Clinical Investigation

Evaluation of oxygen saturation monitoring by pulse oximetry in neonates in the delivery system

Ivan Dimich MD, Prithi Pal Singh MD, Alvin Adell MD, Michele Hendler MD, Norman Sonnenklar MD, Mennakshi Jhaveri MD

The pulse oximeter was evaluated for use in neonates in the delivery room. One hundred neonates, delivered vaginally or by Caesarean section with general or epidural anaesthesia, were studied. After delivery, pulse oximetry probes were placed simultaneously on the ulnar side of the right hand and on the right Achilles tendon to determine whether there was a difference in arterial oxygenation (SpO_2). Measurements of SpO_2 were taken at 1, 5, 10 min, and 24 hr after delivery. At one and five minutes, SpO_2 recorded from the right hand was higher than that recorded from the lower extremities ($71.9\% \pm 6.5\%$ vs $63.4\% \pm 4.3\%$ and $83.3\% \pm 4.2\%$ vs $76\% \pm 4.1\%$, mean $\pm$ SD, respectively). At ten minutes these differences diminished, and had almost completely disappeared after 24 hr. These results can be explained by the presence of R-L shunting at the ductus arteriosus level, producing reduced SaO_2 in the lower extremities. Oxygen saturation did not differ between neonates delivered vaginally or by Caesarean section, regardless of the presence or type of anaesthesia. We concluded that neonates remain relatively desaturated in the immediate postpartum period and that the SpO_2 obtained from the right hand is a better index of neonatal oxygenation than that obtained from the heel.

Key words

ANAESTHESIA: obstetrical, neonates;
MEASUREMENT TECHNIQUES: oximeters;
MONITORING: oxygen;
OXYGEN: blood levels, measurement.

From the Department of Anesthesiology, Mount Sinai Medical School, New York, New York; and City Hospital Center at Elmhurst, Elmhurst, New York.

Address correspondence to: Dr. Ivan Dimich, Department of Anesthesiology, Box 1010, Mount Sinai Hospital, One Gustave L. Levy Place, New York, NY 10029-6574.

Accepted for publication 17th June, 1991.

Le saturomètre de pouls fut évalué chez des nouveaux-nés dans la salle d'accouchement. Cent nouveau-nés après accouchement vaginal ou césarienne avec une anesthésie générale ou épidurale, ont été étudiés. Après l'accouchement les sondes de saturomètre de pouls ont été simultanément placées sur le côté cubital de la main droite et à droite du tendon d'achille afin de déterminer s'il y a une différence dans l'oxygénation artérielle. Les mesures de la (SPO_2) furent prises à une, cinq, dix minutes et 24 heures après l'accouchement. A une et cinq minutes, la SPO_2 enregistrée dans la main droite a été supérieure à celle enregistrée dans les membres inférieurs ($71,9\% \pm 6,5\%$ vs $63,4\% \pm 4,3\%$ et $83,3\% \pm 4,2\%$ vs $76\% \pm 4,1\%$, moyenne $\pm$ SD respectivement). A dix minutes ces différences ont diminué et ont presque complètement disparu après 24 heures. Ces résultats pourraient être expliqués par la présence d'un shunt droit-gauche au niveau du canal artériel produisant une diminution de la saturation d'oxygène dans les membres inférieurs. La saturation d'oxygène n'était pas différente entre les nouveau-nés accouchés par voie vaginale ou par césarienne indépendamment de l'anesthésie utilisée. On conclut que le nouveau-né demeure relativement désaturé à la période immédiate après l'accouchement et que la SPO_2 obtenue de la main droite étant un meilleur indice de l'oxygénation néo-natale obtenue du talon.

Studies in neonatal intensive care units have demonstrated good correlation between values of arterial oxygenation observed by pulse oximetry (SpO_2) and arterial blood sampling (SaO_2).^{1,2} Harris *et al.*³ used the pulse oximeter in the delivery room to measure SpO_2 in neonates by applying a sensor over the Achilles tendon and found that the neonates remained relatively desaturated in the immediate postpartum period. It was concluded that careful monitoring of neonatal oxygenation in the delivery room,

even after normal delivery, may be warranted. However, it was reported by several investigators⁴⁻⁷ that, in the immediate postpartum period, R-L shunting of venous blood through the ductus arteriosus may persist, producing lower SaO₂ in the lower extremities than in the upper part of the body. Therefore, SaO₂ obtained from the Achilles tendon may not represent the "normal" values of SaO₂ in blood perfusing vital organs. The present study was designed to evaluate SaO₂ in neonates by simultaneously placing pulse oximeter sensors over the ulnar side of the right hand and over the right Achilles tendon. The purpose was to determine whether there was a significant difference in SpO₂ between these two locations, and if so, to advise which should be used in the delivery room to evaluate oxygenation.

Method

This study was approved by the Human Investigation Committee at the Mount Sinai Hospital. Written and informed consent was obtained from each mother prior to delivery.

One hundred neonates were studied; 63 had been delivered vaginally and 37 by Caesarean section. Three parturients received general anaesthesia and 54 epidural anaesthesia. All mothers received supplemental 100% oxygen by a non-rebreathing face mask before delivery or Caesarean section. After delivery, each neonate was placed in a radiant warmer and the right hand and foot were cleaned with a gauze sponge. An Ohmeda Biox 3700 pulse oximeter (Ohmeda, Boulder, CO) was used to measure SpO₂. The probes were placed simultaneously, by two investigators, around the ulnar side of the right hand and around the Achilles tendon of the right leg. The right hand was selected because of the proximity of the left subclavian artery to the ductus arteriosus. To limit interference from light, a towel was placed around the hand and the leg. Simultaneously, SpO₂ measurements were recorded at one, five and ten min and at 24 hr after delivery. The paediatricians provided postpartum care and assigned Apgar scores at one and five minutes. Treatment of neonates was according to hospital routine and resuscitation, when required, was performed by the paediatrician and anaesthetist. All data were reported as mean $\pm$ SD. A paired *t* test analysis was performed to determine differences that were deemed to be significant when *P* < 0.05.

Results

Initial values (Table I) were obtained within one minute in 75% of the neonates and within five minutes in 98%. The initial values for SpO₂ at one minute were not obtained in 25%, because of technical difficulties in obtaining simulta-

TABLE I SpO₂ in neonates after birth

Site	Time after birth			
	1 min	5 min	10 min	24 hr
R hand	71.9 $\pm$ 6.5*	83.3 $\pm$ 4.2*	90.7 $\pm$ 4.6	95.7 $\pm$ 2.2
R leg	63.4 $\pm$ 4.3*	76.6 $\pm$ 4.1*	87.1 $\pm$ 5.7	95.2 $\pm$ 2.3

**P* < 0.05 between sites.

Mean ($\pm$ SD).

neous oximetric readings from the arm and foot. One of the major problems was movement artefact. However, it was easier to obtain only one reading from the arm with a newly available probe for neonates (Flex II, Ohmeda Biox. 3700). The mean SpO₂ recorded on the right hand at one and five minutes was higher than the SpO₂ recorded from the lower extremities (*P* < 0.05). At ten minutes these differences diminished and almost completely disappeared after 24 hr. Apgar scores were all between 6 to 10 at one and five minutes. Twenty neonates, for whom Apgar scores for skin colour were assigned at one minute to be excellent, were found to have SpO₂ < 65% which was one standard deviation below the mean SpO₂ for right hand at one minute. Airway suctioning of several newborns immediately after delivery resulted in a reduction in SpO₂ which was reversed by increasing the inspired oxygen concentration. Seven neonates received supplemental oxygen by mask immediately after birth. This oxygenation did not affect the arm-foot saturation difference.

The SpO₂ did not differ between newborns delivered vaginally or by Caesarean section, regardless of anaesthesia used (Table II).

Discussion

In the first minutes of life, major physiological adjustments occur as the fetus becomes a neonate. During this period, the neonate is in a precarious position with regard to tissue oxygen delivery. The combination of persistent right to left shunt at the arterial level, bi-directional shunting through the ductus arteriosus, and ventilation-perfusion mismatching all provide for limited oxygen reserve. Early detection of hypoxia is, therefore, the most important aspect of neonate evaluation in the delivery room.

Previous studies that sought to define the "normal" SaO₂ during the first few minutes of extra-uterine life included only small numbers of neonates and used intermittent blood sampling techniques with only one or, at the most, two measurements obtained during this time interval.^{6,7}

TABLE II SpO₂ in neonates after Caesarean section

Site	Time after Caesarean section			
	1 min	5 min	10 min	24 hr
R hand	69 ± 7.1*	82.0 ± 3.1*	91.2 ± 3.2	96.1 ± 3.4
R leg	61 ± 5.3*	74.4 ± 5.2*	88.1 ± 4.1	95.6 ± 2.3

**P* < 0.05 between sites.
Mean (±SD).

Pulse oximetry is a simple and non-invasive method for the continuous evaluation of SpO₂. Its ability to respond rapidly to changes in SpO₂ makes it extremely useful in the evaluation of neonates in the delivery room. Harris *et al.*³ used pulse oximetry in the immediate postpartum period to evaluate continuous changes in the neonate's SaO₂. They reported a low value for SpO₂ at one minute of 61 ± 5%, followed by an increase to 82 ± 2% at seven minutes. However, values for SpO₂ were lower in neonates delivered by Caesarean section. They concluded that neonates remain relatively desaturated after birth and are at risk for not maintaining adequate oxygen delivery if cardiac output becomes compromised. They suggested careful monitoring of neonatal oxygenation in the delivery room, even after normal delivery. In their study, the pulse oximeter sensor was placed at the Achilles tendon. This location was chosen because of easy access and to be out of the way in case the neonate required resuscitation. It was also presumed that there was no difference in the SaO₂ between the upper and lower extremities.

Our data confirm earlier work,^{3,6} and show that neonates remain relatively desaturated in the immediate postpartum period, but the SaO₂ improves steadily toward normal values during the first 24 hr. In addition, we observed that, during the first ten minutes of life in 90% of neonates, the SpO₂ recorded over the right ulnar region was higher than that obtained at the Achilles tendon. These findings could be explained by the presence of the right-to-left shunting at the ductus arteriosus, producing lower SaO₂ in the legs due to streaming of the venous blood into the descending aorta.

A functionally open ductus and bilateral shunting in the early postpartum period have been reported by several investigators.⁵⁻⁷ Linde *et al.*⁵ demonstrated by an angiographic study in neonates the presence of bilateral shunting through the ductus arteriosus. Oliver *et al.*⁶ showed that in the immediate postpartum period, left atrial samples have a higher oxygen tension than arterial samples from the umbilical artery. Furthermore, Eldridge *et al.*⁷ found, in neonates, a higher oxygen saturation in arterialized capillary finger blood than in samples ob-

tained from the heel, indicating again R-L shunting at the ductus arteriosus.

Higher SaO₂ obtained from the right ulnar region in our study represents arterial oxygenation of preductal circulation. This is the same circulation which supplies the vital organs in the upper part of the body. Therefore, during resuscitation of neonates, SaO₂ obtained from the right hand will reflect oxygenation of the brain or heart more accurately than SaO₂ recorded at the lower extremities. Although R-L shunting through the ductus arteriosus was a transient phenomenon, prolonged shunting has been reported in premature infants as well as in newborns with persistent pulmonary hypertension or hypoxia.⁷ Only one newborn in our study demonstrated the presence of R-L shunting through the ductus after 24 hr. In this case, diagnosis of meconium aspiration and acute respiratory distress was made later.

Apgar scoring, although an excellent method for postpartum evaluation of neonates, uses skin colour to assess oxygenation rapidly. Our data, as well as those reported by Sendak and Harris,⁸ demonstrated that Apgar scores are potentially misleading as predictors of the degree of oxygenation. They reported that even at five minutes after birth, major discrepancies existed between Apgar scoring and SpO₂ values.⁸

In conclusion, pulse oximetry can provide continuous non-invasive information of oxygenation in neonates in the delivery room. To obtain SpO₂ which reflects oxygenation of the vital organs, pulse oximeters should be placed over the right ulnar region. Our data confirm that pulse oximetry may identify neonates at risk for hypoxia that might not otherwise be appreciated clinically. Therefore, pulse oximetry can be a useful objective addition to the evaluation of neonates at birth.

Acknowledgements

We acknowledge cooperation from New York City Health and Hospital Corporation and the City Hospital Center at Elmhurst, where this research was conducted.

References

- 1 Fail CD, Wetzel R, Dean J. Pulse oximetry in critically ill children. *J Clin Monit* 1985; 1: 232-5.
- 2 Yelderman N, New W. Evaluation of pulse oximetry. *Anesthesiology* 1983; 59: 349-52.
- 3 Harris A, Sandak M, Donhaus R. Changes in arterial oxygen saturation immediately after birth in the human neonates. *J Pediatr* 1986; 109: 177-9.
- 4 Dawes GS, Mila ED. The patency of the ductus arteriosus after birth. *J Physiol* 1953; 122: 37-8.
- 5 Linde J, Wegelius R. Human fetal circulation changes in the cardiovascular system at birth and disturbances in

the post-natal closure of the foramen ovale and ductus arteriosus. Cold Spring Harb Symp Quant Biol 1954; 19: 109–25.

- 6 *Oliver TK, Demis JA, Bates GD.* Serial blood gas tension and acid base balance during the first hour of life in human infants. Acta Paediatr Scand 1961; 50: 346–60.
- 7 *Eldridge FL, Hultgreen HN, Wigmore ML.* The physiologic closure of the ductus arteriosus in newborn infants. Science 1954; 119: 731–4.
- 8 *Sendak MJ, Harris AP, Donham RT.* The sensitivity of Apgar scores as an indicator of hypoxia. Anesthesiology 1989; 71: A899.