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ASSOCIATION OF PULSE OXIMETRY-DERIVED PERIPHERAL PERFUSION INDEX WITH CLINICAL SIGNS OF SHOCK IN NEONATES: A PROSPECTIVE OBSERVATIONAL STUDY

Dr Veeresh Channappa Kajagar — Primary DNB, TRSH, Delhi

Dr Sunil Gupta — Senior Consultant, TRSH, Delhi

ABSTRACT **Objective:** To assess the correlation of pulse oximetry-derived peripheral perfusion index (PI) with clinical parameters of shock and evaluate its diagnostic performance in identifying shock among neonates. **Design:** Prospective observational study. Setting: A tertiary-level neonatal intensive care unit in Delhi, India, between January 2024 and December 2025. **Patients:** A total of 140 neonates with gestational age ≥28 weeks requiring haemodynamic monitoring were included. Of these, 28 were classified as having shock and 112 as not having shock. Neonates with major congenital anomalies, gestational age <28 weeks or antenatally diagnosed life-threatening heart disease were excluded. Main Outcome Measures: The primary outcome was the correlation between PI and clinical parameters of shock, including heart rate (HR), capillary refill time (CRT), blood pressure and cold extremities. Secondary outcomes included comparison of PI between shock and non-shock groups and its diagnostic discrimination using receiver operating characteristic (ROC) analysis. **Results:** Mean PI was significantly lower in neonates with shock than in those without shock (0.67±0.22 vs 1.39±0.59; p<0.001). PI demonstrated a moderate negative correlation with CRT (Spearman ρ=−0.552; p<0.001) and a weaker negative correlation with cold extremities (ρ=−0.308; p<0.001). No significant correlation was observed with HR, systolic blood pressure, diastolic blood pressure or mean arterial pressure. PI demonstrated good discrimination for recorded shock status, with an area under the ROC curve of 0.873 (bootstrap 95% CI 0.814–0.927). An exploratory threshold of PI ≤1.00 yielded 100% sensitivity and 80.4% specificity in this cohort. **Conclusions:** PI was associated with clinical indicators of peripheral hypoperfusion and showed good discrimination for recorded shock status. It may serve as a complementary, non-invasive bedside monitoring parameter in neonates. The proposed threshold requires validation in larger, independent multicentre studies

KEYWORDS : Neonatal Shock, Perfusion Index, Peripheral Perfusion, Pulse Oximetry, Capillary Refill Time, Haemodynamic Monitoring, Neonatal Intensive Care

INTRODUCTION

Neonatal shock is a life-threatening state in which inadequate tissue perfusion can lead to cellular dysfunction and organ injury. Early recognition is challenging because clinical signs may be subtle, and blood pressure may remain within an apparently acceptable range despite impaired peripheral circulation. Heart rate, capillary refill time (CRT), peripheral temperature and blood pressure are commonly used in clinical assessment, but no single parameter reliably captures all aspects of neonatal haemodynamics.[1-3]

The peripheral perfusion index (PI), obtained from the pulsatile and non-pulsatile components of the pulse oximetry signal, provides a non-invasive estimate of peripheral perfusion. Changes in peripheral vascular tone may alter PI before conventional haemodynamic measurements become abnormal. However, PI is influenced by several factors, including gestational age, temperature, probe position, movement, device characteristics and vasoactive treatment. Its interpretation therefore requires consideration of the clinical context.[4 5]

This study assessed the relationship between PI and bedside clinical parameters of shock in neonates admitted to a tertiary neonatal intensive care unit. The primary objective was to evaluate the correlation between PI and CRT, heart rate, blood pressure and cold extremities. A secondary objective was to assess the diagnostic discrimination of PI and compare it with other recorded clinical parameters for identifying neonates classified as having shock.

METHODS

Study Design and Setting: This prospective observational diagnostic-accuracy study was conducted in the Department of Pediatrics at Tirath Ram Shah Hospital, a tertiary care teaching hospital in Delhi, India. Recruitment and data collection took place between January 2024 and December 2025.

Participants (Inclusion and Exclusion Criteria): The study included 140 neonates with a gestational age of 28 or more completed weeks who were admitted to the neonatal intensive care unit and required haemodynamic monitoring. Eligible clinical presentations included shock, hypothermia, hypoglycaemia, perinatal asphyxia, respiratory distress, seizures and neonatal sepsis.

Neonates with major congenital anomalies, gestational age below 28 weeks or life-threatening heart disease diagnosed antenatally were excluded. Consecutive eligible neonates were recruited after obtaining informed consent from a parent or legal guardian.

Sampling: The sample size was calculated using the following standard formula for estimation

$$n = [Z_{1-\alpha/2}^2 X p X (1-p)] / d^2$$

where,

- n = required sample size
- Z = Z-score corresponding to the desired confidence level
- p = estimated prevalence of shock
- E = margin of error

Clinical Assessment and PI Measurement: Heart rate was assessed by auscultation when the neonate was calm and not agitated. CRT was measured following blanching pressure over the chest for 3–5 seconds and recording the time taken for colour to return. Cold extremities were assessed by comparing the temperature of the abdomen with that of the foot using the dorsum of the examiner's hand.

Blood pressure was measured non-invasively in the supine position using an appropriately sized cuff on the right upper limb. Systolic blood pressure, diastolic blood pressure and MAP were recorded.

PI was measured using a COMEN pulse oximeter. The probe was placed on the right upper limb, with attention to minimising movement and ensuring an adequate signal. The study protocol specified measurements at 2-hourly intervals for 48 hours in all enrolled neonates. For neonates with shock, monitoring was performed every 20 minutes until perfusion normalised, after which 2-hourly monitoring was resumed.

No therapeutic intervention was administered specifically for study purposes. Treatment was provided according to the hospital protocols.

Outcomes

The primary outcome was the correlation between PI and clinical parameters of shock: CRT, heart rate, blood pressure and cold extremities.

Secondary outcomes included differences in PI and other clinical measurements between neonates with and without recorded shock, and the ability of PI, CRT, heart rate, systolic blood pressure, MAP and cold extremities to discriminate between the two groups.

Statistical Analysis

Continuous variables are summarised as means and standard deviations. Group comparisons were performed using methods appropriate to the distribution of the variables; Welch's t-test and the Mann–Whitney U test were considered for continuous variables. Correlations were assessed using Spearman's rank correlation coefficient.

ROC curves were constructed to assess discrimination for recorded shock status. Because lower PI values were associated with shock, PI was evaluated in the direction of decreasing values. The area under the ROC curve (AUC) was calculated, with a 95% confidence interval based on resampling the study participants. An exploratory PI threshold was selected using the Youden index. Sensitivity, specificity, positive predictive value and negative predictive value were calculated at that threshold.

All tests with $p<0.05$ considered statistically significant. Analyses were performed using SPSS version 22.institutional ethics committee approval and informed consent were taken.

RESULTS

Participant characteristics: A total of 140 neonates were included in the patient-level master chart. Twenty-eight (20.0%) were classified as having shock and 112 (80.0%) as not having shock. The shock group comprised 15 neonates with septic shock, seven with hypovolaemic shock and six with cardiogenic shock.

The cohort included 82 male and 58 female neonates; 78 were outborn and 62 were inborn. Mean gestational age was 33.61±3.60 weeks, mean birth weight was 2234±712 g and mean age at enrolment was 36.52±20.98 hours.

Comparison of clinical parameters by shock status : Neonates classified as having shock had a lower mean PI and longer mean CRT than those without shock. Heart rate was also higher in the shock group. Differences in systolic blood pressure, diastolic blood pressure and MAP were not statistically significant.

Table 1: Distribution of Continuous Variables: Shock Versus Non-Shock

Variable	Shock (n=28) mean ± SD / median (IQR)	Non-shock (n=112) mean ± SD / median (IQR)	Test	p-value
Gestational age (weeks)	33.54 ± 3.00 / 34.00 (31.75–35.25)	33.62 ± 3.75 / 33.00 (30.00–37.00)	Mann–Whitney U	0.8960
Birth weight (g)	2215 ± 738 / 2186.5 (1688–2803)	2238 ± 709 / 2217.5 (1694–2831)	Mann–Whitney U	0.8943
Heart rate (bpm)	170.39 ± 13.79 / 169.0 (160.5–181.25)	152.52 ± 22.91 / 152.5 (132.5–173.0)	Mann–Whitney U	0.0003
CRT (sec)	3.91 ± 0.74 / 4.05 (3.28–4.38)	3.23 ± 1.10 / 3.21 (2.33–4.18)	Mann–Whitney U	0.0028
Perfusion index	0.86 ± 0.29 / 0.82 (0.66–1.05)	1.34 ± 0.63 / 1.34 (0.98–1.76)	Mann–Whitney U	0.0001
Systolic BP (mmHg)	62.89 ± 7.10 / 68.0 (57.19–68.0)	58.08 ± 10.22 / 60.22 (51.12–68.0)	Mann–Whitney U	0.0181
MAP (mmHg)	43.48 ± 8.64 / 44.17 (36.59–52.85)	41.09 ± 8.13 / 41.61 (33.71–47.73)	Mann–Whitney U	0.1725

Association Between PI and Clinical Parameters :

These numeric results confirm that PI aligns closely with microcirculatory signs (CRT, limb temperature) rather than with macro-circulatory pressure variables

Table 2 : Correlation Between Peripheral Perfusion Index and Clinical Parameters of Shock (Crt, Heart Rate, Blood Pressure, Cold Extremities)

Parameter	ρ (Spearman)	p-value
Capillary refill time (CRT)	-0.552	<0.001
Heart rate (bpm)	-0.075	0.378
Systolic BP (mmHg)	0.001	0.986
Diastolic BP (mmHg)	-0.027	0.752
Mean arterial pressure (MAP)	0.015	0.863
Pulse pressure (mmHg)	0.005	0.949
Cold extremities (binary)	-0.301	<0.001

Diagnostic Discrimination:

The AUC for PI was 0.873 (95% CI 0.814 to 0.927), indicating good discrimination for recorded shock status in this cohort. The AUCs for CRT and heart rate were 0.715 and 0.710, respectively. Systolic blood pressure and MAP had lower AUCs of 0.576 and 0.568.

The Youden-index threshold in this dataset was approximately PI ≤1.00. At this threshold, sensitivity was 100% (28/28; Wilson 95% CI approximately 87.9% to 100%) and specificity was 80.4% (90/112; Wilson 95% CI approximately 72.0% to 86.7%). The positive predictive value was 56.0% and the negative predictive value was 100% in this cohort.

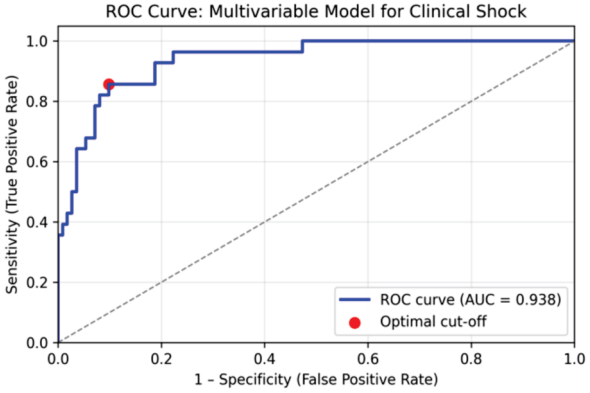


Figure 1 : ROC Analysis of the Multivariable Model

Table 3 : ROC Analysis of the Multivariable Model

Parameter	Value
AUC	0.938
95% CI	0.838 – 1.038
Optimal cut-off (Youden index)	0.328
Sensitivity	0.857
Specificity	0.902
PPV	0.686
NPV	0.962

The high AUC and favourable operating characteristics demonstrate that combining PI with key clinical parameters provides excellent discrimination between shocked and non-shocked infants, far superior to any single variable alone. This supports using integrated scores or structured decision tools rather than isolated measurements in bedside shock assessment

DISCUSSION

In this prospective single-centre cohort, PI was lower in neonates classified as having shock and showed good discrimination for recorded shock status. PI was moderately inversely correlated with CRT and more weakly correlated with cold extremities. It was not significantly correlated with heart rate or blood pressure measurements. These findings suggest that PI may provide information about peripheral perfusion that is not fully captured by conventional bedside haemodynamic parameters.

The association between PI and CRT is clinically plausible. Both reflect aspects of peripheral circulation, although they measure different physiological phenomena and are influenced by temperature, vascular tone, measurement technique and the clinical condition of the neonate. The lack of a significant correlation between PI and blood pressure is also important: blood pressure and peripheral perfusion should not be considered interchangeable measures of circulatory status. The results support evaluating PI as a complementary monitoring parameter rather than a stand-alone test.

The AUC of 0.873 suggests useful discrimination in this cohort. However, this estimate must be interpreted cautiously. The sample included only 28 neonates with shock, the study was conducted at a single centre and the reference classification was derived from the recorded clinical shock type. The available master chart does not establish whether PI measurement was blinded to the clinical

diagnosis or whether the diagnostic criteria were applied independently of PI. These issues may introduce classification or review bias. Furthermore, the exploratory threshold was selected and assessed in the same sample, and the resulting sensitivity and specificity may overestimate performance in a new population.

The study has practical strengths, including prospective recruitment, non-invasive measurements, inclusion of both inborn and outborn neonates, and assessment of multiple bedside parameters. Important limitations include the small number of shock cases, potential variation in PI due to device and clinical factors, and the absence of a patient-level dataset that captures the timing and full sequence of repeated measurements for longitudinal analysis. The current analysis therefore cannot determine whether changes in PI precede clinical deterioration or predict response to treatment. The manuscript also requires reconciliation of the operational shock definition with the approved protocol and confirmation of the ethics approval details before submission.

Further multicentre studies should use a prespecified, clinically independent definition of neonatal shock; standardise the timing and conditions of PI measurement; and evaluate the added value of PI beyond clinical assessment. A candidate threshold should be prespecified or derived in a training cohort and validated in an independent cohort. Future work should also examine serial PI trajectories and clinically meaningful outcomes rather than relying solely on diagnostic discrimination at a single patient-level record.

CONCLUSIONS

PI was lower in neonates classified as having shock and showed good discrimination for recorded shock status in this single-centre cohort. Its association with CRT suggests that it may complement bedside assessment of peripheral perfusion. The exploratory PI threshold of approximately 1.00 should not be adopted as a universal clinical cut-off without independent validation. Larger studies using explicit shock criteria and longitudinal measurements are required to establish the clinical utility of PI in neonatal haemodynamic monitoring.

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