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Accuracy of intrapartum cardiotocography in identifying fetal acidemia by umbilical cord blood analysis in low-risk pregnancies

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SUMMARY

OBJECTIVE: The aim of this study was to evaluate the accuracy of intrapartum cardiotocography in identifying fetal acidemia by umbilical cord blood analysis in low-risk pregnancies.

METHODS: This is a retrospective cohort study of low-risk singleton pregnancies in labor after performing intrapartum cardiotocography categories I, II, and III. The presence of fetal acidemia at birth was identified by analyzing the pH of umbilical cord arterial blood (pH<7.1).

RESULTS: No significant effect of the cardiotocography category on the arterial (p=0.543) and venous (p=0.770) pH of umbilical cord blood was observed. No significant association was observed between the cardiotocography category and the presence of fetal acidemia (p=0.706), 1-min Apgar score <7 (p=0.260), hospitalization in the neonatal intensive care unit (p=0.605), newborn death within the first 48 h, need for neonatal resuscitation (p=0.637), and adverse perinatal outcomes (p=0.373). Sensitivities of 62, 31, and 6.0%; positive predictive values of 11.0, 16.0, and 10.0%; and negative predictive values of 85, 89.0, and 87.0% were observed for cardiotocography categories I, II, and III, respectively.

CONCLUSION: The three categories of intrapartum cardiotocography presented low sensitivities and high negative predictive values to identify fetal acidemia at birth in low-risk pregnancies.

KEYWORDS: Pregnancy outcomes. External cardiotocography. Fetal blood. Blood gas analyses.

INTRODUCTION

Intrapartum cardiotocography (CTG) has been employed to monitor fetal well-being during labor for about 50 years[1]. CTG is also used to monitor fetal cardiac activity, uterine contractions, and the relationship between them, thereby providing essential information about fetal oxygenation[2]. It is also widely used to predict fetal acidemia, asphyxia, neurological injuries, and cerebral palsy[3].

However, no evidence supports the use of intrapartum CTG in low-risk pregnancies, with many guidelines recommending the use of intermittent auscultation (IA) for continuous fetal well-being monitoring[4,5]. Although IA is the gold standard for monitoring low-risk women in labor, only 10.6% of these women receive it in clinical practice[6,7]. In the United States, at least 89% of pregnancies are monitored using CTG during labor[8]. Based on these data, the use of intrapartum CTG is common and widespread in tertiary centers and developed countries, even in low-risk pregnancies. Therefore, although the practice of intrapartum CTG in low-risk pregnancies meets the standard definition of medical and legal care, its continuous use is associated with an increase in the rate of cesarean sections and instrumental vaginal deliveries with no improvement in the rate of adverse perinatal outcomes[9].

The CTG category system can be utilized to help determine the ideal time for pregnancy resolution based on the fetal heart rate (FHR) pattern[10]. This decision is made easier when the CTG category is "normal" (I) or "abnormal" (III). However, the interpretation is challenging in 80% of cases in which the CTG category is "suspected" (II)[11,12].

At birth, venous cord blood reflects the maternal-placental acid–base status with a higher oxygen concentration than arterial blood rich in CO_2, with a lower pH reflecting the neonatal acid–base status[13]. Thus, retrospectively, CTG is used as the gold-standard test to assess fetal well-being during obstetric care. Due to the widespread use of intrapartum CTG in low-risk pregnancies, there is an increase in the rate of instrumentalized deliveries without significant evidence of improvement in perinatal outcomes.

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Therefore, the objective of this study was to evaluate the accuracy of intrapartum CTG in identifying fetal acidemia by umbilical cord blood analysis in low-risk pregnancies.

METHODS

A retrospective cohort study was conducted at the University Hospital by analyzing the medical records of women who attended during labor from November 2019 to November 2021. The study was approved by the Local Research Ethics Committee with the Certificate of Presentation for Ethical Appraisal (No. 52299421.7.0000.5145).

This study included singleton pregnancies during the first stage of labor at term, whether spontaneous or induced, with both cesarean and vaginal deliveries after performing intrapartum CTG categories I, II, or III. The exclusion criteria of this study were[1] cases in which arterial and venous blood gas analysis of the umbilical cord were not performed[2]; blood gas results in which the difference between arterial and venous pH was <0.02; and[3] high-risk pregnancies.

High-risk pregnancy was defined as a condition in which the life or health of the mother, fetus, and/or newborn is more likely to be compromised than those of the mean population considered[14]. The following examples are considered: arterial hypertension, heart diseases, severe pneumopathies, severe nephropathies, endocrinopathies, hematological diseases, neurological, psychiatric, autoimmune diseases, maternal genetic disorders, history of deep vein thrombosis/pulmonary embolism, gynecological diseases, infectious diseases, use of illicit drugs, clinical pathologies that require specialized monitoring, and factors related to reproductive life and current pregnancy[15,16].

According to the institutional protocol, the main indications for performing intrapartum CTG in low-risk pregnant women are maternal temperature >38°C, oxytocin use, misoprostol use, meconium, acute vaginal bleeding, and FRH abnormality auscultation by Doppler sonar. To perform the CTG examination, the woman was positioned either in dorsal decubitus with the head of the bed raised to 45° or in the left lateral decubitus position. The tocodynamometer was placed under the uterine fundus, and the sonar was placed close to the fetal back for continuous auscultation of the FHR for 20 min. A sensor was handed to the pregnant woman for her to signal fetal movements. Fasting of no more than 3 h was observed for the test.

CTG plots were classified according to the recommendation of the American College of Gynecologists and Obstetricians[10]: CTG category I: normal plots predictive of fetuses with normal acid–base status; category II: non-reassuring plots not included in category III and requiring further obstetric surveillance; and category III: abnormal plots, such as sinusoidal patterns, a lack of variability, and frequent decelerations, among other changes associated with abnormal acid–base status.

After clamping a 20-cm segment of the umbilical cord, 1 mL of arterial blood was collected, and 1 mL of venous blood was transferred to a 3-mL blood gas analysis syringe containing heparin (BD Luer Lok, South Hackensack, NJ, USA). Not more than 30 min after collection, blood gas analysis was performed using a Cobas b 221 gasometer (Roche Diagnostics, Switzerland), and arterial and venous pH were analyzed[13,17]. An arterial pH <7.1 was associated with fetal acidemia[17]. When the pH difference was <0.02, blood collection from the same vessel or a mixture of arterial and venous blood was suspected.

The following variables were evaluated: age, ethnicity, smoking, number of pregnancies, number of previous deliveries, pre-existing disease, obstetric risk classification (high- or habitual-risk), presence of meconium, temperature>38°C, oxytocin use, misoprostol use, FHR abnormality, maternal bleeding during the first or second stage of labor, gestational age at delivery, CTG category, type of delivery, duration between cord clamping and pH analysis, venous pH, arterial pH, presence of fetal acidemia at birth, Apgar score at 1st minute, Apgar score at 5th minute, hospitalization in neonatal intensive care unit (ICU), early neonatal death (48 h after delivery), and need for neonatal resuscitation.

The presence of fetal acidemia at birth, the Apgar score at 1st minute<7, the need for hospitalization in the neonatal ICU, early neonatal death, and the need for neonatal resuscitation were considered adverse perinatal outcomes. The presence of at least one adverse perinatal outcome was considered a composite adverse perinatal outcome.

The Gpower 3.1 program was used to calculate the sample size. To determine sensitivity, specificity, false positive rate, false negative rate, positive likelihood ratio, and negative likelihood ratio, considering an effect size of 0.17, a probability of error α of 0.05, and a power of 0.95, a total number of 113 participants would be required.

The data were transferred to an Excel 2019 spreadsheet (Microsoft Corp., Redmond, WA, USA) and analyzed using the SPSS software version 20.0 (SPSS Inc., Chicago, IL, USA) and Prisma GraphPad version 7.0 (GraphPad Software, San Diego, CA, USA). Quantitative variables were submitted to the normality test (D'Agostino–Pearson). Variables with a normal distribution were presented based on their means and standard deviations. Variables with a non-normal distribution were presented as medians and interquartile ranges. Categorical variables were described as absolute and percentage frequencies and

represented in tables. The chi-square test was used to assess the differences between categorical variables and their proportions, whereas analysis of variance (ANOVA) and Kruskal–Wallis tests were used among continuous variables. Dunn's *post-hoc* test was used to compare pairs. Sensitivity, specificity, false-positive and false-negative rates, and positive and negative likelihood ratios were the key outcome measures. The significance level (α) for all tests was 0.05.

RESULTS

From November 2019 to November 2021, 2,861 women in labor were admitted to the hospital. A total of 1,096 cases were excluded because they did not undergo CTG, 899 due to the absence of umbilical cord blood gas tests, 687 because they were classified as high-risk pregnancies, 29 due to inadequate blood conditions (coagulation, duration between collection, and analysis>30 min), and 20 due to differences between venous and arterial pH <0.02. For the final statistical analysis, 90 CTG category I, 30 CTG category II, and 10 CTG category III results were considered.

The clinical characteristics of the study population are presented in Table 1. Significant associations were observed between CTG category and number of pregnancies (p=0.043) and between CTG category and delivery type (p<0.001). CTG category I presented a greater mean number of pregnancies (1.9 vs. 1.1, p=0.048) than CTG category III. CTG categories II and III had higher rates of cesarean deliveries than CTG category I (70 vs. 13.3%, p<0.0001, and 80.0 vs. 13.3%, p<0.0001, respectively). CTG category I had significantly higher 1-min Apgar scores (8.5 vs. 8.0, p=0.031) and 5-min Apgar scores (9.5 vs. 9.0, p=0.022) than category III. The CTG category had no significant effect on the pH of arterial (p=0.543) and venous blood (p=0.770).

The association between CTG category and indications for fetal evaluation during labor is presented in Table 2. CTG

Table 1. Clinical characteristics of the study population.

	Category I (n=90)	Category II (n=30)	Category III (n=10)	p
Age (years)	24.0 (21.0–24.0)	22.5 (17.0–26.0)	22.5 (16.0–25.2)	0.080†
Ethnicity				
White	31.1% (28/90)	53.3% (16/30)	60.0% (6/10)	0.110§
Black	14.4% (13/90)	6.7% (2/30)	0.0% (0/10)	
Mixed	51.1% (46/90)	40.0% (12/30)	30.0% (3/10)	
Asiatic	3.3% (3/90)	0.0% (0/30)	10.0% (1/10)	
Smoking	8.9% (8/90)	13.3% (4/30)	10.0% (1/10)	0.781§
Number of pregnancies	1.9 (1.3)B	1.7 (1.0)	1.1 (0.3)	0.043ƒ
Number of deliveries				
Nulliparous	1.1% (1/90)	0.0% (0/30)	0.0% (0/10)	0.799§
Multiparous	98.9% (89/90)	100% (30/30)	100% (10/10)	
Gestational age (weeks)	40.0 (38–40)	39.5 (38–40)	39.5 (37.2–40.2)	0.808†
Type of delivery				
Vaginal	83.3% (75/90)A,B	30.0% (9/30)	20.0% (2/10)	<0.001§
Cesarean section	13.3% (12/90)A,B	70.0% (21/30)	80.0% (8/10)	
Forceps	3.3% (3/90)	0.0% (0/30)	0.0% (0/10)	
Birth weight (g)	3220.0 (474)	3137 (439)	3117 (543)	0.605ƒ
Apgar score at 1st minute	8.5 (8.0–9.0)B	8.0 (8.0–9.0)	8.0 (8.0–9.0)	0.037†
Apgar score at 5th minute	9.5 (9.0–10.0)B	9.0 (9.0–9.0)	9.0 (8.0–9.0)	0.017†
Time cord clamping and pH analysis	13.9 (3.6)	14.2 (3.3)	16.6 (4.2)	0.506ƒ
pH arterial	7.24 (7.19–7.28)	7.21 (7.17–7.28)	7.22 (7.20–7.29)	0.543†
pH venous	7.29 (7.25–7.34)	7.29 (7.21–7.33)	7.27 (7.23–7.34)	0.770†

pH: hydrogen potential; Kruskal-Wallis †: median (interquartile range); one-way ANOVA ƒ: mean (standard deviation); chi-Square §: percentage (n/N); A: category I vs. category II; B: category I vs. category III; p<0.05.

category II had higher rates of FHR abnormality in intermittent auscultation than CTG category I (30.0 vs. 12.2%, p=0.044, respectively).

There was no significant association between the CTG category and the presence of acidemia at birth (p=0.706), 1-min Apgar score <7 (p=0.260), hospitalization in the neonatal ICU (p=0.605), newborn death within the first 48 h, need for neonatal resuscitation (p=0.637), and composite adverse outcomes (p=0.373) (Table 2). There was not any case of newborn death within 48 h after delivery.

The diagnostic accuracy measures of the CTG categories for identifying acidemia at birth by analyzing cord blood are presented in Table 3. It was observed that all three CTG categories presented low sensitivity and high negative predictive value for identifying acidemia at birth. CTG category I also showed low specificity (29.0%), while categories II and III presented high specificity (78.0 and 92.0%, respectively). CTG proved to be rarely useful in improving the ability to identify truly positive (low positive likelihood ratio values) and truly negative (high negative likelihood ratio values) individuals.

DISCUSSION

This study demonstrated that, compared to CTG category I, CTG categories II and III correlate with a higher prevalence of cesarean sections in low-risk pregnancies without reducing the prevalence of acidemia and other adverse perinatal events[9,13,18].

During fetal life, oxygen supply is dependent on maternal circulatory and respiratory functions, placental perfusion, placental gas exchange capacity, and umbilical and fetal circulations. Changes in any of these values lower the circulating O_2 concentration (hypoxemia). As a result, the fetal tissue concentration of oxygen (hypoxia) decreases, leading to fetal acidemia. The severity of fetal hypoxia depends on the intensity, duration, and frequency of repetition of the event and is associated with each fetus' individual capability of adapting to the situation[19].

The lack of understanding about the individual fetal ability to adapt to hypoxia may lead to the widespread use of intrapartum CTG in low-risk pregnancies in developed countries and tertiary childbirth care centers. Intrapartum fetal surveillance aims to detect fetal hypoxia caused by acute or subacute events during labor that requires medical intervention to reduce the risk of serious complications, such as cerebral

Table 2. Association between cardiotocograph category, indications to perform the fetal evaluation during the labor assistance and adverse perinatal outcomes in low-risk pregnancies.

	Category I (n=90)	Category II (n=30)	Category III (n=10)	p
Indications of CTG				
Bleeding	8.9% (8/90)	6.7% (2/30)	20% (2/10)	0.442
FHR abnormality	12.2% (11/90)[A]	30.0% (9/30)	20.0% (2/10)	0.047
Misoprostol use	30.0% (27/90)	23.3% (7/30)	30.0% (3/10)	0.777
Oxytocin use	37.8% (34/90)	26.7% (8/30)	30.0% (3/10)	0.514
Temperature>38°C	2.2% (2/90)	0.0% (0/30)	0.0% (0/10)	0.637
Meconium	8.9% (8/90)	13.3% (4/30)	0.0% (0/10)	0.442
Adverse perinatal outcomes				
Acidemia at birth	11.1% (10/90)	16.7% (5/30)	10.0% (1/10)	0.706
Apgar score 1st minute<7	6.7% (6/90)	13.3% (4/30)	20.0% (2/10)	0.260
Admission at neonatal ICU	10.0% (9/90)	13.3% (4/30)	20.0% (2/10)	0.605
Need for neonatal resuscitation	2.2% (2/90)	0.0% (0/30)	0.0% (0/10)	0.637
Composite perinatal outcomes	21.1% (19/90)	20.0% (6/30)	40.0% (4/10)	0.373

CTG: cardiotocography; FHR: frequency of heart rate; ICU: intensive care unit. Chi-square test: percentage (n/N). A: category I vs. category II; p<0.05.

Table 3. Measurements of diagnostic accuracy of intrapartum cardiotocography categories for identification of acidemia at birth through umbilical cord blood analysis in low-risk pregnancies.

	OR (95%CI)	Sensibility	Specificity	PPV	NPV	FP	FN	LHR negative	LHR positive
Category I	0.70 (0.25–2.16)	0.62	0.29	0.11	0.85	0.71	0.38	1.31	0.87
Category II	1.61 (0.57–4.80)	0.31	0.78	0.16	0.89	0.22	0.69	0.88	1.41
Category III	0.77 (0.06–5.79)	0.06	0.92	0.10	0.87	0.08	0.94	1.02	0.75

CI: confidence interval; OR: odds ratio; PPV: positive predictive value; NPV: negative predictive value; FP: false positive; FN: false negative; LHR: likelihood ratio.

palsy, hypoxic-ischemic encephalopathy, and neonatal death. The high rate of cesarean sections found in CTG categories II and III is justified because when changes are detected in fetal intrapartum monitoring, actions such as performing maneuvers to improve maternal and fetal oxygen supply are recommended. If the monitoring continues to show alterations after these maneuvers, it is recommended to expedite delivery before the fetus progresses to metabolic acidemia and potential fetal tissue injury[19].

In the present study, although CTG category III presented lower 1- and 5-min Apgar scores than CTG category I, no significant difference was observed in the prevalence of 1-min Apgar score of <7. Apgar scores reflect the neurological, cardiovascular, and pulmonary functions of the newborn, and they are inversely proportional to the duration and intensity of hypoxia. The 1-min Apgar score is an important parameter to assist in the decision about neonatal resuscitation, but it presents a low association with hypoxia or intrapartum acidosis[20]. The 5-min Apgar score is strongly associated with the risk of neonatal death and adverse neurological outcomes, both in the short and long term[21,22]. In the present study, this finding may have corroborated the lack of need for neonatal resuscitation among patients with CTG categories II and III. Conditions such as prematurity, labor trauma, infections, meconial aspiration, preexisting lesions, and medications administered during pregnancy can cause a decrease in Apgar scores[23]. In this study, only pregnancies at term were included to reduce the bias caused by prematurity on the analyzed variables.

There is consensus that a normal FHR pattern, the presence of FHR accelerations, and the absence of decelerations are highly predictive of normal fetal oxygenation. In this case, no additional intervention is required. On the contrary, the presence of recurrent variables and late decelerations, bradycardia, and the absence of FHR variability are predictive of acidemia, determining an urgent resolution of pregnancy[24]. To facilitate the interpretation and decision-making based on the findings of intrapartum CTG and associate these results with a high risk of hypoxia, some scientific entities have created systems for categorizing CTG plots[10,20,25].

Bhatia et al.[26] demonstrated that some CTG categorization systems present similar interobserver agreement when classifying the normal and suspicious categories of hypoxia. Unfortunately, FHR classification does not improve the ability to predict acidemia. A review of the existing FHR algorithms criticized the continuous emphasis placed on describing the morphological characteristics of the decelerations instead of evaluating the fetal capability of adaptation to hypoxia[27]. Additionally, uterine contractions are independently associated with neonatal hypoxia and acidemia[28]. In this study, no difference was observed in arterial and venous pH values even after using the CTG categorization proposed by the American College of Gynecologists and Obstetricians[10]. Moreover, no significant difference was observed in the prevalence of fetal acidemia and adverse perinatal outcomes in CTG categories II and III compared to category I.

In our study, CTG categories had a low positive predictive value for identifying fetal acidemia during the first stage of labor. However, the positive predictive value of CTG category III should be reassessed in light of the duration of labor[29,30] and the presence of terminal bradycardia at the second stage of labor[31]. Our study did not evaluate the association between the duration of labor and fetal acidemia. Cavoretto et al.[29] in a retrospective case-control study on 552 low-risk pregnancies receiving continuous CTG monitoring in labor and immediate hemogas analysis at birth, demonstrated that the risk of neonatal acidemia is directly proportional to the duration of the second stage, irrespective of the presence of CTG abnormalities, increasing 12-fold (1.2–15.3%) from 30 to 180 min. The occurrence of International Federation of Gynecology and Obstetrics (FIGO) 2015 pathological CTG patterns showed a decreasing impact from bradycardia>10 min to decelerations>5 min, recurrent later or prolonged decelerations>30 min, and non-pathological CTG[19]. The risk for acidemia increased moderately across the second stage of labor with non-pathological CTG and quadrupled with pathological CTG requiring expedited delivery. Adjustment for other predictors such as meconium-stained amniotic fluid and nulliparity revealed a significant hazard increase for acidemia associated with pathologic CTG requiring expedited delivery[30]. In our study, we did not perform a multivariate approach with meconium as a covariate due to the small sample size.

As a limitation of this study, based on retrospective analysis, the smaller sample of women in labor who presented CTG category III should be highlighted. This was due to the lower prevalence of this category in obstetric practice in low-risk pregnancies. The analysis was performed with a univariate approach without including a covariate. Further studies comparing different methodologies for the classification of intrapartum cardiotocography in low-risk patients are needed to assess the ability to detect fetal acidemia and predict adverse perinatal outcomes in this population.

CONCLUSION

The three categories of intrapartum CTG presented low sensitivity and a high negative predictive value for identifying

acidemia at birth. When compared to CTG category I, CTG categories II and III showed a higher prevalence of cesarean sections without being associated with a lower prevalence of adverse perinatal outcomes.

AUTHORS' CONTRIBUTIONS

MFT: Data curation. **RSL:** Data curation. **CGP:** Methodology. **EAJ:** Writing – original draft. **PTM:** Investigation. **ABP:** Formal Analysis, Supervision.

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