Annals of Cardiac Anaesthesia

Year : 2016 | **Volume** : 19 | **Issue** : 3 | **Page** : 405--409

Comparison between noninvasive measurement of central venous pressure using near infrared spectroscopy with an invasive central venous pressure monitoring in cardiac surgical Intensive Care Unit

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Abstract

Introduction: Central venous pressure (CVP) measurement is essential in the management of certain clinical situations, including cardiac failure, volume overload and sepsis. CVP measurement requires catheterization of the central vein which is invasive and may lead to complications. The aim of this study was to evaluate the accuracy of measurement of CVP using a new noninvasive method based on near infrared spectroscopy (NIRS) in a group of cardiac surgical Intensive Care Unit (ICU) patients. **Methodology:** Thirty patients in cardiac surgical ICU were enrolled in the study who had an *in situ* central venous catheter (CVC). Sixty measurements were recorded in 1 h for each patient. A total of 1800 values were compared between noninvasive CVP (CVPn) obtained from Mespere VENUS 2000 CVP system and invasive CVP (CVPi) obtained from CVC. **Results:** Strong positive correlation was found between CVPi and CVPn ($R = 0.9272$, $P < 0.0001$). Linear regression equation - CVPi = 0.5404 + 0.8875 × CVPn ($r^2 = 0.86$, $P < 0.001$), Bland-Altman bias plots showed mean difference ± standard deviation and limits of agreement: –0.31 ± 1.36 and – 2.99 to + 2.37 (CVPi-CVPn). **Conclusion:** Noninvasive assessment of the CVP based on NIRS yields readings consistently close to those measured invasively. CVPn may be a clinically useful substitute for CVPi measurements with an advantage of being simple and continuous. It is a promising tool for early management of acute state wherein knowledge of CVP is helpful.

How to cite this article:
Sathish N, Singh NG, Nagaraja P S, Sarala B M, Prabhushankar C G, Dhananjaya M, Manjunatha N. Comparison between noninvasive measurement of central venous pressure using near infrared spectroscopy with an invasive central venous pressure monitoring in cardiac surgical Intensive Care Unit.Ann Card Anaesth 2016;19:405-409

How to cite this URL:
Sathish N, Singh NG, Nagaraja P S, Sarala B M, Prabhushankar C G, Dhananjaya M, Manjunatha N. Comparison between noninvasive measurement of central venous pressure using near infrared spectroscopy with an invasive central venous pressure monitoring in cardiac surgical Intensive Care Unit. Ann Card Anaesth [serial online] 2016 [cited 2016 Jul 12];19:405-409
Available from: http://www.annals.in/text.asp?2016/19/3/405/185520

Full Text

INTRODUCTION

Central venous pressure (CVP) measurement is essential for the assessment of preload and volume status [1] in perioperative management of cardiac patients and Intensive Care Unit (ICU). CVP estimation guides in the management of critically ill patients with congestive cardiac failure, cardiogenic shock, sepsis and others. [2],[3] Clinical estimation of CVP may not be reliable when compared with invasive monitoring of CVP using a catheter in superior vena cava (SVC) and right atrium (RA) junction through an internal jugular vein (IJV) or subclavian vein (SCV) approach. [4] Invasive placement of CVP catheter is time-consuming and complications associated with it are not uncommon. [5] Hence, a quick and reliable tool for measuring CVP without central venous access might be helpful.

Previous studies have reported the use of noninvasive and minimally invasive methods to assess CVP. However, noninvasive methods lack the accuracy and precision for routine use, and minimal invasive techniques which include cannulating peripheral limb veins, external jugular vein (EJV) have shown mixed results when compared with invasive CVP (CVPi). [6],[7],[8],[9],[10],[11],[12],[13],[14],[15]

In the present era of ultrafast tracking in cardiac surgery, there is a need for a reliable noninvasive CVP (CVPn) monitor mostly in high dependency units where the patients are without in situ CVPi catheters. Hence, the purpose of this study was to evaluate the correlation, accuracy, and agreement for measuring CVP using a new noninvasive method-Mespere VENUS 2000 CVP system based on near-infrared spectroscopy (NIRS) in a group of cardiac surgical ICU patients.

METHODOLOGY

After obtaining Institutional Ethics Committee clearance thirty patients who were admitted to postoperative cardiac surgical ICU were enrolled in the study. Informed consent was obtained from these patients before the procedure in postoperative cardiac surgical ICU. Inclusion criteria were patients above 18 years of age who had an indwelling central venous catheter (CVC) placed either in IJV or SCV, during the perioperative period of cardiac surgery. Exclusion criteria were low cardiac output patients, allergic to medical grade adhesive tape and EJV thrombosis.

CVC was placed in each patient after induction of anesthesia into either IJV or SCV (CVPi), which was used for continuous monitoring during perioperative period. CVC was connected to a transducer that was calibrated at the level of the patient's RA. The tubing and transducer were inspected to ensure that there were no technical issues or air bubbles that could cause erroneous recordings.

Mespere VENUS 2000 CVP system (CVPn) consists of five components - CVP sensor, CVP sensor patch, reference patch, docking station and a display monitor [Figure 1]a and b. CVP sensor consists of light emitting diode/photodetector (LED/PD), sensor tube with a stopcock cap and connecting cables. It is to be placed superficially on EJV with the help of sensor patch. Reference patch holder is used to connect reference patch to sensor tube of the MESPERE VENUS 2000 CVP sensor. Reference patch is placed on the reference point (zero reference), i.e., phlebostatic axis (PA) or sternal angle of Louis. PA is used to estimate the position of SVC-RA. It is commonly used as the zero reference point when using a CVP catheter which is at the intersection of the fourth intercostal space and the mid-axillary line. Docking station consists of two points required for the calibration of the CVP sensor. Display monitor shows CVP either in centimeters of H 2 O or mmHg, pulse strength index (which should be >1), plethysmographic waveform and trend display area.{Figure 1}

The MESPERE VENUS 2000 CVP sensor was placed on EJV after calibration, with the patient inclined between 15° and 30° and head slightly tilted to left. Meniscus of the liquid present in the sensor tube should be between the two clips of the reference patch holder. This reference patch holder was later stuck on to reference patch at the PA. Care to be taken to see that stopcock present at the end of sensor tube is kept open during measurement of CVP. Later, sensor was connected using cables to the display monitor. Display monitor was switched on, which displayed the CVP number and plethysmographic waveform.

Simultaneous CVP measurements were obtained from CVC placed invasively (CVPi) using Drager Infinity Delta XL monitor and from Mespere VENUS 2000 CVP system (CVPn) from thirty patients. A total of sixty values were recorded per patient over a period of 60 min. No clinical decision was made on the values obtained from CVPn.

Statistical analysis was done using MedCalc version 12.2.1.0. (Ostend, Belgium). CVPi and CVPn values were analyzed by Pearson test of correlation (R) to determine the strength of relationship between the values. Correlation coefficient values range from negatively correlated (−1) to uncorrelated (0) to positively correlated (+1) (0.0 is no association, +0.2 is weakly positive, +0.5 is moderately positive, +0.8 is strongly positive, +1.0 is perfectly positive).

Linear regression analysis was used to calculate the regression equation between CVPi and CVPn. The coefficient of determination (r2) is the proportion of variation in the dependent variable explained by a linear regression model using the independent variable. For all analysis, $P < 0.05$ was considered statistically significant.

Bland-Altman analysis [16] was used to find the agreement between CVPi and CVPn. The (CVPi-CVPn) difference versus the average value ([CVPi + CPVn]/2) was plotted. Means, standard deviations (SDs), and 95% prediction intervals (limits of agreement [LOA]) were evaluated. The LOA was calculated as a bias ±2 SD.

RESULTS

A total of thirty patients (22 males and 8 females) were included in the study. The average age being 43 ± 17 years (range from 18 to 73 years). Of thirty patients, three patients were postoperative closure of atrial septal defect, five aortic valve replacement, ten coronary artery bypass surgery, eight mitral valve replacement and four patients were preoperative moderate to severe tricuspid regurgitation patients with mitral valve involvement.

A total of 1800 values were analyzed (i.e., 60 values per subject). CVPi value ranged from 2 to 19 mmHg. A strong positive correlation was found between CVPi and CVPn with R = 0.9272 (confidence interval 0.92-0.93) and was statistically significant ($P < 0.0001$). Linear regression equation was derived to estimate CVPi values from CVPn values, i.e. $CVPi = 0.5404 + 0.8875 \times CVPn$ ($r^2 = 0.86$, $P < 0.001$) [Figure 2]a. Bland-Altman bias plots showed mean difference ± SD and LOA: −0.31 ± 1.36 and −2.99 to + 2.37 (CVPi - CVPn). This implies that there is 95% chance of predicted CVPi value to lie within LOA of CVPn value [Figure 2]b.{Figure 2}

DISCUSSION

The principle of NIRS has been widely used in various monitoring devices during cardiac surgery such as Swan-Ganz monitoring catheter, SpO 2 plethysmograph and continuous noninvasive arterial pressure smart pod. [17] Mespere VENUS 2000 CVP system which is used in this study to monitor CVPn is also based on NIRS technology. It uses single wavelength LED and PDs to detect changes in the blood volume. It detects the jugular venous pulse (JVP) in the neck and the height of the JVP column relative to the SVC which requires that the patient lying at a proper inclination angle which aligns JVP pulse in the range of the sensor.

The CVPn could play a promising role in postoperative cardiac patients due to its ability of being reliable and real-time monitoring of CVP. This could further lead to the development of novel protocol for the treatment of patients with fluid sensitive conditions. The majority of other noninvasive measures of CVP, such as ultrasound of the inferior vena cava or the passive leg raise technique are not continuous measures, dependent on the clinician skill and are subjective. However, there are methods to monitor CVP continuously but are invasive. In this study, CVPn monitor is simple, continuous, and reproducible.

Estimation of CVP by physical examination of JVP pulse is mostly done by an experienced clinician. Certain conditions such as tricuspid regurgitation, atrial fibrillation wherein waveforms of JVP are altered could mislead the clinician for an accurate measurement of CVP. [18]

Recent few studies have shown good correlation between invasively measured peripheral venous pressures (PVPs) and CVP. [19],[20],[21] However, there are conflicting results exhibited between PVP and CVP.

Kumar et al. [22] showed poor correlation (R = 0.092 at baseline and R = 0.038 at passive leg raise) and unacceptable LOA (−1.571-11.780 at baseline and −3.180-11.35 at passive leg raise) between invasive PVP and CVP, in group of patients where CVP was <10 mmHg. Thalhammer et al. [14] showed acceptable correlation (R = 0.85) and acceptable bias (−0.7) and LOA (−8.7-8.7) between noninvasive PVP and CVPi measured at heart level. In the present study, mean difference and LOA were −0.31 and −2.99 to +2.37, respectively. Peripheral measurement might be inappropriate in patients who have inadequate visible veins or as a result of multiple venous punctures. It is also noncontinuous with possibility of observers bias when measured using sonographic technique.

Ward et al. [23] have studied impedance-based technique for the assessment of CVP and showed mean difference of −0.26 mmHg, LOA of −2.7-2.2, with correlation value of 0.95. The present study showed similar results but having an advantage of being continuous measurement.

A clinically acceptable LOA was defined as 4 cm of H 2 O (or 3 mmHg) between CVP and PVP, which was comparable with the present study. [20] PVP measured at cephalic, basilic, and brachial veins had a good correlation with SVC due to low resistance to venous return. [13]

In a similar manner, EJV is in continuity with SVC and also reflects the SVC pressure.

Xing et al. [24] reported a new method for noninvasive quantification of CVP, where center of the RA and both cephalic, basilic and brachial veins had a good correlation. Their study showed bias of 0.22 mmHg with LOA of −2.16-2.59 during preoperative measurement which was comparable to the present study.

Noninvasive continuous monitoring of CVP could dictate the management strategy in HDU where invasive lines are not available. Since it adopts NIRS technology it does not require much expertise to interpret the values.

CONCLUSION

CVPn based on NIRS technology is a simple, continuous, reliable, and reproducible method to estimate CVP in postoperative cardiac surgical patients.

Acknowldgement

The authors thank Mespere LifeSciences Inc. Waterloo, Ontario CANADA (Phoenix medicare Pvt. Ltd, India) for providing the technical equipment (Mespere VENUS 2000 CVP System) needed for this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 Magder S. Central venous pressure monitoring. Curr Opin Crit Care 2006;12:219-27.
2 Dellinger RP, Levy MM, Carlet JM, Bion J, Parker MM, Jaeschke R, *et al*. Surviving sepsis campaign: International guidelines for management of severe sepsis and septic shock: 2008. Crit Care Med 2008;36:296-327.
3 Stevenson LW, Perloff JK. The limited reliability of physical signs for estimating hemodynamics in chronic heart failure. JAMA 1989;261:884-8.
4 McGee SR. Physical examination of venous pressure: A critical review. Am Heart J 1998;136:10-8.
5 Schroeder RA, Barbeito A, Bar Yosef S, Mark JB. Miller's Anesthesia. 7 th ed. New York: Churchill Livingstone Inc.; 2009.
6 Baumann UA, Marquis C, Stoupis C, Willenberg TA, Takala J, Jakob SM. Estimation of central venous pressure by ultrasound. Resuscitation 2005;64:193-9.
7 Charalambous C, Barker TA, Zipitis CS, Siddique I, Swindell R, Jackson R, *et al*. Comparison of peripheral and central venous pressures in critically Ill patients. Anaesth Intensive Care 2003;31:34-9.
8 Marcelino P, Fernandes AP, Marum S, Ribeiro JP. Non-invasive evaluation of central venous pressure by echocardiography. Rev Port Cardiol 2002;21:125-33.
9 Ritter S, Tani LY, Shaddy RE, Day RW, Orsmond GS, Pagotto LT, *et al*. Can Doppler systemic venous flow indices predict central venous pressure in children? Echocardiography 2000;17:127-32.
10 Bloch KE, Krieger BP, Sackner MA. Noninvasive measurement of central venous pressure by neck inductive plethysmography. Chest 1991;100:371-5.
11 Jue J, Chung W, Schiller NB. Does inferior vena cava size predict right atrial pressures in patients receiving mechanical ventilation? J Am Soc Echocardiogr 1992;5:613-9.
12 Lipton B. Estimation of central venous pressure by ultrasound of the internal jugular vein. Am J Emerg Med 2000;18:432-4.
13 Ricksten SE, Medegård A, Curelaru I, Gustavsson B, Linder LE. Estimation of central venous pressure by measurement of proximal axillary venous pressure using a "half-way" catheter. Acta Anaesthesiol Scand 1986;30:13-7.
14 Thalhammer C, Aschwanden M, Odermatt A, Baumann UA, Imfeld S, Bilecen D, *et al*. Noninvasive central venous pressure measurement by

controlled compression sonography at the forearm. J Am Coll Cardiol 2007;50:1584-9.
15 Briscoe CE. A comparison of jugular and central venous pressure measurements during anaesthesia. Br J Anaesth 1973;45:173-8.
16 Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1:307-10.
17 Jagadeesh AM, Singh NG, Mahankali S. A comparison of a continuous noninvasive arterial pressure (CNAP™) monitor with an invasive arterial blood pressure monitor in the cardiac surgical ICU. Ann Card Anaesth 2012;15:180-4.
18 Rizkallah J, Jack M, Saeed M, Shafer LA, Vo M, Tam J. Non-invasive bedside assessment of central venous pressure: Scanning into the future. PLoS One 2014;9:e109215.
19 Amar D, Melendez JA, Zhang H, Dobres C, Leung DH, Padilla RE. Correlation of peripheral venous pressure and central venous pressure in surgical patients. J Cardiothorac Vasc Anesth 2001;15:40-3.
20 Desjardins R, Denault AY, Bélisle S, Carrier M, Babin D, Lévesque S, *et al*. Can peripheral venous pressure be interchangeable with central venous pressure in patients undergoing cardiac surgery? Intensive Care Med 2004;30:627-32.
21 Tobias JD, Johnson JO. Measurement of central venous pressure from a peripheral vein in infants and children. Pediatr Emerg Care 2003;19:428-30.
22 Kumar D, Ahmed SM, Ali S, Ray U, Varshney A, Doley K. Correlation between central venous pressure and peripheral venous pressure with passive leg raise in patients on mechanical ventilation. Indian J Crit Care Med 2015;19:648-54.
23 Ward KR, Tiba MH, Draucker GT, Proffitt EK, Barbee RW, Gunnerson KJ, *et al*. A novel noninvasive impedance-based technique for central venous pressure measurement. Shock 2010;33:269-73.
24 Xing CY, Liu YL, Zhao ML, Yang RJ, Duan YY, Zhang LH, *et al*. New method for noninvasive quantification of central venous pressure by ultrasound. Circ Cardiovasc Imaging 2015;8. pii: E003085.