ELECTRONIC FETAL MONITORING CASE REVIEW SERIES

Electronic fetal monitoring (EFM) is a popular technology used to establish fetal well-being. Despite its widespread use, terminology used to describe patterns seen on the monitor has not been consistent until recently. In 1997, the National Institute of Child Health and Human Development (NICHD) Research Planning Workshop published guidelines for interpretation of fetal tracings. This publication was the culmination of 2 years of work by a panel of experts in the field of fetal monitoring and was endorsed in 2005 by both the American College of Obstetricians and Gynecologists (ACOG) and the Association of Women’s Health, Obstetric and Neonatal Nurses (AWHONN). In 2008, ACOG, NICHD, and the Society for Maternal-Fetal Medicine reviewed and updated the definitions for fetal heart rate (FHR) patterns, interpretation, and research recommendations. Following is a summary of the terminology definitions and assumptions found in the 2008 NICHD workshop report. Normal values for arterial umbilical cord gas values and indications of acidosis are defined in Table 1.

Assumptions from the NICHD Workshop

- Definitions are developed for visual interpretation, assuming that both the FHR and uterine activity recordings are of adequate quality
- Definitions apply to tracings generated by internal or external monitoring devices
- Periodic patterns are differentiated based on waveform, abrupt or gradual (eg, late decelerations have a gradual onset and variable decelerations have an abrupt onset)
- Long- and short-term variability are evaluated visually as a unit
- Gestational age of the fetus is considered when evaluating patterns
- Components of FHR do not occur alone and generally evolve over time

Definitions

Baseline FHR

- Approximate mean FHR rounded to increments of 5 beats/min in a 10-minute segment of tracing, excluding accelerations and decelerations, periods of marked variability, and segments of baseline that differ by >25 beats/min
- In the 10-minute segment, the minimum baseline duration must be at least 2 minutes (not necessarily contiguous) or the baseline for that segment is indeterminate
- Bradycardia is a baseline of <110 beats/min; tachycardia is a baseline of >160 beats/min
• Sinusoidal baseline has a smooth sine wave-like undulating pattern, with waves having regular frequency and amplitude

**Baseline Variability**

• Fluctuations in the baseline FHR of two cycles per minute or greater, fluctuations are irregular in amplitude and frequency, fluctuations are visually quantitated as the amplitude of the peak to trough in beats per minute

• Classification of variability:
  
  **Absent:** Amplitude range is undetectable
  **Minimal:** Amplitude range is greater than undetectable to 5 beats/min
  **Moderate:** Amplitude range is 6 to 25 beats/min
  **Marked:** Amplitude range is >25 beats/min

**Accelerations**

• Abrupt increase in FHR above the most recently determined baseline

• Onset to peak of acceleration is <30 seconds, acme is ≥15 beats/min above the most recently determined baseline and lasts ≥15 seconds but <2 minutes

• Before 32 weeks' gestation, accelerations are defined by an acme ≥10 beats/min above the most recently determined baseline for ≥10 seconds

• Prolonged acceleration lasts ≥2 minutes but <10 minutes

**Late Decelerations**

• Gradual decrease in FHR (onset to nadir ≥30 seconds)

• Not below the most recently determined baseline, with nadir occurring after the peak of uterine contractions

• Considered a periodic pattern because it occurs with uterine contractions

**Early Decelerations**

• Gradual decrease in FHR (onset to nadir ≥30 seconds)

• Not below the most recently determined baseline, with nadir occurring coincident with uterine contraction

• Also considered a periodic pattern

**Variable Decelerations**

• Abrupt decrease in FHR (onset to nadir <30 seconds)

• Decrease is ≥15 beats/min below the most recently determined baseline lasting ≥15 seconds but <2 minutes

• May be episodic (occurs without a contraction) or periodic

**Prolonged Decelerations**

• Decrease in the FHR ≥15 beats/min below the most recently determined baseline lasting ≥2 minutes but <10 minutes from onset to return to baseline

• Decelerations are tentatively called recurrent if they occur with ≥50% of uterine contractions in a 20-minute period.

• Decelerations occurring with <50% of uterine contractions in a 20-minute segment are intermittent.

**Sinusoidal FHR Pattern**

• Visually apparent, smooth sine wavelike undulating pattern in the baseline with a cycle frequency of 3 to 5/minute that persists for ≥20 minutes.

**Uterine Contractions**

• Quantified as the number of contractions in a 10-minute window, averaged over 30 minutes.

  - Normal: ≤5 contractions in 10 minutes
  - Tachysystole: >5 contractions in 10 minutes

**INTERPRETATION**

A 3-tier FHR interpretation system has been recommended as follows:

• Category I FHR tracings: Normal, strongly predictive of normal fetal acid-base status and require routine care. These tracings include all of the following:

<table>
<thead>
<tr>
<th>TABLE 1. Arterial Umbilical Cord Gas Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
</tr>
<tr>
<td>----</td>
</tr>
<tr>
<td>Reference range²</td>
</tr>
<tr>
<td>Respiratory acidosis</td>
</tr>
<tr>
<td>Metabolic acidosis</td>
</tr>
<tr>
<td>Mixed acidosis</td>
</tr>
</tbody>
</table>

Baseline rate: 110 to 160 beats/min
Baseline FHR variability: Moderate
Late or variable decelerations: Absent
Early decelerations: Present or absent
Accelerations: Present or absent

- Category II FHR tracings: Indeterminate, require evaluation and continued surveillance and reevaluation. Examples of these tracings include any of the following:
  - Bradycardia not accompanied by absent variability
  - Tachycardia
  - Minimal or marked baseline variability
  - Absent variability without recurrent decelerations
  - Absence of induced accelerations after fetal stimulation
  - Recurrent variable decelerations with minimal or moderate variability
  - Prolonged decelerations
  - Recurrent late decelerations with moderate variability
  - Variable decelerations with other characteristics, such as slow return to baseline

- Category III FHR tracings: Abnormal, predictive of abnormal fetal acid-base status and require prompt intervention. These tracings include:
  - Absent variability with any of the following:
    - Recurrent late decelerations
    - Recurrent variable decelerations
    - Bradycardia
  - Sinusoidal pattern


We encourage readers to examine each strip in the case presentation and make a personal interpretation of the findings before advancing to the expert interpretation provided.

PRESENTATION

History
A 30-year-old, gravida 1, para 0 woman presented to her obstetrician’s office at 38 weeks’ gestation with spontaneous rupture of membranes. Her cervix was 1 cm dilated, 40% effaced, station −2 to −3, midposition, and midconsistency. She was confirmed in her obstetrician’s office to be grossly ruptured with positive ferning and nitrazine test results. Meconium was also noted. She reported mild, rare contractions, denied vaginal bleeding, and reported active fetal movements. She presented to a tertiary care center for admission and evaluation. Her pregnancy was dated by a sure last menstrual period consistent with first trimester ultrasonography results. Her prenatal course had been uncomplicated, and prenatal laboratory findings were unremarkable, with blood type B positive and antibody negative. Her group B Streptococcus status was negative. The fetal presentation was cephalic.

Case Progression
On arrival, the patient’s admission examination revealed a young woman in minimal discomfort who was afebrile with normal vital signs. Her lungs were clear; her heart rhythm was regular without murmurs. Her abdominal
examination findings were benign without fundal tenderness. Uterine tocometry revealed contractions every 2 to 3 minutes. The initial FHR tracing is displayed in Figure 1.

Interpretation of Figure 1
- Variability: Moderate
- Baseline rate: 145 beats per minute
- Episodic patterns: None
- Periodic patterns: None
- Uterine contractions: Every 2 minutes, lasting 30 to 45 seconds
- Interpretation: Category I
- Differential diagnoses: The presence of FHR accelerations is consistent with a normal fetal acid-base status. There are regular contractions on the tocometer.
- Action: Given grossly ruptured membranes with meconium and unfavorable cervix, induction of labor with misoprostol is recommended.

The above-mentioned actions were performed, and a 25-μg tablet of vaginal misoprostol was placed. The FHR tracing continued to be reassuring. Three hours later, a physical examination revealed that the cervix was 2 cm dilated, 80% effaced, and at station −2. The patient remained afebrile with no evidence of infection and no vaginal bleeding. The FHR tracing at this time is shown in Figure 2.

Interpretation of Figure 2
- Variability: Minimal to moderate
- Baseline rate: 150 beats per minute
- Episodic patterns: Variable deceleration (peak to nadir in <30 seconds)
- Periodic patterns: None
- Uterine contractions: Every 2 to 3 minutes, lasting 45 seconds
- Interpretation: Category II
Differential diagnoses: Deceleration may be due to umbilical cord compression or uteroplacental insufficiency.

Action: Given the category II FHR tracing, the patient is repositioned to optimize uterine blood flow. Intravenous fluid bolus was given and close fetal monitoring continued.

The goal of obstetric management in a category II FHR tracing is to optimize blood flow to the uterus to improve fetal oxygenation. Close fetal evaluation by external continuous monitoring is recommended. Periods of loss of a continuous FHR tracing may be rectified by readjusting the placement of the external monitor or by placing an internal fetal scalp electrode. A maternal pulse oximetry probe may also be applied to distinguish the FHR from the maternal heart rate. The FHR tracing an hour later is shown in Figure 3.

Interpretation of Figure 3
- Variability: Minimal to absent
- Baseline rate: 150 beats per minute
- Episodic patterns: None
- Periodic patterns: Oscillations of the sinusoidal waveform above and below the baseline with amplitude of oscillations of 5 beats per minute and frequency of oscillations of 3 cycles per minute
- Uterine contractions: Every 3 minutes, lasting 60 to 80 seconds
- Interpretation: Category III

Differential diagnoses: Sinusoidal FHR pattern may be due to chronic fetal anemia, acute intrapartum asphyxia, fetal-maternal hemorrhage (FMH), or fetal in utero hemorrhage.

Action: Given the category III FHR tracing with sinusoidal pattern and no accelerations remote from delivery, preparation for an emergency cesarean delivery is recommended.

The possibility of an emergency cesarean delivery was discussed with the patient. The FHR tracing 10 minutes later is shown in Figure 4.
Interpretation of Figure 4
- Variability: Absent
- Baseline rate: 150 beats per minute
- Episodic patterns: Variable deceleration (peak to nadir in <30 seconds) to nadir of 80 beats per minute and variable deceleration (peak to nadir >30 seconds) to nadir of 110 beats per minute
- Periodic patterns: Sinusoidal waveform with an amplitude of 5 beats per minute and frequency of 3 cycles per minute
- Uterine contractions: Every 2 minutes, lasting for 60 seconds
- Interpretation: Category III
- Differential diagnoses: Given sudden onset and prolonged sinusoidal FHR pattern, likely fetal anemia due to FMH or fetal in utero hemorrhage
- Action: Given persistent category III FHR tracing with sinusoidal pattern, no accelerations, and recurrent decelerations, immediate emergency cesarean delivery is recommended.

The patient was immediately brought to the operating room for an emergency cesarean delivery, where the FHR was checked before skin incision and noted to be 90 beats per minute.

OUTCOME
A viable female infant at 38+1/7 weeks’ gestation was delivered via emergency cesarean delivery within 20 minutes of the decision to proceed with immediate delivery. No nuchal cord was noted. The cord was clamped and cut, and the infant was handed off to the neonatal intensive care unit team in attendance. With fundal massage, the placenta delivered spontaneously. There was no clot noted on the membranes or the placental surface. The cavity was curetted, and there was no evidence of an old blood clot. The infant weighed 2,675 g and had Apgar scores of 6 at 1 minute and 8 at 5 minutes. The infant emerged with moderate tone and a weak cry. She was intubated and
suctioned due to meconium-stained amniotic fluid, but no meconium was noted below the cords. She was then dried and stimulated with gradual improvement in tone and respiratory effort. Notable pallor was present, and oxygen saturation at 3 minutes after birth was 50% to 60% and rapidly increased to above 90% with blow-by oxygen. By 5 minutes of age, the infant was active and well appearing but continued to be pale on blow-by oxygen and was subsequently brought to the neonatal intensive care unit after briefly visiting with her parents. The infant's heart rate and rhythm were regular with no murmur auscultated. Pulses in the upper and lower extremities were +2. The infant's blood type was B positive with a negative direct antibody test result. Shortly after the infant was admitted to the neonatal intensive care unit, a complete blood cell count with differentials was performed, which revealed a hematocrit of 14.9% (0.15) with a reticulocyte count of 37.1% (0.37); a subsequent test revealed a hematocrit of 16.2% (0.16) and a reticulocyte count of 36.2% (0.36). Because of the finding of extreme anemia, a Kleihauer-Betke test was performed on the mother. The test result was 3%, representing a significant loss of fetal blood to the maternal circulation (172 mL), and the infant subsequently underwent transfusion with a total of 30 mL/kg of packed red blood cells. A follow-up complete blood cell count on day 1 after birth was significant for a hematocrit of 44.3% (0.44) with a reticulocyte count of 14.2% (0.14). She was weaned to room air with oxygen saturations consistently greater than 95% without episodic desaturations. The infant had blood gas analysis performed shortly after admission to the neonatal intensive care unit because of the degree of pallor. The results were significant for pH 7.32, $\text{PCO}_2$ of 22 mm Hg, $\text{PO}_2$ of 51 mm Hg, bicarbonate level of 12 mEq/L (12 mmol/L), and a base deficit of −12. Follow-up blood gas analysis on day 1 after birth was significant for pH 7.33, $\text{PCO}_2$ of 37 mm Hg, $\text{PO}_2$ of 43 mm Hg, and bicarbonate level of 20 mEq/L (20 mmol/L) (Table 2). Initial acidosis was likely due to severe anemia at birth. The infant was transferred to the newborn nursery on day 2 after birth and discharged home with her parents on day 5 after birth after an uneventful stay in the newborn nursery.

**DISCUSSION**

A sinusoidal FHR pattern resembles a smooth sine wave with a periodicity of 3 to 5 cycles per minute and lasting for at least 20 minutes. (1) Prolonged or severe fetal hypoxia with acidemia due to chronic fetal anemia, acute intrapartum

**TABLE 2. Arterial Umbilical Cord Gas Results**

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>$\text{PCO}_2$, mm Hg</th>
<th>$\text{PO}_2$, mm Hg</th>
<th>Base Excess, mEq/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>≥7.20</td>
<td>&lt;60</td>
<td>≥20</td>
<td>≤−10</td>
</tr>
<tr>
<td>Respiratory acidosis</td>
<td>&lt;7.20</td>
<td>&gt;60</td>
<td>Variable</td>
<td>≤−10</td>
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<tr>
<td>Metabolic acidosis</td>
<td>&lt;7.20</td>
<td>&lt;60</td>
<td>Variable</td>
<td>≥−10</td>
</tr>
<tr>
<td>Mixed acidosis</td>
<td>&gt;60</td>
<td>Variable</td>
<td>≥−10</td>
<td></td>
</tr>
<tr>
<td>Patient</td>
<td>7.32</td>
<td>22</td>
<td>51</td>
<td>−12</td>
</tr>
</tbody>
</table>
asphyxia, FMH, or in utero fetal hemorrhage may result in decreased FHR variability because of the effects of hypoxia and acidosis on the fetal central nervous system. (2)(3) The sinusoidal heart rate pattern continued to be present in the neonatal period and did not resolve with oxygen administration until the infant received blood transfusion, suggesting that increased hemoglobin concentrations may have alleviated tissue hypoxia. (4) Animal models in fetal lambs (5) have revealed that anemic fetuses exhibiting sinusoidal FHR patterns have elevated levels of arginine vasopressin, which is a pituitary hormone with vasopressor and antidiuretic effects. However, administration of arginine vasopressin in the absence of cerebral ischemia did not result in sinusoidal heart rate patterns, suggesting that both elevated levels of arginine vasopressin and cerebral ischemia were necessary to elicit the sinusoidal heart rate patterns.

As in our case, sinusoidal FHR patterns may be associated with massive FMH, usually considered to be a FMH of 20 mL/kg (which in this case would be 53.5 mL) or more. An FMH greater than 150 mL, as is seen in our case, is estimated to occur in 1 in 5,000 deliveries. (6) A Kleihauer-Betke test was performed in our case for quantification of FMH. In this test, red blood cells from the maternal circulation are fixed to a slide that is exposed to an acidic solution. Adult red blood cells become pale as hemoglobin A is soluble and eluted across membrane defects in the acidic environment. However, fetal red blood cells remain pink because hemoglobin F is stable at this pH level. The result is reported as the percentage of fetal red blood cells in the total sample.

Risk factors for massive FMH include multiple gestation, nuchal cord, and low birth weight. (7)(8) The pathogenesis of FMH is unclear, and one of the largest series of massive FMHs suggests that most massive FMHs are spontaneous. (9) Decreased or absent fetal movement is the most common antepartum presentation. (10)(11) The mother is usually asymptomatic, although symptoms suggestive of transfusion reactions have been described in case reports. (12)(13) As discussed above, FHR monitoring may reveal a sinusoidal FHR pattern. After delivery, FMH may be suspected, as in our case, because of neonatal anemia. Our finding of increased circulating reticulocyte count suggests that FMH may have occurred 1 to 2 days before birth. (14) For an FMH greater or equal to 150 mL, pooled data from 2 studies yielded a perinatal mortality rate of 37% (6)(14); however, long-term pediatric outcome after massive FMH is less well described.

### American Board of Pediatrics Neonatal–Perinatal Content Specification

- Know the diagnosis and management of maternal/fetal blood loss such as placenta previa, placenta abruption, vasa previa, and maternal-fetal hemorrhage.

### References

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