Is perfusion index a surrogate indicator of left ventricular contractility in neonates? A prospective study

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ABSTRACT

Introduction : **Noninvasive blood pressure monitoring may not accurately reflect cardiac contractility in neonates due to low vascular tone. The perfusion index (PI) is a noninvasive method of assessing the strength of peripheral pulses. It is shown to have a significant correlation with the left ventricular output. This prospective study estimates the correlation between PI and cardiac contractility in neonates.**

Methods and Results : **All hemodynamically stable neonates who were on substantial enteral feeds and not on any respiratory or inotropic support underwent measurement of PI and echocardiography examination. Various indices of left ventricular contractility were estimated, and the correlation coefficient between them and PI was determined. Fifty-six neonates were studied. The median (interquartile range [IQR]) PI was 1.5 (1.25-1.75). The median (IQR) PI in preterm neonates was 1.5 (1.2–1.8) and that in term neonates was 1.8 (1.25–2.7) ($P = 0.064$). PI had a correlation of 0.205 with fractional shortening ($P = 0.129$) and 0.13 with left ventricular ejection fraction ($P = 0.821$). The Spearman's correlation coefficient between PI and velocity of circumference fiber shortening was 0.009 ($P = 0.945$). The Spearman's correlation coefficient between PI and cardiac output was −0.115 ($P = 0.400$).**

Conclusion : **The PI does not correlate with left ventricular contractility parameters in neonates.**

Keywords : Left ventricular contractility, neonates, perfusion index

INTRODUCTION

In newborn infants, particularly preterm, the transition from fetal to extrauterine circulation is physiologically overwhelming as the cardiovascular system must adapt to the newer challenges. These challenges include both structural changes such as closure of ductus arteriosus and foramen Ovale as well as physiological changes such as change in cardiac function, pulmonary and systemic pressure, and vascular tone.

The general vascular tone tends to be lower in neonates, which is more pronounced in preterm babies. Hence,

Access this article online

Quick Response Code:

Website: www.annalspc.com

DOI: 10.4103/apc.apc_71_22

How to cite this article: Seyad SV, Shambhu SK, Doreswamy SM. Is perfusion index a surrogate indicator of left ventricular contractility in neonates? A prospective study. Ann Pediatr Card 2023;16:32-6.

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Submitted: 18-Jun-2022 **Revised:** 31-Aug-2022 **Accepted:** 06-Feb-2023 **Published:** 04-Apr-2023

measurement of non-invasive blood pressure alone may not reliably reflect the cardiac contractility in the initial few days of life.[1,2] A search for a better noninvasive surrogate parameter for assessing the cardiac contractility has led to interest in the perfusion index (PI).

The PI is a noninvasive method of assessing the strength of peripheral pulses.[3] This can be easily measured using pulse oximeter. Computing the ratio between the pulsatile component and the nonpulsatile component of the light, reaching the detector of the pulse oximeter, yields the PI. Low PI indicates peripheral vasoconstriction or severe hypovolemia, and high PI indicates vasodilatation. PI is sensitive to sympathetic nervous system tone (pain and agitation), the temperature of the finger, exogenous vasoactive drugs, and stroke volume. The fingertip is the standard monitoring site.

Although the PI is a direct measure of the status of peripheral pulse, interestingly, it is shown to have a significant correlation with the left ventricular output (cardiac output) in healthy term infants.[4] If the arteries were static conduits for blood flow, it would not be difficult to understand how the stroke volume and hence cardiac output is straight away translated as pulse volume. Since peripheral vascular tone is dynamic with both central and local factors influencing, pulse volume measured as the PI correlating well with the left ventricular output stands out as an odd that needs further study.

The cardiac output is dependent on stroke volume which is heavily influenced by cardiac contractility[5] and heart rate. In this study, we studied individuals with stable hemodynamics and heart rate in normal range for the gestational age and hypothesized that the PI has a significant correlation with left ventricular contractility.

METHODS

This was a prospective observational analytical study conducted in a tertiary-level neonatal unit between June 2019 and May 2021.

All neonates born at 28 weeks and above gestation and hemodynamically stable and on enteral feeds of at least 120 ml/kg/day were eligible for the study. Babies needing medical support such as oxygen, CPAP, ventilation, and inotropes were excluded.

Echocardiac examination was performed using sector probe (10 MHz, Philips CX30, Netherlands, ultrasound machine) by a trained echocardiography technician. The images and the measurements were read and reported by a cardiologist. The examination was performed after initial stabilization of the neonates and any convenient time within the first 10 days of life. All standard views such as parasternal long axis, parasternal short axis, ductal, high parasternal, supra sternal, and subcostal views were imaged. Stroke volume was measured using left ventricular VTi, and cardiac output was calculated by multiplying with the heart rate noted just before the commencement of echocardiography.

The PI was measured using Massimo Rad 6 pulse oximeter when the baby was comfortable and not crying after completing the echo examination. The SpO_2 probe was placed on either foot and left upper limb, and the best reading of PI, after having a signal strength of >1, was used in this study.

Statistical analysis

All the relevant data were tabulated into Microsoft Excel and analyzed with “Analyse-it for excel version 4.3.” Quantitative variables were summarized as mean and standard deviation (SD) or median and interquartile range (IQR) depending on the distribution. Categorical variables were summarized as proportions. The comparison of means was done using the Student’s *t*-test and medians with the Friedman test. The comparison of proportions was done using the Chi-square test. Quantitative homoscedastic values were correlated using the Pearson product-moment correlation. Heteroscedastic data were analyzed with Spearman’s correlation.

Sample size

The literature has shown that the correlation can vary between 40% and 80% depending on the underlying hemodynamic condition. Assuming our study to pick up a correlation of 40% with alpha error of 5% and power of 90%, we needed to study 56 individuals.

Ethics

This study was approved by the institutional ethical committee.

RESULTS

We studied 65 neonates. We could not complete the echocardiography in nine of them as they started crying and their parents refused to continue examination. Fifty-six neonates remained for final analysis. The median (IQR) gestation of our study participants was 36 (36–37) weeks. The mean (SD) birth weight of our participants was 2390.4 (740.5) g. Thirty-one (55.4%) neonates were preterm neonates. Among the neonates included in the study, 41 (73.2%) were appropriate for gestation age, 11 (19.6%) were small for gestation age, and 4 (7.1%) were large for gestation age. Thirty (53.6%) participants were male and 26 (46.4%) were female. The median (IQR) age in hours at examination was 72 (72–120) h. The comparison of baseline characteristics of preterm and term neonates is depicted in Table 1.

The primary diagnosis in our participants apart from preterm care and routine newborn care included neonatal depression in five, transient tachypnea of newborn in one, hypoglycemia in one, and hyperbilirubinemia in one. Among preterm neonates recruited, eight had respiratory distress syndrome (RDS).

The PI values had a skewed distribution. The median (IQR) PI was 1.5 (1.25–1.75). The PI values ranged between 0.5 and 3.5. Excluding both the extreme values (two cases), the PI values ranged between 0.8 and 3. The median (IQR) PI in preterm neonates was 1.5 (1.2–1.8) and that in term neonates was 1.8 (1.25–2.7), and this difference was not statistically significant (*P* = 0.064).

The mean (SD) fractional shortening of the left ventricle in our participants was 38.1 (9%). The mean (SD) FS in preterm neonates was 37.8 (9.6%) and that in term neonates was 39.6 (8.9%). This difference was not statistically significant (*P* = 0.560). The mean (SD) left ventricular ejection fraction (EF) was 70.7 (11.2%). The mean (SD) EF in preterm neonates was 71.3 (11.6%) and that in term neonates was 72.1 (9.4) %. This difference was not statistically significant (*P* = 0.814). The median (IQR) velocity of circumferential shortening (Vcf) was 1.8 (1.5–2.3) cir/s. The median (IQR) Vcf in preterm neonates was 1.8 (1.4–2.4) and in term neonates was 1.9 (1.5–2.4) cir/s, respectively. This difference was not statistically significant (*P* = 0.472). The mean (SD) Tei index was 0.45 (0.1). The mean (SD) Tei index in preterm neonates was 0.45 (0.1) and that in term neonates was 0.43 (0.1). This difference was not statistically significant (*P* = 0.691).

Table 1: Baseline characteristics

Parameter	Preterm	Term	*P*
Maternal age (years)	26 (4.5)	26.1 (4.1)	0.910
Birth weight (g)	2000 (1440-2326)	3060 (2880-3226)	<0.001
Gestation (weeks)	34 (32-35)	38 (37-39)	<0.001
Age at examination (h)	96 (52.7-144)	72 (28-96)	0.059
Axillary temperature (C)	36.2 (0.6)	36.2 (0.5)	0.684
Heart rate (/min)	132 (14)	133 (11)	0.826
Respiratory rate (/min)	42 (4)	42 (5)	0.627
Mean BP (mm Hg)	47 (7.4)	48.4 (6.6)	0.429

BP: Blood pressure

The median (IQR) end-diastolic volume was 2.24 (1.6–3.5) ml. The median (IQR) end-diastolic volume corrected for weight in preterm neonates was 3.1 (1.5–4.1) ml/kg and that in term neonates was 1.9 (1.5–2.3) ml/kg. This difference was statistically significant (*P* = 0.0296). The median (IQR) stroke volume was 2.6 (2.2–3.1) ml and that corrected for weight was 1.1 (0.9–1.6) ml/kg. The median (IQR) corrected stroke volume in preterm neonates was 1.6 (1.0–1.96) ml/kg and that of term neonates was 0.9 (0.8–1.4) ml/kg. This difference was statistically significant (*P* = 0.001). The median (IQR) cardiac output was 144 (122–206) ml/kg/min. The median (IQR) cardiac output in preterm neonates was 202 (127–259) and that of term neonates was 125 (104–176.5) ml/kg/min. This difference was statistically significant (*P* = 0.001).

The PI had a correlation of 0.205 (95% CI – 0.061–+0.444) with FS [Figure 1]. This correlation was not statistically significant (*P* = 0.129). The correlation coefficient of PI with left ventricular EF was 0.13 (95% CI – 0.241–+0.299) which was not statistically significant (*P* = 0.821). The Spearman's correlation coefficient between PI and Vcf was 0.009 (95% CI – 0.262–+0.279) which was not statistically significant (*P* = 0.945). The Spearman's correlation coefficient between PI and cardiac output was –0.115 (95% CI = 0.373 – +0.161). This was not statistically significant (*P* = 0.400). The correlation coefficients of various left ventricular functional parameters in preterm and term neonates are compared in Tables 2 and 3.

Two of the 31 preterm babies eventually died of sepsis. All the term babies improved, and two of them got discharged earlier on request due to financial constraints. The median (IQR) duration of stay was 7 (5–12.2) days.

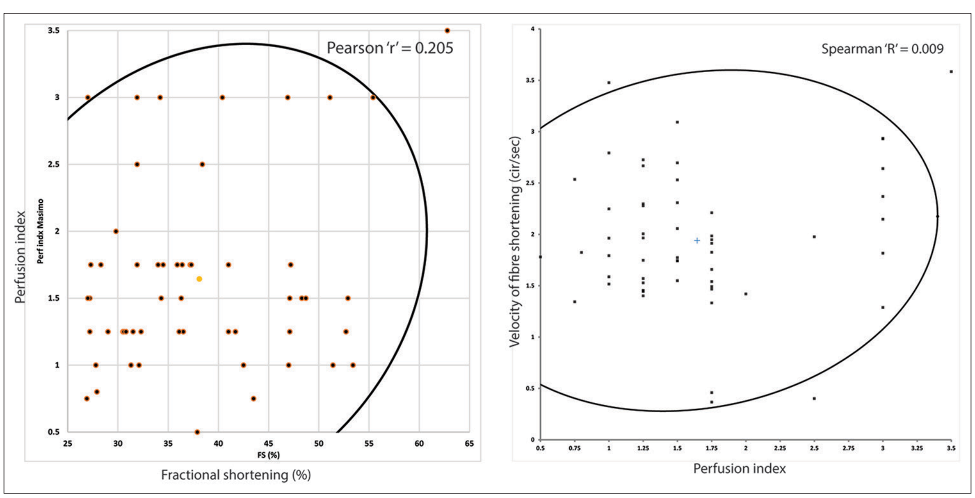

Figure 1: Poor correlation between cardiac contractility and perfusion index

Table 2: Correlation coefficients of perfusion index with various left ventricular contractility parameters in preterm neonates

Parameter	Correlation coefficient	95% CI	*P*
Fractional shortening	0.207*	−0.16-+0.52	0.262
Ejection fraction	0.15*	−0.22-+0.48	0.419
Velocity of fractional shortening	−0.14$	−0.48-+0.23	0.455
Corrected stroke volume	−0.09$	−0.45-+0.27	0.594
Cardiac output	−0.08$	−0.43-+0.29	0.655

*Pearson product-moment correlation, $Spearman's correlation coefficient. CI: Confidence interval

Table 3: Correlation coefficients of perfusion index with various left ventricular contractility parameters in term neonates

Parameter	Correlation coefficient	95% CI	*P*
Fractional shortening	0.143*	−0.27-+0.51	0.494
Ejection fraction	0.136*	−0.27-+0.50	0.516
Velocity of fractional shortening	0.16$	−0.26-+0.53	0.443
Corrected stroke volume	0.059$	−0.38-+0.43	0.875
Cardiac output	0.065$	−0.35-+0.46	0.758

*Pearson product-moment correlation, $Spearman's correlation coefficient. CI: Confidence interval

DISCUSSION

In this prospective study, we studied 56 neonates with echocardiography and simultaneously measured the PI for their correlation. We found no significant correlation between PI and any of the measures of left ventricular contractility such as fractional shortening, EF, or velocity of circumference shortening.

In a study, the PI over the first 5 days was measured, and authors reported the reference values of PI in the early neonatal period.[6] The values we obtained in our study remains in the similar range. The PI in term babies was higher than preterm babies which was statistically significant in their study. We found a very similar trend, but the difference did not achieve statistical significance. We had a higher proportion of preterm babies compared to the above study which makes this comparison more robust and hence true blunting of the significance. Nevertheless, it suffices to say that PI in term babies tends to be higher compared to preterm neonates by a small margin. Kroese *et al.* have reported a PI value range similar to our study.[7]

Corsini *et al.* compared the PI measured with left ventricular output in stable term neonates. The findings of this study were quite interesting as they demonstrated a good correlation between PI and both uncorrected left ventricular output and the one corrected for the weight of the neonate.[4] This finding had a potential to replace precarious echocardiogram examination in sick neonates in most situations as PI is now easily available on almost all multichannel monitors used in the neonatal unit. However, for this transition to happen, it was essential to confirm if PI is correlated with left ventricular contractility. Our study demonstrated a poor correlation between PI and all the parameters of ventricular contractility such as fractional shortening, EF, and velocity of circumferential fiber shortening. We could not demonstrate any reasonable correlation with weight corrected stroke volume and cardiac output in our participants, which is contrary to the above study. In another study with participants similar to ours, authors set out with the same objective as Corsini *et al.*,[4] this time including late preterm neonates. Not surprisingly, they concluded that there was no correlation between PI and both uncorrected left ventricular output and the one corrected for the weight of the baby.[8] Our finding bolsters the fact that the PI is primarily the attribute of peripheral circulation and predominantly influenced by the local factors.[3]

Fractional shortening and Vcf estimated in our preterm neonates are similar to results reported by other authors.[9,10] We could not find studies directly comparing these parameters between term and preterm babies. In this study, we have demonstrated that these left ventricular contractility parameters are not statistically different between preterm and term babies.

The normative values of left ventricular contractility, stroke volume, and cardiac output have been published for both term and preterm babies.[11-13] The values we determined in our study were similar to these published results. An interesting finding in these studies is that the weight-corrected stroke volume and cardiac output were higher in preterm compared to term neonates. Our study confirms the same.

Higher corrected stroke volume in preterm neonates, when the heart rate and cardiac contractility are similar to term neonates, led to further deepen our analysis by reanalyzing our collected data. We found that the end-diastolic volume corrected for weight was significantly higher in preterm neonates compared to their term counterpart. Whether this is due to a higher blood volume per kg and supple cardiac muscles in preterm neonates needs to be investigated. As of now, we do not know the clinical significance of this finding.

The limitation of this study is that we have not measured the correlation between PI and left ventricular contractility in hypotensive neonates.

CONCLUSION

The median PI in neonates was 1.5. These values in preterm and term babies were not statistically different. PI did not correlate with any of the cardiac contractility indices such as fractional shortening, EF, or velocity of fiber shortening either in preterm neonates or term neonates.

Acknowledgments

We would like to acknowledge the help of ECHO technicians in conducting this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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