



## Correlation of cardiotocography with combined APGAR scores and diagnostic performance of umbilical cord parameters in predicting low combined APGAR scores – A prospective Cohort study

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### ARTICLE INFO

#### Keywords:

Combined Apgar scores  
Cardiotocograph  
Umbilical cord parameters  
Lactate levels  
Apgar scores

### ABSTRACT

**Objectives:** Combined Apgar score includes utilization of interventions such as Continuous positive airway pressure, Oxygen, Mask and Bag ventilation, Intubation and ventilation, Neonatal chest compression, Drugs, and newborn assessment. It has been proposed as a substitute for conventional Apgar score which is the gold standard for evaluating newborns right after birth but is impacted by medical interventions and preterm. Combined Apgar scores were examined to check for correlation with CTG tracing and umbilical cord blood parameters which gives an objective assessment of fetal hypoxia, in response to the demand for a more accurate tool for evaluating the neonate and to be used for medico-legal purposes. The study's objectives were to (1) determine the association of combined Apgar scores with suspicious and pathological CTG (2) the association of umbilical cord parameters with low combined Apgar scores and the diagnostic performance of these parameters in predicting low combined Apgar scores.

**Study design:** A prospective observational cohort study was conducted in a tertiary care center in East India. 2350 consecutive laboring mothers who had completed 34 weeks of gestation underwent cardiotocography according to institutional protocol and those with suspicious and pathological CTG who delivered within 1 h of abnormal CTG were recruited. Arterial blood was analyzed and the newborn was evaluated immediately after delivery with a combined Apgar scoring system

**Results:** Of the 2350 women, 50.7 % and 49.3 %, respectively, exhibited suspicious and abnormal CTG tracings. CTG was reported to have low diagnostic accuracy and specificity, with a sensitivity of 66.7 % and 88.9 %, respectively, in detecting combined Apgar at 1 and 5 min. The combined Apgar score at five minutes showed a strong association with acidosis. There was a statistically significant correlation between low combined Apgar and excess lactate and base at one and five minutes. With 100 % sensitivity and 95 % specificity, high lactate levels > 4.1 mM/L were found to predict newborn encephalopathy.

**Conclusion:** Umbilical cord blood parameters were found to be correlated with low combined Apgar scores. Combined Apgar scores may be a more useful tool for neonatal assessment and long-term morbidity of newborns. Additional research is required to determine whether it can take the role of conventional Apgar scores in clinical practice.

### 1. Introduction

A fetus that is oxygen-depleted due to decreased or non-existent blood flow or gas exchange just before, during, or following delivery

is said to have perinatal asphyxia [1]. As a result, the essential organs experience hypoxia or anoxia, which has systemic and neurological effects [1]. The neurological sequelae are known as hypoxic-ischemic encephalopathy, and the diagnostic criteria include features of

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<https://doi.org/10.1016/j.eurox.2024.100329>

Received 21 June 2024; Accepted 22 July 2024

Available online 23 July 2024

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encephalopathy, multiorgan failure, pH of less than 7.0 in blood from an umbilical cord or neonate, a base deficit of  $-12$ , and an Apgar score of 5 at 10 min with ongoing resuscitation needs and exclusion of other conditions causing similar symptoms. It causes high neonatal morbidity and mortality and can cause long-term disabilities in infants [1]. Hence a tool for early assessment and prediction of complications for newborns is essential to provide therapeutic interventions to prevent the progression of hypoxia.

Apgar score has been used as a tool for assessing newborns immediately after birth [2]. A committee of the American College of Obstetricians and Gynaecologists (ACOG) and the American Academy of Paediatrics (AAP) advised against using the Apgar score alone to predict newborn outcomes due to its limitations, as it is influenced by prematurity and medical treatments [3]. Due to these limitations, expanded and specified Apgar scores were suggested for neonatal assessment [4]. Rudiger et al. have proposed a combined Apgar score (CAPGAR) for neonatal assessment which combines the specified and expanded Apgar scores [4,5]. CAPGAR score includes the use of interventions like Continuous positive airway pressure, Oxygen, Mask and Bag ventilation, Intubation and ventilation, Neonatal chest compression, Drugs, and assessment of newborn using parameters like Appearance (skin color), Pulse, Grimacing, Activity, Respiration [4]. The combined APGAR score ranges from 0–17. A score of less than 10 is deemed to be abnormal and a newborn is considered to be depressed [4,6,7]. This score was determined by consulting the studies that have been done and by taking the recommendations provided by ACOG AND AAP into consideration [4,6,7].

Few studies comparing the combined Apgar score to the traditional Apgar score have demonstrated that the combined score is better at predicting unfavorable newborn outcomes, such as neonatal death, across all subgroups of neonates—term, near-term, and preterm [4]. When evaluating intrapartum fetal hypoxia, umbilical cord blood gas levels are thought to be the gold standard of care since they provide an objective assessment of the condition [8–10]. Combined Apgar scores were evaluated to check for association with CTG tracing, which is the most common method of assessing a fetus in utero, and with parameters of umbilical cord blood, which gives an objective assessment of fetal hypoxia. This was done due to the need for a more precise tool for evaluating the neonate and to use it for medicolegal purposes [11,12]. Although there has been much research on the correlation between traditional APGAR scoring and CTG tracing and umbilical cord blood parameters, little is known about the relationship between CAPGAR scoring and CTG and cord blood parameters. The purpose of this study was to ascertain whether low combined Apgar scores were associated with suspicious and abnormal CTG and umbilical cord characteristics.

## 2. Materials and methods

Following ethical committee approval (2021-22/61) and informed consent from the participants, the study was carried out as a prospective observational cohort in the Department of Obstetrics & Gynaecology at a tertiary care hospital in East India. This study is a component of a larger investigation aimed at determining the relationship between abnormal and suspicious CTG and characteristics of umbilical cord arterial blood gas in women who were induced or in labor and whose gestational age was more than 34 weeks.

The study's objectives were to 1) determine the association of CAPGAR scores with suspicious and pathological CTG 2) the association of umbilical cord parameters with low CAPGAR scores and diagnostic performance of these parameters in predicting low combined Apgar scores.

The study was carried out over two years, from July 2021 to June 2023.

The study population consisted of pregnant women with a singleton pregnancy with a gestational age of more than 34 weeks who delivered in the labor ward of the obstetric unit in the tertiary center.

The study excluded pregnant women with multiple pregnancies, obstetric crises, and serious congenital anomalies of the fetus in antenatal USG or diagnosed after delivery.

For the study, 2350 consecutive laboring mothers were enrolled who, by institutional practice, had undergone Cardiotocography (CTG) after 34 weeks of gestation. The women having suspicious and pathological CTG were identified and sociodemographic features were recorded. The women who had delivered within 1 h of having abnormal CTG were included in the study.

The Sonicaid CTG machine with a paper speed of 1 cm per minute was used in the study. CTG tracing was categorized as suspicious or pathological based on the NICE guideline, considering reassuring, non-reassuring, and abnormal features of the tracing. After delivery of the baby, 2–3 mL of arterial blood from the umbilical artery was collected using a pre-heparinized syringe and was analyzed in an ABG machine (stat Profile pHox Ultra) within 10 min of sample collection. The values of cord blood pH  $< 7.2$ , base excess of  $\geq 8$  mmol/L, and lactate level  $> 6$  mmol/L were taken as abnormal. The newborn was evaluated immediately after delivery. We documented any interventions done for newborns. If there was no intervention, the score was 1. Parameters like Appearance, Pulse, Grimacing, Activity, and Respiration were noted. Scores 0 and 1,2 were given according to the findings. Details of fetal outcomes were noted. The data was entered into a Microsoft Excel spreadsheet 2019 version and analyzed using SPSS software version 27. Wilcoxon-Mann-Whitney U Test was used to make group comparisons, t-test or group comparisons for birth weight, the Chi-squared test or Fisher's exact test for categorical data as appropriate was used. Point-Biserial/Cramer's V correlation was used to obtain the result. p-value of  $< 0.05$  was considered statistically significant (Fig. 1).

## 3. Results

Out of the 2350 women who were subjected to continuous CTG, 205 had abnormal CTG tracing. 104 (50.7 %) and 101 (49.3 %) of the participants had suspicious and pathological CTG tracings respectively. The mean age of participants was  $26.54 \pm 3.94$  years and BMI was  $22.87 \pm 2.86$  kg/m<sup>2</sup>. The majority of them had a BMI in the range of  $18.5$ – $22.9$  m<sup>2</sup> (57.1 %). Out of 205 participants, 143 (69.8 %) had obstetric scores of primigravida and 62 (30.2 %) were multigravida. At the time of delivery, 30 (14.6 %) had gestational age from 34 weeks to 36 weeks 6 days and 175 (85.4 %) from 37 weeks to 41 weeks 6 days [Table 1].

The association of low CAPGAR at 1 min (15.8 %) was significantly more in the pathological group. Low CAPGAR at 5 min is also more in the pathological group (2 %) as compared to the suspicious group (1 %) but was not statistically significant [Table 2]. CTG was found to have a sensitivity of 88.9 % and specificity of 54.5 % in predicting CAPGAR scores at 1 min  $< 10$ . The diagnostic accuracy was only 57.6 %. The positive likelihood ratio (LR+) was 1.96 with significant p-value [Table 3]. CTG had a lower specificity and sensitivity for predicting Apgar at 5 min ( $< 10$ ) with a diagnostic accuracy of 51.2 %. The LR+ was 1.36 with a p-value not statistically significant [Table 4].

The area under the ROC curve (AUROC) for pH predicting low CAPGAR at 1 min ( $< 10$ ) was 0.946. At a cutoff of pH  $\leq 7.28$ , it predicts CAPGAR at 1 min  $< 10$  with a sensitivity of 94 %, and a specificity of 82 %. AUROC for Lactate predicting CAPGAR at 1 min:  $< 10$  was 0.956. AUROC for Base Excess predicting CAPGAR at 1 min  $< 10$  was 0.941 (Fig. 2) The association of all parameters with CAPGAR scores at 1 min was found to be statistically significant. At a cutoff of Base Excess (mmol/L)  $\leq -7.8$ , it predicts CAPGAR at 1 min  $< 10$  with a sensitivity of 94 %, and a specificity of 83 %. At a cutoff of Lactate (mmol/L)  $\geq 4.87$ , it predicts CAPGAR at 1 min  $< 10$  with a sensitivity of 100 %, and a specificity of 81 % [Table 5]. There was no significant difference in the diagnostic performance of Lactate and pH, Lactate and Base Excess, and pH and Base Excess (DeLong's Test  $p = 0.644, 0.576, 0.514$  respectively).

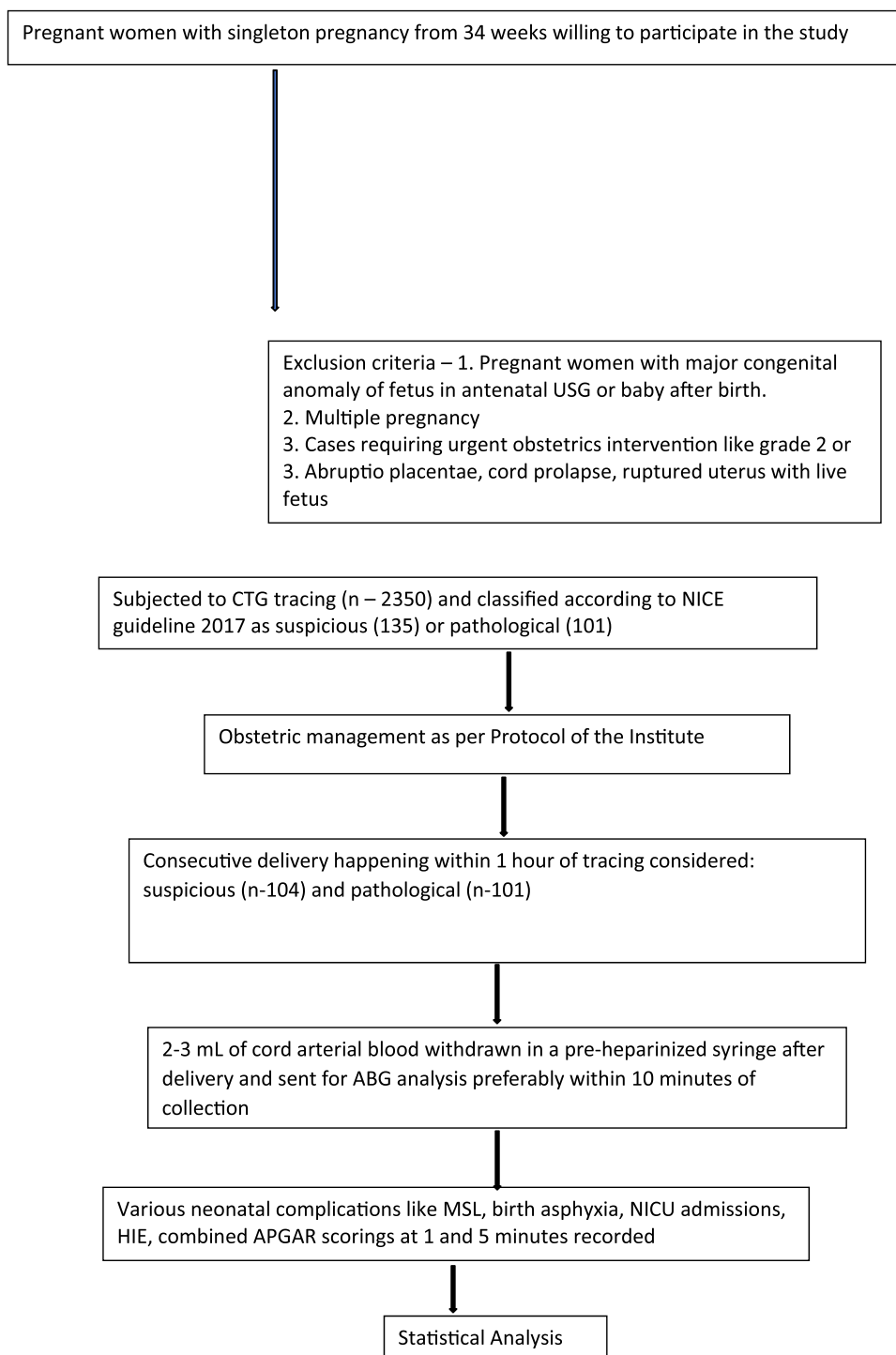


Fig. 1. Work plan for methodology-STROBE flow diagram.

AUROC for pH predicting CAPGAR score of < 10 at 5 min was 0.982. At a cutoff of  $\text{pH} \leq 7.13$ , it predicts CAPGAR Category at 5 min < 10 with a sensitivity of 100 %, and a specificity of 96 %. The AUROC for Base Excess predicting CAPGAR at 5 min < 10 was 0.987. A cut-off of Base Excess ( $\text{mmol/L} \leq -15.1$ ), predicts CAPGAR at 5 min: < 10 with a sensitivity of 100 %, and a specificity of 98 %. The AUROC for Lactate predicting CAPGAR at 5 min < 10 was 0.985 (Fig. 3). At a cutoff of Lactate ( $\text{mmol/L} \geq 9.9$ ), it predicts CAPGAR at 5 min < 10 with a sensitivity of 100 %, and a specificity of 98 % [Table 6]. There was no significant difference in the diagnostic performance of Base Excess and Lactate, Base Excess and pH, and Lactate and pH (DeLong's Test

$p = 0.882, 0.499, \text{ and } 0.819$  respectively).

AUROC for pH predicting HIE vs HIE: None was 0.978. At a cutoff of  $\text{pH} \leq 7.19$ , it predicts HIE with a sensitivity of 100 % and a specificity of 94 %. The AUROC for Base Excess predicting HIE vs HIE: None was 0.973. At a cutoff of Base Excess ( $\text{mmol/L} \leq -11.2$ ), it predicts HIE-3 with a sensitivity of 100 % and a specificity of 94 %. AUROC for Lactate predicting HIE vs HIE: None was 0.989. At a cutoff of Lactate ( $\text{mmol/L} \geq 7.36$ ), it predicts HIE with a sensitivity of 100 % and a specificity of 96 % [Table 7].

There was no significant difference in the diagnostic performance of Lactate and pH, of Lactate and Base Excess, and pH and Base Excess

**Table 1**  
Baseline characteristics.

Basic details	Mean ± SD    Frequency (%)
<b>Age (Years)</b>	26.54 ± 3.94
<b>Obstetric Score</b>	
Primigravida	143 (69.8 %)
Multigravida	62 (30.2 %)
<b>Gestational Age at Delivery</b>	
34 weeks to 36 weeks and 6 days	30 (14.6 %)
37 weeks to 41weeks and 6 days	175 (85.4 %)
<b>BMI (kg/m<sup>2</sup>)</b>	22.87 ± 2.86
<b>BMI*</b>	
< 18.5 kg/m <sup>2</sup>	4 (2.0 %)
18.5–22.9 kg/m <sup>2</sup>	117 (57.1 %)
23–24.9 kg/m <sup>2</sup>	38 (18.5 %)
≥ 25 kg/m <sup>2</sup>	46 (22.4 %)

\* As per Asian standards.

**Table 2**  
Association of combined Apgar score with CTG.

Parameters	CTG finding		p value
	Suspicious (n = 104)	Pathological (n = 101)	
<b>Combined Apgar (1 min)***</b>			< 0.001 <sup>2</sup>
< 10 (low)	2 (1.9 %)	16 (15.8 %)	
≥ 10	102 (98.1 %)	85 (84.2 %)	
<b>Combined Apgar (5 min)</b>			0.618 <sup>1</sup>
< 10 (low)	1 (1.0 %)	2 (2.0 %)	
≥ 10	103 (99.0 %)	99 (98.0 %)	

1: Wilcoxon-Mann-Whitney U Test, 2: Chi-Squared Test, 3: Fisher’s Exact Test, 4: t-test.

\*\*\* Significant at p < 0.05.

(DeLong’s Test p of 0.193, 0.091, and 0.403 respectively).

**4. Discussion**

The association of CAPGAR at 1 and 5 min with cardiotocography (CTG) and umbilical cord blood parameters was done as a part of a study to compare the association of suspicious and pathological cardiotocography with umbilical cord blood parameters.

False positive results are high with CTG even though it is the most commonly used method to evaluate fetal distress [13–17]. The inter and intra-observer variation in the interpretation affects the decision-making. Conventional Apgar score, an effective tool to assess

**Table 3**  
Performance of study parameters for predicting combined APGAR category (1 min): < 10 vs ≥ 10.

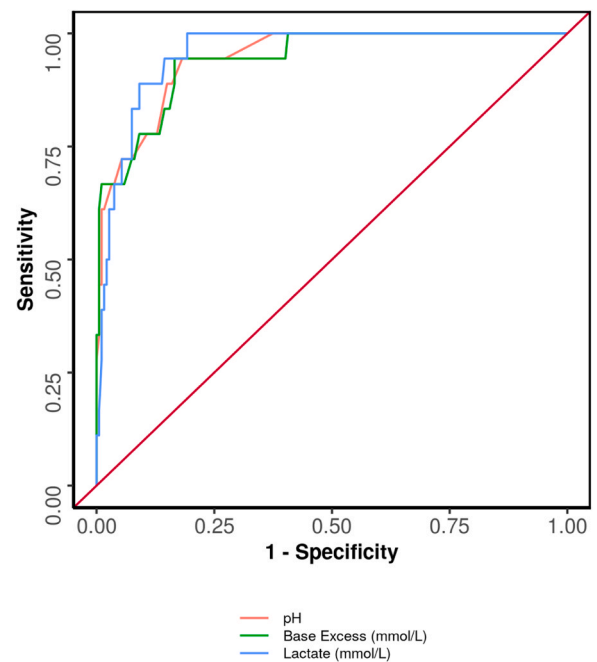
Primary Diagnostic Parameters						
Variable	Sensitivity	Specificity	PPV	NPV	Diagnostic Accuracy	
CTG Finding	88.9 % (65–99)	54.5 % (47–62)	15.8 % (9–24)	98.1 % (93–100)	57.6 % (50–64)	
Other Diagnostic Parameters						
Variable	LR+	LR-	Yuden Index	Odds Ratio	Kappa	P Value
CTG Finding	1.96 (1.56–2.45)	0.2 (0.05–0.76)	43.4	9.6 (2.15–42.93)	0.14	< 0.001

**Table 4**  
Performance of CTG for predicting combined APGAR category (5 min): < 10 vs ≥ 10.

Primary Diagnostic Parameters						
Variable	Sensitivity	Specificity	PPV	NPV	Diagnostic Accuracy	
CTG Finding	66.7 % (9–99)	51.0 % (44–58)	2.0 % (0–7)	99.0 % (95–100)	51.2 % (44–58)	
Other Diagnostic Parameters						
Variable	LR+	LR-	Yuden Index	Odds Ratio	Kappa	P Value
CTG Finding	1.36 (0.6–3.07)	0.65 (0.13–3.26)	17.7	2.08 (0.19–23.31)	0.01	0.544

newborns immediately after birth, and Apgar at 5 min is considered an indicator of newborn response to resuscitation [4]. Conventional Apgar is affected by various factors like the weight of the newborn, maternal drugs, anesthesia and cannot be interpreted as evidence of birth asphyxia. Resuscitation is recommended before calculating a clinical score [1]. Low Apgar’s at 1 min is not predictive of birth asphyxia nor is it predictive of long-term adverse outcomes in fetus while Apgar scoring at 5 min is predictive of long-term morbidity and mortality.

CAPGAR score which includes interventions in the scoring to assess the condition of the newborn immediately after birth is superior to conventional Apgar [5,7,18]. CTG is still the most commonly used method to assess fetal distress due to the limitations of using other adjunct tests in developing countries. Even though CTG was found to have a low specificity and diagnostic accuracy with a sensitivity of 88.9 % and 66.7 % in diagnosing CAPGAR at 1 min and 5 min respectively, a significant association was seen in our study between CAPGAR score at 1 min and pathological CTG. This association was not seen with



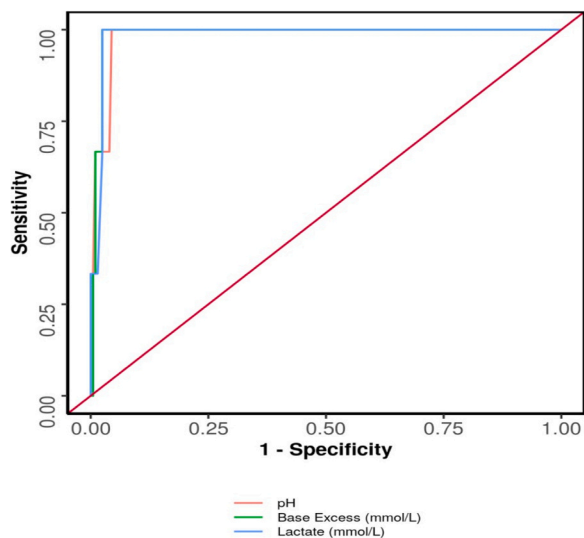
**Fig. 2.** ROC curve in predicting low combined APGAR at 1 min for various umbilical cord parameters.

**Table 5**

Comparison of the diagnostic performance of various predictors in predicting combined APGAR category (1 min): < 10 vs combined APGAR category (1 min): ≥ 10 (full sample).

Predictor	AUROC	95 % CI	P	Sn (%)	Sp (%)	PPV (%)	NPV (%)	DA (%)
pH	0.946	0.902–0.989	< 0.001	94	82	33	99	83
Base Excess (mmol/L)	0.941	0.891–0.992	< 0.001	94	83	35	99	84
Lactate (mmol/L)	0.956	0.925–0.986	< 0.001	100	81	33	100	82

AUROC: Area under ROC curve; CI: Confidence interval; P: P value; Sn: Sensitivity; Sp: Specificity; PPV: Positive predictive value; NPV: Negative predictive value; DA: Diagnostic Accuracy.



**Fig. 3.** ROC curve in predicting low Combined APGAR at 5 min for various umbilical cord parameters.

CAPGAR scores at 5 min. As there was no association between pathological CTG and CAPGAR at 5 min, pathological CTG may not have an association with the long-term morbidity or mortality of the newborn. A study conducted by Junior et al. noted an association of abnormal CTG with low conventional Apgar [19].

Umbilical cord parameters, pH, lactate, and base excess give objective evidence of hypoxia in labor [20,21]. Research comparing traditional Apgar scores to characteristics of umbilical cord blood has shown mixed results, with some demonstrating no link at all and others with low sensitivity and specificity [20,22–24]. Wiberg demonstrated that sensitivity of pH < 7.1 in predicting conventional Apgar of < 7 in 5 min was very low (28.6 %) [20]. In our study, an acidotic pH of < 7.13 had

**Table 6**

Comparison of the diagnostic performance of various umbilical cord parameters in predicting low Combined APGAR at 5 min (< 10) in the full sample.

Predictor	AUROC	95 % CI	P	Sn (%)	Sp (%)	PPV (%)	NPV (%)	DA (%)
pH	0.982	0.955–1	0.004	100	96	25	100	96
Base Excess (mmol/L)	0.987	0.969–1	0.004	100	98	38	100	98
Lactate (mmol/L)	0.985	0.965–1	0.004	100	98	38	100	98

AUROC: Area under ROC curve; CI: Confidence interval; P: P value; Sn: Sensitivity; Sp: Specificity; PPV: Positive predictive value; NPV: Negative predictive value; DA: Diagnostic Accuracy.

**Table 7**

Comparison of the diagnostic performance of various predictors in predicting HIE: Grade 1, Grade 2, Grade 3 vs HIE: None (full sample).

Predictor	AUROC	95 % CI	P	Sn (%)	Sp (%)	PPV (%)	NPV (%)	DA (%)
pH	0.978	0.959–0.996	< 0.001	100	94	58	100	95
Base Excess (mmol/L)	0.973	0.952–0.994	< 0.001	100	94	56	100	94
Lactate (mmol/L)	0.989	0.978–1	< 0.001	100	96	68	100	97

AUROC: Area under ROC curve; CI: Confidence interval; P: P value; Sn: Sensitivity; Sp: Specificity; PPV: Positive predictive value; NPV: Negative predictive value; DA: Diagnostic Accuracy.

high sensitivity and specificity in predicting CAPGAR scores at 5 min while having less predictive value for CAPGAR scores at 1 min. A strong association between neonatal mortality and morbidity was observed in studies when pH was < 7 and 7.1 respectively [25–27]. Studies have shown that pH < 7 is associated with a 10-fold increase in low conventional Apgar scores of < 4 at 1 min and < 7 at 5 min [28,29]. In this study, acidosis had a strong correlation with CAPGAR score at 5 min and hence can be used as a predictor for long-term morbidity of newborns.

Lactate and base excess showed a statistically significant correlation with low CAPGAR of < 10 at 1 min at a cut-off of > 4.87 mmol/L and ≤ 7.8 mmol/L. A significant correlation was seen between bases excess and lactate with low CAPGAR scores at 5 min with high sensitivity and specificity at a cut-off of ≤ − 15.1 mmol/L and ≥ 9.9 mmol/L respectively. There was no significant difference in the diagnostic performance of various parameters in predicting low combined Apgar scores at 1 and 5 min. Therefore, CAPGAR scores may be a better tool for neonatal assessment when compared to conventional Apgar which has a low correlation with an objective assessment of umbilical cord blood parameters.

With 100 % sensitivity and 95 % specificity, high lactate levels > 4.1 mM/L were found to be predictive of newborn encephalopathy. Numerous studies have demonstrated that elevated umbilical cord lactate is a more accurate measure of neonatal morbidity and a dependable indication of acidosis [30]. Lactate was shown by Wiberg et al. to be just as useful as base excess in evaluating the state at birth [20]. In our investigation, at higher cutoffs, base excess, and lactate showed a strong connection with the CAPGAR score at one minute and five minutes. Lactate was as good as base excess in terms of sensitivity, specificity, PPV, and NPV in predicting CAPGAR scores. Studies linking low CAPGAR at 1 and 5 min to the umbilical cord were not found. All three measures were found to be excellent in predicting hypoxic-ischemic encephalopathy (HIE) with a cut-off of pH ≤ 7.19, Base Excess ≤ − 11.2, and Lactate ≥ 7.36. The most effective parameter for HIE diagnosis accuracy was discovered to be lactate.

Strength of the study: Studies that tested the efficiency of combined Apgar scores to assess the condition of newborns after birth are limited.

We evaluated the effectiveness by objectively comparing the CAPGAR score at one and five minutes with the umbilical cord parameters, which are the accepted standard for birth asphyxia.

Limitations: The correlation between CAPGAR scores and short and long-term morbidity were not investigated, nor were they compared to the neonatal outcome. To validate the results and establish an association with newborn outcomes, additional research is required.

## 5. Conclusions

Cardiotocography may not be a reliable indicator of a newborn's status after birth because it showed no correlation with the CAPGAR scores at five minutes and had poor sensitivity and specificity. A correlation was seen between low CAPGAR scores at 1 and 5 min and parameters of umbilical cord blood, an objective indicator of fetal hypoxia that may be a more useful tool for neonatal assessment and long-term morbidity of babies. To determine whether it can take the role of conventional Apgar scores in clinical practice, additional research is needed.

## CRedit authorship contribution statement

**Soumyashree Paikaray:** Conceptualization, Investigation, Methodology. **Saubhagya Kumar Jena:** Supervision, Validation, Writing – review & editing. **Pankaj Kumar Mohanty:** Data curation, Project administration, Resources. **Deepthy Balakrishnan:** Formal analysis, Software, Visualization, Writing – original draft.

## Declaration of Competing Interest

I hereby declare that there is:-

- No conflicts of interest.
- No funding was received from any agency.
- Ethical clearance obtained.
- Informed consent was taken from all the participants.
- AI was not used in writing or editing this article.

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