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Peripheral Venous Pressure as a Predictor of Central Venous Pressure during Neurosurgical Procedures.

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ABSTRACT

Background: Central venous pressure (CVP) measurement is a reliable method for evaluating intravascular volume status and cardiac function, but it is an invasive method that results in some well known complications. To compare CVP with peripheral venous pressure (PVP) transduced from a peripheral intra venous catheter and to assess the reliability of peripheral venous pressure (PVP) as a predictor of central venous pressure (CVP) in the setting of rapidly fluctuating hemodynamics during neurosurgical procedures. **Methods**: Twenty five adult patients with ASA 1and 2 undergoing craniotomy procedures lasting more than three hours were studied in this prospective clinical trial. A subclavian central vein catheter and a 18-G peripheral intravenous catheter over forearm dedicated to measuring PVP were placed in all patients after standard general endotracheal anaesthesia induction and institution of mechanical ventilation. Peripheral venous pressure and CVP were recorded every 5 minutes and/or during predetermined, well-defined surgical events. Simultaneous invasive mean arterial pressure, urine output were also monitored. **Results:** Peripheral venous pressure correlated highly with CVP in every patient, and the overall correlation among all patients calculated using a random-effects regression model was r = 0.893 (P b 0.0001). A Bland-Altman analysis used to determine the accuracy of PVP in comparison to CVP yielded a bias of - 4.12 mmHg and a precision of 1.99 mmHg. **Conclusion**: Our study confirms that PVP correlates with CVP even under adverse hemodynamic conditions in patients undergoing major neurosurgical procedures.

Keywords: Central Venous Pressure, Neurosurgical Procedures, Venous Pressure.

INTRODUCTION

The main functions of the venous system are to return blood to the heart from the periphery and to serve as a capacitance to maintain filling of the heart. Veins contain approximately 70% of total blood volume compared with 18% in arteries and only 3% in terminal arteries.[1] Veins are the most compliant vasculature in the human body and are easily able to accommodate changes in the blood volume. Therefore, they are called capacitance vessels and serve as a reservoir of blood that easily and immediately changes volume in it to maintain filling pressure in the right heart.

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Estimation of Central Venous Pressure (CVP) is an important tool in the assessment of a patient's volume status. A number of techniques have been used over the years to estimate CVP, including inspection of jugular venous pulsations in the neck, measurement of jugular venous height, and detection of hepatojugular reflux. These indirect methods are unreliable in surgical or critically ill patients and have largely been supplanted by direct measurement of CVP through catheters placed into the great vessels of the thorax, most commonly through the internal jugular, subclavian, femoral veins or antecubital vein.[2]

Internal jugular catheterization can be difficult in morbidly obese patients, in whom the landmarks of the neck are often obscured. Subclavian venous catheterization should be avoided in patients with severe hypoxemia, because the complication of pneumothorax is more likely to occur at this site and is less likely to be tolerated by such patients. Femoral catheterization should be avoided in patients who have grossly contaminated inguinal regions because femoral insertion places these patients at high risk for the development of catheter-related infections.

Central venous pressure (CVP) is used clinically to assess blood volume and cardiac function during surgery. In the absence of right ventricular and pulmonary disease, and assuming static pressure/volume relationships, CVP has been shown to correlate with left ventricular preload.[3] Although CVP is not a direct indicator of volume status, it reflects the ratio of intravascular volume to vascular compliance. Under most circumstances, changes in CVP reflect changes in blood volume, and therefore, CVP measurement is useful as a trend monitor.

Correct interpretation of CVP values and changes in these values demand correct positioning of the transducer at the level of zero pressure all the time; periodic rezeroing of the transducer is also needed. Normal CVP per se does not necessarily reflect normovolemia. The body can mobilize and pool blood volume from compliant splanchnic veins. Loss of 10–12% of blood volume does not decrease CVP. Normal CVP may reflect normovolemia or compensated hypovolemia (up to 600–700 ml of blood loss) or compensated hypervolemia[1]: An excessive infusion of fluid may be compensated by accumulation of blood in the splanchnic veins without any change in central hemodynamics including CVP. Combination of factors that have a tendency to decrease and increase CVP may lead to a normal value of CVP despite serious hemodynamic derangements, e.g., the combination of heart failure and hypovolemia, or hypovolemia in the Trendelenburg position. So CVP has to be interpreted carefully.

The majority of complications arising are classically divided into mechanical, infectious, and thromboembolic.[4] The majority of mechanical complications are vascular injuries. Unintended arterial puncture with hematoma formation is the most frequent complication of both internal-jugular and subclavian-vein catheterization.[5] Real-time ultrasound imaging, when compared with the standard landmark technique, has been shown to decrease complications and reduce the number of insertion attempts during internal jugular-vein cannulation.[6,7]

Infectious complications of central venous catheterization remain common cause of significant morbidity and mortality, and are costly to treat. Recommendations regarding the prevention of infections related to central venous catheters can be summarized as follows:[7,8]

(1) hand hygiene
(2) maximal barrier precautions
(3) chlorhexidine skin antisepsis
(4) optimal catheter site selection (the subclavian vein is the preferred site)
(5) use of antibiotic-impregnated catheters
(6) use of catheters having less number of lumen
(7) daily review of line necessity to allow prompt removal of unnecessary catheters.

Patients who require central venous catheterization are at high risk for catheter-related thrombosis. Used routinely, ultrasonography with color Doppler imaging detects venous thrombosis in 33 percent of patients in medical intensive care units[9] and in approximately 15% of these patients the thrombosis is catheter-related. The risk of catheter-related thrombosis varies according to the site of insertion. In one trial, catheter-related thrombosis occurred in 21.5% of the patients with femoral venous catheters and in 1.9 percent of those with subclavian venous catheters ($p<0.001$).[4,7,9] Subclavian venous catheterization carries the lowest risk of catheter-related thrombosis. The clinical importance of catheter-related thrombosis remains undefined, although all thromboses have the potential to embolize.

Above mentioned complications of CVP measurement techniques necessitate non-invasive and reliable alternatives for this technique. In rare circumstances, where attempts to obtain central venous access fails, or it may not be possible during surgery because of patient positioning or inaccessibility under surgical drapes, this reliable alternative technique is useful.

Peripheral venous pressure (PVP) reflects an “upstream” venous variable that is coupled to CVP by a continuous column of blood.[10] During the 1940s, it was demonstrated that the pressure in the venous system of the upper extremity was only slightly higher than right atrial pressure. The venous return concept originally described by Guyton et al. is based on the existence of a pressure gradient between the periphery and the right atrium.[11] The gradient is the difference between mean systemic pressure and CVP. This gradient determines venous return. The concept of venous return implies that PVP must be greater than CVP to allow the blood to circulate towards the heart.

Peripheral veins, unlike central veins, have valves that may interrupt the continuous column of blood between the right atrium and the peripheral vein. Such valves are, by definition, open during steady state venous flow, and should therefore not disrupt fluid continuity between the two sites.[10] Peripheral veins are also thin walled and may be more easily subjected to compression and occlusion by the surrounding soft tissues. However, a correlation between CVP and PVP has been reported in both humans and animals under experimental conditions.

Peripheral venous pressure (PVP) monitoring via peripheral intravenous catheter in the arm has been described to be very safe and convenient with the easy accessibility and suggested as a comparable alternative to CVP measurement.[3,10,12-15] Given that central cannulation places the patients at risk for arterial puncture, pneumothorax, hemothorax, infection, thrombosis and even death, this alternative, minimally invasive monitor is specially appealing.

Neurosurgical patients undergoing craniotomy are at risk for significant blood loss and hemodynamic changes while under anaesthesia. A portion of that risk is associated with the surgery itself, and the remainder is because of the effects of anaesthetics, mechanical ventilation, and positional changes on cardiac function, relative blood volume, and vascular tone. Central venous pressure (CVP) monitoring is widely used especially in patients with decreased cardiovascular reserve, with risk of air emboli and expected bleeding. As various previous studies have been demonstrated that CVP trends well correlate with PVP trends in surgical patients we tested the same hypothesis in major neurosurgical patients. We tested the hypothesis that PVP values are easily obtained, and closely correlated with CVP trends in a variety of major neurosurgical procedures, patient positions, and degrees of hemodynamic instability.

Objective

To asses the reliability of peripheral venous pressure (PVP) as a predictor of central venous pressure (CVP) in the setting of fluctuating hemodynamics during neurosurgical procedures.

MATERIALS AND METHODS

After obtaining institutional ethical committee approval, twenty five patients undergoing elective craniotomy were included in the study. All patients were evaluated before surgery, and written informed consent was obtained during this visit.

After attaching standard monitors (ECG, NIBP, SPO2) patients were induced with usual general anaesthetic technique. Central vein catheter (certofix mono 16G) was placed through right subclavian approach. Arterial cannulation was done for invasive blood pressure monitoring. Peripheral intravenous catheter of 18 G was placed, or used in situ, from dorsal hand or distal forearm veins on left side. The right upper limb was not chosen for PVP cannula placement to avoid any hindrance to venous flow.

The PVP catheters were maintained at midthoracic height throughout each case. After flushing and room air zero calibration, transducer set (pressure monitoring kit) was maintained at midthoracic level throughout surgery. Real time PVP wave form was displayed in the monitor along with CVP. Continuity of the PVP catheter with the downstream venous system was demonstrated at beginning of each case by observing coincident pressure changes in the PVP wave form during circumferential proximal arm occlusion. The measurement arm was protected against external pressure. Drugs and fluids were not administered through the PVP cannula and NIBP was not measured on the same arm.

Hemodynamic data were recorded beginning with placement and calibration of CVP and PVP catheters and positioning of the patients for surgery, and ending at the conclusion of surgery. Real time wave form was displayed throughout the case for both CVP and PVP, and numeric values were noted by the same monitoring system (BPL ultima). All hemodynamic data were recorded to the nearest 1mm Hg at 5 minutes interval throughout the recording period.

No alterations were made in the usual anaesthetic technique for the cases. Anaesthesia was induced with IV sodium thiopental or propofol and maintained by N_2O:O_2:Isoflurane. Muscle relaxation was maintained by intermittent IV doses of vecuronium. All patients were intubated and mechanically ventilated throughout surgery. Decisions regarding IV fluid administration, blood and blood product administration, and treatment with vasoactive medications were made according to the usual judgement of concerned anaesthesiologist without regard to PVP readings

Statistical Analysis

Data entered in MS excel spread sheet and analyzed with the SPSS for Windows software release 10.0.5 (SPSS Inc, Chicago, Ill). The results expressed as means ± SD. $p<0.05$ was considered statistically significant. A Student t test was used for the comparison of mean data. Linear regression analysis was performed to establish the correlation between CVP and PVP. Pearson correlation coefficient was calculated. Bias was defined as the mean difference between simultaneous CVP and PVP measurements. Bland and Altman plots were created to study the limits of agreement (defined as±2 standard deviations from the mean difference) and the relationship of variability of the two measurements as a function of the average venous pressure (PVP+CVP/2).

RESULTS

Total of twenty five patients included 15 males and 10 females. Their mean age and body weight was 48±13.5 yr and 61.2±9.6 kg respectively. All patients were American Society of Anaesthesiologists physical status I (n=11) or II (n= 14). A total of 1235 simultaneous measurements of CVP and PVP were recorded in 25 patients.

In all cases PVP was higher than CVP. Over all mean Peripheral venous pressure (mean ± SD) was 11.5± 2.2 mmHg Vs a CVP of 7.4 ± 1.9 mm Hg; the two measurements differed by an average of 4.12±1.02mmHg. A scatter plot of PVP and CVP with a regression line and line of equality is shown in Figure 1. Peripheral venous pressure correlated highly with CVP in every patient and the overall correlation calculated using a random-effects regression model was r = 0.893 (p 0.0001) [Figure 1]. The Pearson's correlation coefficient calculated from the subgroup analysis was r >0.85 even for patients with estimated blood loss more than 1000ml. PVP could be described as a function of

CVP with an equation calculated from the regression line:

PVP = 4.032 + CVP * 1.013

Bland-Altman analysis demonstrated a bias of 4.12±1.02mmHg and precision was ± 1.99mmHg (Fig. 2). The limit of agreement were 6.11 to 2.13mmHg.

Table 1: Demographic and hemodynamic data of study group

	Mean +/- SD	Range
Age (Yrs)	48+/-13.5	23-64
Body Weight (kg)	61.2+/-9.6	45-90
Gender (M/F)	15/10	
Position(Supine/Prone)	22/3	
Crystalloid(ml)	3670+/- 893.7	600-5800
Colloid(ml)	482+/-382	0-1000
Estimated blood loss(ml)	1052+/-579	200-2600

*Data are presented as means ± SD for age, weight, crystalloid, colloid and EBL.

*Data for gender and position are presented as ratios.

*M indicates male; F, female.

Table 2 :Surgeries

Aneurysm Clipping	5
CP Angle tmour excision	4
Craniopharyngoma Excision	3
Pituatory Tumour Excision	2
Meningioma excision	9
Posterior fossa tumour excision	1
Retrorbital Haemangioma	1

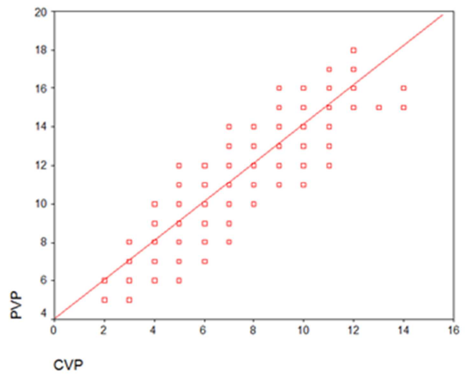

Figure 1: Linear regression plot of CVP Vs PVP with calculation of Pearson's correlation coefficient (r).

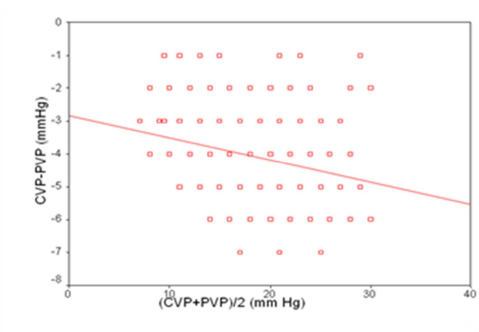

Fig 2: Bland and Altman plot (differences between central [CVP] and peripheral venous pressure [PVP] against their mean). Each point represents one or more measurements.

DISCUSSION

The complication rate during central venous catheterizations is high. The growing popularity of ultrasound-guided venous catheterization in recent years has decreased but not eliminated the complications.

This study confirms that PVP correlates with CVP in Patients undergoing neurosurgical procedures. PVP was on average within 4.12 mmHg (±1.02mmHg) higher than of CVP. Although controversy still exists concerning the role of peripheral veins and their contribution to the central volume in face of blood loss, many studies in the late 1990s and early 2000s have shown a consistent correlation between CVP and PVP.[15,16] Characteristic CVP waveforms can be helpful in diagnosis of various cardiac dysfunctions. PVP waveforms, owing to dampened sinusoidal pattern does not provide any useful information on cardiac function.[11]

Previously, some clinicians have introduced PVP, a simple and less invasive hemodynamic monitoring variable, as an alternative to CVP and found various correlations between them.[16,18-24] PVP instead of CVP has not been widely advocated in the past because peripheral veins have valves that may interrupt the continuous column of blood and are thin walled, and may be more easily subjected to compression and occlusion. In addition, external compression by the operator or blood pressure cuff and overstretching in the catheterized arm can occlude the peripheral vein and increase PVP. Recently, however, numerous studies have reported a strong correlation between CVP and PVP in various surgeries.[3,10,12,13,15,16-29]

As in other studies, we found a consistently higher value for PVP than for CVP. The mean difference of approximately 4mm Hg likely represents peripheral venous resistance upstream from the vena cava. The results of our study demonstrated an excellent convergence of PVP and CVP trends. So PVP is a good surrogate of central venous pressure in most patients undergoing neurosurgery. In certain clinical situations, ie, in patients with expected difficulties in central venous access, we recommend it as the method of choice, as it allows ones to decrease the complications rate, improves outcomes, and reduces costs. However the limits of agreement were not narrow to use the 2 methods interchangeably (6.11 to 2.13mmHg). So we would like to emphasize that PVP as CVP are most valuable in their use as trend monitors rather than for obtaining absolute values.

Limitations

Our study has a few limitations. Firstly, we did not compare the effect of catheter size and peripheral location on pressure measurements. However, previous studies suggest that these factors may have no significant influence on the correlation between CVP and PVP. Secondly, our data cannot be extrapolated to patients who have venous system abnormalities, such as clots or stenoses, as they will likely influence the pressure gradient between locations of PVP and CVP measurement.

CONCLUSION

1) Study confirms that PVP correlates with CVP in patients undergoing neurosurgical procedures
2) PVP may be used when the risk of invasive monitoring may outweigh the benefit
3) PVP monitoring has no risk for pneumothorax, injury of large central vessels, and decreased risk of line infection
4) PVP monitoring is a rapid, easy and less expensive technique compared to CVP monitoring.

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