

BMJ Open Umbilical artery lactate levels and associated maternal and newborn characteristics at Mulago National Referral Hospital: a cross-sectional observational study

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ABSTRACT

Objective To determine the maternal and newborn characteristics associated with high umbilical artery lactate levels at Mulago National Referral Hospital.

Design Cross-sectional observational study.

Setting Department of Obstetrics and Gynecology at a national referral hospital located in the capital of Uganda, Kampala.

Participants We randomly selected 720 pregnant mothers at term who presented in labour and their newborn babies.

Primary outcome Umbilical artery lactate level.

Results During the study, there were 579 vaginal deliveries (18 instrumental) and 141 caesarean sections which met the inclusion criteria. One hundred and eighty-seven neonates (187) had high arterial lactate levels. The following factors were associated with an increased likelihood of high lactate concentration: male sex (adjusted OR (aOR)=1.71; 95% CI 1.16 to 2.54; $p<0.05$), primigravidity (aOR=2.78; 95% CI 1.89 to 4.08; $p<0.001$), meconium-stained liquor (aOR=5.85; 95% CI 4.08 to 8.47; $p<0.001$) and administration of oxytocin (aOR=1.97; 95% CI 1.00 to 3.77; $p<0.05$).

Conclusion About a fifth of the babies born in Mulago National Referral Hospital during the study period had high umbilical artery lactate. The maternal-fetal factors significantly associated with high umbilical artery lactate levels included: baby's sex, mother's gravidity, meconium-stained amniotic fluid and oxytocin administration during labour.

INTRODUCTION

In 2018, the global burden of neonatal mortality was 18 deaths per 1000 live births with almost 80% of this burden in sub-Saharan Africa and Southern Asia (39% and 38%, respectively).¹ In Uganda, birth asphyxia is among the leading causes of neonatal mortality and morbidity. It results from failure to, or breathing poorly, depriving body tissues of oxygen and leading to a hypoxic state, hypercapnia and metabolic acidosis.²

Strengths and limitations of this study

- Simple random sampling at recruitment reduced selection bias based on participant characteristics.
- The large participant sample size powered the study to derive meaningful/significant association between high lactate and associated characteristics.
- We used one arterial blood sample and therefore could not verify each sample as truly arterial and not venous blood.

During severe hypoxic states there is shift in the metabolic pathways to anaerobic glycolysis causing lactic acidemia to rapidly develop.³ The quantification of lactic acid in neonatal cord arterial blood could therefore be a reflection of the current metabolic state of the neonate at birth.

From large observational studies it has been predetermined that newborn arterial cord blood levels greater than the 95th percentile are equivalent to >6.1 mmol/L and greater than the 99th percentile equivalent to >6.7 mmol/L.^{4 5} This study therefore considered a cut-off of 6.1 mmol/L as threshold for high cord blood lactate level.

There is no study known to us published on umbilical cord blood lactate levels in Mulago National Referral Hospital. However, a study on antenatal and intrapartum risk factors for birth asphyxia among obstetric referrals in this hospital found that augmentation of labour with oxytocin, premature rupture of membranes, meconium staining of liquor amni, vacuum-assisted delivery, caesarean section, low birth weight and malpresentations were significantly associated with birth asphyxia.⁶

This study was aimed at determining the maternal-fetal factors associated with high umbilical artery lactate levels at Mulago National Referral Hospital.

METHODS

The study was a cross-sectional observational design. It was conducted at Mulago National Referral Hospital, Department of Obstetrics and Gynecology. The hospital is located centrally in Kampala, the capital of Uganda. This is a tertiary hospital providing comprehensive emergency obstetric and newborn care 24 hours/day. It is also a training hospital for Makerere University College of Health Sciences. There are about 39 080 deliveries at this hospital annually.

The hospital has a level II special care unit for admission of sick newborns and premature babies with a capacity of 60 beds.

The target population was pregnant women who presented to deliver at the hospital labour suite between January and March 2019. The inclusion criteria were: pregnant women admitted in labour, with term gestation determined by a first trimester ultrasound scan or calculation from first day of last normal menstrual period, and a singleton gestation. Pregnant women who were suffering from complications such as eclampsia, antepartum haemorrhage and documented fever $\geq 38^{\circ}\text{C}$ were excluded. Newborns who were delivered and subsequently diagnosed with congenital anomalies were excluded as well. During the study period there were 2968 deliveries and 720 mothers and their babies who met the inclusion criteria were recruited using systematic sampling. The sample size of 720 was arrived at using the formula for logistic regression models ($n=10K/P$).⁷ Reference was made to a study assessing umbilical cord pH and risk factors for acidaemia in neonates choosing the proportion of acidotic babies born through meconium-stained amniotic fluid.⁸

Informed consent was obtained from the sampled mothers. Unique identification numbers were assigned to mothers who agreed to participate in the study as well as their neonates. The participants' baseline characteristics such as age, gravidity, gestational age and blood pressure were collected using a data form. Following vaginal or caesarean delivery, a 20 cm segment of umbilical cord was doubly clamped and one sample of 2 mL arterial blood drawn from between the clamps within 5 min of delivery. We deviated from the norm of paired blood samples to verify a sample as truly arterial and this was due to limited lactate test strips.⁹ The first study assistant immediately used 20–30 μL of sampled blood and measured its lactate concentration using a point-of-care lactate metre (Accutrend Plus system; Roche Diagnostics, Rotkreuz, Switzerland). The precision range of the metre is 0.8–22 mmol/L at 15°C – 35°C and the coefficient of variation is 1.8%–3%. The study assistants did not interfere with the conduction of delivery and/or active management of the third stage of labour.

The newborn characteristics such as mode of delivery, sex, birth weight and exposure to meconium-stained amniotic fluid were also documented. We documented the Apgar score at 1 and 5 min, if the neonate was resuscitated after birth, admitted to the nursery, and if they died.

It was also documented if the mother received any medication during the intrapartum period such as oxytocin, antibiotics, anticonvulsants (magnesium sulfate) and prostaglandins for labour induction.

Data were entered into EpiData V.4.4 (The EpiData Association, Odense, Denmark) and then exported to R V.3.5 (R Foundation for Statistical Computing, Vienna, Austria). All continuous variables were summarised as means, medians and ranges, while the categorical variables were summarised as percentages and proportions. Bivariate analysis was done by fitting a model for all the independent variables with the outcome high lactate and their CIs at 95% CI; all the variables that gave a p value ≤ 0.2 were considered for multivariate analysis. The logistic model was run for all the variables that met the criteria for the multivariate analysis and the variables which were found to be significantly ($p < 0.05$) associated with high lactate were used to form two-way product terms. These product terms were used in the assessment of interaction by dropping the interaction terms one at a time starting with the least significant while the remaining ones were checked if they attained significance.

Patient and public involvement

Patients were not involved in the study design process. They were first involved in the study at recruitment when the study was explained to them and they gave their consent to participate. We only shared with the patients the lactate value of their baby's umbilical cord blood. The findings of the study will be packaged into key messages and disseminated to the patients during health education sessions as they wait to be attended to at prenatal clinics.

RESULTS

Over the study period, samples of unpaired umbilical artery cord blood were obtained from 720 neonates. The mean lactate value was $5.49 \pm \text{SD } 2.44$ mmol/L. The IQR was 4.0–6.2 mmol/L. Of the total, 187 (25.97%) neonates had a high lactate value greater than 6.1 mmol/L. The outcomes for neonates with high lactate differed significantly from those with low lactate; 47 (25.1%) were resuscitated after birth versus 7 (1.3%) with low lactate, $\chi^2(\text{df}=1)=113.22$, $p < 0.001$. Secondly, 60 (32.1%) with high lactate were admitted to the nursery versus 22 (4.1%) with low lactate, $\chi^2(\text{df}=1)=107.22$, $p < 0.001$. Thirdly, 34 (19.8%) with high lactate were diagnosed with asphyxia (Apgar score less than 7 at 5 min) versus 4 (0.75%) with low lactate, $\chi^2(\text{df}=1)=93.41$, $p < 0.001$. Lastly, 16 (8.6%) with high lactate died versus 3 (0.6%) with low lactate, $\chi^2(\text{df}=1)=34.43$, $p < 0.001$. The 16 neonates with high lactate were diagnosed with hypoxic ischaemic encephalopathy (HIE) and this was a likely cause of death while neonatal sepsis was the cause of death in the three neonates with low lactate (one death occurring after discharge from our hospital). See [table 1](#) summarising participant characteristics.

Table 1 Baseline and clinical characteristics of the 720 study participants

Characteristics	Frequency (n)	%
Mother's age (years)		
14–19	112	15.56
20–34	543	75.42
≥35	65	9.03
Gravidity		
Primigravida	259	35.97
Multigravida	461	64.03
Gestational age		
Early term($37\frac{0}{7} - 38\frac{6}{7}$)	266	36.9
Term($39\frac{0}{7} - 40\frac{6}{7}$)	310	43.1
Late term($41\frac{0}{7} - 41\frac{6}{7}$)	76	10.6
Post-term($\geq 42\frac{0}{7}$)	68	9.4
Baby's sex		
Male	374	51.9
Female	346	48.1
Birth weight (g)		
Average 3245.83		
Low (<2500)	11	1.5
Normal (2500–3999)	678	94.2
Macrosomia (>3999)	31	4.3
Maternal blood pressure		
Normal (<140/90)	659	91.5
High (140/90–159/109)	52	7.2
Severe (>159/109)	9	1.3
Medication during labour		
None	584	80.8
Oxytocin	54	7.5
Antibiotics	52	7.2
Anticonvulsants	7	0.9
Antihypertensive	19	2.6
Prostaglandin	4	0.6
Mode of delivery		
Spontaneous vertex delivery	561	77.9
Assisted vaginal delivery	18	2.5
Caesarean section	141	19.6

Unadjusted analysis found that mother's age, baby's sex, mother's gravidity, medication administered, mode of delivery and meconium staining had a p value <0.2 and were considered for multivariate analysis. See [table 2](#) showing unadjusted analysis of factors associated with high umbilical artery lactate levels.

Logistic regression analysis demonstrated that the following factors were associated with an increased

likelihood of high lactate in a neonate: *male sex* (adjusted OR (aOR)=1.71; 95% CI 1.16 to 2.54; $p<0.05$), *primigravida* (aOR=2.78; 95% CI 1.89 to 4.08; $p<0.001$), *meconium-stained liquor* (aOR=5.85; 95% CI 4.08 to 8.47; $p<0.001$) and administration of *oxytocics* (OR=1.97; 95% CI 1.00 to 3.77; $p<0.05$). See [table 3](#) showing multivariate analysis of factors associated with high umbilical artery lactate levels.

DISCUSSION

This study was aimed at determining which maternal-fetal characteristics were significantly associated with newborn acidaemia. This was by a proxy measure of lactic acid concentration in an umbilical artery cord blood segment. From the study, four factors were found significantly associated as follows.

Male babies were 71% more likely to have a high lactate reading compared with female babies. The findings of this study are similar to a study in which male sex had significantly higher cord blood lactate levels ($R^2=0.34$; $p=0.034$) compared with female sex.¹⁰ In addition, a study exploring the effect of race on male predisposition to birth asphyxia concluded that male sex was 16% more likely to have severe birth asphyxia compared with female sex.¹¹ These findings are in agreement with a United Nations report on sex differentials in childhood mortality which stated that in the 2000s, male to female newborn mortality in Uganda had a ratio of 1.26.¹² There has been no conclusive explanation put forward as to why this difference in outcomes is observed. However, in a comprehensive review on the subject, it is concluded that differences in clinical outcomes between sexes may represent a complex interaction between immunological, hormonal and genetic factors and that further research is still warranted.¹³

The study found that primigravidas were more than two times likely to have high cord blood lactate as compared with multigravidas. Primigravidas are considered high-risk mothers because of the predisposition to adverse maternal and neonatal outcomes. Yuichi *et al* similarly found significantly lower cord arterial lactate levels ($R^2=0.34$; $p=0.001$) in babies born to mothers with higher gravidity and parity.¹⁰ In a second study, it was observed that 24 (61.5%) of the babies with birth asphyxia were born to primigravidas and had a significantly higher mean cord arterial lactate (6.423 ± 2.335 mmol/L) compared with 477 (55%) babies without birth asphyxia (3.6 ± 1.832 mmol/L) who were born to multigravidas ($p=0.048$).¹⁴

This study found that babies born through meconium-stained amniotic fluid were more than five times likely to have high cord arterial blood lactate levels compared with babies born through clear amniotic fluid. In a similar study assessing utility of a lactate-creatinine ratio for prediction of HIE, their concentrations were measured in urine passed by babies born through meconium-stained amniotic fluid within 6 hours of life. They found the mean lactate level (21.6 ± 34.83 mmol/L) higher in babies exposed to meconium-stained amniotic fluid compared

Table 2 Unadjusted analysis for the factors associated with the high umbilical artery lactate levels (>6.1 mmol/L) in neonates born in Mulago National Referral Hospital

Characteristics	Low lactate n=533 (%)	High lactate n=187 (%)	OR	95% CI	P value
Mother's age					
20–34	410 (75.5)	133 (24.5)	1.00		
<20	74 (66.1)	38 (33.9)	1.58	1.02 to 2.44	0.04
>35	49 (75.4)	16 (24.6)	1.01	0.54 to 1.79	0.983
Baby's sex					
Female	275 (79.5)	71 (20.5)	1.00		
Male	258 (69)	166 (31)	1.74	1.24 to 2.46	0.001
Birth weight (kg)					
Normal (2500–3999)	502 (74)	176 (26)	1.00		
LBW (<2500)	8 (72.7)	3 (27.3)	1.07	0.23 to 3.74	0.921
Macrosomia (>3999)	23 (74.2)	8 (25.8)	0.99	0.41 to 2.17	0.985
Gestational age					
Term (39–40)	224 (72.3)	86 (27.7)	1.00		
Early term (37–38)	200 (75.2)	66 (24.8)	0.86	0.59 to 1.25	0.427
Late term (41–41)	59 (77.6)	17 (22.4)	0.75	0.40 to 1.33	0.344
Post-term (≥42)	50 (73.5)	18 (26.5)	0.94	0.51 to 1.67	0.832
Gravidity					
Multigravida	373 (80.9)	88 (19.1)	1.00		
Primigravida	160 (61.8)	99 (38.2)	2.66	1.89 to 3.71	0.000
Maternal blood pressure					
Normal (<140/90)	475 (74)	167 (26)	1.00		
High (140/90–159/109)	39 (75)	13 (25)	0.95	0.48 to 1.77	0.873
Severe (>159/109)	5 (55.6)	4 (44.4)	2.26	0.56 to 8.70	0.224
Medication administered					
None	437 (74.8)	147 (25.2)	1.00		
Antibiotics	39 (75)	13 (25)	0.56	0.24 to 1.27	0.164
Anticonvulsants	3 (42.9)	4 (57.1)	2.22	0.45 to 10.91	0.325
Antihypertensive	16 (84.2)	3 (15.8)	0.44	0.13 to 1.52	0.196
Oxytocics	34 (63.0)	20 (37)	0.60	0.34 to 1.07	0.085
Prostaglandins	4 (100)	0 (0)	1.00		
Mode of delivery					
SVD	431 (76.8)	130 (23.2)	1.00		
AVD	6 (33.3)	12 (66.7)	6.13	2.26 to 16.64	0.000
Emergency caesarean section	96 (68.1)	45 (31.9)	1.53	1.03 to 2.29	0.036
Meconium staining					
Clear	398 (86.1)	64 (13.9)	1.00		
MSL	135 (52.3)	123 (47.7)	5.43	3.83 to 7.76	0.000

AVD, Assisted Vaginal Delivery; LBW, Low Birth Weight; MSL, meconium-stained liquor; SVD, Spontaneous Vertex Delivery.

with mean lactate (3.3 ± 2.79 mmol/L) in babies born through clear amniotic fluid.¹⁵ A second study compared neonates born through thick meconium-stained amniotic fluid and those born through thin meconium-stained amniotic fluid; the former group was found with higher gestational age, lower Apgar score and lower pH as well

as higher umbilical cord blood lactate >4.1 mmol/L. This could predict occurrence of pulmonary haemorrhage and need for ventilation in the neonatal intensive care unit.¹⁶ From these findings, one can infer that in low-resource settings, meconium-stained amniotic fluid should be used as a sign of intrapartum fetal compromise

Table 3 Multivariate analysis of factors associated with high umbilical artery lactate levels in neonates born in Mulago National Referral Hospital

Characteristics	Low lactate n=533 (%)	High lactate n=187 (%)	aOR	95% CI	P value
Baby's sex					
Female	275 (79.5)	71 (20.5)	1.00		
Male	258 (69)	116 (31)	1.71	1.16 to 2.54	0.007
Gravidity					
Multigravida	373 (80.9)	88 (19.1)	1.00		
Primigravida	160 (61.8)	99 (38.2)	2.78	1.89 to 4.08	0.000
Medication administered					
None	437 (74.8)	147 (25.2)	1.00		
Antibiotics	39 (75)	13 (25)	0.62	0.27 to 1.30	0.221
Anticonvulsants	3 (42.9)	4 (57.1)	2.52	0.39 to 16.54	0.326
Antihypertensive	16 (84.2)	3 (15.8)	0.33	0.07 to 1.12	0.102
Oxytocics	34 (63.0)	20 (37)	1.97	1.00 to 3.77	0.045
Prostaglandins	4 (100)	0 (0)	1.00		
Meconium staining					
Clear	398 (86.1)	64 (13.9)	1.00		
MSL	135 (52.3)	123 (47.7)	5.85	4.08 to 8.47	0.000

P values in Bold are significant; less than 0.05

aOR, adjusted OR; MSL, meconium-stained liquor.

and a consideration for intervention. In our hospital, mothers in labour with meconium-stained amniotic fluid receive closer fetal heart rate monitoring while being counselled for possibility of emergency operative delivery. An alternative practice of intrapartum amnioinfusion is contentious and has not been adopted at our hospital; however, it could significantly improve neonatal outcome while reducing caesarean delivery rate and we recommend further studies in this subject in our setting.^{17 18} Our study affirms that babies born through meconium-stained amniotic fluid should be monitored closely in the immediate postpartum period considering admission to the nursery if they have breathing difficulty and/or fail to feed. A cord blood lactate level above 6.1 mmol/L would easily aid triage which of these babies need closer monitoring.

Babies born to mothers whose labour was augmented with oxytocin infusions were almost two times more likely to have high cord arterial lactate levels. This is a well-known risk in labour management due to the risk of uterine hyperstimulation and decreased placental perfusion resulting in fetal distress. It has also been found that mothers who received oxytocin for labour augmentation were found to have fetal intermediate/pathological cardiotocography tracings with significantly elevated umbilical cord lactate at birth.¹⁹ Lastly, a study of 80 term newborns delivered vaginally also found that fetal acidosis was significantly associated with oxytocin augmentation (OR 16.48, 95% CI 1.21 to 22.6) during labour management.²⁰ The decision to augment labour with oxytocin

should be taken, well aware of the potential outcomes; communicating to the patient these risks and getting her consent for the intervention.

In our study, birth weight was not found to be significantly associated with differences in umbilical cord lactate concentration. A similar study found no significant difference in cord blood lactate concentration at various birth weight for term babies.²¹ The similarity between our two studies is that we included only term gestations.

To the contrary, studies have found that preterm and low birthweight babies (<2000 g) have been found with low cord blood pH and subsequent high lactate concentration at birth compared with term gestations of normal birth weight (>2500 g).^{22 23}

The mode of delivery, too, was not found to be a risk factor for high umbilical cord blood lactate concentration after adjusted analysis in our study population. This contradicts a study in which neonates delivered by emergency caesarean section, especially for fetal distress, had significantly high lactate.²⁴ The explanation for this difference could be because our study did not stratify its analysis based on the indication of the caesarean section. Secondly, even with assisted vaginal delivery, the number of babies born by this method (18 only) was not sufficient to deduce significant association with high umbilical artery lactate concentration.

As seen above, this study agrees with previous studies that certain maternal-fetal factors can be considered risk factors for fetal and neonatal acidosis. These can therefore be taken into consideration when making decisions



during the peripartum period such as presence of a neonatologist to receive a baby or decision to deliver by emergency caesarean section. This study demonstrated the practicability of a portable point-of-care lactate metre in a busy obstetric unit; we recommend further research in our local setting studying feasibility of measurement of fetal scalp blood lactate using point-of-care devices. This could support decision-making when fetal compromise is suspected in presence of abnormal fetal heart rate patterns and meconium-stained amniotic fluid. This could avert potential adverse outcomes in the perinatal period while curbing the unnecessary rising caesarean section rate.

From the study, too, we observed that neonates with high cord blood lactate values had significantly higher frequency of adverse outcomes such as resuscitation, admission to the nursery, low Apgar score at 5 min and death compared with those with low blood lactate levels. In our setting and the rest of sub-Saharan Africa, umbilical cord lactate could have a role in triaging babies with higher likelihood of adverse outcomes and complications. We reiterate the opinion that this allows efficient allocation of resources such as manpower, limited nursery beds and other supportive interventions to babies with greater need.²⁵

A potential limitation of our study was that we drew one sample of fetal cord arterial blood as opposed to paired samples. This deviated from the standard practice of drawing two samples to validate if the sample is truly arterial and not venous.

We decided this due to resource constraint as analysing two samples per study participant would require more consumables and drastically raise the cost of the study. To mitigate the effect of this on our results, the study assistants were trained on repeated occasions to draw blood from the smaller calibre and thick-walled umbilical arteries. Secondly, establishing the true gestational age of our participants was difficult and we relied on recollection of menstrual dates since few mothers had a first trimester dating ultrasound scan on record. Lastly, our study did not explore the effect of maternal infections such as malaria and HIV on cord blood lactate levels and yet these are prevalent in our setting. A study in Malawi found neonates of mothers diagnosed with malaria although few, with significantly higher cord lactate levels and this deserves further investigation.²⁵

CONCLUSION

We concluded that about a fifth of the babies born in Mulago National Referral Hospital during the study period had high umbilical artery lactate. The maternal-fetal factors significantly associated with high umbilical artery lactate levels included: baby's sex, mother's gravidity, meconium-stained amniotic fluid and oxytocin administration during labour. Mother's age, birth weight, maternal blood pressure and mode of delivery were not significantly associated with high umbilical artery lactate

levels. In one of the busiest labour suites in sub-Saharan Africa, clinical practice is guided mostly by foreign recommendations and data from foreign studies. The findings of this study conducted in the local setting are more likely to influence practice, and encourage implementation research in the applicability of newborn cord blood testing.

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Contributors VO was involved in concept development, data collection, analysis and research report writing. MMuy and MMus were involved in concept development and review of research report. JN was involved in concept development, data collection and review of research report. All the authors have agreed to be accountable for all the aspects of the work in this study.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not required.

Ethics approval The research proposal was vetted by the Department of Obstetrics and Gynecology, Makerere University, and forwarded to the School of Medicine Research Ethics Committee (REC reference 2018-129). The study was also approved by the Mulago Hospital Research and Ethics Committee (reference MHREC 1537).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. Extra data can be accessed via the Dryad data repository at <http://datadryad.org/> with the doi: 10.5061/dryad.crjdfn32f.

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REFERENCES

- 1 UN-IGME, Levels & Trends in Child Mortality. *United nations Inter-agency group for child mortality estimation*. New York: UNICEF, 2018.
- 2 Low JA. Intrapartum fetal asphyxia: definition, diagnosis, and classification. *Am J Obstet Gynecol* 1997;176:957–9.
- 3 Bobrow CS, Soothill PW. Causes and consequences of fetal acidosis. *Arch Dis Child Fetal Neonatal Ed* 1999;80:F246–9.
- 4 White CRH, Doherty DA, Newnham JP, et al. The impact of introducing universal umbilical cord blood gas analysis and lactate measurement at delivery. *Aust N Z J Obstet Gynaecol* 2014;54:71–8.
- 5 Low JA, Lindsay BG, Derrick EJ. Threshold of metabolic acidosis associated with newborn complications. *Am J Obstet Gynecol* 1997;177:1391–4.
- 6 Kaye D. Antenatal and intrapartum risk factors for birth asphyxia among emergency obstetric referrals in Mulago Hospital, Kampala, Uganda. *East Afr Med J* 2003;80:140–3.
- 7 Peduzzi P, Concato J, Kemper E, et al. A simulation study of the number of events per variable in logistic regression analysis. *J Clin Epidemiol* 1996;49:1373–9.
- 8 Modarressnejad V. Umbilical cord blood pH and risk factors for acidaemia in neonates in Kerman. *East Mediterr Health J* 2005;11:96–101.

- 9 Westgate J, Garibaldi JM, Greene KR. Umbilical cord blood gas analysis at delivery: a time for quality data. *Br J Obstet Gynaecol* 1994;101:1054–63.
- 10 Fuyama Y, Shima Y, Shindo F, *et al.* Clinical significance of measuring lactate levels in cord blood to predict development of respiratory distress syndrome in neonates. *JMAJ* 2005;48:268–76.
- 11 Mohamed MA, Aly H. Impact of race on male predisposition to birth asphyxia. *J Perinatol* 2014;34:449–52.
- 12 Department of Economic and Social Affairs. United-Nations, sex differentials in childhood mortality, P. division, editor 2011.
- 13 O'Driscoll DN, Greene CM, Molloy EJ. Immune function? A missing link in the gender disparity in preterm neonatal outcomes. *Expert Rev Clin Immunol* 2017;13:1061–71.
- 14 Einikyte R, Snieckuviene V, Ramasauskaite D, *et al.* The comparison of umbilical cord arterial blood lactate and pH values for predicting short-term neonatal outcomes. *Taiwan J Obstet Gynecol* 2017;56:745–9.
- 15 Ojha RK, Singh SK, Batra S, *et al.* Lactate: creatinine ratio in babies with thin meconium staining of amniotic fluid. *BMC Pediatr* 2006;6:13.
- 16 Mazouri A, Fallah R, Saboute M, *et al.* The prognostic value of the level of lactate in umbilical cord blood in predicting complications of neonates with meconium aspiration syndrome. *J Matern Fetal Neonatal Med* 2021;34:1013–9.
- 17 Pierce J, Gaudier FL, Sanchez-Ramos L. Intrapartum amnioinfusion for meconium-stained fluid: meta-analysis of prospective clinical trials. *Obstet Gynecol* 2000;95:1051–6.
- 18 Fraser WD, Hofmeyr J, Lede R, *et al.* Amnioinfusion for the prevention of the meconium aspiration syndrome. *N Engl J Med* 2005;353:909–17.
- 19 Wiberg N, Källén K. Fetal scalp blood lactate during second stage of labor: determination of reference values and impact of obstetrical interventions. *J Matern Fetal Neonatal Med* 2017;30:612–7.
- 20 Su C-F, Tsai H-J, Huang C-C, *et al.* Fetal acidosis from obstetric interventions during the first vaginal delivery. *Taiwan J Obstet Gynecol* 2008;47:397–401.
- 21 Mongelli DM. Cord blood lactate and pH values at term and perinatal outcome: a retrospective cohort study 2010.
- 22 Wiberg N, Källén K, Herbst A, *et al.* Lactate concentration in umbilical cord blood is gestational age-dependent: a population-based study of 17 867 newborns. *BJOG* 2008;115:704–9.
- 23 Hibbard JU, Hibbard MC, Whalen MP. Umbilical cord blood gases and mortality and morbidity in the very low birth weight infant. *Obstet Gynecol* 1991;78:768–73.
- 24 Kumar N, Yadav A. Role of umbilical cord arterial pH and lactate in newborn assessment of term antenatal women with hypertensive disorders of pregnancy. *Clin Epidemiol Glob Health* 2020;8:927–33.
- 25 Chilinda GK, Gadama LA, Stones W. Point-of-care umbilical arterial lactate and newborn outcomes in a low resource setting: cohort study. *BMC Res Notes* 2018;11:477.