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ORIGINAL ARTICLE

Risk factors of incomplete Apgar score and umbilical cord blood gas analysis: a retrospective observational study

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Abstract

Objective: To investigate whether incomplete umbilical cord blood gas (UCBG) analysis occurs more often than the incomplete reporting of the Apgar score, and risk factors associated with the incomplete values.

Methods: A total of 8824 infants born alive after 26 weeks' gestation between January 2009 and April 2013 were included. We extracted data on five-minute Apgar score, UCBG analysis, gestational age, mode of delivery, time of delivery and multiple pregnancy. Univariate and multivariable logistic regression analyses were performed.

Results: Five-minute Apgar score was incomplete in 15 cases (0.2%) and UCBG analysis in 1960 cases (22.2%), $p < 0.05$. Incomplete UCBG analysis was significantly more likely to occur in situations with Apgar score below seven (Odds ratio (OR) 1.68, 95% CI;1.29-2.19), gestational age between 26 to 27 6/7 and 28 to 31 6/7 weeks (OR 3.14, 95% CI; 2.13-4.62 and OR 1.91, 95% CI; 1.57-2.32), cesarean section (OR 1.31, 95% CI; 1.11-1.55), and multiple pregnancy (OR 2.02, 95% CI; 1.69-2.43). Deliveries during night time had a lower risk of incomplete UCBG analysis (OR 0.78, 95% CI; 0.69-0.88).

Conclusions: Measuring five-minute Apgar score generated less incomplete data compared with UCBG analysis. The risk factors associated with incomplete UCBG analysis were noted. Study outcomes with UCBG analysis as neonatal assessment tool should be interpreted with caution.

Keywords

Apgar score, blood gas analysis, epidemiology, perinatal outcome, umbilical cord blood

History

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Introduction

The Apgar score (AS) and umbilical cord blood gas (UCBG) analysis are two important tools used to evaluate the condition of a neonate immediately after birth. The results of such can be used in clinical studies in obstetrics to assess interventions designed to improve perinatal outcome [1–5]. Nevertheless, based on clinical experience, it is hypothesized that the UCBG analysis is more likely to be incomplete, especially in cases complicated by asphyxia, preterm delivery, instrumental delivery, multiple pregnancy and during night hours. Frequently, incomplete outcome values impedes the evaluation of clinical care and the interpretation of study results.

The Apgar score was developed by Virginia Apgar in 1953 with the aim of arriving at a simple, replicable classification of neonatal condition [6]. This classification can be influenced by immaturity, congenital anomalies, the use of maternal medication and has poor interobserver reliability [7–9]. Recent literature has indicated that AS is as relevant for the prediction of neonatal survival as it was many years ago [10]. The UCBG analysis is another measurement that is used to define perinatal outcome [11–13]. As soon as possible after delivery, clinicians obtain a blood sample from the umbilical artery to calculate arterial pH and base excess (or deficit). These values are useful for interpreting the condition of the neonate [14,15]. Low umbilical artery pH at delivery is closely associated with an increased risk of neonatal mortality, and morbidity (mostly cerebral palsy in childhood) [15]. Previous studies have shown percentages of absent UCBG analyses, but specific situations at risk for these incomplete values have never been identified, nor have consequences of this been discussed for the study results [15–20].

In the context of clinical studies on neonatal outcome, missing outcome values can be excluded or imputed. Such results may however be biased. Simple imputation techniques are in fact based on the idea that any subject in a study sample can be replaced by a new randomly chosen subject from the same source population, wherein missing values are independent of specific situations [21,22]. The purpose of this

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study was to compare the absence of five-minute AS and UCBG analysis and to identify determinants of its absence. We hypothesized that UCBG analysis is incomplete more often than five-minute AS, and that this incomplete UCBG analysis occur more frequently in complicated situations.

Methods

We carried out a retrospective observational cross-sectional study from January 2009 to April 2013 at the Máxima Medical Center (MMC, Veldhoven, the Netherlands). MMC is a teaching hospital, which is one of the 10 Dutch perinatal referral centers and has an annual delivery rate of almost 2500 deliveries. Details on obstetric care for all women who gave birth, as well the neonatal care, are registered in a computerized database (Chipsoft, Amsterdam, the Netherlands). The hospital obstetric team is staffed by maternity nurses, obstetrics nurses, clinical midwives, residents and gynecologists. All neonates, born alive in the study period beyond 26 weeks of gestation were included in this study. Neonates with a gestational age less than 26 weeks were excluded because their treatment may have been influenced by nationwide changes in the policy of actively treating neonates with a gestational age of 24 weeks from ''none, unless'' to ''yes, unless'' during the study period [23]. The accredited Medical Ethics Committee of MMC judged that ethical approval is not required for this type of study in the Netherlands and confirmed this study as consent exempt.

The AS after 5 min, the UCBG analysis, gestational age, mode of delivery, time of delivery and multiple pregnancy regarding all neonates were obtained from the mothers patient files. The primary outcome of interest was incomplete five-minute AS and/or UCBG assessment. Incomplete UCBG analysis was defined as missing documentation of either arterial or venous pH values, or as a difference between arterial and venous pH of less than 0.02 considering the Westgate et al.'s criteria [16,24]. Because partial pressure of carbon dioxide (pCO2) was not analyzed in the hospital, the Westgate criterion for pCO2 difference was excluded.

We assessed risk factors for incomplete AS and/or UCBG analysis. As potential risk factors, we considered specific clinical situations including five-minute AS below seven, umbilical artery pH below 7.00, preterm birth, postterm birth, non-spontaneous vaginal delivery, delivery during night time and multiple pregnancy. Five-minute AS was categorized as poor to fair for scores between 1 and 6, and good to excellent for scores between 7 and 10 [10,25]. Preterm birth was classified in groups with gestational age between 26 and 27 6/7, 28 and 31 6/7, 32 and 33 6/7, and 34 and 36 6/7 weeks [23]. Postterm birth was defined as a delivery beyond 42 weeks of gestational age. The mode of delivery was categorized as either spontaneous vaginal delivery, ventouse delivery or cesarean section. Time of delivery was classified into three groups, which represented ward shifts. Multiple pregnancy was defined as carrying more than one fetus.

In all live-born infants, both umbilical arterial and venous blood samples were drawn from a double clamped umbilical cord into non-heparinized capillary tubes and directly transported to the hospital laboratory for measurement of pH and base excess according to hospital protocol. Both umbilical cord artery and vein results were screened to ensure that separate vessels were sampled. AS at one and five minutes were routinely assigned to all newborns, either by the clinical midwife, obstetric resident, gynecologist, pediatric resident or pediatrician, depending on risk factors during the delivery.

For the analysis, five-minute AS and UCBG analysis were dichotomized into complete and incomplete. Five-minute AS, gestational age, mode of delivery, time of delivery and multiple pregnancy were analyzed as categorical variables. Univariate and multivariable logistic regressions were performed with incomplete AS and incomplete UCBG analysis as the dependent variables. All variables significantly associated with the outcome in univariate analysis were included into the multivariable model. To evaluate the effect of dependency of measurements between siblings, we performed a subgroup analysis in the singleton population. In addition, we performed a logistic regression analysis in the group of multiple pregnancies, with incomplete UCBG analysis for the second child as the dependent variable. The results were expressed as odds ratio (OR) with 95% confidence interval (95% CI). Statistical significance was accepted at a two-sided p values of 0.05. All analyses were performed using SPSS (Version 21, IBM, San Jose, CA).

Results

A total of 8824 children were included in this study. 261 children were excluded because their gestational age was below 26 weeks or they were not born alive. Characteristics are shown in Table 1. In our study group of 8824 children, five-minute AS were incomplete for 15 children [0.2% (95% confidence interval (CI); 0.1–0.3)], compared with 1960 incomplete UCBG analyses [22.2% (95% CI; 21.4–23.1)], $p < 0.05$. Both umbilical arterial and venous samples were incomplete for 381 cases (4.3%). Only umbilical arterial blood sample was absent for 386 cases (4.4%), and umbilical venous blood sample was absent for 815 infants (9.2%). For 79 cases (0.9%), the difference between arterial and venous pH was 0.00, and for 299 cases (3.4%) this difference was 0.01. Both five-minute AS and UCBG analysis were incomplete for six infants (0.1%).

Univariate regression analysis showed a higher chance of incomplete UCBG analysis in the group with AS below seven compared with the group with AS above seven [Odds ratio (OR) 2.54, 95% CI; 1.99–3.23, $p < 0.01$] (Table 2). Moreover, the results showed an increased OR for the groups with preterm gestational age, cesarean section and multiple pregnancy (Table 2). A decreased risk of incomplete UCBG analysis was found for children born during night hours compared to children born during day time (OR 0.77, 95% CI; 0.68–0.87, $p < 0.01$).

Multivariable logistic regression analysis was performed to estimate the independent effects of the variables significantly associated with the outcome in the univariate analysis (Table 2). The results showed a correlation between absent UCBG analysis and five-minute AS below seven, gestational age between 26 and 27 6/7 weeks, between 28 and 31 6/7 weeks, cesarean section and multiple pregnancy (Table 2). Children born between 11:00 PM and 08:00 AM were at

Table 1. Baseline characteristics of the study population.

	Total group, *N* (%)	Missing UCBG analysis, *N* (%*)	Missing AS, *N* (%*)
N	8824 (100)	1960 (22.2)	15 (0.2)
Apgar score, median	10	10	–
AS 1–6	285 (3.2)	117 (41.1)	–
AS 7–10	8524 (96.6)	1837 (21.6)	–
Incomplete	15 (0.2)	6 (40.0)	–
Umbilical-artery pH, median	7.24	–	7.27
pH < 7.00	59 (0.7)	–	1 (1.7)
pH ≥ 7.00	6805 (77.1)	–	8 (0.1)
Incomplete	1960 (22.2)	–	6 (0.3)
Gestational age in weeks, median	39 3/7	39	35 6/7
26–27 6/7	120 (1.4)	64 (53.3)	0 (0.0)
28–31 6/7	600 (6.8)	244 (40.7)	5 (0.8)
32–33 6/7	188 (2.1)	51 (27.1)	1 (0.5)
34–36 6/7	612 (6.9)	147 (24.0)	3 (0.5)
37–41 6/7	7208 (81.7)	1440 (20.0)	6 (0.1)
≥42	95 (1.1)	14 (14.7)	0 (0.0)
Incomplete	1 (<0.1)	0 (0.0)	0 (0.0)
Mode of delivery, median	Spontaneous	Spontaneous	Spontaneous
Spontaneous vaginal delivery	7197 (81.6)	1547 (21.5)	13 (0.2)
Ventouse delivery	762 (8.6)	164 (21.5)	0 (0.0)
Cesarean section	865 (9.8)	249 (28.8)	2 (0.2)
Time of delivery, median	01:06PM	01:18PM	0:23
08:00 AM–06:00 PM	4308 (48.8)	1029 (23.9)	7 (0.2)
06:00 PM–11:00 PM	1878 (21.3)	417 (22.2)	4 (0.2)
11:00 PM–08:00 AM	2634 (29.9)	512 (19.4)	3 (0.1)
Incomplete	4 (<0.1)	2 (50.0)	1 (25.0)
Multiple pregnancy, median	No	No	Yes
No	8097 (91.8)	1654 (20.4)	7 (0.1)
Yes	727 (8.2)	306 (42.1)	8 (1.1)

AS: five-minute Apgar score; UCBG: umbilical cord blood gas; *N*: number.

*Row percentage of total group.

Table 2. Univariate and multivariable logistic regressions for risk factors of incomplete UCBG analysis for total group.

Risk factors incomplete UCBG analysis	Crude odds ratio*	95% CI	*p* Values	Adjusted odds ratio**	95% CI	*p* Values
Apgar score						
AS 1–6	2.54	1.99–3.23	<0.01	1.68	1.29–2.19	<0.01
AS 7–10	Reference	Reference		Reference	Reference	
Gestational age in weeks						
26–27 6/7	4.66	3.24–6.71	<0.01	3.14	2.13–4.62	<0.01
28–31 6/7	2.75	2.31–3.26	<0.01	1.91	1.57–2.32	<0.01
32–33 6/7	1.49	1.08–2.07	0.02	1.10	0.78–1.54	0.60
34–36 6/7	1.27	1.04–1.54	0.02	1.00	0.82–1.23	0.97
37–41/7	Reference	Reference		Reference	Reference	
≥42	0.69	0.39–1.22	0.21	0.69	0.39–1.22	0.20
Mode of delivery						
Spontaneous vaginal delivery	Reference	Reference		Reference	Reference	
Ventouse delivery	1.00	0.84–1.20	0.99	1.09	0.91–1.31	0.42
Cesarean section	1.48	1.26–1.73	<0.01	1.31	1.11–1.55	<0.01
Time of delivery						
08:00 AM–06:00 PM	Reference	Reference		Reference	Reference	
06:00 PM–11:00 PM	0.91	0.80–1.04	0.15	0.94	0.82–1.07	0.32
11:00 PM–08:00 AM	0.77	0.68–0.87	<0.01	0.78	0.69–0.88	<0.01
Multiple pregnancy						
No	Reference	Reference		Reference	Reference	
Yes	2.83	2.42–3.31	<0.01	2.02	1.69–2.43	<0.01

*Univariate logistic regression.

**Multivariable logistic regression.

UCBG: umbilical cord blood gas; AS: five-minute Apgar score; CI: confidence interval.

decreased risk for incomplete UCBG compared to children born during day time (OR 0.78, 95% CI; 0.69–0.88, $p < 0.01$).

Univariate and multivariable regression analyses were also performed to describe the association between predefined situations and incomplete Apgar scores (Table 3). The number of absent Apgar scores was too small to generate reliable estimates for all variables. However, in the multivariable logistic regression analysis, Apgar scores were incomplete more among neonates with umbilical artery pH below 7.00, and part of a multiple pregnancy (Table 3).

Table 3. Univariate and multivariable logistic regressions for risk factors of incomplete Apgar scores for total group.

Risk factors incomplete AS	Crude odds ratio*	95% CI	*p* Values	Adjusted odds ratio**	95% CI	*p* Values
Umbilical–artery pH						
pH < 7.00	11.18	1.35–92.29	0.03	10.70	1.14–100.15	0.04
pH 7.00–7.05	–	–	–	–	–	–
pH 7.06–7.10	–	–	–	–	–	–
pH 7.11–7.15	–	–	–	–	–	–
pH 7.16–7.20	0.51	0.06–4.04	0.51	0.74	0.09–6.20	0.78
pH > 7.21	Reference	Reference		Reference	Reference	
Gestational age in weeks						
26–27 6/7	–	–	–	–	–	–
28–31 6/7	10.09	3.07–33.15	<0.01	3.88	0.64–23.60	0.14
32–33 6/7	6.42	0.77–53.58	0.09	–	–	–
34–36 6/7	5.91	1.48–23.70	0.01	3.09	0.47–20.33	0.24
37–41/7	Reference	Reference		Reference	Reference	
≥42	–	–	–	–	–	–
Mode of delivery						
Spontaneous vaginal delivery	Reference	Reference		–	–	
Ventouse delivery	–	–	–	–	–	–
Cesarean section	1.28	0.29–5.69	0.75	–	–	–
Time of delivery						
08:00 AM–06:00 PM	Reference	Reference		–	–	
06:00 PM–11:00 PM	1.31	0.38–4.49	0.67	–	–	–
11:00 PM–08:00 AM	0.70	0.18–2.71	0.70	–	–	–
Multiple pregnancy						
No	Reference	Reference		Reference	Reference	
Yes	12.86	4.65–35.56	<0.01	6.38	1.28–31.73	0.02

*Univariate logistic regression.

**Multivariable logistic regression.

UCBG: umbilical cord blood gas; AS: five-minute Apgar score, CI: confidence interval.

Since each baby of a multiple pregnancy was represented as an independent measurement, univariate and multivariable analyses were performed with exclusion of the multiple pregnancies. No statistically significant differences in OR were found between the analysis of the total group and the subanalysis of the group without multiple pregnancies. In the multiple pregnancy group of 727 children, 680 infants were twins, 33 were triplets and 14 were undefined because the gestational age of the other half of the multiple pregnancy was below 26 weeks or not born alive. Univariate logistic regression in the group of twin pregnancies with incomplete UCBG analysis for the second child as the dependent variable showed a higher risk of absent UCBG for the second child if UCBG analysis was incomplete for the first child (OR 2.16, 95% CI; 1.39–3.36, $p < 0.01$).

Discussion

This study showed that UCBG analysis generates more incomplete data compared with five-minute AS. Neonates with five-minute AS below seven, a gestational age between 26 and 32 weeks, born by a cesarean section or as part of a multiple pregnancy were at increased risk for absent UCBG analysis. However, if a neonate was born during the night there was a decreased risk. The percentage of incomplete Apgar scores was very low and did not allow for reliable analysis of predictive risk factors.

The strength of this study is the large number of neonates that were included in this study, including premature infants. Moreover, all data were obtained from one perinatal referral center with a protocolized collection of both umbilical arterial and venous samples after every delivery. The limitations of our study include the small number of neonates with very low five-minute AS, gestational age between 26 and 27 6/7, and 32 and 33 6/7 weeks. Furthermore, we excluded neonates delivered with a gestational age between 24 and 26 weeks. Due to the retrospective nature of our study, we cannot exclude that measurements may have been recorded incorrectly or were obtained but failed to be recorded. Additionally, the Westgate criterion for pCO2 difference was excluded, because partial pressure of carbon dioxide was not analyzed in our hospital. Another limitation is that we could not study all causal factors for incomplete values since we did not have data on potential confounders such as congenital anomalies. It is however unlikely that recording errors and residual confounding explain the large difference in frequency of absent data for UCBG and AS.

The high percentage of incomplete UCBG analyses has also been found in previous research [16–20]. Casey et al. [10] showed that when UCBG analysis was not available, the incidence of neonatal death was significantly increased. Moreover, a discussion continues about selection criteria for validating UCBG samples [26]. When considering Westgate criterion, only 75% of UCBG analyses in an average hospital population had validated data [16]. Our study also showed that when only one UCBG sample was available, this was mostly recorded as arterial UCBG analysis. However, a venous sample is more likely to be obtained as the smaller diameter of the umbilical artery limits the volume of blood that can be sampled.

This study adds that several specific clinical circumstances are associated with absent UCBG analysis. Exclusion of the cases with incomplete values or the use of simple imputation techniques should be avoided in statistical analyses to avoid

biased estimates. This is particularly important when interpreting studies about the association between UCBG analysis and perinatal outcome, and when planning to carry out a clinical trial in obstetrics on perinatal outcome. Obtaining and analyzing samples of both the umbilical artery and vein is promoted by most authors and professional societies in specific defined situations, such as low five-minute AS [16,17,27,28]. Our study shows that the risk of absent UCBG analysis is significantly increased in situations as low five-minute AS, even in a hospital with protocolized collection of both umbilical arterial and venous samples after every delivery. Accordingly, it may be questionable to obtain and analyze both the umbilical artery and vein for all cases. However, cost-effectiveness was not included in this study.

The risk factors for incomplete UCBG analysis may be due to a number of reasons. One of these reasons could be a situation with poor fetal condition in which clinicians may focus on the newborn. As a result, obstetric caregivers are more likely to forget blood sampling, collect blood in the wrong way or forget to note the results. This hypothesis is supported by the result that neonates with five-minute AS below seven are more prone to absent UCBG analysis. Another reason could be a smaller umbilical cord containing a smaller amount of blood, which makes it more difficult to sample enough blood for analysis. Our study showed that preterm delivery was at increased risk for incomplete UCBG analysis. A third reason may be that care workers focus on the method of delivery. This study showed an increased risk for absent UCBG analysis after cesarean section. Unfortunately, differences in primary and secondary cesarean section were not investigated in this study. However, Ernst et al. [29] showed that an emergency cesarean section led to more non-valid samples, compared to an elective cesarean section.

The high percentage of incomplete UCBG analysis for multiple pregnancies may be due to the focus on the next child instead of sampling blood out of the umbilical cord. Our results of the univariate logistic regression in the group of twin pregnancies showed that each baby of a multiple pregnancy cannot be represented independently. However, exclusion of the multiple pregnancies did not affect the results of the remaining risk factors. Potential problems during transport and analysis in the hospital laboratory could also have resulted in incomplete UCBG analysis.

A decreased risk for absent UCBG analysis was found for children born during the night. This may be due to decreased workload during night shifts with generally less women in labor, less interrupting phone calls and more experienced clinicians in the workplace. Moreover, expected complicated deliveries and (elective) cesarean sections are usually planned during day shifts. The relative ease of completing the five-minute AS could explain why it was almost always present. Further studies should investigate whether close attention for the situations at risk for absent values may decrease the high percentage of incomplete values.

The UCBG analysis generates more incomplete data compared with five-minute AS. Situations with five-minute AS below seven, preterm delivery, cesarean section and multiple pregnancy are at increased risk for absent UCBG analysis. However, night time deliveries were at decreased risk. Further studies should investigate whether close attention for these situations may decrease the high percentage of incomplete values. Moreover, because several specific clinical circumstances are associated with absent UCBG analysis, study outcomes with UCBG analysis as neonatal assessment tool should be interpreted with caution.

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M. Smith reviewed the manuscript (native English speaker).

Declaration of interest

All authors declare that they have no financial, personal, political, intellectual or religious competing interests. This study is not funded by any organization. All researchers are independent from any funder.

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