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Correlation Between Perfusion Index, Oxygen Saturation and Cord Blood Gas in Infants Delivered Vaginally or with Cesarean Section

Vajinal veya Sezaryen Doğumla Doğan Yenidoğanlarda Perfüzyon İndeksi, Oksijen Satürasyonu ve Kordon Kan Gazı Arasındaki İlişki

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Abstract

Objective: Determining fetal/neonatal well-being by monitoring physiological changes, evaluating oxygenation/alveolar ventilation and circulation/perfusion, and the need for resuscitation are considered necessary during the fetal/neonatal transition period after delivery. This study aims to investigate the correlation between non-invasive methods oxygen saturation (SpO_2), perfusion index (PI), and cord blood gas parameters during the postnatal transition in term or near-term infants delivered vaginally or with cesarean section.

Methods: Sixty-four healthy term/near term infants were enrolled into this study. The blood gases of the umbilical artery (UA) and umbilical vein (UV) were analyzed in each case. SpO_2 and PI were recorded with a pulse oximeter.

Results: SpO_2 and PI values of vaginal births were significantly higher than who were born with cesarean section. A significant correlation between PI and SpO_2 values of both UA and UV was found in the vaginal birth group, while no correlation was found in the cesarean group. The trend of the PI was time-independent, and PI reached stability before SpO_2.

Conclusion: Non-invasive PI and SpO_2 measurements could be promising in monitoring the oxygenation and circulation of neonates during the postnatal transition period.

Keywords: Neonates, newborn, perfusion index, transition period, umbilical cord blood gases

Öz

Amaç: Doğum sonrasında gerçekleşen fetal/neonatal geçiş döneminde fizyolojik değişikliklerin izlenmesi, oksijenasyon/alveolar ventilasyon ve dolaşım/perfüzyonun değerlendirilmesi ile resüsitasyon gereksiniminin belirlenmesi, fetal/yeni doğan iyilik halinin saptanmasında gerekli kabul edilmektedir. Bu çalışma, vajinal ya da sezaryen ile doğan miadında veya miada yakın bebeklerde, postnatal geçiş sürecinde non-invaziv yöntemlerle ölçülen oksijen satürasyonu (SpO_2), perfüzyon indeksi (PI) ve kordon kan gazı parametreleri arasındaki korelasyonu araştırmayı amaçlamaktadır.

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Öz

Yöntem: Bu çalışmaya 64 sağlıklı miadında/miada yakın yenidoğan dahil edilmiştir. Her bir olguda umbilikal arter (UA) ve umbilikal ven (UV) kan gazları analiz edilmiştir. SpO_2 ve PI değerleri pulse oksimetre ile kaydedilmiştir.

Bulgular: Vajinal doğumla dünyaya gelen bebeklerin SpO_2 ve PI değerleri, sezaryen ile doğanlara kıyasla anlamlı derecede daha yüksek bulunmuştur. Vajinal doğum grubunda PI ve SpO_2 değerlerinin hem UA hem UV kan gazı parametreleriyle anlamlı korelasyon gösterdiği, buna karşın sezaryen grubunda herhangi bir korelasyon saptanmadığı belirlenmiştir. PI'nın zamandan bağımsız bir eğilim gösterdiği ve PI'nin SpO_2 değerlerinden daha önce stabil düzeye ulaştığı görülmüştür.

Sonuç: Non-invaziv PI ve SpO_2 ölçümleri, yenidoğanların postnatal geçiş döneminde oksijenasyon ve dolaşımın izlenmesinde umut vaat eden yöntemler olabilir.

Anahtar Kelimeler: Neonatoloji, yenidoğan, perfüzyon indeksi, geçiş dönemi, umbilikal kordon kan gazları

Introduction

The early postnatal transition a period during which significant changes occur as circulation shifts from fetal to neonatal circulation. During this time, when the umbilical cord is cut, the placental blood flow stops, the lungs fill with air, and gas exchange begins, more oxygen (O_2) is carried to the tissues, the systemic vascular resistance increases, and the intracardiac shunts (foramen ovale, ductus arteriosus) are closed. This adaptation process is primarily influenced by the gestational age, the mode of delivery, and the type of maternal anesthesia[1]. Therefore, during this period after birth, it is crucial to obtain information about fetal/neonatal well-being, to monitor physiological changes during the transition, and to evaluate oxygenation/alveolar ventilation, circulation, and the need for resuscitation. Hence, we used umbilical cord blood gas analysis and some non-invasive methods for these purposes.

Hemoglobin oxygen saturation (SpO_2), and perfusion index (PI) measurements with a pulse oximeter are recommended in many guidelines, such as newborn care, resuscitation, and screening of congenital heart diseases (CHDs). They are widely used in current clinical practice during and after delivery, including in neonatal intensive care units. SpO_2 and PI measurement are preferred because they are non-invasive especially in monitoring these transitional changes in the early postnatal period and determining the need for intensive care[2-7]. The PI is an important non-invasive indicator of peripheral circulation in clinical practice for newborns. Hemodynamic and respiratory changes during the transition period may affect peripheral perfusion[8]. These findings suggest that the PI is not affected by the mode of delivery in healthy term newborns[9]. Obtaining and analyzing umbilical cord blood gases immediately after delivery is the most important method for evaluating fetal and neonatal well-being[10-12]. There are a few study investigating the effect of mode of delivery and anaesthesia on the non-invasive monitorization parameters (SpO_2/PI) and umbilical artery (UA)/umbilical vein (UV) blood gas values in the transition period of healthy term infants.

This study aimed to investigate the relationship and compatibility between umbilical cord blood gas values and non-invasive measures (such as SpO_2 and PI), as well as delivery and anesthesia methods, during the transition period in term and near-term infants.

Materials and Methods

Sixty-four healthy term newborn infants (38 girls, 26 boys) born by [vaginal route (VR); 20] or [cesarean section (C/S); 44], without any prenatal or natal risk factors, were included in the study between February and April 2017. In our country, in non-emergent situations where urgent C/S is not necessary, the decision regarding the mode of delivery is left to the mother's preference. Our study included only infants born to women who underwent elective C/S. Individuals requiring resuscitation at birth and those with Apgar scores below 8 at the 5th minute were excluded from the study. Ethical approval was obtained from the Ethics Committee of Gazi University Faculty of Medicine (approval number: 2017-52, date: 19.01.2017). Written informed consent was obtained from the parents of all newborns included in the study.

Demographic characteristics of all infants included in the study and maternal characteristics were recorded. The gender, gestational week, birth weight, height, and head circumference of newborns; type of delivery; type of anesthesia applied at birth; maternal age; first- and fifth-minute Apgar scores; and postpartum interventions were recorded. All newborns were examined by a pediatrician in the operating or delivery room according to the mode of delivery.

After birth, 0.5-1 mL of blood was taken from the UA and the UV of each newborn infant using a special dry heparin blood gas injector, which was clamped on both sides. "Radiometer ABL 800 Basic blood gas analyzer" working with an ion-selective electrode system was used to determine blood gas parameters (pH, SpO_2 and partial pressure of carbon dioxide (pCO_2) immediately. Blood gases were evaluated.

After stabilization and evaluation of Apgar scores, Masimo set pulse oximeter rad-5v probe was attached to the right arm of the infants (preductal), SpO_2 and PI values were recorded continuously for the first 20 minutes.

Statistical Analysis

Mean, standard deviation, median, minimum, maximum, and percentile values in descriptive statistics for continuous data; percent values are given in the discrete data.

Pearson and Spearman correlation coefficients were used to evaluate the relationship of the UA and UV measurements with SpO_2, PI measurements at the 5th, 10th, 15th, and 20th minutes.

Either the t-test or the Mann-Whitney U test was used to compare data obtained from measurements of patients born by C/S and VR, after evaluating the conformity of the data to the normal distribution.

The Kaplan-Meier curve was used to calculate the stabilization time of the PI and SpO_2 measurements. P<0.05 was considered statistically significant.

Results

The mean gestational age of 64 cases was 38.6±1.1 (37-41 weeks). The delivery modes of the cases were C/S in 44 (69%) and vaginal in 20 (31%). General anesthesia was administered four (9%) C/Ss, and spinal anesthesia was administered in epidural anesthesia was used in four (20%) vaginal births, while induction was performed in nine (45%) vaginal births. The fifth-minute Apgar score was ≥9 in 93% of the infants. There have been no cases in which postpartum resuscitation was required.

Comparison of cord blood gas values by delivery type is shown in Table 1. Among those whose birth type was C/S or VR, there were significant differences between UA and UV in pH and pCO_2 values (Table 1). Among those whose birth type was C/S, both UA and UV pH values were significantly higher than in those with VR (p<0.001) (Table 1). In those with VR delivery, both UA and UV pCO_2 values were significantly higher than in those with C/S (p<0.05). There were no differences in UA and UV SpO_2 values between those with C/S and VR delivery types (p>0.05) (Table 1).

The median of preductal SpO_2 values at 10, 15, and 20 minutes in VR was significantly higher than in those born by C/S (Table 2). There was no difference in 5th-minute SpO_2 values between those delivered by C/S and those delivered by VR (p>0.05) (Table 2).

The comparison of the 5th-, 10th-, 15th-, and 20th-minute preductal PI averages , measured by the Masimo device, according to the mode of delivery, is shown in Table 3. There was no difference in terms of 5th and 10th-minute PI values in those whose mode of delivery was C/S or VR (p>0.05) . The difference between the 15th- and 20th-minute PI values was significant in those whose delivery type was C/S or VR (p<0.05). The median PI values at the 15th and 20th minutes were significantly higher in those with VR delivery (Table 3).

A positive correlation was observed between the 5th-min UA pO_2 value and the 5th-, 10th-, 15th-, and 20th-min PI values in infants born vaginally (p<0.05). There was no significant correlation between UA pO_2 and PI values at 10, 15, and 20 minutes (p>0.05) (Table 4). A positive correlation was also found between UV pO_2 and 10th- and 15th-minute PI values in vaginally born infants (p<0.05) (Table 4). There was no relationship between cord blood gas parameters and PI in those born by C/S.

Table 1. Comparison of cord blood gas parameters of cases according to delivery type

		C/S (n=44)		Vaginal route (n=20)		
		Mean ± SD (min-max)	Median	Mean ± SD (min-max)	Median	p-value*
Umbilical artery	pH	7.32±0.04 (7.18-7.39)	7.32	7.27±0.04 (7.2-7.37)	7.28	**0.000**
	pCO_2	46.1±5.8 (37.3-59.6)	45.2	49.6±5.3 (37.8-58.6)	50	**0.029**
	SpO_2	22.3±4.2 (13.4-29.9)	23	24.4±9.8 (14.1-46)	19.5	0.249
Umbilical vein	pH	7.36±0.04 (7.22-7.42)	7.36	7.32±0.04 (7.24-7.40)	7.32	**0.000**
	pCO_2	40.5±5.2 (31.7-54.6)	39.1	43.6±5.0 (33-52)	44.4	**0.029**
	SpO_2	30.9±5.2 (23.4-45.8)	30	31.5±8.7 (20-49)	29.4	0.727

*: T-test, pCO_2: Pressure of carbon dioxide, SpO_2: Oxygen saturation, SD: Standart deviation, C/S: Cesarean section

Table 2. Comparisons of preductal SpO_2 measurements by delivery type

	C/S	VR	
SpO_2	**Median (min-max)**	**Median (min-max)**	**p-value***
5th min	96 (83-100)	96 (84-100)	0.610
10th min	97 (80-100)	98.5 (86-100)	**0.025**
15th min	97 (86-100)	99 (84-100)	**0.027**
20th min	97.5 (89-100)	100 (88-100)	**0.020**

*: Mann-Whitney U test, SpO_2: Oxygen saturation, C/S: Cesarean section, VR: Vaginal route

Table 3. Comparison of perfusion index measurements according to delivery type

	C/S		VR		
PI	**Mean ± SD**	**Median (min-max)**	**Mean ± SD**	**Median (min-max)**	**p-value***
5th min	2.1±0.7	1.9 (0.5-3)	2.2±0.7	2 (1.25-3)	0.539
10th min	2.1±0.9	1.9 (1-5)	2.4±1.1	2 (1.25-5)	0.361
15th min	1.9±0.6	1.8 (1.25-3)	2.4±0.9	2 (1.25-5)	**0.009**
20th min	1.9±0.7	1.5 (0.50-3)	2.2±0.6	2 (1.25-3)	**0.012**

*: Mann-Whitney U test, C/S: Cesarean section, VR: Vaginal route, SD: Standard deviation

Table 4. The relationship between umbilical artery (UA) and vein (UV) pH, PCO_2 and SpO_2 values and perfusion index values in babies born by vaginal route

PI		UA pH	UA pCO_2	UV pH	UV pCO_2	UV SpO_2	UA SpO_2
5th min	r*	0.05	-0.04	0.23	-0.23	0.43	0.49
	p	0.85	0.88	0.32	0.33	0.06	**0.029**
10th min	r*	0.2	-0.18	0.11	0.13	0.57	0.4
	p	0.4	0.44	0.65	0.57	**0.009**	0.08
15th min	r*	0.22	0.03	0.43	-0.09	0.49	0.24
	p	0.36	0.9	0.06	0.69	**0.026**	0.31
20th min	r*	0.09	0.13	0.16	0.05	0.26	0.08
	p	0.72	0.59	0.52	0.83	0.27	0.75

*: Spearman correlation coefficient, pCO_2: Pressure of carbon dioxide, SpO_2: Oxygen saturation, PI: Perfusion index

Time-dependent univariate linear regression model results of the first quarter, second quarter, and third quarter values for pulse, SpO_2, and PI in the first 10 minutes, showed that time had no role in the change of PI, while the effect of time was high in explaining the change of pulse and SpO_2 (Table 5) (Figure 1). The PI and the stability times for SpO_2 were calculated using the Kaplan-Meier curve. The stability time within 5 consecutive sections for PI (less than 20% change) and SpO_2 (less than 1% change) was measured. The PI reached a stable state by one minute postnatal age in 37 newborns (59.7%). SpO_2 stabilized one minute after birth in 15 newborns (25.4%). While the PI reached a stable state within ≤5 minutes in 88.7% of cases, SpO_2 reached a steady state within ≤5 minutes in 52.6% of cases (Figure 2).

Discussion

The relationships between umbilical cord venous and umbilical cord arterial blood gas parameters at birth and PI and SpO_2 values measured by pulse oximetry in vaginal and C/S deliveries were investigated during postnatal transition in the present study. Our results showed that, SpO_2 and PI values of vaginal births were significantly higher than those, born with C/S. A significant correlation between PI and SpO_2 values in both UA and UV was found in the vaginal group, while no correlation was found in the caesarean group. The trend of PI was time independent, and PI reached stability before SpO_2. The evaluation of the compatibility between these measurements allowed discussion of how much it

Table 5. Time-dependent univariate linear regression model results of 25th, 50th, and 75th percentile values for perfusion index, SpO_2, and heart rate in the first 10 minutes

			R^2
SpO_2	1st quartile (25.p*)	Y=90.17+0.61*x	0.679
	2nd quartile (50.p*)	Y=93.97+0.37*x	0.778
	3rd quartile (75.p*)	Y=96.47+0.28*x	0.802
Pulse	1st quartile (25.p*)	Y=144.27-0.44*x	0.591
	2nd quartile (50.p*)	Y=153.97-0.74*x	0.895
	3rd quartile (75.p*)	Y=166.03-1.10*x	0.853
PI	1st quartile (25.p*)	Y=1.52-0.002*x	0.030
	2nd quartile (50.p*)	Y=2.00-0.002*x	0.030
	3rd quartile (75.p*)	Y=2.983-0.002*x	0.003

*: Percentile, SpO_2: Oxygen saturation, PI: Perfusion index

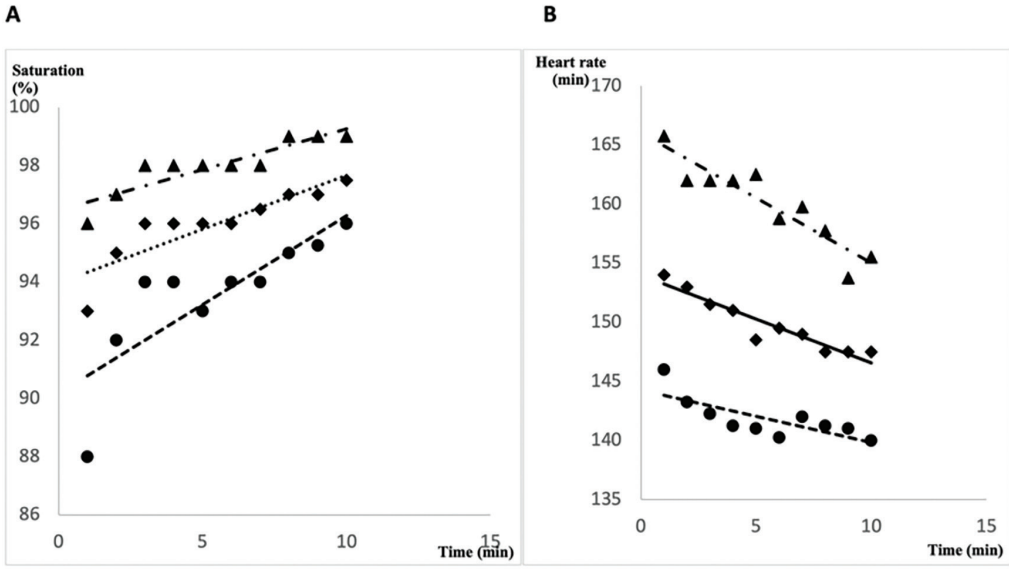

Figure 1. Time-dependent graph of 1st, 2nd and 3rd quartile values for oxygen saturation in the first 10 minutes (A); for heart rate in the first 10 minutes (B) ▲: 75.percentile, ◆: 50.percentile, ●: 25.percentile

could help in obtaining information about fetal well-being and early postnatal transition, and in determining the appropriate degree of respiratory support when resuscitation is required.

The transitional period in newborns is a critical interval during which significant changes occur in the transition from fetal circulation. During this period, a series of rapid physiological and anatomical changes occurs: placental blood flow ceases with clamping of the umbilical cord; the lungs begin gas exchange; pulmonary vascular resistance decreases; and intracardiac shunts close as systemic vascular resistance increases[1]. Few studies have examined the monitoring of infants during this period. Our study aimed to observe changes during the transition period and to evaluate the compatibility of pulse oximeter measurements with the blood gas data obtained from UA and UV by the invasive route.

Some methods have been developed that provide information on the well-being and prognosis of newborns and guidance for postpartum interventions. The most important of these is the analysis of umbilical cord blood gas parameters, which has become increasingly common. Apgar scoring, used in the

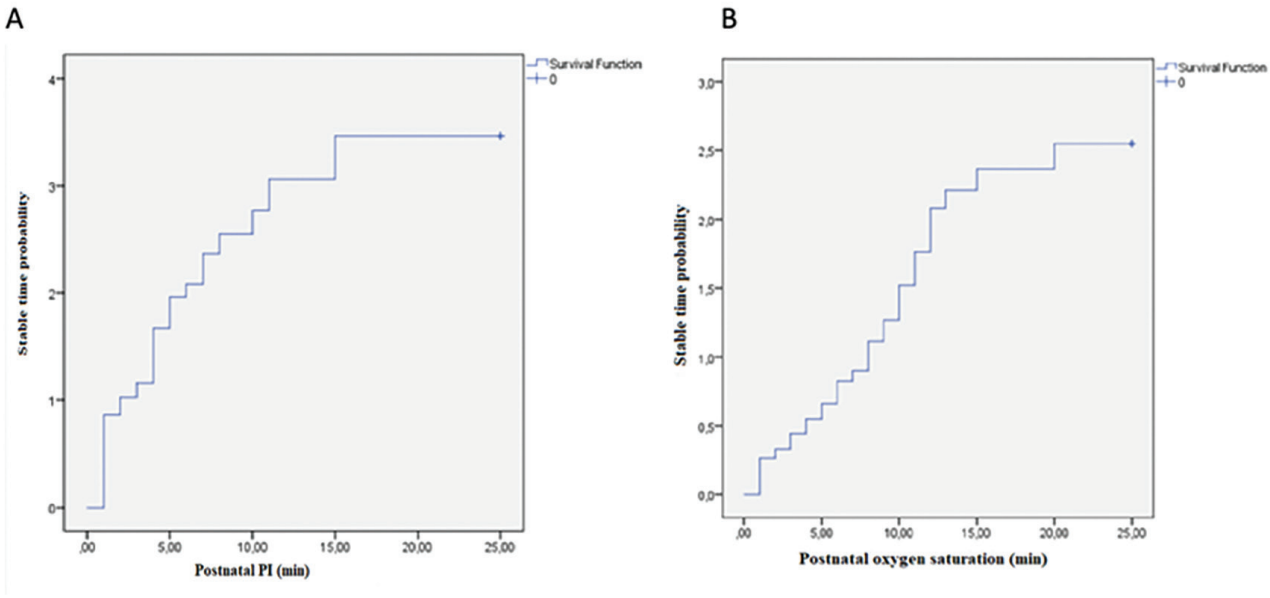

Figure 2. Kaplan-Meier curve for time to stable measurement for perfusion index (A), of oxygen saturation (B)

postnatal evaluation of newborns, helps distinguish normal newborns from those with noticeable signs of perinatal asphyxia. However, Apgar scoring is not sensitive enough to detect less severely affected infants. Clinical evaluation of newborns, combined with umbilical cord blood gas analysis after birth, guides early treatment approaches[13,14]. Arterial blood gas measurement is the gold-standard method for demonstrating acid-base disorders and for monitoring alveolar ventilation and oxygenation. The correction of acid-base and oxygenation disorders has a significant impact on mortality and morbidity[15]. Umbilical cord blood gas measurement is currently the most widely accepted method for evaluating fetal well-being and detecting perinatal asphyxia. However, in some emergency situations, umbilical cord blood gas samples cannot be collected or evaluated because of difficulties with blood withdrawal and technical problems, as collection is an invasive procedure. Technical issues, such as improper removal of blood gas, excess heparin in the injector, residual air in the blood sample, or inability to operate immediately, can cause incorrect results. Moreover, cord blood obtained from the UV or from mixed samples, rather than from the UA, may reflect the mother's condition rather than the infant's. Hence, non-invasive, validated, quantitative markers or measurements are needed to evaluate hypoxia and perfusion in term infants during the early postnatal transition period.

Pulse oximetry measures the percentage of oxygenated hemoglobin using the difference in absorbance between red and infrared light and calculates the ratio of oxygenated hemoglobin in the pulsatile component. When tissue perfusion decreases, the skin, subcutaneous tissues, muscles, and gastrointestinal tract are initially affected, whereas vital tissues (brain, heart, adrenal glands) are protected temporarily. Thus, detection of decreased perfusion in nonvital tissues could be used as an early marker[16-19].

The PI, representing variable light absorption caused by pulsatile arterial blood flow reflects the ratio relative to the constant light absorption from non-pulsatile components, including venous blood, connective tissue, skin, bone, and other tissues. It reflects momentary changes in peripheral blood flow[19,20]. The PI is a promising non-invasive method for assessing peripheral capillary circulation and, indirectly, organ perfusion[21]. Soon, thanks to the development and widespread use of devices that measure advanced PI, quantitative monitoring of the transition period from birth will be possible. Since the 2000s, many studies have been conducted to evaluate the PI in assessing neonatal well-being and in the early detection of life-threatening conditions. Many studies have determined PI threshold values in both term and preterm infants[22]. PI levels below the threshold value in neonatal intensive care units have been proposed as objective indicators of acute disease. For instance, some

studies have shown that the PI value is low in CHDs, and its measurement has been suggested for diagnosing these diseases[20,23,24].

Schena et al.[23] screened 42.169 healthy term newborns by measuring PI and SpO_2 and detected CHD in three of them. Two of these were found to have low SpO_2, and one had a low PI. This study showed that PI and SpO_2 should be used in CHD screening[23,25-27]. Recent evidence supports adding PI to pulse oximetry to improve screening performance and reduce false positives in selected protocols[26,27]. Granelli and Ostman-Smith[20] measured preductal and postductal PI in 1000 healthy newborns within the first 1-120 hours of their lives and reported a mean PI of 1.70 (1.18-2.5). In that study, heart anomalies were detected in two infants with PI values below 0.7. In nine infants followed up as a control group for left heart obstruction disease, the PI was found to be below 1. Of them, five had PI values below 0.7. They stated that the PI indicates the severity of cardiac dysfunction and that a PI below 0.7 can be used as a marker for detecting CHDs[24].

Perrone et al.[28] also aimed to evaluate the role of peripheral PI and pulse oximetry screening during the first 24 hours of life in the early detection of CHDs and non-CHDs (perinatal infection and suspected respiratory disease) in newborns. This study concluded that combining peripheral saturation with the peripheral PI during the first 24 hours of life is predictive of minor CHDs and neonatal clinical conditions that require attention[28].

In our study, the PI was measured and recorded preductally at five-minute intervals for twenty minutes. Mean PI values were 2 (0.5-3) at the 5th minute, 2 (1-5) at the 10th minute, 1.75 (1.25-5) at the 15th minute, and 1.75 (0.5-3) at the 20th minute. The mean values were similar to those reported in the literature[9,23,24]. No apparent changes in the PI were observed within the first twenty minutes. De Felice et al.[24] also measured the PI between 0 and 1 minute and between 1 and 5 minutes after birth and reported no difference between those values. In our study, the lowest measured PI was 0.5. However, as it increased during follow-up, it was thought that this could be due to cold hands and feet resulting from vasomotor imbalance, which causes physiological peripheral cyanosis in newborns, along with vasospasm due to hypothermia. Nevertheless, hypothermia was excluded, as all measurements were made in incubators at ideal temperatures. In some measurements, PI exceeded 5; this was attributed to the babies being very active and crying during the measurement, because babies' crying can cause vasodilation and thus elevate PI.

Unal et al.[8] found the mean postductal PI at 10 minutes and at 1 hour to be 1.41 (1.17-1.78) in tachypneic and healthy term newborns. There was no significant difference in PI values between healthy and tachypneic infants[8]. According to our study, the lower measurements could be due to postductal measurement sites. On the other hand, in our study, we were not able either to to measure preductal and postductal PI simultaneously or to monitor body temperature continuously due to technical limitations. Hakan et al.[22] measured preductal and postductal SpO_2, PI, and pulse in the first five days of life in 196 terms and 45 preterm newborns. They reported the mean pre-ductal and postductal PI, measured over the first 6 hours of life in term infants, as 1.35 (1.02-1.91) and 0.88 (0.62-1.22), respectively. They stated that preductal PI was significantly higher than postductal PI in the first three days, and attributed the low values to regional and racial differences. As in our study, they observed fluctuations in PI during crying and activity[22].

In a study of 125 healthy term infants, Yiğit et al.[29] found that PI was higher in C/S births. This condition was assessed as indicative of more significant hemodynamic changes during the early transitional period after C/S delivery[29]. Our study found that 15th- and 20th-min PI values in those born vaginally were significantly higher than in those born by C/S. This could be attributed to vaginal delivery being a more physiological process. In our study, spinal anesthesia was applied in births with C/S where it adversely affects uteroplacental circulation and oxygenation. Although the duration of the effects of anesthetic agents on the neonate is unknown, a low PI in infants born by C/S may indicate circulatory disorders related to anesthesia.

In a study by Taguchi et al.[16], PI, pulse rate, and SpO_2 were measured for 10 minutes after birth in 60 newborns born between 35 and 41 weeks. The PI was 1.5 after birth in 45% of newborns, and in 90% of newborns it was measured as stable after 3 minutes. The stable PI value was always obtained before the SpO_2 measurement. It has been reported that there is no relationship between the course of PI and heart peak beat and SpO_2[30]. Our study also found that PI stabilized earlier than SpO_2. While the PI reached a stable state after the first minute postpartum in 37 newborns (59.7%), SpO_2 did so in only 15 newborns (25.4%). It was thought that PI would be low due to poor peripheral perfusion immediately after birth and would increase with time, such as SpO_2 or pulse. So we looked at how PI, SpO_2, and pulse changed over time in the first 10 minutes. At the tenth minute, 75% of the pulses were ≥155/min, 50% ≥145/min, and 25% ≤140/min

with 75% of PIs ≥3, 50% ≥2, 25≥1.5. It was seen that 75% of the SpO_2s were ≥98, 50% were ≥96 and 25% were 94. The measured values were consistent with the SpO_2 target table for the first 10 min, as determined by neonatal resuscitation program[6,7]. Additionally, recent percentile data among term infants show higher early SpO_2 levels under specific cord-clamping conditions[31]. If a PI target table can be created during the transition period, monitoring oxygenation and circulatory status and managing resuscitation steps can help inform decisions on intervention and hospitalization for the neonates. Contrary to the expectations from our study, PI followed a different course apart from the changes in pulse, and SpO_2 and remained in approximately the same value ranges after birth. A high PI indicates adequate perfusion of each organ immediately after birth. PI fluctuations observed from the first measurement may reflect individual differences in postnatal adaptability.

Changes in pulse and SpO_2 showed that the effect of time was significant, unlike in PI. Taguchi et al.[16] reported that infants born vaginally had higher SpO_2. While some studies indicate that SpO_2 is higher in vaginal delivery, some studies have shown no significant difference in SpO_2 according to the mode of delivery[32-36]. In our study, the SpO_2 values of the 10th, 15th, and 20th min vaginal births were significantly higher than those born with C/S. This situation can be explained by the more physiologic transition from fetal to neonatal circulation that occurs during vaginal delivery. In addition, the negative effects of anesthesia for C/S on circulation and oxygenation should not be ignored. However, we could not evaluate the effects of different forms of anesthesia because epidural and general anesthesia were insufficiently applied in the vaginal/CS groups.

Alderliesten et al.[36] followed up PI for 72 hours in 311 newborns younger than 32 weeks and found that PI was negatively related to dopamine, mean blood pressure, follow-up on mechanical ventilation, and SpO_2. However, it was positively associated with female gender, gestational age, pulse pressure, and patent ductus arteriosus (PDA). They suggested that the elevated pulse pressure in PDA caused blood to shunt into the pulmonary artery during diastole. Stroke volume is increased to eliminate the adverse effect of this condition on perfusion. PI was higher because peripheral vasodilation decreased diastolic blood pressure. A negative relationship between SpO_2 and PI was attributed to the effect of SpO_2 on vascular tone[36].

Our study found no relationship between mode of delivery (vaginal or C/S) and SpO_2 and PI values, in accordance with the study of Hakan et al.[22]. This situation might be due to the similarity between the two studies, both of which were conducted on healthy infants.

In the present study, we found a positive relationship between UA and UV SpO_2 and between UA and PI in vaginal births, while there was no relationship between umbilical cord blood gas parameters and PI in those delivered by C/S. To our knowledge, no studies in the literature have compared umbilical cord blood gas parameters with PI and SpO_2. The gold standard for demonstrating tissue oxygenation is arterial SpO_2. The PI is a parameter that helps us detect early deterioration of tissue perfusion, prevent tissue hypoxia and organ failure, and intervene in a timely manner. As a non-invasive method, the PI can evaluate blood flow and oxygenation simultaneously by measuring the ratio of pulsatile to non-pulsatile flow. Therefore, the positive relationship between SpO_2, the gold standard for demonstrating tissue oxygenation, and PI was considered an expected situation. The SpO_2 value, an indicator of oxygenation in both UV and UA blood gases, was positively associated with PI among infants born vaginally. It can be attributed to the fact that PI measurements reflect oxygenation more accurately during the transition from fetal to neonatal circulation, owing to the better physiological adaptation associated with vaginal delivery.

Study Limitations

This study has several limitations. First, the relatively small sample size and single-center design may limit the generalizability of our findings and reduce the statistical power to detect subtle differences between groups. Therefore, the results should be interpreted with caution. Second, the unequal distribution of participants between the vaginal and cesarean delivery groups and the limited number of cases receiving each type of anesthesia restricted our ability to perform detailed subgroup analyses of anesthesia effects. Third, preductal and postductal PI measurements could not be obtained simultaneously because of technical limitations, and continuous body temperature monitoring was unavailable during measurements; these limitations may have influenced peripheral perfusion values.

Future large-scale, multicenter studies with balanced group distributions and standardized anesthesia protocols are needed to confirm our findings and further clarify the relationship between PI, SpO_2, and umbilical cord blood gas parameters during the neonatal transition period.

Conclusion

This study evaluated the use of non-invasive pulse oximetry and PI in newborns during the postpartum transition period as a supplement to cord blood gas. In the near future, we hope it will be possible to use these non-invasive methods to support monitoring during the transition period and the resuscitation of newborns.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Ethics Committee of Gazi University Faculty of Medicine (approval number: 2017-52, date: 19.01.2017).

Informed Consent: Written informed consent was obtained from the parents of all newborns included in the study.

Footnotes

This study was derived from the medical specialty thesis of Merve Yavuz.

Authorship Contributions

Surgical and Medical Practices: M.Y., E.K., İ.H., E.E., E.Ö., C.T., Concept: E.K., C.T., Design: E.E., C.T., Data Collection or Processing: M.Y., Analysis or Interpretation: M.Y., İ.H., Literature Search: M.Y., Writing: M.Y.

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