Journal of Acute Disease

Original Article

doi: 10.4103/2221-6189.379275 jadweb.org

Correlation of umbilical cord blood pH, base deficit, and lactate levels with outcomes of hypoxic newborns: A prospective study

Sumbul Qamar, Mohd Ayub Ansari, J. N. Mohapatra, Sana Salim Khan✉

Department of Pediatrics, Hamdard Institute of Medical Sciences and Research, New Delhi, India

ABSTRACT

Objective: To determine the association of the three umbilical cord blood parameters: umbilical cord pH, base deficit, and lactate levels, with neonatal outcomes.

Methods: This prospective observational study was conducted from April 2021 to September 2022 with 100 term and late preterm (>35 weeks) neonates whose umbilical cord blood pH was <7.10, Apgar score was <7 at 1 min, and required positive pressure ventilation. Umbilical cord blood was assessed for pH, base deficit, and blood lactate levels. The neonatal outcomes of neonatal intensive care unit admission, Apgar score at 1 min, and Apgar score at 5 min were assessed.

Results: The mean of umbilical cord blood pH was 7.04±0.07, mean base deficit was (−9.3±3.9) mmol/L, and mean lactate levels were (6.51±2.29) mmol/L. Neonatal intensive care unit (NICU) admission was needed in 78 (78%) neonates. The mean NICU stay length was (2.4±2.2) days ranging from 0 to 12 days with a median of 2 days. Univariate analysis showed no significant difference in cord blood pH (P=0.736) and base deficit (P=0.393) between neonates without NICU admission and neonates who required NICU admission, but lactate level was significantly higher in neonates who required NICU admission (P<0.001). There was no significant difference in cord blood pH (P=0.400) and base deficit (P>0.999) between neonates with Apgar scores 4-7 at 1 min and neonates with Apgar scores <4, but lactate level was significantly higher in neonates with Apgar scores <4 at 1 min (P<0.001).

Conclusions: Umbilical cord blood pH, base deficit, and lactate levels are useful novel markers showing a significant correlation with neonatal intensive care unit admission and adverse neonatal morbidities among hypoxic newborns. Overall, lactate was a better predictor of adverse neonatal outcomes as compared to umbilical cord blood pH and base deficit.

KEYWORDS: Base deficit; Hypoxia; Lactate; Neonates; Outcomes

1. Introduction

Birth hypoxia is a potential threat to neonates because it can lead to acidosis, asphyxia, neuronal injury, and sometimes even death[1,2]. An objective assessment of the development of hypoxia is thus needed in today's medical practice to achieve an early understanding and prediction of adverse neonatal events[3,4].

The parameters which have been conventionally used for measuring acidosis are umbilical cord blood pH and base deficit, also known as negative base excess. Recently, lactate levels have also been employed, which is an easier calculating parameter that requires less amount of blood in comparison to umbilical blood pH and base deficit analysis[3,5].

Studies conducted on the association between acidosis and adverse

Significance

Outcomes of hypoxic newborns remain grave in terms of high neonatal intensive care unitadmission, low APGAR scores and neonatal morbidities. This study found that umbilical cord blood pH, base deficit, and lactate levels are useful novel markers with lactate being the best marker out of the three. The application of the easily measurable parameters (novel markers) may allow for taking appropriate measures for improving the outcomes of hypoxic neonates.

✉To whom correspondence may be addressed. E-mail: drkhan007@gmail.com

How to cite this article: Qamar S, Ansari MA, Mohapatra JN, Khan SS. Correlation of umbilical cord blood pH, base deficit, and lactate levels with outcomes of hypoxic newborns: A prospective study. J Acute Dis 2023; 12(3): 114-120.

Article history: Received 19 April 2023; Revision 15 May 2023; Accepted 21 June 2023; Available online 30 June 2023

neonatal outcomes found that not all infants born with hypoxia will result in adverse consequences[6-8], however, most of them have a high risk of developing adverse events. Hence, the assessment of hypoxic acidosis based on three parameters, umbilical cord blood pH, base deficit, and umbilical cord blood lactate becomes more essential[3,9].

In this regard, we conducted this study to find the association of the three parameters, that is, umbilical cord blood pH, base deficit, and lactate levels with adverse neonatal outcomes and determine the cut-off value that may best and correctly prognosticate the outcomes in neonates so that appropriate measures can be taken for improving the outcomes of neonates.

2. Patients and methods

2.1. Study setting and design

This prospective cohort study was conducted for 12 months (from April 2021 to September 2022) at a tertiary care hospital in New Delhi. Term and late preterm (more than 35 weeks) neonates delivered at the hospital were the participants of the study.

2.2. Ethical approval

A written informed consent was taken from the parents or the guardians of the neonates before enrolling them into the study. Ethical approval was given by the institutional ethical committee (HIMSR/IEC/073/2021, dated 19.03.2021).

2.3. Inclusion and exclusion criteria

Neonates who were term and late preterm (>35 weeks) with an umbilical cord pH of <7.10, Apgar score <7 at 1 min, and required positive pressure ventilation, were included in the study. The newborns who were preterms ≤35 weeks, had major congenital anomalies or structural abnormalities, and not being exclusively breastfed till 6 weeks of age, were excluded from the study.

2.4. Sample collection

Before sample collection, a detailed antenatal history was obtained from the participants, and neonates' details were recorded.

Umbilical cord blood was collected routinely by placing clamps on the umbilical cord so that the collection of the cord blood was done at the middle segment. The cord was cut and clamped from either side and routine care was provided to the mothers and the newborns. Arterial blood gas (ABG) was conducted with a GEM Premier 3500 blood gas analyzer, wherein umbilical cord blood pH, base deficit, and lactate levels were assessed.

2.5. Neonatal outcomes assessment

Neonatal outcomes were assessed in the follow-up period in terms of the need for resuscitation, neonatal intensive care unit (NICU) admission, morbidities of neonatal convulsions, respiratory distress (respiratory rate >60/min or chest retractions or SpO_2 <94%)[10], feed intolerance, hypoglycemia, hypocalcemia (serum calcium <7 mg/dL and ionized calcium <4 mg/dL), and hypothermia (axillary temperature below 36.5 °C). The neonates were followed up for 7 days or till discharge due to development of adverse events.

2.6. Statistical analysis

The sample size calculation was based on a previous study conducted by Knutzen *et al.* which reported a 5.67% prevalence rate of composite adverse outcomes among hypoxic children[11]. Based on this finding, with a 95% confidence interval and a 5% alpha error, the proposed sample size of this study was 100.

Quantitative variables such as "fetus born" were classified as single or twins; birth weight was categorized as small, appropriate, or large for gestational age. Based on the WHO's standard of weight for age, neonates' weight were classified into <10th percentile, 10-90 percentile, or >90th percentile, respectively. The sex of the neonates was classified as male or female.

Statistical analysis was done by IBM SPSS Statistics 23.0 (Chicago, USA), in which data were presented as mean±SD, median, range, and frequency (*n*, %). Fisher's exact test was used for association of cord blood pH, cord blood base deficit (mmol/L) and cord blood lactate (mmol/L) with NICU admission and Apgar score at 5 min. Cord blood pH was associated with Apgar score at 1 min using Chi-square test and cord blood base deficit (mmol/L) and cord blood lactate (mmol/L) were associated with Apgar score at 1 min using

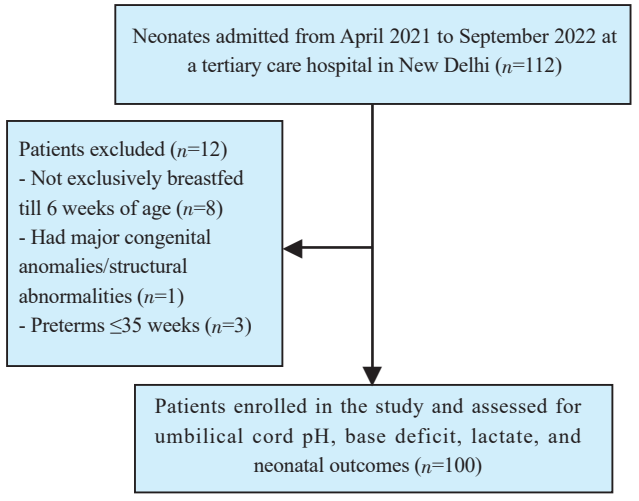

Figure 1. The study flowchart.

Fisher's exact test. Receiver operating characteristic curves (ROC) were employed to find the sensitivity, specificity, positive predictive values, negative predictive values, and diagnostic accuracy of blood parameters: pH, base deficit, lactate in the prediction of neonatal intensive care unit admission and Apgar score at 1 min <4 and 5 min <4. Statistical significance was set at $P<0.05$.

3. Results

At the beginning of the study, 112 neonates admitted to the hospital were considered for the study, out of which 12 were excluded based on exclusion criteria. A total of 100 neonates were enrolled in the study as shown in the study flowchart (Figure 1).

Table 1. Demographic and clinical characteristics.

Parameters	
Fetus, *n*, %	
Single	78 (78%)
Twin	22 (22%)
Period of gestation, week, mean±SD	37.8±1.4
Period of gestation, week, mean±SD	2.9±0.5
Birth weight categories as per POG, *n*, %	
Small for GA	6 (6%)
Appropriate for GA	88 (88%)
Large for GA	6 (6%)
Anthropometry, cm, mean±SD	
Length	53.6±1.2
Head circumference	33.8±0.9
Sex, *n*, %	
Male	55 (55%)
Female	45 (45%)
Apgar score, mean±SD	
at 1 min	2.78±1.39
at 5 min	4.32±0.78
Need for resuscitation, *n*, %	70 (70%)
Tactile stimulation, *n*, %	
Present	100 (100%)
Absent	0 (0%)
BMV > 30 s, *n*, %	
Present	25 (25%)
Absent	75 (75%)
pH, mean±SD	7.04±0.07
Base deficit, mmol/L, mean±SD	−9.3±3.9
Lactate, mmol/L, mean±SD	6.51±2.29
Cord clamping, *n*, %	
Early	65 (65%)
Delayed	35 (35%)
Early neonatal outcomes, *n*, %	
Feed intolerance	53 (53%)
Non-invasive ventilation	63 (63%)
Invasive ventilation	8 (8%)
Antiepileptic use	13 (13%)
Intravenous fluid administration	65 (65%)
NICU admission	78 (78%)
Seizure	14 (14%)
Lethargy	21 (21%)
Respiratory discomfort	76 (76%)

POG: period of gestation; GA: gestational age; BMV: bag & mask ventilation; NICU: neonatal intensive care unit

3.1. Demographics and clinical characteristics

There were 78 (78%) singleton and 22 (22%) twin pregnancies. The median period of gestation was 38 weeks. The median birth weight of the neonates was 3 kg. On comparing birth weight with the period of gestation, 88 (88%) of the neonates had appropriate birth weight for gestation age (GA), while 6 (6%) were small for GA and 6 (6%) were large for GA. The mean length and head circumference were 53.6 cm and 33.8 cm, respectively. Out of the 100 enrolled neonates, 55 (55%) were males and 45 (45%) were females. The mean Apgar scores at 1 min and 5 min were 2.78 and 4.32, respectively. All neonates (100%) were given tactile stimulation. A total of 70 (70%) neonates needed resuscitation. Bag & mask ventilation for > 30 s was needed in 25 (25%) of them. The majority of the neonates (65%) had early cord clamping, and the rest (35%) had delayed cord clamping. For the cord ABG analysis parameters, the mean umbilical cord blood pH was 7.04±0.07, the mean base deficit was (−9.3±3.9) mmol/L, and mean lactate levels were (6.51±2.29) mmol/L (Table 1).

NICU admission was needed in 78 (78%) neonates. The mean NICU stay length ranged from 0 to 12 days with a median of 2 days. Among the early neonatal outcomes, 76 (76%) had respiratory discomfort, 53 (53%) had feed intolerance, and 65 (65%) needed intravenous fluid administration. Lethargy and seizure were present in 21 (21%) and 14 (14%) neonates. Antiepileptic was used in 13 (13%) neonates. Invasive ventilation was used in 8 (8%) subjects, while non-invasive ventilation was used in 62 (62%) among which O_2 by nasal prong was used in 38 (38%) neonates, followed by indigenous continuous positive airway pressure machine 18 (18%) and bubble continuous positive airway pressure machine in 6 (6%) (Table 1).

3.2. Association of arterial blood gas analysis parameters with adverse neonatal outcomes

3.2.1. Neonatal intensive care unit admission

Among the 78 NICU admissions, 67 (85.90%) neonates had low umbilical cord blood pH of <7.1, 77 (98.72%) had excess base deficit (<−1.5 mmol/L) and 67 (85.90%) had excess lactate levels (>4.7 mmol/L). Univariate analysis showed that there was no significant difference in cord blood pH ($P=0.736$) and base deficit ($P=0.393$) between neonates without NICU admission and neonates who required NICU admission, but lactate level was significantly higher in neonates who required NICU admission ($P<0.001$), as shown in Table 2.

3.2.2. Apgar score at 1 min

Apgar score at 1 min was <4 in 63 neonates and 4-7 in 37 neonates. Among the 63 neonates with Apgar score <4, 55 (87.30%) neonates had low umbilical cord blood pH of <7.1, 62 (98.41%) had an excess of base deficit (<−1.5 mmol/L) and 56 (88.89%) had excess lactate levels (>4.7 mmol/L). There was no significant difference in cord blood pH ($P=0.400$) and base deficit ($P>0.999$) between neonates

with Apgar scores 4-7 at 1 min and neonates with Apgar scores <4, but lactate level was significantly higher in neonates in neonates with Apgar scores <4 at 1 min, (P<0.001) as shown in Table 3.

3.2.3. Apgar score at 5 min

Apgar score at 5 min was <4 in 5 neonates and 4-7 in 95 neonates. Statistically, there was no significant difference in ABG analysis parameters between neonates with low (<4) and high (4-7) Apgar scores at 5 min as shown in Table 4.

3.3. Cut-off values of arterial blood gas analysis for predicting adverse neonatal outcomes

3.3.1. Neonatal intensive care unit admission

All three ABG analysis parameters had significant discriminatory power to predict NICU admission (P<0.001). Discriminatory power of cord blood lactate (mmol/L) (AUC=0.803; 95% *CI*: 0.711-0.876) was excellent while discriminatory power of cord blood pH (AUC=0.735; 95% *CI*: 0.637-0.818) and cord blood base deficit (mmol/L) (AUC=0.759; 95% *CI*: 0.663-0.839) was acceptable. Among all the ABG analysis parameters, cord blood lactate (mmol/L) was the best predictor of NICU admission at a cut-off point of >5.8 mmol/L with a sensitivity and specificity of 73.08% and 86.36%, respectively.

3.3.2. Apgar score at 1 min

All the parameters had significant discriminatory power to predict Apgar score <4 at 1 min (P<0.001) Among them, cord blood lactate (mmol/L) was the best predictor of Apgar score <4 at 1 min at a cut-off point of >6.4 mmol/L with a sensitivity and specificity of 65.08%

Table 2. Univariate analysis of blood parameter variables associated with neonatal intensive care unit admission (n, %).

Arterial blood gas parameters	NICU admission (n=78)	No NICU admission (n=22)	P
Cord blood pH			
Normal (7.1 to 7.35)	11 (14.10%)	4 (18.18%)	0.736*
<7.1	67 (85.90%)	18 (81.82%)	-
Cord blood base deficit (mmol/L)			
Normal (9.3 to -1.5)	1 (1.28%)	1 (4.55%)	0.393*
<-1.5	77 (98.72%)	21 (95.45%)	-
Cord blood lactate (mmol/L)			
Normal (2.55 to 4.7)	9 (11.54%)	11 (50.00%)	<0.001*
< 2.55	2 (2.56%)	1 (4.55%)	-
> 4.7	67 (85.90%)	10 (45.45%)	-

*Fisher's exact test

Table 3. Univariate analysis of blood parameter variables associated with Apgar score at 1 min (n, %).

Arterial blood gas parameters	<4 (n=63)	4–7 (n=37)	P
Cord blood pH			
Normal (7.1 to 7.35)	8 (12.70%)	7 (18.92%)	0.400#
<7.1	55 (87.30%)	30 (81.08%)	-
Cord blood base deficit (mmol/L)			
Normal (9.3 to -1.5)	1 (1.59%)	1 (2.70%)	>0.999*
<-1.5	62 (98.41%)	36 (97.30%)	-
Cord blood lactate (mmol/L)			
Normal (2.55 to 4.7)	6 (9.52%)	14 (37.84%)	<0.001*
< 2.55	1 (1.59%)	2 (5.41%)	-
> 4.7	56 (88.89%)	21 (56.76%)	-

#Chi square test, *Fisher's exact test

Table 4. Univariate analysis of blood parameter variables associated with Apgar score at 5 min (n, %).

Arterial blood gas parameters	<4 (n=5)	4–7 (n=95)	P
Cord blood pH			
Normal (7.1 to 7.35)	0 (0.00%)	15 (15.79%)	>0.999*
<7.1	5 (100.00%)	80 (84.21%)	-
Cord blood base deficit (mmol/L)			
Normal (9.3 to -1.5)	0 (0.00%)	2 (2.11%)	>0.999*
<-1.5	5 (100.00%)	93 (97.89%)	-
Cord blood lactate (mmol/L)			
Normal (2.55 to 4.7)	0 (0.00%)	20 (21.05%)	0.641*
< 2.55	0 (0.00%)	3 (3.16%)	-
> 4.7	5 (100.00%)	72 (75.79%)	-

*Fisher's exact test

and 81.08%. In comparison, blood pH at a cut-off of ≤ 7.06 had a sensitivity and specificity of 76.19% and 75.68% while base deficit had a sensitivity and specificity of 84.13% and 48.65%, respectively.

3.3.3. Apgar score at 5 min

All the parameters had significant discriminatory power to predict Apgar score <4 at 5 min (P<0.001). Interpretation of the area under the ROC curve showed that the performance of cord blood lactate (mmol/L) (AUC=0.939; 95% *CI*: 0.873-0.977) was outstanding while the discriminatory power of cord blood pH (AUC=0.864; 95% *CI*: 0.781-0.925) and cord blood base deficit (mmol/L) (AUC=0.867; 95% *CI*: 0.785-0.927) was excellent. Among all the parameters, cord blood lactate (mmol/L) was the best predictor of Apgar score <4 at 5 min at a cut-off point of >8.6 mmol/L with a sensitivity and specificity of 100% and 88.42% as shown in Table 5. The ROC curves for the ABG analysis parameters for prediction of the adverse neonatal outcomes are shown in Figure 2A-C.

4. Discussion

The study objectively determined the role that umbilical cord blood pH, base deficit, and lactate levels played in the outcomes of hypoxic newborns. The results hold significance as we found that all three parameters at the individual cut-off values carry a significant accuracy for prediction of Apgar scores and NICU admission. Among the three parameters, only higher lactate levels showed a relationship with NICU admissions.

Among other studies, different parameters have shown different associations. Eltaieb *et al.* found that both umbilical cord blood lactate levels and umbilical cord arterial pH showed a significant association with Apgar score <7 at 1 and 5 min, NICU admission, and unfavorable neonatal clinical outcomes[5]. Kumar *et al.* also found that cord arterial blood pH showed a significant association with low Apgar scores, requirement of neonatal resuscitation, NICU admission, and occurrence of neonatal complications (P<0.05) [12]. It was also found that cord arterial blood pH values <7.2 lead to more neonatal resuscitation (44.6%), NICU admission (67.6%), early neonatal complications (53.4%), and early neonatal death (10.1%)[12]. Similarly, higher lactate levels resulted in higher rates of neonatal resuscitation (61.6%), NICU admission (90.2%), early neonatal complications (72.3%), and early neonatal death (14.3%) [12]. Furthermore, Gamboa *et al.* found that among the neonates with acidemia, pH, base deficit, and lactate showed an association with adverse outcomes, including global, systemic, and neurological morbidities[13]. In addition, Tuuli *et al.* found that both arterial

Table 5. Receiver operating characteristic analysis of blood parameters in the prediction of neonatal intensive care unit admission and Apgar score at 1 and 5 min.

Variables	Cut-off	AUC (95% *CI*))	Sensitivity (%)	Specificity (%)	*P*
For NICU admission prediction					
pH	≤7.04	0.735 (0.637-0.818)	56.41	90.91	<0.001*
Base deficit (mmol/L)	≤−6.4	0.759 (0.663-0.839)	82.05	63.64	<0.001*
Lactate (mmol/L)	>5.8	0.803 (0.711-0.876)	73.08	86.36	<0.001*
For Apgar score <4 at 1 min prediction					
pH	≤7.06	0.733 (0.635-0.816)	76.19	75.68	<0.001*
Base deficit (mmol/L)	≤−6.4	0.693 (0.592-0.781)	84.13	48.65	<0.001*
Lactate (mmol/L)	>6.4	0.769 (0.675-0.848)	65.08	81.08	<0.001*
For Apgar score <4 at 1 min prediction					
pH	≤7.01	0.864 (0.781-0.925)	100.00	73.68	<0.001*
Base deficit (mmol/L)	≤−12.0	0.867 (0.785-0.927)	100.00	80.00	<0.001*
Lactate (mmol/L)	>8.6	0.939 (0.873-0.977)	100.00	88.42	<0.001*

NICU: neonatal intensive care unit. *Significant at α=0.05.

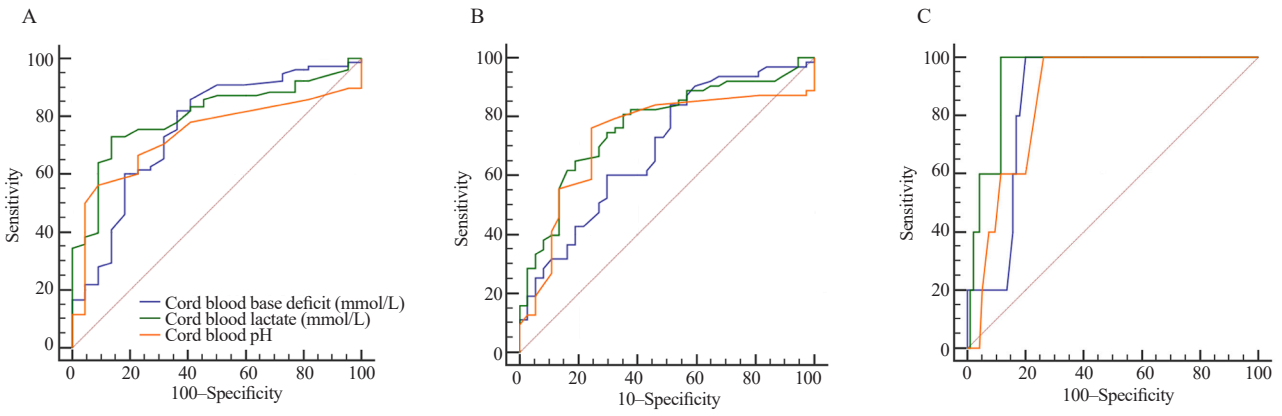

Figure 2. (A) Receiver operating characteristic (ROC) analysis of blood parameters in the prediction of neonatal intensive care unit admission. (B) ROC analysis of blood parameters in the prediction of Apgar score at 1 min. (C) ROC analysis of blood parameters in the prediction of Apgar score at 5 min.

lactate and pH showed an association with the composite morbidity in neonates[14]. Also, the difference was more significant for lactate compared to that for pH as the mean lactate levels were about two-fold greater in those with the composite neonatal morbidity (6.49 mmol/L *vs.* 3.26 mmol/L), whereas the values of mean pH were less distinct (7.19 mmol/L *vs.* 7.29 mmol/L) (P<0.001 for both). The different findings of other studies with respect to our study may be because of population heterogeneity and variable condition of the neonates. However, almost all studies showed that higher lactate levels were associated with adverse neonatal outcomes.

On comparing ABG analysis parameters, we found that as per the ROC curves, lactate had the highest AUC for predicting NICU admission and low Apgar scores. Similar findings were reported by Kumar *et al.* who found that on plotting ROC curves for predicting neonatal mortality in hypoxic babies, the AUCs for cord blood lactate and arterial pH were 0.967 and 0.870, respectively, indicating lactate to be a superior marker[12].

Likewise, Eltaieb *et al.* observed that on plotting ROC curves, the AUCs for serum lactate levels and umbilical artery pH were in the range of 0.8-0.9 and 0.7-0.8, respectively for predicting the neonatal clinical outcomes, which suggested serum lactate levels to be an outstanding test for prediction of neonatal outcomes as compared to umbilical artery pH[5]. Gamboa *et al.* also reported that lactate had a significantly better ability to predicate global and neurological morbidity in comparison with pH and base deficit, but the ability to predicate systemic morbidity was similar[13].

Neacsu *et al.*'s finding supported that lactate and umbilical cord pH are accurate predictors of neonatal morbidity caused by intrapartum hypoxia at a cut-off value of 3.75 mmol/L and 7.24 respectively with lactate being a superior marker to pH[15]. This was also supported by Eltaieb *et al.*,who also observed serum lactate levels to be better than umbilical artery pH in predicting neonatal mortality[5]. Even, Kumar *et al.* found cord blood lactate to be better compared to cord blood arterial pH in predicting neonatal mortality[12]. Gamboa *et al.* also found lactate to be better than pH and base deficit in predicting morbidities, but the difference was insignificant[13]. Moreover, Neacsu *et al.* reported that lactate proved to be superior to pH in terms of prediction of adverse neonatal outcomes[15]. So overall, lactate can be used as a superior marker as compared to pH and base deficit.

The superiority of lactate as a marker for predicting adverse neonatal outcomes in comparison to umbilical cord blood pH and base deficit might be ascribed to the reason that lactate is the end product of anaerobic metabolism and it is an objectively measured substance produced as a result of continuous hypoxia[16]. Moreover, this nature has also been used among adult patients for predicting mortality in a critical care setup[17].

One of the drawbacks of this study is the small sample size. In this study, an objective method was used for estimating the "optimal" cut-off values of lactate that were based on the maximal Youden index and these values cannot be used for preterm neonates, which is also a limitation of this study.

In conclusion, umbilical cord pH, base deficit, and lactate levels are novel markers for predicting adverse neonatal outcomes in hypoxic newborns. Among the three parameters, lactate holds the highest accuracy in predicting NICU admission and low Apgar scores. Moreover, all three parameters hold a direct correlation with NICU admission and thus may be used practically for the management of newborns.

Conflict of interest statement

The authors report no conflict of interest.

Funding

This study received no extramural funding.

Authors' contributions

SQ defined the intellectual content, performed literature search, conducted the clinical study, and edited the manuscript. MAA performed statistical analysis. All authors contributed to developing concepts, designing the study, acquiring data, analyzing data, preparing and reviewing the manuscript.

References

[1] Admasu FT, Melese BD, Amare TJ, Zewude EA, Denku CY, Dejenie TA. The magnitude of neonatal asphyxia and its associated factors among newborns in public hospitals of North Gondar Zone, Northwest Ethiopia: A cross-sectional study. *PLoS One* 2022; **17**(3): e0264816.

[2] Lemma K, Misker D, Kassa M, Abdulkadir H, Otayto K. Determinants of birth asphyxia among newborn live births in public hospitals of Gamo and Gofa zones, Southern Ethiopia. *BMC Pediatr* 2022; **22**(1): 280.

[3] Allanson ER, Waqar T, White C, Tunçalp Ö, Dickinson JE. Umbilical lactate as a measure of acidosis and predictor of neonatal risk: A systematic review. *BJOG* 2017; **124**(4): 584-594.

[4] Yilmaz S, Kuskucu A, Horoz OO, Suakar O, Imamova N, Gongor G, et al. Polymorphism of hypoxia-inducible factor-1 α gene in pediatric acute respiratory distress syndrome. *J Acute Dis* 2019; **8**: 67-71.

[5] Eltaieb E, Elkholy H. Umbilical cord arterial blood gas study and cord blood lactate predictability for unfavorable neonatal outcomes. *Int Gyn Women's Health* 2018; **1**(5): 104-110.

[6] Sundberg TM, Wiberg N, Källén K, Zaigham M. Adverse neonatal outcome and veno-arterial differences in umbilical cord blood pH (ΔpH) at birth: A population-based study of 108,629 newborns. *BMC Pregnancy Childbirth* 2023; **23**(1): 162.

[7] Yeh P, Emary K, Impey L. The relationship between umbilical cord arterial pH and serious adverse neonatal outcome: Analysis of 51,519 consecutive validated samples. *BJOG* 2012; **119**(7): 824-831.

[8] Hafstrom M, Ehnberg S, Blad S, Noren H, Renman C, Rosen KG, et al. Developmental outcome at 6.5 years after acidosis in term newborns: A population-based study. *Pediatrics* 2012; **129**(6): e1501-e1507.

[9] Labrecque L, Provencal M, Caqueret A, Wo BL, Bujold E, Lariviere F, et al. Correlation of cord blood pH, base excess, and lactate concentration measured with a portable device for identifying fetal acidosis. *J Obstet Gynaecol Can* 2014; **36**(7): 598-604.

[10]Mathai SS, Raju U, Kanitkar M. Management of respiratory distress in the newborn. *Med J Armed Forces India* 2007; **63**(3): 269-272.

[11]Knutzen L, Svirko E, Impey L. The significance of base deficit in acidemic term neonates. *Am J Obstet Gynecol* 2015; **213**(3): 373.e1-373.e3737.

[12]Kumar N, Yadav A. Umbilical cord arterial blood lactate dehydrogenase and pH as predictors of perinatal outcome in high-risk term pregnancies: A cohort study. *JMC* 2022; **26**(1): 27-34.

[13]Gamboa SM, Pascual Mancho J, Rodrigo Rodríguez M, Ruiz Sada J, Castán Mateo S. pH, base deficit or lactate, which is better for predicting neonatal morbidity? *J Matern Fetal Neonatal Med* 2017; **30**(19): 2367-2371.

[14]Tuuli MG, Stout MJ, Shanks A, Odibo AO, Macones GA, Cahill AG. Umbilical cord arterial lactate compared with pH for predicting neonatal morbidity at term. *Obstet Gynecol* 2014; **124**(4): 756-761.

[15]Neacsu A, Herghelegiu CG, Voinea S, Dimitriu MC, Ples L, Bohiltea RE, et al. Umbilical cord lactate compared with pH as predictors of intrapartum asphyxia. *Exp Ther Med* 2021; **21**(1): 80.

[16]Wiberg N, Källén K, Herbst A, Olofsson P. Relation between umbilical cord blood pH, base deficit, lactate, 5-minute Apgar score and development of hypoxic ischemic encephalopathy. *Acta Obstet Gynecol Scand* 2010; **89**(10): 1263-1269.

[17]Tontu F, Asar S, Oren Bilgin B. Effect of pH, lactate, electrolyte, and strong ion difference variability on prediction of intensive care unit mortality: A retrospective study. *J Acute Dis* 2022; **11**(5): 194-198.

Publisher's note