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REVIEW ARTICLE

CME

Fetal Assessment for Anesthesiologists: Are You Evaluating the Other Patient?

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Suboptimal communication between anesthesiologists and obstetricians can be associated with unintended poor maternal and neonatal outcomes, especially for emergency cesarean deliveries. Obstetricians use the results of antepartum and intrapartum fetal assessments to assess fetal well-being and to make decisions about the timing and method of delivery. Because abnormal results may lead to the need for urgent or emergency cesarean deliveries, these decisions may directly impact anesthetic care. Lack of familiarity with fetal assessments and the significance of the results may thus hinder the communication necessary for optimal patient care. In this review article, we discuss the current antepartum and intrapartum fetal assessment modalities, including the nonstress test, biophysical profile, Doppler velocimetry, electronic fetal heart rate monitoring, fetal electrocardiogram (STAN-ST waveform analysis), and fetal pulse oximetry. The physiologic basis behind these modalities and the available evidence regarding their utility in clinical practice are also reviewed. The 2008 National Institute of Child Health and Human Development workshop report on electronic fetal monitoring categories, which are incorporated into the American College of Obstetricians and Gynecologists guidelines for intrapartum care, is examined. The implications of test interpretation to the practice of obstetric anesthesiology is also discussed. Anesthesia provider understanding of fetal assessment modalities is essential in improving communication with obstetricians and improving the planning of cesarean deliveries for high-risk obstetric patients. (Anesth Analg 2013;116:1278–92)

FETAL ASSESSMENT FOR ANESTHESIOLOGISTS: ARE YOU EVALUATING THE OTHER PATIENT?

A 32-year-old G4P2 at 35 weeks' gestation presents for induction of labor for a biophysical profile of 4 of 10 and decreased umbilical artery Doppler flow. At a cervical examination of 4 cm dilation/80% effacement/−2 cm station, recurrent late decelerations occur and an emergency cesarean delivery is requested. The anesthesiologist meets the patient and learns that her weight is 100 kg, and she has a Mallampati class 4 airway with a thyromental distance of <4 cm. In the operating room, the fetal heart monitor shows fetal bradycardia and the obstetrician calls for a stat operative delivery . . .

Could this scenario have been prevented? Do most anesthesiologists understand the implications of abnormal fetal assessments for the laboring patient? If unprepared for the anesthetic management of a parturient with a compromised fetus, poor maternal and neonatal outcomes are probable.

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WHY SHOULD ANESTHESIOLOGISTS UNDERSTAND THE FETAL STATUS?

According to the 2009 American Society of Anesthesiologists Closed Claims Database analysis of liability associated with obstetric anesthesia,[1] the most common claims were newborn death or brain damage (21%). Seventy-one percent of those claims were associated with urgent or emergency cesarean deliveries. Factors contributing to the cases in which anesthetic care was deemed at least partially responsible for the newborn death or brain damage included poor communication between the obstetrician and anesthesiologist, anesthesia delay, and substandard anesthetic care. Poor communication regarding urgency of delivery was also noted to result in suboptimal choice of anesthetic technique.[1] Lack of anesthesia providers' familiarity with fetal assessments may contribute to poor communication with obstetricians. A recent survey[a] performed in the United Kingdom revealed that 61% of anesthesia providers claimed they could interpret electronic fetal heart monitoring, yet surprisingly only 20% knew the correct range of the baseline fetal heart rate (FHR). Two-thirds of providers were interested in further training in fetal assessment. In 2009, the American College of Obstetricians and Gynecologists (ACOG) adopted new terminology to describe intrapartum FHR tracings. This terminology may be used to justify the urgency of cesarean delivery, and knowledge of the new terminology may not have been adequately disseminated to

[a]Salman M, Kumar R, James E. Intrapartum fetal assessment: do obstetric anaesthetists know enough? SOAP Meeting 2011. Poster Session #2, Abstract #180. Las Vegas, Nevada.

Chronic Maternal Conditions	Pregnancy-Related Conditions
Anti-phospholipid syndrome	Hypertensive disorders
Hyperthyroidism (poorly controlled)	Decreased fetal movement
Hemoglobinopathies (hemoglobin SS, SC, S-thalassemia)	Oligohydramnios
Cyanotic heart disease	Polyhydramnios
Systemic lupus erythematosus	Intrauterine growth restriction
Chronic renal disease	Postterm pregnancy
Type I diabetes mellitus	Isoimmunization (moderate to severe)
Hypertensive disorders	Previous fetal demise (unexplained or recurrent risk)
	Multiple gestation (with significant growth discrepancy)

Figure 1. Indications for antepartum fetal assessment. Chronic maternal and pregnancy-related conditions that increase the risk of intrauterine fetal demise and are therefore indications for antepartum fetal assessment. This table was adapted from the ACOG Practice Bulletin.[8]

Baseline –Mean fetal heart rate observed in a 10-min period
- Normal: 110-160 bpm[a]
- Fetal bradycardia: < 110 bpm
- Fetal tachycardia: > 160 bpm

Baseline Variability – Measure of the amplitude (peak-to-trough) in beats per minute of momentary heart rate deflections from baseline observed in a 10-min period.
- Absent (undetectable amplitude), minimal (< 5 bpm), moderate (6-25 bpm), marked (> 25 bpm)

Accelerations – Abrupt increase from baseline
- ≥ 15 bpm increase, peaking in < 30 s
- Duration: ≥ 15 s and < 2 min

Decelerations

Early – Gradual decrease (≥ 30 s from baseline to nadir) and return to baseline
- Coincident with uterine contraction

Variable – Abrupt decrease (< 30 s from baseline to nadir) of ≥ 15 bpm, lasting 15 s - 2 min
- +/- Coincident with uterine contraction

Late – Gradual decrease (≥ 30 s from baseline to nadir) and return to baseline
- Onset: After beginning of contraction
- Nadir: After peak of contraction
- Recovery: After resolution of contraction

Prolonged Deceleration – Duration of 2-10 min

Intermittent Deceleration – Decelerations with fewer than one-half of uterine contractions in a 20-min period

Recurrent Deceleration – Decelerations with more than one-half of uterine contractions in a 20-min period

Figure 2 Legend

[a]bpm – Beats per minute

Figure 2. Definition of terms to describe fetal heart tracings. Definition of terms developed by the National Institute of Child Health and Human Development used to describe fetal heart tracings for both nonstress testing and intrapartum electronic fetal heart monitoring. This table was adapted from Macones et al.[2]

Table 1. Nonstress Test Interpretation

	Significance
Result	
Reactive	
2 accelerations in 20 min	No acidosis, neurologically intact
Nonreactive	
0 or 1 acceleration in 20 min (patient may be observed for total of 40 min)	Fetal sleep, immaturity (<32 weeks' gestation), fetal cardiac or neurologic anomalies, systemic sedatives
Abnormalities	
No baseline variability, recurrent variable decelerations, recurrent late decelerations, tachycardia, bradycardia, arrhythmias	Fetal hypoxia, acidosis, uteroplacental insufficiency

This table was adapted from ACOG Practice Bulletin,[8] Devoe,[10] and Devoe and Jones.[13]

the anesthesia community.[2,3] Understanding this terminology may allow anesthesiologists to better anticipate, prepare, and understand the urgency of cesarean deliveries. Meaningful communication with obstetricians can optimize anesthesia care for a safe delivery.[4,5]

This article reviews the currently available fetal assessment modalities, new developing modalities, and perhaps most important, discusses the significance of fetal assessment as it relates to anesthetic management of labor and delivery. We believe and will demonstrate that understanding fetal conditions will enhance communication with obstetricians, sharpen situational awareness, potentially improve neonatal and maternal outcome, improve patient safety, and elevate workplace morale.[4,6,7]

ANTEPARTUM FETAL ASSESSMENT

Antepartum fetal assessment is currently advocated by the ACOG to decrease the risk of intrauterine fetal demise.[8] Although ultrasound examination is performed routinely for most pregnant women to estimate gestational age and fetal weight, assess fetal growth, and diagnose congenital malformations,[9] patients at increased risk of intrauterine fetal demise are further evaluated with nonstress testing (NST), contraction stress testing (CST), biophysical profile (BPP), and/or Doppler velocimetry (Fig. 1).[10] These assessments indirectly evaluate for a possible hypoxic or acidotic intrauterine environment, both of which cause neurologic damage and eventual fetal death. The assessment results may be an indication for early delivery by induction of labor or cesarean.[9] Due to their already compromised state, these fetuses may not tolerate labor and may be at higher risk than normal for emergency cesarean delivery.

Nonstress Testing

NST is generally the initial fetal assessment modality used to evaluate those women at risk for intrauterine fetal asphyxia.[11] NST is similar to the electronic FHR monitoring used for women in labor, except that it is performed late in the second and specifically in the third trimester, before labor, to assess presence or absence of fetal hypoxia and acidosis. An external Doppler ultrasound transducer measures FHR, and an external tocodynamometer monitors uterine contraction presence and frequency. NST is customarily performed for 20 minutes or longer. After monitoring is completed, visual interpretation of the tracing is performed by an obstetrician.[11]

At approximately 32 to 34 weeks' gestation, the fetal autonomic pathways regulating heart rate begin to mature, and oscillations in the baseline FHR (variability) and increases in the FHR in response to fetal movement (accelerations) are observed.[10] Moderate variability and accelerations are normal and correlate with absence of acidosis.[12] The terms used to describe FHR tracings are defined by the 2008 National Institute for Child Health and Human Development workshop on electronic fetal monitoring[2] and are summarized in Figure 2.

The basic goal of NST is to demonstrate an increase in FHR (reactivity) in response to fetal movement. FHR tracings are categorized as reactive if 2 accelerations occur in 20 minutes (Appendix 1, which illustrates a reactive NST) or nonreactive if 1 or 0 accelerations occur in 20 minutes[8,10] (Appendix 2, which illustrates a nonreactive NST). NST interpretation is summarized in Table 1.

Significance of Nonstress Test Results for Delivery Planning

A history of nonreactive or abnormal NST may be a warning signal for maternal and/or fetal pathology.[13] Depending on gestational age, fetal condition, and maternal condition, these patients are generally referred for additional testing, such as a BPP.[11] They may be admitted to the hospital for further care and possible delivery. On the patient's arrival, it is prudent to discuss the antepartum test results, status of mother and baby, and plan of care with the obstetrician before initiating analgesia or anesthesia. Discussion of the status of these patients during regular team "huddles" with anesthesia providers, obstetricians, and labor nurses helps to maintain communication.

Contraction Stress Test (Oxytocin Challenge Test)

Originally described in 1972,[14] the CST was the first fetal assessment tool and "gold standard" for many years for evaluation of high-risk pregnancies.[10] The premise of the test is to observe FHR response to uterine contractions. Because the CST has a high false positivity rate and could induce labor, it is not used routinely in current obstetric practice.

Amniotic Fluid Volume

Multiple factors affect amniotic fluid volume, including fetal skin permeability, tracheobronchial tree secretions, gastrointestinal swallowing, transplacental and membranes fluid exchange, and fetal urination. With other factors being stable, in the latter part of pregnancy, fetal urination is a major determinant of amniotic fluid volume. In hypoxic states, the fetal brain and heart are preferentially perfused via redistribution of cardiac output away from the kidneys. Thus, renal blood flow and urine output decrease, hence decreasing amniotic fluid volume.[15] Semiquantitative measures estimate amniotic fluid volume: the maximum vertical pocket (MVP)

Table 2. Biophysical Profile

Biophysical variable	Normal (score = 2)	Abnormal (score = 0)
Breathing movements	≥1 FBM ≥20 s duration in 30 min	No FBM or No episode ≥20 s duration in 30 min
Gross body movements	≥2 body/limb movements in 30 min	<2 body/limb movements in 30 min
Tone (flexion, extension)	≥1 active extension with return to flexion of fetal limb(s) or trunk	Extension only Slow extension; return to partial flexion No movement
Amniotic fluid volume (semiquantitative: MVP)	≥1 pocket of AF measuring ≥2 cm in vertical axis	No AF pockets or largest AF pocket <2 cm in vertical axis
Fetal heart rate reactivity	≥2 accelerations associated with fetal movement >15 bpm for >15 s in 20 min	0 or 1 acceleration, or acceleration <15 bpm in 20 min

Total biophysical profile score is the sum of the individual variable scores (maximum score is 10).
FBM = fetal breathing movement; MVP = maximum vertical pocket; AF = amniotic fluid; bpm = beats per minute.
Adapted from Manning.[15]

and the amniotic fluid index (AFI). Using ultrasound, amniotic fluid is assessed in each of the 4 uterine quadrants. The MVP (measurement of vertical dimension of amniotic fluid pocket) is measured in each quadrant. Individual quadrant MVP measurements are used in BPP scoring.[15] The AFI is the summation of the 4 MVPs. The normal AFI ranges from 8 to 18 cm; oligohydramnios is defined as an AFI <5 cm and polyhydramnios as an AFI >24 cm.[10]

Biophysical Profile

The BPP is an ultrasound examination that evaluates fetal movements (breathing movements, gross body movements, tone) and amniotic fluid volume to indirectly assess the likelihood of acute and chronic fetal hypoxia. Since the fetal nervous system regulates muscle activity, and neuron metabolism is highly oxygen dependent, a decrease in fetal movements often reflects central nervous system hypoxia.[16] More specifically, decreased breathing movements and gross body movements may be effects of acute hypoxia, whereas abnormal tone and low amniotic fluid volume are effects of chronic hypoxia.[10] Because the BPP variables are dependent on maturity, BPP evaluations generally begin into the third trimester.[15]

For BPP assessment, each of the 4 variables is assigned a score of 2 (normal) or 0 (abnormal).[b] The test result is a sum of the scores, with a maximum score of 8 of 8.[15] A full BPP also includes the NST results, with a reactive tracing receiving a score of 2 and a nonreactive tracing receiving a score of 0. Thus, a full BPP maximum score is 10 of 10.[15] A modified BPP is occasionally used to assess fetal well-being and is hence used for decision making for intervention and possibly delivery as well. It is the combination of the NST result (assessment of acute fetal hypoxia) and the AFI measurement (assessment of chronic fetal hypoxia). Table 2 summarizes the BPP variables and guidelines for scoring.

Significance of BPP Results for Delivery Planning

BPP scores correlate directly with possible fetal acidemia[17,18] as well as neonatal Apgar scores.[19] Therefore, fetuses with low BPP scores may require earlier delivery. BPP scores of 8 of 10 or 10 of 10 are normal and require no intervention. An intermediate score of 6 of 10 is suspected fetal acidemia and is an indication for repeat testing, customarily performed within 24 hours, or possibly delivery, depending on gestational age, fetal lung maturity, and whether the overall BPP reflects acute or chronic asphyxia.[15] A score of 0 to 4 of 10 is increased likelihood of fetal acidemia and is generally an indication for prompt delivery. If delivery is elected for a BPP score of 2 to 6, the mode of delivery is decided on the basis of obstetrical factors and maternal condition, such as presentation, pelvic adequacy, and previous uterine surgery. If vaginal delivery is deemed safe, induction of labor is usually attempted with close observation of fetal heart tracing patterns. Abnormalities of FHR patterns, such as recurrent late decelerations and variable decelerations, can occur more commonly in these fetuses, leading to need for operative delivery.[15] A score of 0 is rare, and emergency cesarean delivery may be preferred to induction of labor for concern about fetal intolerance to labor.

Umbilical Artery Doppler Velocimetry

Umbilical artery Doppler velocimetry (UADV) is currently the primary antepartum test for evaluation of intrauterine growth restriction (IUGR), because abnormal results have been shown to correlate with increased perinatal mortality.[20–22] It is based on the principal of impedance of blood flow in the umbilical arteries. Resistance refers to direct current flow, whereas impedance refers to alternating current flow. In normal fetal–placental

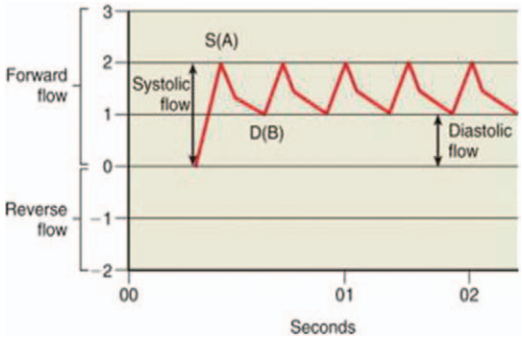


Figure 3. Umbilical artery Doppler velocimetry. Normal umbilical artery Doppler velocity waveform. Flow is forward during both systole and diastole. (A) = S for peak systolic frequency shift; (B) = D for peak end diastolic frequency shift. This figure is adapted from Druzin.[11]

[b]If the amniotic fluid MVP is ≥2 cm, but the amniotic fluid index is <5 cm (oligohydramnios), there may be concern for fetal hypoxia and further evaluation may be indicated.

circulation, 1 large umbilical vein delivers oxygenated blood from the placenta to the fetus. Deoxygenated blood flows through 2 umbilical arteries from fetus to placenta. During the first and second trimesters, extensive angiogenesis of the placenta creates a large capillary network with a high total cross-sectional area and thus a low impedance.[23] Therefore, *diastolic* blood flow in the umbilical arteries is high. Pathologic states affecting angiogenesis, such as preeclampsia, increase the impedance and cause *decreased*, *absent*, or *reversed* end-diastolic umbilical artery flow.[23] The measured flow variables include peak systolic frequency shift (S), end-diastolic frequency shift (D), and mean peak frequency shift over the cardiac cycle (A)[11,23] (Fig. 3). Results are reported in terms of the systolic to diastolic ratio (S/D; *increased* in pathologic states), and obstetricians may refer to abnormal results as "increased Dopplers" or "elevated Dopplers." Other reported flow indices may include resistance index S-D/S (*increased* in pathologic states) and pulsatility index S-D/A (*increased* in pathologic states).[8] Abnormal flow indices usually indicate poor fetal oxygenation and correlate with fetal acidosis[23] (Appendix 3, which illustrates normal, decreased, absent, and reversed end-diastolic flows). Ductus venosus and middle cerebral artery Dopplers are also available modalities for evaluation of IUGR, but are more rarely used and beyond the scope of this review.[11]

Significance of Umbilical Artery Doppler Velocimetry for Delivery Planning

Abnormal Doppler results may be an indication for early labor induction or cesarean delivery. Absent and reversed end-diastolic flows are commonly associated with FHR abnormalities (late decelerations, severe variable decelerations, absent variability) and fetal scalp pH <7.2.[24] Thus, for patients whose labor is being induced, fetuses with abnormal Doppler results may not tolerate decreased oxygenation associated with uterine contractions and may require emergency cesarean delivery.

INTRAPARTUM FETAL ASSESSMENT

The goal of intrapartum fetal assessment is to assure fetal well-being and detect significant abnormalities that guide subsequent intervention to prevent fetal neurologic injury and death. In current practice, monitoring and decision making are also influenced by other factors, including obstetric liability risk.[25] Electronic FHR monitoring is the primary tool for intrapartum fetal assessment. Because nonreassuring fetal heart tracings have not been shown to correlate with umbilical artery pH, low Apgar scores, perinatal mortality, or cerebral palsy,[3,26,27] new monitoring techniques are being developed to confirm or refute nonreassuring tracings. For anesthesia providers, recognition of nonreassuring fetal status allows for better planning of urgent or emergency cesarean deliveries.

Electronic FHR Monitoring

Monitoring Devices for FHR and Uterine Contractions

FHR can be monitored using external or internal devices. External monitoring includes a Doppler ultrasound transducer to detect FHR and a tocodynamometer to detect uterine contractions. Internal monitoring includes a fetal scalp electrode to detect FHR and an intrauterine pressure catheter to detect uterine contractions. External monitoring is used initially, but if poor-quality FHR and uterine contractility tracings are obtained (maternal obesity, active fetus), internal monitoring is used. Risks associated with intrauterine pressure catheter use include uterine perforation, intrauterine infection, placental abruption, and entanglement of the umbilical cord.[28] Although rare, many of these complications will necessitate immediate administration of anesthesia for delivery.

Table 3. Fetal Heart Rate (FHR) Interpretation System

Category	Baseline heart rate	Baseline variability	Accelerations	Early decelerations	Variable or late decelerations
I	• 110–160	• Moderate	• Present • Absent	• Present • Absent	• Absent
II	• Bradycardia (not accompanied by absent baseline variability) • Tachycardia	• Minimal • Absent (not accompanied by recurrent[a] decelerations) • Marked	• Absence of induced accelerations after fetal stimulation		Periodic[b] or episodic[c] decelerations: • Recurrent variable decelerations (with minimal or moderate baseline variability) • Variable decelerations with other characteristics, such as slow return to baseline • Recurrent late decelerations (with moderate baseline variability) • Prolonged deceleration ≥ 2 min but < 10 min

III	• Bradycardia
	• Sinusoidal pattern
		• Absent baseline variability and any of the following:
		  • Recurrent late decelerations
		  • Recurrent variable decelerations
		  • Bradycardia
		• Sinusoidal pattern
					• Recurrent late decelerations
					• Recurrent variable decelerations

This table was adapted from Macones et al.[2]

[a]Recurrent—Occurring with more than one-half of uterine contractions in a 20-min period.

[b]Periodic—FHR patterns associated with uterine contractions.

[c]Episodic—FHR patterns not associated with uterine contractions.

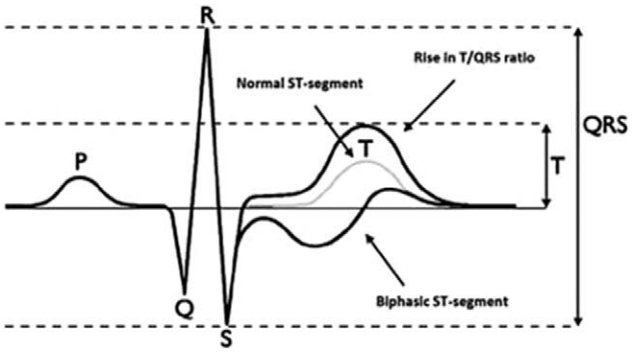


Figure 4. Fetal electrocardiogram ST waveform analysis. T/QRS ratio is monitored during labor to assess intrapartum fetal hypoxia. This figure is adapted from Amer-Wåhlin and Maršál.[38]

Physiologic Basis of Electronic Fetal Monitoring

During labor, uterine contractions are associated with progressively increasing intrauterine pressure and decreased uterine blood flow. Subsequent hypoxia leads to fetal catecholamine release, hypertension, and reflex bradycardia or myocardial depression, commonly manifesting as FHR decelerations.[10] With progress of labor, uterine contractions cause fetal head descent into the pelvis, leading to fetal head compression and resulting in "early" decelerations (Appendix 4, which illustrates early decelerations). Umbilical cord compression causes "variable" decelerations (Appendix 5, which illustrates a variable deceleration), and significant uteroplacental insufficiency leads to "late" decelerations (Appendix 6, which illustrates a late deceleration).

Electronic Fetal Monitoring Interpretation

During labor, the fetal heart tracing is categorized using guidelines developed by the 2008 National Institute of Child Health and Human Development workshop report on electronic fetal monitoring[2] (Table 3). The same *terms* are used to describe fetal heart tracings (*baseline rate, variability, accelerations, decelerations*) for both antepartum NST and intrapartum monitoring, but *interpretations* are different. Antepartum NST tracings are interpreted as *reactive* or *nonreactive*. Intrapartum tracings are currently interpreted as *category I*, *II*, or *III*.[2]

A category I tracing is predictive of normal fetal acid-base status, and routine obstetric care is continued. A category II tracing predicts that the fetal acid-base homeostatic system may be compromised. Observed changes may include: fetal bradycardia with maintained moderate variability, tachycardia, decreased baseline variability, or periodic variable or late decelerations. Close surveillance is continued, and the fetus is reevaluated periodically. A category III tracing (absent baseline variability in addition to bradycardia, recurrent significant variable decelerations, or late decelerations) is predictive of fetal acidosis and requires prompt intervention, including intrauterine resuscitation (administration of maternal oxygen, left uterine displacement or other change in maternal position, treatment of hypotension, discontinuation of exogenous uterotonic drugs, possible administration of tocolytic drugs, possible amnioinfusion), and if unresolved, delivery of the fetus,[3] usually within 30 to 45 minutes. Operative vaginal delivery may be an option if the fetus is at the appropriate position and station.

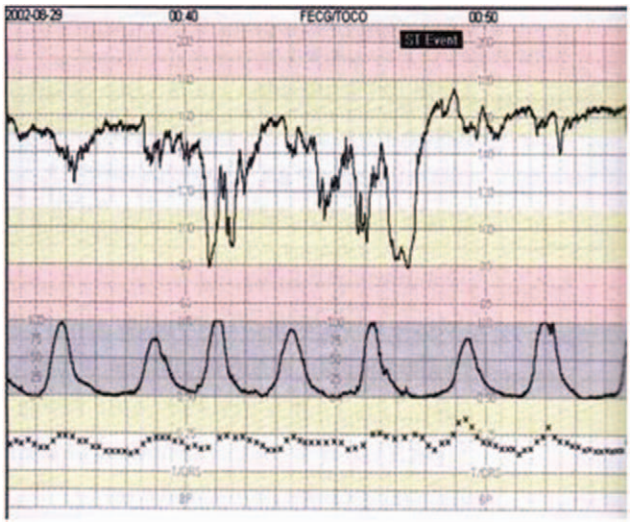


Figure 5. STAN Monitoring with an ST Event. The STAN recording shows a fetal heart rate with baseline of 150 to 160 beats per minute (top tracing), uterine contractions (middle tracing), and x's representing the T/QRS ratio (lower tracing). The "ST Event" denotes an episodic increase in T/QRS, which correlates with a variable deceleration. ST events also include an increase in baseline T/QRS and biphasic ST segments. This figure is adapted from Kazmi et al.[40]

Significance of Intrapartum Electronic Fetal Monitoring for Delivery Planning

Intrapartum electronic FHR monitoring increases the likelihood of cesarean delivery by two-thirds;[3,27] the sensitivity and positive predictive value for fetal acidemia have been reported as 26.4% and 28.3% respectively, and the sensitivity and positive predictive value for 5-minute Apgar scores <7 are 27.3% and 3.3%, respectively.[26] Despite these drawbacks, electronic FHR monitoring is the most commonly used intrapartum monitor.

ACOG provides general management recommendations for intrapartum FHR monitoring, including close surveillance of category II tracings, because they may deteriorate into category III tracings.[3] Attempts to resolve category III tracings by intrauterine resuscitation is recommended, and delivery is recommended for sustained category III tracings.[3] Of note, >80% of intrapartum FHR tracings are classified as category II.[29]

To provide more specific clinical management guidance, a 5-tier color-coded system for categorizing tracings based on risk of potential fetal acidemia was first proposed by Parer and Ikeda in 2007.[30] A table is read to determine how to categorize the tracing based on FHR variability, baseline rate, and presence and severity of variable and late decelerations. For each category, clinical management is specified regarding the need for: conservative management (position change, supplemental oxygen, correction of hypotension, tocolysis, amnioinfusion), informing the obstetrician, anesthesia provider, and newborn infant resuscitator, as well as the status of the operating room (available versus open).[30] In a retrospective analysis, this system was more sensitive in predicting fetal pH <7.0 than the currently used 3-tier categorization system from the National Institute of Child Health and Human Development.[2,29] In another retrospective study, the 5-tier system correlated with severity of neonatal metabolic acidosis.[31] In a hospital caring for mostly low-risk

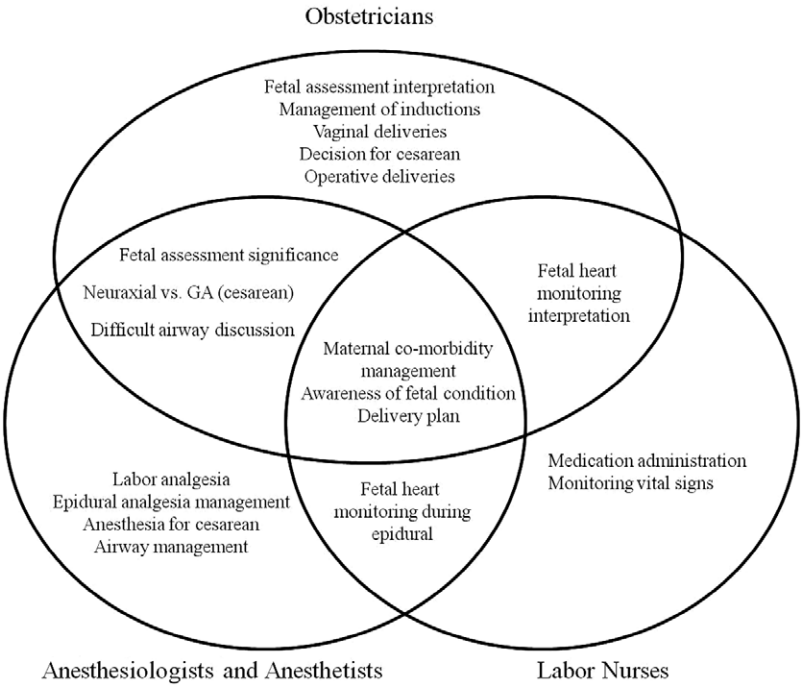


Figure 6. Teamwork among anesthesia providers, obstetricians, and labor nurses. Venn diagram illustrating both the individual responsibilities and common goals of the physicians and nurses involved in obstetric care on the labor floor. GA = general anesthesia.

patients, when physicians and nurses were educated about the 5-tier categorization system and corresponding clinical management, the rates of umbilical arterial pH <7.15 (1.51% vs 0.18%, $P < 0.05$) and base excess < −12 mEq/L (1.76% vs 0.25%, $P < 0.05$) decreased significantly after training.[32] The rate of unscheduled cesarean deliveries and vacuum-assisted deliveries did not change significantly.[32]

However, no randomized controlled trials evaluating the sensitivity and positive predictive value of the 5-tier system have been performed. This would involve randomizing patients to the 3-tier and 5-tier systems, then measuring operative and cesarean delivery rates and umbilical artery pH and base excess. Logistically, managing a labor and delivery service using 2 different management systems would be chaotic. More prospective observational trials, in which outcomes are measured after the entire staff has been educated on the 5-tier system and its associated management guidelines, may provide more clinical efficacy for the 5-tier system.

Adjuncts to Electronic Fetal Heart Monitoring During Labor

Because of the high false positive rate associated with electronic fetal heart monitoring,[3] additional assessments may help predict whether the fetus is acidotic. Fetal scalp pH was performed in the past, and vibroacoustic stimulation and scalp stimulation are well-established modalities,[33–36] but newer modalities of fetal electrocardiogram (ECG) and fetal pulse oximetry have been recently developed. Although not used routinely in the United States, both are currently used in clinical practice in Europe.

Fetal ECG (STAN—ST Waveform Analysis)

Fetal ECG monitoring was designed to detect acute intrapartum fetal asphyxia. The technique was developed in Sweden and has been approved by the United States Food and Drug Administration.[c] An electrode is placed on the fetal scalp to acquire the fetal ECG. STAN computer analysis of the ECG is based on the physiologic principle that fetal hypoxia causes catecholamine release and subsequent fetal ST or T wave changes. The ratio of the T wave amplitude to the QRS amplitude (T/QRS) is calculated and recorded automatically throughout labor[37] (Fig. 4). The baseline T/QRS ratio is calculated using the first 20 T/QRS ratios recorded during the first stage of labor.[37] An ST event is an episodic increase from baseline T/QRS (<10 minutes), an increase in baseline T/QRS (>10 minutes), or biphasic ST segments[37–39] (Fig. 5). A more detailed description of fetal ST analysis is beyond the scope of this review but is described in the literature.[37–41]

A 2012 Cochrane meta-analysis of 6 randomized controlled trials concluded that the combination of electronic FHR and ST waveform analysis compared with electronic FHR monitoring without ST waveform analysis did not decrease the incidence of severe neonatal metabolic acidosis, Apgar scores <7 at 5 minutes, neonatal encephalopathy, or the number of cesarean deliveries.[42] All of the trials were performed in Europe or Asia. Because the current evidence does not show that fetal ST waveform analysis decreases the cesarean delivery rate, it has not gained popularity in the United States. However, the National Institute of Child Health and Human Development is currently recruiting participants for a multicenter, randomized controlled trial comparing neonatal outcomes in fetuses monitored with both electronic FHR monitoring and STAN versus electronic FHR monitoring alone.[d] Primary outcome measures include intrapartum fetal death, neonatal death,

[c]FDA Approval of STAN®S31 Fetal Heart Monitor. Available at: http://www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/Device-ApprovalsandClearances/Recently-ApprovedDevices/ucm078446.htm. Accessed August 26, 2012.

[d]Fetal ST Segment and T Wave Analysis in Labor (STAN). Available at: http://clinicaltrials.gov/ct2/show/study/NCT01131260. Accessed August 26, 2012.

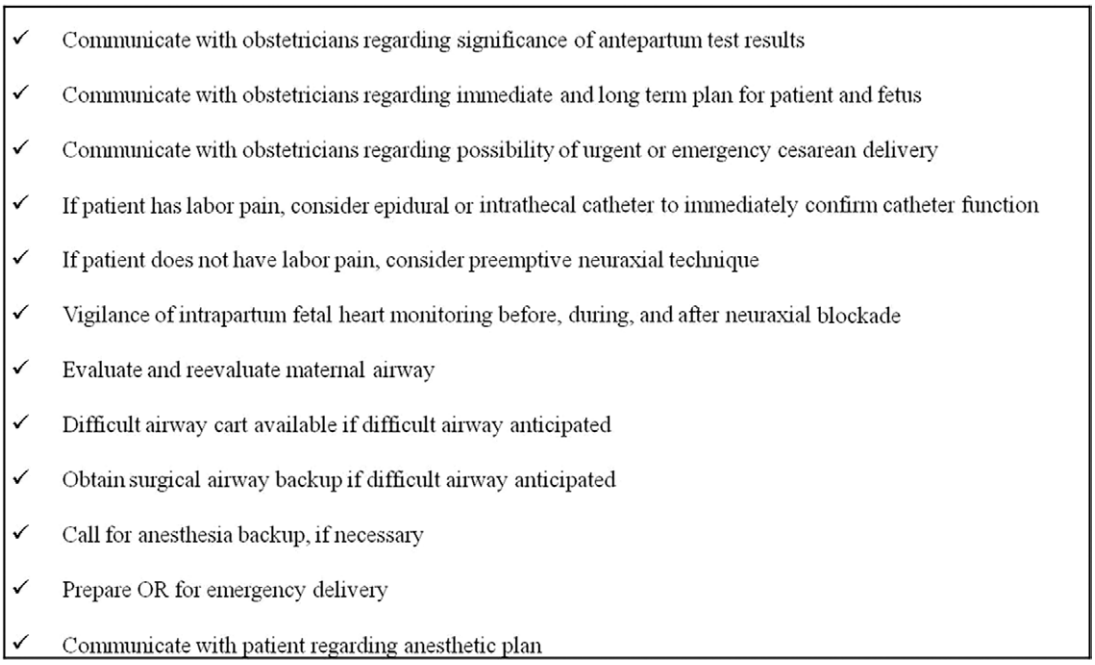


Figure 7. Checklist for a patient with abnormal fetal assessments. OR = operating room.

Apgar score ≤3 at 5 minutes, neonatal seizure, umbilical cord artery pH ≤7.05 and base deficit ≥12 mmol/L, intubation at delivery, and presence of neonatal encephalopathy.

Fetal Pulse Oximetry

Adult pulse oximetry has been shown to increase the early detection of hypoxemia in both the operating room and the recovery room.[43,44] Fetal pulse oximetry was developed as an adjunct to confirm or refute nonreassuring FHR tracings, with the goal of reducing the number of unnecessary or unindicated operative vaginal deliveries (vacuum, forceps) and cesarean deliveries.[45] The pulse oximetry probe is placed on the fetal cheek, temple, back, or buttocks.[41,46] The probe functions on the principle of reflectance (as opposed to the principle of transmittance in adult pulse oximeters), thus the light-emitting diode and photodetector are adjacent to each other (as opposed to opposite). Normal fetal Spo_2 is 30% to 60%; fetal Spo_2 <30% for ≥10 minutes in the last 60 minutes before delivery has been shown to correlate with umbilical artery pH <7.15, whereas Spo_2 >30% correlates with umbilical artery pH >7.15.[47,48] Currently, the ACOG Committee on Obstetric Practice does not endorse fetal pulse oximetry because its use has not decreased the overall cesarean delivery rate.[49–51] Their concern is that the "introduction of this technology to clinical practice could further escalate the cost of medical care without necessarily improving clinical outcome."[51]

ANESTHETIC MANAGEMENT OF THE PATIENT WITH SUSPECTED UTEROPLACENTAL INSUFFICIENCY

The patient presenting with potential uteroplacental insufficiency may have had 1 or more antepartum NSTs, BPPs, and UADV evaluations. She may present in spontaneous labor, for induction of labor, or for cesarean delivery. Although the fetal risks and benefits of individual anesthesia techniques for these patients is unknown, it is recognized that the fetus will experience additional hypoxia during uterine contractions, which may lead to FHR decelerations and need for emergency cesarean delivery. In addition, decreased uteroplacental blood flow associated with maternal hypotension in the labor room or operating room may further compromise the fetus. The goals of the anesthesiologist should optimally include early anesthesia evaluation, early epidural catheter placement when appropriate, reassessment of both the mother and fetus during labor, and communication with the obstetricians and nurses regarding the delivery plan (Fig. 6).

Early Anesthesia Evaluation

An early anesthesia evaluation and management plan is recommended for safe delivery of the fetus with suspected uteroplacental insufficiency (Fig. 7, which shows a checklist for a patient with abnormal fetal assessments). Emphasis should be placed on the airway examination, as airway complications remain the predominant cause of anesthesia-related death in obstetric patients.[52,53] Situational factors relating to emergency deliveries, including unpreparedness for a potentially difficult airway, contribute to failed tracheal intubation.[53,54]

Early Epidural Catheter Placement

Because fetuses with suspected uteroplacental insufficiency based on abnormal antepartum (NST, BPP, UADV) and/or intrapartum (electronic fetal monitoring) assessments may not tolerate additional decreases in uteroplacental blood flow associated with uterine contractions, they are at higher risk for emergency cesarean deliveries. It is important that whenever feasible, these patients have functioning epidural catheters. The case-fatality ratio of anesthesia-related deaths during cesarean delivery is shown to be decreased with the use of neuraxial anesthesia compared with general anesthesia (GA).[55] Placement of a preemptive epidural catheter

may improve the likelihood of avoiding GA if an emergency cesarean delivery is required.[56] Some anesthesiologists recommend avoiding combined spinal-epidural analgesia in these cases. The effectiveness of a conventional epidural or intrathecal catheter can be confirmed immediately after placement, whereas the effectiveness of a catheter placed using a combined spinal-epidural technique cannot be fully confirmed until the spinal medication wears off.

Consider Possible Fetal Effects of Intrathecal Opioids

Fetal bradycardia has been described in healthy fetuses after the administration of neuraxial local anesthetic and opioids. Increased uterine tone has been observed with administration of intrathecal fentanyl and sufentanil.[57,58] Initiation of neuraxial analgesia causes a rapid decrease in circulating maternal epinephrine levels. It is hypothesized that the lower epinephrine levels lead to decreased β-agonism (uterine relaxation) and increased α-agonism (uterine contraction). Increased uterine tone may lead to decreased uteroplacental blood flow and subsequent fetal hypoxia and bradycardia.[59] There is inconsistency among studies regarding the incidence of fetal bradycardia and whether the incidence is opioid dose-dependent.[59–64] Wong et al. found no significant differences in the incidence of nonreassuring FHR abnormalities among parturients randomized to receive intrathecal opioids in doses ranging from 0 to 25 mcg for fentanyl[63] and 2.5 to 10 mcg for sufentanil.[64]

Because the data are inconsistent, and some studies suggest a relationship between intrathecal opioids and fetal bradycardia, some anesthesiologists suggest that using a conventional epidural technique may be a safer alternative for fetuses with known or suspected uteroplacental insufficiency. An already compromised fetus may not tolerate the decreased oxygen delivery associated with uterine tachysystole. Unfortunately, no studies have been published comparing the incidence of fetal heart monitoring abnormalities after combined spinal-epidural versus conventional epidural for fetuses with various BPP scores, UADV abnormalities, or category II and III tracings.

Continuous Electronic Fetal Monitoring During Initiation of Neuraxial Blockade

In labor, assessing the fetus *before* neuraxial blockade is important, as fetal hypoxemia associated with neuraxial blockade may be even more poorly tolerated in the already compromised fetus. The 2007 Practice Guidelines for Obstetric Anesthesia state that "the FHR should be monitored by a qualified individual before and after administration of neuraxial analgesia for labor" since "perianesthetic recording of the FHR reduces fetal and neonatal complications."[56] Although the Practice Guidelines also state that "continuous electronic recording of the FHR may not be necessary in every clinical setting and may not be possible during initiation of neuraxial anesthesia,"[56] it may be especially beneficial for the already compromised fetus to have continuous monitoring, even during epidural catheter placement. If an FHR tracing is not obtainable, and epidural catheter placement is difficult and prolonged, temporarily stopping the procedure at regular intervals to confirm a reassuring FHR tracing may minimize periods of acute fetal hypoxia. Alternatively, intermittent auscultation of fetal heart tones every 5 minutes or fetal scalp electrode placement can also provide monitoring during placement of neuraxial blockade.

In addition, anesthesiologists practicing in hospitals in which obstetricians are not continuously in-house may consider requesting that the obstetrician be present before initiation of neuraxial blockade.

Vigilance of Intrapartum Fetal Heart Monitoring

Understanding intrapartum fetal heart tracings is essential for the anesthesia provider, since it is the primary monitoring tool influencing the need for urgent intrapartum operative vaginal and cesarean deliveries. Some category II tracings may deteriorate into category III tracings, thus communication with the obstetricians regarding their level of concern for possible operative delivery allows for early anesthesia evaluation and planning.

Excellent communication with the parturient, obstetrician, and labor nurse is of key importance. Emphasizing the strong preference for neuraxial anesthesia and a plan to place a preemptive epidural catheter, if cesarean delivery is likely, may improve maternal safety. The anesthesia provider can also assess the need for preemptive difficult airway preparation (such as calling for additional anesthesia provider backup, video laryngoscope, supraglottic airway device, fiberoptic laryngoscope, surgical backup, etc.).

For patients entering the operating room without functioning neuraxial catheters, understanding that an FHR tracing may deteriorate from category II to III may improve communication with obstetricians regarding the urgency of delivery, limiting repeated attempts to initiate neuraxial blockade, and the need for immediate induction of GA. The benefit to the compromised fetus of prompt delivery after induction of GA may outweigh the risks of repeated attempts at a difficult neuraxial blockade, especially for parturients without anticipated difficult airways.

Choice of anesthetic technique is a risk-benefit discussion between the obstetrician and anesthesiologist that considers the well-being of both mother and fetus. The American Society of Anesthesiologists Task Force on Obstetric Anesthesia states that "the decision to use a particular anesthetic technique for cesarean delivery should be individualized, based on several factors. These include anesthetic, obstetric, or fetal risk factors (*e.g.*, elective *vs.* emergency), the preferences of the patient, and the judgment of the anesthesiologist. Neuraxial techniques are preferred to GA for most cesarean deliveries."[56] GA may be the most appropriate choice for situations demanding immediate delivery, including profound fetal bradycardia.[56]

A conversation between the obstetrician and anesthesiologist for every clinical scenario, particularly for category III tracings, regarding time available to initiate anesthesia, as well as maternal anesthetic risks, is necessary. Some tracings may allow for a brief time period to attempt neuraxial anesthesia, while immediate GA may be preferred for other tracings.

Avoiding Hypotension in the Patient with Suspected Uteroplacental Insufficiency

Avoiding maternal hypotension before cesarean delivery of fetuses with uteroplacental insufficiency may be particularly important in maintaining neonatal acid-base status.[65]

Mueller et al.[66] reported that among 5800 elective cesarean deliveries in healthy parturients with uncomplicated singleton term pregnancies, neonatal acidemia was significantly increased in the neuraxial (spinal and epidural) anesthesia group compared with the GA group due to *hypotension*. Although term healthy infants seem to tolerate mild maternal hypotension,[67] it is possible that an already compromised fetus may develop postnatal complications subsequent to placental hypoperfusion.[68] The degree and duration of fetal metabolic acidosis correlates linearly with umbilical cord base deficit values, and values >12 mmol/L are associated with moderate to severe newborn encephalopathy.[68]

Low-dose combined spinal-epidural anesthesia and aggressive use of fluids and vasopressors to maintain maternal arterial blood pressure at baseline may be useful methods to avoid further fetal hypoxia. Recent clinical studies[69–73] have demonstrated that ephedrine is associated with a greater propensity toward fetal acidosis compared with phenylephrine, however minimal data are available comparing vasopressor use in potentially compromised fetuses. In 1 retrospective study, Cooper et al.[74] found no significant difference in umbilical artery base excess between ephedrine and phenylephrine use during cesarean delivery with spinal anesthesia for patients with high-risk conditions including nonreassuring FHR, hypertensive disorders of pregnancy, IUGR, and cord prolapse. Factors such as low ephedrine doses and short time interval between administration of anesthesia and delivery may have contributed to the results.[74] Continuous FHR monitoring during neuraxial blockade may detect a deteriorating tracing and need for maternal position change or an anesthesia plan change (neuraxial to general). Presence of the obstetrician in the operating room, ready for these changes, will also expedite delivery.

Reevaluation During Labor

Reevaluation of the pregnant patient during labor is essential. The FHR tracing may deteriorate, a previously functioning epidural catheter may become ineffective and require evaluation or replacement, and Mallampati scores can increase throughout labor.[75,76] Labor is an ever-changing dynamic state that may require analgesia and anesthesia management plans to change as well.

Teamwork

Teamwork is an essential component of effective communication and prevention of medical errors. This is especially relevant to the labor and delivery unit, as many health care providers (obstetricians, labor nurses, midwives, anesthesiologists, nurse anesthetists, pediatricians, operating room technicians) participate in the care of the parturient, fetus, and neonate. Lack of communication is the leading cause of medical errors in obstetric care.[4] A component of effective teamwork is planning and decision making among team members,[77] thus anesthesiologists' understanding of the fetal assessments that influence obstetric management may enhance interdisciplinary teamwork.

In addition, protocols for nurses to notify *both* obstetricians and anesthesiologists with category II or III fetal heart tracings may facilitate patient care. Obstetricians can evaluate the fetus, anesthesia providers can reevaluate the maternal airway and existing neuraxial catheter function, and the entire team can discuss the delivery plan and timing of interventions. If a cesarean delivery is deemed necessary, a discussion can occur regarding the possibility of a difficult airway and the time available to obtain an anesthetic level using a neuraxial technique. Simulation-based training with obstetricians, anesthesiologists, and nurses can provide a setting to practice teamwork and communication.

Use of protocols, team training, and electronic fetal heart monitoring certification for staff involved in FHR interpretation have decreased the incidence of adverse sentinel events and compensation payments,[78] as well as improved the staff members' perception of teamwork, safety, and job satisfaction.[7,79] Electronic FHR monitoring certification for anesthesiologists has not been described in the literature, but we believe this education would enhance communication with the obstetric staff.

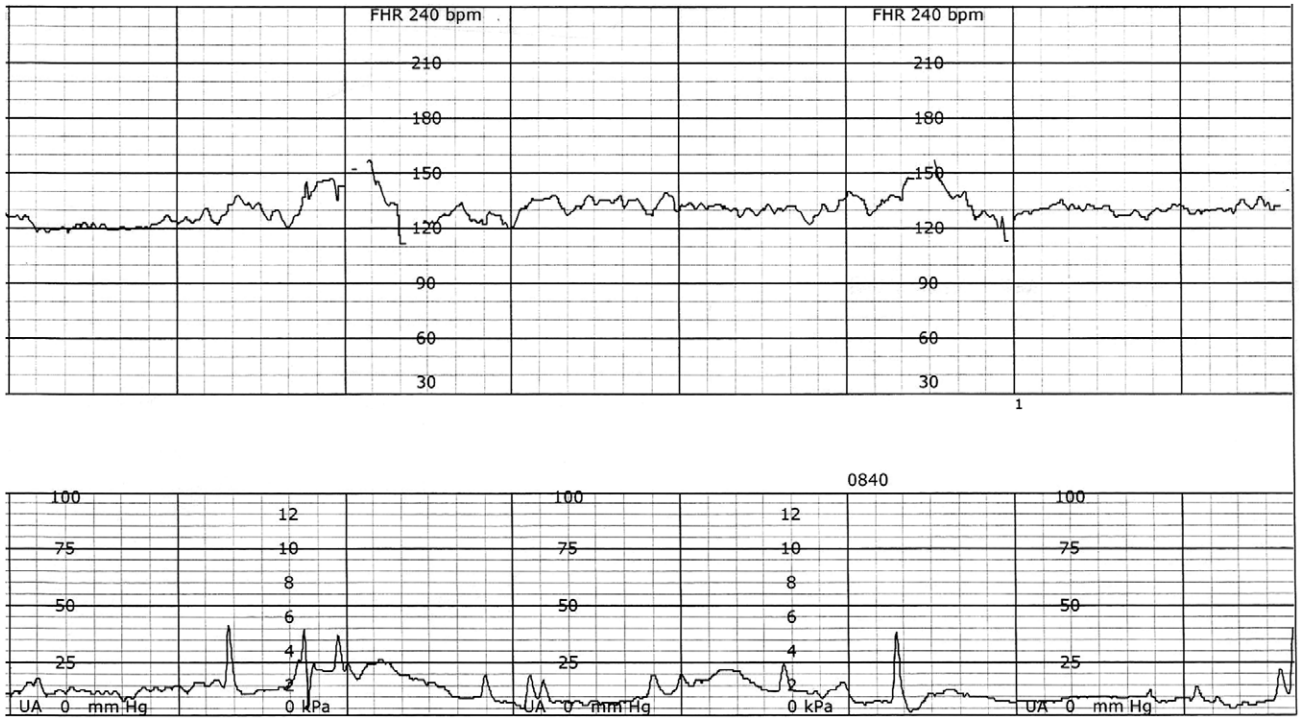
Case—Revisited

A 32-year-old G4P2 at 35 weeks' gestation presents for induction of labor for a BPP of 4 of 10 and decreased umbilical artery Doppler flow. The obstetrician shares this information with the anesthesiologist, who evaluates the patient and learns that she is obese and has a difficult airway. The anesthesiologist counsels her regarding the benefits of a neuraxial block, including avoiding potential complications of GA if she needs an emergency cesarean delivery. On examination of her back, a potentially difficult neuraxial catheter placement is anticipated due to her obesity. A decision is made to place a preemptive neuraxial catheter using ultrasound.[80] Backup airway equipment is checked and placed in or near the operating room, and the backup anesthesiologist is made aware. At a cervical examination of 4 cm dilation/80% effacement/−2 cm station, the labor nurse notices recurrent late decelerations, calls the obstetrician and anesthesia providers, and an emergency cesarean delivery is planned. An adequate anesthetic level is acquired using the in situ neuraxial catheter and the surgery proceeds successfully without complications.

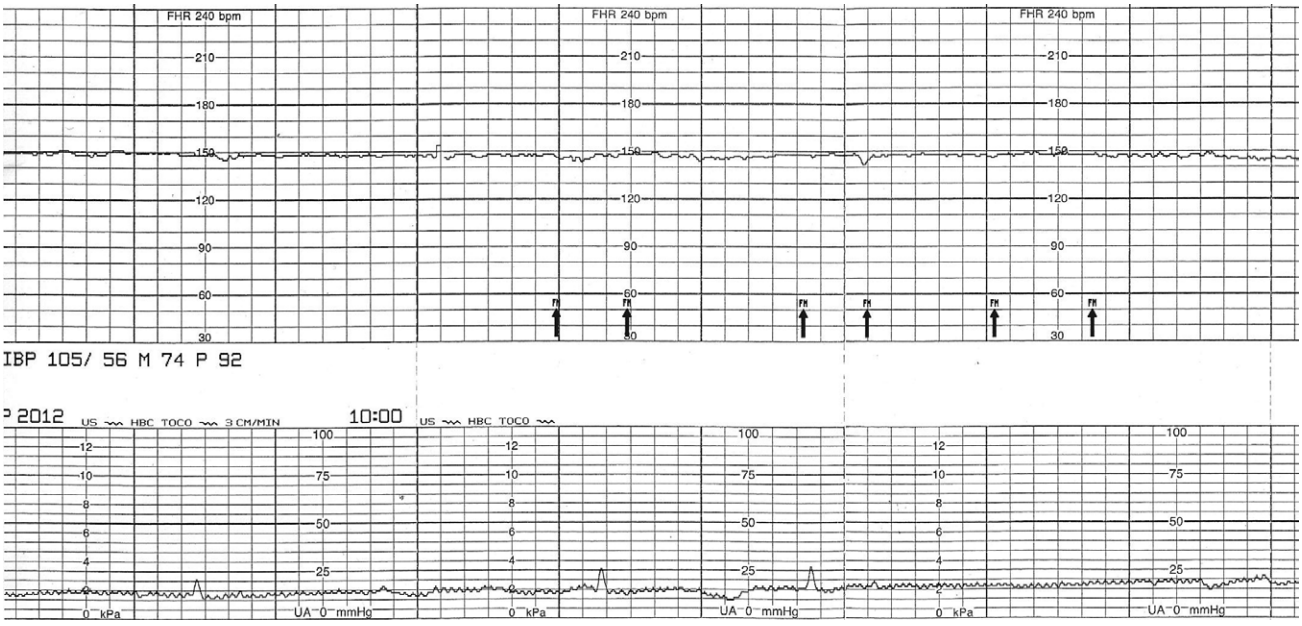
CONCLUSION

Anesthesiologists are integral to the safe care of laboring women and those in need of operative deliveries. Effective teamwork requires that labor nurses, obstetricians, midwives, anesthesiologists, and nurse anesthetists speak the same language and understand each other's concerns. An important first step is anesthesiologists learning about obstetric concerns and obstetricians learning about the anesthetic concern of airway management. It is our hope that this review will motivate anesthesiologists to promote mutual understanding and ultimately improve patient safety.

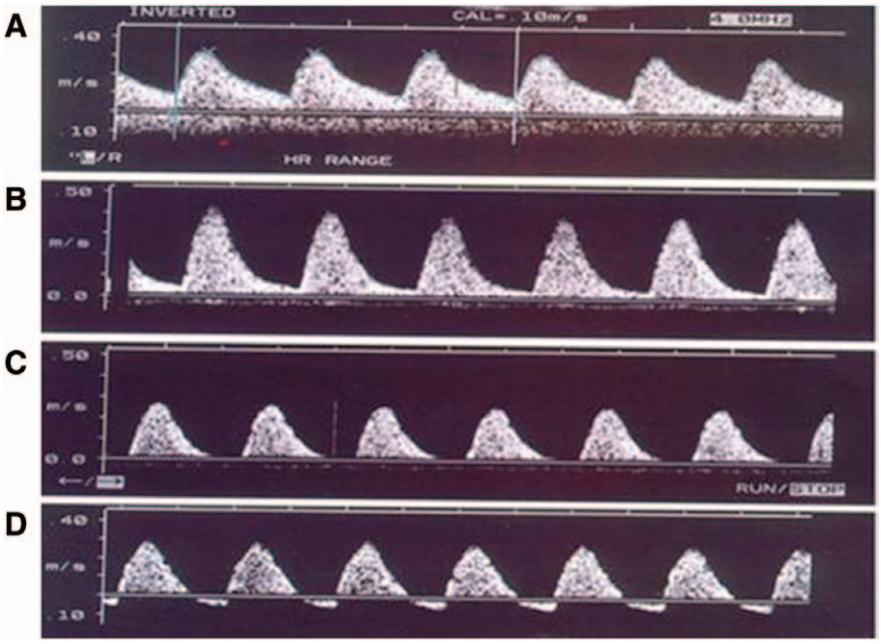
APPENDIX



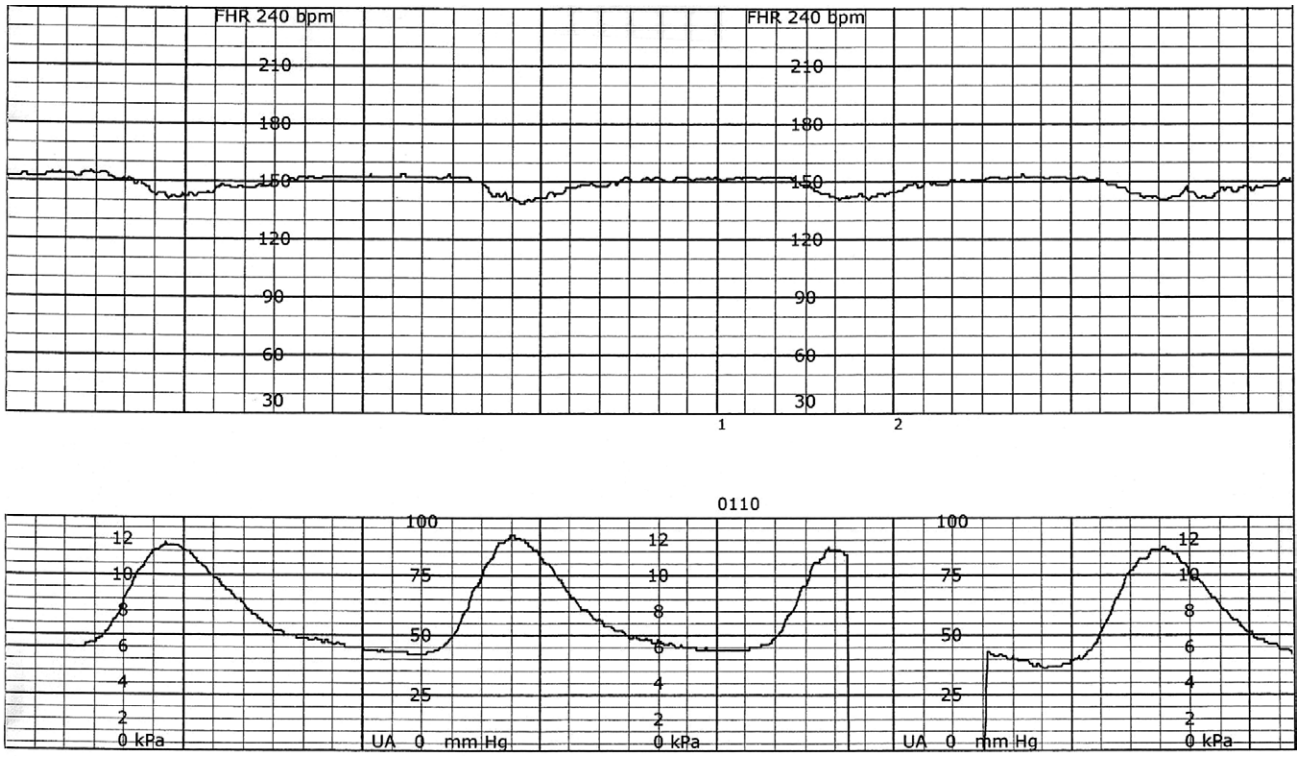
Appendix 1. Figure of a reactive nonstress test: 2 accelerations in 20 minutes. FHR = fetal heart rate; bpm = beats per minute.



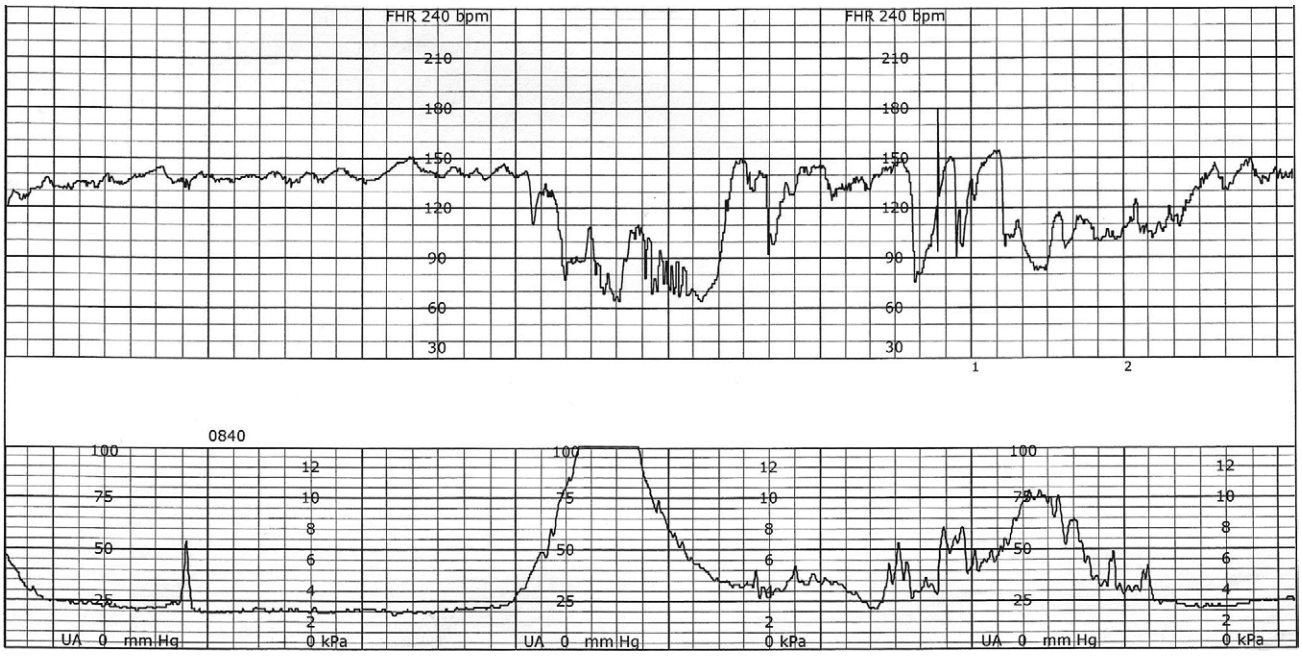
Appendix 2. Figure of a nonreactive nonstress test: fewer than 2 accelerations in 20 minutes (9 minutes shown). FHR = fetal heart rate; bpm = beats per minute.



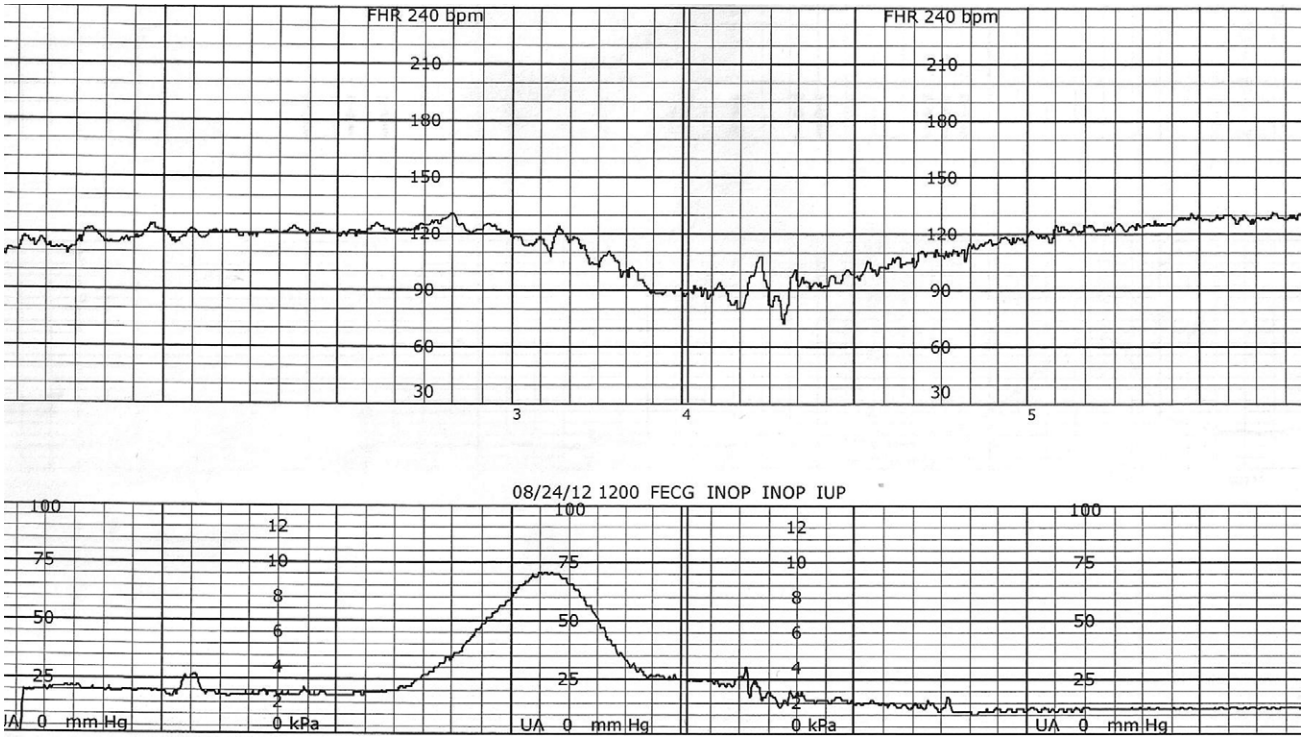
Appendix 3. Figure of umbilical artery Doppler velocimetry flows. A, Normal end-diastolic flow. B, Decreased end-diastolic flow. C, Absent end-diastolic flow. D, Reversed end-diastolic flow. This figure adapted from the Website http://bestpractice.bmj.com/best-practice/monograph/326/resources/image/bp/2.html.



Appendix 4. Figure of early decelerations: gradual decrease in fetal heart rate coincident with uterine contractions. FHR = fetal heart rate; bpm = beats per minute.



Appendix 5. Figure of a variable deceleration: rapid decrease in fetal heart rate and rapid return to baseline. FHR = fetal heart rate; bpm = beats per minute.



Appendix 6. Figure of a late deceleration: gradual decrease in fetal heart rate occurring after the uterine contraction. FHR = fetal heart rate; bpm = beats per minute.

DISCLOSURES

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