Utilizing perfusion index for early identification of circulatory shock in neonates

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ABSTRACT

Introduction: Neonatal circulatory shock poses a significant challenge in intensive care settings and necessitates early recognition and intervention to prevent adverse outcomes. The perfusion index (PI), derived from pulse oximetry signals, is a potential adjunct tool for assessing peripheral perfusion and predicting shock in neonates. This prospective observational study aimed to evaluate the correlation between PI and circulatory shock in neonates with the goal of establishing PI as an objective parameter for early shock identification.

Materials and Methods: Study was conducted in the neonatal intensive care unit (NICU) of Saveetha Medical College Hospital, India, in 2023, between January and June. This study enrolled 100 neonates who underwent hemodynamic monitoring over 48-72 hours. Hemodynamic parameters including heart rate, blood pressure, and PI were systematically recorded. Statistical and Receiver operating characteristic curve analyses were used to assess the relationship between PI and shock.

Results: Neonates experiencing shock exhibited significantly lower PI values than those without (P < 0.05). ROC curve analysis identified a PI threshold of 0.7 for predicting shock, demonstrating a high sensitivity (92.5%) and specificity (94.78%). Additionally, a significant association was observed between PI and serum lactate level (p < 0.05), underscoring the utility of PI as a predictor of shock severity.

Conclusion: The study suggests that a PI < 0.7 may serve as an indicator of circulatory shock in neonates, offers good sensitivity and specificity. The PI, along with clinical parameters and serum lactate levels, is a valuable tool for early shock identification in neonatal intensive care. Further research, including multicenter studies, are warranted to validate these findings.

KEYWORDS:
Perfusion index, neonatal shock, reliable predictor, NICU,peripheral hypoperfusion

INTRODUCTION

The peripheral hemodynamics of a newborn baby ultimately determines the amount of oxygen and nutrients that reach its tissues. The rate of oxygen delivery had no effect on oxygen consumption in neonates with adequate perfusion. Infants born with compromised blood flow have oxygen consumption rates linked to tissue microcirculation. Tissue perfusion is only considered "normal" when all three of the following conditions are met: cardiac output, vasomotor tone, and oxygen delivery capacity of the blood. Shock, characterized by an acute breakdown of the circulatory system, is a clinical condition that fails to maintain nutrition and perfusion to tissues.[1] The strength of the pulse can be assessed by a tool, the perfusion index, which indirectly measures the perfusion at the peripheries. A pulse oximeter is commonly used to assess blood oxygen levels. There are two distinct parts of the signal: the arterial, pulsating part, and the non-arterial, non-pulsating part that comes from places like bone and connective tissue.[2] The pulsatile part shifts when the peripheral perfusion changes, leaving the non-pulsatile components unchanged. The ratio, as shown by the pulse oximeter, was varied. Because changes in arterial saturation are more likely to cause interference with red light signals, infrared light is preferred.[3,4]

$$\text{Perfusion index (PI)} = \frac{\text{Pulsatile signals of infrared}}{\text{Non pulsatile signals of infrared}} \times 100$$

PI is commonly reported as a percentage ranging from 0.02% (very weak pulse) to 20% (very strong pulse). To evaluate neonatal shock,clinicians use parameters that are subject to individual interpretation. The PI displayed by a pulse oximeter is an objective parameter that provides an indirect measure of perfusion in the peripheries. To obtain an objective measure of PI, we aimed to study the correlation between PI and BP to predict shock.

MATERIALS AND METHODS

A prospective observational study was conducted after obtaining approval from our institutional ethical committee, including all neonates with hemodynamic instability admitted to the Level 3 Neonatal Intensive Care Unit (NICU) of Saveetha Medical College Hospital located in Tamil (India) between January 2023 and June 2023. Informed written consent for the study was obtained from the parents of the neonates. We hypothesized that a lower perfusion index is expected in neonates with shock and should correlate with other shock parameters. This study included neonates with shock, respiratory distress, hypoglycemia,

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Table I: Haemodynamic parameters noted among babies

Haemodynamic parameters	Babies with shock	Babies without shock	p-value
Systolic Bp (in mmHg)	64.21±7.9	68.5±2.4	0.03
Diastolic Bp (in mmHg)	40.21±4.9	47.15±3.9	0.04
Mean Arterial Pressure(MAP) (in mmHg)	46.79±5.8	49.15±2.54	0.05
Heart Rate (bpm)	152.12±13.67	146.14±3.45	0.04

Table II: Association between shock and perfusion index

Perfusion index(PI)	Shock Present (number of babies)	Shock Absent (number of babies)	p-value
≤0.7	24	2	
>0.7	3	71	<0.04
Total	27	73	

Table III: Association between PI and serum lactate

PI	Serum Lactate (≥5)	Serum Lactate (≤5)	p-value
≤0.7	20	7	
>0.7	4	69	<0.04
Total	24	76	

Majority of babies who had serum lactate more than 5 had a perfusion index less than 0.7. Hence, the association is statistically significant (P<0.05)(Table III).

sepsis, seizures, and perinatal asphyxia. Children with major congenital anomalies and other life-threatening illnesses diagnosed during the antenatal period were excluded.

Neonates in the level 3 NICU requiring hemodynamic monitoring were enrolled in the study after obtaining written consent from their parents. A sample size of 100 was chosen, and the children were recruited using a convenient sampling method. Perfusion parameters were monitored by the principal investigator from the time of enrollment until 48 hours in stable neonates and for 72 hours in sick neonates. 8th hourly monitoring were done for all babies from the time of recruitment until 48 h.

Neonates with shock were monitored for 20 min until perfusion normalized and continued as planned until 72 h. The following parameters were monitored: heart rate, Blood Pressure (BP) including [Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP),Mean Arterial Pressure (MAP)], PI using a pulse oximeter, and at least one value for blood lactate levels. The following criteria were set for definition:

Shock/poor perfusion was defined as having a weak and fast pulse (HR > 180/min), Capillary Refill Time (CRT) >3 s, cold extremities, and with or without the following signs in addition: lethargy, not responding to stimulation, and very pale. As per the unit policy, the shock and comorbid conditions were treated.

Monitoring: Heart rate was assessed using stethoscopes in non-agitated babies. Blood pressure was measured in the right upper limb in the supine posture in a quiet environment, and an appropriately sized cuff was used.4 Selection of BP cuff was made based on the criterion that the width of the cuff should be 2/3rd of the arm length. Blood Lactate levels were obtained from arterial blood gas analysis, which is often performed for all babies admitted to the NICU and requires hemodynamic monitoring. PI in the right upper limb was measured using pulse oximetry.

STATISTICAL ANALYSIS

Data were collected and consolidated using Microsoft Excel software and analyzed using JAMOVI software, version 2.3.28. Frequency analysis was performed for descriptive variables, percentage analysis was used for categorical variables, and mean and standard deviation were used for continuous variables. The correlation between the PI and other shock parameters was calculated using the area under the ROC curve. The cutoff value of PI was set, and values below or above it were used to predict babies in shock/not.

RESULTS

In this study, 34% of neonates were born with a gestational age below 34 weeks, and 66% had a gestational age above 34 weeks, with a mean gestational age of 35.78 weeks and a standard deviation of 2.23 weeks. Almost 47 babies were delivered via lscs, with 53 delivered via normal delivery. Approximately 28 babies had a birth weight of less than 1.75 kg while the rest had above 1.75 kg of birth weight. Certain neonatal complications were noted in the study population, such as birth ashyxia (12 babies), Respiratory Distress Syndrome (36 babies), apnea (4 babies), Meconium Aspiration Syndrome (MAS)(22 babies), sepsis (14 babies), hyperbilirubinemia (35 babies), 5 babies required ventilator support, 2 babies, intraventricular hemorrhage (IVH) and 4 babies developed Retinopathy of Prematurity (ROP)(Figure I).

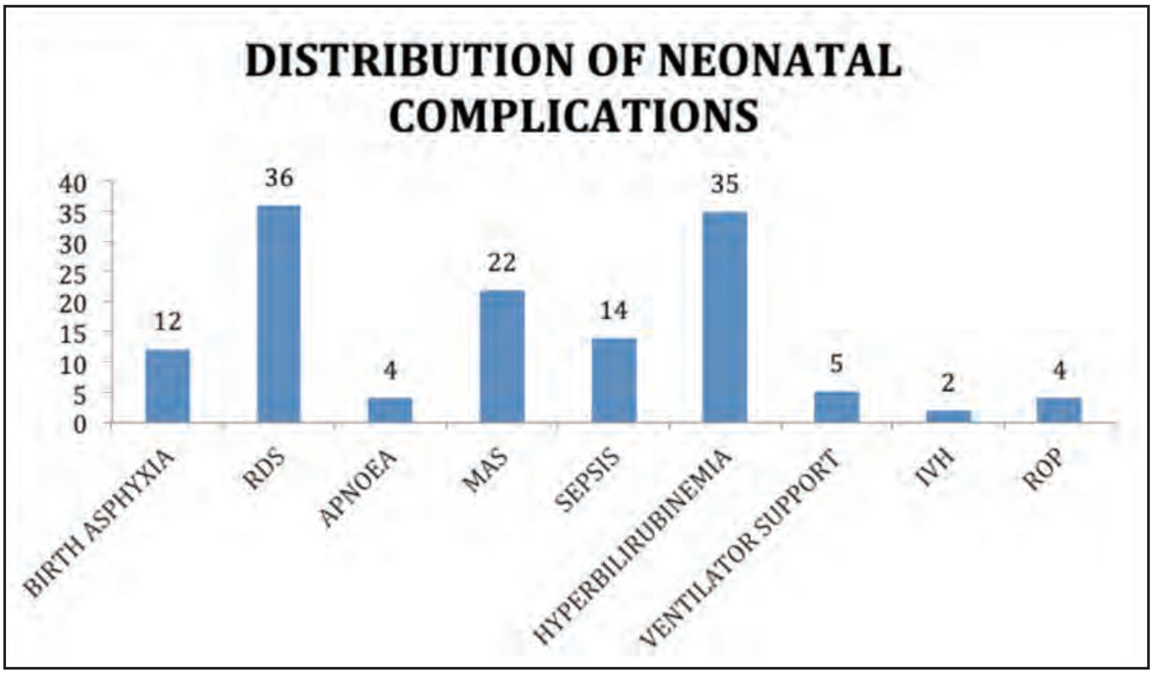

Fig. 1: Distribution of neonatal complications among study population

Mean systolic BP of 64.21±7.9 (mmHg) was recorded in babies with shock while 68.5±2.4 (mmHg) was recorded in non shock babies. Mean Diastolic BP of 40.21±4.9 (mmHg) respectively, in babies with shock, whereas non-shock babies had a Mean Diastolic BP of 47.15±3.9 (mmHg). The mean MAP was 46.79±5.8 (mmHg) in babies who had shock, while the rest of the babies had a mean MAP of 49.15±2.54 (mmHg). Mean Heart rate was 152.12±13.67 (Beats per minute) in neonatal shock while non shock babies had a mean heart rate of 146.14±3.45 (Beats per minute). All of the above cardiovascular parameters were statistically significant (Table I).

In our study population of 100 babies, 27 had clinical features of shock, of which 24 babies had a PI less than 0.7. Out of 73 non-shock babies, two had a PI of less than 0.7. This association was statistically significant ($p<0.05$) (Table II) and emphasized that PI can be utilized as a reliable predictor of neonatal shock in the NICU.

Association between neonatal shock and PI has a Sensitivity of 92.5% and a specificity of 94.78% with a positive predictive value of 81.24% and negative predictive value of 96.43%.

DISCUSSION

Neonatal shock is a diagnosis with many indulging parameters and subjective decisions on management.1 Although babies have more blood volume(ml/kg) than adults, even a small quantity of blood loss will result in neonatal shock. There are numerous reasons for shock, such as sepsis, IVH, poor feeding, cardiac causes, and pneumothorax, and early detection of neonatal shock is the primary factor for early management and recovery.[1]
Oscillatory automatic BP measurements are reliable and are routinely used in all NICU. Manual BP cannot be recorded because babies' artery pulsations are not loud enough to be heard with a stethoscope.[2] The relationship between heart rate, blood pressure, and serum lactate levels is substantially less. Increased ICU and hospital mortality are linked to elevated serum lactate levels. Although lactate levels play a crucial role in ICU care, many times, it becomes an oversimplification that equates hyperlactatemia with hypoperfusion.[2] Most of the parameters used for clinical assessment of shock in neonates are subjective,which leads to unnecessary treatment of shock. These clinical factors result in greater interobserver variability. This creates a demand for objective assessment of shock, which can detect hypoperfusion in neonates, resulting in the early identification and management of shock in newborns.

In the ICU, normal serum lactate levels are present in approximately 50% of critically ill septic patients.[4] Uncertainty surrounds the pathophysiology underlying the normal serum lactate levels in some critically ill ICU patients. Even among patients who ranked among the sickest in the highest quartile, serum lactate level was a reliable predictor of mortality. When a patient presents to the emergency department (ED) with septic shock, the initial serum lactate level is independently correlated with mortality. Therefore, measurement of the first serum lactate level may be a reliable indicator of prognosis in patients with septic shock. Perfusion index (PI) is a marker of hypoperfusion. Therefore, a drop in PI indicates activation of the sympathetic system, which is seen on many occasions such as shock,pain, stress,etc.[5,6] We created a receiver operating characteristic (ROC) curve that can detect impending shock by changing the percentage of the perfusion index (PI). Certain factors like pain, stress, hypothermia can influence the values of PI.[7] In medical literature, only few studies have been done for predicting hypoperfusion using PI. Few studies have used PI to assess the severity of illness and correlate low flow in the superior vena cava (SVC) with PI in neonates.[8,9] Hence, the present study aimed to determine whether the perfusion index can be used to predict shock. Certain parameters such as temperature and gestational age can influence PI.[10]

In the present study, about 66% were above 34 weeks of gestational age and 34% were below 34 weeks of GA, Mean GA was 35.78 and SD was 2.23. Approximately 53% of the patients were male and 47% were female. Nearly 47% had normal deliveries and 53% had LSCS. Approximately 29% had a birth weight less than 1.75 kg. The mean birth weight was 2.02 kg and the standard deviation was 0.85 kg. Certain neonatal complications noted in the study population included birth asphyxia (12 babies), RDS (36 babies), Apnea (4 babies), MAS (22 babies), sepsis (14 babies), hyperbilirubinemia (35 babies), ventilator support (5 babies), IVH (2 babies had IVH and ROP (4 babies developed ROP. Mothers of babies had certain antenatal complications, such as gestational diabetes mellitus(37%), pregnancy-induced hypertension (22%), obesity (4%), Overt Diabetes mellitus (2%), and no other complications.

In a study, a significant positive correlation was detected values of PI (less than 0.44) and low flow rate in superior vena cava in preterm neonates.5 In a study done in the adult population, the values of PI (1.4) detected hypo perfusion in patients with shock.[6]

PI measurements can be affected by artificial factors such as temperature, skin pigmentation, and motion artifacts, which could lead to inaccuracies.[11-13] Another prospective study showed that PI ranging from 0.30 to 10.0, with a median value of 1.4, had skewed distribution and concluded that PI can be used to monitor peripheral perfusion in critically ill patients.[9] Severity of illness using the SNAP score was studied by De Felice et al., in which a value of 0.86 PI detected the severity of sickness in newborn.[14] This study also showed a high sensitivity value. He et al. and Lian et al. found that changes in PI post-resuscitation are predictive of mortality, especially in septic patients.[15-17] The study done in 2020 showed a positive correlation between PI and Cardiac Index during the early treatment phase of septic shock.[18] PI showed moderate ability to detect fluid responsiveness in patients with septic shock on norepinephrine infusion. Increased PI after a 200 mL crystalloid challenge can detect fluid responsiveness with a positive predictive value of 92%.[19]

Similar to the above studies, but with comparatively lower values, the majority of the neonates in the present study population who had shock had a perfusion index less than 0.7. This association was statistically significant ($p<0.05$). The majority of neonates with serum lactate levels > 5 had a perfusion index less than 0.7. This association was also statistically significant ($p<0.05$).

CONCLUSION

Clinical shock in neonates can be predicted with reasonable accuracy when the perfusion index is below 0.7. A perfusion index below 0.7 exhibits high sensitivity and low false positivity in anticipating clinical shock. The perfusion index, displayed on modern pulse oximeters, could serve as an additional valuable parameter for assessing peripheral perfusion. Furthermore, it correlates with serum lactate levels, aiding the prediction of shock. A more extensive study with a larger sample size may be necessary to gain deeper insights into the perfusion index and its ability to predict impending shocks.

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