Research Article

Correlation between central venous pressure and peripheral venous pressure with passive leg raise in patients on mechanical ventilation

Dharmendra Kumar, Syed Moied Ahmed, Shahna Ali, Utpal Ray[1], Ankur Varshney, Kashmiri Doley

Abstract

Background: Central venous pressure (CVP) assesses the volume status of patients. However, this technique is not without complications. We, therefore, measured peripheral venous pressure (PVP) to see whether it can replace CVP. **Aims:** To evaluate the correlation and agreement between CVP and PVP after passive leg raise (PLR) in critically ill patients on mechanical ventilation. **Setting and Design:** Prospective observational study in Intensive Care Unit. **Methods:** Fifty critically ill patients on mechanical ventilation were included in the study. CVP and PVP measurements were taken using a water column manometer. Measurements were taken in the supine position and subsequently after a PLR of 45°. **Statistical Analysis:** Pearson's correlation and Bland–Altman's analysis. **Results:** This study showed a fair correlation between CVP and PVP after a PLR of 45° (correlation coefficient, $r = 0.479$; $P = 0.0004$) when the CVP was <10 cmH_2O. However, the correlation was good when the CVP was >10 cmH_2O. Bland–Altman analysis showed 95% limits of agreement to be −2.912–9.472. **Conclusion:** PVP can replace CVP for guiding fluid therapy in critically ill patients.

Keywords: Central venous pressure, correlation, mechanical ventilation, passive leg raise, peripheral venous pressure

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Introduction

Central venous pressure (CVP) is widely used to guide fluid therapy in the Intensive Care Unit (ICU). However, its placement is associated with various drawbacks such as vascular injury, pulmonary complications, nerve injury, and infection.[1] Peripheral venous catheterization is done to almost all patients admitted in the hospital. If peripheral venous pressure (PVP) is demonstrated as reliable, utilization of PVP in clinical volume status assessment holds the obvious advantage of widespread potential application.

Peripherally acquired venous pressure (PVP) has been demonstrated to correlate with CVP in a number of studies in the operating theater and intensive care settings.[2-7] Most of the previous studies were done on a particular subgroup of patients with similar pathophysiological status.

The aim of this study was to evaluate whether correlation and agreement exist between PVP and CVP in a mixed population of critically ill patients on mechanical ventilation with varying conditions of volume load.

From:
Department of Anaesthesiology, JN Medical College, AMU, Aligarh, Uttar Pradesh, [1]Baharampur Medical College, West Bengal, India

Correspondence:
Dr. Syed Moied Ahmed, JNMCH, AMU, Aligarh,
Uttar Pradesh - 202 002, India.
E-mail: sma99@rediffmail.com

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Methods

This study was conducted in the ICU of a tertiary care hospital. After obtaining ethical clearance from the Institutional Ethical Committee, 50 mechanically-ventilated patients, of both sexes, between 20 and 50 years of age were included in the study. Informed consent was taken from the relatives of the patients.

A central venous access was obtained through the right internal jugular vein and a 22G intravenous catheter was placed either on the dorsum of the hand or in the forearm of the patient. CVP and PVP were recorded initially in the supine position and subsequently after passively raising both the legs to 45°. The passive leg raise (PLR) to 45° was taken as fluid challenge to the patient. The parameters were recorded after 1 min of leg rise once the hemodynamic changes settled. The CVP and PVP were recorded during the end-expiratory phase.

Patients

We studied sequentially admitted patients in the ICU who needed mechanical ventilation and did not have history of any cardiovascular disease. Only those patients who had at least one clinical sign of inadequate tissue perfusion were included in the study. Clinical signs of inadequate tissue perfusion were defined as (a) systolic blood pressure <90 mm Hg or the need for vasopressor drugs; (b) urine output <0.5 mL/kg/h for >2 h; (c) tachycardia (heart rate >100/min); or (d) presence of skin mottling.

Study design

Pressure measurements were done in two sequential steps. A first set of measurements was obtained in the supine position. Using a manual bed elevation technique, the lower limbs were then raised to a 45° angle. Measurements were taken using water column manometer by the author himself.

Statistical analysis

All statistical analysis were done using SPSS version 17, SPSS Inc., 233 South Wacker Drive, 11th Floor, Chicago, IL 60606-6412.Patent No. 7,023,453. A sample size of 50 in each group was based on power analysis in which alpha level was fixed at 0.05, anticipated effect size (Cohen's *d*) of 0.8, and for a desired statistical power level of 0.8, a minimum required sample size per group was calculated to be 26, and minimum total required sample size was calculated to be 52. Pearson correlation test was used to measure the correlation significance ($P < 0.05$), and regression analysis was used to calculate the regression equation between CVP and PVP. Bland–Altman analysis was used to find the agreement between CVP and PVP in the supine position and after a PLR of 45°. The PVP − CVP difference versus the average value ([CVP + P PV]/2) was plotted. Means, standard deviations (SDs), and 95% prediction intervals (limits of agreement) were evaluated. The limit of agreement (LOA) was calculated as a bias +2SD.

Results

The demography and the diagnosis of the patients are shown in Table 1. For better statistical analysis, we divided our study population into two groups based on the value of baseline CVP such that:

- Group A: Baseline CVP ≥10 cm H_2O (n = 24)
- Group B: Baseline CVP <10 cm H_2O (n = 26).

Table 2 shows CVP and PVP measurements taken in supine (baseline) and after 45° PLR. Tables 3 and 4 show CVP and PVP measurements of patients in group A and group B, respectively.

Table 5 shows the correlation between CVP and PVP in the supine position (baseline) of all the 50 patients.

Table 1: Diagnosis of the patients included in the study

Diagnosis	Number of patients	Percentage
Perforation peritonitis	12	46
Preeclampsia/eclampsia	6+3	
Blunt trauma abdomen	2	
RTA (HI) + CVA	6+3	34
Poisoning	3	
Snake bite	2	
COPD/pneumonia	3	
Others	10	20
Total	50	100

COPD: Chronic obstructive pulmonary disease; RTA: Road traffic accident; HI: Head injury; CVA: cerebrovascular accident

Table 2: Comparison of CVP and PVP with PLR

	Mean±SD			Bland–Altman 95% limits of agreement
	CVP	PVP	Mean difference	
Baseline	9.68±2.22	14.12±3.13	4.44±2.82	−1.078-9.958
45° PLR	11.69±2.82	14.97±3.33	3.28±3.16	−2.912-9.472

SD: Standard deviation; CVP: Central venous pressure; PVP: Peripheral venous pressure; PLR: Passive leg raise; SD: Standard deviation

Table 3: Comparison of (mean±SD) of CVP and PVP of group A at baseline and after 45°PLR

	Mean±SD			
	CVP	PVP	Mean difference	Bland–Altman
Baseline	11.62±2.01	15.143±2.393	3.524±1.289	0.997–6.051
45° PLR	14.167±2.400	16.310±2.630	2.143±1.733	−1.254–5.540

SD: Standard deviation; CVP: Central venous pressure; PVP: Peripheral venous pressure; PLR: Passive leg raise

Both were found to be positively correlated (Pearson correlation coefficient, $r = 0.479$) and this correlation was highly significant ($P = 0.0004$). Figure 1 shows a linear trend line showing the correlation between CVP and PV*P* values of all 50 patients at baseline ($r = 0.479$). All the points are concentrated over a specific area and in a linear fashion. This denotes that there is a fair correlation between CVP and PVP at the baseline. Linear regression equation is CVP = 0.3429 × PVP + 4.8381 (constant), $r^2 = 0.2291$. Figure 2 shows bias plotting, for agreement between CVP and PVP, of all the 50 patients in the supine position (baseline). It shows 95% LOA to be −1.078–9.958, which are narrow and denotes good agreement.

In the Tables 6 and 7, Pearson correlation test was applied between CVP and PVP measurements of group A and group B patients, respectively. Group A values were found to be positively correlated ($r = 0.843$) and it was highly significant ($P < 0.0001$), while group B values were also positively correlated ($r = 0.092$), but it was not significant ($P = 0.6360$).

Table 4: Comparison of (mean±SD) of CVP and PVP of group B at baseline and after 45°PLR

	Mean±SD			
	CVP	PVP	Mean difference	Bland–Altman
Baseline	8.276±0.922	13.379±3.364	5.103±3.405	−1.571-11.780
45° PLR	9.879±1.341	14±3.487	4.121±3.688	−3.180-11.35

SD: Standard deviation; CVP: Central venous pressure; PVP: Peripheral venous pressure; PLR: Passive leg raise

Table 5: Correlation between CVP and PVP at baseline

Supine	CVP-baseline	PVP-baseline
CVP-baseline		
Pearson correlation	1	0.479
Significant (two-tailed)		0.0004
n	50	50
PVP-baseline		
Pearson correlation	0.479	1
Significant (two-tailed)	0.0004	
n	50	50

CVP and PVP of all 50 patients were found to be positively correlated (Pearson correlation coefficient, $r=0.479$) and this correlation was highly significant ($P=0.0004$). CVP: Central venous pressure; PVP: Peripheral venous pressure

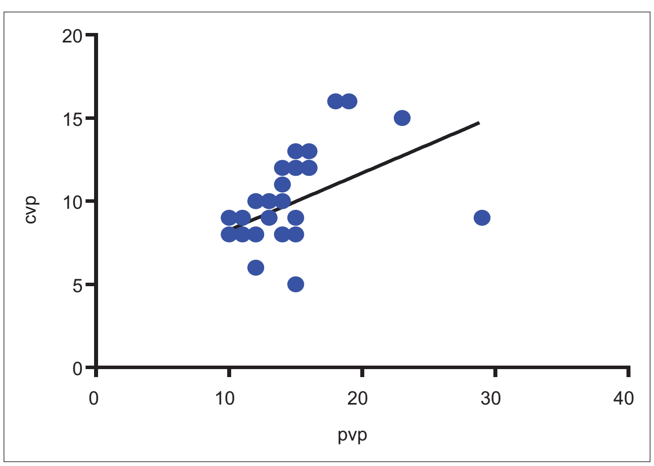

Figure 1: Correlation between central venous pressure and PVP values ($r = 0.479$)

In Figures 3 and 4, a linear trend line is showing the correlation between CVP and PV*P* values, at baseline, of group A and group B patients, respectively. Linear regression equation for group A is CVP = 0.7082 × PVP + 0.8944 (constant) $r^2 = 0.7099$, while that for group B is CVP = 0.3348 × PVP + 10.61 (constant) $r^2 = 0.008$. Group B values are distributed over a wide area and are in a nonlinear fashion. This denotes that there is a poor correlation between CVP and PVP in group B patients.

Figures 5 and 6 show bias plotting for agreement between CVP and PVP of group A and group B in the supine position. It shows 95% LOA to be 0.997–6.051 for group A, which is narrow and denotes good agreement, while −1.571–11.780 for group B, which is wide and denotes poor agreement.

In Table 8, the Pearson correlation test was applied between CVP and PVP measurements taken after applying PLR of 45° in all the 50 patients. Both were found to be positively correlated (Pearson correlation coefficient, $r = 0.4827$) and it was also highly significant ($P = 0.0004$). Figure 7 shows a linear trend line showing this correlation and the linear regression equation is CVP = 0.4088 × PVP + 5.55698 (constant), $r^2 = 0.2331$. In Figure 8, bias plotting has been done for agreement between these CVP and PV*P* values. It shows 95% LOA to be −2.912–9.472, which is narrow and denotes good agreement.

Tables 9 and 10 show correlation between CVP and PV*P* values of group A and group B, respectively, taken after applying PLR of 45°. Both were found to be

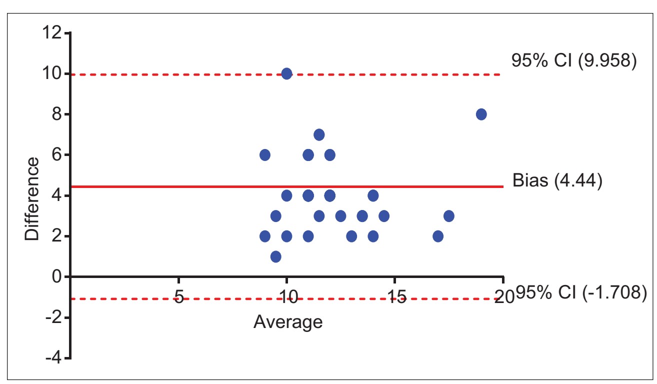

Figure 2: Bias plotting of central venous pressure and PVP values at baseline (no fluid challenge)

positively correlated (r = 0.766), which is highly significant (P < 0.0001) in group A, while for group B, it was positively correlated (r = 0.038), but not significant (P = 0.84).

Figures 9 and 10 show linear trend lines depicting the correlation between CVP and PVP values of group A and B, respectively, after PLR of 45°. Linear regression equation for group A is CVP = 0.6993 × PVP + 2.762 (Constant), r^2 = 0.5869 and that for group B is CVP = 0.01468 × PVP + 9.674 (Constant), r^2 = 0.00145. This denotes that there is a poor correlation between CVP and PVP of group B after applying a PLR of 45°.

In Figures 11 and 12, bias plotting has been done for agreement between CVP and PVP of group A and group B, respectively, after a PLR of 45°. It shows 95% LOA of group A to be −1.254–5.540, which is narrow and denotes good agreement, while for group B, it is −3.180–11.350, which is wide and denotes poor agreement.

Table 6: Correlation between CVP and PVP of group A at baseline

Supine	CVP-baseline	PVP-baseline
CVP-baseline		
Pearson correlation	1	0.843
Significant (two-tailed)		<0.0001
n	24	24
PVP-baseline		
Pearson correlation	0.843	1
Significant (two-tailed)	<0.0001	
n	24	24

CVP and PVP of group A is positively correlated (r=0.843) and it is highly significant (P<0.0001). CVP: Central venous pressure; PVP: Peripheral venous pressure

Table 7: Correlation between CVP and PVP of group B at baseline

Supine	CVP-baseline	PVP-baseline
CVP-baseline		
Pearson correlation	1	0.092
Significant (two-tailed)		0.6360
n	26	26
PVP-baseline		
Pearson correlation	0.092	1
Significant (two-tailed)	0.6360	
n	26	26

Pearson correlation test was applied between CVP and PVP. Both were found to be positively correlated (r=0.092) but it was not significant (P=0.6360). CVP: Central venous pressure; PVP: Peripheral venous pressure

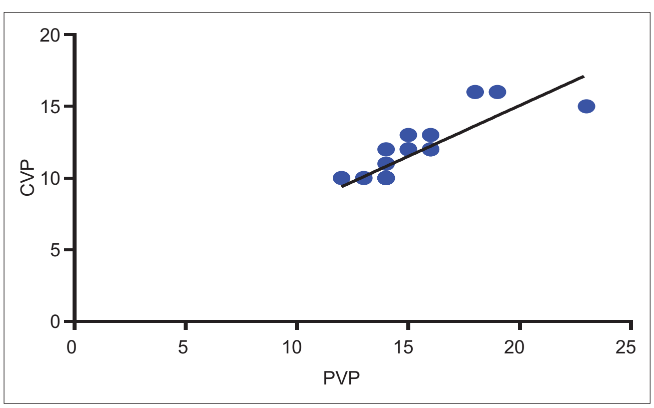

Figure 3: Correlation between central venous pressure and PVP values of group A (r = 0.843) at baseline

Discussion

In the present study, overall, there was a fair correlation between CVP and PVP after applying a fluid challenge by PLR of 45°. Further, CVP and PVP had a narrow 95% LOA. This was in accordance with the previous studies, although most of them have been conducted in the operation theater.[8-13]

Munis *et al*. in 2001 tested the hypothesis that PVP trends parallel to CVP trends and that their relationship was independent of the patients' position.[9] Repeated-measures analysis of variance indicated a highly significant relationship between PVP and CVP (P < 0.001), with a Pearson correlation coefficient of 0.82. The correlation was best in cases with significant blood loss (estimated blood loss >1000 ml; r = 0.885) or hemodynamic instability (SD of CVP >2; r = 0.923). Similarly, Desjardins *et al*. in 2004 were of the opinion that PVP monitoring can accurately estimate CVP under various conditions encountered in the operating room and the ICU.[10]

Anter and Bondok in 2004 did a similar study in children during major surgery and during recovery. It showed that during periods of intraoperative hypotension and fluid resuscitation, within-patient changes in PVP mirrored changes in CVP (r = 0.92).[11]

However, contrary to our findings (r = 0.483; P = 0.004), Munis *et al*. (r = 0.82, P < 0.001) and Anter and Bondok (r = 0.92) showed a good correlation.[9,11] The difference in observation could be due to the fact that those studies had been done in a specific group of patients. Munis *et al*.

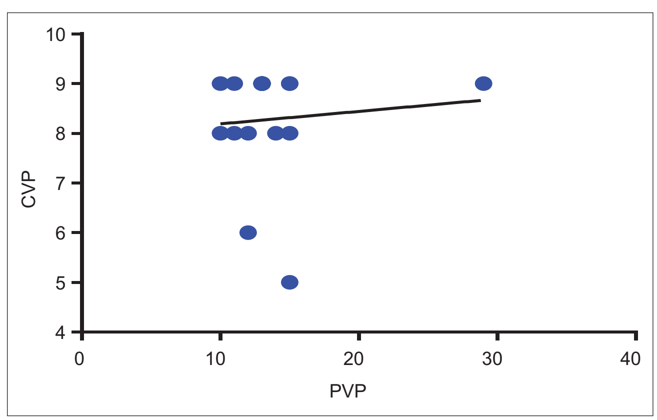

Figure 4: Correlation between central venous pressure and PVP values of group B (r = 0.092) at baseline

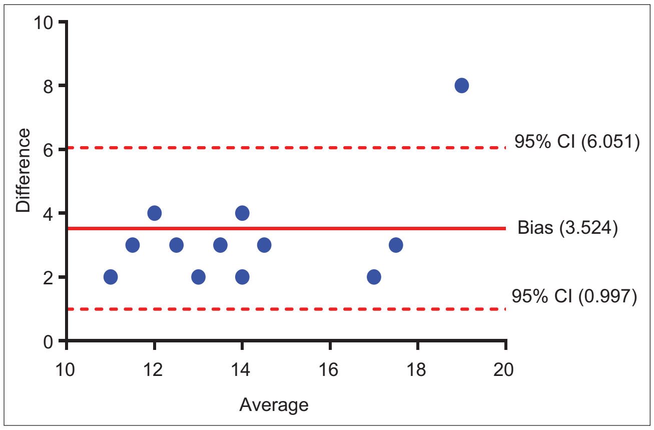

Figure 5: Bias plotting of central venous pressure and PVP of group A at baseline (no fluid challenge)

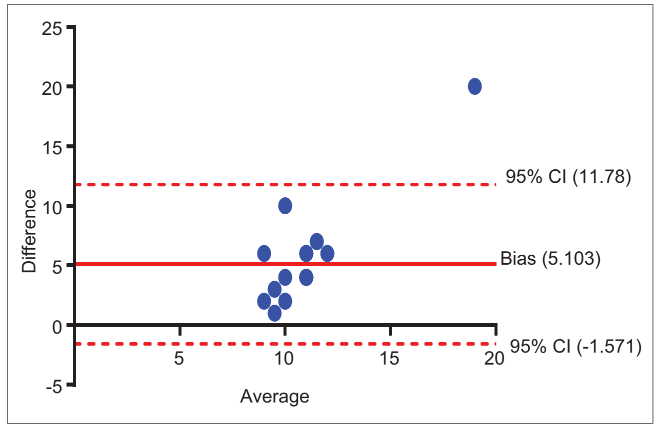

Figure 6: Bias plotting of central venous pressure and PVP of group B at baseline (no fluid challenge)

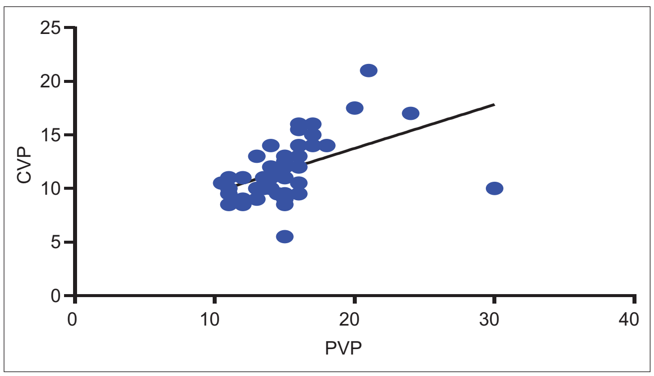

Figure 7: The correlation between central venous pressure and PVP after applying fluid challenge by passive leg raise of 45°

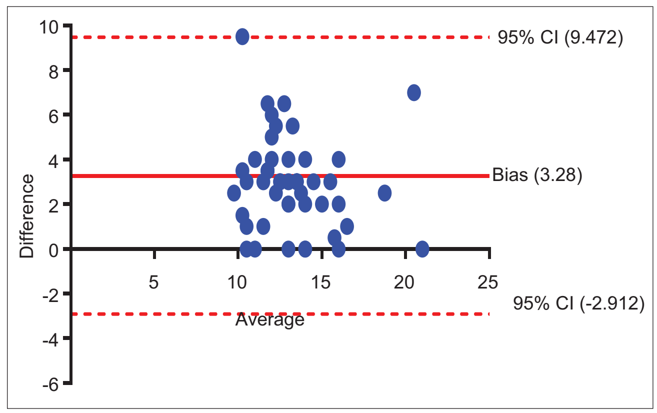

Figure 8: Bias plotting of central venous pressure and PVP values after passive leg raise of 45°

Table 8: Correlation between CVP and PVP after PLR 45°

	CVP	PVP
CVP		
Pearson correlation	1	0.483
Significant (two-tailed)		0.0004
n	50	50
PVP		
Pearson correlation	0.483	1
Significant (two-tailed)	0.0004	
n	50	50

The Pearson correlation test was applied between CVP and PVP. Both were found to be positively correlated (Pearson correlation coefficient, r=0.4827) and it was highly significant (P=0.0004). CVP: Central venous pressure; PVP: Peripheral venous pressure; PLR: Passive leg raise

did their study in patients undergoing neurosurgery and Anter *et al*. did their study in patients undergoing major elective surgery; whereas our study was done in a variety of disease processes, both medical and surgical specialty requiring mechanical ventilation (mixed group).

Contrary to our observations, Charalambous *et al*. and Tugrul *et al*. were of the opinion that PVP measurement does not give an accurate estimate of the absolute value of CVP in individual patients.[14,15] However, as changes in PVP parallel, in direction, changes in CVP, serial measurements of PVP could be useful in determining volume status and guiding fluid therapy in critically ill patients.

Interestingly, when we subdivided our study population into two subsets of patients, based on baseline CVP, we observed the patients with baseline CVP ≥10 cm H_2O (group A) had a better correlation (r = 0.766) than patients with baseline CVP ≤10 cm H_2O (group B, r = 0.038). This showed that CVP and PVP strongly correlated at a higher baseline CVP than that at a lower baseline CVP. This could be probably due to the presence of adequate intravascular volume in patients with baseline CVP >10 cm H_2O so that even slight fluid challenge led to increase in CVP and PVP, and hence a better correlation between the two parameters. Whereas patients with baseline CVP <10 cm H_2O were probably having inadequate intravascular volume so that the fluid challenge was well adjusted within the intravascular compartment without a significant rise in CVP or PVP leading to poor correlation between the two parameters. This is in accordance with a study done by Harvey and Cave and Hoftman *et al*.[12,16]

Table 9: Correlation between CVP and PVP of group A after PLR of 45°

PLR 45°	CVP	PVP
CVP		
Pearson correlation	1	0.766
Significant (two-tailed)		<0.0001
n	24	24
PVP		
Pearson correlation	0.766	1
Significant (two-tailed)	<0.0001	
n	24	24

Pearson correlation test was applied between CVP and PVP. Both were found to be positively correlated (r=0.766) and it was highly significant (P<0.0001). CVP: Central venous pressure; PVP: Peripheral venous pressure; PLR: Passive leg raise

Table 10: Correlation between CVP and PVP of group B after PLR of 45°

PLR 45°	CVP	PVP
CVP		
Pearson correlation	1	0.038
Significant (two-tailed)		0.844
n	26	26
PVP		
Pearson correlation	0.038	1
Significant (two-tailed)	0.844	
n	26	26

Pearson correlation test was applied between CVP and PVP. Both were found to be positively correlated (r=0.038), but it was not significant (P=0.844). CVP: Central venous pressure; PVP: Peripheral venous pressure; PLR: Passive leg raise

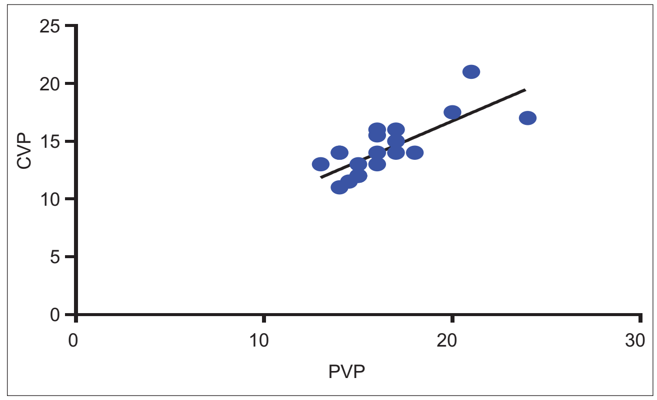

Figure 9: The correlation between central venous pressure and PVP of group A after passive leg raise of 45° (r = 0.766)

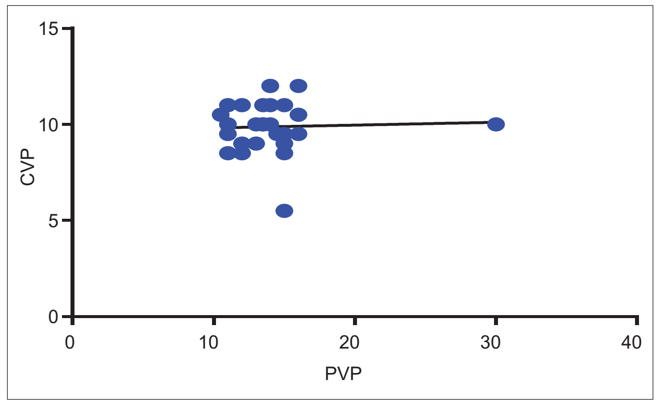

Figure 10: The correlation between central venous pressure and PVP of group B after passive leg raise of 45° (r = 0.038)

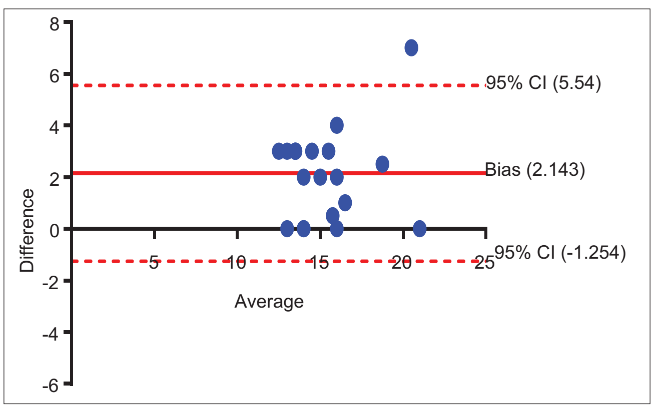

Figure 11: Bias plotting of central venous pressure and PVP values of group A after passive leg raise of 45°

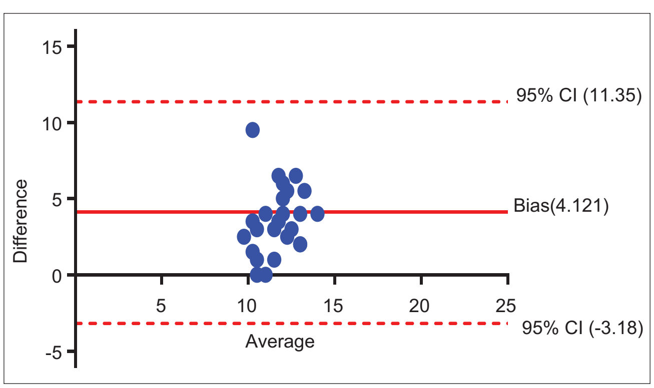

Figure 12: Bias plotting of central venous pressure and PVP values of group B after passive leg raise of 45°

As in the case of other studies, our study also has some limitations. First, our study was not designed to study fluid responsiveness to PLR, but simply to assess the correlation between the changes in CVP and PVP. Second, measurements were taken using water column manometer, which can lead to observer-based bias. However, the strength was that we studied in a mixed group of patients. This would enable the study inference to be applied in all sections of patients. Further, we identified the subset of patients with CVP >10 cm H_2O whose PVP will correlate better with CVP.

Conclusion

Based on the above discussions, we conclude that CVP has a fair correlation with PVP in our study. Hence, PVP can replace CVP in all the study population, especially in patients who are hemodynamically stable. However, a larger prospective study may be conducted so as to avoid all the limitations of this study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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