OBSTETRICS

A prospective cohort study of fetal heart rate monitoring: deceleration area is predictive of fetal acidemia

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BACKGROUND: Intrapartum electronic fetal monitoring is the most commonly used tool in obstetrics in the United States; however, which electronic fetal monitoring patterns predict acidemia remains unclear.

OBJECTIVE: This study was designed to describe the frequency of patterns seen in labor using modern nomenclature, and to test the hypothesis that visually interpreted patterns are associated with acidemia and morbidities in term infants. We further identified patterns prior to delivery, alone or in combination, predictive of acidemia and neonatal morbidity.

STUDY DESIGN: This was a prospective cohort study of 8580 women from 2010 through 2015. Patients were all consecutive women laboring at ≥37 weeks' gestation with a singleton cephalic fetus. Electronic fetal monitoring patterns during the 120 minutes prior to delivery were interpreted in 10-minute epochs. Interpretation included the category system and individual electronic fetal monitoring patterns per the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development criteria as well as novel patterns. The primary outcome was fetal acidemia (umbilical artery pH ≤7.10); neonatal morbidities were also assessed. Final regression models for acidemia adjusted for nulliparity, pregestational diabetes, and advanced maternal age. Area under the receiver operating characteristic curves were used to assess the test characteristics of individual models for acidemia and neonatal morbidity.

RESULTS: Of 8580 women, 149 (1.7%) delivered acidemic infants. Composite neonatal morbidity was diagnosed in 757 (8.8%) neonates within the total cohort. Persistent category I, and 10-minute period of category III, were significantly associated with normal pH and acidemia, respectively. Total deceleration area was most discriminative of acidemia (area under the receiver operating characteristic curves, 0.76; 95% confidence interval, 0.72—0.80), and deceleration area with any 10 minutes of tachycardia had the greatest discriminative ability for neonatal morbidity (area under the receiver operating characteristic curves, 0.77; 95% confidence interval, 0.75—0.79). Once the threshold of deceleration area is reached the number of cesareans needed-to-be performed to potentially prevent 1 case of acidemia and morbidity is 5 and 6, respectively.

CONCLUSION: Deceleration area is the most predictive electronic fetal monitoring pattern for acidemia, and combined with tachycardia for significant risk of morbidity, from the electronic fetal monitoring patterns studied. It is important to acknowledge that this study was performed in patients delivering ≥37 weeks, which may limit the generalizability to preterm populations. We also did not use computerized analysis of the electronic fetal monitoring patterns because human visual interpretation was the basis for the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development categories, and importantly, it is how electronic fetal monitoring is used clinically.

Key words: acidemia, deceleration area, electronic fetal monitoring, neonatal morbidity, pregnancy, term infants

Introduction

Intrapartum electronic fetal monitoring (EFM) is the most commonly used tool in obstetrics in the United States, with 85% of the >4 million deliveries each year having EFM.[1] Over the last 60 years, EFM has become the standard of care in US hospitals to monitor the fetus during labor, despite the lack of evidence to support its ability to reduce neonatal morbidity and mortality.[2,3] Acidemia at the time of birth is a risk factor for neonatal morbidity, including neurologic injury and mortality,[4,5] and EFM promised to be a noninvasive tool to reduce adverse outcomes by identifying fetuses developing acidemia.[6,7] It gained widespread use without supportive scientific evidence. Obstetric care providers use EFM patterns to identify fetuses at risk for acidemia and to make clinical decisions regarding delivery, often by cesarean. This has contributed, at least in part, to the dramatic rise in the cesarean rate.[8]

Data regarding EFM patterns and their association with acidemia are limited.[9] After an early description, in 1969, associating groups of EFM patterns with progressively worse umbilical artery pH,[10] randomized controlled trials failed to demonstrate improved outcomes with the use of EFM during labor.[11-16] A recent meta-analysis of >37,000 women evaluated the effectiveness of EFM during labor and concluded the use of continuous EFM was not associated with improved Apgar scores, or reduced hypoxic ischemic encephalopathy or neonatal mortality.[12] Despite widespread adoption of the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (NICHD) category system in the United States,[17] which EFM patterns predict acidemia remains unclear. Moreover, obstetric care providers need guidance to help them use the patterns seen at the bedside to understand the likelihood of normal pH or acidemia.

We aimed to describe the frequency of EFM patterns seen in labor using modern nomenclature, and assess their association with acidemia and neonatal morbidity. We hypothesized that some visually interpreted EFM patterns are associated with acidemia and morbidities in term

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AJOG at a Glance

Why was this study conducted?

We aimed to measure electronic fetal monitoring patterns in the 2 hours before delivery and assess their association with acidemia and neonatal morbidity among term infants.

Key findings

Deceleration area, and deceleration area combined with tachycardia, were most discriminatory for acidemia and neonatal morbidity, respectively.

What does this add to what is known?

In the setting of high total deceleration area, the number of cesareans needed-to-be performed to prevent 1 case of acidemia or morbidity is relatively low. These specific features of electronic fetal monitoring patterns should be incorporated into clinical interpretation and algorithms to improve the performance of electronic fetal monitoring.

infants, while others can help identify infants with a normal pH. We further aimed to identify EFM patterns, which alone or in combination, are predictive of acidemia and neonatal morbidity.

Materials and Methods

This was a single-center prospective cohort study of all consecutive women in labor at ≥37 0/7 weeks' gestation with a singleton, nonanomalous infants from 2010 through 2015. The Washington University School of Medicine Human Research Protection Office approved this study prior to enrollment (identification no. 201102438). Universal continuous EFM and umbilical artery pH are standard of care at our institution. Patients were included if they had umbilical artery pH availability and sufficient EFM, defined as at least 30 minutes of EFM data in the 120 minutes prior to delivery. This definition prevented exclusion of cases with clinical events precluding optimization of continuous monitoring, as well as to enable generalizability. Participants who did not experience labor, did not have continuous EFM, or did not have an umbilical artery pH were excluded.

The primary outcome was fetal acidemia, defined as umbilical artery pH ≤7.10. A pH ≤7.10 was chosen to test the possibility that EFM patterns could assist in identifying term fetuses developing an abnormal pH but not severe enough to cause morbidity. To obtain the umbilical artery pH, a segment of the umbilical artery cord was clamped immediately after delivery. Whole blood was analyzed centrally using an automated benchtop analyzer (GEM Premier 4000; Instrumentation Laboratory, Bedford, MA) to measure the umbilical artery pH and associated components. Secondary outcomes included neonatal

TABLE 1
***Eunice Kennedy Shriver* National Institute of Child Health and Human Development definitions of fetal heart rate parameters**

Uterine activity: presence of contractions
Baseline fetal heart rate: approximation of mean fetal heart rate of increments of 5 bpm, using 10-min window, and excluding periodic changes; at least 2 of 10 min must be spent at baseline, or baseline for that period is indeterminate • Normal: 110–160 bpm • Bradycardia: <110 bpm • Tachycardia: >160 bpm
Baseline fetal heart rate variability: visual quantification of amplitude of fluctuations of fetal heart rate at baseline; thought to be physiologic result of interplay between fetal sympathetic and parasympathetic nervous systems • Absent: undetectable amplitude • Minimal: amplitude 1–5 bpm • Moderate: amplitude 6–25 bpm • Marked: amplitude >25 bpm
Accelerations: visually apparent abrupt increase in fetal heart rate, moving from baseline to peak in <20 s; must be at least 15 bpm above baseline and last at least 15 s
Decelerations: visually apparent decrease in fetal heart rate at least 15 bpm below baseline, and further classified by type • Late deceleration: visually apparent, often symmetric, gradual decrease (onset to nadir ≥30 s) and return of fetal heart rate to baseline, but delayed—often with onset, nadir, and resolution after beginning, peak, and end of contraction • Variable deceleration: visually apparent abrupt decrease in fetal heart rate, onset to nadir in <30 s, and return to baseline; onset, depth, and duration often vary when occurring with contraction • Early deceleration: visually apparent, often symmetric, graduate increase (onset to nadir ≥30 s) and return of fetal heart rate to baseline associated with uterine contraction, with nadir occurring with peak of contraction • Prolonged deceleration: >2 min, by <10 min (>10 min is baseline change)

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