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Base deficit estimation in umbilical cord blood is influenced by gestational age, choice of fetal fluid compartment, and algorithm for calculation

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Objective: The purpose of this study was to explore the influences of gestational age, the choice of fetal fluid compartment, and the algorithm for calculation on the estimation of the base deficit in umbilical cord arterial blood at birth.

Study design: From 1995 to 2002, cord arterial blood gases and obstetric data were available for 43,551 newborn infants at 37+ weeks of gestation (cohort I). The mean base deficit in blood and the base deficit in extracellular fluid were estimated from pH and P_{CO_2} values in 28,213 newborn infants with a 5-minute Apgar score of ≥ 9 (cohort II) with the use of 3 different calculation algorithms (base deficit in blood, base deficit in extracellular fluid [A], and base deficit in extracellular fluid [B]).

Results: In cohort II, the base deficit in blood, the base deficit in extracellular fluid (A), and the base deficit in extracellular fluid (B) increased with advancing gestational age (linear regression; $P < .0001$). The curves run almost parallel, with the base deficit in blood being higher than the base deficit in extracellular fluid (A) and (B). With the use of receiver operating characteristic curves in cohort I, the area under curve to indicate a 5-minute Apgar score of <7 and <4 showed the area under curve–pH to be greater than the area under curve–base deficit in extracellular fluid (A) and (B), the area under curve–base deficit in blood to be greater than the area under curve–base deficit in extracellular fluid (A) and (B) for a 5-minute Apgar score of <7, and the area under curve–base deficit in blood to be greater than the area under curve–base deficit in extracellular fluid (A) and (B) for an Apgar score of <4. The cutoffs with highest sensitivity and lowest false-positive rate for a 5-minute Apgar score of <7 and <4 were, for both scores, a pH value of 7.15, a base deficit in blood of 10 mmol/L, a base deficit in extracellular fluid (A) of 8 mmol/L, and a base deficit in extracellular fluid (B) of 6 mmol/L.

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† The Perinatal Revision South Register comprises data from Obstetric and Neonatal units at the University Hospitals in Lund and Malmö, the Central Hospitals in Halmstad, Helsingborg, Karlskrona, Kristianstad and Växjö, and the County Hospitals in Ljungby and Ystad.

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Conclusion: The calculated values of the base deficit in umbilical cord arterial blood are influenced decisively by gestational age, the choice of fetal fluid compartment, and the calculation algorithms that are used. The power of the base deficit to indicate neonatal distress depends on the choices of fluid compartment and the algorithm that is used to calculate the base deficit.

Sustained fetal hypoxia and the development of metabolic acidosis implies an increased risk of manifest motor and cognitive defects.[1,2] Umbilical cord blood gases at birth therefore are used comparatively to quantify the degree of acidosis and retrospectively to estimate the extent of fetal exposure and response to hypoxia. Determinations of cord arterial blood pH and base deficit (BD) are key elements. However, both pH and BD measurements are liable to considerable methodologic confounding, which may influence the settlement of an acidosis diagnosis.

pH and BD and other cord blood gases change with progression of pregnancy. pH, bicarbonate and Po_2 decrease, and Pco_2 and BD increase.[3-8] The traditionally used stationary cutoffs for defining abnormal values may then result in false-positive or -negative diagnoses.[7] Moreover, blood gas analyzers measure pH and Pco_2 by electrodes, whereas BD is calculated from algorithms that are based on these parameters. Different brands of blood gas analyzers use different calculation algorithms, which may result in different BD values. Finally, calculation of the BD in blood (BD_{blood}) and extracellular fluid (BD_{ecf}) may result in different values.

The aim of the present study was to explore the influence on cord arterial BD calculations from 3 different methodologic confounders: the physiologic increment of BD with advancing gestational age,[8] the choice of fetal fluid compartment, and the difference between algorithms to calculate BD. In addition, the power of different BD calculations and of pH to indicate neonatal distress was estimated.

Material and methods

Data about pregnancy course, delivery, and the neonatal period were collected from the Perinatal Revision South Register (PRSR) database between 1995 and 2002. The PRSR comprises all 9 delivery units in the southern Swedish region, with a population of 1.6 million and approximately 17,000 annual deliveries. The main purpose of the PRSR is quality assurance of perinatal care.[9] Registry-based scientific research, without identification of individual cases, and rules for publication have been approved by the Research Ethics Committee at the Lund University Medical Faculty and by the South Swedish Regional Board of Chairmen, which represent the involved delivery units.

Inclusion criteria were appropriate information in the database about obstetric and neonatal courses, umbilical cord arterial pH and Pco_2 (only arterial blood gases are reported to the PRSR), year of birth, delivery unit, maternal age and parity, and singleton pregnancy $\geq 37 + 0$ completed weeks + days (confirmed by an early second-trimester ultrasound fetometry) aimed for vaginal delivery. Two cohorts were compiled from the PRSR: Cohort I comprised all 43,551 newborn infants who fulfilled the inclusion criteria, and cohort II 28,213 comprised newborn infants with a 5-minute Apgar score of ≥ 9. Cohort I data were retrieved from all 9 hospitals, but cohort II data were retrieved only from the 2 university clinics, because the Malmö and Lund university clinics perform cord blood gases determinations routinely. The other 7 hospitals perform these determinations only on indication. Cohort I thus contained cohort II.

Immediately after delivery and before spontaneous breathing, umbilical cord arterial blood was sampled in preheparinized syringes and analyzed within 5 minutes in automatic blood gas analyzers (ABL 520; Radiometer, Copenhagen, Denmark). The analyzers work by measuring pH and Pco_2 at a temperature of 37°C, whereas the concentrations of bicarbonate (HCO_3^-), BD_{blood}, and BD_{ecf} are calculated from equations and algorithms. From the determinations of pH and Pco_2, the following parameters were calculated post hoc:

Bicarbonate (HCO_3^-) in plasma according to the algorithm given in the Radiometer ABL 520 manual[10]: $HCO_3^- = 0.23 \times Pco_2 \times 10^{(pH - 6.1)}$.

BD_{blood} according to the algorithm given in the Radiometer ABL 520 manual[10]: $BD_{blood} = 0.5 \times (8 \times [0.00404 + 0.000425 \times 9.3087] - 0.919)/(0.00404 + 0.000425 \times 9.3087) + 0.5 \times (0.919 - 8 \times [0.00404 + 0.000425 \times 9.3087])/(0.00404 + 0.000425 \times 9.3087)^2 - 4 \times (24.47 - cHCO_3^-[5.33])/(0.00404 + 0.000425 \times 9.3087)^{1/2}$, where 9.3087 represents the calculated total hemoglobin concentration (in millimoles per liter), which corresponded to a value of 150 g/L.

BD_{ecf}^A according to the algorithm given in the Radiometer ABL 520 manual[10]: $BD_{ecf} = BD_{blood}$ at a ctHb = 3 mmol/L, where ctHb represents the calculated concentration of total hemoglobin in blood (deoxy-, oxy-, carboxy-, met-, and sulfhemoglobin).

BD_{ecf}^B according to the algorithm derived from the Siggaard-Andersen Acid Base Chart[11]: $BD_{ecf} = -0.9149 (0.23 \times Pco_2 \times 10^{[pH - 6.1]} - 24.1 + 16.21 \times [pH - 7.4])$.