Original Research Article

Maternal arterial blood gas values during delivery: Effect of mode of delivery, maternal characteristics, obstetric interventions and correlation to fetal umbilical cord blood

Mehreen Zaigham1 | Sara Helfer1 | Karl Heby Kristensen1 | Per-Erik Isberg2 | Nana Wiberg1,3

1Department of Obstetrics and Gynecology, Institution of Clinical Sciences Malmö, Lund University, Lund, Sweden
2Department of Statistics, Lund University, Lund, Sweden
3Department of Gynecology and Obstetrics, Skåne University Hospital, Ystad, Sweden

Correspondence
Mehreen Zaigham, Department of Obstetrics and Gynecology, Institution of Clinical Sciences Malmö, Lund University, Malmö 205 01, Sweden.
Email: mehreen.zaigham@med.lu.se

Funding information
Lund University

Abstract

Introduction: Obstetricians routinely use biochemical parameters from non-pregnant women to assess the condition of the laboring mother. However, it is well known that pregnancy leads to significant physiological changes in most organ systems. The aim of this study was to determine normal values for maternal arterial blood gases during vaginal deliveries as compared with control values from planned cesarean sections. We also wanted to elucidate the effect of various maternal characteristics, mode of delivery and obstetric interventions on blood gas values.

Material and methods: We carried out a randomly selected, prospective-observational cohort study of 250 women undergoing vaginal delivery and 58 women undergoing planned cesarean section at the Department of Obstetrics and Gynecology, Skåne University Hospital, Malmö, Sweden.

Results: We found significant differences for gestational age, parity, umbilical venous blood pH, pCO2 and lactate values between the two study groups (P < .005). Significantly lower pH, pCO2, PO2 and SO2 were found in mothers delivering vaginally. Higher base deficit, hemoglobin, bilirubin, potassium, glucose and lactate were found in vaginal deliveries than in planned cesarean sections (P < .02). Maternal body mass index (BMI), smoking and hypertension were not significantly correlated to acid base parameters in women with vaginal deliveries. On the other hand, multiple regression showed significant associations for the use of epidural anesthesia on maternal pH (P < .05) and PO2 (P < .01); and synthetic oxytocin on pCO2 (P = .08), glucose (P < .00) and lactate (P < .02) levels in maternal arterial blood. Maternal arterial pH, pCO2 and lactate values correlated significantly to values in venous umbilical cord blood (P < .000).

Conclusions: Maternal arterial blood gas parameters varied significantly according to mode of delivery, the use of epidural anesthesia and synthetic oxytocin.
1 | INTRODUCTION

It is well known that there are significant changes in almost all maternal organ systems during pregnancy and that these physiological changes enable the mother optimally to nourish the fetus as well as prepare her for labor. Klajnbard and Maguire showed large variations in most maternal venous parameters during the three trimesters of pregnancy. Despite this knowledge, obstetricians routinely use reference values from non-pregnant women to assess the condition of the pregnant patient. Few studies have focused on physiological variations during pregnancy and delivery, and arterial blood gases including electrolytes, bilirubin, glucose and lactate have seldom been studied. In addition, the possible impact of different maternal and obstetric factors commonly encountered during delivery, has not been studied. With Labor and Delivery Units throughout the world catering to women possibly infected by the Novel Corona Virus, obstetricians need to be aware of any differences in arterial blood gas parameters for mothers at risk. Establishing normal blood gas values for healthy women under labor is therefore imperative.

One of the most frequently encountered maternal risk factors during pregnancy and delivery is obesity. Maternal obesity is associated with increased fat deposition, lower body muscle mass, decreased respiratory capacity and chronic inflammatory changes, with an increased risk for prolonged labor and adverse maternal-neonatal outcome. Smoking during pregnancy is another potentially detrimental risk factor which can affect maternal acid base balance via vasoconstrictive effects on blood vessels and it is well recognized that maternal smoking is associated with hypertension and decreased lung capacity.

Among obstetric factors, synthetic oxytocin used to augment labor, has powerful effects on uterine contractions and maternal physiology. Similarly, the use of spinal/epidural anesthesia (EDA) to provide intrapartum analgesia can result in decreased peripheral vascular resistance, which in turn causes alterations to uteroplacental blood flow with impaired oxygenation. EDA is well known to prolong labor and increase the risk for adverse maternal outcome and obstetric intervention.

Thus, the main aim of this study was to investigate physiological variations in maternal arterial blood gases during vaginal delivery (VD) compared with a control group of women who were delivered by planned cesarean section (CS). We also wanted to determine normal values for maternal arterial blood values during VD and study the effect of various maternal characteristics and obstetric interventions on maternal acid base values. Correlations between maternal acid base values and fetal umbilical cord venous blood were also explored.

2 | MATERIAL AND METHODS

2.1 | Study design

The study was carried out at the Department of Obstetrics and Gynecology, Skåne University Hospital, Sweden. Swedish-speaking women, admitted for vaginal labor or planned cesarean section, were randomly informed about the study. The original study consisted of two parts: determination of maternal blood gas values at delivery and determination of reference values for fetal scalp blood lactate. Women could choose to participate in one or both arms of the study or decline participation. The participating women were enrolled as followed: women intended for vaginal delivery (February 2010 to September 2011) and patients undergoing planned cesarean section (October 2006 to January 2007 and December 2009 to July 2011). It was established from a previously published paper on reference values for lactate in fetal scalp blood that the maternal and fetal characteristics of the vaginal delivery group were similar to the background population, except for proportions of primipara, diabetes/gestational diabetes and 39 gestational weeks.

Inclusion criteria for women intended for VD were: active labor with a cervix dilation of 5-6 cm, singleton pregnancy as dated by an early second trimester ultrasound, cephalic presentation and non-pathological cardiotocography at admission. For women in the cesarean section arm, we included singleton pregnancies where the mother was planned for a CS due to reasons other than fetal distress. No emergency CS were included, since the aim of the study was elucidate physiological variations in maternal biochemical parameters in the absence of labor contractions. We only included women with vaginal delivery in our calculations of normal maternal arterial blood gas values and while studying the impact of various obstetrical interventions during labor.

Immediately after delivery of the baby, before the first cry, a blood gas sample was obtained from the mother’s right radial artery by a specialist obstetrician (N.W.). Simultaneously, a midwife/junior nurse collected blood from the umbilical cord artery and
vein using 2 mL pre-heparinized syringes (Product name: the safe PICO arterial blood gas syringe by Radiometer) as per routine at the department. In the planned CS group, a maternal arterial blood gas sample was collected by the anesthesiologist on call at the exact time point when the fetus was delivered with simultaneous sampling from the umbilical cord by N.W. All blood samples were analyzed within 10 minutes after delivery to ensure optimal analysis quality.

For both groups, neonatal and obstetric data of significance were entered into the study database directly after the delivery of the infant while the mother was still admitted to the department.

### 2.2 Research methods

Maternal and fetal umbilical cord blood were analyzed using the blood gas analyzer ABL 800 Flex (Radiometer, Copenhagen, Denmark). In Lund, the blood gas analyzer was programmed automatically to calculate base deficit in extracellular fluid (BD_{ecf}), whereas in Malmö, the ABL was set to calculate base deficit (BD) in whole blood. Since the latter is known to introduce a serious confounding factor, we standardized all BD values to BD_{ecf} post hoc using the algorithms in the ABL 800 manual.

#### 2.3 Statistical analyses

Fisher’s exact test was used for comparison of categorical variables. Group comparison of continuous variables was performed using the Kruskal-Wallis test or the Mann-Whitney U test, when appropriate. Values were reported as mean with standard deviation (SD) and median with 2.5th and 97.5th percentile values. Association between variables was reported using regression analysis and, when appropriate, multiple regression analysis. Significance of correlation between two variables was calculated by Spearman’s test. A two-sided P value <.05 was considered significant. Analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (SPSS Inc.).

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### TABLE 1 Maternal and fetal characteristics of the two study groups

|                          | Vaginal delivery | Planned cesarean section | P value |
|--------------------------|------------------|--------------------------|---------|
| | n = 250             | n = 58           |                      |
| Mean ± SD (Median, 97.5th percentile) |                   |                     |
| Maternal BMI             | 24.1 ± 4.4 (23.2 (18.6, 33.4)) | 24.9 ± 4.9 (23.4 (17.6, 39.5)) | .36<sup>a</sup> |
| Gestational age (days)   | 278 ± 9.6 (279 (255, 295)) | 270 ± 4.5 (270 (258, 282)) | <.00<sup>a</sup> |
| Infant weight (g)        | 3599 ± 504 (3558 (2619, 4685)) | 3587 ± 554 (3535 (2578, 5019)) | .78<sup>a</sup> |
| Infant venous pH         | 7.33 ± 0.08 (7.34 (7.13, 7.45)) | 7.36 ± 0.04 (7.37 (7.23, 7.45)) | <.00<sup>a</sup> |
| Infant venous pCO<sub>2</sub> (kPA) | 5.36 ± 1.2 (5.21 (3.29, 7.55)) | 5.92 ± 0.82 (5.82 (4.45, 7.53)) | <.00<sup>a</sup> |
| Infant venous lactate (mmol/L) | 4.7 ± 1.9 (4.4 (2.1-9.7)) | 1.7 ± 0.5 (1.5 (1.1-3.8)) | <.00<sup>a</sup> |
| Primipara                | 150 (60)         | 23 (39.7)               | .01<sup>b</sup> |
| Hypertension/ preeclampsia | 14 (6)          | 5 (9)                   | .32<sup>b</sup> |
| Diabetes                 | 9 (4)            | 2 (3)                   | NA       |
| Smoking                  |                  |                         |          |
| None                     | 200 (80)         | 48 (82.8)               | .43<sup>b</sup> |
| <10 cigarettes daily     | 14 (5.6)         | 5 (8.6)                 |          |
| >10 cigarettes daily     | 2 (0.8)          | 1 (1.7)                 |          |
| 5-minute AS ≤7           | 4 (1.6)          | 1 (1.7)                 | NA       |

Abbreviations: AS, Apgar Score; BMI, body mass index; NA, not available.

<sup>a</sup>Mann-Whitney U Test.

<sup>b</sup>Fisher’s exact test.
|                        | pH     | P value | pCO₂  | P value | pO₂  | P value | ctHb (g/L) | P value | glucose | P value | lactate | P value |
|------------------------|--------|---------|-------|---------|-------|---------|------------|---------|---------|---------|---------|---------|
| **BMI**                |        |         |       |         |       |         |            |         |         |         |         |         |
| <18.5 n = 9            | 7.43 (0.05) | .41     | 3.31 (0.48) | .30     | 16.06 (8.85) | .15     | 141 (9)   | .12     | 7.1 (2)  | .47     | 4.4 (2)  | .22     |
| 18.5-24.9 n = 128      | 7.42 (0.06) | .41     | 3.36 (2.38) | .29     | 15.63 (2.43) | .30     | 135 (11)  | .12     | 7.2 (1.3) | .47     | 5.0 (1.6) | .22     |
| 25-29.9 n = 41         | 7.41 (0.06) | .41     | 3.36 (2.22) | .31     | 15.61 (11.31) | .15     | 137 (115) | .12     | 7.1 (5.10) | .47     | 4.8 (2.3) | .22     |
| >30 n = 19             | 7.40 (0.04) | .41     | 3.38 (2.79) | .31     | 14.71 (12.30) | .15     | 131 (118) | .12     | 7.0 (6.0)  | .47     | 4.1 (3.2)  | .22     |
| **Smoking**            |        |         |       |         |       |         |            |         |         |         |         |         |
| No n = 173             | 7.41 (0.06) | .40     | 3.37 (2.18) | .31     | 15.60 (11.20) | .95     | 135 (115) | .93     | 7.26 (1.3) | .731    | 4.9 (1.6)  | .42     |
| Yes n = 14             | 7.40 (0.05) | .40     | 3.36 (2.64) | .31     | 15.60 (11.60) | .95     | 134 (118) | .93     | 7.1 (5.1)  | .731    | 4.7 (2.1)  | .84     |
| **Hypertension/ Preeclampsia** |        |         |       |         |       |         |            |         |         |         |         |         |
| No n = 187             | 7.41 (0.06) | .72     | 3.35 (2.19) | .42     | 15.53 (2.29) | .07     | 136 (111) | .06     | 7.2 (1.3)  | .729    | 5.0 (1.7)  | .10     |
| Yes n = 9              | 7.40 (0.04) | .72     | 3.51 (2.68) | .42     | 14.17 (1.09) | .07     | 130 (7)   | .06     | 7.1 (5.1)  | .729    | 4.9 (1.2)  | .10     |
| **EDA**                |        |         |       |         |       |         |            |         |         |         |         |         |
| No n = 159             | 7.41 (0.06) | .05     | 3.34 (2.18) | .07     | 15.72 (2.00) | .01     | 136 (11)  | .41     | 7.2 (1.3)  | .977    | 5.0 (1.7)  | .36     |
| Yes n = 55             | 7.42 (0.05) | .05     | 3.39 (1.99) | .07     | 14.90 (2.52) | .01     | 135 (111) | .41     | 7.1 (5.1)  | .977    | 4.8 (2.18) | .36     |
| **NO₂**                |        |         |       |         |       |         |            |         |         |         |         |         |
| No n = 27              | 7.42 (0.07) | .29     | 3.31 (2.27) | .38     | 16.53 (3.01) | .06     | 133 (13)  | .50     | 7.3 (1.3)  | .836    | 4.9 (1.6)  | .97     |
| Yes n = 177            | 7.41 (0.06) | .29     | 3.35 (2.18) | .38     | 15.42 (1.95) | .06     | 136 (111) | .50     | 7.1 (5.1)  | .836    | 4.3 (2.6)  | .97     |
| **Oxytocin**           |        |         |       |         |       |         |            |         |         |         |         |         |
| No n = 99              | 7.42 (0.05) | .24     | 3.39 (0.50) | .08     | 15.86 (2.17) | .07     | 136 (12)  | .41     | 6.8 (1.2)  | .000    | 4.6 (1.5)  | .02     |
| Yes n = 115            | 7.41 (0.06) | .24     | 3.30 (0.51) | .08     | 15.20 (2.11) | .07     | 135 (10)  | .41     | 6.8 (1.2)  | .000    | 4.6 (1.5)  | .02     |

"n" is the number of valid cases per parameter. For two-group comparison, Mann-Whitney U test was used and for multiple group comparison, Kruskal-Wallis test.

Abbreviations: ctHb, total concentration of hemoglobin; EDA, epidural anesthesia; NO₂, nitrous dioxide; pCO₂, partial pressure of carbon dioxide; pO₂, partial pressure of carbon dioxide.
4 Ethical approval

The study was approved by the Central Ethical Board, Stockholm (Dnr: Ö50-2005; Date of approval 1 February 2006.

3 RESULTS

A total of 309 women agreed to participate in the study. In the group with planned VD, one case was excluded due to emergency CS performed under general anesthesia, leaving 250 cases for final analysis in the VD group and 58 cases in the planned CS group.

The maternal and fetal characteristics are reported in Table 1. Significant differences were seen in the frequency of nulli- vs primipara (P < .005), gestational age (P < .000) and for values in umbilical cord venous blood (P < .008). Although the differences in cord venous pH and pCO₂ were significant, the most remarkable difference was seen for lactate (P < .000).

Table 2 illustrates the influence of maternal characteristics and obstetrical interventions on acid-base parameters. For biochemical parameters not shown in Table 2, the use of nitrous oxide gas (N₂O) was found significantly to affect potassium ion concentration (K⁺) (3.8 vs 4.0 mmol/L, P < .000) and bilirubin levels (12.2 vs 18.4 µmol/L, P < .012). Similarly, the use of oxytocin had a significant impact on sodium concentrations (Na⁺) (134.6 vs 135.9 mmol/L, P < .000) and oxygen saturation (98.1% vs 98.4%, P < .01). Multiple regression analysis with all measured values in arterial blood as dependent variables and augmentation with oxytocin, epidural anesthesia, N₂O only to K⁺, and maternal age only to Na⁺ and lactate.

Normal maternal acid base values according to mode of delivery are given in Table 3. Not surprisingly, significant differences were observed in most biochemical parameters between the groups.

| Vaginal delivery (n = 250) | Planned cesarean section (n = 58) | P value |
|---------------------------|----------------------------------|---------|
| **Mean ± SD**              | **Mean ± SD**                    |         |
| **Median (2.5th, 97.5th percentile)** | **Median (2.5th, 97.5th percentile)** |         |
| **pH**                    | 7.41 ± 0.06                      | 7.44 ± 0.05 | <.00 |
|                           | 7.41 (7.32, 7.54)                | 7.44 (7.31, 7.57) |         |
| **pCO₂ (kPa)**            | 3.3 ± 0.5                        | 4.2 ± 0.6 | <.00 |
|                           | 3.4 (2.2, 4.2)                   | 4.3 (2.8, 6) |         |
| **pO₂ (kPa)**             | 15.7 ± 4                         | 20.7 ± 7.4 | <.00 |
|                           | 15.6 (11.5, 21.3)                | 19.2 (14.4, 33.7) |         |
| **sO₂ (%)**               | 98.2 ± 1.1                       | 99.1 ± 0.5 | <.00 |
|                           | 98.4 (96.2, 99.4)                | 99.1 (96.2, 99.4) |         |
| **BD (mmol/L)**           | 7.2 ± 2.9                        | 2.2 ± 1.4 | <.00 |
|                           | 7 (3 −13.4)                     | 2.1 (−1.1, −5.3) |         |
| **ctHb (g/L)**            | 136 ± 10                         | 113 ± 19 | <.00 |
|                           | 137 (117, 156)                  | 110 (81, 182) |         |
| **Hctc**                  | 0.42 ± 0.03                      | 0.35 ± 0.06 | <.00 |
|                           | 0.42 (0.36, 0.48)                | 0.34 (0.25-0.56) |         |
| **FHbF (%)**              | 6.4 ± 6.3                        | 7.2 ± 5.3 | .18 |
|                           | 5 (0, 28.4)                     | 5.5 (0, 18.9) |         |
| **ctBil (µmol/l)**        | 13 ± 8                           | 10 ± 7 | <.00 |
|                           | 12 (0, 35)                      | 9 (0, 34) |         |
| **Na⁺ (mmol/L)**          | 135 ± 2.6                        | 136 ± 1.1 | .07 |
|                           | 135 (130, 140)                  | 136 (134, 139) |         |
| **K⁺ (mmol/L)**           | 3.9 ± 0.3                        | 3.7 ± 0.2 | <.00 |
|                           | 3.8 (3.3, 4.5)                  | 3.7 (3.2, 4.2) |         |
| **Glucose (mmol/L)**      | 7.2 ± 1.3                        | 4.6 ± 0.6 | <.00 |
|                           | 7.1 (5.1, 10.4)                 | 4.5 (3.6, 6.4) |         |
| **Lactate (mmol/L)**      | 4.9 ± 1.6                        | 1.2 ± 0.3 | <.00 |
|                           | 4.7 (2.2, 8.7)                  | 1.1 (0.7, 1.9) |         |

Abbreviations: BE, base deficit; ctBil, total concentration of bilirubin; ctHb, total concentration of hemoglobin; Hctc, hematocrit; pCO₂, partial pressure of carbon dioxide; pO₂, partial pressure of carbon dioxide; sO₂, oxygen saturation.

Table 3 Normal values for maternal arterial blood gases according to mode of delivery. Blood collected from radial artery and analyzed by ABL800™ (Radiometer, Copenhagen, Denmark). Mann-Whitney U test used for two-group comparison.
Significantly lower pH, pCO$_2$, pO$_2$ and sO$_2$ were found in mothers giving birth vaginally as compared with planned CS. On the other hand, BD, total hemoglobin concentration (ctHb), hematocrit (Hctc), total concentration of bilirubin (ctBil), potassium ion concentration (K$^+$), glucose and lactate were significantly higher with VD than with planned CS.

Based on the findings from Table 2 and the multiple regression analysis, blood gas values were calculated after exclusion of women with EDA or augmentation with oxytocin (Table 4). Compared with the whole cohort, only pO$_2$, Na$^+$ and glucose showed small but significant differences.

Maternal arterial pH, pCO$_2$ and lactate values correlated significantly to values in venous umbilical cord blood ($P < .00$) (Table not shown), with the correlation coefficient ($R^2$) values as follows: pH $R^2 = .22$, pCO$_2$ $R^2 = .07$ and lactate $R^2 = .38$. Although significant, the total duration of active "pushing" during the second stage of labor correlated poorly to both maternal and fetal lactate concentration ($R^2 = .06$, $P < .00$). In addition, we found no significant correlation between placental weight and fetal lactate concentration ($R^2 = .01$, $P = .43$).

### DISCUSSION

To the best of our knowledge, this is the first study to present normal values in maternal arterial blood according to mode of delivery. Although data collection and analysis were performed some years ago, the Radiometer ABL800 is still popular for blood gas analysis in many parts of the world, making our results relevant today.

Vaginal delivery is often compared to running an exhausting marathon for the delivering mother. To highlight the drastic effect on maternal arterial blood gas values during a vaginal delivery, we compared them with women undergoing planned CS as a control group. The significant differences in acid base values according to mode of delivery came as no surprise. With VD, the sheer force of uterine contractions and bearing down results in impaired oxygenation and anaerobic glycolysis with lactate accumulation in both the mother and fetus. The higher BD values in the VD group strengthened this observation, showing a tendency towards metabolic acidemia in the VD group. The lower pCO$_2$ concentration can be explained by maternal hyperventilation, which is used as a compensatory mechanism for the metabolic component (respiratory compensated)

### Table 4

|                   | Cohort without epidural and oxytocin (n = 85) | Cohort with Epidural and oxytocin (n = 88) | P value |
|-------------------|-----------------------------------------------|--------------------------------------------|---------|
| pH                | 7.42 ± 0.05                                   | 7.40 ± 0.06                               | .28     |
| pCO$_2$ (kPa)     | 3.4 ± 0.5                                      | 3.24 ± 0.6                                | .14     |
| pO$_2$ (kPa)      | 15.9 ± 2.2                                     | 15.6 ± 1.7                                | <.00    |
| sO$_2$ (%)        | 98.4 ± 0.7                                     | 98.3 ± 0.7                                | .09     |
| BD (mmol/L)       | 6.8 ± 2.3                                      | 7.8 ± 3.6                                 | .73     |
| ctHb (g/L)        | 136 ± 12                                       | 136 ± 9                                   | .29     |
| Hctc              | 0.42 ± 0.03                                    | 0.42 ± 0.03                               | .37     |
| FHBf (%)          | 5.5 ± 4.5                                       | 7 ± 6.8                                   | .68     |
| ctBil (μmol/l)    | 11.7 ± 6.1                                    | 13.4 ± 9                                  | .37     |
| Na$^+$ (mmol/L)   | 136 ± 2.2                                      | 135 ± 2.7                                 | <.00    |
| K$^+$ (mmol/L)    | 3.8 ± 0.3                                      | 3.9 ± 0.3                                 | .13     |
| Glucose (mmol/L)  | 6.8 ± 1.2                                       | 7.6 ± 1.3                                 | .01     |
| Lactate (mmol/L)  | 4.7 ± 1.5                                       | 5.2 ± 1.7                                 | .57     |

Abbreviations: BE, base deficit; ctBil, total concentration of bilirubin; ctHb, total concentration of hemoglobin; Hctc, hematocrit; pCO$_2$, partial pressure of carbon dioxide; pO$_2$, partial pressure of carbon dioxide; sO$_2$, oxygen saturation.
metabolic acidosis) to help keep maternal pH within a normal range. In addition, low maternal pCO₂ facilitates the elimination of fetal pCO₂ (Double Bohr effect), thereby protecting the fetus from severe fetal respiratory acidosis. The lower hemoglobin concentration in the CS group is explained by the practice of giving a bolus of intravenous fluids when administering local anesthesia, and higher glucose values in maternal arterial blood during vaginal deliveries can be attributed to a heightened sympathetic reaction prompting the body to release more glucose via glycogenolysis.

We were able to show significant differences in the VD group according to type of obstetric intervention used. EDA inhibits neuronal feedback from sensory nerves in the uterus to the brain, resulting in a reduction in the endocrine pain response and decreasing adrenaline secretion from the adrenal medulla. There is also a reduction in oxytocin release from the pituitary gland which, together with decreased sympathetic response, results in maternal hypotension, motor blockade, low blood pressure and respiratory depression. Although we were unable to see any difference in pCO₂ levels, pO₂ levels were found to be significantly lower in women receiving EDA. We also saw higher pH and prominently lower lactate levels in the EDA subgroup, which can be explained by less effective muscle contractions, including uterine contractions. Clinically, the use of EDA increased the likelihood of using synthetic oxytocin to augment uterine contractions and thus maintain normal “progress” during the first and second stages of labor. Stimulation with synthetic oxytocin, however, is not synonymous with normal physiological labor. First, synthetic oxytocin does not cross the blood-brain barrier. Second, during normal labor, oxytocin is released as small narrow peaks. Synthetic oxytocin is administered as a continuous infusion resulting in uniform levels, which are suggested to influence the uterine muscle work, with an increased risk for hyperstimulation and lactate accumulation. Of all the obstetric interventions studied, augmentation of vaginal labor with oxytocin was the most significant contributor to changes in maternal arterial blood gases.

We explored the correlation of various maternal characteristics such as body mass index (BMI), smoking and hypertension on arterial acid base values and electrolytes. Although no significant changes could be shown, a larger study cohort than ours may be needed to investigate these characteristics further.

We did not find a strong correlation between pushing time and maternal pH (not surprisingly, since the value of pH is logarithmic) and lactate. In a smaller material, Nordström et al showed a sharp increase in both maternal and fetal lactate during the second stage of labor. The vast majority of fetal lactate is produced during this stage, and a prolonged stage of expulsion is associated with higher lactate concentrations in both umbilical cord and fetal scalp blood. Sub-analysis of our data showed that an increase in maternal lactate was associated with a corresponding increase in umbilical cord venous lactate values, which in turn were positively associated with lactate values sampled from fetal scalp blood. However, the regression model only accounted for 38% of the venous fetal lactate increase, indicating that the rest must originate from the fetus itself. Transfer of lactate across the placenta may thus contribute minimally to the total fetal lactate concentration increase during the second stage of labor. The placenta is a metabolic organ with lactate generation but we were unable to demonstrate any association between the weight of the placenta and fetal lactate concentration. Therefore, like previous studies, we concluded that the majority of fetal lactate was produced through endogenous lactate production within the fetus itself. This finding reinforces the use of fetal lactate from scalp blood sampling as a reliable tool in the evaluation of fetal distress.

One of the major strengths of the current study was that blood sampling was conducted by trained professionals in both the groups. A specialist obstetrician (N.W.) took fetal scalp lactate and maternal arterial blood gas samples in the VD group. In addition, all blood gas samples were analyzed immediately upon procurement, aided by a blood gas analyzer machine located within the Labor and Delivery department of the hospital. Relevant obstetric and neonatal data were also entered directly after delivery into the study data base. We hope that the study can help obstetricians assess the condition of the laboring mother and differentiate cases where the wellbeing of the mother can be at risk.

5 | CONCLUSION

Reference values for maternal arterial blood gases in vaginal deliveries from term pregnancies have been outlined with this study. We found that most arterial blood gas parameters varied significantly according to mode of delivery. In addition, different obstetrical interventions such as the use of epidural anesthesia or synthetic oxytocin, resulted in significant, albeit very small changes in blood gas values. It may, therefore, be concluded that laboring women have altered biochemical parameters and therefore that reference values based on non-pregnant women should be interpreted with caution.

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CONFLICT OF INTEREST

None.

ORCID

Mehreen Zaigham https://orcid.org/0000-0003-0129-1578
Karl Heby Kristensen https://orcid.org/0000-0003-3209-2459
Nana Wiberg https://orcid.org/0000-0002-9032-5428

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