

1 **Maternal arterial blood values during delivery: effect of mode of delivery, maternal**
2 **characteristics, obstetric interventions and correlation to fetal umbilical cord blood**

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16 **Short title:** Maternal arterial blood gases during delivery

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26 **Abstract**

27 **Objective**

28 To determine a reference interval for maternal arterial blood values during vaginal delivery and
29 to elucidate the effect of common maternal characteristics and obstetric interventions on
30 maternal acid base values during vaginal and planned cesarean section (CS).

31 **Design**

32 Prospective, observational study of randomly selected women undergoing vaginal deliveries
33 and planned CS at Skåne University Hospital, Malmö, Sweden.

34 **Results**

35 Two hundred and fifty women undergoing vaginal delivery (VD) and fifty-eight women
36 undergoing planned CS were recruited. We found significant differences for gestational age,
37 parity, artery pH, pCO₂, pO₂, sO₂ and cord venous pH, pCO₂ and lactate between the two study
38 groups ($P < 0.005$). For women undergoing vaginal delivery, we found significant changes in
39 base deficit, hemoglobin, bilirubin, potassium, glucose and lactate values as compared to
40 women with planned CS ($P < 0.02$). Maternal characteristics did not significantly affect acid
41 base parameters however, multiple regression showed significant associations for the use of
42 epidural anesthesia on maternal pH ($P < 0.05$) and pO₂ ($P < 0.01$); and synthetic oxytocin on
43 pCO₂ ($P = 0.08$), glucose ($P < 0.00$) and lactate ($P < 0.02$) in maternal blood. Maternal arterial
44 pH, pCO₂ and lactate correlated significantly to values in venous umbilical cord blood ($P <$
45 0.000).

46 **Conclusions**

47 Reference values for maternal arterial blood gases in vaginal deliveries for term pregnancies
48 were outlined and we found that most arterial blood gas parameters varied significantly

- 49 according to mode of delivery. The use of different obstetrical interventions like epidural
50 anesthesia or synthetic oxytocin, resulted in significant changes in blood gas values.

51 **Introduction**

52 It is well known that there are significant changes in almost all maternal organ systems during
53 pregnancy and that these physiological changes enable the mother to optimally nourish the fetus
54 as well as prepare her for labor (1). Klajnbard and Maguire (2, 3) showed large variations in
55 most maternal venous parameters during the three trimesters of pregnancy. Despite this
56 knowledge, obstetricians routinely use reference values from non-pregnant women to assess
57 the condition of the pregnant patient. Few studies have focused on physiological variations
58 during pregnancy and delivery, and arterial blood gases including electrolytes, bilirubin,
59 glucose and lactate have seldom been studied. In addition, the possible impact of mode of
60 delivery on different maternal and obstetric factors commonly encountered during delivery, has
61 not been studied.

62 One of the most frequently encountered maternal risk factors during pregnancy and delivery is
63 obesity. Maternal obesity is associated with increased fat deposition, lower body muscle mass,
64 decreased respiratory capacity and chronic inflammatory changes with an increased risk for
65 prolonged labor and adverse maternal-neonatal outcome (4). Smoking during pregnancy is
66 another potentially detrimental risk factor which can affect maternal acid base balance via
67 vasoconstrictive effects on blood vessels and it is well recognized that maternal smoking is
68 associated with hypertension and decreased lung capacity (5, 6).

69 Among obstetric factors, synthetic oxytocin used to augment labor, has powerful effects on
70 uterine contractions and maternal physiology (7). Similarly, the use of spinal/epidural
71 anesthesia (EDA) to provide intrapartum analgesia can result in decreased peripheral vascular
72 resistance which in turn causes alterations to uteroplacental blood flow with impaired
73 oxygenation (8). EDA is well known to prolong labor and increase the risk for adverse maternal
74 outcome and obstetric intervention (7, 9).

75 Thus, the main aim of this study was to determine reference values for maternal arterial blood
76 values during vaginal delivery. We also wanted to elucidate the effect of common maternal
77 characteristics and obstetric interventions on maternal acid base values during vaginal and
78 planned CS. Correlations between maternal acid base values and cord venous blood were also
79 explored.
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81 **Materials and Methods**

82 **Study population**

83 The study was carried out at the Department of Obstetrics and Gynecology, Skåne University
84 Hospital, Sweden. Our study population consisted of two subgroups: patients intended for
85 vaginal delivery (VD) from whom the reference interval was calculated (February 2010 to
86 September 2011) and patients undergoing planned caesarean section (CS) (October 2006 to
87 January 2007 and December 2009 to July 2011). It was established from a previously published
88 paper that the demographic and obstetrical data of the VD subgroup were comparable to the
89 background population i.e. non-participating women who gave birth at the hospital during the
90 same time period as the study (10).

91 Swedish speaking women in active labor with a cervix dilation of 5-6 centimeters (cm) intended
92 for vaginal delivery alternatively, women intended for planned CS, were randomly informed
93 about the study and participating women were required to give written consent before
94 enrollment in the study. All participants had singleton pregnancies dated by an early second
95 trimester ultrasound, cephalic presentation and non-pathological cardiotocography (CTG) at
96 inclusion.

97 Immediately after delivery of the baby, before the first cry, a blood gas sample was obtained
98 from the mother's right radial artery by N.W. Simultaneously, a midwife/junior nurse collected
99 blood from the umbilical cord artery and vein using 2 mL pre-heparinized syringes as per
100 routine at the department. In the planned CS subgroup, a maternal arterial blood gas sample
101 was collected by the anesthesiologist on call at the exact time point when the fetus was delivered
102 with simultaneous sampling from the umbilical cord by N.W. All blood samples were analyzed
103 within 10 minutes after delivery to ensure optimal analysis quality.

104 For both groups, neonatal and obstetric data of significance were entered in to the study's
105 database directly after the delivery of the infant whilst the mother was still admitted to the
106 department.

107 **Biochemical analyses**

108 Maternal and fetal umbilical cord blood were analyzed using the blood gas analyzer, ABL 800
109 Flex, Radiometer, Copenhagen, Denmark. In Lund, the blood gas analyzer programmed to
110 automatically calculate base deficit in extracellular fluid (BD_{ecf}) whilst in Malmö, the ABL was
111 set to calculate base deficit (BD) in whole blood. Since the latter is known to introduce a serious
112 confounding factor (11, 12), we standardized BD values to BD_{ecf} post hoc using the algorithms
113 in the ABL 800 manual:

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$$115 \quad \log cHCO_3^- = pH + \log(pCO_2 \times 0.2325) - 6.095$$

$$116 \quad cBase(BD) = 0.5 \times \left(\frac{8a' - 0.910}{a'} \right) + 0.5 \times \sqrt{\left(\frac{0.919 - 8a'}{a'} \right)^2 - 4 \times \frac{24.47 - cHCO_3^- - 3(5.33)}{a'}}$$

$$117 \quad a' = 4.04 \times 10^{-3} + 4.25 \times 10^{-4} cHb$$

$$118 \quad cHCO_3^-(5.33) = 0.23 \times 5.33 \times 10^{\left[\frac{pH(st) - 6.161}{0.9524} \right]}$$

$$119 \quad pH(st) = pH + \log\left(\frac{5.33}{pCO_2}\right) \times \left\{ \frac{pH(Hb) - pH}{\log pCO_2(Hb) - \log(7.5006 pCO_2)} \right\}$$

$$120 \quad pH(Hb) = 4.06 \times 10^{-2} ctHb + 5.98 - 1.92 \times 10^{(-0.16169 ctHb)}$$

$$121 \quad \log pCO_2(Hb) = -1.7674 \times 10^{-2} ctHb + 3.4046 + 2.12 \times 10^{(-0.15158 ctHb)}$$

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123 where “c” denotes concentration and “ctHb” denotes total concentration of hemoglobin

124 (deoxy-, oxy-, carboxy-, and methemoglobin)

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127 **Statistical analyses**

128 Fisher's exact test was used for comparison of categorical variables. Group comparison of
129 continuous variables was performed using the Kruskal-Wallis test or the Mann-Whitney *U* test,
130 when appropriate. Values were reported as mean with standard deviation (SD) and median with
131 interquartile range (IQR). Association between variables was reported using regression
132 analysis. Correlation between variables was calculated by Spearman's test. A two-sided *P*-value
133 < 0.05 was considered significant. Analyses were performed using IBM SPSS Statistics for
134 Windows, version 25.0 (SPSS Inc. Chicago, Illinois, USA).

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136 **Ethical Approval**

137 The study was approved by the Central Ethical Board, Stockholm, Dnr: Ö50-2005.

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151 Results

152 A total of 309 women agreed to participate in the study. In the group with planned VD, one
 153 case was excluded due to emergency CS performed in general anesthesia, leaving 250 cases for
 154 final analysis in the VD group and 58 cases in the planned CS group.
 155 The maternal and fetal characteristics are reported in Table 1.

Table 1. Maternal and fetal characteristics of the two study groups.

	Vaginal delivery N = 250	Planned cesarean section N = 58	P value
	Mean ± SD Median (2.5, 97.5 percentile)	Mean ± SD Median (2.5, 97.5 percentile)	
Maternal BMI	24.07 ± 4.39 23.2 (18.58, 33.35)	24.84 ± 4.89 23.4 (17.64, 39.46)	0.359 [†]
Gestational age (days)	278 ± 9.6 279 (255, 295)	270 ± 4.5 270 (258, 282)	<0.000 [†]
Infant weight (g)	3599 ± 504 3558 (2619, 4685)	3587 ± 554 3535 (2578, 5019)	0.784 [†]
Infant venous pH	7.33 ± 0.08 7.34 (7.13, 7.45)	7.36 ± 0.04 7.37 (7.23, 7.45)	0.001 [†]
Infant venous pCO₂ (kPA)	5.36 ± 1.2 5.21 (3.39, 7.55)	5.92 ± 0.82 5.82 (4.45, 7.53)	0.000 [†]
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)	0.000 [†]
	N (%)	N (%)	
Primipara	150 (60)	23 (39.7)	0.005 [‡]
Smoking			0.434 [‡]
None	200 (80)	48 (82.8)	
< 10 cigarettes daily	14 (5.6)	5 (8.6)	
> 10 cigarettes daily	2 (0.8)	1 (1.7)	
5 min AS ≤ 7	4 (1.6)	1 (1.7)	-

BMI: body mass index, AS: Apgar Score

[†]: Mann Whitney U Test

[‡]: Fisher's exact test

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158 Significant differences were seen in the frequency of nulli- versus primipara ($P < 0.005$),
159 gestational age ($P < 0.000$) and for values in umbilical cord venous blood ($P < 0.008$). Although
160 the differences in pH and pCO₂ were significant, the most remarkable difference was seen for
161 lactate ($P < 0.000$).

162 Reference values for common maternal acid base values are reported in Table 2.

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164 **Table 2. Reference values for maternal arterial blood gases according to mode of delivery.**
165 **Blood collected from radial artery and analyzed by ABL800™ (Radiometer, Copenhagen,**
166 **Denmark). Mann Whitney *U* Test used for two group comparison.**

	Vaginal delivery	Planned cesarean section	P value
	N = 250	N = 59	
	Mean \pm SD Median (2.5, 97.5 percentile) [Range]	Mean \pm SD Median (2.5, 97.5 percentile) [Range]	
pH	7.41 \pm 0.06 7.41 (7.32, 7.54) [7.32-7.83]	7.44 \pm 0.05 7.44 (7.31, 7.57) [7.29-7.57]	< 0.000
pCO₂ (kPa)	3.29 \pm 0.52 3.35 (2.18, 4.22) [1.03-4.37]	4.16 \pm 0.62 4.25 (2.81, 5.95) [2.59-6.45]	< 0.000
pO₂ (kPa)	15.7 \pm 4 15.6 (11.5, 21.3) [7.3-64.5]	20.7 \pm 7.4 19.2 (14.4, 53.7) [14.3-57.5]	< 0.000
sO₂ (%)	98.2 \pm 1.1 98.4 (96.2, 99.4) [89.4-99.5]	99.1 \pm 0.5 99.1 (96.2, 99.4) [97.5-100]	< 0.000
BD (mmol/L)	7.2 \pm 2.9 7 (3 -13.4) [-10.6, 21.6]	2.2 \pm 1.4 2.1 (-1.1, -5.3) [-1.3, 5.6]	< 0.000
ctHb (g/L)	136 \pm 10 137 (117, 156) [97-190]	113 \pm 19 110 (81, 182) [78-196]	< 0.000
Hctc	0.417 \pm 0.032 0.42 (0.36, 0.48) [0.3-0.55]	0.35 \pm 0.056 0.34 (0.25-0.56) [0.24-0.6]	< 0.000
FHbF (%)	6.4 \pm 6.3 5 (0, 28.4) [0-33]	7.2 \pm 5.3 5.5 (0, 18.9) [0-19]	0.175
ctBil (μmol/l)	13 \pm 8 12 (0, 35) [0-48]	10 \pm 7 9 (0, 34) [0-38]	0.004
Na⁺ (mmol/L)	135 \pm 2.6 135 (130, 140) [126-142]	136 \pm 1.1 136 (134, 138.6) [134-139]	0.073
K⁺ (mmol/L)	3.9 \pm 0.3 3.8 (3.3, 4.5) [3.1-5.1]	3.7 \pm 0.2 3.7 (3.2, 4.2) [3.2-4.2]	< 0.000
Glucose (mmol/L)	7.2 \pm 1.3 7.1 (5.1, 10.4) [4.9-11.2]	4.6 \pm 0.6 4.5 (3.6, 6.4) [3.6-6.7]	< 0.000
Lactate (mmol/L)	4.9 \pm 1.6 4.7 (2.2, 8.7) [1.2-9.6]	1.2 \pm 0.3 1.1 (0.7, 1.9) [0.7-1.9]	< 0.000

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

168 The table also illustrates the differences in maternal arterial blood gas parameters according to
169 mode of delivery. Not surprisingly, significant differences were observed in most biochemical
170 parameters between the groups. A significantly lower pH, pCO₂, pO₂, and sO₂ were found in
171 mothers giving birth vaginally as compared to planned CS. On the other hand, BD, total
172 hemoglobin concentration (ctHb), hematocrit (Hctc), total concentration of bilirubin (ctBil),
173 potassium ion concentration (K⁺), glucose and lactate were significantly higher with VD as
174 compared to planned CS. Comparison of nulli- and multipara women with VD showed
175 significant differences in pO₂, sodium ion concentration (Na⁺) and glucose levels ($P < 0.02$)
176 (Table not shown).

177 Table 3 illustrates the influence of maternal characteristics and obstetrical interventions on acid-
178 base parameters.

Table 3

Correlation of different maternal arterial acid-base values with respect to body mass index (BMI), smoking during pregnancy, the presence of hypertension/preeclampsia and the use of epidural anesthesia, oxytocin (intravenous) or nitrous oxide during labor.

			pH	P value	pCO ₂	P value	pO ₂	P value	ctHb (g/L)	P value	Glucose	P value	Lactate	P value
BMI	<18.5	N=9	7.43 (0.05) 7.42 (7.36, -)	0.41	3.31 (0.48) 3.53 (2.38, -)	0.303	16.06 (8.85) 16.00 (15.10, -)	0.145	141 (9) 141 (123, -)	0.119	7.1 (2) 6.3 (5.5, -)	0.47	4.4 (2) 3.4 (2.5, -)	0.221
	18.5-24.9	N=128	7.42 (0.06) 7.41 (7.33, 7.54)		3.29 (0.48) 3.36 (2.23, 4.21)		15.63 (2.43) 15.6 (11.31, 21.97)		135 (11) 137 (115, 156)		7.2 (1.3) 7.1 (5, 10.4)		5.0 (1.6) 4.8 (2.3, 8.9)	
	25-29.9	N=41	7.41 (0.06) 7.40 (7.32, 7.51)		3.18 (0.61) 3.32 (1.08, 3.93)		15.33 (1.99) 15.7 (10.36, 20.86)		135 (9) 135 (118, 154)		7.4 (1.3) 7.3 (5.1, 10.5)		5.0 (1.9) 4.7 (1.2, 9.5)	
	>30	N=19	7.40 (0.04) 7.38 (7.34, 7.39)		3.53 (0.48) 3.38 (2.79, -)		14.71 (1.38) 14.8 (12.30, -)		131 (11) 131 (108, -)		7.0 (0.9) 7.0 (6.0, -)		4.3 (0.9) 4.1 (3.2, -)	
Smoking	No	N=173	7.41 (0.06) 7.41 (7.32, 7.54)	0.398	3.3 (0.51) 3.37 (2.18, 4.22)	0.805	15.46 (2.18) 15.60 (11.20, 20.48)	0.949	135 (11) 135 (115, 156)	0.926	7.26 (1.3) 7.1 (5.1, 10.4)	0.731	4.9 (1.6) 4.7 (2.1, 8.4)	0.421
	Yes	N=14	7.4 (0.05) 7.39 (7.34, -)		3.37 (0.56) 3.22 (2.64, -)		16.04 (3.36) 15.60 (12.6, -)		134 (11) 138 (118, -)		7.1 (0.9) 6.7 (5.9, -)		5.4 (2) 4.9 (3, -)	
Hypertension/ Preeclampsia	No	N=187	7.41 (0.06) 7.41 (7.32, 7.53)	0.723	3.29 (0.52) 3.35 (2.19, 4.22)	0.420	15.53 (2.29) 15.60 (11.60, 21.20)	0.065	136 (11) 137 (116-155)	0.063	7.2 (1.3) 7.1 (5.1-10.3)	0.729	5.0 (1.7) 4.7 (2.1-8.7)	0.998
	Yes	N=9	7.41 (0.04) 7.41 (7.33, -)		3.40 (0.33) 3.51 (2.68, -)		14.17 (1.09) 14.7 (10.30, -)		130 (7) 130 (119, -)		7.2 (1.7) 7.1 (5.7, -)		4.9 (1.2) 5.2 (3.4, -)	
EDA	No	N=159	7.41 (0.06) 7.40 (7.32, 7.53)	0.047	3.29 (0.51) 3.34 (2.18, 4.23)	0.872	15.72 (2.00) 15.70 (11.90, 19.55)	0.01	136 (11) 137 (118, 155)	0.407	7.2 (1.3) 7.1 (5.1, 10.5)	0.977	5.0 (1.7) 4.8 (2.1-8.7)	0.363
	Yes	N=55	7.42 (0.05) 7.42 (7.32, 7.54)		3.28 (0.55) 3.39 (1.99, 4.22)		14.90 (2.52) 15.10 (7.85, 21.67)		135 (11) 135 (111, 157)		7.2 (1.3) 7.1 (5, 10.4)		4.7 (1.5) 4.5 (2.2, 8.7)	
NO₂	No	N=27	7.42 (0.07) 7.42 (7.32, -)	0.291	3.23 (0.54) 3.13 (2.27, -)	0.377	16.53 (3.01) 16.00 (11.70, -)	0.061	133 (13) 135 (97, -)	0.496	7.3 (1.3) 6.9 (5.8, -)	0.836	4.9 (1.6) 4.3 (2.6, -)	0.967
	Yes	N=177	7.41 (0.06) 7.41 (7.32, 7.53)		3.30 (0.51) 3.35 (2.18, 4.22)		15.42 (1.95) 15.60 (11.79, 19.46)		136 (11) 137 (118, 156)		7.2 (1.3) 7.1 (5.1, 10.4)		4.9 (1.7) 4.7 (2.1-8.7)	
Oxytocin	No	N=99	7.42 (0.05) 7.41 (7.33, 7.53)	0.239	3.39 (0.50) 3.43 (2.25, 4.28)	0.08	15.86 (2.17) 15.70 (12.03, 22.31)	0.067	136 (12) 138 (112, 154)	0.409	6.8 (1.2) 6.5 (5.0, 10.0)	0.000	4.6 (1.5) 4.5 (2.1, 8.1)	0.019
	Yes	N=115	7.41 (0.06) 7.41 (7.32, 7.55)		3.20 (0.51) 3.28 (2.13, 4.14)		15.20 (2.11) 15.40 (10.14, 21.05)		135 (10) 136 (116, 158)		7.6 (1.3) 7.4 (5.4, 10.6)		5.2 (1.7) 4.9 (2.3, 8.8)	

“N” is the number of valid cases per parameter. For two group comparison Mann Whitney U test. For multiple group comparison Kruskal-Wallis test.

EDA: epidural anesthesia, NO₂: nitrous dioxide, pCO₂: partial pressure of carbon dioxide, pO₂: partial pressure of carbon dioxide, ctHb: total concentration of hemoglobin

180 For biochemical parameters not shown in Table 3, the use of nitrous oxide gas (N₂O) was found
181 to significantly effect potassium (3.8 mmol/L versus 4.0 mmol/L, $P < 0.000$) and bilirubin
182 levels (12.2 μ mol/L versus 18.4 μ mol/L, $P < 0.012$). Similarly, the use of oxytocin had a
183 significant impact on sodium concentrations (134.6 mmol/L versus 135.9 mmol/L, $P < 0.000$)
184 and oxygen saturation (98.1% versus 98.4%, ($P < 0.01$).

185 Calculated only for women with VD, multiple regression analysis with pH, pCO₂, pO₂, glucose
186 and BD and lactate as dependent variables and the use of EDA, oxytocin and N₂O respectively
187 as independent variables, significant associations were found for the use of oxytocin and pCO₂
188 ($P = 0.016$), glucose ($P = 0.000$) and lactate ($P = 0.013$) levels in maternal blood. Maternal
189 arterial pH, pCO₂ and lactate values correlated significantly to values in venous umbilical cord
190 blood ($P < 0.000$) (Table not shown) with the correlation coefficient (R²) values as follows: pH
191 R²=0.22, pCO₂ R²=0.07 and lactate R²=0.38. Although significant, the total duration of active
192 “pushing” during the second stage of labor correlated poorly to both maternal and fetal lactate
193 concentration (R²=0.06, $P < 0.000$). In addition, we found no significant correlation between
194 placental weight and fetal lactate concentration (R² = 0.01, $P = 0.431$).

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205 **Discussion**

206 To the best of our knowledge, this is the first study to present reference values in maternal
207 arterial blood at delivery. Although data collection and analysis were performed some years
208 ago, the Radiometer ABL800 is still popularly used for blood gas analysis in many parts of the
209 world making our results relevant today (13).

210 **Values in maternal arterial blood**

211 Vaginal delivery is often compared to running an exhausting marathon for the delivering
212 mother. To highlight the drastic effect on maternal arterial blood gas values during a vaginal
213 delivery, we choose women undergoing planned CS as a control group. The significant
214 differences in acid base values according to mode of delivery came as no surprise.

215 With VD, the sheer force of uterine contractions and bearing down results in impaired
216 oxygenation and anaerobic glycolysis with lactate accumulation in both the mother and fetus
217 (14, 15). The higher BD values in the VD group strengthened this observation, showing a
218 tendency towards metabolic acidemia in the VD group. The lower pCO₂ concentration can be
219 explained by maternal hyperventilation, which is used as a compensatory mechanism for the
220 metabolic component (respiratory compensated metabolic acidosis) to help keep maternal pH
221 within a normal range. In addition, low maternal pCO₂ facilitates the elimination of fetal pCO₂
222 (Double Bohr effect) (15) thereby protecting the fetus from severe fetal respiratory acidosis.
223 The lower hemoglobin concentration in the CS group is explained by the practice of giving a
224 bolus of intravenous fluids when administering local anesthesia whilst higher glucose values in
225 maternal arterial blood during vaginal deliveries can be attributed to a heightened sympathetic
226 reaction prompting the body to release more glucose via glycogenolysis (16).

227 We were able to show significant differences in the VD group according to type of obstetric
228 intervention used. EDA, inhibits neuronal feedback from sensory nerves in the uterus to the
229 brain, resulting in a reduction in the endocrine pain response and decreasing adrenalin secretion

230 from the adrenal medulla. There is also a reduction in oxytocin release from the pituitary gland
231 which, together with decreased sympathetic response, results in maternal hypotension, motor
232 blockade, low blood pressure and respiratory depression (7). Although we were unable to see
233 any difference in pCO₂ levels, pO₂ levels were found to be significantly lower in women
234 receiving EDA. We also saw higher pH and prominently lower lactate levels in the EDA
235 subgroup, which can be explained by less effective muscle- including uterine contractions.
236 Clinically, the use of EDA increased the likelihood of using synthetic oxytocin in order to
237 augment uterus contractions and thus maintain normal “progress” during the first and second
238 stages of labor (9). Stimulation with synthetic oxytocin, however, is not synonymous to normal
239 physiological labor. Firstly, synthetic oxytocin does not cross the blood-brain barrier and
240 secondly, during normal labor, oxytocin is released as small narrow peaks. Synthetic oxytocin
241 is administered as a continuous infusion resulting in uniform levels which are suggested to
242 influence the uterine muscle work with increased risk for hyperstimulation and lactate
243 accumulation (17). The active transportation of the lactate ion into the maternal circulation
244 leads to an increase in the level of lactate as seen from our results.

245 We explored the relationship of various maternal characteristics like BMI, smoking and
246 hypertension on arterial acid base values and electrolytes. Although no significant changes
247 could be shown, a larger study cohort than ours may be needed to investigate these
248 characteristics further.

249 **Correlation between maternal and fetal lactate**

250 We did not find a strong correlation between pushing time and maternal pH (not surprisingly
251 since the value of pH is logarithmic) and lactate. In a smaller material. Nordström et al showed
252 a sharp increase in both maternal and fetal lactate during the second stage of labor (18). The
253 vast majority of fetal lactate is produced during this stage, and a prolonged stage of expulsion
254 is associated with higher lactate concentrations in both umbilical cord- and fetal scalp blood

255 (10, 20). Sub-analysis of our data showed that an increase in maternal lactate was associated
256 with a corresponding increase in umbilical cord venous lactate values which, in turn, were
257 positively associated with lactate values sampled from fetal scalp blood. However, the
258 regression model only accounted for 38% of the venous fetal lactate increase, indicating that
259 the rest must originate from the fetus itself. Transfer of lactate across the placenta may thus
260 contribute minimally to the total fetal lactate concentration increase during the second stage of
261 labor. The placenta is metabolic organ with lactate generation but we were unable to
262 demonstrate any association between the weight of the placenta and fetal lactate concentration.
263 Therefore, like previous studies, we concluded that the majority of fetal lactate was produced
264 through endogenous lactate production within the fetus itself. This finding reinforces the use of
265 fetal lactate from scalp blood sampling as a reliable tool in the evaluation of fetal distress (19,
266 20).

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268 **Strengths and limitations**

269 One of the major strengths of the current study was that blood sampling was conducted by
270 trained professionals in both the groups. A specialist obstetrician (N.W) took fetal scalp lactate
271 and maternal arterial blood gas samples in the VD group. In addition, all blood gas samples
272 were analyzed immediately upon procurement, aided by a blood gas analyzer machine located
273 within the Labor and Delivery department of the Hospital. Relevant obstetric and neonatal data
274 was also entered directly after delivery into the study's data base.

275

276 **Conclusions**

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

284

285 **Acknowledgments**

286 Our sincere thanks to all the participating women in the study.

287

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