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Comparative utility of centrally versus peripherally transduced venous pressure monitoring in the perioperative period in spine surgery patients

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Abstract

Study Objective—To compare central venous pressure (CVP) with peripheral venous pressure (PVP) monitoring during the intraoperative and postoperative periods in patients undergoing spine surgery.

Design—Prospective observational study.

Setting—University-affiliated teaching hospital.

Patients—35 ASA physical status 1, 2, and 3 patients.

Interventions—A peripheral catheter in the forearm or hand and a central catheter into the internal jugular vein were placed for PVP and CVP monitoring, respectively.

Measurements—CVP and PVP values were collected simultaneously and recorded electronically at 5-minute intervals throughout surgery and in the recovery room. The number of attempts for catheter placement, ease of use, maintenance, and interpretation were recorded. Patient comfort, frequency of complications, and cost were analyzed.

Main results—The correlation coefficient between CVP and PVP was 0.650 in the operating room ($P < 0.0001$) and 0.388 in the recovery room ($P < 0.0001$). There was no difference between groups in number of attempts to place either catheter, maintenance, and interpretation with respect to PVP and CVP monitoring in the operating room. In the recovery room, the nurses reported a higher level of difficulty in interpretation of PVP than CVP, but no differences were noted in ease of maintenance. There were no complications related to either central or peripheral catheter

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placement. Patient comfort and cost efficiency were higher with a peripheral than a central catheter.

Conclusion—During clinically relevant conditions, there was limited correlation between PVP and CVP in the prone position during surgery and postoperatively in the recovery room.

Keywords

Central venous pressure; correlation study; peripheral venous pressure

1. Introduction

Placement of a central venous catheter for the measurement of central venous pressure (CVP) is frequently done during spine surgical cases. However, its placement is associated with potential complications, patient discomfort, and considerable cost. A number of studies have suggested that peripherally transduced venous pressures (PVPs) correlate well with centrally derived values and thus could be used interchangeably [1–8]. However, this recommendation was based on data collected in highly controlled, investigative settings providing results with small margins of error [1–8]. It may not represent the use of venous pressure monitoring in a more routine clinical setting.

With few exceptions, the scope of available studies has been limited to the intraoperative period only [1,3,8,9], and has ignored the value of venous pressure monitoring in the immediate postoperative period. Factors concerning patient satisfaction, safety and cost remain largely unstudied in this context. Recent clinical research targeted at comparing different interventions and strategies to determine the most optimal approach to a medical goal, has become a major priority of health care research [10] in an effort to develop best practices and reduce cost. We compared centrally to peripherally transduced venous pressure monitoring during the intraoperative and postoperative period in patients undergoing elective spine surgery, while taking into account comparative effectiveness, measures of patient safety and satisfaction, as well as procedural cost. To achieve an environment more in line with a “real world” setting, as demanded by principles of comparative effectiveness research [10], we designed our study more in the style of a practical clinical trial, in which data were collected blindly and operators of monitoring modalities were not restricted in their clinical practice. We hypothesized that PVP monitoring correlated well with CVP measurement in the perioperative period during and after large blood loss procedures such as spinal fusion surgery. We also hypothesized that PVP monitoring was associated with lower costs than was CVP monitoring, while not negatively affecting patient satisfaction, ease of use and initiation, or measures of safety.

2. Materials and methods

After obtaining approval from the Hospital for Special Surgery’s Institutional Review Board and written, informed consent, 35 patients undergoing posterior spine surgery in the prone position were enrolled in this prospective, observational study from February 2010 to February 2011. Only patients who were deemed by the anesthesiologist to require CVP monitoring were enrolled in the study. Exclusion criteria were inability to place a central or peripheral intravenous (IV) catheter and infection of the skin at the intended site of insertion.

After patient transfer to the operating room (OR), general anesthesia was induced and maintained at the discretion of the attending anesthesiologist. Monitoring was conducted according to ASA standards. As part of the research protocol, a peripheral 18-gauge (G), 3.2 cm catheter (Optiva; Smiths Medical Intl., Ltd., Rossendale, UK) was placed only in the forearm or hand for PVP monitoring. While observing sterile technique, a central 16-G, 3.97

cm catheter (Arrow Intl., Inc., Reading, PA, USA) was placed in the internal jugular vein. After placement of a 20-G, 3.2 cm radial arterial catheter (Optiva; Smiths Medical, Intl., Ltd.), the patient was positioned prone for surgery on a Maquet table. The arms were abducted at the shoulder at 90°, flexed at the elbow at 90°, and positioned on cushioned arm boards. Both continuous flush transducers (Edwards Life Sciences LCC, Irvine, CA, USA) were zeroed in the prone position at the level of the phlebostatic axis, defined as the horizontal line extending from the midaxillary line and the fourth intercostal space. A Valsalva maneuver (5 sec to a pressure of 30 cm H₂O) was performed to confirm an increase of transduced pressures in response to an increase in intrathoracic pressure, thus indicating the presence of a continuous fluid column from the central vasculature to the peripheral catheter site [8]. Real-time pressure data were displayed on a monitor (Datex Ohmeda General Electric, New York, NY, USA).

Data pairs were collected electronically at 5-minute intervals throughout the surgery, but without the anesthesiologist's knowledge as to when these measurements were recorded. Data were downloaded from the monitor and stored on a hard drive for analysis. Individual anesthesiologists did receive an explanation of the principles of CVP and PVP monitoring before the study commenced, but intraoperative management was left to the discretion of each practitioner to approximate actual clinical practice conditions. After surgery, the patient was transferred to the recovery room. On patient arrival there, the peripheral and central pressure transducers were zeroed using the phlebostatic axis as a reference. A chest radiograph was performed to confirm position of the central venous catheter in the superior vena cava. Hemodynamic parameters were displayed on the patient monitor and recorded electronically at 5-minute intervals in the recovery room for 4 hours or until discharge, whichever occurred first. Medical treatment given in the recovery room remained at the discretion of the care team at all times and practitioners were unaware of when study recordings took place. After surgery, the anesthesiologist who placed the peripheral and central catheter in the OR was asked to grade the ease of initiation of PVP and CVP monitoring (0=very easy to 10=very difficult); the number of attempts was recorded. Anesthesiologists and nursing staff were asked to grade the ease of maintenance and interpretation of either mode of measurement (0=very easy to 10=very difficult) for each patient. At the end of the measurement period, patients were asked to grade their comfort at the catheter sites using a scale from 0–10 (where 0=no discomfort and 10=extremely uncomfortable). The cost associated with either type of catheter placement and maintenance, as well as potential treatment of complications, were calculated using institutional material cost and Medicare reimbursement equivalents.

2.1 Statistical analysis

Pearson correlation was calculated to measure the association between CVP and PVP. Wilcoxon sum rank test was conducted to compare patients' level of comfort with the central and the peripheral catheters and to compare the number of attempts, ease of placement, maintenance, interpretation and use of PVP versus CVP in the OR, and ease of maintenance, interpretation, and use of PVP versus CVP in the recovery room.

Bland and Altman's approach was used to assess agreement between absolute CVP and PVP readings [11]. In this analysis, the difference of the two measurements is plotted against the average of the two measurements. Agreement is evaluated by calculating the mean difference (bias) and standard deviation of the differences. The limit of agreement was calculated as a bias plus/minus twice the observed standard deviation of the observed differences.

Based on achieving a coefficient correlation of 0.85, the suggested sample size with a power of 0.85 and type I error of 0.05, was 8 patients. However, to increase the robustness of our results we included 35 patients.

3. Results

Thirty-five patients were included in this prospective observational study. A total of 1,340 data pairs were collected in the OR and 797 in the recovery room. Patient characteristics are shown in Table 1.

An increase in both CVP and PVP of at least 5 mmHg was documented in all patients in response to the Valsalva maneuver. In the OR, the mean PVP was 17 mmHg (range, 1 – 48 mmHg) and the mean CVP was 15 mmHg (range, 3 – 33 mmHg) ($P < 0.0001$). The correlation coefficient was 0.650 ($R^2 = 0.423$, $P < 0.0001$; Fig. 1). In the recovery room, the mean PVP was 15 mmHg (range, –12 – 47 mmHg) and the mean CVP was 8 mmHg (range, –11 – 42 mmHg) ($P < 0.0001$). The correlation coefficient was 0.388 ($R^2 = 0.1501$, $P < 0.0001$; Fig. 2).

Fig. 3 shows the Bland-Altman plot of the relationship between the observed differences and the mean of the two measures recorded in the OR. The bias was 2 ± 5 mmHg and the limits of agreement were 12 to –8 mmHg. Fig. 4 shows the Bland-Altman plot for the two measures recorded in the recovery room. The bias was 7 ± 10 mmHg and the limits of agreement were 27 to –13 mmHg.

Central venous pressure and PVP values trended in the opposite direction in 10% of data pairs in the OR and in 21% in the recovery room, respectively.

The anesthesiologists reported one, two, and three or more attempts needed for placement of a central venous catheter in 29, 5, and 3 patients, respectively, and for placement of peripheral catheter in 32, 2, and 3 patients, respectively ($P = 0.42$).

Results of the questionnaire that was completed by the anesthesiologists and nurses are shown in Table 3. There was no difference in ease of placement, maintenance, interpretation, or use with regard to PVP and CVP monitoring in the OR, as reported by the anesthesiologists. In the recovery room, the nurses reported a higher level of difficulty in interpreting the PVP than the CVP but there were no differences in ease of maintenance. Patients' level of comfort was higher with the PVP than the CVP catheter (1 ± 2 and 2 ± 2 , respectively, $P = 0.022$).

No complications were noted that were related to either central or peripheral catheter placement.

The overall cost, as calculated by material expenses for our institution and charges to the payer in standardized Medicare reimbursement rates, were \$17.00 U.S. dollars (USD) for a PVP and \$180.00 USD for a CVP, excluding additional charges associated with ultrasonographic guidance (\$42.00 USD) and radiographic confirmation (\$29.00 USD) of a central venous catheter (total of \$250.00 USD for a CVP).

4. Discussion

In our study of 35 patients undergoing spine surgery, we found limited correlation between PVP and CVP in the prone position during surgery and postoperatively, although the correlation was higher in the intraoperative period. Specifically, the Pearson coefficient for intraoperative measurements was 0.650, which represents the upper limit of a weak positive

correlation. In contrast, postoperative correlation was inferior, with a Pearson coefficient of 0.388.

During surgery, PVP was on average within 2 mmHg of CVP, with limits of agreement of 12 to -8 mmHg and 72 of 1,341 measurements (5%) falling out of this range. The limits of agreement reported in our study were wider than in other studies. In our previous study measuring CVP and PVP in a similar setting, we found measurements to be within 2.04 ± 1.39 mmHg of each other, with limits of agreement between 4.82 and -0.74 mmHg [9]. Kim et al recently compared CVP with PVP in patients undergoing laparoscopic surgery and found an average difference of 0.9 mmHg, with limits of agreement of -1.2 and 2.9 mmHg [1]. Amar et al [2] measured PVP and CVP at random points in mechanically ventilated patients during surgery and in spontaneously breathing patients in the Postanesthesia Care Unit (PACU). They reported a high correlation between PVP and CVP in the OR (PVP 9 ± 3 mmHg vs mean CVP of 8 ± 3 mmHg; $P < 0.001$), with a bias of -1.6 ± 1.7 mmHg. Munis et al measured CVP and PVP in patients undergoing craniotomy in the supine position and complex spine surgery in the prone position. They found a highly significant relationship between CVP and PVP, with a correlation coefficient of 0.82 [3]. The larger variation found in our study may be explained by the fact that we created conditions approximating our clinical scenario, reducing the practitioners' chance to be biased by a Hawthorne effect, attempting to optimize factors influencing measurement. This scenario may have led to a clinical setting in which the recordings were influenced by factors such as malpositioning of IV catheters (ie, kinking) and transducers after the initial calibration procedure, thus accounting for the relatively larger limits of agreement. This hypothesis is also consistent with our findings in the recovery room, where the limits of agreement were even wider. The mean difference between PVP and CVP monitoring in the recovery room was 7 mmHg, with limits of agreement of 27 to -13 mmHg and 270 of 797 (33%) of measurements falling out of this range. Although it must be mentioned that Amar et al, when measuring PVP and CVP in the PACU, reported a high correlation between PVP and CVP (PVP 7 ± 4 mmHg vs mean CVP of 5 ± 4 mmHg; $P < 0.001$), with a bias of -2.2 ± 1.9 mmHg during experimental conditions [2]. In our study, patients were transferred to the recovery room and, after the transducers of the PVP and CVP were zeroed, their management was left to the discretion of the critical care team, who was educated about the principles of CVP and PVP monitoring a priori, without specific instructions to alter their usual patient care. The aim was to assess how the two modes of pressure monitoring correlate in a non controlled clinical environment, so as to evaluate the feasibility and applicability of PVP as an alternative to CVP in the routine clinical setting. In addition to factors influenced by practitioners, patient factors such as movement, may explain the larger range of measurements observed in the recovery room setting. Further, although all patients in this study had an arterial catheter for blood pressure monitoring and noninvasive measurements are not routinely used, it cannot be ruled out with absolute certainty that a noninvasive pressure cuff was present in the same arm where the PVP was transduced, acting as a tourniquet and thus affecting measurements in rare instances.

We observed higher CVP and PVP pressures intraoperatively than postoperatively. Higher pressures recorded in the OR [PVP 17 mmHg (range, 1 - 48 mmHg) and CVP 15 mmHg (range, 3 - 33 mmHg)] may be explained by the effect of the increased intrathoracic pressure induced by mechanical ventilation and restriction to thoracic movement by prone positioning.

In the recovery room, where patients mostly were breathing spontaneously and positioned supine, CVP decreased to 8 mmHg (range, -11 - 42 mmHg) while PVP remained at a high value of 15 mmHg (range, -12 - 47 mmHg). This finding may be explained by the additional hydrostatic effect of the blood column between the heart and peripheral veins, as

the head of the bed was elevated about 30°. In the OR, with the patient positioned prone, both pressure transducers and peripheral catheter insertion site were maintained at the level of the phlebostatic axis. The high PVP and the difference between PVP and CVP also may explain why, in the recovery room, nurses reported a higher level of difficulty in interpreting the PVP than the CVP as compared with the OR, where the attending anesthesiologist found no difference. Furthermore, patient movement, which could increase the chances of malpositioning of catheters, may have influenced the latter observation in the recovery room. When patients were asked to rate the level of comfort associated with central and peripheral catheters, we found that satisfaction was higher with the peripheral than the central catheter ($P = 0.022$).

The overall cost, as calculated by material expenses, to our institution and charges in standardized Medicare reimbursement rates was higher for CVP measurements than PVP (\$180.00 USD for CVP vs \$17.00 USD for PVP, excluding the additional \$42.00 USD associated with US guidance and \$29.00 USD for radiographic confirmation when using a CVP).

Although the study was underpowered to detect differences in complications, no difference was found using either mode of measurement. However, one advantage of PVP monitoring is the low morbidity associated with its placement and the avoidance of central catheter-associated complications such as line infections, vessel damage, accidental carotid puncture, and pneumothorax. Therefore, while considering patient satisfaction and the remarkable difference in costs, the opportunity to use PVP as an alternative to CVP is certainly attractive, provided that highly controlled conditions may be reproduced in an investigational setting.

Our study has several limitations. First, the study was aimed at assessing the agreement of PVP with CVP. Thus, no conclusions may be drawn about the usefulness of venous pressure monitoring in terms of fluid management during spine fusion. In this context, a number of authors have recently questioned the utility of venous pressure as a marker of fluid responsiveness [12]. However, for practitioners questioning the utility of CVP monitoring, the argument for a less invasive and more cost-effective alternative gains additional attraction.

Second, our data cannot be extrapolated to patients with venous system abnormalities, such as clots or stenoses, as these conditions are likely to influence the pressure gradient between the PVP and CVP measurement location. Furthermore, in this study we did not take into account that central venous catheters are often placed not solely for CVP monitoring, but for IV access and infusion for vasoactive agents, and this fact certainly needs to be considered when deciding on the approach to use.

We also asked anesthesiologists and nurses to grade ease of maintenance and interpretation of either mode of pressure measurement for each patient (0=very easy and 10=very difficult), as there is no validated scale to measure these factors. The same consideration needs to be applied to the evaluation of patient comfort (0= no discomfort and 10=extremely uncomfortable).

Finally, although we attempted to create a reproducible scenario, the fact remains that this study was performed at one institution only, which limits its external validity.

In conclusion, we showed a limited correlation between PVP and CVP during conditions associated with prone spine surgery and also postoperatively, although the correlation was higher in the intraoperative period. The level of correlation and the levels of agreement

between the two modes of measurement were reduced when compared with previous reports.

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Fig. 1. Scatter plot of peripheral venous pressure (PVP) and central venous pressure (CVP) from 1,341 data pairs of 35 subjects, which were recorded while patients were placed prone for spine surgery.

Fig. 2. Scatter plot of peripheral venous pressure (PVP) and central venous pressure (CVP) from 797 data pairs of 35 subjects placed supine in the recovery room.

Fig. 3.
Relationship of the observed differences in central venous pressure (CVP) and peripheral venous pressure (PVP) measurements in the prone position during spine surgery. Horizontal lines = estimated bias and limits of agreement.

Fig. 4.
Relationship of the observed differences in central venous pressure (CVP) and peripheral venous pressure (PVP) measurements in the supine position in the recovery room. Horizontal lines = estimated bias and limits of agreement.

Table 1

Patient demographic data

Age (yrs)	61 ± 12
Weight (kg)	84 ± 22
Height (cm)	169 ± 10
Gender (M/F)	18/17
ASA physical status	
Classification (1/2/3)	4/23/8

Data are means ± SD for age, weight, and height. Data for gender and ASA physical status are ratios.

Table 2

Questionnaire

	Means $\pm$ SD	P -value
Operating room		
ease of placement		
CVP	2 $\pm$ 1	0.143
PVP	1 $\pm$ 1	
ease of maintenance		
CVP	1 $\pm$ 1	0.398
PVP	2 $\pm$ 2	
ease of interpretation		
CVP	1 $\pm$ 0	0.125
PVP	2 $\pm$ 2	
Recovery room		
ease of maintenance		
CVP	2 $\pm$ 2	0.125
PVP	3 $\pm$ 3	
ease of interpretation		
CVP	2 $\pm$ 2	0.002
PVP	5 $\pm$ 4	

CVP=central venous pressure, PVP=peripheral venous pressure