Monitoring Fetal Health

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Case Objectives

- Define fetal heart rate monitoring.
- Describe the current state of evidence regarding fetal heart rate monitoring.
- List the known hazards of centralized fetal heart rate monitoring.
- Describe the impact of increasing the number of displays that need to be monitored on overall vigilance and detection of critical signals.
- Appreciate the importance of safety culture on labor and delivery units.

The Case

A 29-year-old woman had an uncomplicated pregnancy with a healthy fetus and presented to the hospital at term (40 weeks) in early labor. She progressed slowly over the first night. By the next morning, she had a completely dilated cervix and was ready to push. She pushed for approximately 2 hours without any difficulty or any sign of problems with the fetus. Unfortunately, when the infant was born, he was cyanotic and flaccid with very low Apgar scores. An arterial blood gas at the time showed a pH of 6.70 (normal: 7.25–7.35), a profound acidosis. The infant required extensive resuscitation but survived and was transferred to the neonatal intensive care unit.

The infant subsequently had multiple seizures typical of hypoxic-ischemic encephalopathy (brain injury from inadequate oxygenation of the brain that occurred during childbirth) and other problems related to the complicated delivery. He spent a month in the neonatal intensive care unit before being transferred to a neuro-rehabilitation unit. He is likely to be severely disabled for the remainder of his life.

A root cause analysis of the case found that the mother had been appropriately monitored and had not shown any evidence of distress. The fetus had been monitored using the standard fetal heart rate tracings throughout the time of labor. The fetal heart rate tracings had shown evidence of Category 2 and 3 abnormalities (moderate-to-severe fetal distress) for at least 90 minutes prior to the delivery. These abnormalities, which likely would have prompted an urgent cesarean delivery, had not been recognized by any of the physicians or nursing staff.

In this institution, continuous fetal heart monitoring of all of the women in labor was displayed centrally on a large 40-inch monitor at the nurses' station. On this screen, the individual fetal heart monitoring strips for the 16 rooms were displayed continuously in small windows. Two nurses at the nursing station were assigned to watch the monitor at the time of the concerning abnormalities. When asked about the incident, they both replied that they "just didn't see the bad tracings" and commented how difficult it can be sometimes to identify abnormalities and to continuously watch all 16 small windows. The responsible obstetrician was busy throughout the period of abnormal tracings with another complicated childbirth.

The Commentary

The case presented above involves failure to recognize concerning fetal heart rate (FHR) tracings during labor. Electronic fetal monitoring was introduced in 1958 and was quickly adopted because it offered a continuous measure of FHR activity and was expected to reduce infant mortality.(1-4) Both FHR activity and maternal contractions are recorded by transducers placed on the maternal abdomen and tracings can be displayed either on a paper strip or a computer screen.(4,5) The baseline heart rate is measured in beats per minute (bpm) and measured over a 10-minute period.(6) Normal mean values for FHR range from 110 to 160 bpm. Deviations in the baseline activity are classified as absent (no noticeable bpm variation), minimal (up to 5 bpm), moderate (variability ranges from 6 to 25 bpm), or marked (exceeding 25 bpm).(6) The normal baseline activity of the fetal heart rate is dependent on adequate oxygenation to the brain; if the fetal brain is receiving enough oxygen, then there is substantial heart rate variability. The presence of decreased oxygen saturation in the blood results in reduced and ultimately absent baseline variation. Thus, loss of fetal heart rate variability is a strong predictor of fetal compromise.

Patterns of FHR activity can be interpreted as reassuring, nonreassuring, or ominous.(4) Reassuring patterns indicate that the fetus is stable and generally predict the birth of a healthy fetus. Nonreassuring patterns generally have little FHR variability and indicate that the fetus may not be stable. Ominous patterns, such as complete loss of beat-to-beat variability, indicate the fetus is in distress and immediate intervention is recommended.

The National Institute of Child Health and Human Development (NICHD) recently presented a new classification of FHR that is intended to standardize communication among health care providers and stratify fetal risk.(6) In this classification, three patterns of FHR abnormalities are described: Category 1 is reassuring of a normal fetal status, Category 2 is intermediate requiring close observation and monitoring, and Category 3 is possibly suggestive of fetal compromise. These categories are devised based upon the baseline variability in the fetal heart rate as well as the presence of temporary slowing in fetal heart rate; temporary decelerations may also suggest the presence of decreased oxygen levels in the fetal circulation. It appears the fetus in this case displayed evidence of Category 2 and 3 abnormalities that should have prompted enhanced monitoring and possible emergent cesarean delivery.

The risks and benefits of FHR monitoring during labor have been the subject of several studies.(7) Although the technology is designed to detect fetal compromise from acute oxygen deprivation, the presence of a fetal insult remote from labor and the associated high false-positive rate (normal outcome newborn with a nonreassuring fetal heart tracing) often result in lack of consistency in interpretation. In essence, a major fetal insult may occur during pregnancy that results in fetal compromise, such as a stroke; if the fetus recovers from this episode and oxygenation is restored to the fetal circulation, at the time of labor the fetal heart rate tracing may appear normal despite a significant fetal brain injury with long lasting sequelae.

Traditionally, FHR monitors were analog devices located at the patient's bedside.(5) Signals were traced with a pen onto a printed grid on paper that scrolled at a standard rate. However, technological advancements made it possible to digitize the signals and present them on a computer display and enabled patient signals to be monitored from a remote location.(8) As in this case, more hospitals are now turning to centralized monitoring—usually placed in the nursing suite of the labor and delivery unit—because it allows many patients to be monitored simultaneously in a single location.(9) Several systems are currently available that differ in important ways.(10) Some simply aggregate several tracings onto one display, allowing providers to monitor multiple patients on one screen. Some include other key patient data (e.g., vital signs, oximetry, etc.) in addition to the FHR tracing and maternal contractions. Other systems include computerized analysis of the signals and detection of specific events (e.g., contractions, FHR variability, etc.). A few provide visual or audio alerts to specific conditions (e.g., tachycardia, bradycardia, abnormal variability, FHR decelerations).

Some studies have examined the efficacy of these systems by comparing computer-generated detections or alarms with expert judgments. The studies have shown that levels of agreement vary greatly depending on methodology and specific features studied. In one 3-year retrospective study, there was no difference in rates of cesarean delivery, admissions to the neonatal intensive care unit (NICU), or low Apgar scores between periods with and without centralized fetal monitoring.(9) At present, however, there are no agreed upon standards for comparing computerized and clinical analysis of fetal heart rate. This has hampered efforts to evaluate centralized computer monitoring systems.(10)

The rationale behind placing many FHR monitors in one central location is that it would facilitate monitoring of all patients simultaneously. Previously when FHR tracings occurred only at the bedside, a nurse or physician would have to visit the bedside frequently, and it was not possible to continuously monitor all patient tracings for signs of fetal distress. It was believed that centralized, continuous monitoring of all patients could lead to better outcomes.

Although well intended, there are two fundamental differences inherent in centralized monitoring that have led to some unanticipated, and problematic, consequences. The first difference concerns the nature of the display itself. The digitization of FHR signals allows one or more tracings to be displayed on a standard computer screen. In the present case, data from 16 patients were displayed on a single 40-inch monitor. However, this arrangement limits the amount of information available for review at a single glance. In order to display data from 16 patients each tracing would be limited to about a 10-minute window of activity (assuming a 4 x 4 matrix on the screen with little or no reduction in size compared to paper strips). Unlike traditional paper tracings where a clinician can quickly scan 30 minutes or more of activity, the windows for digitized tracings are significantly reduced. If the system allows selection and expansion of an individual patient's tracing, that can only be accomplished by obscuring, degrading, or reducing the size of other patient's tracings because the screen display size is limited. Thus, focusing in on one patient's data is done at the expense of others, even if temporarily.

The second, and perhaps less obvious difference that emerges from centralized monitoring, concerns the attentional challenges it creates for those required to monitor the displays. The primary concern is vigilance or the ability to maintain attention and respond to stimuli over long periods of time. Numerous studies have shown that when asked to monitor displays over extended periods of time, an observer's ability to detect critical signals can wane. This phenomenon is known as "vigilance decrement" and has been replicated in numerous studies.(11,12) This problem is far from unique to labor and delivery, or even to health care. Many jobs require observers to maintain attention to displays for extended intervals including: nuclear power plant operators, air traffic control personnel, and security guards monitoring surveillance cameras. Often an important part of a health care professional's job is to monitor critical life signals of patients in the ICU, labor and delivery units, or individuals under anesthesia.(13-15) Failures of vigilance in the real world are well documented in the literature (e.g., aviation, health care [16,17]). They compromise safety and can result in fatalities. Thus, centralized fetal monitoring can foster the same conditions that lead to vigilance failures seen in other industries.

Characteristics of signals themselves exert an important influence on vigilance performance. Decreases in critical signal rate and amplitude can all harm detection performance and exacerbate the vigilance decrement; thus critical signals which occur less frequently or are of a low intensity may easily be missed by observers.(18) Monitoring multiple displays or multiple sources of information depicted within a single display also tends to harm performance. In one study, observers asked to monitor multiple displays detected fewer signals and had more false alarms than those observing only a single display.(19) A subsequent study concluded that monitoring multiple displays places an additional burden on observers and that equipment designers should try to avoid creating displays with multiple components that need to be monitored.(20)

Our research team has examined the ability of individuals to monitor displays of simulated FHR tracings and distinguish important FHR variability from benign FHR variability.(21) Subjects were assigned to monitor one, two, or four FHR tracings shown in separate windows on the computer display. The participants detected fewer critical signals as the number of tracings to be monitored increased. Further, correct detections decreased as time on task progressed, consistent with numerous other vigilance studies. It is worth noting that the monitoring conditions in this study might be considered ideal. The simulated maternal contractions were uncharacteristically smooth, eliminating any ambiguity in their appearance and the participants were alone in a room focused solely on this task. By contrast, labor and delivery providers work in environments that are busy, noisy, and have many tasks competing for their attention.

While the technical and logistical issues are important, in our experience, a major factor contributing to interpretation of FHR is related to the safety culture that prevails on labor and delivery units. The accurate interpretation of FHR requires an understanding of the physiology of fetal monitoring, open and clear communication between the health care teams, and a common acceptance and understanding of the chain of command on the unit. It is not unusual, when sentinel events occur on labor and delivery, that the main cause is traced to lack of clear communication and a culture that does not promote openness and reporting of near-misses. Labor and delivery is a busy environment, which involves patient transitions from triage to a labor room, to a delivery or operating room, and a recovery room. This complicated patient flow requires dedicated specialized teams with strong commitment to safety. Having a centralized monitoring station with insufficient number of available, well trained, vigilant, and undistracted personnel to monitor can be a recipe for bad outcomes.

The practical implications of vigilance research are that requiring individuals to monitor many patients simultaneously may impose a unreasonable attentional burden on the staff. There are methods that can be used to improve the detectability of critical signals and minimize vigilance decrements. Simple solutions include: (i) additional training, (ii) having more than one person monitor the displays, and (iii) limiting the duration of watchkeeping shifts.(11,22) Unfortunately, none of these methods will completely eliminate vigilance failures. More sophisticated possibilities include amplifying the signals or using systems that provide warnings generated by computerized analysis of the FHR tracings. These methods have been applied in other high-risk domains (e.g., aviation, processing plant operations) and have reduced vigilance failures but not eliminated them completely. There are several reasons for this. First, creating more sophisticated computer-based detection systems actually shifts much of the monitoring burden from the users to the system designers.(23) Second, unless a computer-based detection or warning system is completely reliable, users may err by either overtrusting it or completely ignoring it, leaving themselves less able to detect anomalies when they do occur.(24) Ultimately, best practices rely on creating work environments where observers are actively engaged and interact with information displays instead of being reduced to passive monitors.

Given the significance of the fetal heart rate tracing in labor especially in the presence of Category 2 and Category 3 tracings, several steps should be adopted by hospitals to ensure adequate recognition and action when abnormal fetal heart rate tracings are encountered. Achieving this requires open and transparent communication between the health care teams, ongoing education and training to help identify subtle fetal heart rate abnormalities, and chain-of-command protocols to allow for quick resolution of disagreement when it arises. Ongoing review of near-misses and poor outcomes is also an essential step towards building a safer system and a safety culture.

Take-Home Points

- Fetal heart rate monitoring on labor and delivery is a complex process that is often affected by staff education and training, staffing levels, and the unit safety culture.
- Centralized monitoring introduces significant changes in the way patients are monitored. These changes are accompanied by some obvious advantages and some less obvious disadvantages.
- Attempts to combat monitoring deficits in other high-risk domains with more sophisticated technology have reduced but not eliminated failures of attention.
- Improving communication on the labor and delivery unit and establishing an ultrasafe and resilient culture that promotes transparency are two major components of accurate interpretation of FHR.

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