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# Umbilical Cord Blood LDH and Delta (Δ) PH as Predictors of Perinatal Outcome in High-Risk Pregnancies

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**Abstract:** ***Objectives*: High-risk pregnancies are associated with increased risk of fetal hypoxia, metabolic acidosis, and adverse neonatal outcomes. Umbilical cord blood analysis provides an objective assessment of fetal metabolic status at birth. Lactate dehydrogenase (LDH) and delta pH (ΔpH) have emerged as potential predictors of neonatal compromise. The study was conducted to evaluate the association of umbilical cord blood LDH and ΔpH with immediate neonatal outcomes in term high-risk pregnancies. *Methods*: This prospective observational study was conducted over two years in the Department of Paediatrics at tertiary care teaching hospital. Sixty term neonates born to high-risk mothers were included. Umbilical cord blood samples were collected immediately after delivery for estimation of LDH and pH. ΔpH was calculated as the difference between umbilical venous and arterial pH. Neonates were assessed using Apgar scores and monitored for resuscitation requirement, oxygen therapy, NICU admission, delayed feeding, convulsions, and hypoxic ischemic encephalopathy (HIE). *Results*: The mean cord blood LDH was 565 ± 339 U/L and mean ΔpH was 0.08 ± 0.04. Neonates with high ΔpH (>0.08) had significantly lower umbilical arterial pH and higher LDH levels (964 ± 213 U/L vs 333 ± 84 U/L; p<0.001). Low Apgar scores, oxygen requirement, NICU admission, and HIE were significantly more common in the high ΔpH group (p<0.001). A strong positive correlation was observed between ΔpH and LDH (r=+0.805). *Conclusion*: Umbilical cord blood LDH and ΔpH are simple and reliable predictors of adverse perinatal outcomes in high-risk pregnancies and may help in early neonatal risk stratification.***

**Keywords:** Cord blood, LDH, Delta pH, Perinatal outcome, High-risk pregnancy, Neonatal morbidity

## 1. Introduction

Perinatal outcome is an important indicator of the quality of maternal and neonatal healthcare and reflects the overall health status of a population. It is widely used as a comprehensive indicator of obstetric and neonatal care quality. Perinatal outcome encompasses multiple domains including survival, physiological stability, neurological integrity, and early neonatal adaptation. The outcome is influenced by antenatal complications, intrapartum fetal hypoxia, and immediate postnatal neonatal care. The assessment of perinatal outcome relies on standardized clinical and biochemical parameters that objectively reflect fetal well-being and neonatal adaptation after birth [1].

Early identification of fetal compromise is essential to prevent irreversible neonatal injury. However, conventional intrapartum surveillance methods such as cardiotocography and fetal heart rate monitoring are limited by subjective interpretation and high false-positive rates. The Apgar score, although routinely used to assess neonatal condition at birth, may also be influenced by multiple external factors. These limitations highlight the need for objective biochemical markers that accurately reflect fetal metabolic status.

Umbilical cord blood analysis provides a reliable evaluation of fetal acid–base balance because samples are collected immediately after delivery. Umbilical cord blood pH is considered the gold standard for detecting fetal acidemia; however, maternal metabolic status can influence fetal pH values. Delta pH (ΔpH), defined as the difference between maternal venous pH and fetal umbilical arterial pH, has been proposed as a better indicator of intrapartum fetal hypoxic burden.

Lactate dehydrogenase is an intracellular enzyme essential for anaerobic glycolysis and is released into the bloodstream following cellular membrane disruption. Elevated LDH in umbilical cord blood reflects both intensified anaerobic metabolism and structural tissue damage resulting from hypoxic injury. Unlike lactate, which reflects metabolic stress, LDH indicates cellular destruction and loss of membrane integrity [2].

Although cord blood pH and LDH have been studied independently, limited evidence exists regarding their combined predictive value for immediate neonatal outcomes in term high-risk pregnancies, particularly in resource-limited settings. Evaluating these simple and cost-effective biochemical markers may help in early identification of neonates at risk and improve perinatal care.

## 2. Aims and Objectives

### Aim

The study was conducted to evaluate the predictive role of umbilical cord blood lactate dehydrogenase (LDH) and delta pH in determining perinatal outcomes among term high-risk pregnancies and to assess their association with immediate neonatal outcomes such as Apgar score, need for resuscitation, NICU admission, and early neonatal morbidity and mortality.

**Objectives**

1) To determine association between umbilical cord blood ΔpH and LDH with immediate neonatal outcome measured by APGAR score measured at 1 and 5 minutes.
2) To determine association between umbilical cord blood ΔpH and LDH with need for resuscitation, requirement of oxygen, need for NICU admission, delay in attaining full feeds, convulsions or encephalopathy.

## 3. Materials and Methods

The cohort study was conducted at the the Department of Paediatrics at AJ Institute of Medical Sciences and Research Centre, Mangalore, over a period of 18 months (July 2024 to February 2026).

All newborns delivered to women at a gestation of 37 weeks or more who had a singleton pregnancy and were at high risk due to factors such as Anaemia, Hypertensive Disorders During Pregnancy, Malpresentation, Thyroid Disorders, Gestational Diabetes Mellitus, Seizure Disorders, Rh Incompatibility, Intrauterine growth restriction with or without Polyhydromnios/Oligohydromnios, Premature Rupture Of Membranes (Prom) in high-risk pregnancies, Maternal Infections, Intrahepatic Cholestasis During Pregnancy were included in the study.

Intrauterine fetal death, congenitally malformed fetus, Multifetal gestation were excluded from the study.

**Ethical Clearance**

Ethical clearance was obtained from the Institutional Ethics Committee before starting the study. Written informed consent was obtained from the parents/guardians of the neonates.

## 4. Methodology

**Interventional Protocol**

All eligible neonates born to high-risk antenatal mothers and fulfilling the inclusion criteria were enrolled consecutively at birth. Immediately after delivery and clamping of the umbilical cord, cord blood samples were collected under strict aseptic precautions.

Both arterial and venous cord blood samples were obtained using pre-heparinized syringes. The arterial sample reflects the fetal metabolic status at birth, while the venous sample reflects placental function. Care was taken to correctly identify the vessels, avoid air bubbles, and prevent clot formation. The samples were transported immediately for analysis.

The arterial cord blood sample was analyzed within 10 minutes using an automated arterial blood gas (ABG) analyzer to measure Cord blood pH and Delta pH (ΔpH). A separate portion of cord blood was sent to the central biochemistry laboratory for estimation of lactate dehydrogenase (LDH) using a standardized automated analyzer.

**Outcome Assessment**

Immediately after birth, each neonate was assessed by the attending pediatrician or neonatologist. Immediately after birth, each neonate was evaluated by the attending pediatrician or neonatologist. Apgar scores at 1 and 5 minutes were recorded, along with the need for neonatal resuscitation as per standard guidelines, including bag-and-mask ventilation, endotracheal intubation, or advanced resuscitative measures, which served as indicators of neonatal compromise and birth asphyxia. All neonates were subsequently followed throughout their hospital stay to assess perinatal outcomes such as NICU admission, duration of hospitalization, and survival or mortality. Neonatal complications including hypoxic ischemic encephalopathy (HIE), meconium aspiration syndrome (MAS), transient tachypnea of the newborn (TTN), respiratory distress syndrome (RDS), and the requirement for respiratory support in the form of oxygen therapy, CPAP, or mechanical ventilation were also documented.

All neonates received routine care as per institutional neonatal management protocols, and no aspect of clinical management was altered for study purposes.

## 5. Outcomes

The primary neonatal outcomes assessed in the study included admission to the Neonatal Intensive Care Unit (NICU), duration of hospital stay, and survival or mortality during the hospitalization period. In addition, neonatal morbidity was evaluated by documenting the occurrence of complications such as hypoxic ischemic encephalopathy (HIE), meconium aspiration syndrome (MAS), transient tachypnea of the newborn (TTN), and respiratory distress syndrome (RDS). The requirement for respiratory support, including supplemental oxygen therapy, continuous positive airway pressure (CPAP), or mechanical ventilation, was also recorded as an indicator of neonatal respiratory compromise and adverse perinatal outcome.

**Sample Size**

The sample size for the present study was calculated using the standard formula for estimating is the standard normal deviate corresponding to a 5% level of significance (1.96), (P) is the anticipated overall accuracy (68% or 0.68), and (L) is the allowable margin of error (12% or 0.12). Substituting these values into the formula yielded a calculated sample size of approximately 58 newborns (\left[N = \frac{(1.96)^2 \times 0.68 \times (1-0.68)}{(0.12)^2} \approx 58.0\right]). To account for potential data loss and to ensure adequate statistical precision and reliability of the study findings, the sample size was rounded up, and a total of 60 newborns were included in the study.

$$N = \frac{(Z_{\alpha/2})^2 \times P \times (1 - P)}{L^2}$$

**Sampling Technique**

A consecutive sampling technique was used and 60 newborns were selected for the study.

**Statistical Analysis**

All the data was collected in a pre-designed structured proforma, entered into Microsoft Excel and statistically analysed using the SPSS version 21.0. Descriptive statistics of LDH and ΔpH were expressed using mean ± standard deviation. A p value of less than 0.05 was considered statistically significant.

## 6. Result

**Table 1:** Baseline Maternal and Neonatal Characteristics of the Study Population (N=60)

| Variable | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Gender | Male | 32 | 53.3 |
| | Female | 28 | 46.7 |
| Gestational Age (weeks) | 37–38 | 16 | 26.7 |
| | 38–39 | 15 | 25.0 |
| | 39–40 | 20 | 33.3 |
| | >40 | 9 | 15.0 |
| Birth Weight | LBW (<2500 g) | 7 | 11.7 |
| | Normal (2500–4000 g) | 53 | 88.3 |
| Maternal Risk Factors | Hypertensive disorders | 24 | 40.0 |
| | Anaemia | 21 | 35.0 |
| | IUGR | 9 | 15.0 |
| | GDM | 7 | 11.7 |
| | Oligohydramnios | 6 | 10.0 |
| | Thyroid disorders | 5 | 8.3 |
| | Malpresentation | 5 | 8.3 |
| | PROM | 3 | 5.0 |
| | Maternal infections | 3 | 5.0 |
| | Polyhydramnios | 3 | 5.0 |
| | Rh incompatibility | 1 | 1.7 |
| | Seizure disorders | 1 | 1.7 |
| Mode of Delivery | Emergency LSCS | 20 | 33.3 |
| | Normal vaginal delivery | 20 | 33.3 |
| | Assisted vaginal delivery | 11 | 18.3 |
| | Elective LSCS | 9 | 15.0 |

Mean gestational age: 39.1 ± 1.1 weeks (Range: 37.2–40.9 weeks)

Mean birth weight: 2958 ± 414 g

The study included 60 neonates, with males accounting for 53.3% and females 46.7%. Most neonates were delivered between 39–40 weeks of gestation (33.3%), with a mean gestational age of 39.1 ± 1.1 weeks, showing that the majority were term babies. The mean birth weight was 2958 ± 414 g, and most neonates (88.3%) had normal birth weight, while 11.7% had low birth weight. Hypertensive disorders (40.0%) and anaemia (35.0%) were most prevalent maternal risk factors, followed by IUGR (15.0%) and GDM (11.7%), reflecting the typical high-risk pregnancy spectrum. Emergency LSCS and normal vaginal delivery were equally common (33.3% each), with an overall cesarean rate of 48.3% reflecting the high-risk nature of the study population.

**Table 2:** Summary of Outcome Parameters According to Delta pH Groups

| Outcome Parameter | Normal ΔpH (≤0.08) (n=38) | High ΔpH (>0.08) (n=22) | p-value |
|---|---|---|---|
| Umbilical Arterial pH | 7.30 ± 0.05 | 7.03 ± 0.10 | <0.001 |
| Cord Blood LDH (U/L) | 333 ± 84 | 964 ± 213 | <0.001 |
| Apgar Score (1 min) | 8.3 ± 0.8 | 4.5 ± 1.1 | <0.001 |
| Apgar Score (5 min) | 9.2 ± 0.9 | 6.7 ± 1.1 | <0.001 |
| Time to Attain Full Feeds (hours) | 2.2 ± 0.9 | 20.7 ± 12.8 | <0.001 |
| Composite Adverse Outcome, n (%) | 12 (31.6) | 21 (95.5) | <0.001 |
| NICU Admission, n (%) | 7 (18.4) | 16 (72.7) | <0.001 |
| Resuscitation Required, n (%) | 5 (13.2) | 17 (77.3) | <0.001 |
| Hypoxic Ischemic Encephalopathy (HIE), n (%) | 0 (0.0) | 4 (18.2) | 0.015 |

Abbreviations: ΔpH = Delta pH; LDH = Lactate Dehydrogenase; NICU = Neonatal Intensive Care Unit; HIE = Hypoxic Ischemic Encephalopathy.

The present study demonstrated that neonates with elevated ΔpH (>0.08) had significantly poorer perinatal outcomes compared with those having normal ΔpH (≤0.08). Elevated ΔpH was associated with markedly lower umbilical arterial pH and substantially higher cord blood LDH levels, indicating severe fetal hypoxia, metabolic acidosis, and cellular injury. These neonates exhibited significantly lower Apgar scores at both 1 and 5 minutes, delayed attainment of full enteral feeds, and a greater need for neonatal resuscitation. Furthermore, the incidence of NICU admission, hypoxic ischemic encephalopathy, and composite adverse neonatal outcomes was significantly higher in the elevated ΔpH group. The findings suggest that an increased ΔpH reflects significant intrapartum fetal compromise and is strongly associated with early neonatal morbidity. Therefore, ΔpH, in conjunction with cord blood LDH estimation, may serve as a valuable biochemical marker for early identification of neonates at risk for adverse perinatal outcomes and facilitate timely neonatal intervention and intensive monitoring.

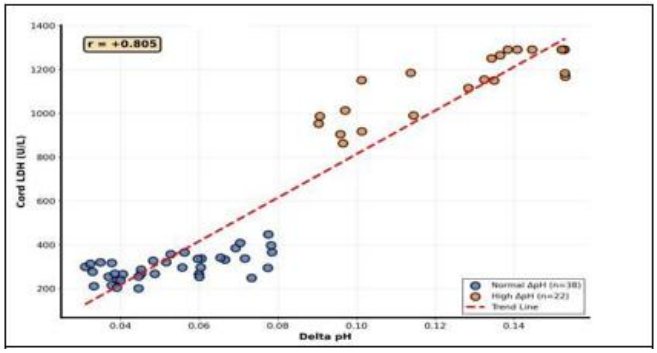


**Figure 1:** Scater Plot-Delta Ph and Cord Blood LDH

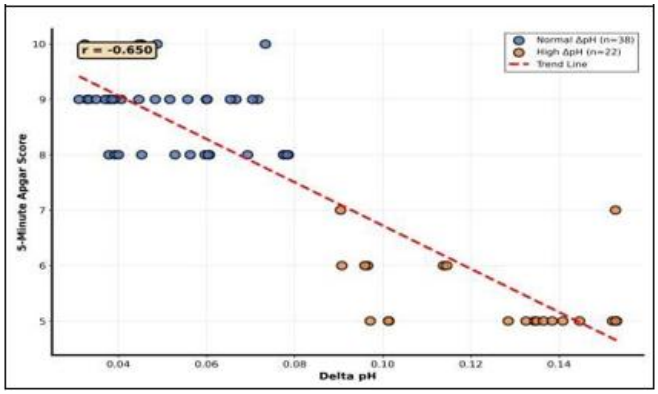


**Figure 2:** Scatter Plot - Delta pH and 5-Minute Apgar Score

## 7. Discussion

The primary aim of this study was to evaluate the role of umbilical cord blood lactate dehydrogenase and Delta pH as predictors of perinatal outcome in high-risk pregnancies.

The present study included 60 term , with a slight male predominance (53.3%) and females accounting for 46.7%. The near-equal gender distribution minimizes the possibility of gender-related bias in the assessment of biochemical and clinical outcomes. Similar findings were reported by Andersson et al. [3], who observed a balanced sex distribution in a large cohort of term neonates. The mean gestational age in the present study was 39.1 ± 1.1 weeks, indicating that the majority of neonates were delivered at term. Inclusion of only term neonates helped eliminate prematurity as a confounding factor and allowed better assessment of intrapartum hypoxia and metabolic compromise. Comparable gestational age findings were reported by Khoshnow et al. [4] and Andersson et al. [3].

The mean birth weight in the present study was 2958 ± 414 g, and most neonates had normal birth weight. Despite this, significant neonatal morbidity was observed, suggesting that metabolic compromise rather than fetal growth restriction was the major contributor to adverse outcomes. Similar observations were reported by Gruccio et al. [5], who demonstrated biochemical evidence of cellular injury even in neonates without severe growth restriction.

Among maternal risk factors, hypertensive disorders (40%) and anaemia (35%) were the most common conditions. These disorders are known to impair uteroplacental circulation and contribute to fetal hypoxia. Kumar et al. [6] reported significantly lower cord blood pH and higher LDH levels in neonates born to mothers with hypertensive disorders, findings that are comparable with the present study.

Regarding mode of delivery, emergency LSCS and normal vaginal delivery each accounted for 33.3% of deliveries, reflecting the high-risk nature of the study population. Increased rates of operative delivery in compromised fetuses have also been described by Wiberg-Itzel et al. [7] who showed that intrapartum stress influences biochemical markers such as lactate and LDH.

The present study demonstrated significantly lower umbilical arterial pH and markedly elevated cord blood LDH levels in neonates with high ΔpH (>0.08) compared to those with normal ΔpH. The mean UApH in the high ΔpH group was 7.03 ± 0.10, while LDH levels reached 964 ± 213 U/L, indicating severe metabolic acidosis and cellular injury. Similar findings were reported by Kumar et al. [6], who observed elevated LDH levels and lower arterial pH in neonates born to eclamptic mothers. Kumar et al. [8] also demonstrated strong associations between elevated LDH, low pH, and adverse neonatal outcomes in high-risk pregnancies. These findings support the role of ΔpH and LDH as sensitive indicators of intrapartum hypoxia and fetal metabolic stress.

Apgar scores were significantly lower in neonates with elevated ΔpH. The mean 1-minute and 5-minute Apgar scores in the high ΔpH group were 4.5 ± 1.1 and 6.7 ± 1.1 respectively, compared to 8.3 ± 0.8 and 9.2 ± 0.9 in the normal group. These findings indicate poor neonatal adaptation in neonates with biochemical evidence of acidosis. Similar observations were reported by Khoshnow et al. [4], who found a strong association between elevated lactate levels and low Apgar scores. Misra et al. [9] also demonstrated a positive correlation between cord blood pH and Apgar scores. The present study reinforces that elevated ΔpH is associated with immediate neonatal depression at birth.

Neonates with elevated ΔpH showed significantly delayed attainment of full feeds compared to the normal ΔpH group. The mean time to attain full feeds was 20.7 ± 12.8 hours in the high ΔpH group versus 2.2 ± 0.9 hours in the normal group. Delayed feeding likely reflects systemic compromise and feeding intolerance secondary to hypoxic injury. Kamath et al. [10] reported prolonged neonatal morbidity and respiratory support in neonates with elevated LDH levels, indirectly supporting delayed feeding as part of neonatal compromise. The present findings suggest that ΔpH and LDH may help identify neonates at risk of feeding difficulties.

More than half of the neonates (55%) in the present study experienced at least one adverse neonatal outcome. This high proportion reflects the severe burden of neonatal morbidity in high-risk pregnancies. Kumar et al. [8] similarly reported high rates of neonatal complications in neonates with elevated LDH and low pH values. The findings indicate that biochemical markers at birth are strongly associated with overall neonatal outcome.

A highly significant association was observed between elevated ΔpH and adverse neonatal outcomes. Among neonates with ΔpH >0.08, 95.5% experienced adverse outcomes compared to 31.6% in the normal group. Similar findings were reported by Kumar et al. [8], who showed significant associations between biochemical acidosis and neonatal morbidity. Andersson et al. [3] also demonstrated increased neonatal complications even with moderate reductions in cord blood pH. The present study confirms that elevated ΔpH is a strong predictor of poor neonatal outcome.

NICU admission was significantly higher in neonates with elevated ΔpH, with 72.7% of the high ΔpH group requiring intensive care compared to 18.4% in the normal group. Khoshnow et al. [4] reported that elevated biochemical markers significantly increased the likelihood of NICU admission. Kumar et al. [8] also demonstrated strong

associations between elevated LDH, low pH, and NICU admission. These findings highlight the usefulness of ΔpH and LDH in identifying neonates requiring intensive monitoring and treatment.

The need for neonatal resuscitation was markedly higher in neonates with elevated ΔpH. Resuscitation was required in 77.3% of neonates in the high ΔpH group compared to only 13.2% in the normal group. Similar observations were reported by Kumar et al. [8], who found that elevated LDH and low pH were significantly associated with increased resuscitation requirements. These findings emphasize that ΔpH can help anticipate delivery room interventions in high-risk pregnancies.

All cases of hypoxic ischemic encephalopathy (HIE) in the present study occurred exclusively in the high ΔpH group, demonstrating a strong relationship between elevated ΔpH and neurological injury. Andersson et al. [3] reported that severe neonatal morbidity, including seizures and neurological complications, increased significantly with lower cord blood pH values. Kumar et al. [8] also observed higher neurological morbidity in neonates with elevated LDH and low pH. The present findings support the role of ΔpH as an early biochemical marker of neurological compromise.

The present study demonstrated a strong positive correlation between ΔpH and cord blood LDH ($r = +0.805$, $p<0.001$), indicating that increasing placental-fetal pH gradients are associated with greater cellular injury. Kumar et al. [6] similarly reported elevated LDH levels in neonates with metabolic acidosis and adverse outcomes. The findings confirm that ΔpH and LDH are closely related markers of fetal hypoxic stress.

A moderate negative correlation was observed between ΔpH and 5-minute Apgar score ($r = −0.650$, $p<0.001$), indicating that increasing ΔpH is associated with poorer neonatal adaptation. Similar findings were reported by Misra et al. [9], who showed that worsening acidosis was associated with lower Apgar scores. The present findings reinforce the clinical relevance of ΔpH in predicting neonatal condition at birth.

The present study showed a strong negative correlation between umbilical arterial pH and cord blood LDH ($r = −0.828$, $p<0.001$). Lower arterial pH values were associated with higher LDH levels, reflecting severe metabolic acidosis and tissue injury. Kumar et al. [6] and Kumar et al. [8] also reported similar relationships between acidosis and elevated LDH levels in high-risk pregnancies. These findings confirm the interrelationship between biochemical acidosis and cellular damage.

A strong negative correlation was observed between cord blood LDH and 5-minute Apgar score ($r = −0.782$, $p<0.001$), indicating that higher LDH levels are associated with poorer neonatal condition at birth. Khoshnow et al. [4] and Kumar et al. [8] similarly demonstrated that elevated biochemical markers of hypoxia correlate with adverse neonatal outcomes and low Apgar scores. The present study confirms that LDH is a reliable marker of neonatal compromise and poor perinatal outcome in high-risk pregnancies.

The present study is strengthened by inclusion of only term neonates, paired arterial and venous cord blood analysis for ΔpH calculation, and assessment of cord blood LDH as an objective marker of hypoxic injury. Significant associations between elevated ΔpH, increased LDH levels, and adverse neonatal outcomes support the clinical value of these biomarkers in high-risk pregnancies. However, the study was limited by its small sample size, single-center design, and lack of long-term neurodevelopmental follow-up. Serial postnatal biochemical assessment and ROC-based cutoff analysis were not performed. Despite these limitations, the study demonstrates that ΔpH and cord blood LDH are useful predictors of early adverse perinatal outcomes.

## 8. Conclusion

This study demonstrates that umbilical cord blood Delta pH and lactate dehydrogenase are powerful and reliable biochemical predictors of adverse perinatal outcomes in high-risk term pregnancies. Despite all neonates being delivered at term and the majority having normal birth weight, a substantial proportion exhibited significant metabolic compromise at birth, emphasizing that gestational maturity and anthropometric parameters alone are insufficient indicators of neonatal well-being. Elevated ΔpH was consistently associated with lower umbilical arterial pH, markedly increased LDH levels, and significantly poorer clinical outcomes, including low Apgar scores, need for resuscitation, oxygen dependency, NICU admission, delayed feeding, and neurological morbidity. Their routine use has the potential to enhance early neonatal assessment, guide timely intervention, and ultimately improve neonatal morbidity and survival.

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