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ORIGINAL ARTICLE

Relationship Between Oxygen Saturation and Umbilical Cord pH Immediately After Birth

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Key Words
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Background: The aim of this study is to determine the relationship between oxygen saturation (SpO_2) by pulse oximetry levels and umbilical cord arterial pH values in healthy newborns during the first 15 minutes of life.
Methods: The study was performed with healthy term, appropriate-for-gestational-age newborn infants. The infants were divided in two groups: umbilical cord arterial blood pH value $\leq$7.19 (group 1) and $>$7.19 (group 2); SpO_2 levels during the first 15 minutes of life were compared between groups.
Results: The study was completed with 129 infants (33 in group 1 and 96 in group 2). A significant correlation was found between first-measured preductal and postductal SpO_2 levels by pulse oximetry and umbilical cord arterial pH values ([r^2:0.72(0.62 -0.79); $p < 0.001$] and [r^2:0.32(0.25 − 0.54); $p < 0.001$], respectively). In group 1, infants had lower SpO_2 levels at both preductal and postductal measurements during the first 11 minutes of life and time to reach $\geq$90% SpO_2 level was longer compared with infants in group 2.
Conclusion: Determination of umbilical arterial blood pH values, in addition to clinical findings and oxygen saturation measurements, might be helpful in deciding the concentration of oxygen and whether or not to continue oxygen supplementation in the delivery room.

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1. Introduction

Resuscitation of the newborn in the delivery room is the fundamental approach to ensure the maintenance and quality of life. Although they are determining factors for the continuity of life, modern rules for newborn resuscitation are often associated with clinical experience and not completely based entirely on scientific evidence.[1] Published research proposes that the neonatal resuscitation decision-making and oxygen supplementation be guided according to clinical findings (respiratory effort, heart rate) and oxygen saturation monitoring.[2–4]

Worldwide, more than one million newborns per year need resuscitation.[5] Studies indicate that 100% oxygen supplementation during resuscitation may be harmful due to oxygen free radicals that influence the pathogenesis of many diseases of the newborn and children (including leukemia and childhood cancer).[6–8] The most important finding is that 21% oxygen was associated with lower neonatal mortality.[9] Therefore, it is obvious that much stronger evidence is needed to determine the concentration and duration of oxygen used in neonatal resuscitation. For this purpose, a considerable number of studies were conducted with the new generation pulse oximeters to evaluate the oxygenation early in the delivery room. In previous studies, oxygen saturation (SpO_2) levels obtained by pulse oximeters from resuscitated asphyxiated newborns and healthy term and preterm newborns were found to be effective on saturation levels and in identifying fetal acidosis.[10–15]

Umbilical cord blood gas analysis is considered to be an objective indicator of fetal acid-base balance and fetal response to birth stress.[16] Despite the continuing discussions about umbilical cord blood gas threshold values, it is proposed that blood gas analysis should be taken into account when evaluating fetal hypoxemia.[17,18]

To the best of our knowledge, there are no studies available evaluating both oxygen saturation levels and umbilical arterial (UA) blood pH values together, which are accepted as objective indicators of accurate newborn oxygenation status determination. The primary goal of our study is to reveal the relationship between oxygen saturation levels during the first 15 minutes of life in the delivery room and UA blood pH values in healthy newborns, to ensure that evidence-based medicine will guide newborn resuscitation. The secondary goals are to compare mean preductal and postductal SpO_2 levels in healthy term newborns during the first 15 minutes of life, and to determine the effect of delivery route, sex, and umbilical cord pH values on the mean time to reach a preductal and postductal SpO_2 level of 90%.

2. Patients and Methods

2.1. Study population

This was a prospective, observational cohort study. The study was performed between May 1, 2009 and June 1, 2009 in the neonatal intensive care unit of Sisli Etfal Children Hospital in Istanbul, Turkey. The study was approved by regional ethical committee and written approval forms were obtained from the parents. The inclusion criteria were healthy term, appropriate-for-gestational-age (AGA) neonates born by vaginal or caesarean delivery (C/D). General anesthesia was used for caesarean deliveries with the same established procedures. Exclusion criteria were as follows: gestational age <37 or >42 weeks; small-for-gestational-age (SGA) or large-for-gestational-age (LGA); Apgar scores at 1, 5, and 10 minutes <7; fetal malnutrition; supplemental oxygen requirement and ventilation and/or medications requirements at birth; congenital anomalies; multiple pregnancies; complicated pregnancy (maternal infections, fever, bleeding, oligohydramnios, rupture of membranes up to 12 hours, meconium-stained amniotic fluid, and other maternal and placental diseases, etc); and developing respiratory distress or oxygen therapy requirement within the first 24 hours.

All infants were assessed at birth. Two pediatric specialists and one neonatal nurse attended each delivery. When necessary, resuscitation was performed by different doctors and nurses. Resuscitation protocols followed the Neonatal Resuscitation Program guidelines.[19] The time of birth was determined at the time of cord clamping, which routinely occurred immediately after birth. Demographic findings (mode of delivery, relevant antenatal history, maternal age, obstetric gestational age, and duration of rupture of membranes) and Apgar scores were recorded on data collection forms. Gestational age was defined according to the criteria of Usher and McLean.[20] Investigators participating in the study trained for 1 month before the initiation of the study to gain experience in saturation probe placement and umbilical blood gas sampling.

2.2. Pulse oximetry measurement procedure

Pulse oximetry measurements were performed using two new-generation pulse oximeters (Masimo Radical, Masimo Corporation, Irvine, CA, USA) secured with a Coban wrap (3M Health Care, St. Paul, MN, USA). The sensors were placed at the right hand for the preductal SpO_2 measurements and the dorsum of the foot for the postductal SpO_2 measurements immediately after cord clamping by the investigators, who were not involved in newborn resuscitation. Next, the probe was connected to the pulse oximetry. The maximum sensitivity setting was chosen and all monitor alarms were muted.

The chronometer was started at clamping of the cord. The time to apply the sensor and the time elapsed from birth until the first reliable reading of SpO_2 level were noted. Next, SpO_2 levels were recorded and downloaded automatically every 2 seconds to a computer. Pulse oximetry measurement was continued for a minimum of 15 minutes. The averages of SpO_2 levels 30 seconds before and after each minute of age were accepted as a 1-minute result of that interval.

2.3. Blood sample

At delivery, the umbilical cord was clamped before any signs of breathing, and blood was drawn from the UA into 2-mL plastic syringes flushed with a 1000-U/mL heparin solution. The arterial blood gas analysis was performed within 2 minutes in automatic blood gas analyzers (Roche Omni C blood gas analyzer, Roche Diagnostic, Diamond diagnostics, USA).

2.4. Determination of patient groups

In previous studies, it was stated that low UA blood pH showed strong, consistent, and temporal associations with clinically important neonatal outcomes.[21] Significant pH level for important neonatal outcomes was determined as 7.20 in some studies.[22–24] First, we arranged measured pH values starting with the highest 7.41 pH value, to the lowest pH value of 7.10. Afterward we divided the study group into two for each pH value; neonates in the first group had less than or equal to ($\leq$) and the second group had greater than ($>$) evaluated pH value. The means of the first obtained oxygen saturation levels of groups were compared in sequence to determine which pH value had significant difference in oxygen saturation levels. The first UA pH value (cutoff level) that created a significant difference between the first obtained mean oxygen saturation level of groups was found at 7.19. The first obtained mean oxygen saturation level of newborns whose UA blood pH values were $\leq$7.19 (*n*: 33) was significantly lower than that of infants with UA blood pH values of $>$7.19 (*n*: 96) (69.3 $\pm$ 3 .2% vs. 76.1 $\pm$ 1.5%, $p < 0.05$ for preductal measurement; and 62.8 $\pm$ 5.1% vs. 68.2 $\pm$ 7.6%, $p < 0.05$ for postductal measurement). In accordance with these findings, infants were divided into two groups: UA blood pH value $\leq$7.19 (group 1) and $>$7.19 (group 2); SpO_2 levels during the first 15 minutes of life were compared between these groups.

2.5. Statistical methods

Descriptive statistics, Kolmogorov-Smirnov normality test, Spearman rank correlation test, regression analysis, and Mann-Whitney U test were used for statistical data processing. The cutoff level for pH value was determined by using receiver operating characteristic curves. All data are expressed as means and 95% confidence intervals. Data were analyzed using SPSS software (SPSS Inc., version 18, Chicago, IL, USA and Medcalc version 10 statistical software, Medcalc Software, Mariakerke, Belgium). A *p* value $<$0.05 was considered to be statistically significant.

3. Results

During the study period 276 babies were born in our hospital. Of these, 34 were preterm ($<$37 weeks), one was posterm ($>$42 weeks), 14 were term SGA, 17 were term LGA, five had fetal malnutrition (without SGA), 13 required suplemental oxygen, six needed resuscitation, eight were of multiple gestation, three had congenital anomalies, 18 were born by complicated pregnancies, five had parents who were not suitable to give informed consent, and 23 were excluded for other reasons (they developed respiratory distress or required oxygen therapy within the first 24 hours, had insufficient records, simultaneous delivery, delayed arrival of the research team, etc.).

After enrollment, a total of 129 neonates were analyzed in the study. Although there were 33 in group 1 whose UA blood pH values were $\leq$7.19, there were 96 in group 2 whose pH values were $>$7.19. There were no significant differences between the groups with respect to demographic data (Table 1). Oxygen saturation levels could be detected as preductal in 121 (group 1: 30 and group 2: 91 measurements) and postductal in 117 (group 1: 28 and group 2: 89 measurements) within the first minute of life. From the second minute, SpO_2 measurements were obtained from all infants. The median times of sensor placement after delivery for preductal and postductal regions were 23 (15-31) and 22 (15-30) seconds, respectively. The first reading median times of SpO_2 for preductal and postductal regions were 43 (30-36) and 45 (29-70) seconds, respectively.

During the first 12 minutes after birth, preductal SpO_2 levels were significantly higher than postductal SpO_2 levels in all newborns (Figure 1). Times to reach $\geq$90% SpO_2 level preductally and postductally were 7.3 $\pm$ 2.7 and 9.0 $\pm$ 3.5 minutes, respectively ($p < 0.001$). The mean times to reach a preductal and postductal SpO_2 level of 90% with respect to sex, route of delivery, and pH value are shown in Table 2. In neonates born by C/D and with a UA blood pH value $\leq$7.19 it took longer to reach $\geq$90% SpO_2 level both preductally and postductally. Sex was found to have no effect on duration to reach to 90% SpO_2 levels at either preductal or postductal measurements.

Mean umbilical cord arterial blood pH value of all infants in group 1 and group 2 were found to be 7.25 $\pm$ 0.06, 7.16 $\pm$ 0.02, and 7.28 $\pm$ 0.04, respectively. Correlation between the first preductal and postductal SpO_2 levels and umbilical artery blood pH values at the time of delivery is shown in Figure 2. A significant correlation was found between preductal and postductal SpO_2 levels determined by pulse oximetry and umbilical artery blood pH values ([r^2:0.72 (0.62 $-$ 0.79); $p < 0.001$] [$y = 6.2515 + 0.0135$ x] and [r^2:0.32 (0.25 $-$ 0.54); $p < 0.001$] [$y = 6.9038 + 0.0052$ x], respectively). There was no correlation between preductal and postductal SpO_2 levels and umbilical artery blood base excess values ([r^2:0.12(0.04 $-$ 0.29); $p > 0.05$] and [r^2:0.03 (0.17 $-$ 0.19); $p > 0.05$], respectively). Preductal and postductal SpO_2 levels of infants in group 1 and 2 during the first 15 minutes are shown in Figure 3. In the first 11 minutes of life, both preductal and postductal SpO_2 measurements were significantly lower in group 1 than group 2 ($p < 0.05$).

Table 1 Demographic characteristics of infants.

Characteristics	Group 1 (n = 33)	Group 2 (n = 96)	*p*
Sex, *n*(%)			
Male	17 (51.5)	49 (51)	0.963
Female	16 (48.5)	47 (49)	
Route of delivery, *n*(%)			
Vaginal	20 (60.6)	59 (61.5)	0.931
Cesarean	13 (39.4)	37 (38.5)	
Birth weight* (g)	3110 $\pm$ 384	3116 $\pm$ 380	0.926
Gestation of age* (wk)	38.5 $\pm$ 1.3	38.4 $\pm$ 1.2	0.343

*Data are presented as means $\pm$ standard deviation.

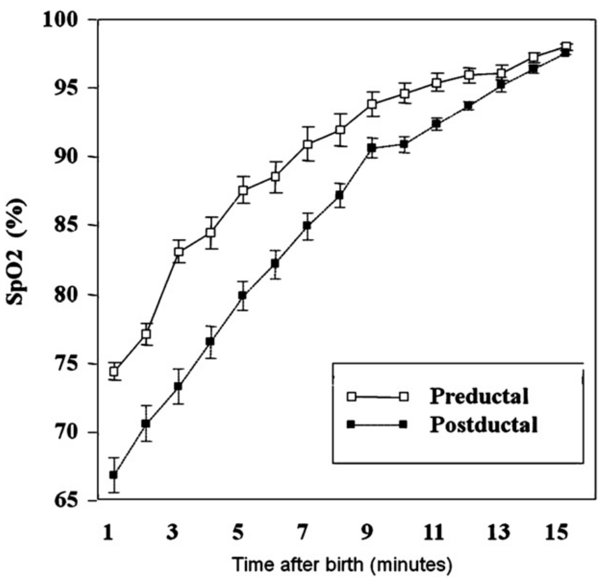

Figure 1 Preductal and postductal SpO_2 levels during the first 15 minutes after birth (means; 95% confidence interval for mean). Postductal SpO_2 levels were significantly lower than preductal measurements during the first 12 minutes ($p < 0.05$).

4. Discussion

The recommendations of oxygen use in the delivery room for newborns are limited to empirical experience and lack scientific evidence. Clinical signs are still relied upon because of the difficulty in obtaining accurate, direct measurements of oxygenation in the neonate. There is growing evidence that excessive administration of oxygen may lead to prolonged oxidative injury.[25,26] Therefore, clinical practices are currently in question and new approaches are being sought. Pulse oximetry is widely used in newborns, and some clinicians regard it to be a vital sign.[27] Umbilical arterial blood pH value is also touted as valuable in guiding neonatal resuscitation in the delivery room.[28,29] Although UA blood pH values[30–32] and oxygen saturation level[5,10–13] immediately after birth have been addressed in previous studies, there are no data on the relationship between UA blood pH value and SpO_2 level.

In the current study, the relationship between UA blood pH values and SpO_2 levels was investigated in the first 15 minutes of life. We found that there was a significant correlation between both preductal and postductal SpO_2 levels and UA blood pH values. Newborns with pH $\leq$ 7.19 had lower SpO_2 levels at both preductal and postductal measurements in the first 11 minutes of life, and they took longer to reach $\geq$90% SpO_2 level compared with babies with pH > 7.19.

Several studies have addressed the correlations between oxygen saturation measured by intrapartum pulse oximetry and pH in fetal blood.[33,34] Kühnert et al.[35] stated that when the arterial oxygen saturation fell below 30%, it was highly predictive of a pH below 7.20 and evolving blood acidosis. Arikan et al.[36] found that low preductal fetal oxygen saturation measured at birth seemed to be associated with low fetal pH and base excess. Significant correlation between UA blood pH values and SpO_2 levels determined in our study, however, was not valid for base excess parameter. This was most likely caused by the fact that at the time of measurement some of the fetuses were experiencing the early symptoms of an impaired blood supply. In case of a prolonged period of hypoxia, an anaerobic metabolism would result and base excess would be increased secondary to the presence of lactic acidosis.[37]

In some previous trials it was shown that, in healthy newborns, the postductal SpO_2 level was lower than the preductal SpO_2 level due to high pulmonary artery pressure and right-to-left shunt through the ductus arteriosus.[13,38] Similar to previous studies, we found that postductal SpO_2 levels were lower than preductal SpO_2 levels in the first 12 minutes of life. Our study demonstrated that infants born by cesarean delivery had lower oxygen saturation and required longer to reach oxygen saturation $\geq$90% compared with infants born vaginally. This result is similar to previous studies and this situation is described as secondary to delayed clearance of lung fluid during caesarean section.[10,12,38,39]

In previous studies, it was noted that the first data could be obtained in approximately 68 seconds to 3 minutes after birth.[10,12,38,40] There was no standard practice and method of sensor application in these studies (including methods and region of sensor application, gestational age, or need for ventilation). In our study, median time from birth to obtain reliable preductal and postductal SpO_2 measurements (43 and 45 seconds, respectively) is shorter than in previous studies. We attribute this condition to the following factors: the participation of more experienced

Table 2 The mean time to reach preductal and postductal SpO_2 level of 90%.

Characteristics		*n*	Time to reach SpO_2 level of 90% (minutes, means ± standard deviation)			
			Preductal	*p*	Postductal	*p*
Sex	Male	66	7.4 ± 2.8	>0.05	9.3 ± 3.2	>0.05
	Female	63	7.6 ± 2.9		9.5 ± 3.4	
Route of delivery	Vaginal	79	6.7 ± 2.7	<0.001	8.8 ± 3.3	0.01
	Cesarean	50	8.7 ± 2.7		10.3 ± 3.2	
pH Value	pH ≤ 7.19	33	9.0 ± 3.5	0.006	12.0 ± 3.1	<0.001
	pH > 7.19	96	7.3 ± 2.7		8.2 ± 2.6	

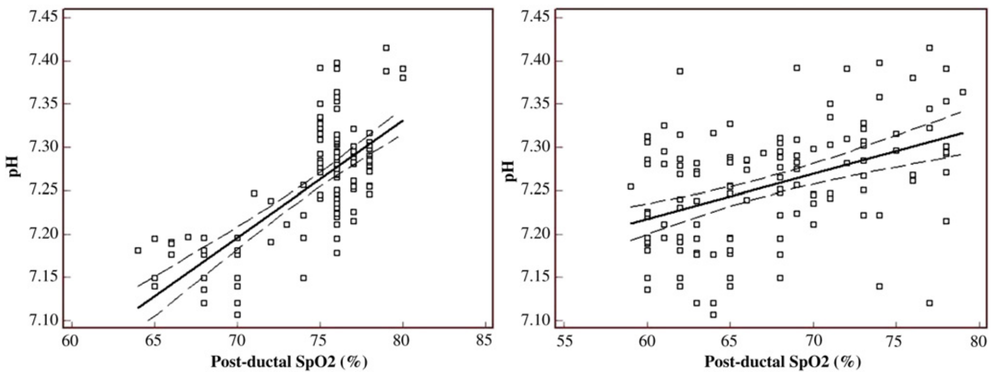

Figure 2 The correlation and regression analysis between the first preductal and postductal SpO_2 levels and umbilical artery blood pH value at the time of delivery. A significant correlation was found between preductal and postductal SpO_2 levels and umbilical artery blood pH values.

researchers to delivery; the use of the maximum sensitivity mode of pulse oximetry; application of sensors at early basic steps of resuscitation as healthy term babies included in the study; and the fact that the practice of skin-to-skin contact between baby and mother is not used in our hospital.

The most important limitation of the study was that there was a loss of crucial time when obtaining a blood sample for UA blood gases and evaluation of results to be able to make the decision about starting oxygen supplementation. However, development of a new technology (use of a developed blood gas analyzer, which provided the results in less than 1 minute using a few drops of blood in the delivery room) to shorten this loss of time would be an important approach to overcome this handicap in the future.

According to our study's results, there is a significant correlation between UA blood pH values and SpO_2 levels measured with pulse oximeters immediately after birth. Newborns whose UA blood pH values were lower than 7.20 were found to have lower SpO_2 levels in the first 11 minutes of life and needed longer to reach a SpO_2 level of 90%. In that case, UA blood pH values may be used to predict the oxygen saturation level of the newborns immediately after birth. UA blood pH and blood gas analysis provide an objective method of assessing the immediate newborn condition and they have a strong and consistent association with neonatal mortality, morbidity, and long-term outcome.[21] Our results support that determination of UA blood pH values in addition to clinical findings and SpO_2 measurements might be helpful in deciding in which concentration to give oxygen and whether or not to continue oxygen supplementation in delivery room.

We hope to give guidance to further studies (in premature, resuscitated, and hypoxic newborns) for the evidence-based medicine to work more efficiently in the future with the approach of combining UA blood gas analysis and monitoring of SpO_2 with pulse oximeters during oxygen supplementation in the resuscitation of the neonates in the delivery room.

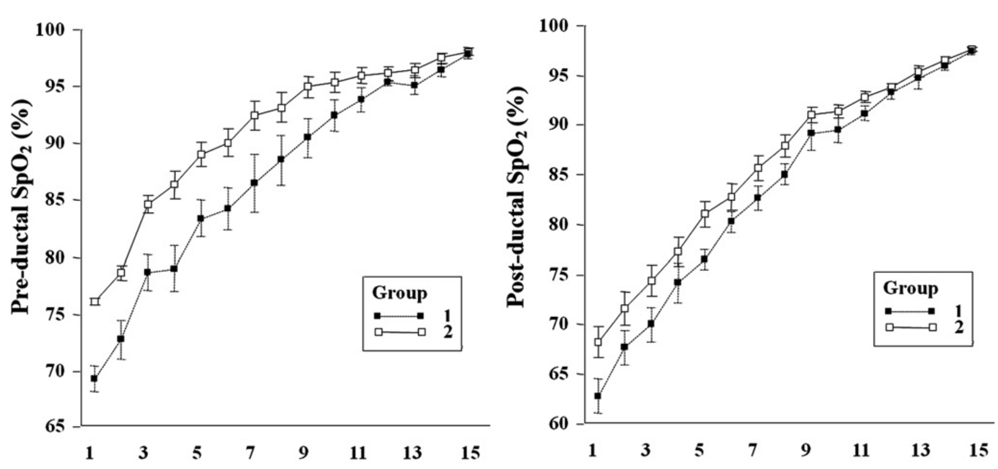

Figure 3 Preductal and postductal SpO_2 levels during the first 15 minutes after birth for both groups (means; 95% confidence interval for mean). In group 1, preductal and postductal SpO_2 levels were significantly lower than those of group 2 during the first 11 minutes of life ($p < 0.05$). (Group 1: umbilical arterial blood pH value $\leq$7.19, group 2: umbilical arterial blood pH value $>$7.19).

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