, BMI <15, sepsis, hyponatremia, anemia, hypoxemia, severe renal insufficiency (CrCl <30 mL/min) and ongoing lithium therapy. (9) We included patients at admission to ICU after surgery. During the study period all patients were analgosedated with sufentanyl and midazolam and relaxed with rocuronium bromide. All patients were mechanically ventilated (tidal volume 8 ml/kg) and ventilator settings were kept constant during the study period.

At admission to ICU the following variables were measured: heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressure (MAP), central venous pressure (CVP), pulse pressure variation (PPV), stroke volume variation (SVV), cardiac output (CO), cardiac index (CI), global oxygen delivery (DO2), oxygen consumption (VO2), oxygen extraction ratio (ERO2), mixed venous oxygen saturation (SVO2), systemic vascular resistance index (SVRI), and lactic acid. Patients were divided into 2 groups, hemodynamically stable and hemodynamically unstable. Hemodynamically unstable patients were defined as those with a mean arterial blood pressure (MAP) ≤65 mmHg. After LIDCO measurement, hemodynamically unstable patients were treated with volume and a vasoactive drug (norepinephrine) to maintain MAP≥65 mmHg. Both groups had comparable oxygenation (FiO2 0,4), SpO2≥94% and hemoglobin parameters within normal range.

Hemodynamic measurements were recorded in supine position with all transducers positioned at the level of fourth intercostal space in the mid-axillary line. Zero was measured at the atmospheric pressure. As with the measuring of the central venous pressure, dynamic parameters were measured with the LiDCOT-Mplus system in patients with a central venous catheter via the internal jugular or subclavian vein. The patients also had an intra-arterial line via one of the 3 peripheral arteries (radial, cubital or femoral). The arterial line was via a pressure transducer and a primary monitoring system (Dräger, Infinity Delta XL, Germany) connected to a secondary LiDCOTM monitor. Lithium chloride (LiCl) in the amount of 2 mL (0,3 mmol) was administered via a central or peripheral venous line. After the administration a lithium sensor, connected via a peripheral artery, we were able to detect changes in the concentration of lithium ions in the arterial blood over time. The LiDCOTM system then uses the information gathered from the arterial blood pressure waveform analysis, pulse pressure analysis, the lithium sensor, and the age, weight and height of the patient to calculate a range of hemodynamic parameters via software analysis. (10) The values of all observed parameters were compared to normal means and ranges for the corresponding hemodynamic parameters for adults (Table 1) (11,12).

Analyses were done with the STATISTICA software package v12 (StatSoft, Inc. (2014). Most of the data are reported as mean ± SD or percentage (%). The Kolmogorov-Smirnov test was used to assess normality of distribution and corresponding non-parametric (Mann-Whitney U test, Kruskal-Wallis ANOVA) and parametric (Student's t-test, ANOVA) tests were employed in subsequent analysis. A p value under 0.05 was considered as statistically significant.

RESULTS

Demographic and clinical characteristics of the hemodynamically stable and hemodynamically unstable groups of patients are presented in Table 2. Patients were comparable between hemodynamically stable and unstable groups in terms of gender (p=0,169; chi-square test with Yates correction) and BMI (p=0,395; t-test), while age difference showed borderline statistical significance (p=0,079; t-test). The difference in the CVP between the hemodynamically stable (13,2±3,74 mmHg) and hemodynamically unstable group of patients (10,1±5,6 mmHg) was statistically insignificant (p=0,144; t-test). The hemodynamically stable group compared to hemodynamically unstable group showed statistically significant different values of the SVV (10,2±6,48% in stable group compared to 18,8±7,04% in unstable group) and PPV (11,5±6,65% in stable group compared to 18±6,32% in unstable group) with p values of 0,005 and 0,022 respectively. Furthermore, the values of the DO2 also showed a statistically significant difference in the hemodynamically stable group (551,7±178,92 mL/min/m2 in comparison to the hemodynamically unstable group of patients (321±105,31 mL/min/m2) with a p value of <0,001. Similar results were obtained for the CI (4,1±1,35 L/min/m2 for the hemodynamically stable and 2,3±0,71 L/min/m2 for the hemodynamically unstable group of patients) with a p value of <0,001. CO values were also statistically significant different (7,9±2,47 L/min for the hemodynamically stable and 4,8±1,46 L/min for the hemodynamically unstable group of patients) with a p value of <0,001. Differences in the value of SvO2 (74,9±7,01 % for the hemodynamically stable and 59±14,41 % for the hemodynamically unstable group of patients) were also statistically significant with a p value of 0,003. The differences between the values of the blood lactates concentration (1,5±0,85 mmol/L for the hemodynamically stable and 4,2±1,99 mmol/L for the hemodynamically unstable group of patients) were also statistically significantly different with a p value of <0,001 (Table 2). Body mass index, (BMI); Central venous pressure, (CVP); Pulse pressure variation, (PPV); Stroke volume variation, (SVV); Cardiac output, (CO); Cardiac Index, (CI); Global oxygen delivery, (DO2); Oxygen extraction ratio, (ERO2); Oxygen consumption, (VO2); Mixed venous oxygen saturation, (SvO2); Systemic vascular resistance index, (SVRI); Intra-thoracic blood volume index, (ITBVI).

Independent Student t-test was used for obtaining statistical difference between groups, p values below 0.05 (<0,05) were considered statistically significant.

Table 1. Normal means and ranges from the literature for hemodynamic parameters observed in our study.

Parameter	Normal range in this study
Hemoglobin(Hb)	120-175 g/L
Heart rate (HR)	60-100
Arterial blood pressure (BP)	Systolic: 90-140 mmHg
	Diastolic: 60-90 mmHg
Mean arterial pressure (MAP)	70-105 mmHg
Central venous pressure (CVP)	3-8 mmHg
Pulse pressure variation (PPV)	<10% unlikely to be preload responsive
	>13-15% likely to be preload responsive
Stroke volume variation (SVV)	<10% unlikely to be preload responsive
	>13-15% likely to be preload responsive
Cardiac output (CO)	4.0 - 8.0 l/min
Cardiac index (CI)	2.5 - 4.0 l/min/m2
Global oxygen delivery (DO2)	950-1150 ml/min
Oxygen extraction ratio (ERO2)	22 – 30 %
Oxygen consumption (VO2)	200 -250 ml/min
Mixed venous oxygen saturation (SvO2)	60 – 80 %
Lactic acid	0.5 - 2.2 mmol/L
Systemic vascular resistance index (SVRI)	1970 - 2390 dynes • sec/cm5/m2
Intra-thoracic blood volume index (ITBVI)	850 to 1000 ml/m2

Table 2. Demographic and clinical characteristics of the hemodynamically stable and hemodynamically unstable groups of patients.

Parameter	Hemodynamically stable	Hemodynamically unstable	P value
Age (years)	58 (15,12)	70,2 (17,12)	0,080
BMI (kg/m2)	24,6 (1,33)	26 (5,19)	0,395
CVP (mmHg)	13,2 (3,74)	10,1 (5,6)	0,144
LiDCO: SVV (%)	10,2 (6,48)	18,8 (7,04)	0,005
LiDCO: PPV (%)	11,5 (6,65)	18 (6,32)	0,022
SvO2 (%)	74,9 (7,01)	59 (14,41)	0,003
Lactic acid (mmol/L)	1,5 (0,85)	4,2 (1,99)	<0,001
DO2 (ml/min/m2)	551,7 (178,92)	321 (105,31)	<0,001
ERO2 (%)	49,3 (24,59)	41,2 (14,45)	0,335
CI (l/min/m2)	4,1 (1,35)	2,3 (0,71)	<0,001
CO (l/min)	7,9 (2,47)	4,8 (1,46)	<0,001
SVRI (dynes · sec/cm5/m2)	1557,5 (392,14)	1730,5 (707,35)	0,496
ITBVI (mL/m2)	1492,3 (461,66)	1712,1 (665,58)	0,470

DISCUSSION

The cornerstone of managing patients in the ICU is assessing their preload and identifying those who are more likely to benefit from fluid loading. The importance of this study lies in the fact that the major surgical postoperative patients are particularly at risk for reduced preload. Impaired preload occurs due to many factors such as decreased preoperative intravascular volume due to fasting, vasodilatative effect of anesthetics, long and extensive operations with fluid losses and shifts. A suboptimal supply of oxygen and nutrients to vital organs and peripheral tissues in postoperative patients leads to possible long-term consequences such as ischemic-reperfusion injury, infection and even death.

We have demonstrated that dynamic parameters (SVV, PPV) are more adequate than static parameters (CVP). In this study, CVP did not show volume deficit in hemodynamic unstable patients in our group of postoperative major surgical patients.

Traditionally CVP is still used to guide fluid therapy. A survey of European intensivists a few years ago reported that 90% of doctors still use CVP (13). The concept for using CVP to guide fluid therapy arrives

from CVP reflecting intravascular volume. It is still widely believed that patients with a low CVP are volume depleted while patients with a high CVP are volume overloaded. This can be misleading as shown in this study.

In this study the hemodynamically stable patients had a statistically insignificantly higher CVP (13,2 ± 3,74 mmHg) than hemodynamically unstable patients (10,1 ± 5,6 mmHg), (p=0,144). This finding is in agreement with a large number of studies. A rising number of studies claim that the correlation between CVP and the circulating blood volume is lower than previously thought. (14, 15) Additional studies also show weaknesses of the static hemodynamic parameters such as CVP to assess not only the circulating blood volume but also the patient's response to volume overload especially in critically ill patients (16,17).

The present study demonstrated that dynamic parameters such as SVV and PPV measured using the LiDCOTMplus system could predict decreased preload in mechanically ventilated patients, which is in agreement with other reports. (18, 19, 20) The values of the blood lactates were also different between the two groups which has a considerable predictive value for postoperative patients hospitalized in the ICU, which is in agreement with other studies (21).

Our study had some limitations, primarily the relatively low number of patients in the sample. The reason being that a small number of patients are being monitored by LiDCOTM because of the need for muscular relaxation and inability of patients to breathe on their own, which is not a common practice in our ICU. Therefore, the sample size is small. In the future, we will plan a study with a larger number of included patients.

In conclusion, although some guidelines today still advice the use of CVP in assessment of preload, dynamic parameters should be used. The study confirmed the inability of CVP to provide valid assessment of the preload as a reason for hemodynamic instability in comparison to dynamic LiDCOTMplus system parameters in mechanically ventilated major surgical patients. It was shown that the hemodynamically unstable patients had signs of hypoperfusion resulting in a reduced DO2 and increased lactic acid. Therefore, in patients who are postoperatively mechanically ventilated and relaxed, according to our results, SVV and PPV monitored by LiDCOTM are good options to choose for preload assessment due its minimal invasiveness.

REFERENCES

1. Wadhwa J, Sood R. Multiple organ dysfunction syndrome. Natl Med J India 1997; 10:277-82.
2. Lees N, Hamliton M, Rhodes A: Clinical review: Goal-directed therapy in high risk surgical patients. Crit Care 2009,13:231.
3. Funk D, Sebat F, Kumar A: A systematic approach to the early recognition and rapid administration of best practice therapy in sepsis and septic shock. Curr Opin Crit Care 2009,15:301-7.
4. Swan HJ, Ganz W, Forrester J et al. Catheterization of the heart in man with use of a flow-directed balloon-tipped catheter. N Engl J Med 1970;283:447-51.
5. Dellinger RP, Carlet JM, Masur H et al. Surviving Sepsis Campaign guidelines for management of severe sepsis and septic shock. Crit Care Med 2004;32:858–73.
6. Button D, Weibel L, Reuthebuch O, Genoni M, Zollinger A, Hofer CK. Clinical evaluation of the FloTrac/VigileoTM system and two established continuous cardiac output monitoring devices in patients undergoing cardiac surgery. Br. J. Anaesth 2007; 99:329-36.
7. Dhillon P, Singh KS, Krishnan K, Mallick AA. National Survey of Current Trends in Cardiac Output Monitoring in the UK Intensive Care Units. Anaesthesiology 2008; 109:1451.
8. Pearse RM, Ikram K, Barry J. Equipment review: An appraisal of the LiDCO™ plus method of measuring cardiac output. Crit Care Med, 2008;8:190.
9. Lim W, Dentali F, Eikelboom JW, Crowther MA. Meta-analysis: low-molecular-weight heparin and bleeding in patients with severe renal insufficiency. Ann Intern Med 2006;144:673-84.
10. Rhodes A, Sunderland R. Arterial Pulse Power Analysis: The LiDCOTMplus System. In: Michael R. Pinsky MR, Payen D, editors. Functional hemodynamic monitoring, Springer Berlin Heidelberg; 2005:183-192.
11. Dabbagh A, Esmailian F, Aranki SF. Postoperative critical care for cardiac surgical patients. Heidelberg: Springer; 2014.
12. Marik, PE. Hemodynamic parameters to guide fluid therapy. Transfusion Alternatives in Transfusion Medicine, 2011;11:102–12.
13. Kastrup M, Markewitz A, Spies C, Carl M, Erb J, Grosse J, et al.: Current practice of hemodinamic monitoring and vassopresor and inotropic therapy in post-operative cardiac surgery patients in Germany: results from a postal survey. Acta Anaesthesiol Scand 2007;51:347-58.
14. Kumar A, Anel R, Bunnell E, Habe K, Zanotti S, Marshall S, et al. Pulmonary artery occlusion pressure and central venous pressure fail to predict ventricular filling volume, cardiac performance, or the response to volume infusion in normal subjects. Crit Care Med 2004;32:691-9.
15. Marik PE, Baram M, Vahid B. Does central venous pressure predict fluid responsiveness? A systematic review of the literature and the tale of seven mares. CHEST J 2008;134:172-8.
16. Bakker J, Coffernils M, Leon M, Gris P, Vincent J. Blood lactate levels are superior to oxygen-derived variables In predicting outcome in human septic shock. CHEST 1991; 99:956-62.
17. Forrester JS, Diamond G, McHugh TJ, Swan HJ. Filling pressures in the right and left sides of the heart in acute myocardial infarction: a reappraisal of central-venous-pressure monitoring. N Engl J Med 1971;285:190-3.
18. Benes J, Chytra I, Altmann P, Hluchy M, Kasal E, Svitak R, et al. Intraoperative fluid optimization using stroke volume variation in high risk surgical patients: results of prospective randomized study. Crit Care 2010;14:R118.

19. McGee WT. A simple physiologic algorithm for managing hemodynamics using stroke volume and stroke volume variation: physiologic optimization program. J Intensive Care Med 2009;24:352-60.

20. Marik PE, Cavallazzi R, Vasu T, Hirani A. Dynamic changes in arterial waveform derived variables and fluid responsiveness in mechanically ventilated patients: a systematic review of literature. Crit Care Med 2009,37:2642-7.

21. Shippy C, Appel P, William C. Reliability of clinical monitoring to assess blood volume in critically ill patients. Crit Care Med 1984;2:107-12.