Original Article

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Peripheral Perfusion Index in Assessment of Shock in Paediatric Intensive Care Unit of A Tertiary Care Hospital

Monir Ullah[1] Suman Biswas[2] Md. Saiful Islam[3] Mohammed Hossain[4] Muhammad Jabed Bin Amin Chowdhury[2] Rana Chowdhury[5] Mohammad Musa Meah[2] Nasir Uddin Mahmud[6] Farid Uddin Ahmed[7*]

ABSTRACT

Background: *Measures of peripheral perfusion can be used to assess the hemodynamic status of critically ill patients. The peripheral Perfusion Index (PI) based on analysis of the pulse oximetry signal has been implemented in monitoring systems as an index of peripheral perfusion. The aim of this study was to evaluate clinical state of shock by PI in a Pediatric Intensive Care Unit (PICU) of a tertiary care hospital of Bangladesh.*

Materials and methods: *This prospective observational study was carried out in the PICU of Chittagong Medical College Hospital. Children aged 1 month to 12 years who needed hemodynamic monitoring were included and categorized into five age groups. Demographic data, vital parameters and PI were recorded. Hemodynamic monitoring was started as early as possible within 24 hours of arrival in PICU, then 30 minutes after, then 8 hourly for a total 4 observations.*

Results: *In total, 199 children were included with or without features of shock and 796 hemodynamic measurements were taken and analyzed. Mean/median PIs were significantly higher in patients without shock compared to patients with shock in all age groups except age group 10-12 years of age. Clinical shock can be reasonably detected when PI value was < 1.25 in children <1 year of age, < 2.05 in 1 to 3 years of age, <2.55 in 3 to 5 years, and <1.95 in 5-10 years of age. These values had low sensitivity but high specificity in detecting clinically assessed shock in that particular age group. Overall, PI had good correlation with systolic, diastolic, mean arterial blood pressure and pulse pressure. Children with different features of shock had significantly lower mean PI compared to children without features of shock.*

Conclusion: *PI can be used as a non-invasive, continuous parameter to monitor peripheral perfusion in critically ill children managed in PICU.*

Key words: Children; Infants; Peripheral Perfusion Index; Pediatric intensive care unit; Shock.

Introduction

Pediatric practitioners treating acutely ill children are faced with different degrees and causes of shock on a regular basis. Shock in infants and children one of the most common and, often, life-threatening conditions encountered.[1] Major modalities that are used to assess shock and measure peripheral perfusion status include pulse rate, pulse volume, Respiratory Rate (RR), Capillary Refill Time (CRT), Blood Pressure (BP), temperature.[2-4] However, Subjective and objective measurements of these parameters have important limitations.[4,5]

Peripheral Perfusion Index (PI) has been investigated for its use in hemodynamic monitoring. The PI is derived from the photoelectric plethysmographic signal of the pulse oximeter. The changes in the PI reflect changes in peripheral vasomotor tone.[6] In critically ill patients, the same value was found to represent a very sensitive cutoff point for determining abnormal peripheral perfusion, as defined by a prolonged Capiullary Refile Time (CRT). Therefore, PI can be used for monitoring peripheral perfusion in critically ill patients.[7]

There is scarcity of research in our country regarding assessment of shock by PI. In resource limited setting like Bangladesh where monitoring of shock in PICU is challenging as central venous catheter for monitoring ScvO2 is not always possible in very young children.

1. Junior Consultant of Paediatrics
Banshkhali Upazila Health Complex, Chattogram.
2. Assistant Professor of Paediatrics
Chittagong Medical College. Chattogram.
3. Resident Physician of Paediatrics
Chittagong Medical College Hospital, Chattogram.
4. Junior Consultant of Paediatrics
Sitakunda Upazila Health Complex, Chattogram.
5. Assistant Professor of Paediatrics
Chattogram Maa-O-Shishu Hospital Medical College, Chattogram.
6. Director
Institute of Public Health Nutrition, Dhaka.
7. Associate Professor of Community Medicine
Rangamati Medical College, Rangamati.

*Correspondence : **Dr. Farid Uddin Ahmed**
Cell : +88 017 27 78 97 00
Email : fuahmed_34@yahoo.com

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Other invasive monitoring like frequent serum lactate measurement is not always feasible due to economic constrained. Some other measures demand high technological and logistic support which may not affordable. Manpower limitation is another challenge for close clinical monitoring of patient with shock or risk of shock. But PI is one of the simplest method by which we can overcome all of our limitations in monitoring shock in our PICU setting. In this background this study was conducted to evaluate the utility of PI in the assessment of shock in a PICU setting of Bangladesh.

Materials and methods

This prospective observational study was conducted in the PICU of Chittagong Medical College Hospital, Chittagong, Bangladesh form November 2019 to October 2020. Before starting the study, ethical clearance was obtained from the Ethical Review Committee of Chittagong Medical College and informed written consent was taken from the parents of the patients.

Children admitted or transferred to Paediatric ICU, aged 1 month to 12 years, and stayed in PICU for at least 24 hours were included. Children who died within 24 hours of PICU stay, who left PICU before completion of 24 hours of arrival in PCU, and children with poor signal pickup of perfusion index were excluded.

Data were analyzed by using SPSS V.23.0. As this study was done in wide age group of children from 1 month to 12 years of age, the study population was broken down into 5 age groups for wide analysis and to identify the changes in PI value predicting shock in different age groups of children. Continuous variables were recorded either as the means ± SD or median (Interquartile range) and categorical variables were reported as frequency (Percentages). Distribution of PI in various age groups was analyzed. Correlation coefficient between PI and BP was done by Pearson correlation coefficient. Receiver Operating Characteristic (ROC) was constructed between PI and shock to determine the optimal cutoff point. Continuous variables were compared by Mann-Whitney U test. Statistical significance was defined as $p < 0.05$.

Results

In this study 199 children admitted in the PICU who fulfilled the inclusion criteria were studied. Hemodynamic measurements were done for 4 times in each patient. In total there were 141 patients (70.9%) < 1 year of age, 28 (14.1%) in 1 to 3 year age group, 9 (4.5%) in 3 to 5 year of age, 12 (6.0%) with 5 to 10 year of age and 9 (4.5%) in 10 to 12 year age group. A total of 796 observations were recorded and analyzed in the study. Of the total 796 observation, in 572 observations (71.9%) children were not at the state of clinical shock and in rest of the 224 (28.1%) observation children had features of clinical shock (Table I).

Table I Clinical shock at different follow up in different age groups

Age group	Time	Without shock	With shock	Total
<1 Year				
	0 hour	90 (63.8)	51 (36.2)	141
	Half an hour	106 (75.2)	35 (24.8)	141
	8 hour	111 (78.7)	30 (21.3)	141
	16 hour	109 (77.3)	32 (22.7)	141
1-3 Year				
	0 hour	18 (64.3)	10 (35.7)	28
	Half an hour	19 (67.9)	9 (32.1)	28
	8 hour	20 (71.4)	8 (28.6)	28
	16 hour	19 (67.9)	9 (32.1)	28
3-5 Year				
	0 hour	5 (55.6)	4 (44.4)	9
	Half an hour	5 (55.6)	4 (44.4)	9
	8 hour	4 (44.4)	5 (55.6)	9
	16 hour	6 (66.7)	3 (33.3)	9
5-10 Year				
	0 hour	10 (83.3)	2 (16.7)	12
	Half an hour	10 (83.3)	2 (16.7)	12
	8 hour	10 (83.3)	2 (16.7)	12
	16 hour	9 (75.0)	3 (25.0)	12
10-12 Year				
	0 hour	3 (33.3)	6 (66.7)	9
	Half an hour	5 (55.6)	4 (44.4)	9
	8 hour	7 (77.7)	2 (22.2)	9
	16 hour	6 (66.7)	3 (33.3)	9
Grand total		572 (71.9)	224 (28.1)	796

Table II shows that in all age groups, PI had a skewed distribution as mean and median values did not coincide. Mean or median PI value with shock was lower than mean or median PI value without shock in all age group except the age group of 10 to 12 years of age where the trend was reverse.

Table II Mean (±SD) and Median (IQR) PI with and without shock in all age group

Age group	Without shock (n=224)	With shock (n=572)	p value*
<1 Year			
Mean (±SD)	2.81±1.52	1.77±1.53	<0.001
Median (IQR)	2.70 (1.73-3.90)	1.20 (0.50-2.30)	
1-3 Year			
Mean (±SD)	3.16±1.43	2.28±1.97	<0.001
Median (IQR)	3.65 (2.30-4.05)	1.90 (0.90-2.90)	

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3-5 Year			
Mean (±SD)	4.45±2.66	2.70±1.31	0.015
Median (IQR)	3.65 (2.90-5.33)	2.30 (1.93-4.05)	
5-10 Year			
Mean (±SD)	3.95±2.94	1.51±0.68	0.006
Median (IQR)	3.90 (1.90-5.70)	1.90 (0.70-2.00)	
10-12 Year			
Mean (±SD)	6.57±2.52	6.27±2.60	0.612
Median (IQR)	5.80 (4.30-9.30)	5.20 (4.10-8.40)	

*Mann-Whitney U test, SD: Standard Deviation, IQR: Interquartile Range.

The cutoff values for PI based on the maximum Youden index are shown in Table III with their respective sensitivity, specificity, positive predictive value and negative predictive value for differentiating shock state from non-shock state. The Table depicts that, cutoff values for PI to detect the clinically assessed shock vary with age groups with different sensitivity and specificity. In general, values had high specificity but low sensitivity.

Table III Accuracy of PI in identifying shock in children of all age groups

Age group	AUC	Cutoff value of PI	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
<1 Year	0.721	1.25	52.0	83.9	51.93	83.92
1-3 Year	0.701	2.05	55.6	81.6	58.82	79.49
3-5 Year	0.736	2.55	56.4	90.0	81.82	72.00
5-10 Year	0.792	1.95	77.8	71.8	38.89	93.33
10-12 Year	0.552	4.05	20.0	95.2	79.95	55.64

AUC: Area Under the ROC Curve, PPV: Positive Predictive Value, NPV: Negative Predictive Value.

Overall, PI had positive correlation with SBP, DBP and MAP. In children 1-3 year of age the correlation of PI with SBP, DBP, PP and MAP were significant and in children 10-12 years of age there was no significant correlation of PI with SBP, DBP, PP and MAP were observed. Overall there was no significant correlation between PI and SPO_2 in the study.

Table IV Correlation of PI with different blood pressure and SPO_2 in different age group

Parameters	<1 year	1-3 year	3-5 year	5-10 year	10-12 year	Total
PI vs. SBP						
r value	0.260	0.322	0.315	0.142	-0.088	0.310
p value	<0.001	0.001	0.062	0.377	0.611	<0.001
PI vs. DBP						
r value	NC	0.240	0.119	0.284	0.027	0.252
p value	NC	0.011	0.046	0.002	0.780	<0.001
PI vs. Pulse pressure						
r value	NC	0.189	0.024	-0.092	-0.086	0.038
p value	NC	0.046	0.888	0.536	0.616	0.560
PI vs. MAP						
r value	NC	0.284	0.437	0.204	-0.037	0.267
p value	NC	0.002	0.008	0.165	0.828	<0.001
SPO_2						
r value	-0.010	0.027	0.016	0.100	-0.014	0.007
p value	0.810	0.780	0.845	0.500	0.934	0.848

NC: Not Calculated as the pressure was measured. r: Correlation coefficient, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, MAP: Mean Arterial Pressure.

PI value was significantly lower in patients with decompensated shock than the patients with compensated shock. Different components of shock were also found to be related with PI. Mean/median PI values were significantly lower in patients with altered mental status, weak or absent peripheral pulse, capillary refill time >2 second, hypo or hyperthermia, and patients with cold calmy extremities than their counterpart (Table V).

Table V Comparison of PI in different features of shock

Features of shock	PI		p value*
	Mean ±SD	Median (IQR)	
Shock state			
Compensated	2.95±1.96	2.40 (1.60-4.20)	<0.001
Decompensated	1.67±1.85	0.90 (0.50-2.10)	
Altered mental status			
No	3.19±1.84	2.90 (2.00-4.10)	<0.001
Yes	2.61±2.04	2.10 (0.98-3.70)	
Peripheral pulse			
Good volume	3.25±1.95	2.90 (1.90-4.20)	<0.001
Weak or absent	1.35±1.14	0.90 (0.50-1.99)	
Capillary refill time			
2 second	3.19±1.94	2.90 (1.90-4.10)	<0.001
>2 second	1.05±0.82	0.70 (0.50-1.80)	
Temperature			
95.0-99.5 ^{O}F	2.75±1.92	2.30 (1.35-3.90)	0.003
<95.0 or >95.0 ^{O}F	3.20±2.08	2.90 (1.80-4.20)	
Extremities			
Warm & pink	3.39±1.98	3.10 (2.10-4.30)	<0.001
Cool/ Cold, calmly	1.73±1.37	1.30 (0.65-2.20)	

*Mann-Whitney U test, SD: Standard Deviation, IQR: Interquartile Range.

Discussion

Care of critically ill children remains one of the most demanding and challenging aspects in the field of pediatrics.[8] Hemodynamic monitoring is crucial to identify inadequate tissue perfusion in order to prevent organ dysfunction and death.[9] Clinicians shift from global to peripheral perfusion monitoring to promptly

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recognize deteriorating clinical status like shock and to assess the effectiveness of resuscitation therapy.[10] However, shock is often under-reported in children attending hospitals in developing countries and very few study to date evaluated the association of PI with clinical state of shock in pediatric patients admitted in a PICU. The present study demonstrated that, PI reflected the clinical state of shock in such patient population.

Sivaprasath et al. reported that, PI values were low in the presence of shock in all age groups.[11] In the present study, PI had a skewed distribution as a whole and in each age group. Mean or median PI value with shock was lower than mean or median PI value without shock in all age group except the age group of 10 to 12 years of age where the trend was reverse. Mean and median PI values differed in different age groups in the present study which was in line with other studies.[11-15]

In the present study ROC curves were drawn to compare the predictive values of PI for differentiating shock from non-shock state. It was revealed that, PI had good and significant AUC for differentiating shock from non-shock state in all age group except in children 10-12 years of age. The AUC ranges from 0.701 to 0.729 in children aged 10 years or less. It was in agreement with the study of Sivaprasath et al.[11] In the current study, based on the maximum Youden index different cut off values for PI were calculated for differentiating shock state from non-shock state. In contrast to the study of Sivaprasath et al cutoff values for PI to detect the clinically assessed shock had high specificity but low sensitivity in the current study.[11]

Overall, PI had positive correlation with SBP, DBP and MAP in the present study. In children 1-3 year of age the correlation of PI with SBP, DBP, PP and MAP were significant and in children 10-12 years of age there was no significant correlation of PI with SBP, DBP, PP and MAP were observed. Sivaprasath et al.have reported moderate positive correlation of PI with the SBP, strong positive correlation with pulse pressure, weak correlation with DBP and MAP in all age groups.[11]

Present study also assesses the association of PI with individual features of shock. Van Genderen et al found that peripheral PI changes during central Hypovolemia.[7] The present study was one of the only few studies that have evaluated the PI in pediatric population. PI determination has emerged as an important bedside diagnostic and monitoring tool with applications in multiple clinical settings.[16] With further use and study, PI is likely to prove useful for evaluating patient outcomes and monitoring progress in PICU setting where peripheral perfusion and circulatory status should be evaluated.

Limitations

The sample size was small and collected from a single center.PI is affected by conditions such as Nail varnish or pigment on finger/toes, bright light on probe, patient movement, and poor perfusion. Such conditions should be considered in the evaluation of PI.

Conclusion

PI can measure in shock with high specificity and low sensitivity in PICU. PI is real time and its advantages are the non-invasive nature, ease of use, low costand affordability.

Recommendations

Along with other clinical assessment tool PI, can be used during monitoring of shock patients in PICU to detect poor perfusion.Further multi-center prospective study to determine the value of PI for predicting shock in early stages is necessary.

Disclosure

All the authors declared no competing interest.

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