EFM Case Study #5: pH Implications

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INTRODUCTION

This monograph focuses on the pH implications of various fetal heart rate (FHR) patterns and the impact of umbilical cord pH in the diagnosis of neonatal encephalopathy (NNE). New scientific knowledge regarding various FHR patterns consistent with an acute peripartum or intrapartum event are defined in the new NNE Task Force report (ACOG & AAP, 2014). The report is a collaborative resource from the American College of Obstetricians and Gynecologists (ACOG) and the American Academy of Pediatrics (AAP). Our discussion includes critical thinking drills and a case study that incorporates the 2008 National Institute of Child Health and Human Development (NICHD) terms and guidelines, as well as, the ACOG intrapartum management algorithms (2015). This is part of an EFM Case Study Series.

FETAL ACID-BASE BALANCE - AN OVERVIEW

Fetal pH values often remain a mystery until the time of birth. The accuracy of electronic fetal monitoring (EFM) to determine fetal acid-base status is limited as various maternal, uterine, placental and fetal factors change during labor and birth. Umbilical cord blood pH, carbon dioxide levels, and base deficit values are commonly obtained at delivery to determine the acid-base status of a fetus and subsequent risk of NNE in a newborn. Critical pH values are defined by ACOG & AAP in the new second edition, Neonatal Encephalopathy & Neurologic Outcomes resource (2014). Currently, there is a knowledge and skill gap among perinatal practitioners regarding correct interpretation of FHR patterns signaling a decline in fetal pH, as well as, application of new critical umbilical cord blood pH values. This monograph will assist learners to improve their pH knowledge and skills.

SUPERIOR CENTRALIZED DOCUMENTS SYSTEM
Critical Thinking Drill #1

1. Rank the four EFM strip patterns in the order of estimated fetal pH values; lowest pH/acidotic/abnormal is #1 and the most normal is #4.
Critical Thinking Drill #2

1. Rank the four EFM strip patterns in the order of estimated fetal pH values; lowest pH/acidotic/abnormal is #1 and the most normal is #4.
Fetal oxygenation is dependent upon blood flow and oxygen content of the maternal, uteroplacental, umbilical, and fetal circulations. The path of oxygen transport begins with the mother and ends with the fetus. Oxygen diffuses from the maternal circulation, across the placental intervillous space and through the umbilical cord to the fetus. Any interruption in this pathway may lead to a drop in fetal oxygen levels, blood pressure, or both. These conditions may increase the risk of acid-base imbalance, hypoxic-ischemic injury (HIE), NNE, and cerebral palsy. Certain FHR patterns provide insight to these underlying conditions.

Despite the vast amount of research regarding fetal heart rate and uterine contraction patterns, there is inconclusive scientific evidence to support the ability of practitioners to predict neonatal neurologic injury (HIE or NNE), cerebral palsy, or stillbirth using EFM (ACOG & AAP, 2014). Yet there are several FHR characteristics and patterns that have been substantiated and are important for perinatal practitioners to understand and apply to EFM interpretation during clinical practice. These include:

- 97-98% of EFM tracings with moderate FHR variability & presence of accelerations is associated with a pH >7.0 (ACOG & AAP, 2014; Parer et al, 2006; Williams et al, 2003).
- 23%-50% of EFM tracings with absent or minimal FHR variability in the presence of concurrent late or variable decelerations predicted newborn acidemia (ACOG & AAP, 2014; Parer et al, 2006; Williams et al, 2003).
- There is a positive correlation between the degree of acidemia and the depth of decelerations or bradycardia (Parer et al, 2006).
Except for sudden profound bradycardia, fetal acidemia with minimal FHR variability in combination with decelerations develops over a period of time approximating one hour (Parer et al, 2006).

Increased numbers of late, variable, and prolonged decelerations are associated with an umbilical artery pH of < 7.10 (ACOG & AAP, 2014; Sameshima et al, 2004).

In the last 60 minutes prior to birth, the presence of bradycardia, absence of accelerations, and reduced (absent or minimal) variability is associated with HIE and a positive predictive value of 50% (ACOG & AAP, 2014; Lama et al, 2007).
NICHD 3-Tier FHR Interpretation System offers an evidence-based framework for categorizing FHR patterns based on probability of acid-base imbalance. All practitioners should apply this system into clinical practice daily (NICHD, 2008).

A Category I or Category II FHR pattern when associated with Apgar scores of 7 or higher at 5 minutes, normal umbilical cord arterial blood pH, or both is not consistent with an acute hypoxic-ischemic intrapartum event (ACOG & AAP, 2014).

There is a significant difference between a patient who initially presents to labor and delivery with an abnormal FHR pattern and one who develops an abnormal FHR pattern during labor. The latter is often associated with HIE or NNE (ACOG & AAP, 2014).

A Category II FHR pattern lasting 60 minutes or more that was identified on initial presentation with persistently minimal or absent variability and lacking accelerations, even in the absence of decelerations, is suggestive of a previously compromised or injured fetus. An emergent cesarean delivery may not benefit a fetus under these conditions (ACOG & AAP, 2014).

A fetus who presents with a Category I FHR pattern that later evolves into a Category III pattern over the course of labor and birth is suggestive of a hypoxic-ischemic intrapartum event (ACOG & AAP, 2014).

Additional FHR patterns that develop after a Category I FHR pattern on presentation, which may suggest intrapartum timing of a HIE event, include tachycardia with recurrent decelerations and persistent minimal variability with recurrent decelerations (ACOG & AAP, 2014).
Critical Thinking Drill #3

Using the NICHD 3-Tier FHR Interpretation system, categorize the four EFM strips as Category I/II/III.

A. EFM Strip A: _______
B. EFM Strip B: _______
C. EFM Strip C: _______
D. EFM Strip D: _______
Critical Thinking Drill #4

1. Using the NICHD 3-Tier FHR Interpretation system, categorize the four EFM strips as Category I/II/III.

A. EFM Strip A: _______
B. EFM Strip B: _______
C. EFM Strip C: _______
D. EFM Strip D: _______
ACID-BASE BALANCE

There are two important questions when discussing acid-base balance: 1) What role does oxygen play? and 2) How is acid-base balance maintained?

Oxygen is the cornerstone of cellular function and plays a key role in maintaining pH balance. If oxygen exchange between mother and fetus is decreased or blocked for any reason, pH is affected. Oxygen transfer may be interrupted due to various maternal, uterine, placental, umbilical cord, or fetal conditions; such as: maternal hemorrhage, prolonged tachysystole, placental abruption, umbilical cord prolapse, or fetal dysrhythmias. Being aware of conditions that may decrease fetal oxygen delivery is the first step in pH awareness. The second step includes an understanding of how fluctuations in oxygen and carbon dioxide affect the balance of blood pH.

Acid-base balance is determined by lung and kidney function. If respiration in an adult is altered or a fetus’ umbilical cord is entangled, an accumulation of carbon dioxide (CO\(_2\)) builds up and lowers pH. As pH falls, hydrogen ion levels rise and acidosis evolves. Buffers such as hemoglobin and bicarbonate (HCO\(_3\)) released from the kidneys work together to limit acidosis. These buffers bind to hydrogen ions, negating their negative effects. If acidosis is severe and or prolonged, buffers are depleted increasing risk of injury. A significant rise in CO\(_2\), a fall in HCO\(_3\), or both may lead to an acidic pH imbalance.
UMBILICAL CORD PH & RISK OF NNE OR CEREBRAL PALSY

Acidosis varies based on the accumulation of gas (CO₂) or depletion of buffers (HCO₃/bicarbonate). Retention of CO₂ leads to a milder form of acidosis known as respiratory, whereas a reduction in HCO₃ results in metabolic acidosis. A base deficit (BD) occurs once buffers are depleted and the ability to control acidosis is lost. A base deficit translates into an excess of acid that results in the most severe and damaging form of acidosis: metabolic. Metabolic acidosis is a pH imbalance in which the body has accumulated too much acid and does not have enough bicarbonate (HCO₃) to neutralize the effects of the acid. Mixed acidemia is metabolic acidosis that develops after respiratory acidosis is prolonged.

New guidelines from ACOG & AAP outlined in the NNE Task Force report define critical pH values (Table 1) (2014). A fetal umbilical artery pH < 7.0-7.10, a base deficit greater than or equal to 12 mmol/L, or both increases the probability of NNE with an intrapartum hypoxic component (ACOG & AAP, 2014). Arterial cord gas pH levels greater than 7.20 are not associated with neonatal encephalopathy.

Perinatal practitioners must be knowledgeable about critical pH values and indications for umbilical cord blood sampling. ACOG & AAP developed a data collection guideline for infants delivered at 35 weeks of gestation or more with risk of NNE (2014). In cases with delivery of a depressed newborn with Apgar scores of 5 or less at 5 minutes, the following is recommended:

- Obtain umbilical artery pH from a clamped section of umbilical cord
  - Draw and send two samples: venous & arterial (*superior)
    - *If a delay > 20 min before obtaining samples: put cord sample on ice for up to 60 min*

- Submit placenta for pathologic evaluation

Acidotic umbilical cord blood pH results are a strong indicator that hypoxic-ischemic fetal conditions occurred immediately prior to birth. Obstetricians are encouraged to obtain results when clinically indicated. More often than not, testing results often rule out that an HIE event occurred.
FETAL pH DRILLS

In our next set of drills, you will apply your new pH knowledge into clinical practice by matching umbilical cord pH values to the EFM strip most likely to correspond with the results.

Critical Thinking Drill #5

1. If delivery occurred within the next 5 minutes, which EFM strip would most likely result in the umbilical cord pH values shown here?

   EFM Strip A: _______
   EFM Strip B: _______

UMBILICAL ARTERY PH VALUES:

> PH: 7.22
> PCO₂: 66
> BD: 5
Critical Thinking Drill #6

1. If delivery occurred within the next 5 minutes, which EFM strip would most likely result in the umbilical cord pH values shown here?

   EFM Strip A: _______
   EFM Strip B: _______
Our case study resulted in the umbilical artery pH values listed above. Each value is abnormal. These results are typically seen as a result from a catastrophic sentinel event.

EFM strip #1 is the admission strip. Moderate variability exists and rules out current acid-base imbalance. This multiparous patient is at 36 weeks gestation. She has a history of preterm labor that was treated with terbutaline and magnesium sulfate. She is admitted to labor and delivery with spontaneous labor and a cervix at 4 cm dilated.

Critical Thinking Drill #7

1. What is the FHR baseline rate & variability?
2. What Category is this FHR pattern?
3. What is the fetal pH: normal, indeterminate, abnormal?
Approximately 1 hour later, the labor and delivery RN enters the room to find EFM strip #2 and an audible fetal heartbeat in the 70’s. She places a fetal scalp electrode on the fetal head at the end of this tracing.

**Critical Thinking Drill #8**

1. List 2 intervention required at this time?
EFM strip #3 occurs immediately after placement of the fetal scalp electrode. Fetal bradycardia is now confirmed and documented. There was no vaginal bleeding noted during the cervical exam. The RN positions the patient to her left side, increased the IV fluids, and assessed the maternal blood pressure (145/81). The fetal heart rate resolves to a baseline of 120, 10 minutes after this tracing. She pages the resident on-call to come and perform a bedside assessment.

Critical Thinking Drill #9

1. What Category is this FHR pattern?
2. What is the fetal pH: normal, indeterminate, abnormal?
The attending physician was notified and the patient was prepped for an emergent cesarean birth. Fetal cardiac output is minimal with a FHR baseline rate of 60.

Critical Thinking Drill #10

1. What is the likely cause of this FHR pattern?
2. List 2 interventions required at this time?
3. If this fetus were delivered in the middle of this strip, what interventions would be required?
4. How many practitioners skilled in NRP should be in attendance at this delivery?
EFM CASE STUDY: SUMMARY

- Apgar Scores: 1\(^1\)/5\(^2\)/10\(^5\)/15\(^1\) (*Assisted: Intubated & medication administration)
- Seizures began @ 12 hours of life
- Hypoxic-ischemic neonatal encephalopathy diagnosed at 7 days of life
- Cerebral palsy diagnosed at 13 months of age
- Medical-malpractice claim: $2.4M settlement paid to plaintiff

This final outcome of this case study was a 75% placental abruption. Diagnostic error in detecting an occult placental abruption and failure to intervene in a timely manner were the primary allegations in the medical-malpractice claim. Both the hospital and resident physicians were found negligent. Plaintiff experts drew attention to the umbilical cord pH results of severe mixed acidosis at birth, low Apgar scores, and subsequent MRI studies. Each supports the timing of injury to be intrapartum.

As fetal pH values often remain a mystery until the time of birth, there is scientific evidence that supports certain FHR patterns signal a decline in pH. Be particularly alert at admission on how a fetus presents. Any deviation from this is cause for heightened surveillance. As a FHR pattern evolves from a Category I, perinatal practitioners must be diligent to watch for deterioration characteristics that correlate with a decline in pH values. The pH implications of EFM data impacts both short and long term interpretation, as well as, newborn outcomes. Apply the new ACOG & AAP pH critical values and various FHR patterns consistent with an acute peripartum or intrapartum event into clinical practice, hospital policy, and EFM interpretation for improved patient safety.
DRILL #1- (EFM STRIP & PH ESTIMATES)

1. Rank the four EFM strip patterns in the order of estimated fetal pH values; lowest pH/acidotic/abnormal is #1 and the most normal is #4:
   I. C
   II. A
   III. D
   IV. B

DRILL #2- (EFM STRIP & PH ESTIMATES)

1. Rank the four EFM strip patterns in the order of estimated fetal pH values; lowest pH/acidotic/abnormal is #1 and the most normal is #4:
   I. A
   II. C
   III. B
   IV. D

DRILL #3- (CATEGORIZING EFM STRIPS)

1. Using the NICHD 3-tier FHR interpretation system, categorize the four EFM strips as category I/II/III.
   A. EFM Strip A: ___III___
   B. EFM Strip B: ___I___
   C. EFM Strip C: ___III___
   D. EFM Strip D: ___II___

DRILL #4- (CATEGORIZING EFM STRIPS)

1. Using the NICHD 3-tier FHR interpretation system, categorize the four EFM strips as category I/II/III.
   A. EFM Strip A: ___III___
   B. EFM Strip B: ___II___
   C. EFM Strip C: ___II___
   D. EFM Strip D: ___II___

DRILL #5- (UMBILICAL CORD PH VALUES & EFM STRIPS)

1. If delivery occurred within the next 5 minutes, which EFM strip would most likely result in the umbilical cord pH values shown here?
   EFM Strip A: ___X___
   EFM Strip B: ______
DRILL #6- (UMBILICAL CORD PH VALUES & EFM STRIPS)

1. IF DELIVERY OCCURRED WITHIN THE NEXT 5 MINUTES, WHICH EFM STRIP WOULD MOST LIKELY RESULT IN THE UMBILICAL CORD PH VALUES SHOWN HERE?

   EFM STRIP A: _____
   EFM STRIP B: __X__

EFM CASE STUDY -

EFM STRIP #1: ADMISSION STRIP (DRILL #7)

1. What is the FHR baseline rate & variability?
   
   ANSWER: 140, moderate

2. What Category is this FHR pattern?
   
   ANSWER: Category I

3. What is the fetal pH: normal, indeterminate, abnormal?
   
   ANSWER: normal

EFM STRIP #2: ONE HOUR LATER (DRILL #8)

1. List 2 interventions required at this time?
   
   ANSWER: Notify primary practitioner, reposition laterally, increase IVF if not contraindicated, assess & correct maternal blood pressure, oxygen therapy, discontinue uterine stimulants-if applicable.

EFM STRIP #3: FSE IN PLACE (DRILL #9)

1. What Category is this FHR pattern?
   
   ANSWER: Category II

2. What is the fetal pH: normal, indeterminate, abnormal?
   
   ANSWER: indeterminate
1. What is the likely cause of this FHR pattern?
   ANSWER: placental abruption

2. List 2 interventions required at this time?
   ANSWER: Prepare for emergent cesarean delivery, notify primary practitioner/OR team/Anesthesia personnel/Neonatal Rapid Response Team, reposition laterally, increase IVF if not contraindicated, assess, correct maternal blood pressure, oxygen therapy, and discontinue uterine stimulants-if applicable.

3. If this fetus were delivered in the middle of this strip, what interventions would be required?
   ANSWER: Full cardiopulmonary resuscitation.

4. How many practitioners skilled in NRP should be in attendance at this delivery?
   ANSWER: Due to the severe conditions, there should be 2 individuals skilled in NRP to attend to the immediate needs of the newborn. Once should have all skills required to perform all resuscitative measures (intubation and UVC placement). Preparations for a full code should be anticipated. Therefore, drawing up medications, set up several ETT tubes, and have a UVC set-up immediately available with IVF ready for infusion. A fetus experiencing a severe placental abruption will have significant volume deficits and volume replacement is the key to NRP success.
EFM CASE STUDY #5: pH IMPLICATIONS

[*Accessed: September 15, 2015]

QUICK LINKS -


REFERENCES -


