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Evaluation of peripheral circulation in low-birth-weight infants using the peripheral perfusion index

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Abstract

The peripheral perfusion index (PPI), mean arterial blood pressure, lactic acid value (Lac), left ventricular end-diastolic dimension (LVDd), and left ventricular ejection fraction (EF) within 24 hr and 48-72 hr after birth were measured in 16 infants admitted to a Neonatal Intensive Care Unit (NICU) to assess the usefulness of PPI for the evaluation of peripheral circulation in low-birth-weight infants. The mean PPI was 0.66±0.4 (24 hr after birth) and 0.57±0.19 (48-72 hr after birth). The mean arterial blood pressure was 33.8±6.0 mmHg (24 hr after birth) and 34.3±4.1 mmHg (48-72 hr after birth). EF was 66.6±6.5% (24 hr after birth) and 70.3±5.3% (48-72 hr after birth), and LVDd was 1.24±0.17 cm (24 hr after birth) and 1.21±0.14 cm (48-72 hr after birth). The correlation between variations in PPI and LVDd at two points showed a positive correlation ($r=0.74$, $p<0.05$), and PPI and mean arterial blood pressure ($r=0.72$, $p<0.05$), as well as PPI and EF ($r=0.85$, $p<0.05$), also showed positive correlations 24 hr after birth. These results suggest that PPI could be an effective way to evaluate peripheral circulation in low-birth-weight infants.

Key words : peripheral perfusion index(PPI), infant, low birth weight, blood circulation, intensive care, neonatal

Introduction

Cardiac muscles in the embryonic stage contain low levels of catecholamines with weak reactivity. Cardiac compliance is also low because of the high numbers of stromal cells and lower numbers of sarcomeres.[1] Therefore, the ability to increase stroke volume may be limited, cardiac output is regulated predominantly by alterations in heart rate, and there is a higher than normal risk of heart or circulatory failure in more premature infants.[2] In addition, a high risk of intracranial events including intracranial hemorrhage and periventricular leukomalacia, such as by changes in blood pressure in the hyperacute phase within 72 hr after birth, can strongly affect short-term and long-term prognoses.[3] Therefore the evaluation of hemodynamic changes may be important. Nevertheless, to date, no reliable method has been developed to evaluate peripheral circulation in premature infants both continuously and objectively.

A model of a pulse oximeter has been developed recently that displays the variable PPI, which indicates the signal strength of the pulse in arterioles.[4,5] The percentage of pulse components related to arterial blood and that of non-pulse components related to tissues such as the skin and venous blood at the measurement site of transcutaneous oxygen concentration are calculated as the perfusion index.[6] Its primary objective is to determine the accuracy of displayed transcutaneous oxygen saturation because the reliability of the monitoring of transcutaneous oxygen saturation is obscure in low-perfusion states.[7] However, it has been noted that PPI decreased in low-perfusion states. Some previous reports have suggested its utilization in the

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evaluation of peripheral circulation in adults[4] and in the screening of congenital heart diseases in full-term neonates.[8] However, to the best of our knowledge, there is no report that describes the utilization of PPI in low-birth-weight infants, of which the increase in number has become a serious concern in combination with decreases in the total number of live births in Japan.[9] Normal values of PPI have not yet been determined. Peripheral circulation is currently evaluated by objective observation, such as the presence of cold extremities.

In this study, we measured PPI within 72 hr after birth in low-birth-weight infants admitted to a Neonatal Intensive Care Unit (NICU) to examine its effectiveness in the evaluation of peripheral circulation.

Subjects and methods

Subjects

Table indicates the clinical characteristics of subjects that participated in this study. Subjects were 16 of 29 low-birth-weight infants weighing less than 2,000 g who were admitted to the NICU of Kinki University Hospital, Faculty of Medicine, between March 2011 and August 2012. one case diagnosed with congenital heart disease other than patent ductus arteriosus attributable to prematurity, 8 cases in which the direct measurement of arterial pressure was not conducted, 2 cases in which blood samples could not be obtained within 1 hr before and after the measurement of PPI , and 2 cases in which echocardiography could not be conducted within 2 hr after the measurement of PPI were eliminated. Subjects included 9 extremely low-birth-weight infants, 5 very low-birth-weight infants, and 2 low-birth-weight infants. The mean gestational age was 30 weeks and 1 day±22 days. The mean weight was 1,079 ±346 g.

Methods

Data were collected at two points of 24 hr and 48-72 hr after birth. The sensor (Nellcor-N25 ; Covidien AG) of the pulse oximeter was placed on a foot, was fixed at only one point using the adhesiveness of the sensor, was then connected to a patient monitor (Intelli Vue MP50 ; Philips Medical Systems), and PPI was recorded. PPI was obtained as the mean of three points at 10-minute intervals to show a 30-minute trend. Figure 1 shows the actual monitor screen view reflecting PPI and trend values. At the same time, mean arterial blood pressure by direct measurement of arterial pressure was obtained as the mean of three points at 10-minute intervals to show a 30-minute trend. Direct measurement of arterial pressure was conducted continuously using a patient monitor (Intelli Vue MP50 ; Philips Medical Systems) by connecting a blood pressure transducer to a 24G catheter indwelling in the radial or ulnar artery of the infant. The

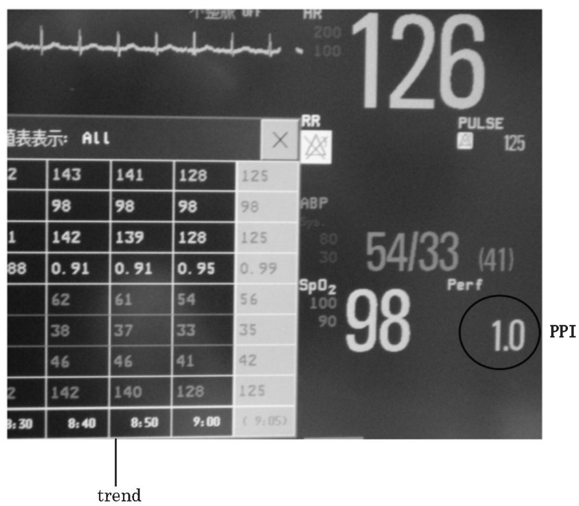

Fig. 1 Actual monitor screen view reflecting PPI and trend values (PHILIPS Intelli Vue MP50)

Table Clinical characteristics of subjects

Characteristics	Subjects (n=16)
Gestational age, mean±SD (range)	30w1d±22d (24w4d-34w3d)
Birth weight(g), mean±SD (range)	1079±346 (652-1640)
Extremely low birth weight infant (birth weight<1000g)	9 (56%)
Very low birth weight infant (birth weight<1500g)	5 (31%)
Low birth weight infant (birth weight<2000g)	2 (13%)
Apgar score at 1 min, mean (range)	5.1 (1-8)
Apgar score at 5 min, mean (range)	7.2 (3-10)
Gender, male (%)	50
dopamine hydrochloride administration	7 (44%)

lactic acid value (Lac) was recorded from blood gas analysis that was conducted because of medical needs within 1 hr before and after the PPI measurement. Blood gas analysis was conducted with a blood gas analyzer (ABL 800FLEX ; Radiometer Medical). Echocardiography was carried out within 2 hr of the PPI measurement to record the left ventricular end-diastolic dimension (LVDd) and left ventricular ejection fraction (EF). Echocardiography was performed using an ultrasound system (EnVisor ; Philips Medical Systems).

Statistical analysis

Statistical analysis was carried out using *t*-tests to evaluate differences between the values of PPI, mean arterial blood pressure, Lac, LVDd, and EF 24 hr and 48-72 hr after birth, and by Pearson's correlation coefficients for the other variables. The significance level was set as $P<0.05$.

Results

Figure 2 indicates the PPI, mean arterial blood pressure, EF, and LVDd 24 hr and 48-72 hr after birth. The mean PPI was 0.66±0.4 (24 hr after birth) and 0.57±0.19 (48-72 hr after birth). The mean arterial blood pressure was 33.8±6.0 mmHg (24 hr after birth) and 34.3±4.1 mmHg (48-72 hr after birth). EF was 66.6±6.5% (24 hr after birth) and 70.3±5.3% (48-72 hr after birth), and LVDd was 1.24±0.17 cm (24 hr after birth) and 1.21±0.14 cm (48-72 hr after birth). In addition, Lac was 2.6±1.1 mg/dl (24 hr after birth) and 1.7±1.0 mg/dl (48-72 hr after birth). No significance was found between values 24 hr and 48-72 hr after birth in any of these results.

The correlation between variation in PPI and LVDd 24 hr and 48-72 hr after birth are shown on Figure3. The variation in PPI 24 hr and 48-72 hr after birth was calculated as follows. (PPI at 48-72 hr after birth - PPI at 24 hr after birth)/ PPI at 24 hr after birth. The variation in LVDd 24 hr and 48-72 hr after birth was also calculated as follows. (LVDd at 48-72 hr after birth - LVDd at 24 hr after birth)/ LVDd at 24 hr after birth. It showed a positive correlation ($r=0.74$, $p<0.05$), and Figure 4 indicated PPI and mean artrial blood pressure 24 hr after birth also showed a positive correlation ($r=0.72$, $p<0.05$). In addition, Figure 5 demonstrated that there was a positive correlation between PPI and EF 24 hr after birth ($r=0.85$, $p<0.05$). However, no significant correlation was found between PPI and mean artrial blood pressure 48-72 hr after birth ($r=-0.35$, $p=0.35$). Additionally, the

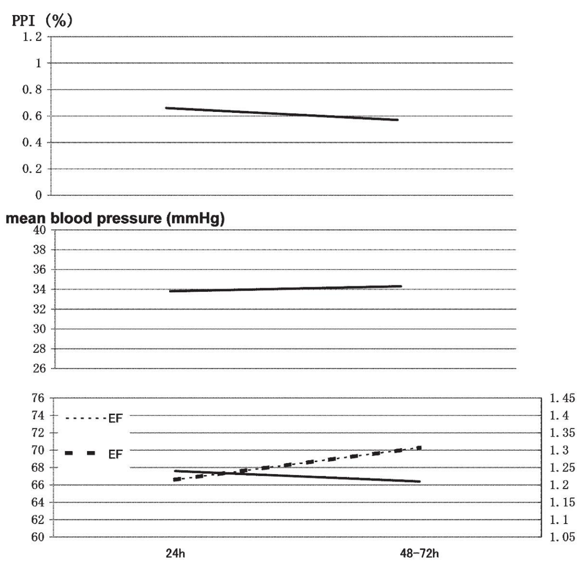

Fig. 2 PPI, mean blood pressure, EF and LVDd at 24 h and 48-72 h (mean±standard deviation)

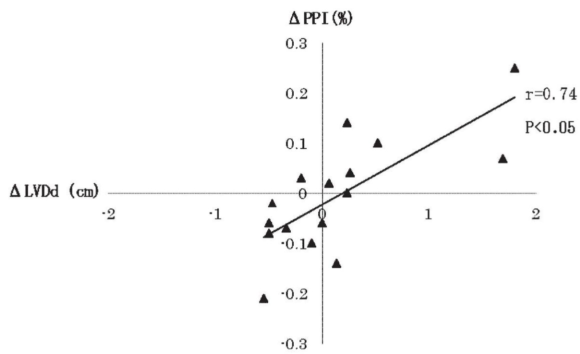

Fig. 3 The relationship between variations in PPI and LVDd 24 hr and 48-72 hr after birth A positive correlation was found in two scores.

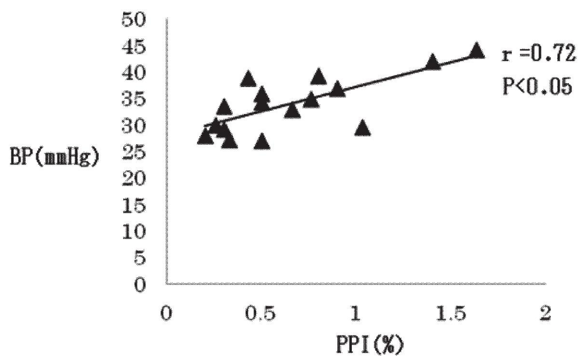

Fig. 4 The relationship between PPI and mean blood pressure 24 hr after birth A positive correlation is demonstrated.

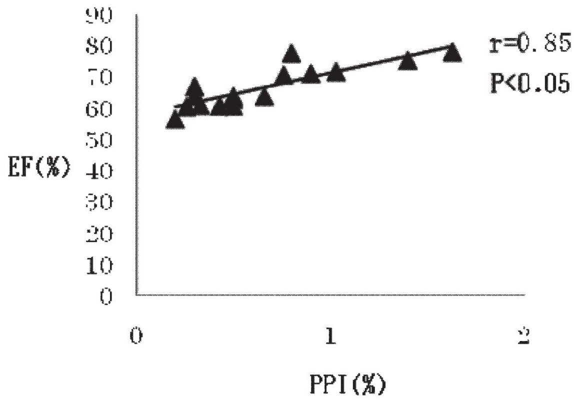

Fig. 5 The relationship between PPI and EF 24 hr after birth A positive correlation is demonstrated.

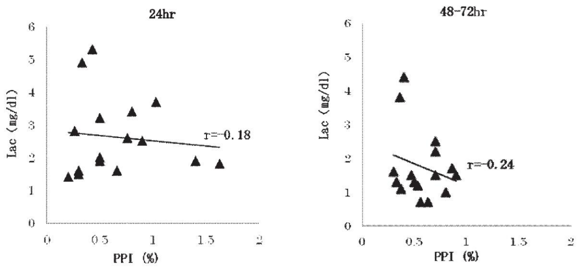

Fig. 6 The relationship between PPI and Lac 24 hr and 48-72 hr after birth No significant correlation either at 24 hr after birth or 48-72 hr after birth was found.

relationship between PPI and Lac showed no significance either 24 hr after birth ($r=-0.18$, $p=0.52$) 48-72 hr after birth ($r=-0.24$, $p=0.39$) (Figure 6). No significant correlation was found between PPI and EF 48-72 hr after birth ($r=-0.003$, $p=0.99$).

Discussion

As reliable methods for peripheral monitoring, near-infrared spectroscopy and laser Doppler flowmetry are available at present.[10,11] In addition, orthogonal polarization spectroscopy has also become available for clinical use in NICUs in recent years.[12,13] However, the cost and availability of these diagnostic methods may limit their routine use in NICUs, while PPI is automatically measured using oxygen saturation monitoring.

PPI is calculated using the amplitude of the displayed pulse wave. It roughly correlates with changes in blood flow in the digits. Therefore, an increase in PPI has been considered to indicate an increase in peripheral blood flow.[8] Lima et al.[4] reported that PPI<1.4 showed the highest correlation with low perfusion in critically ill patients, with relation to normal values in adults. Granelli et al.[8] carried out a cohort study of 10,000 neonates, and concluded that PPI<0.7 suggests the presence of clinical abnormalities in full-term neonates, and that PPI is a reliable index for improving the screening accuracy of left heart obstructive lesions. However, to our knowledge, there have been no reports on the utilization of PPI in low-birth-weight infants: thus, normal values have not been determined yet.

LVDd in echocardiography reflects the intravascular volume. It is also used as an indicator of dehydration in neonatal care.[14] The positive correlation between variations in PPI and LVDd 24 hr and 48-72 hr after birth could suggest that PPI in low-birth-weight infants reflects increases and decreases in peripheral blood flow.

PPI and mean arterial blood pressure, as well as EF, also showed a positive correlation 24 hr after birth, but showed no significant correlation 48-72 hr after birth. Blood pressure is defined as the product of cardiac output and peripheral vascular resistance, which is affected by catecholamines with vasoconstrictive capacities.[15] In the present study, 7 of 16 patients received dopamine hydrochloride at the time of measurement. Neonates have a weak capacity to convert dopamine into norepinephrine. As such, they are less sensitive to catecholamines.[16] The pharmacologic effect of catecholamines in neonates is believed to increase over time after birth.[17] Therefore, it was inferred that, although catecholamines had little effect on the hemodynamics at measurement within 24 hr after birth, catecholamines, in addition to increased cardiac output attributable to the administered water volume, had an effect the blood pressure increase 48-72 hr after birth. Although peripheral vasoconstriction increases blood pressure, it decreases peripheral blood flow, reducing PPI. Therefore, PPI and mean arterial blood pressure 48-72 hr after birth may have shown a negative correlation. Additionally, EF is calculated as follows: (left ventricular end-diastolic volume - left ventricular end-systolic volume)/left ventricular end-diastolic volume, and is dependent on volume.[18] However, the value is known to decrease when blood pressure is increased.[19] It was supposed that PPI and EF showed no significant correlation because blood pressure increased by peripheral vasoconstriction, resulting from the effect of catecholamines in addition to the administered water volume 48-72 hr after birth. Therefore, the evaluation of peripheral circulation solely by PPI was regarded as difficult in situations where other factors such as the catecholamine PPI affected peripheral vessels. As other examples, Lac 24 hr and 48-72 hr after birth showed a weak negative correlation, although it was not significant. Lac increases in peripheral circulatory failure by enhanced anaerobic metabolism.[20] If the number of sample is greater, it might be suggested that PPI reflects peripheral circulatory failure.

In conclusion, this study demonstrated that PPI in low-birth-weight infants is also related to variables that are possibly affected by peripheral circulation and further suggested that PPI is effective for evaluating peripheral circulation in low-birth-weight infants. To date, peripheral hemodynamics have been evaluated mainly through subjective evaluation, such as the presence of cold or warm hands. If PPI is useful for evaluation, it can be used as a patient monitor for quantitative as well as almost automatic, noninvasive, and continuous monitoring of peripheral hemodynamics. It is necessary to accumulate cases for further investigation of these issues.

Conflict of Interest Statement

The author does not have a financial relationship with a commercial entity that has an interest in the subject of this manuscript.

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