

Neonate capillary blood gas reference values

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Objectives

Because biological data are instrument-dependent and because technology has evolved over the last two decades, the published capillary blood reference values for blood gases, lactate, ionized calcium (iCa) and glucose may not reflect the present day situation. Hence, we report such values for healthy term neonates at 48 ± 12 h of life.

Design and methods

The Institution Ethics Review Board for Research on Human Subjects has accepted the protocol. Extra blood sample was obtained at the time heel-pricks were performed in the frame of the Quebec genetic screening program. One hundred twenty-six term neonates (39.6 ± 1.2 weeks of gestation) were included in the study.

pH, pO_2 , pCO_2 , lactate, ionized calcium and glucose were simultaneously measured with selective electrodes on a blood gas analyzer.

Results

All variables exhibited a Gaussian distribution. Since there was no gender effect, all data were pooled.

Even though present in reference textbooks published 10 years ago, normative data for a number of chemistries listed in clinical biochemistry and neonatology textbooks have often been derived more than 20 years ago [1–4].

Because the rapid evolution of technology over the past two decades has led to more refined and stable instruments and because data are instrument-dependent, the published values may not reflect the present day situation.

Furthermore, close examination of the methodology reveals that, in many instances, timing of blood sampling, post-natal age and neonates' characteristics were not closely monitored.

It is known that the perinatal period is critical in terms of changes in cardiorespiratory status since the newborn infant must adapt from mother-dependent situation to an autonomous state [5, 6]. In doing so, it may induce rapid shifts in blood biochemical variables.

Such an adaptation phenomenon has also been exemplified for the thyroid axis as well as for vitamins A, E and D [7–10]. Heel-prick sampling is customary in the neonatal ward because of the limited sample volume.

Hence, most vital biochemical variables reported are likely to be those of capillary blood. The aim of this study is to report capillary blood reference values for blood gases, lactate, ionized calcium (iCa) and glucose for well-defined healthy term neonates.

Materials and methods

The Institution Ethics Review Board for Research on Human Subjects has approved the protocol. One extra blood sample was obtained at the time heel-pricks were performed in the frame of the Quebec genetic screening program. One hundred twenty-six term neonates (64 males, 62 females) were included in the study. Their gestational age was 39.6 ± 1.2 weeks and birth weight was 3426 ± 406 g (Mean \pm 1 SD).

All were the products of normal pregnancies and were delivered normally and all breathed without assistance. All had APGAR scores ≥ 7 at 5 and 10 min. All were healthy on physical examination.

Exclusion criteria included: hyperbilirubinemia requiring phototherapy before 48 h of age, admission to the

NICU or intermediate care unit, parents understanding neither French nor English or absence of informed consent form signed by the parents.

After having warmed the heel, free-flowing capillary blood samples were collected at 48 ± 12 of life in 125 mL plastic capillary tubes coated with balanced Li-Heparin as anticoagulant, kept on ice and analyzed within 1/2 h after sampling.

pH, pO_2 , pCO_2 , lactate, ionized calcium and glucose were simultaneously measured with selective electrodes on a blood gas analyzer. Results were obtained between 118 and 122 samples of the 126 samples, depending on volumes, sample loss or clotting. Data are expressed as mean \pm standard deviation (SD). Descriptive statistics and regression analysis were performed.

Results

The analytical imprecision (CV) for each of the variables measured was either equal to or better than those recommended by Brouillette and Waxman [11] and Ehrmeyer et al. citing the CLIA [12]. The CVs were $<0.06\%$, $<2\%$, $<5\%$, $<1.3\%$ and $<2\%$ for pH, pCO_2 , pO_2 , hemoglobin and ionized calcium, respectively. Those for lactate and glucose were concentration-dependent and varied with an inter-assay between 2.1% and 3.5% for the first and 2.5% and 1.5% for the second. The values of capillary blood gas variables are presented in Table 1. All variables exhibited a Gaussian distribution. Since there was no gender effect, all data were pooled.

Variables	N	Mean	1 SD	2.5 % ile	97.5 % ile
pH	119	7.395	0.037	7.312	7.473
pCO_2 (mm Hg)	119	38.7	5.1	28.5	48.7
pO_2 (mm Hg)	119	45.3	7.5	32.8	61.2
Lactate (mmol/L)	114	2.6	0.7	1.4	4.1
Hb (G/L)	122	193	23	145	234
Glucose (mmol/L)	122	3.8	0.8	2.1	5.3
iCa (mmol/L)	118	1.21	0.07	1.06	1.34

Table 1: Pediatric references for blood capillary pH, pCO_2 , pO_2 , hemoglobin, lactate, glucose and ionized calcium

N: number of samples analyzed

Table revised by the author for publication on bloodgas.org

Discussion

Adequate reference values are important for the proper appraisal of the clinical status of neonates during their adaptation to the extra uterine life. It is well known that the first few days of post-natal life witness major physiological and developmental changes, some of which may have an impact on blood biochemistry variables [13–16]. Hence, when determining reference values in neonates, knowledge of their health status and sampling conditions including timing is crucial. The short hospital stay of the newborn baby, more or less 2 days, mandates that clinicians use appropriate reference values for that period.

We report reference values for 118 to 122 healthy term newborn babies between 36 and 60 h of age. Literature on capillary blood biochemical parameters in normal neonates being limited, comparison with other studies is difficult. Most of the available studies reporting on blood gases are either done on infants in pediatric or neonatal intensive care units [17–20].

Relevant to the group of infants included in the present study, Brouillette and Waxman [11] have published review on blood gas measurements and complementary non-invasive monitoring techniques in normal term neonates from birth until 120 min of life. However, the arterial pH, $p\text{CO}_2$, $p\text{O}_2$ and lactate values reported in the form of figures, stemmed from textbook published in 1976 [21]. In terms of pH and $p\text{CO}_2$, our data are close to those of Dollberg et al. [22], despite the fact that they reported values for term healthy neonates much closer to birth (2 to 4 h of life).

The mean capillary lactate concentration observed in this study differs only by 0.1 mmol/L from those of Fauchère et al. [23] and Frey and Losa [24]. These authors have also shown that capillary blood lactate measurements in newborn babies correlated with arterial measurements over a large concentration range in both term and preterm infants. However, the blood lactate concentration is markedly lower than that reported by Dollberg et al. [22] whose mean lactate concentration was 3.9 mmol/L with normal range of 1.6 to 9.8 mmol/L.

As noted above, their samples were obtained at 2 to 4 h post-partum. On the contrary, the mean whole blood lactate concentration observed in this study (2.6 mmol/L) is higher than that observed by Nielsen et al. [25] (1.24 mmol/L). In this case, methodological and blood sample timing differences could explain the discordance. Indeed, they measured lactate by HPLC after protein precipitation at 4 days of life.

Measurement of iCa has benefited from major technical refinements and is now reliable. In the present study, the mean iCa (1.21 mmol/L) is lower than that reported by Loughhead et al. [26]. This difference is explained by the fact that, in our study, blood was obtained at 48 ± 12 h of life when calcium levels are near the nadir [27]. Whether reliable blood glucose concentration reference values in neonates are warranted is matter of discussion, as it is influenced by the timing of blood collection after the last feeding and by the type and source of milk (colostrum or formula).

Two studies report on capillary blood glucose concentrations in term neonates [22, 28]. In the first, as mentioned previously, data had been obtained at 2 to 4 h of life and presents values with a range from 5.1 to 16.1 mmol/L with a mean close to ours. The second reports the values as figures. Hence, it is difficult to draw a meaningful comparison with our data.

In conclusion, we present capillary blood gases, lactate, iCa and glucose reference values in a healthy well-defined group of newborn infants that are likely to be useful for clinical decision making.

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