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Authors

Cortes, Christina N

Cagino, Kristen A

Roberts, Aaron W

et al.

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Original Article

Association of Fetal Heart Rate Tracing with Adverse Neonatal Outcomes at $32^{0/7}$ to $36^{6/7}$ Weeks

Christina N. Cortes[1], Kristen A. Cagino[1], Aaron W. Roberts[1], Rachel L. Wiley[2], Shareen Patel[1], Fabrizio Zullo[3], Hector Mendez-Figueroa[1], Suneet P. Chauhan[4]

Affiliation addresses are listed at the end of the article.

ABSTRACT

Objective The objective of this study is to determine if patterns of fetal heart rate tracings (FHRT) were associated with an increased rate of composite adverse neonatal outcomes (CANO) among preterm deliveries at $32^{0/7}$ to $36^{6/7}$ weeks.

Study Design This was a retrospective review of intrapartum FHRT between 20 and 120 minutes before birth, among nonanomalous singletons delivered at $32^{0/7}$ to $36^{6/7}$ weeks. The study was conducted at a Level IV maternal center during a consecutive 15-month period. Obstetricians reviewing FHRT were blinded to the maternal characteristics, intrapartum course, and neonatal outcomes. FHRT patterns were categorized based on time spent in the final 2 hours before delivery (<50 vs. ≥50%). The primary outcome was the CANO, which included any of the following: 5-minute Apgar < 7, mechanical ventilation > 6 hours, umbilical artery pH < 7.00, bronchopulmonary dysplasia, interventricular hemorrhage, necrotizing enterocolitis, neonatal seizures, neonatal confirmed sepsis, hypoxic ischemic encephalopathy, birth injury, meconium aspiration syndrome, or neonatal death.

Results Of 5,160 patients, 672 (13%) met the inclusion criteria. CANO occurred in 57 (8.5%) newborns. Overall, FHRT patterns that differed significantly between those without versus with CANO included minimal variability (8.8 vs. 19.3%, $p = 0.01$, PLR = 2.2 [positive likelihood ratio], PPTP 17% [positive posttest probability]), moderate variability (76.4 vs. 52.6%, $p < 0.001$, NLR = 2.01 [negative likelihood ratio], NPTP 15.7% [negative posttest probability]), accelerations (58.4 vs. 40.4%, $p = 0.009$, NLR = 1.43, NPTP = 11.7%), and severe variable decelerations (3.5% $p = 0.003$, PLR = 10.79, PPTP = 50.1%). Category III FHRT pattern was also associated with an increased posttest probably of CANO (0.3 vs. 1.8%, $p = 0.12$, PLR = 5.39, PPTP = 27%).

Conclusion While moderate variability and accelerations were associated with significantly lower likelihood of CANO among newborns delivered at $32^{0/7}$ to $36^{6/7}$ weeks, minimal variability and severe variable decelerations were significantly more common in preterm newborns with CANO.

Keywords accelerations, hypoxic ischemic encephalopathy, intraventricular hemorrhage, minimal variability, mechanical ventilation, moderate variability, nonreassuring fetal heart rate tracing, preterm pregnancies, variable decelerations, 5-minute Apgar < 7

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Correspondence Suneet P. Chauhan, MD, Hon DSc, Delaware Center for Maternal-Fetal Medicine of ChristianaCare, Newark, Delaware 19807, United States, Email: schauhan@dcmfm.com

Introduction

Intrapartum fetal heart rate tracing (FHRT) monitoring is the most common obstetric procedure in the United States and is used in over 80% of births.[1] The goal of FHRT monitoring is to decrease adverse neonatal outcomes that may develop during labor. However, reports have shown that while FHRT monitoring may decrease the rate of neonatal seizures, it does not decrease the rate of cerebral palsy or neonatal mortality.[2] FHRT monitoring is associated with an increased maternal risk, mostly in higher risk of operative vaginal deliveries and cesarean sections.[3] Additionally, FHRT is associated with several shortcomings, including high intra- and interobserver variability, high false positive rate, and nonuniversal nomenclature and varying management algorithms.[2,4]

There are knowledge gaps on FHRT in preterm newborns as blinded review of FHRT is typically limited to term deliveries.[5–8] Further, complicating the utility of FHRT in preterm pregnancies are differences in FHRT patterns among term versus preterm fetuses. These differences are presumably secondary to immature sympathetic and parasympathetic nervous systems and structural differences in the umbilical cord and myocardium leading to higher baselines, decreased variability, fewer accelerations, and increased variable decelerations.[9] Additionally, preterm infants may more acutely develop FHRT abnormalities and progress to severe findings quicker than term infants. Chen et al[1] reported a

Key Points

- At 32 to 36 weeks, CANO occur in approximately 8% of neonates.
- Severe variable decelerations and minimal variability increase risk of CANO.
- The PPTP of CANO is 33%, if Category III FHRT is noted before birth.
- The PPTP is 13%, if there is persistent Category II FHRT in the last 120 minutes.

smaller number needed to test (NNT, defined as number of FHRT needed to prevent one neonatal death) to prevent preterm neonatal deaths compared with term neonates. For example, the NNT to prevent one early neonatal death within the first 6 days was 29 at 32 to 33 weeks compared with 1,449 at 34 to 36 weeks and 10,949 at 37 weeks.[1]

To address knowledge gaps of FHRT among preterm fetuses, we undertook this retrospective cohort study. The primary objective was to determine if specific patterns of FHRT are associated with composite adverse neonatal outcome (CANO) among preterm deliveries from $32^{0/7}$ to $36^{6/7}$ weeks. We hypothesized that FHRT patterns would differ significantly among those without versus with CANO among singleton preterm fetuses.

Materials and Methods

We conducted an analysis of all individuals who delivered from July 2020 to September 2021 at a Level IV maternal center. The University of Texas Health Science Center at Houston Institutional Review Board approved this as an informed consent waived study (approval no.: HSC-MS-21-0383).

A previous publication using this dataset had focused on FHRT characteristics among term ($\geq$37 weeks) neonates, comparing cases with to those without adverse neonatal outcomes. Methods of our analysis have been previously described in detail.[5] For our current analysis, we included all nonanomalous singletons deliveries at $32^{0/7}$ to $36^{6/7}$ weeks. Intrapartum FHRT from the last 20 to 120 minutes before delivery was reviewed by obstetricians (4 OBGYN residents, 5 MFM fellows, and 3 OBGYN attendings) blinded to maternal characteristics, gestational age, and peripartum outcomes. Time was measured from the last recorded minute of FHRT to reflect cesarean deliveries that may have had gaps in FHRT during transport. FHRTs were reviewed in 20-minute segments and information on individual patterns of FHRTs and American College of Obstetricians and Gynecologists (ACOG) category system classification were recorded.[2] FHRT features were categorized as present if they occurred in >50% of segments in up to the last 2 hours prior to delivery. Additionally, to explore the relationship of severity of the decelerations with CANO, we adopted the definitions proposed by Parer and Ikeda for mild, moderate, and severe variable, late, and prolonged decelerations.[10] Training was provided (by K.A.C. and S.C.P.) to each obstetrician interpreting the FHRT to ensure consistency in data collection and standardized rubrics with pictographic nomograms were used as reference during the collection process.

Baseline fetal heart rate was determined by the mean of at least 10 minutes of FHRT, rounded to the nearest 5 beats per minute (bpm). Variability was classified as absent (undetectable), minimal (<5 bpm), moderate (6–25 bpm), or marked (>25 bpm). Accelerations were classified as absent, mild (>10 bpm for >10 seconds), moderate (>15 bpm for >15 seconds), or severe (>15 bpm over 2 minutes). For the purposes of analysis, we only analyzed accelerations as present or absent. Decelerations were classified as early, variable, or late in accordance with the ACOG guidelines and further classified based on severity. Early decelerations were classified as mild (15 bpm below baseline), moderate (30 bpm below baseline), or severe (45 bpm or more below baseline). Variable decelerations were classified as moderate (30–60 second duration with nadir <70–80 bmp), severe (60–120 second duration with nadir < 80), or mild if either previous criterion were not met. Lastly, late decelerations were classified as mild (<15 bpm below baseline), moderate (15–45 bpm below baseline), or severe (>45 bpm or more below baseline). Prolonged decelerations were analyzed and reported as absent, mild (decrease from baseline < 15 bpm and >30 seconds and <2 minutes), moderate (decrease from baseline <15 bpm and >2 minutes and <6 minutes), or severe (decrease from baseline <15 bpm and >6 minutes). The reviewers then classified the FHRT as Category I, II, or III using the ACOG classification system.[2]

The primary outcome was the rate of CANO that included any of the following: 5-minute Apgar < 7, mechanical ventilation > 6 hours, umbilical artery (UA) pH < 7, bronchopulmonary dysplasia, interventricular hemorrhage, necrotizing enterocolitis, neonatal seizures, neonatal confirmed sepsis, hypoxic ischemic encephalopathy, birth injury, meconium aspiration syndrome, or neonatal death.

Maternal and intrapartum characteristics were compared using Pearson's chi-squared or Fisher exact test. A p-value of <0.05 was considered significant. Adjusted odds ratios were calculated using logistic regression, along with 95% confidence interval. Sensitivity, specificity, PLR (positive likelihood ratio), NLR (negative likelihood ratio), PPTP (positive posttest probability), and NPTP (negative posttest probability) were calculated for each FHRT pattern. Unadjusted PLR and NLR were calculated for each individual component of the FHRT pattern interpretation, and separately groupings of FHRT patterns and ACOG pattern classifications representing various real-world clinical scenarios were analyzed using adjusted odds ratios and PLR and NLR. Haldane's correction was applied when zero observations were present in either group by adding 0.5 to all observations in the 2×2 matrix prior to calculation, to prevent divide-by-zero errors. Using guidelines from the Evidence-Based Medicine Working Group, PLR and NLRs were considered definitively useful if >10 or <0.1, moderately useful if the LR was 5 to 10, or 0.1 to 0.2, slightly useful if the LR was 2 to 5, or 0.2 to 0.5, and not useful if the LR was 1 to 2 or 0.5 to 1.[11] Posttest probabilities were calculated using a pretest probability equal to the overall CANO rate for preterm deliveries in this cohort. All analyses were performed using R Statistical Software (v4.3; R Core Team 2023). The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology)

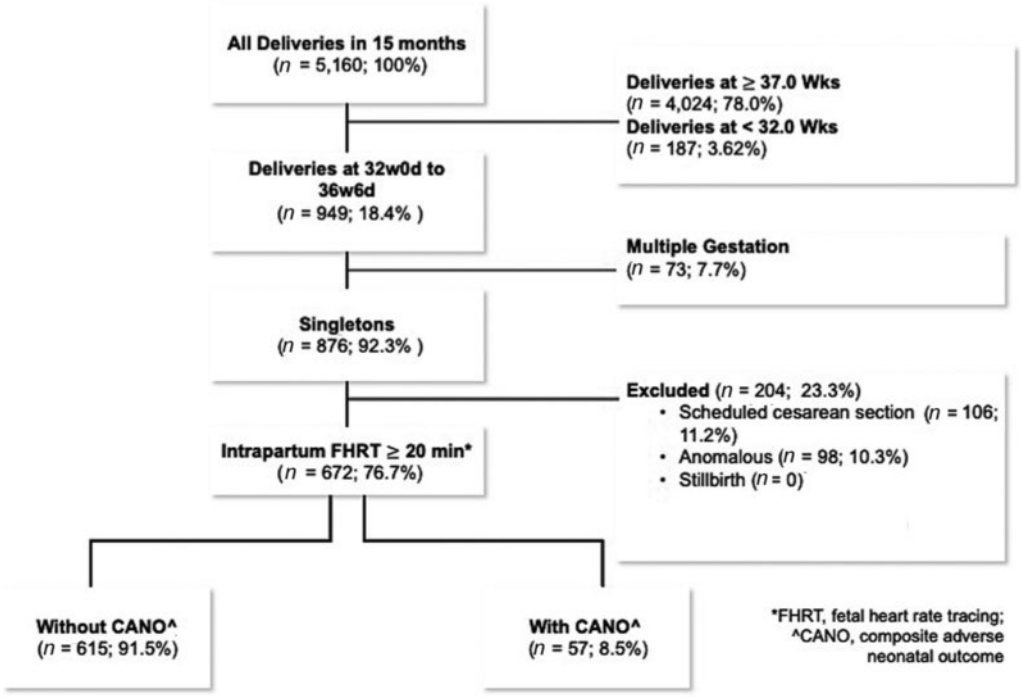

Fig. 1 A $32^{0/7}$ to $36^{6/7}$ weeks' FHRT reviewed by physicians, ^CANO, composite adverse neonatal outcome; *FHRT, fetal heart rate tracing.

guidelines for reporting observational studies were followed throughout the manuscript.[12]

Results

During the study period, there were 5,160 deliveries. Of these, 949 (18.4%) were within the target gestational age and 672 (70.8%) met inclusion criteria. A total of 277 deliveries were excluded secondary to multifetal gestations ($n = 73$), scheduled cesarean sections ($n = 106$), and presence of anomalous fetus ($n = 98$). CANO occurred in 8.5% (57/672) of the cohorts (**Fig. 1**). The number of 20-minute epochs reviewed for those without versus with CANO differed significantly ($p = 0.004$; **Supplementary Table S1**, available in online version)

Maternal characteristics did not statistically differ between groups with regard to maternal age, nulliparity, maternal body mass index, race, tobacco use, or insurance status (**Table 1**). Intrapartum characteristics did not differ statistically between groups with regard to induction of labor, use of magnesium sulfate, amnioinfusion, cook balloon, prostaglandin cervical ripening, or method of rupture of membrane (spontaneous rupture of membrane vs. artificial rupture of membrane). Use of neuraxial anesthesia ($p < 0.001$), route of delivery ($p < 0.001$), and nonreassuring fetal heartrate tracing as indication for cesarean section ($p = 0.005$) were statistically different (**Table 2**). We calculated unadjusted test performance statistics for each individual component of the FHRT pattern interpretation (**Table 3**). When we analyzed various combinations of FHRT patterns that represent different clinical scenarios (**Table 4**), adjustment for neuraxial anesthesia was performed as it was the only independent baseline characteristic that differed between the two groups. We did not adjust for route of delivery, because that is an outcome (dependent variable) of FHRT interpretation and therefore would not be appropriate for adjustment with logistic regression.

The three most frequent components of CANO were mechanical ventilation > 6 hours (54.4%), 5-minute Apgar < 7 (42.1%), and intraventricular hemorrhage (12.3%). There were no cases of neonatal death or birth injury (**Table 5**).

Minimal variability (8.8 vs. 19.3%, $p = 0.01$, PLR = 2.2, PPTP = 17%) and severe variable decelerations (0.3 vs. 3.5% $p = 0.003$, PLR = 10.79, PPTP = 50.1%) were more likely to occur with CANO compared with without CANO. Two features of FHRT occurred significantly less often with CANO: moderate variability (76.4 vs. 52.6%, $p < 0.001$, PLR = 0.69, PPTP = 15.7%) and presence of accelerations (58.4 vs. 40.4%, $p = 0.009$, PLR = 0.69, PPTP = 11.7%, **Table 3**). Persistent Category II prior to delivery was associated with CANO (22.1 vs. 35.1% $p = 0.03$, PLR = 1.59, PPTP = 12.9%). When moderate variability is absent >50% of the time, the posttest probability of CANO was increased (NLR = 2.48, NPTP = 18.7%) and was even further increased if absent the entire time (NLR = 5.16, NPTP = 32.4%). The absence of accelerations at any time conferred a higher risk of CANO (NLR = 3.16, NPTP 22.7%). If accelerations were present >50% of the time, then the posttest probability of CANO was not increased in the presence of decelerations (PLR = 0.74, PTPP = 6.4%) or severe decelerations (PLR = 0.91, PTPP = 7.8%, **Table 4**). Category III FHRT pattern was also associated with an increased PPTP of CANO (0.3 vs. 1.8%, $p \leq 0.12$, PLR = 5.39, PPTP = 33.4%, **Table 4**).

Discussion

Principle Findings

Compared with a pretest probability of CANO of 8.5% in our cohort, no feature of FHRT using the ACOG nomenclature or

Table 1 Baseline characteristics

	Without CANO[a]	With CANO[a]	*p*-Value
	(*N* = 615)	(*N* = 57)	
Maternal age (y)			0.12
< 18	38 (6.2)	1 (1.8)	
18–34	461 (75)	40 (72)	
35 or more	116 (18.9)	16 (28.1)	
Nulliparous	200 (32.5)	20 (35.1)	0.69
Race			0.59
Black	108 (17.6)	9 (15.8)	
Hispanic	238 (38.7)	23 (40.4)	
White	181 (29.4)	18 (31.6)	
Asian	24 (3.9)	4 (7)	
Others	64 (10.4)	3 (5.3)	
BMI $\geq$ 30 kg/m^2	400 (65)	39 (69.6)	0.49
Private insurance	213 (34.6)	23 (40.4)	0.39
Smoking/tobacco use	28 (4.6)	6 (10.5)	0.05
Hypertensive disorder of pregnancy[b]	317 (51.5)	31 (54.4)	0.68
Diabetes mellitus[c]	127 (20.7)	17 (29.8)	0.11
Hypothyroidism	19 (3.1)	0 (0)	0.18
Hyperthyroidism	4 (0.7)	0 (0)	0.54
Anemia Hgb < 10	63 (10.2)	5 (8.8)	0.72
DVT/PE	8 (1.3)	0 (0)	0.39
Asthma	66 (10.7)	3 (5.3)	0.19
Seizure disorder	16 (2.6)	4 (7)	0.06
Cardiac disease	6 (1)	0 (0)	0.45
Kidney disease	5 (0.8)	0 (0)	0.49
Major infection (HIV, hepatitis, etc.)	7 (1.1)	1.0 (1.8)	0.68
Psychiatric disorder	82 (13.3)	6 (10.5)	0.55
COVID-19	43 (7)	6 (10.5)	0.33

Abbreviations: BMI, body mass index; CANO, composite adverse neonatal outcome; COVID-19, coronavirus disease 2019; Hgb, hemoglobin; PE/DVT, pulmonary embolism/deep venous thrombosis.

Notes: Data presented as *N* (%).

[a]CANO, which included any of the following: Apgar < 7 at 5 minutes, mechanical ventilation > 6 hours, bronchopulmonary dysplasia, intraventricular hemorrhage, necrotizing enterocolitis, seizures, sepsis, brachial plexus palsy, hypoxic ischemic encephalopathy or neonatal death.

[b]Hypertensive disorder is a composite of any hypertension disorder in pregnancy including pre-eclampsia, chronic hypertension, and gestational hypertension.

[c]Diabetes is any diabetes disorder including preexisting type 1 or type 2 and gestational.

classification reduced the posttest probability of CANO to lower than 3%. In our cohort of preterm newborns, minimal variability and severe variable decelerations were associated with CANO, whereas moderate variability and accelerations were associated with decreased risk of CANO.

Results in the Context of What Is Known

Our findings reaffirm ACOGs stance on FHRT patterns, specifically for preterm fetuses—Category I is reassuring, Category III requires intervention, and if persistent then prompt delivery to mitigate CANO, and Category II is broad requiring further evaluation of specific patterns. ACOG Practice Bulletin No. 116 discusses the reassuring nature of accelerations and moderate variability even in the presence of a Category II pattern.[3] Our data support this, as we observed moderate variability, even in the presence of nonsevere decelerations, was associated with a decrease in the risk of CANO.[3,13,14]

Timms et al investigated FHRT patterns in laboring preterm patients from 23 to 36$^{6/7}$ weeks and found the only factor to increase odds of pH < 7.1 was decreased variability.[13] Our data also demonstrated an increased risk of CANO with minimal variability >50% of the time with a PPTP of 13%.

Our data also showed that severe variable decelerations were predictive of CANO with a PPTP of 50.1%, albeit with only four cases. There are several studies investigating preterm neonatal outcomes in the setting of decelerations with conflicting results. Some studies do not show an association between decelerations and decreased UA pH; however, one study did show an increase in

Table 2 Intrapartum Characteristics

	Without CANO[a] (*N* = 615)	With CANO[a] (*N* = 57)	*p*-Value
Induction of Labor	241 (39.2)	22 (38.6)	0.93
Magnesium use			0.16
None	430 (69.9)	32 (56.1)	
Antepartum	149 (24.2)	19 (33.3)	
In Labor	21 (3.4)	4 (7)	
Postpartum	15 (2.4)	2 (3.5)	
Neuraxial anesthesia[b]	546 (96.1)	46 (82.1)	**<0.01**
Amnioinfusion	45 (7.3)	5 (8.8)	0.69
Mechanical dilation	118 (19.2)	14 (24.6)	0.33
Prostaglandin ripening	40 (6.5)	5 (8.8)	0.51
Oxytocin use	331 (53.8)	26 (45.6)	0.24
ROM type[c]			0.59
AROM	430 (76.6)	40 (80)	
SROM	131 (23.4)	10 (20)	
Route of delivery			**<0.01**
Vaginal	324 (52.7)	15 (26.3)	
Cesarean[d]	291 (47.3)	42 (73.7)	
Labor Arrest	40 (6.5)	3 (5.3)	0.71
NRFHT	57 (9.3)	12 (21.2)	**<0.01**
Repeat/failed TOLAC	136 (22.1)	18 (31.6)	0.11
Malpresentation	37 (6)	6 (10.5)	0.18
Various[e]	55 (8.9)	6 (10.5)	0.69

Abbreviations: AROM, artificial rupture of membranes; CANO, composite adverse neonatal outcome; NRFHT, nonreassuring fetal heart rate tracing; SROM, spontaneous rupture of membranes; TOLAC, trial of labor after cesarean section.
Notes: Data presented as *N* (%). Bolded if significantly different.
[a]CANO, which included any of the following: Apgar < 7 at 5 minutes, mechanical ventilation > 6 hours, bronchopulmonary dysplasia, intraventricular hemorrhage, necrotizing enterocolitis, seizures, sepsis, brachial plexus palsy, hypoxic ischemic encephalopathy, or neonatal death.
[b]Missing data in 48.
[c]Missing data in 61.
[d]An individual may have more than one indication for cesarean delivery.
[e]Various included: intrapartum bleeding, intrapartum infection, parturients request, provider preference, maternal medical condition exacerbation (asthma, seizure, hypertension, sepsis, emergency).

hypoxic ischemic encephalopathy with variable decelerations.[13,15] Furthermore, reports differ by quantification of deceleration (such as frequency of deceleration and area of deceleration). While Zanini et al found decreased UA pH when variable decelerations occurred with more than 75% of uterine contractions, Henkel et al found no significant difference in total deceleration area and UA pH.[16,17] In terms of late decelerations, Matsuda et all found that recurrent late decelerations with loss of variability and prolonged decelerations were related to fetal acidemia in preterm infants at $26^{0/7}$ to $36^{6/7}$.[18] Our findings showed that decelerations, in the presence of moderate variability or accelerations, were not associated with adverse neonatal outcomes.

Clinical Implications

Our findings reaffirm that moderate variability and accelerations are reassuring in the presence of a Category II tracing. This is an important finding which may support continued augmentation of labor in the presence of decelerations (as long as there is moderate variability), thereby decreasing the risk of morbidity associated with cesarean sections and operative deliveries mortality.[19]

One challenge with the ACOG Category system is that Category II is broad and indeterminate to reliably assess fetal status in labor. This resulted in a division between nebulous definitions of "nonconcerning" and "concerning" Category II FHRT and may also explain an increase in the observed cesarean rate overall.[20] Our study provides further clarity on those Category II features that may require intervention, and just as importantly, those that do not. The absence of moderate variability or presence of severe decelerations (early, late, or variable) conferred increases in posttest probability of CANO.

No feature of FHRT, as classified by ACOG nomenclature, reduced the posttest probability of CANO below 3% in this cohort. This underscores that FHRT patterns alone can never fully rule out the risk of adverse neonatal outcomes, highlighting the critical role of shared decision-making between patients and their care teams.[21]

Table 3 Individual patterns of fetal heart rate tracings with neonatal outcomes

	Without CANO[a] (*N* = 615)	With CANO[a] (*N* = 57)	*p*-Value	Sens (%)	Spec (%)	PLR (95% CI)	NLR (95% CI)	PPTP (%)	NPTP (%)
Tachycardia	7 (1.1)	0 (0)	0.42	0.9	99.4	1.52 (0.09–24.55)	1.00 (0.06–16.14)	12.4	8.5
Bradycardia	3 (0.5)	0 (0)	0.59	0.9	98.8	0.71 (0.09–24.55)	1.00 (0.06–16.14)	6.2	8.5
Variability									
Minimal	54 (8.8)	11 (19.3)	**0.01**	19.3	91.2	2.20 (1.29–3.74)	0.88 (0.52–1.51)	17.0	7.6
Moderate	470 (76.4)	30 (52.6)	<**0.01**	52.6	23.6	0.69 0.52–0.92)	2.01 (1.51–2.67)	6.0	15.7
Accelerations	359 (58.4)	23 (40.4)	<**0.01**	40.4	41.6	0.69 (0.50 0.96)	1.43 (1.03–1.99)	6.0	11.7
Decelerations									
Any[c]	434 (70.6)	36 (63.2)	0.24	63.2	29.4	0.89 (0.71–1.13)	1.25 (0.99–1.58)	6.0	11.7
Early									
Mild	5 (0.8)	0 (0)	0.49	0.9	99.1	0.97 (0.06–15.63)	1.00 (0.06–16.19)	8.3	8.5
Moderate	2 (0.3)	0 (0)	0.67	0.9	99.6	2.12 (0.13–34.38)	1.00 (0.06–16.11)	16.5	8.5
Severe	0 (0)	1 (1.8)	<**0.01**	2.6	99.9	31.86 (6.48–156.76)	0.97 (0.2–4.8)	74.7	8.3
Late									
Mild	16 (2.6)	2 (3.5)	0.69	3.5	97.4	1.35 (0.35–5.26)	0.99 (0.25–3.87)	11.1	8.4
Moderate	4 (0.7)	0 (0)	0.54	0.9	99.3	1.18 (0.07–19.1)	1.00 (0.06–16.16)	9.9	8.5
Severe	1 (0.2)	0 (0)	0.76	0.9	99.8	3.54 (0.22–57.29)	0.99 (0.06–16.08)	24.7	8.4
Variable									
Mild	69 (11.2%	3 (5.3)	0.16	5.3	88.8	0.47 (0.16–1.41)	1.07 (0.35–3.21)	4.2	9.0
Moderate	20 (3.3)	1 (1.8)	0.53	1.8	96.7	0.54 (0.08–3.76)	1.02 (0.15–7.09)	4.8	8.7
Severe	2 (0.3)	2 (3.5)	<**0.01**	3.5	99.7	10.79 (2.77–42.1)	0.97 (0.25–3.78)	50.1	8.3
Prolonged									
Mild	32 (5.2)	2 (3.5)	0.58	3.5	94.8	0.67 (0.17–2.63)	1.02 (0.26–3.97)	5.9	8.7
Moderate	2 (0.3)	1 (1.8)	0.12	1.8	99.7	5.39 (0.77–37.64)	0.99 (0.14–6.98)	33.4	8.4

Abbreviations: CANO, composite adverse neonatal outcome; NLR, negative likelihood ratio; NPTP, negative posttest probability; PLR, positive likelihood ratio; PPTP, positive posttest probability.

Notes: Data presented at *N* (%), *p*-values are unadjusted. Bolded if significantly different.

[a]CANO, which included any of the following: Apgar < 7 at 5 minutes, mechanical ventilation > 6 hours, bronchopulmonary dysplasia, intraventricular hemorrhage, necrotizing enterocolitis, seizures, sepsis, brachial plexus palsy, hypoxic ischemic encephalopathy or neonatal death.

[b]There were no epoch marked as "Absent" or "Marked" Variability, or "severe" prolonged decelerations.

[c]Any decelerations included a composite of late, variable, or prolonged decelerations.

Research Implications

We are unable to determine whether intervention, at all or at a certain time period, in cases of nonreassuring FHRT characteristics improves neonatal outcomes in preterm newborns delivered at $32^{0/7}$ to $36^{6/7}$ weeks. Studies indicate that the time with a Category II FHRT does not affect neonatal outcomes; however, these publications included term infants and do not specify characteristics within Category II FHRT.[5,7,8,22] Further investigation is required to assess how the impact of intervention and the timing affect neonatal outcomes in preterm infants with NRFHT patterns.

Table 4 Combination and trends of fetal heart rate patterns and risk of composite neonatal morbidity

	Without CANO[a] (*N* = 615)	With CANO[a] (*N* = 57)	*p*-Value	aOR (95% CI)	Sens (%)	Spec (%)	PLR (95% CI)	NLR (95% CI)	PPTP (%)	NPTP (%)
Category I—always	155 (25.2%)	14 (24.6%)	0.92	0.90 (0.47–1.72)	24.6	74.8	0.97 (0.62–1.54)	1.01 (0.64–1.59)	8.3	8.6
Category II										
Always Category II	136 (22.1%)	20 (35.1%)	**0.03**	1.84 (1.09–3.36)	35.1	77.9	1.59 (1.11–2.26)	0.83 (0.58–1.19)	12.9	7.2
Any time Category II	460 (74.8%)	43 (75.4%)	0.92	1.12 (0.58–2.10)	75.4	25.2	1.01 (0.82–1.23)	0.97 (0.80–1.19)	8.6	8.3
Tachycardia										
With any decelerations[b]	7 (1.1%)	0 (0%)	0.42	–	0.9	98.9	0.71 (0.04–11.46)	1.00 (0.06–16.24)	6.2	8.5
With severe decelerations only[c]	113 (18.4%)	16 (28.1%)	0.08	1.59 (0.84–3.01)	28.1	81.6	1.53 (0.09–24.55)	0.88 (0.06–16.14)	12.4	7.6
Moderate variability										
Always moderate variability	436 (70.9%)	32 (56.1%)	**0.02**	0.56 (0.32–0.98)	56.1	29.1	0.79 (0.61–1.03)	1.51 (1.16–1.96)	6.8	12.3
With decelerations[c]	286 (46.5%)	17 (29.8%)	**0.02**	0.57 (0.31–1.05)	29.8	53.5	0.64 (0.43–0.96)	1.31 (0.87–1.97)	5.6	10.8
With severe decelerations[c]	75 (12.2%)	6 (10.5%)	0.71	0.94 (0.38–2.30)	10.5	87.8	0.86 (0.40–1.84)	1.02 (0.48–2.17)	7.4	8.7
Moderate variability at any time	592 (96.3%)	46 (80.7%)	<**0.01**	0.18 (0.08–10.4)	80.7	3.7	0.84 (0.55–1.28)	5.16 (3.39–7.86)	7.2	32.4
With decelerations[c]	415 (67.5%)	29 (50.9%)	**0.01**	0.55 (0.31–0.97)	50.9	32.5	0.75 (0.57–1.00)	1.51 (1.14–2.00)	6.5	12.3
With severe decelerations[c]	107 (17.4%)	12 (21.1%)	0.49	1.21 (0.60–2.46)	21.1	82.6	1.21 (0.73–2.00)	0.96 (0.58–1.58)	10.1	8.2
Moderate variability (>50% time)	554 (90.1%)	43 (75.4%)	<**0.01**	0.32 (0.17–0.64)	75.4	9.9	0.84 (0.63–1.11)	2.48 (1.87–3.38)	7.2	18.7
With decelerations[c]	381 (62.0%)	26 (45.6%)	**0.02**	0.59 (0.31–0.96)	45.6	38.0	0.74 (0.54–0.99)	1.43 1.06–1.93)	6.4	11.7
With severe decelerations[c]	99 (16.1%)	10 (17.5%)	0.78	1.03 (0.48–2.21)	17.5	83.9	1.09 (0.62–1.92)	0.98 (0.56–1.73)	9.2	8.3
Accelerations										
Accelerations present always	252 (41.0%)	19 (33.3%)	0.26	0.73 (0.23–1.09)	33.3	59.0	0.81 (0.56–1.18)	1.13 (0.78–1.64)	7.0	9.5
With decelerations[c]	138 (22.4%)	9 (15.8%)	0.25	0.74 (0.35–1.56)	15.8	77.6	0.70 (0.39–1.28)	1.09 (0.6–1.98)	6.1	9.2
With severe decelerations[c]	74 (12%)	7 (12.3%)	0.30	0.38 (0.05–2.85)	1.8	95.3	0.37 (0.05–2.6)	1.03 (.015–7.2)	3.3	8.7
Accelerations present any time	574 (93.3%)	45 (78.9%)	<**0.01**	0.27 (0.13–0.56)	78.9	6.7	0.85 (0.61–1.17)	3.16 (2.28–4.37)	7.3	22.7
With decelerations[c]	399 (64.9%)	28 (49.1%)	**0.02**	0.58 (0.33–1.02)	49.1	35.1	0.76 (0.57–1.01)	1.45 (1.09–1.93)	6.6	11.9
With severe decelerations[c]	99 (16.1%)	9 (15.8%)	0.95	0.93 (0.42–2.05)	15.8	83.9	0.98 (0.54–1.79)	1.00 (0.55–1.83)	8.3	8.5
Accelerations present (>50% time)	359 (58.4%)	23 (40.4%)	**0.01**	0.51 (0.29–0.89)	40.4	41.6	0.69 (0.50–0.96)	1.43 (1.03–1.99)	6.0	11.7
With decelerations[c]	262 (42.6%)	18 (31.6%)	0.11	0.69 (0.38–1.24)	31.6	57.4	0.74 (0.50–1.09)	1.19 (0.81–1.76)	6.4	10.0
With severe decelerations[c]	59 (9.6%)	5 (8.8%)	0.84	0.95 (0.36–2.52)	8.8	90.4	0.91 (0.40–2.11)	1.01 (0.44–2.33)	7.8	8.6
Decelerations										
Any decelerations	434 (70.6%)	36 (63.2%)	0.24	0.80 (0.44–1.44)	63.2	29.4	0.89 (0.71–1.13)	1.25 (0.99–1.58)	7.6	10.4

(*Continued*)

Table 4 (*Continued*)

	Without CANO[a] (*N* = 615)	With CANO[a] (*N* = 57)	*p*-Value	aOR (95% CI)	Sens (%)	Spec (%)	PLR (95% CI)	NLR (95% CI)	PPTP (%)	NPTP (%)
Variable and late (>50% time)	18 (2.9%)	1 (1.8%)	0.61	0.69 (0.09–5.31)	1.8	97.1	0.60 (0.09–4.18)	1.01 (0.15–7.06)	5.3	8.6
Variable, late, and prolonged (>50% time)	2 (0.3%)	0 (0%)	0.67	–	0.9	99.6	2.12 (0.13–34.38)	1.00 (0.06–16.11)	16.5	8.5
Severe decelerations (any % time)	109 (17.7%)	16 (28.1%)	0.06	1.73 (0.89–3.23)	28.1	82.3	1.58 (1.04–2.40)	0.87 (0.58–1.33)	12.8	7.5
Category III—(any % time)	2 (0.3%)	1 (1.8%)	0.12	6.04 (0.53–67.9)	1.8	99.7	5.39 (0.77–37.64)	0.99 (0.14–6.88)	33.4	8.4

Abbreviations: aOR, adjusted (for neuraxial anesthesia); CANO, composite adverse neonatal outcome; CI, confidence interval; Sens, sensitivity; NLR, negative likelihood ratio; NPTP, negative posttest probability; PLR, positive likelihood ratio; PPTP, positive posttest probability; Spec, specificity.
Notes: **Bolded** if significantly different. Data presented as *N* (%), *p*-values are unadjusted.
[a]CANO, which included any of the following: Apgar < 7 at 5 minutes, mechanical ventilation > 6 hours, bronchopulmonary dysplasia, intraventricular hemorrhage, necrotizing enterocolitis, seizures, sepsis, brachial plexus palsy, hypoxic ischemic encephalopathy, or neonatal death
[b]Any decelerations included a composite of late, variable, or prolonged decelerations.
[c]Present any time in the available analyzed epochs in the 2 hours prior to delivery.

While the association between severe variable decelerations and Category III tracing with CANO was present in our cohort, the incidence was small (*N* of 4 and 3, respectively), this highlights the need for additional study. Our study investigated preterm infants from $32^{0/7}$ to $36^{6/7}$ weeks. Additional research is needed for early preterm infants to see if increased prematurity affects FHRT patterns and CANO. Our study provides baseline pre- and posttest probability estimates for CANO in preterm fetuses undergoing trial of labor to guide the development of these future studies.

Strengths and Limitations

Strengths of our study include a large sample size, with a racially and ethnically diverse population. We included all consecutive preterm, singleton, nonanomalous infants. We had no other restriction criteria, which reduced possible selection bias. Additionally, FHRT were interpreted by obstetricians (residents, fellows, and faculty) who were blinded to maternal characteristics and fetal outcomes, thereby further reducing bias. We focused on a composite of adverse neonatal outcomes, as compared with UA pH alone, which is not routinely collected.[23]

Table 5 Composite adverse neonatal outcome

	N	Rate among all cohort (%)	Rate among those with composite (%)
Composite adverse neonatal outcome[a]	57	8.5	100
5-min Apgar <7	24	3.6	42.1
Mechanical ventilation > 6 hrs.	31	4.6	54.4
Hypoxic ischemic encephalopathy	2	0.3	3.5
Seizure	3	0.4	5.3
Sepsis	2	0.3	3.5
Bronchopulmonary dysplasia	2	0.3	3.5
Intraventricular hemorrhage	7	1	12.3
Necrotizing enterocolitis	3	0.4	5.3
Birth Injury	0	0	0
Meconium aspiration syndrome	1	0.1	1.8
Neonatal death	0	0	0
Umbilical arterial pH < 7.00[b]	9	0.3	N/A

Abbreviation: N/A, not applicable.
Notes: Data presented as *N* (%). *N* for all cohorts = 672.
[a]CANO, composite adverse neonatal outcome, which included any of the following: Apgar < 7 at 5 minutes, mechanical ventilation > 6 hours, bronchopulmonary dysplasia, intraventricular hemorrhage, necrotizing enterocolitis, seizures, sepsis, brachial plexus palsy, hypoxic ischemic encephalopathy, or neonatal death.
[b]Umbilical arterial pH was obtained in 468/672 singletons (69.6%).

We acknowledge several limitations to our study. As this study was performed at a Level IV maternal center, individuals may have had medical complications that further complicated their deliveries. For example, over 50% of our patient population had a hypertensive disorder of pregnancy, one of the most common indications for a preterm induction of labor. Therefore, results may not be applicable to spontaneous preterm birth.[24,25] Additionally, we studied preterm deliveries from $32^{0/7}$ to $36^{0/7}$ and cannot address FHRT patterns in early preterm fetuses $<$ 32 weeks, which may be more pronounced. We also acknowledge the potential for interobserver variability within the analysis of these FHRT, which was not assessed for this study but has been done previously at our center.[26] Given that we only reviewed the FHRT up to 120 minutes before birth, we are unable to make assumptions about FHRT patterns that occurred more than 120 minutes from delivery.

Conclusion

Our data showed that among preterm infants at $32^{0/7}$ to $36^{6/7}$ weeks, there is an increase in adverse outcomes with minimal variability and severe variable decelerations. Our findings also demonstrate that certain FHRT features of the broadly defined "Category II" FHRT confer increased posttest probability of CANO. These findings may inform clinic decision-making, patient counseling, and shared decision-making model of care between a laboring patient and their physician based on both their individual risk tolerances. Trials are needed to determine if implementing intervention strategies could achieve other goals such as reduction in cesarean delivery rate and of adverse outcomes with preterm birth.

Author Affiliations

1 Department of Obstetrics, Gynecology and Reproductive Sciences, McGovern Medical School at UTHealth Houston, Houston, Texas, United States

2 Department of Obstetrics, Gynecology, and Reproductive Sciences, University of California San Diego, San Diego, California, United States

3 Department of Maternal and Child Health and Urological Sciences, Sapienza University of Rome, Rome, Italy

4 Delaware Center for Maternal-Fetal Medicine of ChristianaCare, Newark, Delaware, United States

Statements and Additional Information

Conflict of Interest The authors declare that they have no conflict of interest.

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References

1 Chen HY, Chauhan SP, Ananth CV, Vintzileos AM, Abuhamad AZ. Electronic fetal heart rate monitoring and its relationship to neonatal and infant mortality in the United States. Am J Obstet Gynecol 2011;204(06):491.e1–491.e10

2 American College of Obstetricians and Gynecologists. ACOG Practice Bulletin No. 106: Intrapartum fetal heart rate monitoring: nomenclature, interpretation, and general management principles. Obstet Gynecol 2009;114(01):192–202

3 American College of Obstetricians and Gynecologists. Practice Bulletin No. 116: Management of intrapartum fetal heart rate tracings. Obstet Gynecol 2010;116 (05):1232–1240

4 Chauhan SP, Klauser CK, Woodring TC, Sanderson M, Magann EF, Morrison JC. Intrapartum nonreassuring fetal heart rate tracing and prediction of adverse outcomes: interobserver variability. Am J Obstet Gynecol 2008;199(06):623.e1–623.e5

5 Cagino KA, Wiley RL, Roberts AW, Zullo F, Mendez-Figueroa H, Chauhan SP. Proportion of time in category II fetal heart rate tracing and adverse outcomes. Am J Perinatol 2025. Doi: 10.1055/a-2601-8862

6 Zullo F, Di Mascio D, Raghuraman N, et al. Three-tiered fetal heart rate interpretation system and adverse neonatal and maternal outcomes: a systematic review and meta-analysis. Am J Obstet Gynecol 2023;229(04):377–387

7 Wiley RL, Roberts AW, Cagino KA, Zullo F, Mendez-Figueroa H, Chauhan SP. Characteristics and categories of fetal heart rate tracings and adverse neonatal outcomes at term. Am J Perinatol 2025. Doi: 10.1055/a-2708-4947

8 Patel S, Cagino KA, Roberts AW, et al. Fetal heart rate tracings and adverse outcomes among term small versus appropriate for gestational age. Am J Perinatol 2025. Doi: 10.1055/a-2729-1189

9 Hurtado-Sánchez MF, Pérez-Melero D, Pinto-Ibáñez A, González-Mesa E, Mozas-Moreno J, Puertas-Prieto A. Characteristics of heart rate tracings in preterm fetus. Medicina (Kaunas) 2021;57(06):528

10 Parer JTMDP, Ikeda T. A framework for standardized management of intrapartum fetal heart rate patterns. Am J Obstet Gynecol 2007;197(01):26.e1–26.e6

11 Jaeschke R, Guyatt GH, Sackett DL. Users' guides to the medical literature. III. How to use an article about a diagnostic test. B. What are the results and will they help me in caring for my patients? The Evidence-Based Medicine Working Group. JAMA 1994;271(09):703–707

12 Vandenbroucke JP, von Elm E, Altman DG, et al; STROBE Initiative. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. Epidemiology 2007;18(06):805–835

13 Timms D, Egan J, Smith K, Gurram P, Campbell W. 614: Does NICHD category II fetal heart rate tracing in the 30. minutes prior to delivery predict fetal acidosis in preterm infants? Am J Obstet Gynecol 2012;206(01):S276–S276

14 Krebs HB, Petres RE, Dunn LJ, Jordaan HV, Segreti A. Intrapartum fetal heart rate monitoring. I. Classification and prognosis of fetal heart rate patterns. Am J Obstet Gynecol 1979;133(07):762–772

15 Holmes P, Oppenheimer LW, Gravelle A, Walker M, Blayney M. The effect of variable heart rate decelerations on intraventricular hemorrhage and other perinatal outcomes in preterm infants. J Matern Fetal Med 2001;10(04):264–268

16 Henkel JE, Aziz MM, Reynolds CO, Goedecke PJ, Schenone MH. 763: Predicting fetal acidemia with continuous fetal monitoring in extreme preterm birth. Am J Obstet Gynecol 2019;220(01):S500–S500

17 Zanini B, Paul RH, Huey JR. Intrapartum fetal heart rate: correlation with scalp pH in the preterm fetus. Am J Obstet Gynecol 1980;136(01):43–47

18 Matsuda Y, Maeda T, Kouno S. The critical period of non-reassuring fetal heart rate patterns in preterm gestation. Eur J Obstet Gynecol Reprod Biol 2003;106 (01):36–39

19 American College of Obstetricians and Gynecologists. ACOG Practice Bulletin operative vaginal delivery. Int J Gynaecol Obstet 2001;74(01):69–76

20 Clark SLMD, Nageotte MPMD, Garite TJMD, et al. Intrapartum management of category II fetal heart rate tracings: towards standardization of care. Am J Obstet Gynecol 2013;209(02):89–97

21 American College of Obstetricians and Gynecologists. Informed consent and shared decision making in obstetrics and gynecology: ACOG Committee Opinion, Number 819. Obstet Gynecol 2021;137(02):e34–e41

22 Weissbach T, Heusler I, Ovadia M, et al. The temporal effect of Category II fetal monitoring on neonatal outcomes. Eur J Obstet Gynecol Reprod Biol 2018;229:8–14

23 ACOG Committee on Obstetric Practice. ACOG Committee Opinion No. 348, November 2006: umbilical cord blood gas and acid-base analysis. Obstet Gynecol 2006;108(05):1319–1322

24 Ananth CV, Joseph KS, Oyelese Y, Demissie K, Vintzileos AM. Trends in preterm birth and perinatal mortality among singletons: United States, 1989 through 2000. Obstet Gynecol 2005;105(5 Pt 1):1084–1091

25 Ananth CV, Vintzileos AM. Maternal-fetal conditions necessitating a medical intervention resulting in preterm birth. Am J Obstet Gynecol 2006;195 (06):1557–1563

26 Blackwell SC, Grobman WA, Antoniewicz L, Hutchinson M, Gyamfi Bannerman C. Interobserver and intraobserver reliability of the NICHD 3-tier fetal heart rate interpretation system. Am J Obstet Gynecol 2011;205(04):378.e1–378.e5