FHR Case Presentation #4 An Unexpected Outcome

Expires Monday, July 31, 2023 Nursing Edward J. Quilligan , M.D.

Objectives

1. Describe the function of an external Doppler fetal heart-monitoring device.;
2. List the limitations of the external Doppler fetal heart-monitoring device ;
3. Discuss the potential complications of utilizing an internal fetal heart-monitoring device.;
4. Explain the importance of making sure that the fetus is being accurately monitored during the course of labor.

Article

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Editor: Edward J. Quilligan, M.D.

Objectives: Upon the completion of this CNE article, the reader will be able to

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2. List the limitations of the external Doppler fetal heart-monitoring device
3. Discuss the potential complications of utilizing an internal fetal heart-monitoring device.
4. Explain the importance of making sure that the fetus is being accurately monitored during the course of labor.

Case Presentation:

A 24-year-old female Gravida 2 Para 0 was admitted to labor and delivery at 39 4/7 weeks gestation with a complaint of regular uterine contractions. The patient had regular prenatal care with normal prenatal laboratory results except that she declined the triple marker genetic screen. Her past medical history was negative for any major medical disorders. Her vital signs on admission revealed a blood pressure of 118/72, pulse of 82, and a temperature of 36.9^{0}C. The initial vaginal exam was 2 cm dilated, 50% effaced, at –2 station. External monitors were applied and the fetal heart monitor tracing, shortly after admission, is seen in Strip #1.

Three to four hours later, the patient's evaluation was as follows: cervix 3-4 cm dilated, 90% effaced at –1 station, blood pressure 122/74, pulse 96, and temperature 37.3^{0}C. The fetal heart monitor tracing at that time is seen in Strip #2. She had become much more uncomfortable and an epidural anesthetic was placed about an hour later. Approximately 4 hours after this, her evaluation revealed that she was now 8 cm dilated, completely effaced, at zero station with a blood pressure of 120/70, pulse of 104, and a temperature of 37.1^{0}C. The fetal heart-monitoring tracing seen in Strip #3 and Strip #4 had been occurring for about 45 minutes.

About an hour later, she was found to be completely dilated at zero station with a blood pressure of 128/78, pulse of 118, and a temperature of 37.5^{0}C. The fetal heart monitor transducer had been adjusted because of occasional windows of signal loss and the pattern had corrected itself as seen in Strip #5. She began to push and roughly an hour after this, she began to crown and then spontaneously delivered a 3375 gram female infant with Apgar scores of 0 at 1 minute, 1 at 5 minutes, and 3 at 10 minutes. The arterial cord blood gas revealed a pH of 6.74, pCO_2 of 119, pO_2 of 4, bicarbonate of 8.7, and a base excess of –22.9. The fetal heart monitor tracings right up to

the delivery are seen in Strip #6 and Strip #7.

Discussion:

The external fetal heart-monitoring device is the primary instrument used in evaluating fetal status in labor in the United Stated. For the most part, the majority of patients can adequately be managed through labor using this device. However, it is important to understand the limitations of the external monitor that is in use today. To begin with, it is not a microphone, but instead utilizes Doppler ultrasound. This device both transmits and receives ultrasonic signals. These ultrasonic signals are extremely high in frequency and well beyond the level that can be heard by humans or any other animal. These ultrasound beams can penetrate tissue; however, like all sound waves, they will reflect off of objects. Thus, as the ultrasonic beams are transmitted from the device, some ultrasound signals return as they are reflected back off the underlying objects. If the object is stationary, the reflected beam is of a constant frequency. If the object is moving, such as the fetal heart or pulsations seen in large arteries (fetal or maternal), the reflected frequency will change. The external fetal heart-monitoring device detects these changes in frequency and converts them into electronic signals that can then be recorded onto the moving fetal heart monitor paper. In addition, the monitor is also able to convert these frequency changes into artificially created "audible" heart beat sounds. Again, it is important to remember that the audible heart beat sound that comes from the fetal heart-monitoring devices in use today is created by the machine and is not a microphone recording. Likewise, when a fetus moves in utero, no true sound is made because the unborn child is in a water filled environment. However, the fetal monitor machine will generate a sound in response to that movement.

Because the fetal heart monitor tracing that is created by an external fetal heart-monitoring device is "artificially" electronically created, limitations exist. Though the generated ultrasound beams cannot be heard, as stated above, the reflected beams are not pure and aberrant or indistinct reflections occur, which are often described as "noise". To affectively deal with ultrasound "noise", the machines have filters and logic built in. The fetal heart monitoring devices (besides sending and receiving ultrasonic signals) also have components that measure the time intervals (in seconds) between these frequency changes and then converts them into "beats per minute" by dividing that time interval into 60. Because the time interval in seconds between successive heart beats is not exactly the same from heartbeat to heartbeat or blood vessel pulsation to blood vessel pulsation, these slight differences are recorded on the moving heat heart-monitoring paper as a squiggly line, which we know as variability. If the time interval between heartbeats is exactly identical, the line is flat (no squiggliness), which would be classified as absent variability.

Oftentimes, external fetal heart-monitoring machines are classified as first-generation or second-generation devices. If one recalls and electrocardiogram (EKG or ECG) readout, each heartbeat cycle produces a "P-QRS-T" wave where the "R" wave coincides with the ventricular contraction and this is called the peak wave. First-generation devices primarily used continuous wave Doppler ultrasound that calculated the heart rate based on the detection of these peak waves or "R" waves. Second-generation models employ a system called "autocorrelation" that actually examines the full wave of received information and creates 200 to 300 digitized points along the wave curve. This information is then compared to the previous set of information that came from the prior heartbeat curve. By doing this, artifact signals and "noise" can further be eliminated to make a more accurate pattern that prints out on the paper. In addition, some second-generation machines use pulsed Doppler ultrasound rather than continuous wave Doppler ultrasound (see ref. 1 & 2).

Before the next topic is discussed, however, a brief review of "variability" needs to occur. There are two basic forms of variability – long-term variability (LTV) and short-term variability (STV). STV is beat-to-beat variability and is the millisecond difference seen between successive heartbeats. The only "true" way to determine STV is by way of an ECG – fetal scalp electrode or internal monitor. LTV is the larger cycling squiggles seen on a fetal monitor tracing over time excluding periodic changes (which are called fetal heart rate accelerations and decelerations). The 1997 National Institute of Child Health and Human development (NICHHD) Research Planning Workshop did not differentiate between LTV and STV because they are visually ascertained as one entity and these guidelines were adopted by The American College of Obstetricians and Gynecologists (ACOG) and the Association of Women's Health Obstetric and Neonatal Nursing (AWHONN) in 2005-2006. Variability is defined as: "marked" if the amplitude variation (peak-to-trough) is > 25 beats per minute (BPM); "moderate" (normal) if the amplitude range is 6 to 25 BPM; "minimal" if the amplitude range is detectable but $\leq$ 5 BPM; and "absent" if it is undetectable (see ref. 3 & 4).

Despite the advances of external fetal heart monitoring devices, because the tracing is electronically created, the machines still have built in buffer systems and logic. Older monitors take a running average of the prior 2 to 3 heartbeats that is then compared to the next heartbeat, whereas newer models use a buffer system that averages several weighted heartbeats. This logic or buffer system can still lead to an "artificially" created increase in short-term variability when external tracings are compared to fetal scalp electrode (internal monitor) strips. However, it is important to remember that external monitors will not "artificially" decrease variability. Also, because of these buffer systems and logic, wide variations in successive heart beats (as seen with cardiac arrhythmias or sudden deep decelerations – variable decelerations) may be recorded as a "doubling" of slow rates or a "halving" of fast rates on the tracing. The other finding that may occur with external monitoring devices is that if the signal is weak, or there are wide fluctuations in successive heartbeats, excessive "noise" from fetal movement, or maternal movement, the pen may "lift off" the moving monitor paper producing a non-readable strip (pen markings that are haphazard) or no tracing at all. This is often referred to as "signal loss". Factors that may lead to a weak signal are maternal body habitus (increased abdominal adipose tissue or scarring from prior abdominal surgeries) or fetal position or movement in relation to the placement of the external monitoring device (see ref. 5 & 6).

In review, external fetal heart-monitoring devices are noninvasive, but are affected by maternal and fetal movement, maternal body habitus, and built in logic and buffer systems. All of these factors can lead to signal loss, a halving or doubling of the true heart rate, and an "artificial" increase in variability. Furthermore, since the external fetal heart-monitoring device is not directly attached to the fetus, it can also record the maternal heart rate. Most recorded maternal heart rates will demonstrate moderate or minimal variability and can display fluctuations that look like accelerations and decelerations. Because the normal fetal heart rate baseline is 110 to 160 BPM and most maternal heart rates are less that 100 BPM, the issue of recording maternal heart rate is not consciously contemplated. However, many women can develop a tachycardia (where their heart rate exceeds 100 BPM), especially when they begin to push in the second stage of labor, and this can lead to the potential lack of awareness that the generated tracing is actually the maternal heart rate and not the fetus. Thus, anytime a mother's heart rate in labor exceeds 100 BPM, the healthcare providers need to verify that the recorded tracing is indeed the fetus and that it is different from the maternal heartbeat pattern.

The last statement in the preceding paragraph may seem obvious and elementary; however, when a mother enters the second stage of labor, nursing duties and activity in the labor room usually increase, and this aspect of care can easily be overlooked. A simple solution when faced with this scenario is to apply a fetal scalp electrode. If this occurred universally in the United States anytime a mother's heart rate exceeded 100 BPM, the issue of monitoring the mother and not the baby would become close to non-existent. From surveys of medical malpractice claims in the Untied States in obstetrics, 25% to 33% of the cases that involve a poor neonatal outcome and the fetal heart monitor tracing, implicate the monitoring of the mother's heart rate instead of the fetus.

Internal monitoring (also called direct fetal monitoring) involves the use of a fetal scalp electrode that is attached to the presenting part in labor (usually the scalp but could be the buttocks in the case of a vaginal breech delivery). This apparatus actually measures the true time interval between "R" waves of the fetal heart ECG and converts these data into beats per minute – recalculating this for each successive heartbeat (thus supplying "true" beat-to-beat variability). Furthermore, this form of monitoring is unaffected by fetal movement or maternal body habitus and movement. The device is a bipolar electrode that involves a stainless steel spiral conductor that is attached to the fetus (penetrating about 2 mm deep at the most) and the second conductor is the maternal vaginal secretions. This form of monitoring can only occur once the membranes are ruptured, or if applied with intact membranes will causes the membranes to become ruptured.

Though some individuals voice concern regarding the use of an internal monitor, the risks basically fall into two categories. The first is placement on the face or some other undesired anatomical location and this can be minimized by making sure that the exact presenting part is known prior to attachment (see ref. 7). The second is transmitting infection. Though the risk of infection is real, the incidence in most studies is < 1% and the vast majority of these are localized to the scalp and easily treated. The use of a scalp electrode in patients with human immunodeficiency virus (HIV) or an active genital herpes infection is not recommended, though most of these patients now undergo cesarean section. The use of an electrode in patients with a history of genital herpes but no active lesions is deemed appropriate, if clinically indicated (see ref. 8). Likewise, the use of direct fetal monitoring in group B streptococcal carriers and hepatitis B surface antigen positive patients is also acceptable because both of these instances will be adequately treated if recommended protocols are followed (see ref. 9 & 10). Mothers who are group B streptococcus positive will receive intrapartum antibiotics and newborns of patients with a positive hepatitis B surface antigen will receive hepatitis B immunoglobulin (HBIG) and the vaccine series. If the

full literature is reviewed, other extremely rare scalp infections have been described, but again, these case reports alone should not deter the use of internal monitoring.

One final infectious agent that needs to be discussed is hepatitis C, which is an unknown factor. The risk of transmission following the use of a fetal scalp electrode in a patient that is positive for hepatitis C has not been examined. In addition, remember that the spiral electrode is a solid needle, not hollow. Transmission of blood-borne infections (such as hepatitis C) is greater from hollow bore needles, but again, this has not been analyzed. The perinatal transmission rate of hepatitis B prior to the advent of HBIG and the vaccine on average was 50% (with a range of 10% to 90% depending on the hepatitis B e-antigen / e-antibody status of the mother). There currently is no effective treatment for hepatitis C and the perinatal transmission rate is only about 5% to 8% (or 9 to 10 times less that that of hepatitis B). The risk of transmission seems to be higher in cases where the mother has high blood titers of hepatitis C viral RNA (HCV-RNA). Since no recommendations on this topic exist, management will be based on the preferences of the individual healthcare providers.

One of the primary purposes for this review is not to say that all laboring patients need internal monitoring. If a laboring patient is being monitored externally and a quality strip is generated, then continue with the external monitor. However, it is very important to understand the limitations of external monitoring and consider using an internal monitor if the tracing is hard to maintain or there are continuous episodes of signal loss and especially in cases where the maternal heart rate exceeds 100 BPM. All of these are good acceptable indications for using a fetal scalp electrode.

Case Presentation Outcome and Summary:

Not stated in the above case presentation, was that the maternal heart rate over the final hour of pushing was documented between 116 and 154 on several occasions. Also, remember that the tracings of 5,6 & 7 were recorded after the external monitor was adjusted because of windows of signal loss. The neonate developed seizures in the first 24 hours of life with laboratory studies that demonstrated an elevated serum creatinine and elevated liver function tests, and had central nervous system studies consistent with recent global hypoxic injury. The child later on was found to have spastic quadriplegia cerebral palsy.

In reviewing the fetal heart monitor tracings, Strip #1 shows a normal baseline in the 140's with moderate variability and an irregular contraction pattern. Strip #2 demonstrates a similar baseline around 140 with moderate variability and also several accelerations. One might say that this portion of the strip could be labeled "reactive", but remember, the term "reactive" is applied to a specified number of accelerations noted in a particular time period and this finite definition will often vary from institution to institution. Strip #3 and Strip #4 depict moderate variability with variable decelerations that drop to a nadir in the 80's with good return to the baseline. The NICHHD meeting did not create parameters for defining variable decelerations (as mild, moderate, or severe) and many different definitions have been presented in the literature. Most of these definitions have tried to describe severe variable decelerations and if those parameters are not met, then the variable deceleration is considered mild. As one might expect, there can be wide fluctuations in the appearance of variable decelerations (which is part of the reason why they are called variable). However, the variable decelerations seen in Strip #3 and Strip #4 would not be classified as severe by any publication.

Strip #5 demonstrated a baseline around 120 with moderate variability and two accelerations. Strip #6 and Strip #7 depict moderate variability with a baseline between 105 and 120 and numerous accelerations. With this type of fetal heart monitor tracing up to the point of delivery, one would expect a vigorous newborn with normal Apgar scores (excluding some final event such as a severe shoulder dystocia, etc.). Why then did we end up with a neonate that has a 5-minute Apgar score of 1 and a severe metabolic acidosis? The answer lies in the fact that the maternal heart rate was recorded during the final hour and a half of this labor instead of the fetal heart rate.

In examining Strips #5, 6, & 7 several other issues can be discussed. Why would a fetal heart tracing with a baseline in the 140's and frequent variable decelerations convert to a completely normal appearing tracing with a baseline of 110 to 120 in an hours' time without some significant change in treatment (such as amnioinfusion, etc.)? Though the elimination of the variable decelerations might occur with maternal position change, the baseline should not adjust by a level of 20 to 30 beats per minute unless the mother's temperature also significantly decreased. In addition, when examining Strips 6 & 7, one sees fetal heart rate accelerations that coincide with every contraction or push. Remember that fetal heart rate accelerations primarily occur in response

to fetal movement or stimulation (i.e. scalp stimulation, etc.). Accelerations that coincide with contractions can occasionally be seen earlier in labor that when followed will convert to variable decelerations. This phenomenon is consistent with cord compression where only the umbilical vein is compressed in the early stage of labor. The deceleration part of a variable deceleration occurs in response to the umbilical artery being compressed. Thus, the accelerations seen in Strips 6 & 7 would also be unexpected. For argument sake, one might say that the baseline in Strips 6 & 7 is really in the 150's and what occurs in the 105 to 120 range is deceleration. However, of the 5 time windows depicted in these two strips that demonstrate the heart rate between 105 and 120, three are straight across (not consistent with a deceleration that should be sloped), there is moderate (or normal) variability throughout, and the period of time at 105 to 120 is twice as long as the time periods at 150. Thus, with these parameters, one should expect at least minimal variability if not absent variability with worsening of the deceleration phase of the tracing over time, if indeed the baseline is 150 and the 105 to 120 recordings are decelerations.

In conclusion, what occurred in this case was that the maternal heart rate was recorded in the final hour and a half, not the fetal heart rate. This is also consistent with the maternal heart rates that were documented in the 116 to 154 range while she was pushing. If 25% to 33% of fetal heart-monitoring medical malpractice obstetrical cases involve the monitoring of the mother rather than the fetus, this unfortunately tells us that this phenomenon probably occurs much more frequently than one might expect. Remember that the majority of laboring patients go on to deliver non-asphyxiated children. Therefore, if a neonate is not hypoxic and is tolerating labor well, the outcome will be normal even if the mother was really monitored in the final stages of labor instead of the fetus. However, one could define this just described scenario with the age-old statement of "better lucky than good".

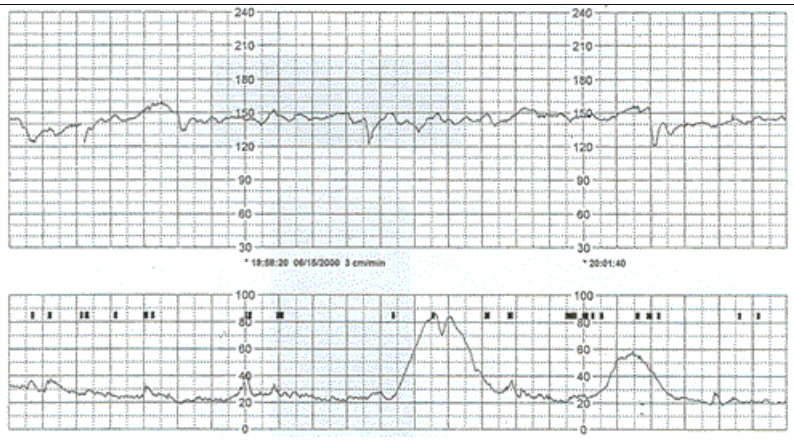
In review, there are 4 essential criteria that define an acute intrapartum hypoxic event that was sufficient to cause cerebral palsy, and these are: (see ref.11)

1. Evidence of a metabolic acidosis in the fetal umbilical artery (cord blood gas) obtained at delivery with a pH < 7.0 and a base deficit ≥ 12 mmol/L (or base excess of ≤ -12 mmol/L))
2. Early onset of severe or moderate neonatal encephalopathy in infants ≥ 34 weeks of gestation
3. Cerebral palsy of the spastic quadriplegic or dyskinetic type
4. Exclusion of other identifiable etiologies (such as trauma, coagulation disorders, infectious conditions, genetic disorders, pre-existing, etc.)

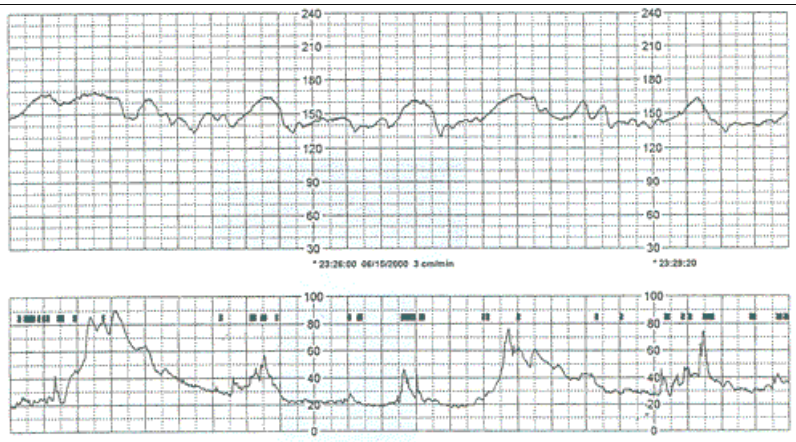
There are 5 criteria that collectively are suggestive of an intrapartum event (within close proximity to labor and delivery – 0 to 48 hours), but are nonspecific to asphyxial insults and these are: (see ref. 11)

1. A sentinel (single) hypoxic event occurring immediately before or during labor
2. A sudden sustained fetal bradycardia or the absence of fetal heart rate variability in the presence of persistent late, or variable decelerations, usually seen after a sentinel hypoxic event when the pattern was previously normal
3. Apgar scores of 0 to 3 beyond 5 minutes
4. Onset of multisystem (multi-organ) involvement within 72 hours of birth
5. Early neurologic imaging studies showing evidence of an acute nonfocal cerebral abnormality

Unfortunately, this child demonstrated acute intrapartum asphyxia based on the umbilical artery blood gas, the neurological issues within 24 hours, and the development of spastic quadriplegia (along with the confirmatory Apgar scores, neurologic imaging studies, and multi-organ involvement). It is conceivable that all of this could have been avoided by placing an internal fetal scalp monitor when the mother's heart rate exceeded 100 beats per minute.



Strip 1



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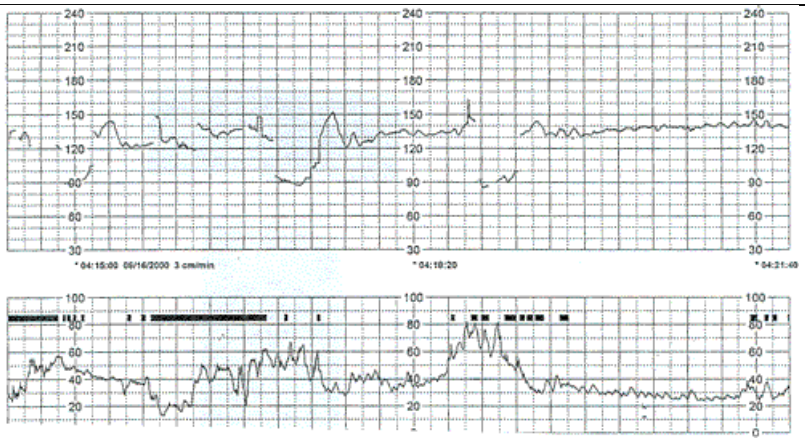
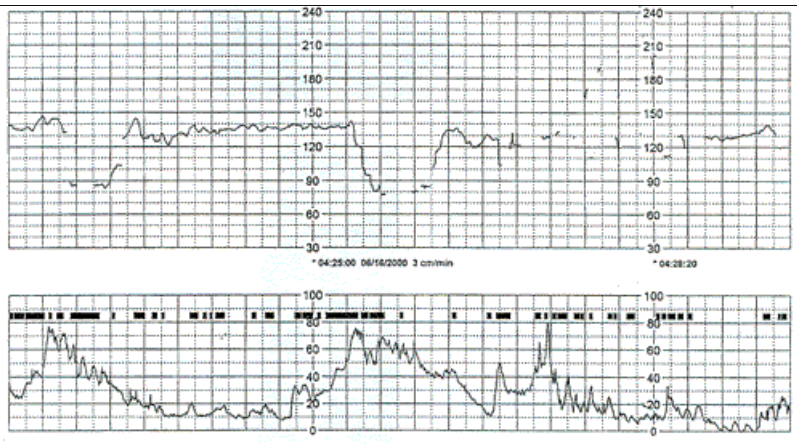


Strip 3



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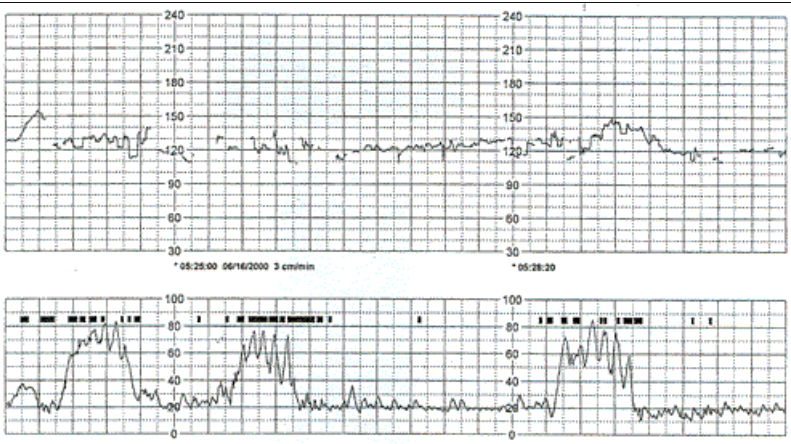
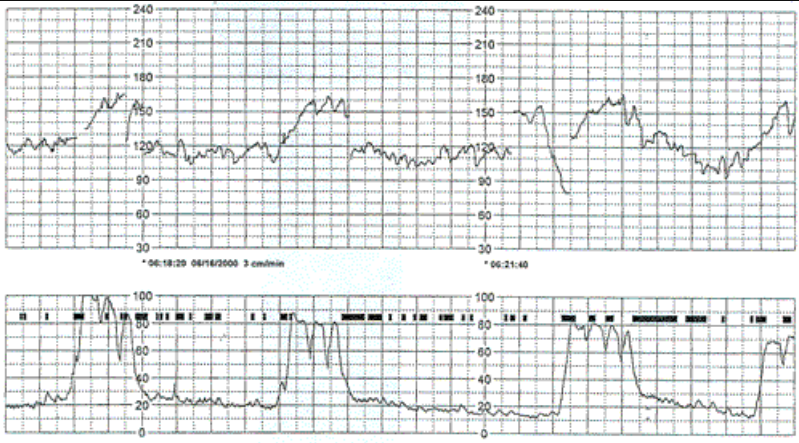
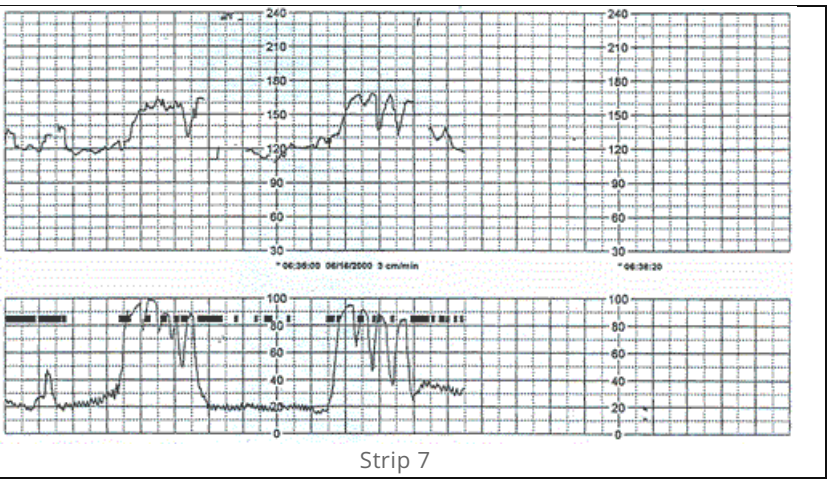


Strip 5



Strip 6



Strip 7

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About the Author(s)

Dr. Quilligan is currently Editor Emeritus of the American Journal of Obstetrics & Gynecology. He was the Co-Chair of the National Institute of Child Health and Human Development (NICHHD) Research Planning Workshop on “Electronic Fetal Heart Rate Monitoring” regarding research guidelines and interpretation that was held in 1997. The terminology developed at this workshop has now been adopted by ACOG and AWHONN.

In Dr. Quilligan’s distinguished career, he has authored numerous peer review articles, has edited and authored several major textbooks in the field of obstetrics, and has given lectures on a wide variety of topics nationwide. He is also the past Chairman of the Departments of Obstetrics & Gynecology at Yale University, University of Southern California, University of California at Davis, and University of California at Irvine. Dr. Quilligan reports no conflicts of interest.