ORIGINAL ARTICLE

Peripheral Perfusion Index for Prediction of Fluid Responsiveness in Spontaneously Breathing Critically Ill Patients: A Prospective Observational Study

Jayaprakash Narayanan B[1], Shoma V Rao[2], Subramani Kandasamy[3]

Received on: 16 December 2024; *Accepted on*: 03 January 2025; *Published on*: 31 January 2025

Abstract

Background: Peripheral perfusion index (PPI), measured via plethysmography using a pulse oximeter, provides noninvasive, continuous insights into peripheral circulation. This study evaluates PPI's potential as a predictive marker for fluid responsiveness in critically ill patients, aiming to reduce vasopressor use.

Methods: A 20-month prospective study was conducted in the multidisciplinary surgical ICU of Christian Medical College, Vellore. Patients meeting specific inclusion criteria were enrolled. Parameters including blood pressure, pulse pressure (PP), heart rate, left ventricular outflow tract velocity time integral (LVOT VTI), oxygen saturation, and PPI were recorded before and after a passive leg raise (PLR) test. Positive PLR responders received fluid resuscitation, and PPI changes were monitored at regular intervals. The study excluded patients with peripheral vascular disease, burns involving extremities, those on nitroglycerin or other vasodilator infusions, and those on high doses of vasopressors.

Results: A 39% increase in PPI was identified as the threshold for fluid responsiveness. Subgroup analysis revealed variability: trauma patients showed a 55% increase, obstetrics patients 41%, and postoperative patients 6%. Notably, the study found that spontaneous breathing and minimal vasopressor requirements enhanced the reliability of PPI as a fluid responsiveness marker.

Conclusion: Peripheral perfusion index is a reliable and practical tool for predicting fluid responsiveness in spontaneously breathing critically ill patients. It offers a noninvasive and dynamic method to guide volume resuscitation, particularly when combined with established hemodynamic markers such as LVOT VTI and PP changes. This study underscores the importance of using PPI in conjunction with other parameters for comprehensive fluid management. Further validation in larger and more diverse patient populations is warranted to confirm these findings and optimize resuscitation strategies.

Keywords: Fluid responsiveness, Fluid resuscitation, Hemodynamic instability, Intensive care unit, Noninvasive blood pressure, Peripheral Perfusion Index, Pulse oximetry, Pleth variability index monitoring, Shock, Spontaneous ventilation.

Indian Journal of Critical Care Medicine (2025): 10.5005/jp-journals-10071-24898

Highlights

- The peripheral perfusion index (PPI) predicts fluid responsiveness in critically ill patients.
- A 39% increase in PPI following a passive leg raise (PLR) test indicates fluid responsiveness.
- Ideal for spontaneously breathing patients with low vasopressor needs.

Introduction

Resuscitating critically ill patients often focuses on achieving hemodynamic targets such as heart rate and blood pressure. However, despite reaching these macrocirculatory goals, organ failure can still occur due to impaired microcirculation. Microcirculation can be effectively assessed using noninvasive parameters, including skin temperature, capillary refill time, peripheral perfusion index (PPI), and skin mottling index. Peripheral perfusion index is defined as the difference between the pulsatile and non-pulsatile portions of pulse waves, measured by plethysmography.[1] It is typically measured in well-perfused regions of the body, such as the fingertip. Peripheral perfusion index is an indirect, noninvasive, numerical, dynamic, and continuous measure of peripheral perfusion obtained from a pulse oximeter, providing useful information regarding peripheral circulation. The normal range of PPI is from 0.02 to 20%, with a mean value of 2.4%.[2] This study aims to predict fluid responsiveness in spontaneously breathing, critically ill hypotensive patients using noninvasive techniques, primarily PPI. Given that hypotension is a common complication in ICU patients, finding a noninvasive method to determine hypotension and predict fluid responsiveness is the focus of this study. This is an observational study where patients used various noninvasive equipment to measure blood pressure, heart rate, lactate level, and PPI.

[1–3]Department of Critical Care Medicine, Christian Medical College, Vellore, Tamil Nadu, India

Corresponding Author: Jayaprakash Narayanan B, Department of Critical Care Medicine, Christian Medical College, Vellore, Tamil Nadu, India, Phone: +91 8667018586, e-mail: jai.narayanan12@gmail.com

How to cite this article: Narayanan BJ, Rao SV, Kandasamy S. Peripheral Perfusion Index for Prediction of Fluid Responsiveness in Spontaneously Breathing Critically Ill Patients: A Prospective Observational Study. Indian J Crit Care Med 2025;29(2):151–154.

Source of support: Nil

Conflict of interest: None

© The Author(s). 2025 Open Access. This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted use, distribution, and non-commercial reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.

Materials and Methods

Study Setting

This study was conducted in the Surgical Intensive Care Unit (SICU) of a tertiary care teaching hospital in Southern India over a 13-month period from November 2022 to November 2023. Critically ill patients who were unintubated, not sedated, and spontaneously breathing with hypotension and a positive PLR (Passive Leg Raise) test were included. Patients with peripheral vascular disease, burns involving extremities, those on nitroglycerin or other vasodilator infusions, conditions compromising the measurement of peripheral perfusion, and those on vasopressors exceeding 15 µg/min were excluded. All patients admitted to SICU were screened, and eligible patients were recruited.

Sample Size Justification

A sample size of 47 participants was chosen based on several considerations. A review of similar studies, such as those by Smith et al. and Johnson et al., suggests that sample sizes between 40 and 60 are commonly used, indicating that our sample size is consistent with established research norms.[3,4] A power analysis using G*Power software determined that a minimum sample size of 45 participants was necessary to achieve 80% power to detect a significant change in fluid responsiveness, given an effect size of 0.5 and a significance level of 0.05.[5] Therefore, our sample size of 47 participants is sufficient. Additionally, the expected effect size based on previous research is 0.5, and our sample size allows for narrow confidence intervals, ensuring precise and reliable estimates. Practical and ethical considerations also influenced our decision, as recruiting more participants was not feasible due to the critical condition of the patients.

Study Procedures

The PPI was measured using a pulse oximeter, while the PLR test was conducted by the bedside ICU staff. Echocardiographic measurements of the left ventricular outflow tract velocity time integral (LVOT VTI) were performed by the primary investigator. Passive leg raise-positive patients subsequently received fluid resuscitation, with the type and amount of fluid determined at the discretion of the treating physician. A detailed patient information sheet was provided to the patient's primary relative, and the procedure was explained to them in their native language. Informed consent was obtained from all participants. In this study, blood pressure, pulse pressure (PP), heart rate, LVOT VTI, oxygen saturation, and PPI were monitored before and after the PLR test. If PP and LVOT VTI increased by 12% with the PLR test, the corresponding increment in PPI was monitored, followed by fluid resuscitation. These parameters were monitored before and after fluid resuscitation and correlated with changes in PP and LVOT VTI. A trend in the changes in the PPI readings was monitored and analyzed. Initial measurements were taken from 2 to 3 fingers of the dominant hand with the patient in a head-up position upon ICU admission and documented after the PLR test. Second measurements were taken in the same position after fluid replacement, following standard ICU protocol. All measurements were recorded after waiting for 1–2 minutes for device stabilization. Patient demographic details such as name, hospital number, age, and gender were collected from the patient's chart. Diagnosis details were obtained from patient records. Peripheral perfusion index was measured as a percentage using a pulse oximeter. LVOT VTI was measured using 2D-ECHO. Heart rate was collected from the ECG. Blood pressure and mean arterial pressure were recorded using NIBP (Noninvasive blood pressure) or ABP (Arterial blood pressure) as applicable. Data entry was performed using EPI Data 3.1, and analysis was conducted using SPSS 21.0. Descriptive statistics were reported as frequency and percentage for categorical variables, and as mean ± SD for continuous variables. The ability of the PPI to predict the response to fluid bolus administration in hypotensive patients was evaluated using linear regression.

Results

Study Population

Of 374 patients screened, 47 were included in the study based on inclusion criteria.

- Gender distribution: 63.8% male and 36.2% female.
- Age distribution: The majority (38.3%) were aged 41–60 years, followed by 20–40 years (31.9%).
- Comorbidities: 48.9% had no comorbidities, while 25.5% had multiple comorbidities.

Physiological Changes Post-PLR

- Pulse pressure: Increased by 19% (41.02–48.64 mm Hg).
- Left ventricular outflow tract velocity time integral: Increased by 20% (18.58–22.26).
- Peripheral perfusion index: Increased by 39% (1.23–1.70).

Subgroup Analysis

- Trauma patients: Showed the largest PPI increase (55%).
- Obstetrics patients: Showed a 41% increase.
- Postoperative patients: Had a smaller PPI increase (6%).

Discussion

This study evaluated the role of PPI as a noninvasive marker of fluid responsiveness in critically ill patients with hypotension or shock. Peripheral perfusion index demonstrated an average increase of 39% in patients who achieved the recommended 12% rise in PP and LVOT VTI post-PLR.[6,7,8] Among the patients, 9 (19.2%) were on vasopressors and required ongoing fluid resuscitation, which was confirmed through PLR. The other 38 (80.8%) patients were not on vasopressor support and received the resuscitation bolus before the initiation of vasopressors. To avoid the confounding effects of vasopressors, which can cause peripheral vasoconstriction and alter preload and perfusion, our study included only those patients whose vasopressor requirement was less than 10 µg of noradrenaline.[9] Ten (21%) patients received 5% albumin as the resuscitation fluid bolus, while the remaining 37 (79%) patients received Plasmalyte. Consistent with other studies, no significant difference in PPI increase was found based on the type of fluid used.[10] Of the 37 patients who received a crystalloid bolus, 12 (32%) received 500 mL, while the remaining 68% received 250 mL. Our study observed a 39% increase in PPI after PLR and fluid resuscitation, which is higher than the increase reported in many other studies.[11] This could be attributed to the absence of high-dose sedation, as all patients were spontaneously breathing.[12] Additionally, minimal vasopressor requirements resulted in less peripheral vasoconstriction, leading to a wider variation in PPI.

Trauma patients showed a 55% increase in the perfusion index (PI), higher than the overall average, possibly due to lower APACHE 2 and SOFA scores, and the effect of age on the intactness of the autonomic nervous system and peripheral blood vessels, as most trauma patients were under 50 years old.[13] Obstetrics and Gynecology patients experienced a 41% increase in PPI.[14] Postoperative surgical patients had only a 6% rise in PPI after PLR and the fluid bolus, possibly due to changes in body temperature from prolonged exposure to the operating theatre temperature, resulting in a drop in peripheral temperature where the PPI was recorded.[15–17]

Limitations of the Study

Despite its strengths, this study has several limitations:

- Sample size: While the sample size of 47 participants was adequate to detect statistical significance, a larger cohort would enhance the generalizability of the findings.
- Confounding variables: Factors such as ambient temperature, patient body temperature, and peripheral vascular conditions (e.g., atherosclerosis) were not directly controlled or measured. These may have influenced PPI variability and warrant further investigation.
- Noninvasive measurement constraints: Peripheral perfusion index readings were reliant on pulse oximetry, which can be affected by technical issues such as sensor placement, skin pigmentation, or hypoperfusion in severe shock.
- Subgroup analysis: While the subgroup analysis (e.g., trauma, obstetrics, postoperative) revealed important trends, the small number of patients in each subgroup limits the strength of these conclusions.
- Single-center study: Conducted in a tertiary care center in Southern India, the findings may not be directly applicable to other settings or populations with different comorbidities and ICU practices.

Future studies should consider a multicenter design with a larger, more diverse population to address these limitations and validate the findings.

Clinical Significance

The PPI holds significant potential as a noninvasive, easy-to-use tool for guiding fluid resuscitation in critically ill patients. Based on the findings of this study, the following recommendations can be made:

- Peripheral perfusion index threshold: A 39% increase in PPI following a PLR test should be used as a reliable indicator of fluid responsiveness in spontaneously breathing, critically ill patients.
- Combined parameters: PPI should be integrated with other hemodynamic markers, such as LVOT VTI and PP changes, to enhance the accuracy of fluid responsiveness predictions.
- Minimizing vasopressors: PPI measurements are most reliable in patients with minimal vasopressor support (<10 µg/min of noradrenaline), as higher doses may cause peripheral vasoconstriction and interfere with PPI readings.
- Trauma and obstetrics subgroups: Trauma and obstetrics patients demonstrated greater increases in PPI, suggesting that this marker may be particularly useful in these populations.
- Routine ICU use: Peripheral perfusion index can be a practical addition to routine ICU monitoring for fluid management, providing critical care teams with a noninvasive method to optimize resuscitation strategies.

Conclusion

This study observed a 39% increase in the PI after PLR, highlighting its potential utility in predicting fluid responsiveness in critically ill patients. There was considerable variability in PI changes across different patient groups. For example, trauma patients showed a 55% increase, obstetrics and gynecology patients showed a 41% increase, and postoperative patients showed a 6% increase. These variations underscore the importance of using PI in conjunction with other established parameters for a more comprehensive assessment. While PI can be a valuable tool, it is most effective when used alongside parameters such as changes in PP and LVOT VTI following a PLR test. This combined approach enhances the accuracy of fluid responsiveness assessments. Further validation with a larger and more diverse patient population will be beneficial to fully determine the efficacy of PI as a predictor of fluid responsiveness.

Orcid

Jayaprakash Narayanan B https://orcid.org/0000-0001-9120-5295
Shoma V Rao https://orcid.org/0000-0002-7483-5575
Subramani Kandasamy https://orcid.org/0000-0002-7628-5335

References

1. Lima AP, Beelen P, Bakker J. Use of a peripheral perfusion index derived from the pulse oximetry signal as a non-invasive indicator of perfusion. Crit Care Med 2002;30(6):1210–1213. DOI:10.1097/00003246-200206000-00025.
2. Højlund J, Agerskov M, Clemmesen CG, Hvolris LE, Foss NB. The peripheral perfusion index tracks systemic haemodynamics during general anaesthesia. J Clin Monit Comput 2020;34(6):1177–1184. DOI:10.1007/s10877-020-00489-2.
3. van Genderen ME, Bartels SA, Lima A, Bezemer R, Ince C, Bakker J, et al. Peripheral perfusion index as an early predictor for central hypovolemia in awake healthy volunteers. Anesth Analg 2013;116(2):351–356. DOI:10.1213/ANE.0b013e318271f6f3.
4. Klijn E, Groeneveld AB, van Genderen ME, Betjes M, Bakker J, van Bommel J. Peripheral perfusion index predicts hypotension during fluid withdrawal by continuous veno-venous hemofiltration in critically ill patients. Blood Purif 2015;40(1):92–98. DOI:10.1159/000441541.
5. Kroese JK, van Vonderen JJ, Narayen IC, Walther FJ, Hooper S, te Pas AB. The perfusion index of healthy term infants during transition at birth. Eur J Pediatr 2016;175(4):475–479. DOI:10.1007/s00431-015-2667-8.
6. Shi X, Xu M, Yu X, Lu Y. Peripheral perfusion index predicting prolonged ICU stay earlier and better than lactate in surgical patients: An observational study. BMC Anesthesiol 2020;20(1):153. DOI:10.1186/s12871-020-01068-4.
7. Zimmermann M, Feibicke T, Keyl C, Prasser C, Moritz S, Graf BM, et al. Accuracy of stroke volume variation compared with pleth variability index to predict fluid responsiveness in mechanically ventilated patients undergoing major surgery. Eur J Anaesthesiol 2010;27(6):555–561. DOI:10.1097/EJA.0b013e328338f610.
8. Broch O, Bein B, Gruenewald M, Höcker J, Schöttler J, Meybohm P, et al. Accuracy of the pleth variability index to predict fluid responsiveness depends on the perfusion index. Acta Anaesthesiol Scand 2011;55(6):686–693. DOI:10.1111/j.1399-6576.2011.02427. x.
9. Desgranges FP, Desebbe O, Ghazouani A, Gilbert K, Keller G, Chiari P, et al. Influence of the site of measurement on the ability of plethysmographic variability index to predict fluid responsiveness. Br J Anaesth 2011;107(3):329–335. DOI:10.1093/bja/aer185.
10. Shi R, Monnet X, Teboul JL. Parameters of fluid responsiveness. Curr Opin Crit Care 2020;26(3):319–326. DOI:10.1097/MCC.0000000000000716.

11. Sebastiani A, Philippi L, Boehme S, Closhen D, Scherhag A, Markstaller K, et al. Perfusion index and plethysmographic variability index in patients with interscalene nerve catheters. Can J Anaesth 2012;59(12):1095–1101. DOI:10.1007/s12630-012-9774-8.
12. Monnet X, Guerin L, Jozwiak M, Bataille A, Julien F, Richard C, et al. Pleth variability index is a weak predictor of fluid responsiveness in patients receiving norepinephrine. Br J Anaesth 2013;110(2):207–213. DOI:10.1093/bja/aes384.
13. Hong DM, Lee JM, Seo JH, Min JJ, Jeon Y, Bahk JH. Pulse pressure variation to predict fluid responsiveness in spontaneously breathing patients: Tidal vs. forced inspiratory breathing. Anaesthesia 2014;69(7):717–722. DOI:10.1111/anae.12730.
14. Bapteste L, Carrillon R, Javelier S, Guyotat J, Desgranges FP, Lehot JJ, et al. Pulse Pressure variations and plethysmographic variability index measured at ear are able to predict fluid responsiveness in the sitting position for neurosurgery. J Neurosurg Anesthesiol 2020;32(3):263-267. DOI:10.1097/ANA.0000000000000615.
15. Godai K, Matsunaga A, Kanmura Y. The effects of hemodynamic management using the trend of the perfusion index and pulse pressure variation on tissue perfusion: A randomized pilot study. JA Clin Rep 2019;5(1):72. DOI:10.1186/s40981-019-0270-4.
16. Rao SS, Lalitha AV, Reddy M, Ghosh S. Electrocardiometry for hemodynamic categorization and assessment of fluid responsiveness in pediatric septic shock: A pilot observational study. Indian J Crit Care Med 2021;25(2):185–192. DOI:10.5005/jp-journals-10071-23730.
17. Jayaprakash D, Subramanian S, Rajesh R, Srinivasan S. Predictive value of peripheral perfusion index in assessing fluid responsiveness in critically ill patients: A prospective observational study. Indian J Crit Care Med 2022;26(1):45–50. DOI:10.5005/jp-journals-10071-24145.