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Original research article

The Relationship between Respiratory Variations in Pulse Oximetry Plethysmographic Waveform Amplitude and Arterial Pulse Pressure in Mechanically Ventilated Patients-an Observational Study

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Abstract

Introduction: Fluid resuscitation is essential to treat hypovolemia and restore organ perfusion. Respiratory variation in arterial pulse pressure is a reliable predictor of fluid responsiveness in mechanically ventilated patients with circulatory failure. Respiratory variation in arterial pulse pressure is a reliable predictor of fluid responsiveness in mechanically ventilated patients. Respiratory variations in Pulse Oximetry Plethysmographic waveform peaks also correlate with pulse pressure variability in similar settings.

Aim and objective: The purpose of this study was to assess the relationship between respiratory variations in pulse oximetry plethysmographic waveform amplitude and arterial pulse pressure in ICU patients of a tertiary care hospital in south India.

Methodology: A hospital-based prospective observational study was done at MDICU Department of Anaesthesiology, College Hospital, Trivandrum, s tertiary care hospital for a period of 1 year and 6 months. A total of 77 participants were included in this study.

Result: The correlation between Pulse Pressure and Pulse Oximetry Plethysmography was statistically not significant.

Conclusion: The Large variability of ΔPOP and poor agreement between ΔPP and ΔPOP limit the calculation of POP as a potential non-invasive tool for fluid responsiveness in ICU patients. The same analysis should be done with a non-processed plethysmographic signal before ruling out ΔPOP as a surrogate of ΔPP.

Keywords: Anaesthesia, Arterial BP, Critical care, Fluid management, pulse pressure variability, respiratory variations; pulse oximeter; plethysmographic variability.

Introduction

Patients in shock needing fluids are always at risk of getting too much, hence the need for predicting fluid responsiveness before actual administering came into existence. One of the commonly used dynamic techniques was pulse pressure respiratory variation using an arterial pressure wave tracing [1]. This requires an invasive arterial Cather placement. Studies have shown that non-invasive pulse oximeter plethysmograph correlates with pulse pressure variation in shocked patients. This study is done to assess the correlation of Pulse pressure variation with Pulse Oximetry Plethysmography variations[2] in shocked hypovolemic patients needing fluid resuscitation.

Arterial cannulation with continuous pressure transduction remains the accepted reference standard for blood pressure monitoring despite its risk, cost, and need for technical expertise for placement and management. Its superiority over non-invasive techniques for early detection of intra-operative hypotension was confirmed by The Australian Incident Monitoring Study of 1993. [3]

More recently, though, the use of waveform analysis in physiologic monitoring has become more popular. This was initially proposed more than a half-century ago by Eather and associates, who advocated monitoring of arterial pressure and pressure pulse contours in anaesthetized patients. [4]

Arterial pressure waveform characteristics used in current clinical practice include a respiratory-induced variation in an array of directly measured and derived pressure measurements to indicate preload reserve and volume responsiveness [1].
Variations in Pulse Pressure as assessed by the analysis of arterial waveform using software can help predict fluid responsiveness. These are largely based on cyclic variations in arterial blood pressure resulting from respiratory-induced changes in intrathoracic pressure.
In general, normal PPV is less than 13% to 17% [5-7]. When these measures exceed 10% to 13%, the patient is likely to have a positive response to volume expansion. [8]

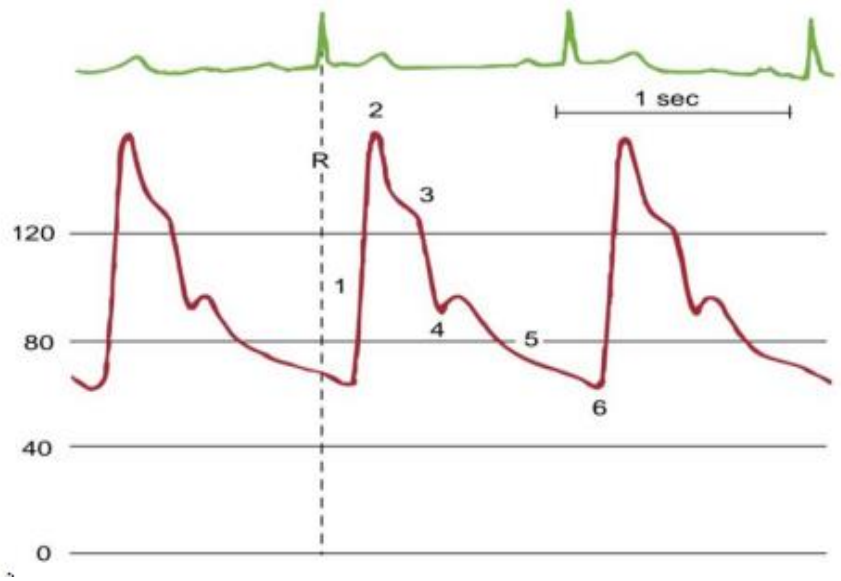

Fig No 1: Normal arterial blood pressure waveform and its relation to the electrocardiographic R wave. (1) Systolic upstroke, (2) systolic peak pressure, (3) systolic decline, (4) dicrotic notch, (5) diastolic runoff, and (6) end-diastolic pressure.

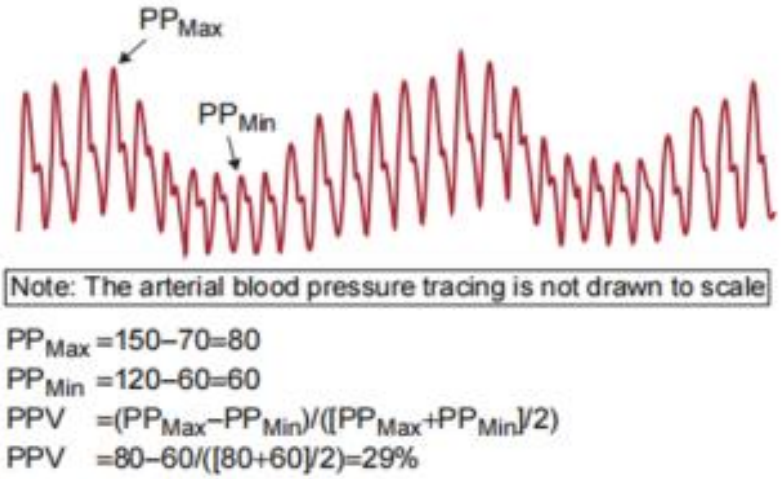

Fig. 2 Pulse pressure variation. Pulse pressure variation (PPV)is calculated as the difference between maximal (PPMax) and minimal (PPMin) pulse pressure values during a single mechanical respiratory cycle, divided by the average of these two values.

Pulse oximetry has been an integral component of intraoperative anaesthetic management since the first anaesthetic monitoring standards were introduced in 1986. It was adopted as a minimum monitoring standard by the ASA the same year and has subsequently been defined as a minimum standard for intraoperative monitoring by the World Federation of Societies of Anaesthesiologists and the World Health Organization.

Xavier Monnet, Bouchra Lamia et al[2] in their study Pulse oximeter as a sensor of fluid responsiveness: do we have our finger on the best solution states that the pulse oximetry plethysmographic signal resembles the peripheral arterial pressure waveform, and the degree of respiratory variation in the pulse oximetry wave is close to the degree of respiratory arterial pulse pressure variation.

Maxime Cannesson, Cyril Besnard et al[9] studied the relationship between respiratory variations in pulse oximetry plethysmographic waveform amplitude and arterial pulse pressure in ventilated patients and found that there was a strong correlation ($r2 = 0.83$; $P < 0.001$) and a good agreement (bias = 0.8 +/- 3.5%) between respiratory variation in arterial pulse pressure and respiratory variation in POP waveform amplitude. A respiratory variation in POP waveform amplitude value above 15% allowed discrimination between patients with respiratory variation in arterial pulse pressure above 13% and those with a variation of 13% or less (positive predictive value 100%).
B Bein et al [10] in their study accuracy of the pleth variability index to predict fluid responsiveness depends on the perfusion index, pointed out that the Pleth Variability Index (PVI) was not able to predict fluid responsiveness with sufficient accuracy. In patients with higher perfusion states, the PVI improved its ability to predict haemodynamic changes, strongly suggesting a relevant influence of the Perfusion index on the PVI.

Methodology
A hospital-based prospective observational study was done at MDICU Department of Anaesthesiology, Medical college Hospital, Trivandrum, s tertiary care hospital for a period of 1 year and 6 months. Shocked patients who were mechanically ventilated with adequate sedation were included in the study. The variables were collected within 30 minutes of

initiating mechanical ventilation in patients with shock. Patients included were on intra-arterial blood pressure and pulse oximeter monitoring. Patients who were on positioners pressure of more than 8, and had bronchospasm or cardiac arrhythmias were excluded from the study.

Heart rate (HR), respiratory rate (RR), invasive mean arterial pressure (MAP), electrocardiography, plethysmographic waves of pulse oximetry, airway pressure (Pmean), PEEP, and tidal volume were continuously monitored, and tracings were simultaneously registered. Invasive arterial, pulse oximetry plethysmographic tracings, and time-pressure respiratory curves will be simultaneously registered thrice in five-minute intervals and transferred from a multiparametric monitor (Philips) to a personal computer

During data acquisition, no spontaneous respiratory movements will be present. Therefore, respiratory-induced changes in arterial and plethysmographic waves are exclusively due to the effects of mechanical ventilation on intrathoracic pressures. The analysis of pressure and plethysmographic waveforms will be performed off-line on a computer. We will first identify the arterial pressure respiratory variation and the systolic and diastolic pressures. Then, systolic pressure and pulse pressure during inspiratory (Psmax and Ppmax) and expiratory (Psmin and Ppmin) phases will be identified in each respiratory cycle. Maximal PP(PPmax) and minimal PP (PPmin) values were determined over the same respiratory cycle. To assess ΔPP, the percentage change in PP was calculated ΔPP (%) = 100 × ([PPmax - PPmin]/ [(PPmax+ PPmin)/2]).

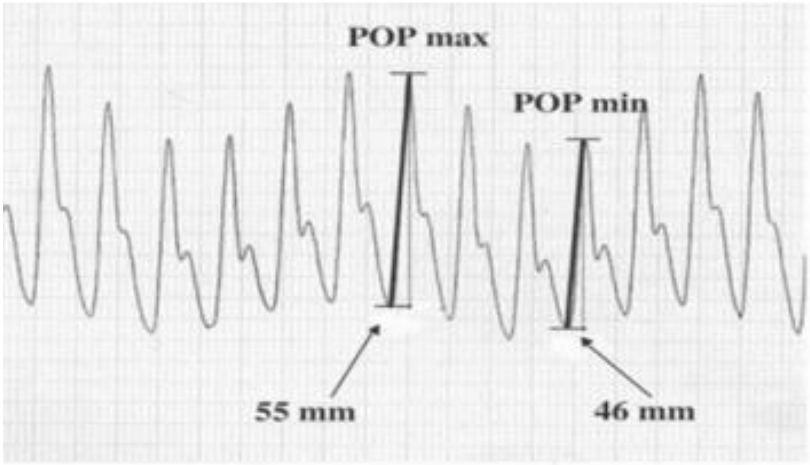

Fig. 3: Pulse oximetry wave form analysis

The measurements were repeated on three consecutive respiratory cycles and averaged for statistical analysis. Plethysmographic waveforms will also be evaluated using a similar methodology. Plethysmographic and arterial waveforms will be simultaneously recorded and selected for analysis

Statistical analysis

Data were entered in a Microsoft excel sheet. The collected data were subjected to statistical analysis using appropriate statistical tools. All data were represented as frequency and percentage (for categorical variables). In order to check the relation between the two variables correlation was employed. Multiple bar diagrams and scatter diagrams have been plotted to visualize the numerical results obtained. A calculated P value less than 0.05 is considered statistically significant. All the analyses were carried out with the help of the commercially available statistical package SPSS v.23 for WINDOWS.

Result and Discussion

Majority of patients were in the 41-60 age group (48%) and males (72%). 71% of patients had a heart rate of less than 100/minute. 53% had a respiratory rate >12 per minute. A tidal volume of 8ml per kg predicted body weight was used in the majority of patients and 80% had a PEEP 5cm of water or less. The correlation between ΔPP and ΔPOP is -0.125 which is statistically not significant (P>0.05). Thus, there is no statistically significant correlation between the PP and POP of participants.

Table1: Relation between delta Pulse pressure and delta Pulse Oximeter Plethysmography

r	N	P value
-0.125	77	0.281NS

NS: Not Significant

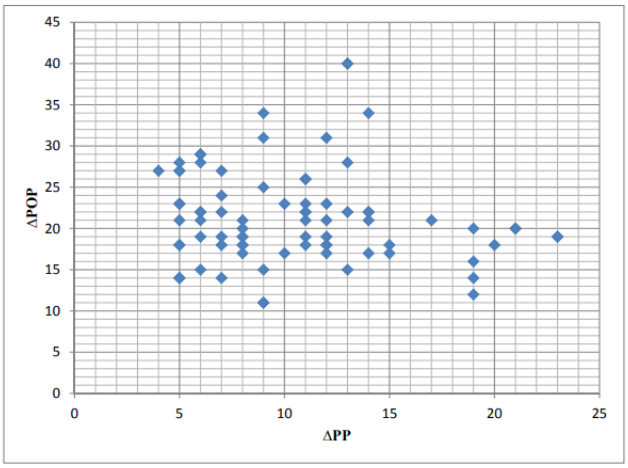

Fig. 4: Diagrammatic representation of the relation between delta Pulse pressure and delta pulse oximetry Plethysmography.

The correlation between PP and POP is -0.125 which is statistically not significant (P>0.05). Thus, there is no statistically significant correlation between the PP and POP of participants. Different medications, dosages, causes of admission to the ICU, and pulse oximetry technologies could explain some of the differences between the main variables.

A non-invasive alternative would be attractive to extend a goal directed fluid management in the operative room to patients not requiring an arterial line. However, the results of studies comparing the clinical use of the two dynamic indices are conflicting. The correlations between ΔPP and ΔPOP have been found to be poor. Site of measurement, signal processing of the plethysmogram, oscillation of the sympathetic system activity, or thermoregulation all these factors are not exclusive and could be brought into play during patient monitoring[10]. This could impair the ability of the plethysmographic derived parameters to follow the pulse pressure variations. The amplitude of the pulse oximetry plethysmographic waveform is influenced by changes in vascular tone from all tissue compartments present in the fingertip, and vasoconstriction narrows the amplitude of the waveform. These changes can create large oscillations in skin microcirculation. Slow oscillations are related to the sympathetic nervous

system and local vascular control mediated from the vascular wall, known as vasomotion [11]. Sedative and anaesthetic drugs impair these oscillations.

The sympathetic nervous system activity change was advocated by Landsverk et al.[11] to explain the poor correlation between ΔPP and ΔPOP observed in intensive care unit patients and more recently during abdominal surgery. Besides the sympathetic nervous system activity, the distensibility could vary according to the arterial pressure. The loops of arterial pressure versus the plethysmogram exhibit a sigmoid-shaped curved, the arterial wall being more compliant at a low level of arterial pressure. At this level, a pressure oscillation is likely to induce a higher plethysmogram oscillation than at a higher-pressure level. Finally, the loop of the arterial pressure versus the plethysmogram depends on the dynamic compliance, meaning that the distensibility depends on the rate of the pressure change. Therefore, any variation of the heart rate could induce a change in the rate of pressure variation and therefore in the dynamic distensibility. The pulse oximeter used in this study has filters built in, like other commercial pulse oximeters, and the signal from the analogue output is therefore not raw signal., so cannot exclude the possibility that the respiratory variations could have been altered by the pre-processing. Besides the distensibility, the signal processing itself should be taken into consideration to explain the discrepancy between ΔPP and ΔPOP. The original signal of plethysmogram is usually highly processed in standard monitors in order to provide clear display on screens. The difference in filtering process between the pressure and the plethysmographic signals could also explain the variability shown between threshold values of PP and POP.

Conclusion

Large variability of ΔPOP and poor agreement between ΔPP and ΔPOP limit the calculation of POP as a potential non-invasive tool for fluid responsiveness in ICU patients. The same analysis should be done with a non-processed plethysmographic signal before ruling out ΔPOP as a surrogate of ΔPP.

Conflict of interest

Nil

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