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Intrapartum Fetal Heart Rate Tracing Among Small-for-Gestational Age Compared With Appropriate-for-Gestational-Age Neonates

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Abstract

Objective: To compare fetal heart rate (FHR) patterns during the last hour of labor between small- (SGA; birthweight <10th percentile for GA) and appropriate-for-gestational-age (AGA; birthweight at 10–90th percentile) neonates at ≥36 weeks of gestation. We also compared the rate of cesarean delivery and composite neonatal morbidity among SGA and AGA newborns.

Methods: This is a secondary analysis of a randomized trial of intrapartum fetal ECG ST-segment analysis. We excluded women with chorioamnionitis, insufficient duration of FHR tracing in the hour before delivery, and anomalous newborns. Fetal heart rate patterns were categorized by computerized pattern recognition software (PeriCALM Patterns). Composite neonatal morbidity was defined as any of the following: intrapartum fetal death, Apgar score ≤3 at 5 minutes, cord artery pH ≤7.05 and base deficit ≥12 mmol/L, neonatal seizure, intubation at delivery, neonatal encephalopathy, neonatal death. Logistic regression was used to evaluate the association between FHR patterns and SGA adjusted for magnesium sulfate exposure and stage of labor.

Results: Of the 11,108 women randomized, 85% (n=9,402) met inclusion criteria, of whom 9% were SGA. In the last hour, the likelihood of accelerations was significantly lower among SGA than AGA neonates (72.4% vs. 66.8%; P=0.001). Variable decelerations lasting >60 seconds, with depth >60 bpm or nadir <60 bpm were significantly more common with SGA than AGA (all P<0.001). The rate of late decelerations, prolonged decelerations, or bradycardia were similar between SGA and AGA (all P>0.05). Cesarean delivery for fetal indications was significantly more common with SGA (7.0%) than AGA (4.0%; P<0.001). The composite neonatal morbidity was 1.4% among SGA and 1.0% among AGA (OR 1.40; 95% CI 0.74, 2.64).

Conclusions: Although the FHR patterns in the last hour of labor differ among SGA and AGA infants, as does the rate of cesarean delivery, the composite neonatal morbidity was similar.

Précis

Rate of variable decelerations in the last hour of labor differed significantly between small- compared with appropriate-for-gestational-age, but the composite neonatal morbidity was similar.

Introduction

Intrapartum fetal heart rate (FHR) monitoring, the most common obstetric procedure in the United States, is utilized in approximately 85% of live births (1,2). One reason for its ubiquitousness is that during labor the interplay of multiple factors—placental dysfunction, suboptimal uterine perfusion, antepartum or intrapartum complications—may lead to adverse neonatal outcomes, such as seizures and hypoxic ischemic encephalopathy (1), which purportedly are preventable. Small for gestational age (SGA; birth weight below 10th percentile for gestational age) is an obstetric condition where the aforementioned factors interact to increase the likelihood of cesarean delivery for non-reassuring FHR, and neonatal morbidities, including HIE (1,3–7). Due to chronic hypoxemia, growth restricted fetuses are considered to have delayed maturation of both their sympathetic and parasympathetic nervous systems, with resultant abnormalities in their FHR tracings (8,9).

Despite the acknowledged association between growth restriction and abnormal FHR patterns (3,4,10–12), most SGA fetuses with non-reassuring patterns do not have neonatal acidemia or adverse perinatal outcomes (6,7). The lack of sensitivity for intrapartum monitoring to identify newborns with morbidity may be related to inherent limitations of FHR tracing (13–17). Thus, for the vulnerable growth restricted newborns, an alternate method of assessing fetal well-being during labor has the potential to improve outcomes (18).

The objective of this secondary analysis of a randomized clinical trial (19) was to compare the type of fetal heart rate (FHR) patterns during the last hour of labor among SGA versus appropriate for gestational age (AGA; birth weight at 10–90th percentile for gestational age) newborns. Our hypothesis was that computerized interpretation of FHR tracing (18) would identify differences in abnormal fetal heart patterns among SGA versus AGA newborns. Additional objectives were to compare the rate of cesarean delivery and composite neonatal morbidity (CNM) among SGA vs. AGA.

Materials and Methods

We conducted a secondary analysis of a multicenter randomized trial conducted at 14 centers of the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (NICHD) Maternal Fetal Medicine Units (MFMU) Network from 2010 to 2013. In the parent trial, women with a singleton fetus who were attempting vaginal delivery at more than 36 weeks of gestation and who had cervical dilation of 2 to 7 cm were randomly assigned to “masked” or “open” monitoring with fetal electrocardiographic (ECG) ST-segment analysis. The masked system functioned as a normal fetal heart-rate monitor; the open system displayed ST-segment events that were used to guide clinical management (19). Monitors in the open mode displayed ECG ST-segment information which was to be used when uncertain fetal heart-rate (FHR) patterns were detected. Management of the labor and delivery for women in this group was dictated by the ST-segment analysis guidelines. If, for example, the FHR pattern was in yellow zone, then expectant management was to be continued if there were no ST segment event; if there were ST segment then evaluation by a physician, intrauterine resuscitation as needed, and expeditious delivery if there was no

improvement in fetal condition. Women from both study arms were included in the analysis cohort, since no effect of the intervention was observed during the trial (19). Fetal heart rate and uterine activity were digitally stored.

The main exclusion criteria of the parent trial were non-cephalic presentation, planned cesarean delivery, a need for immediate delivery, absent fetal heart-rate variability, a sinusoidal pattern, minimal fetal heart-rate variability in the 20 minutes before randomization, or other fetal or maternal conditions that would preclude a trial of labor or the placement of a scalp electrode. After spontaneous or artificial membrane rupture, a Goldtrace fetal scalp electrode (Neoventa Medical) was placed in each woman who consented to participate in the trial. Additional details about the randomized study are described in the parent trial (19). For this secondary analysis, we also excluded women with less than 30 minutes of FHR tracing recorded in the hour before delivery, birthweight > 90th percentile for gestational age, chorioamnionitis and anomalous newborns.

An enhanced sex and race/ethnicity-specific Alexander's nomogram (20) was used to categorize newborns as SGA or AGA. After the trial ended, digitally-stored FHR and uterine activity data from the last hour before delivery were categorized by computer pattern recognition software (PeriCALM Patterns, Cary, NC), as previously described (13,21).

For our secondary analysis, the CNM was defined as any of the following: intrapartum fetal death, Apgar score of 3 or less at 5 minutes, neonatal seizures, umbilical cord artery pH ≤ 7.05 with base deficit ≥12 mmol/liter (L), intubation for ventilation at delivery, neonatal encephalopathy, or neonatal death.

Demographic and other patient characteristics between mothers of SGA and AGA fetuses, as well as the characteristics of various FHR patterns, were compared using the Wilcoxon rank-sum test for continuous variables and the chi-square test for categorical variables. Exact confidence limits and Fisher's exact tests were used when frequencies of events were rare. Logistic (categorical outcomes) and linear (continuous outcomes) regression models, both with adjustment for magnesium sulfate and stage of labor (first or second), were used to further evaluate the association between SGA status and FHR characteristics. Odds ratios (OR) and 95% confidence limits were calculated to estimate the association between SGA or AGA and CNM, with and without considering several FHR patterns. Analyses were performed using SAS software Version 9.4. A nominal P-value of <0.05 was chosen to denote significance. No adjustments were made for multiple comparisons. No imputation for missing data was performed.

RESULTS

Of the 11,108 women randomized in the parent trial, 1,706 women were excluded from this secondary analysis (61 for anomalous newborns, 1,199 for insufficient length of FHR tracing in the last hour before delivery, and 446 for chorioamnionitis). Of the remaining 9,402 neonates, 8.7% (n=816) were SGA and 83.9% (n=7,887) were AGA, with 7.4% (n=699) being large for gestational age (LGA). Since the aim was to compare SGA to AGA, LGA cases were excluded from further analysis.

The maternal characteristics among SGA and AGA neonates varied significantly with regards to age at delivery, race/ethnicity, nulliparity, pre-pregnancy body mass index (BMI), as well as BMI at delivery (Table 1). The duration from enrollment in the trial to delivery was significantly shorter among SGA (median 3.2 hours; interquartile range 1.9, 5.5 hours) than AGA (3.6 hours; 2.1, 5.8 hours; P=0.01) newborns.

The intrapartum characteristics differed in that magnesium sulfate was significantly more likely to be used in the SGA group (6.4%) than in the AGA group (3.2%, p<0.001). Whether the labor was induced, augmented or spontaneous did not differ between the two groups. The duration of the tracing in the last hour available for analysis was similar in the two groups (P=0.08). The route of delivery differed in that women who had a SGA newborn were more likely to have a cesarean delivery (12.0%) than those with an AGA newborn (9.2%; P=0.01). Within the SGA and AGA, the cesarean rate did not differ between the open and masked intervention groups (p=0.97 and 0.41, respectively). The indications for cesarean delivery also differed between the two groups (Table 2). The rate of abruption was similar.

The computer pattern recognition software identified two significant differences in the FHR tracings between the groups: the frequency of accelerations was lower with SGA (66.8%) than with AGA newborns (72.4%; adjusted P=0.001); variable decelerations lasting >60 seconds, with depth >60 bpm or with nadir <60 bpm were significantly more common with SGA than AGA (all P<0.001). The rate of fetal tachycardia, late decelerations, prolonged decelerations, or bradycardia were similar between the two groups (Table 3).

The CNM among the two groups were 1.4% (n=11) for SGA and 1.0% (n=76) for AGA (P=0.30; Table 4). The rate of CNM for SGA and for AGA was similar in the presence or absence of accelerations, as it was for variable decelerations lasting > 60 seconds or depth > 60 bpm (Table 5), however there was limited power to detect a difference.

DISCUSSION

The key findings of this analysis are that frequency of types of fetal heart tracing patterns and of cesarean delivery differed between SGA and AGA newborns, but composite neonatal morbidity did not. We noted that in the last hour of labor, compared to AGA, the SGA fetuses were significantly less likely to have accelerations and more likely to have variable decelerations lasting more than 60 seconds. Previous investigators have also noted that SGA newborns are less likely to have accelerations (6,8), purportedly because hypoxia alters the maturation of both the parasympathetic and sympathetic nervous systems (9,10). Variable decelerations were also more common among SGA than AGA fetuses, which may be secondary to oligohydramnios (4).

The rate of cesarean delivery for fetal indications differed by 75% for the two groups: 7% for SGA and 4% for AGA. While some reports suggest that growth restriction is associated with an increased rate of cesarean delivery (4), others do not (22). The differing conclusions may be due to differences in comorbidities in the cohorts, the proportion of preterm versus term, the clinician's knowledge of whether the estimated fetal weight was < 10th percentile

for gestational age (23), and differing interpretation of FHR tracings (17). Notwithstanding the differences the maternal characteristics, the FHR tracing and the rate of cesarean delivery, in this cohort the CNM was not significantly different between SGA and AGA neonates. Also, the different FHR patterns could not predict which SGA neonates were more likely than their AGA counterparts to have CNM.

We acknowledge the limitations of this secondary analysis. Our findings are applicable to women who met the inclusion criteria of being at least 36 weeks gestation with cervical dilation of 2 to 7 cm, had a planned trial of labor, and who did not have chorioamnionitis. Since the tracing was interpreted by computerized pattern recognition software, the findings may not be applicable when tracings are interpreted by humans. However, the design of this study avoids the pitfall of interobserver variation in interpretation of FHR tracing (17). The majority of women were recruited at teaching hospitals and thus our findings may not be applicable to all centers. Since a majority of SGA newborns are not detected before birth (23,24), it is uncertain if the findings of this analysis are applicable when clinicians are aware that sonographic estimated fetal weight is below 10th percentile for GA (fetal growth restriction). Lastly, although we have data on nearly 10,000 labors and neonates, severe neonatal morbidity was very rare in this unselected cohort.

The strengths of the study include a geographically and ethnically diverse multicenter study and the largest sample size on the topic of interpretation of FHR tracing with fetal growth abnormalities. The neonatal morbidities were predefined and are associated with long-term adverse sequela. The outcomes were rigorously collected and specific approaches at the time of collection as well as in the analysis of the arterial cord gases were instituted to ensure that the cord gases were arterial and not venous or mixed.

In conclusion, compared to newborns with appropriate growth, those who are small for gestational age are more likely to lack accelerations and have variable decelerations. The neonatal morbidity, however, was similar among both groups. Future investigation is warranted to assess how FHR may differ between those suspected to have fetal growth restriction and those thought to have an AGA fetus, and whether interpretation can be refined to help lower the rate of cesarean delivery without increasing composite neonatal morbidity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Maternal Characteristics

	SGA N = 816	**AGA N = 7,887**	**P**
Maternal age (years) ≤19 20-34 ≥35	91 (11.2) 633 (77.6) 92 (11.3)	648 (8.2) 6,310 (80.0) 929 (11.8)	0.02
Race / ethnicity Black / African-American White Hispanic / Latino Others	154 (18.9) 373 (45.7) 245 (30.0) 44 (5.4)	1,806 (22.9) 3,488 (44.2) 2,340 (29.7) 253 (3.2)	0.001
Nulliparous	415 (50.9)	3,004 (38.1)	<0.001
Pre-pregnancy BMI (kg/m^2)	25.5 ± 6.4	27.2 ± 6.9	<0.001
BMI at delivery (kg/m^2)	30.2 ± 6.3	32.4 ± 6.6	<0.001
Education level (year)	12.7 ± 2.6	12.9 ± 2.6	0.02

Data presented as N (%) or mean ± standard deviation

BMI, body mass index; SGA, small for gestational age (birthweight < 10^{th} percentile for gestational age); AGA, appropriate for gestational age (birthweight 10-90^{th} percentile for gestational age)

Table 2.

Intrapartum characteristics

	SGA N = 816	AGA N = 7,887	P
Gestational age (weeks)	39.1 ± 1.1	39.4 ± 1.2	<0.001
Gestational hypertension / preeclampsia	113 (13.9%)	755 (9.6%)	< 0.001
Magnesium sulfate treatment	52 (6.4)	255 (3.2)	<0.001
Labor Spontaneous Spontaneous, augmented Induced	74 (9.1) 237 (29.0) 505 (61.9)	659 (8.4) 2,620 (33.2) 4,608 (58.4)	0.05
Abruption	13 (1.6)	85 (1.1)	0.18
Anesthesia Regional only General (alone or following regional) None	772 (94.6) 6 (0.7) 38 (4.7)	7,363 (93.4) 43 (0.6) 481 (6.1)	0.20
Tracing in last hour before delivery (mins) 30-39 40-49 50-60	69 (8.5) 57 (7.0) 690 (84.6)	577 (7.3) 430 (5.5) 6,880 (87.2)	0.08
Reached second stage of labor	723 (88.6)	7,289 (92.5)	<0.001
Route of delivery Vaginal Cesarean	718 (88.0) 98 (12.0)	7,160 (90.8) 727 (9.2)	0.01
Cesarean indication * Fetal indications≠ Dystocia/CPD/arrest Other	57 (7.0) 40 (4.9) 1 (0.1)	312 (4.0) 396 (5.0) 19 (0.2)	<0.001
ST-segment analysis (open group)	423 (51.8)	3,877 (49.2)	0.14

Data presented as N (%) or mean ± standard deviation

SGA, small for gestational age (birthweight < 10th percentile for gestational age); AGA, appropriate for gestational age (birthweight 10-90th percentile for gestational age)

*Percentages are of all deliveries

≠Fetal indication was determined according to fetal electrocardiographic ST-segment analysis guidelines in the open group and according to local protocol and ACOG guidelines (reference #1) for fetal heart-rate monitoring in the masked group.

Table 3.

Fetal heart rate abnormalities during the last hour before delivery

	SGA N = 816	AGA N = 7,887	Unadjusted p-value	Adjusted p-value *
Average variability for last 15 min (bpm)	15.3 ± 4.9	15.3 ± 4.7	0.67	0.31
Average variability for last 30 min (bpm)	14.3 ± 4.1	14.2 ± 4.0	0.68	0.15
Variability ≤5 bpm for 10 min or more	86 (10.5%)	756 (9.6%)	0.38	0.88
Variability ≤5 bpm for 30 min or more	5 (0.6%)	71 (0.9%)	0.40	0.23
Variability <10th %ile for 10 min or more †	375 (46.0%)	3,711 (47.1%)	0.55	0.24
Variability <10th %ile for 30 min or more †	110 (13.5%)	928 (11.8%)	0.15	0.55
Bradycardia (<110) for 10 min or more	26 (3.2%)	177 (2.2%)	0.09	0.11
Tachycardia (>160) for 10 min or more	91 (11.2%)	833 (10.6%)	0.60	0.17
Acceleration present (any)	545 (66.8%)	5,707 (72.4%)	<0.001	0.001
Late deceleration present (any)	361 (44.2%)	3,398 (43.1%)	0.53	0.42
Variable deceleration present (any)	782 (95.8%)	7,560 (95.9%)	0.98	0.48
Variable deceleration >60 sec (any)	675 (82.7%)	6,184 (78.4%)	0.004	<0.001
Variable deceleration with depth >60 bpm (any)	591 (72.4%)	4,971 (63.0%)	<0.001	<0.001
Variable deceleration with nadir <60 bpm (any)	328 (40.2%)	2,456 (31.1%)	<0.001	<0.001
Prolonged deceleration (any)	326 (40.0%)	3,069 (38.9%)	0.56	0.36

Data presented as N (%) or mean ± standard deviation

SGA, small for gestational age (birthweight < 10th percentile for gestational age); AGA, appropriate for gestational age (birthweight 10-90th percentile for gestational age)

* Adjusted for magnesium sulfate treatment and stage of labor

† 10th percentile of variability = 9 beats per minute

Table 4.

Composite neonatal morbidity

	SGA N = 816	AGA N = 7,887	OR (95% CI)
Composite neonatal morbidity	11 (1.4)	76 (1.0)	1.40 (0.74, 2.64)
Intrapartum fetal death	0	0	
Apgar score ≤ 3 at 5 min	4 (0.49)	7 (0.09)	
Neonatal seizures	1 (0.12)	3 (0.04)	
Umbilical cord artery pH ≤7.05 and base deficit ≥12 mmol/L	7 (0.89)	45 (0.59)	
Intubation for ventilation at delivery	3 (0.37)	29 (0.37)	
Neonatal encephalopathy	0	5 (0.06)	
Neonatal death	1 (0.12)	1 (0.01)	

Data presented as N (%)

SGA, small for gestational age (birthweight < 10th percentile for gestational age); AGA, appropriate for gestational age (birthweight 10-90th percentile for gestational age)

OR, odds ratio; CI, confidence interval; L, liter

Table 5.

Rate of composite neonatal morbidity with or without FHR abnormalities, stratified by growth percentile at birth.

	Accelerations			Variable decelerations >60 sec			Variable decelerations depth >60 bpm		
	Present	Absent	OR (95% CI)	Present	Absent	OR (95% CI)	Present	Absent	OR (95% CI)
SGA	7/527 (1.3)	4/259 (1.5)	0.86 (0.22, 4.04)	9/650 (1.4)	2/136 (1.5)	0.94 (0.19, 9.05)	9/567 (1.6)	2/219 (0.9)	1.75 (0.36, 16.8)
AGA	44/5482 (0.8)	32/2095 (1.5)	0.52 (0.32, 0.85)	58/5936 (1.0)	18/1641 (1.1)	0.89 (0.52, 1.61)	47/4780 (1.0)	29/2797 (1.0)	0.95 (0.58, 1.57)

Data presented as N (%)

SGA, small for gestational age (birthweight < 10^{th} percentile for gestational age); AGA, appropriate for gestational age (birthweight 10-90^{th} percentile for gestational age)

OR, odds ratio; CI, confidence intervals; bpm, beats per minute