**Original article**

# Peripheral perfusion index-reference range in healthy Portuguese term newborns

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## Abstract

**Introduction**: Peripheral perfusion index (PPI) is a non-invasive numerical value of peripheral perfusion derived from a pulse oximeter signal. It has been suggested that PPI may be a valuable adjunct diagnostic tool to detect early clinically significant hemodynamic embarrassment. The aim of this paper was to determine normal PPI in healthy newborns, in order to establish cut-off values that can be use in different pathologic settings.

**Material and Methods**: Prospective observational study performed with term newborns, born in a tertiary level care hospital between January 1st to December 31st 2012. Demographic data such as gender, gestational age, birth weight and Apgar score were collected. PPI, heart rate (HR) and arterial blood oxygen saturation ($SpO_2$) were evaluated simultaneous on the right hand (preductal) and on the left foot (postductal) of the newborn, before discharge from the hospital.

**Results**: 2,032 newborns, 52% male, with a mean birth weight of 3,237 ± 432 g and median gestational age of 39 weeks, were evaluated. PPI values obtained were: preductal median of 1.6 with interquartile range of 1.2-2.3, postductal median of 1.4 with interquartile range of 1-2 (p < 0.001).

**Conclusions**: PPI is an easily applicable non invasive method to monitor peripheral perfusion changes. We established normal PPI values in healthy Portuguese newborns. PPI was higher on the upper limb (preductal) when compared to the lower limb (postductal).This finding has important implications, in the time of choosing a single probe placement, and in the interpretation of the results.

## Keywords

Newborn, peripheral perfusion index, pulse oximeter, preductal, postductal, peripheral flow.

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## How to cite

## Introduction

An important aim of hemodynamic monitoring is the early detection of inadequate tissue perfusion and oxygenation, in order to institute early therapy and guide resuscitation [1].

During circulatory disturbance, redistribution of blood flow, caused by increased vasoconstriction, results in decreased perfusion of the skin. As peripheral tissues are sensitive to alterations in perfusion, monitoring of the peripheral circulation could be an early marker of tissue hypoperfusion. Poor peripheral perfusion can be assessed from clinical signs such as cold, pale, clammy and mottled skin associated with an increase in capillary refill time, central-to-toe temperature difference, laser doppler and capillary microscopy [1-3]. Recently, pulse oximetry signal has been suggested, as well, to reflect changes in peripheral perfusion.

Peripheral perfusion index (PPI) is a noninvasive measure that reflects the real time changes in peripheral flow [4-6]. It is an assessment of the pulsatile strength at a specific monitoring site (e.g. the hand, finger or foot) and is calculated from the ratio between the pulsatile component (arterial component) and the nonpulsatile component of the light (skin, other tissues), reaching the pulse oximeter detector [1, 2, 6]. When peripheral hypoperfusion exists, the pulsatile component decreases, and because the nonpulsatile component does not change, the ratio drops [2]. PPI is therefore primarily influenced by the amount of blood at the site of measurement and not by the oxygen saturation [4, 6].

Recent studies have been demonstrating the potential use of PPI in the neonatal setting.

PPI was found to be correlated significantly with other indirect estimates of cutaneous blood flood, i.e. cardiac activity and central-to-peripheral temperature gradients in low birth weight infants [6].

Low PPI values have been showed to be a predictor for high illness severity in newborns [7]; PPI monitoring could help in the early detection of perinatal inflammatory disease such as subclinical chorioamnionitis [8].

In newborns with critical congenital heart disease, with duct dependent systemic circulation, PPI may increase the rate of detection, since some left heart obstructive diseases are undetected using only pulse oximetry screening [6].

There are few publication studies for the reference values of PPI in neonatal period and none in our country. Thus, the aim of this study was to assess the reference PPI values in term healthy newborns, in Portuguese population.

## Methods

This prospective observational study was performed with term newborns (gestational age > 37 weeks) that were born in a tertiary level care hospital (Centro Hospitalar São João, Porto, Portugal) in the last year (January 1st to December 31st 2012).

Newborns were evaluated for PPI, heart rate (HR) and arterial blood oxygen saturation ($SpO_2$) in a single and simultaneous determination. This took place in the regular nursery, incorporated in ordinary nursing routines, at the bedside of the mother, after the first 24 hours of life, before discharge from the hospital. The monitoring sites were the right hand and the left foot of the newborn. PPI values were assessed using the new generation Masimo SET® Radical pulse oximeter, during at least 30 seconds or until the establishment of a valid signal (variance < 2% of $SpO_2$ and < 0.3 of PPI) (**Fig. 1**). The determinations took place when the babies were asleep or quietly awake and normothermic. Newborn's hour of life, at the time of the measurement, was also registered.

The exclusion criteria were: i) preterm newborns, ii) newborns admitted in the neonatal intensive care unit, iii) neonates with major malformations (including congenital heart diseases), iv) clinically ill newborns (including infections). It was also established that none of the newborns selected was readmitted, subsequently, with congenital heart disease after discharge (6 months follow-up).

Regarding demographic data, gestational age (GA), gender, birth weight and Apgar score were collected from the clinical records of the selected newborns.

This study was authorized by the São João Hospital Ethical Committee.

Statistical analysis, including analysis of distributions, was carried out on commercial software SPSS. Data are expressed as mean and medians with the 5th to 95th percentiles. Differences between groups were assessed by using the Mann-Whitney test for nonparametric data. A p value less than 0.05 was considered statistically significant.
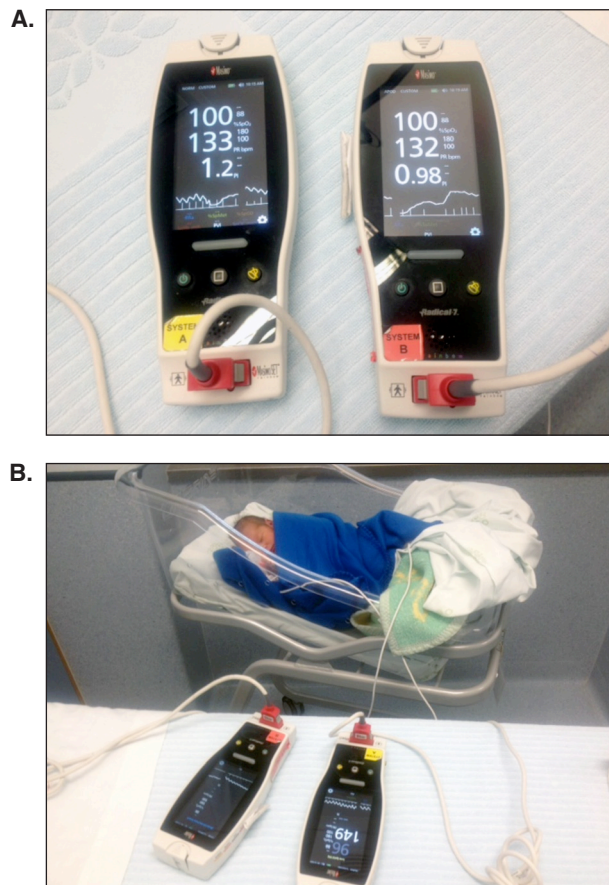
**A.**

**B.**

**Figure 1.** New generation Masimo SET® Radical pulse oximeter.

## Results

This study included 2,032 newborns. Demographic and clinic data are summarized in **Tab. 1**. All the newborns presented a normal clinical examination or physiologic jaundice, but without otherwise physical examination alterations. None was discharged home with less than 48 hours of life.

The median PPI, HR and $SpO_2$ values were evaluated (**Tab. 2**). Preductal PPI was measured on the right hand and postductal PPI on the left foot of the newborn.

The measurements obtained were significantly higher on the right hand comparing with the left foot (preductal median = 1.6, postductal median = 1.4; p < 0.001). The cut-off values for PPI between the 5th and 95th percentile were: 0.77 and 3.9 preductally; 0.64 and 3.4 postductally. (**Tab. 3**). The mean difference between pre and postductal PPI was 0.25.

## Discussion

Peripheral vasoconstriction is an early warning sign of circulatory embarrassment, as blood flow

**Table 1.** Demographic data of the study population.

| Study sample characteristics | |
|---|---|
| **Male Gender** | 52% |
| **Gestational age (weeks)**<br>Min-Max<br>Median | <br>37-41<br>39 |
| **Weight (g)**<br>Min-Max<br>Mean ± SD | <br>1,940-4,990<br>3,237 ± 432 |
| **Apgar score at 1 minute**<br>Median | <br>9 |
| **Apgar score at 5 minutes**<br>Median | <br>10 |

**Table 2.** Median values for age at measurement, PPI, HR and $SpO_2$.

| | Preductal | Postductal |
|---|---|---|
| **Hour of life at the measurement (hours)**<br>Median<br>(range) | 35<br>(24-94) | |
| **PPI**<br>Median | 1.6 | 1.4 |
| **HR (beats/min)**<br>Median | 126 | 126 |
| **$SpO_2$ (%)**<br>Median | 100 | 100 |

HR: heart rate; PPI: peripheral perfusion index; $SpO_2$: arterial blood oxygen saturation.

**Table 3.** Preductal and postductal percentiles.

| Percentile | | | | | |
|---|---|---|---|---|---|
| | **5** | **25** | **50** | **75** | **95** |
| Preductal PPI | 0.77 | 1.2 | 1.6 | 2.3 | 3.9 |
| Postductal PPI | 0.64 | 1 | 1.4 | 2 | 3.4 |
| P Value* | < 0.001 | | | | |

*Mann-Whitney Test.

is diverted from the less important tissues to vital organs [1-3]. Noninvasive monitoring of peripheral perfusion can be a complementary approach that allows early and prompt intervention avoiding organ damage. Because the pulse oximeter is used extensively in intensive care units, the PPI can be easily obtained. Low PPI suggests peripheral vasoconstriction (or severe hypovolemia) and high PPI suggests vasodilation.

There are several works in adult population regarding application of PPI in clinical practice, but few in neonatal age.

Zaramella et al. correlated PPI in 43 term newborns (GA 39.1 ± 1.4 weeks, age at evaluation 2.6 ± 0.9 days) with calf muscle perfusion. They

have obtained a mean PPI of 1.2 ± 0.3 and have showed a positive correlation between PPI and both calf blood flow and oxygen delivery [10]. De Felice et al. evaluated 101 newborns (gestational age 34.7 ± 4.0 weeks) during the first 24 hours of life, and have obtained a mean PPI of 1.54 ± 0.8 [7]. In both studies a single place measurement was used, the lower limbs. Our results, corresponding to a large sample, are similar (mean foot PPI 1.6 ± 0.9) despite De Felice study included pre and term newborns.

Granelli et al. published the largest study of PPI in healthy newborns (n = 10,000), between 1 and 120 hours of age, and compared with those with left duct dependent heart disease. PPI values obtained in the healthy group were preductal median = 1.68 with interquartile range 1.18-2.4 and postductal median = 1.71 with interquartile range of 1.20-2.5; mean difference of -0.02 (nonsignificant) [6]. In contrast to these results, we found preductal PPI significantly higher than postductal PPI (mean difference 0.25 ± 1); a finding that was also noted by Kinoshita et al. but in preterm newborns (< 32 weeks) during the first 48 hours [9]. This knowledge has implications at the time of choosing the site of measurement, since a low postductal value compared to preductal PPI must be carefully interpreted before assuming lower limb hypoperfusion.

Granelli also reported that PPI < 0.7 in at least one limb gave an odds ratio for left heart obstructive disease (LHOD) of 23.75 [6]; in our study we have obtained a PPI < 0.7 either pre or postductally in 8% of the newborns, in which no cardiac disease was diagnosed.

Our experience in conducting this study revealed that PPI is easy, relatively low-cost, free of subjective interpretation and low time consuming; as such the determinations were integrated into the regular nursing routines. It can be a useful tool in estimating peripheral perfusion non-invasively and continuously.

This study has some limitations. We did not evaluate other haemodynamic parameters such as skin temperature and blood pressure at the time of PPI measurements. Photoplethysmographic analysis is relatively sensitive to newborn movement and other several factors such as stress (pain) and anxiety. At last, the within individual PPI variability in the first days of life was not studied.

Our results established the normal preductal and postductal PPI in healthy Portuguese term newborns. This work contributes to enhance the knowledge of PPI in this age group, in order to create standardized reference values. Normal values have to be defined, before using this additional tool in different clinical settings.

## Contributors and supporting agencies

## Declaration of interest

The Authors declare that there is no conflict of interest.

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