Experimental
&
Clinical Article

Cord Blood pH and Lactate- A Step Ahead in Diagnosis of Fetal Acidaemia in Patients with Abnormal Cardiotocography

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ABSTRACT

OBJECTIVES: Electronic fetal monitoring (EFM) is used to identify early signs of fetal deterioration. However, caution is advised when interpreting cardiotocographic parameters. A promising alternative is umbilical cord blood sampling. The analysis of blood gases and lactate levels in the cord within the initial minutes of life is a recommended approach.

STUDY DESIGN: This prospective cohort study, conducted over eighteen months from June 2021 to December 2022, enrolled 70 patients with non-reactive and 70 with reactive cardiotocograph (CTG) patterns. APGAR scores were recorded at 1 and 5-minute intervals. 1 ml of umbilical artery blood was assessed in an arterial blood gas machine and fetal acidosis was defined as pH <7.0 and a lactate concentration exceeding 4 mmol/L.

RESULTS: In the non-reactive CTG group, 35.7% had early decelerations, 37.1% had variable decelerations, and 17.1% had late decelerations (p<0.001). The mean cord blood lactate was 5.220±1.970 mmol/L in the non-reactive CTG group and 3.400±0.228 mmol/L in the reactive CTG group. Similarly, the mean cord blood pH was 7.030±0.007 in the non-reactive CTG group and 7.170±0.076 in the reactive CTG group (p<0.001). 14.3% of cases in the non-reactive CTG group had a 5-minute APGAR <7, with a higher APGAR score in the reactive group.

CONCLUSION: The study suggests that abnormal or indeterminate CTG readings are linked to a higher risk of intrapartum fetal acidosis. Non-reactive CTG results were associated with higher mean cord blood lactate and pH levels and more number of Neonatal Intensive Care Unit (NICU) admissions. There is a definite correlation between abnormal CTG patterns and poorer neonatal outcomes.

Keywords: Cord blood pH; Electronic fetal monitoring; Fetal distress; Intrapartum; Lactate

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Introduction

In contemporary obstetrics, the rising cesarean section rates prompt a critical examination of intrapartum Electronic Fetal Monitoring (EFM) tracings as vital evidence in adverse events. While EFM has long been regarded as a dependable marker for detecting early signs of fetal hypoxia, caution is warranted in interpreting CTG parameters for asphyxia due to their low positive predictive value for non-reassuring patterns. An abnormal trace yields a 50-65% likelihood of predicting a very low APGAR score, contributing to erroneous diagnoses of fetal distress and subsequently escalating cesarean section rates (1).

Fetal distress, linked to oxygen deprivation, is a significant driver of cesarean section rates, affecting around 29.1% of pregnancies and ranking as the third leading cause of neonatal mortality (2). Hypoxia often occurs during labor and pregnancy, prompting cells to shift from aerobic to anaerobic metabolism, resulting in lactate and H^+ production. Newborn metabolic acidosis, indicative of asphyxia, is characterized by umbilical artery pH <7.0, lactate values > 4.1 mmol/L, and base deficit (BD) >12 mmol/L (3,4). Meconium staining of amniotic fluid, typically benign showing gut maturation, can pose risks when coupled with fetal acidaemia. Meconium aspiration, tied to unpredictable episodes of acidaemia, is considered an obstetrical hazard (5).

Neuronal loss during the asphyxial event (primary neu-

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ronal necrosis) and subsequent processes (secondary neuronal necrosis) contribute to motor and cognitive impairments (6). Cord blood gas sampling stands out as an effective approach for detecting fetal hypoxia, recommended routinely by the Society of Obstetricians and Gynaecologists of Canada Guidelines for neonates (7). Cord blood gas analysis offers more reliable evidence of asphyxia than clinical assessments like the APGAR score (8,9). The intricate relationship between hypoxia and fetal heart rate changes remains unclear, contributing to inaccuracies in diagnosing asphyxia solely based on cardiotocography. This study seeks to scrutinize EFM limitations and the pathophysiological basis of birth asphyxia by correlating suspicious tracings with umbilical cord pH values and lactate levels.

Material and Method

The primary objective of the study was to find out the association between cardiotocograph and cord blood pH and lactate levels. The secondary goals were to explore the connection between abnormal CTG traces, cord blood pH, and lactate levels, considering different delivery modes and meconium staining of liquor. Additionally, neonatal outcomes in each scenario were examined.

Study design and Study population: This prospective cohort study encompassed patients registered at our Antenatal Out Patient Department (OPD), transitioning to the labor room and ward during labor, across eighteen months (Jun 2021 to Dec 2022) at our tertiary care center in Western Maharashtra, India. A sample size of 140 was calculated using a Two-tailed Test assuming an alpha error of 5% and power of the study of 80%.

The research included 70 pregnant women with non-reactive CTG and an equal number with reactive CTG. The sample size was based on the parameters of testing the difference in the proportion of normal lactate levels to non-stress test/cardiotocographic findings and testing the difference in the proportion of abnormal pH levels to non-stress test/cardiotocographic findings.

The study's inclusion criteria encompassed term patients admitted to the labor room or antenatal ward with singleton pregnancy, cephalic presentation, and ages ranging from 20 to 35 years. Exclusion criteria involved cases with multifetal pregnancy or malpresentation, pre-existing chronic maternal illnesses, polyhydramnios or oligohydramnios, preterm labor, and anomalous fetuses.

Methodology: Following thorough clinical assessments and obtaining informed consent, the study subjects were closely observed during labor, with continuous monitoring of fetal heart rate using a standardized cardiotocography machine equipped with an external transducer. The transducer was affixed to the maternal abdominal wall, and the CTG tracings, produced at a paper speed of 1 cm/min, were utilized to diagnose fetal distress. These tracings were meticulously recorded for further analysis. Using the three-tiered system of the American College of Obstetricians and Gynecologists 2010 (ACOG) Bulletin, a reactive CTG was defined as a Category I trace (10). Category I trace included normal traces carried out over 20 minutes with at least two FHR accelerations associated with fetal movements, with a normal baseline of 110 -160 beats per minute, moderate fetal heart variability, absent late/variable decelerations, and present/absent early decelerations.

Non-Reactive CTG included Category II and III traces. Category II traces included all those not defined by Category I and III. Category III traces included Absent baseline FHR variability and Recurrent late decelerations/Recurrent variable decelerations/Bradycardia/Sinusoidal pattern.

In cases where meconium-stained amniotic fluid was identified after spontaneous or induced rupture of membranes, the correlation with cardiotocography findings was recorded. APGAR scores were documented at 1 and 5 minutes post-delivery.

Upon clamping the umbilical cord and delivering the baby, aseptically collected one milliliter of umbilical arterial blood was obtained using a heparinized syringe. This blood was subsequently evaluated in a standardized arterial blood gas (ABG) machine to assess fetal acidosis. Fetal acidosis was defined as a pH level below 7.0 or a lactate level exceeding 4 mmol/L.

Results

The two groups of 70 women each with reactive and non-reactive CTG findings were similar with regard to antepartum variables i.e., maternal age, gravidity, parity, and gestational age. The mean gestational age was 37.70±2.51 weeks for the reactive CTG group and 38.31±1.40 weeks for the non-reactive CTG group which was similar statistically when the t-test was applied (p=0.069). The gestational age in weeks was grouped and the chi-square test was applied as depicted in Table 1 between two groups and that was not statistically significant (P>0.05).

Table I: *Distribution of gestational age*

Gestational age (Completed weeks)	Reactive CTG*	Non-Reactive CTG*	Chi-square test
< 37 weeks	6 (8.6%)	4 (5.7%)	
37 weeks	13 (18.6%)	14 (20%)	χ^2=10.072 p=0.226
38 weeks	27 (38.6%)	20 (28.6%)	
39 weeks	15 (21.4%)	16 (22.9%)	
40 weeks	9 (12.9%)	16 (22.9%)	
Total	70 (100%)	70 (100%)	

**Cardiotocograph*

The bar diagram (Figure 1) given below shows the mode of delivery in study groups. The majority in the reactive CTG group had a normal vaginal delivery (60%) and in the non-reactive CTG group majority underwent lower segment cesarean section (65.7%). Also, we found that the non-reactive CTG group (12.9%) had a higher rate of vacuum and forceps-assisted delivery (12.9%) compared to the reactive CTG group (1.4%). This difference was statistically significant when the chi-square test was applied (p<0.001).

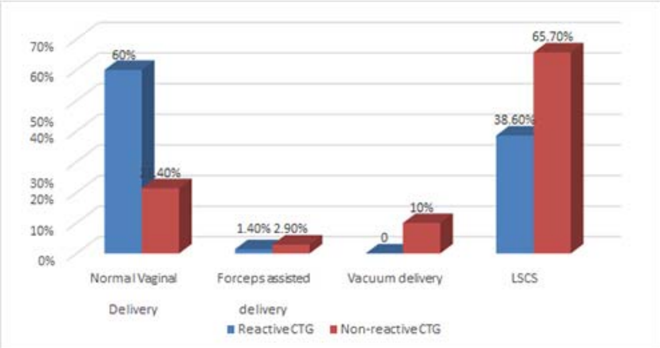

***Figure 1:** Bar diagram showing the mode of delivery among study groups*

Early decelerations were present in 35.7% of the non-reactive CTG group, 37.1% had variable decelerations, and 17.1% had late decelerations, however, there were no decelerations observed in the reactive CTG group as depicted in Figure 2.

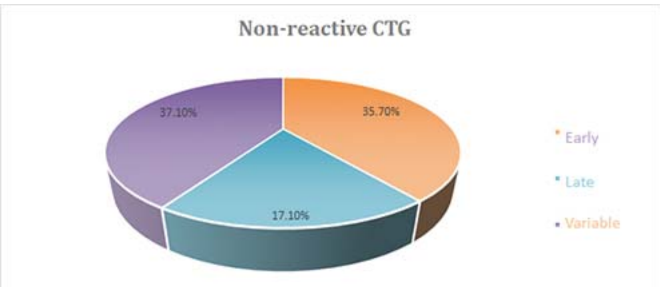

***Figure 2:** Pie-chart showing the type of decelerations in non-reactive Cardiotocograph (CTG)*

Mean cord blood lactate among non-reactive CTG group cases was 5.220±1.970 mmol/L and in reactive CTG cases was 3.400±0.220 mmol/L. The line graph in Figure 3 illustrates that the difference in mean cord blood lactate was statistically significant. The mean cord blood pH among non-reactive CTG group cases was 7.030±0.000 and in reactive CTG cases was 7.170±0.070. This difference in mean cord blood pH was statistically significant (p<0.001).

There was no significant difference in mean cord blood lactate and blood pH among deceleration categories in the non-reactive CTG group (p>0.05) as depicted in Figure 4.

In our study, we have classified the colour of amniotic fluid as, clear, thin/ thick meconium. Figure 5 shows the nature of amniotic fluid in study groups. The reactive CTG group had clear amniotic fluid in all cases and in the non-reactive CTG group, about 54.3% of cases had meconium-stained liquor and this difference is statistically significant

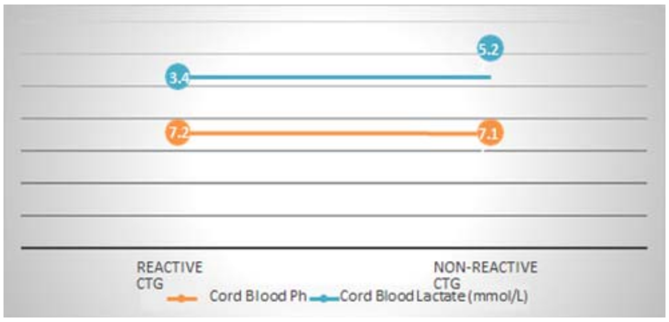

***Figure 3:** Line graph showing Cord Blood Lactate (mmol/L) and Cord Blood pH comparison*

(p<0.001).

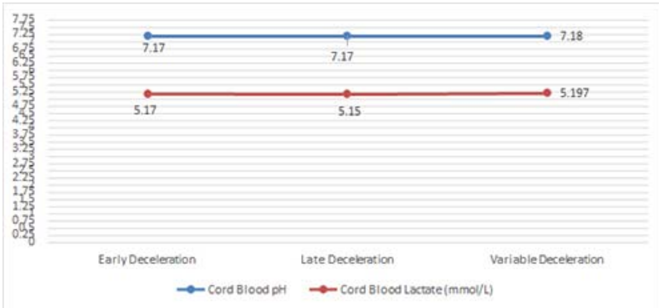

***Figure 4:** Line graph showing cord blood lactate(mmol/L) and cord blood pH comparison in deceleration category in non-reactive Cardiotocograph (CTG) group*

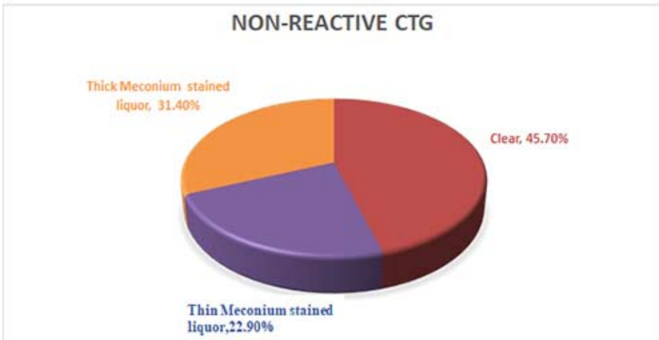

***Figure 5:** Pie chart showing the nature of amniotic fluid among in non-reactive Cardiotocograph (CTG) group*

The 1 min APGAR <7 was seen in 1.4% of the reactive CTG group and 41.4% in non-reactive CTG group. The mean APGAR score in the reactive CTG group was 7.01 and in the non-reactive CTG group was 5.90 and the difference in the occurrence of APGAR score <7 was statistically significant (p<0.001) as depicted in Table 2. None of the reactive CTG group cases had 5 min APGAR <7 but 14.3% in the non-reactive CTG group had 5 min APGAR <7. The mean APGAR score in the reactive CTG group was 9.03 and in the non-reactive CTG group was 8.14 and the difference in the occurrence of the APGAR score <7 was statistically significant (p<0.001).

***Table II:** APGAR Score at 1 and 5 minutes in the Study group*

APGAR Score (At 1 min)	Reactive CTG*	Non-Reactive CTG*	Chi-square test
<7	1 (1.4%)	29 (41.4%)	χ^2=33.261
≥7	69 (98.5%)	41(58.6%)	p <0.001
Total	70 (100%)	70 (100%)	-
APGAR Score (At 5 min)			
<9	1 (1.4%)	27 (38.6%)	χ^2=30.18
≥9	69 (98.5%)	43 (61.4%)	p <0.001
Total	70 (100%)	70 (100%)	

**Cardiotocograph*

The majority of the patients as shown in Figure 6, in the reactive CTG group had no Neonatal Intensive Care Unit admission (NICU) and in the non-reactive CTG group, 15.7% had NICU admission at birth for various morbidities like birth asphyxia, neonatal seizures, and meconium aspiration. This difference was statistically significant when the chi-square test was applied ($p<0.05$).

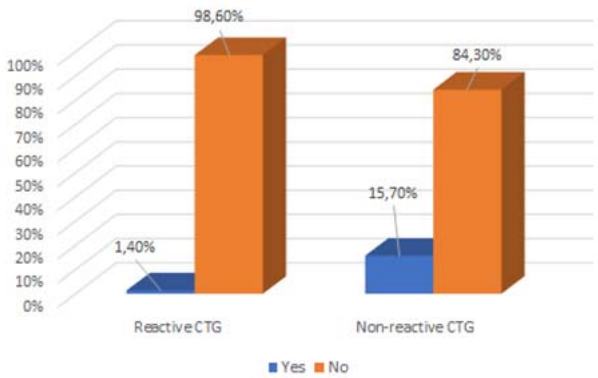

***Figure 6:** Bar Diagram showing admission to NICU in the Reactive and the Non Reactive CTG groups*

Discussion

The evolution of fetal heart rate monitoring since the 1960s has led to the widespread adoption of cardiotocography, a continuous electronic method, replacing traditional approaches. Despite its prevalence, CTG has not shown clear superiority over intermittent auscultation for low-risk pregnancies in terms of maternal and neonatal outcomes (11,12). Emerging techniques like cordocentesis, involving ultrasound-guided aspiration of umbilical cord blood, have gained prominence (13). This procedure aids in identifying hypoxia that can lead to central nervous system damage resulting in lifelong disabilities such as mental retardation, epilepsy, and cerebral palsy (14,15).

Various international organizations offer differing recommendations for umbilical artery and vein blood sample usage. The Society of Obstetricians and Gynaecology Canada advises measuring both, with arterial sampling preferred if only one is possible (7). Conversely, ACOG suggests umbilical artery sampling for cord blood gases selectively (15), while the Royal College of Obstetricians and Gynaecologists (2001) recommends minimum selective umbilical artery acid-base status assessment (16).

pH is vital in detecting fetal hypoxia, crucial for quantifying perinatal asphyxia. The umbilical cord's base deficit/base excess acts as the ultimate threshold, effectively distinguishing respiratory and metabolic acidosis. Metabolic acidosis arises when oxygen depletion in tissues hampers aerobic glucose metabolism, forcing cells into less efficient anaerobic pathways. Consequently, ATP production drops, causing an accumulation of metabolic acids, primarily lactic acid, impacting cell function and survival (17,18).

This study involved 70 pregnant women with non-reactive CTG and 70 with reactive CTG, with comparable antepartum variables i.e., maternal age, gravidity, parity, and gestational age.

Non-reassuring fetal heart rate (FHR) patterns are prevalent in up to 60% of preterm labor cases, often manifesting as deceleration and bradycardia. A study following ACOG Bulletin 2009 revealed 8.6% preterm births in reactive CTG, 5.7% in non-reactive CTG, and 91.4% term pregnancies in the former group (19). Gestational age exhibited no significant distinction between both groups. Intriguingly, Wiberg N et al. demonstrated a surge in mean umbilical cord blood lactate levels after 34 gestational weeks (20).

In our study, late deceleration was the most common non-reactive CTG finding (37.1%). ACOG noted FHR accelerations as reassuring (19). Holzmann et al. found high lactacidemia frequency with late/severe variable decelerations and tachycardia (21).

The presence of meconium-stained liquor was observed in 44.3% of cases in the non-reactive CTG group. None of the reactive CTG groups had meconium-stained liquor. According to research by Upadhyay M et al, the passing of meconium is a less reliable sign of intrapartum suffocation than an unsettling fetal heart rate (22).

In our study, among the non-reactive CTG group, 46 cases (65.7%) had lower segment cesarean section (LSCS), among them 11 had early decelerations, 7 had late decelerations and 22 had variable decelerations. We found a strong correlation between the mode of delivery and cord lactate and pH levels. In a study by Guta Kune et al, cesarean and assisted vaginal birth had a 4-6-fold higher rate of birth asphyxia compared to those who delivered by spontaneous vaginal delivery (23). In our study, LSCS was performed on 38.6% of the non-reactive CTG group and 65.7% of the reactive CTG group. Although there is a statistically significant difference in how cases and controls were delivered, this does not affect the outcomes of the study.

In 1952, Virginia APGAR introduced the APGAR score for swift newborn health assessment. Our study revealed that at one minute, <7 APGAR scores were prevalent in 98.5% of reactive CTG cases and 58.6% of non-reactive ones. Similar trends were observed (<9 scores) at five minutes, with 98.5% and 61.4% for reactive and non-reactive CTG groups, respectively. Statistically, significant differences existed in scores at both time points. Notably, lower APGAR scores (<7) correlated with seven NICU admissions, and scores <9 resulted in six NICU hospitalizations. Improved APGAR scores corresponded to reduced NICU admissions.

In the non-reactive group, those with late deceleration had a mean 1-minute APGAR of 4.1, while early deceleration patients had 6.2, and variable deceleration patients had 6.5.

A study by Khoshnow and Mongelli demonstrated that elevated neonatal cord blood lactate is a noteworthy indicator of diminished APGAR scores, wherein all infants with low scores at 5 minutes exhibited metabolic acidosis and required NICU admission (24). Sykes GS et al's research involving 1210 infants revealed that only 21% of newborns with a 1-minute APGAR score of 7 and 19% with a 5-minute APGAR score of 7 had severe acidosis (25). Intriguingly, 73% of those with severe acidosis received an APGAR score of 7 at 1 minute and 86% at 5 minutes. Interestingly, in our study, fewer infants with lactic acidosis had low APGAR scores, possibly due to the fetal catecholamine surge in response to hypoxia, potentially enhancing scores by heightening newborn alertness.

1.4% of neonates in the reactive CTG group and 15.7% of newborns in the non-reactive CTG group were admitted to the NICU, respectively. This difference in NICU admission between cases and controls is statistically significant.

Our study revealed a strong correlation between low pH and higher cord blood lactate levels in NICU-admitted infants. Among them, 33 infants with a pH of 7.2 avoided NICU admission, while 8 infants were admitted. When pH dropped below 7.2, NICU admission occurred in 26.09% of cases. Naina Kumar et al. and Ahmadpour Mousa et al. supported our findings regarding newborn outcomes (26,27). Victory et al. observed increasing acidemia linked to higher NICU admission rates in term infants (28). Syed et al.'s study demonstrated that with pH >7.2, 7.40% of infants needed NICU admission, unlike pH <7.2 where 66.66% of cases needed resuscitation and NICU admission, aligning with our study (29).

Research suggests that a low APGAR score at 5 minutes and significant arterial base deficit predict neonatal morbidity in newborns with umbilical cord arterial pH under 7.00. Moreover, Ali Bijani and Nasseri propose that an umbilical cord pH below 7.2 post-birth serves as a prognostic indicator for adverse short-term outcomes in neonates (27).

Our study revealed noteworthy disparities in mean Cord Blood Lactate levels between non-reactive and reactive CTG groups. Specifically, the non-reactive group exhibited a mean of 5.220±1.970 mmol/L, while the reactive group displayed a mean of 3.400±0.228 mmol/L. This variance in mean cord blood lactate was established as statistically significant.

In a parallel manner, Ray C et al.'s research indicated a correlation between CTG categories and the presence of acidosis (30). Notably, 22.7% of indeterminate CTG cases and 52.5% of abnormal CTG cases demonstrated acidosis, compared to 7.3% in normal CTG cases. Similar trends were observed in the Aboulghar W et al. study, where 19.2% with questionable CTG and 50% with abnormal CTG experienced acidosis, further influenced by pathogenic CTG (31).

This study's outcomes align with Kaban et al.'s investigation, encompassing 101 term pregnant women, wherein 85 newborns had normal cord arterial pH, while 13 exhibited fetal acidosis based on cord arterial pH levels (32). Collectively, these findings reinforce the importance of monitoring cardiotocographic findings and pH parameters during pregnancy.

Lactate's ability to differentiate between respiratory and metabolic acidosis makes it a valuable pH analysis alternative. Prolonged and severe oxygen deprivation leading to anaerobic metabolism triggers metabolic acidemia. Research reveals robust links between CTG and infant early status indicators such as Apgar scores, umbilical artery pH, base excess values, and lactate levels (33,34).

Mean Cord Blood Lactate among non-reactive CTG group cases was 5.22±1.97 mmol/L and in reactive CTG cases was 3.4±0.228 mmol/L. This difference in mean cord blood lactate was statistically significant.

In contrast to pH, lactate in arterial umbilical cord blood may be a more accurate indication of fetal hypoxia at delivery, according to Gjerris and colleagues (35). In the circumstances of the current investigation, higher levels of lactate in neonatal cord blood and lower levels of pH in cord blood indicate the presence of a hypoxic condition. In our investigation, we found a significant relationship between intrapartum hypoxia and cord blood lactate/pH in concurrence with other studies (24,36).

Geetha Damodaran K et al. conducted a descriptive cross-sectional study on the APGAR score and levels of lactate and creatinine in umbilical cord blood in perinatal asphyxia, concluding that cord blood lactate assay of newborns will help to evaluate the severity of anoxia and it will remove any subjective errors produced during the clinical assessment of newborn babies by APGAR score (37). Similarly, Borruto F et al. found that infants suffering from suffocation have higher lactate levels, and there is a direct link between fetal distress and lactic acidosis (38). This was further validated by Varkilova et al who found that higher lactate levels after birth were a stronger indicator of severe Hypoxic Ischaemic Encephalopathy (39).

Therefore, it may be concluded that cord blood lactate levels are the most sensitive parameter for diagnosing fetal asphyxia and should be carried out in all high-risk births. This may help in providing the newborn with the proper care at birth as well as in preventing and reducing neonatal morbidity and mortality.

Conclusion

Our study aimed to establish a connection between CTG tracings and key markers, including umbilical cord pH and lactate values. The results underscored a significant finding: instances of abnormal or indeterminate CTG patterns that were strongly linked to a heightened likelihood of intrapartum fetal acidosis. Conversely, the presence of a normal CTG pattern correlated with a reduced probability of such acidosis. Additionally, the study revealed elevated mean cord blood lactate levels in cases where CTG readings indicated a lack of fetal reactivity.

While electronic fetal monitoring has gained widespread adoption, it's important to note that the conventional interpretation of late decelerations-historically indicative of poor neonatal outcomes, predicted acidosis in less than half of cases. As we endeavor to maximize the benefits of EFM, refining assessment strategies for accurately gauging fetal pH remains a pivotal objective within the field of obstetrics. Achieving this objective would allow for more precise interventions, targeting interventions specifically toward fetuses facing genuine risks.

Ultimately, this study underscores the critical role of effective cardiotocographic monitoring during labor in mitigating neonatal morbidity and mortality rates. However, it's essential to recognize a notable constraint or limitation in assessing fetal acid-base status, as it involves invasive procedures that may not be universally accessible across medical centers. As we confront this challenge, the potential to enhance neonatal outcomes through strategic and well-considered interventions remains an ongoing priority.

Declarations

Ethics approval and consent to participate: All participants signed informed written consent before being enrolled in the study. The study was reviewed and approved by the ethics committee of AFMC (Ethics approval reference number: IEC/2021 date 09.01.2021. All procedures were performed according to the Declaration of Helsinki.
Availability of data and materials: The data supporting this study is available through the corresponding author upon reasonable request.
Competing interests: The authors declare that they have no competing interests.
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Authors' contributions: Concept: I.M., Design: I.M., Data Collection or Processing: SK., I.M., Analysis, and Interpretation: S.S., Literature Search: S.K.., I.M., Writing: Y.D., Critical Review: S.S. All authors have read and approved the final manuscript.
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This research was based on a university Thesis.
Data would be available on request.

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