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Electronic Fetal Monitoring Case Review Series

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

Assumptions From the NICHD Workshop

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

Definitions

Baseline FHR

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

Baseline Variability

- Fluctuations in the baseline FHR of two cycles per minute or greater; fluctuations are irregular in amplitude and frequency; and fluctuations are visually quantitated as the amplitude of the peak to trough in beats per minute.
- Classification of variability:
  - Absent: Amplitude range is undetectable.
  - Minimal: Amplitude range is greater than undetectable to 5 beats per minute.
  - Moderate: Amplitude range is 6 to 25 beats per minute.
  - Marked: Amplitude range is >25 beats per minute.
Accelerations

• Abrupt increase in FHR greater than the most recently determined baseline.
• Onset to peak of acceleration is <30 seconds, acme is ≥15 beats per minute greater than the most recently determined baseline, and lasts ≥15 seconds but <2 minutes.
• Before 32 weeks’ gestation, accelerations are defined by an acme ≥10 beats per minute greater than the most recently determined baseline for ≥10 seconds.
• Prolonged acceleration lasts ≥2 minutes but <10 minutes.

Late Decelerations

• Gradual decrease in FHR (onset to nadir ≥30 seconds) to less than the most recently determined baseline, with nadir occurring after the peak of uterine contractions.
• Considered a periodic pattern because it occurs with uterine contractions.

Early Decelerations

• Gradual decrease in FHR (onset to nadir ≥30 seconds) less than the most recently determined baseline, with nadir occurring coincident with uterine contraction.
• Also considered a periodic pattern.

Variable Decelerations

• Abrupt decrease in FHR (onset to nadir <30 seconds).
• Decrease is ≥15 beats per minute less than the most recently determined baseline lasting ≥15 seconds but <2 minutes.
• May be episodic (occurs without a contraction) or periodic.

Prolonged Decelerations

• Decrease in the FHR ≥15 beats per minute less than the most recently determined baseline lasting ≥2 minutes but <10 minutes from onset to return to baseline.

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

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

Sinusoidal FHR Pattern

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

Uterine Contractions

• Quantified as the number of contractions in a 10-minute window, averaged over 30 minutes.
Normal: ≤5 contractions in 10 minutes.
Tachysystole: >5 contractions in 10 minutes.

Table 1. Arterial Umbilical Cord Gas Values

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<tr>
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<td>Respiratory acidosis</td>
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<td>Metabolic acidosis</td>
<td>&lt;7.20</td>
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Interpretation

A three-tier FHR Interpretation system has been recommended as follows:

• Category I FHR tracings: Normal, strongly predictive of normal fetal acid–base status and require routine care. These tracings include all of the following:
  - Baseline rate: 110 to 160 beats per minute
  - Baseline FHR variability: Moderate
  - Late or variable decelerations: Absent
  - Early decelerations: Present or absent
  - Accelerations: Present or absent
• Category II FHR tracings: Indeterminate, require evaluation and continued surveillance and reevaluation. Examples of these tracings include any of the following:
  - Bradycardia not accompanied by absent variability
  - Tachycardia
  - Minimal or marked baseline variability
  - Absent variability without recurrent decelerations
Absence of induced accelerations after fetal stimulation
Recurrent variable decelerations with minimal or moderate variability
Prolonged decelerations
Recurrent late decelerations with moderate variability
Variable decelerations with other characteristics, such as slow return to baseline

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


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

History

A 16-year-old G1P0 woman at 32–3/7 weeks’ gestation presents as a transfer from an outside hospital for abnormal fetal heart tracing while being monitored for oligohydramnios. Her prenatal laboratory values were all within normal limits, with a normal 1-hour glucose tolerance test. Her fetal anatomy ultrasound was normal at 20 weeks’ gestation with normal fluid. The patient was initially noted to a fundal height measuring size less than dates at her routine prenatal care visit at 24 weeks. Her ultrasound indicated that the estimated fetal weight was in the 52th percentile (1283 g) with normal umbilical cord Doppler values but a low amniotic fluid index (AFI) of 4.3 cm. Amniotic fluid volume is estimated using ultrasonography. One widely used definition of oligohydramnios is no measurable vertical pocket of amniotic fluid >2 cm, and another is an AFI of ≤5 cm. (1)(2) On a subsequent ultrasound 2 weeks later, she was noted to have a persistent low AFI of 4.6 cm with normal umbilical cord Doppler values. Follow-up ultrasound after another 2 weeks again revealed an AFI of 4.4 cm with normal umbilical cord Doppler values; however, the estimated fetal weight was falling off the growth curve at the 32th percentile (1598 g). Doppler ultrasonography is a noninvasive technique used to assess the hemodynamic components of vascular impedance. Umbilical artery Doppler flow velocimetry has been adapted for use as a technique of fetal surveillance, based on the observation that flow velocity waveforms in the umbilical artery of normally growing fetuses differ from those of growth-restricted fetuses. Specifically, the umbilical flow velocity waveform of normally growing fetuses is characterized by high-velocity diastolic flow, whereas with intrauterine growth restriction, there is diminution of umbilical artery diastolic flow. (3)(4)(5) In some cases of extreme intrauterine growth restriction, flow is absent or even reversed. The perinatal mortality rate in such pregnancies is quite high. (6)

The patient presents to the family birth center at the outside hospital for extended monitoring because of the documented oligohydramnios and decline in fetal growth. A sterile speculum examination is performed, and the patient is ruled out for premature rupture of membranes. While undergoing monitoring, she is noted to have prolonged variable decelerations to 60 beats per minute for almost 3 minutes. The first betamethasone injection is given before transfer to our hospital. On arrival, she denies contractions, vaginal bleeding, or leakage of fluid and reports normal fetal movement. She denies headaches, visual changes, abdominal pain, or right upper quadrant pain. She has never noticed leakage of fluid throughout her pregnancy and only reports having minimal spotting in the first trimester.

Case Progression

On physical examination on arrival, her blood pressure is 125/83 mmHg, her pulse is 101 beats per minute, her temperature is 36.9°C (98.4°F), and she has a urine drug screen that is negative. Her repeat sterile speculum examination is again negative for evidence of rupture of membranes, and her cervix appears closed. All laboratory values are within normal limits. A decision is made to continue the betamethasone course started at the outside hospital (two doses, 24 hours apart), to place the patient on prolonged continuous fetal monitoring, and to repeat the fetal ultrasound at our hospital. A fetal heart rate (FHR) tracing is obtained on admission (Fig 1).

Figure 1. External fetal monitoring (EFM) Strip #1.
Findings on EFM Strip #1 are:

• Variability: Moderate
• Baseline rate: 130 beats per minute
• Episodic pattern: Acceleration
• Periodic pattern: None
• Uterine contractions: None
• Interpretation: Category I tracing
• Differential diagnosis: Normal fetal tracing
• Action: No intervention required. The patient is admitted for prolonged monitoring, completion of the betamethasone course, repeat ultrasound, and close observation.

Patient is placed on continuous external fetal monitoring, and neonatology is consulted to discuss the risks of prematurity at 32 weeks' gestational age, particularly in the setting of oligohydramnios, which is associated with genitourinary abnormalities in the fetus, premature rupture of membranes, uteroplacental insufficiency, and postterm pregnancy. Oligohydramnios has been linked to increased rates of perinatal morbidity and mortality. (1) In the preterm fetus, depending on the maternal and fetal condition, expectant management may be the most appropriate course of action. Once oligohydramnios is diagnosed, if delivery is not undertaken, follow-up amniotic fluid volume and fetal growth assessments are indicated. If the oligohydramnios is persistent, close monitoring of the maternal condition and ongoing antepartum fetal surveillance should be performed to guide further management. (7) Oligohydramnios is linked with pulmonary hypoplasia, postural deformity, fetal distress, and perinatal morbidity and death. (8)

An official ultrasound is ordered to reassess fetal growth, amniotic fluid index, and umbilical cord Doppler studies. Approximately 6 hours after admission, the patient is noted to have a spontaneous prolonged late deceleration. The FHR tracing is shown in Fig 2.
Findings on EFM Strip #2 are:

- Variability: Minimal
- Baseline rate: 140 beats per minute
- Episodic pattern: Unclear
- Periodic pattern: Unclear
- Uterine contractions: None
- Interpretation: Category II tracing
- Differential diagnosis: Likely prolonged late deceleration. Prolonged late decelerations seen with the contractions are usually due to uteroplacental insufficiency. The differential diagnosis includes uteroplacental insufficiency, intratropical cord compression, umbilical cord prolapse, and placental abruption. The maternal pulse oximeter demonstrates that the maternal heart rate is 110 beats per minute, suggesting the deceleration from 140 to 60 beats per minute is likely fetal rather than maternal. It is critical to use an ultrasound to document the FHR if it is unable to be determined definitively with external fetal monitors as well as to distinguish the maternal heart rate from the FHR.
- Action: Resuscitative measures should be performed, including intravenous fluids, oxygen, and position changes.

The patient’s nurse presents to her bedside, applies oxygen (10 L/min) via facemask, and the patient’s position is changed first to the right lateral decubitus position and then left lateral decubitus position. Management of recurrent variable decelerations should be directed at relieving umbilical cord compression. Maternal positioning as an initial therapeutic maneuver is a reasonable first step. (9) Recurrent late decelerations are thought to reflect transient or chronic uteroplacental insufficiency. (10) Common causes include maternal hypotension (eg, postepidural), uterine tachysystole, and maternal hypoxia. Management involves maneuvers to promote uteroplacental perfusion, which may include maternal lateral positioning, intravenous fluid bolus, maternal oxygen administration, and evaluation for tachysystole. Adjunctive measures to promote fetal oxygenation also may be useful depending on the severity and duration of the recurrent variable decelerations. (10) The physicians are notified and the ultrasound is brought to the bedside as the nurse is having difficulty identifying fetal heart tones. The FHR identified via ultrasound is noted to be ~60 beats per min, and the EFM is replaced. Maternal pulse oximeter is applied, and her pulse is 90 to 110 beats per minute. Maternal position is again changed to right lateral and then left lateral decubitus position in an effort to improve the FHR, which remains at 60 beats per minute. An intravenous fluid bolus is started. The FHR recovers to 140 beats per minute after 4 minutes. The FHR tracing remains Category I.

An official ultrasound is performed 6 hours later. The results are remarkable for an enlarged placenta, a low AFI of 4.8 cm, and the umbilical cord being wrapped multiple times around a fetal extremity. Cord abnormalities, including a nuchal cord, are found in approximately 30% of normal births and may be an incidental finding. (11) The fetus
is normally grown with normal umbilical cord Doppler studies. Although the cord location may account for some of the decelerations, it does not fully explain the decreased amniotic fluid level or the enlarged placental size. There is no evidence of fetal hydrops, and the fetal stomach, kidneys, and bladder were visualized, making an anatomic cause for low fluid less likely. Differential for the oligohydramnios includes: normal variant, genetic syndrome, infectious cause, or uteroplacental insufficiency. The patient denies tobacco use or substance abuse, and has a negative urine drug screen.

The patient continues to receive intravenous fluids and is on continuous fetal monitoring. Six hours after her ultrasound (12 hours into her admission), the patient has another spontaneous deceleration. The FHR tracing is shown in Fig 3.
Findings on EFM Strip #3 are:

- Variability: Minimal/moderate
- Baseline rate: 130 beats per minute
- Episodic pattern: Variable deceleration × 1 minute
- Periodic pattern: None
- Uterine contractions: Every 30 minutes
- Interpretation: Category II tracing
- Differential diagnosis: Severe variable deceleration. The differential diagnosis for severe variable decelerations includes intrauterine cord compression, uteroplacental insufficiency, umbilical cord prolapse, and placental abruption. In this case, it is most likely intrauterine cord compression and/or uteroplacental insufficiency given the oligohydramnios and cord wrapped around the fetal extremity.
- Action: Resuscitative measures should be performed, including intravenous fluids, oxygen, and position changes. If there are recurrent moderate-severe variable decelerations and the patient is ruptured, it is ideal to place an intrauterine pressure catheter and start an amnioinfusion.

The physician is called to the patient’s bedside. The patient is already receiving oxygen and intravenous fluids. She is rotated first to the left decubitus position and then to the right decubitus position. The severe variable deceleration resolves within 1 minute and is not recurrent. Because the patient is not yet committed to delivery given her premature gestation and incomplete steroid course, it is not appropriate to artificially rupture the patient to place an intrauterine pressure catheter and start an amnioinfusion.

The FHR tracing returned to a Category I tracing and remained stable for 2 hours. At the time, there is again noted to be a prolonged deceleration. The FHR tracing is shown in Fig 4.
Findings on EFM Strip #4 are:

- Variability: Minimal
- Baseline rate: 130 beats per minute
- Episodic pattern: None
- Periodic pattern: Prolonged deceleration to 60 beats per minute × 5 minutes
- Uterine contractions: Every 30 minutes
- Interpretation: Category II tracing, concerning for Category III tracing
- Differential diagnosis: The differential diagnosis includes intrauterine cord compression, umbilical cord prolapse, and uteroplacental insufficiency.
- Action: Resuscitative measures should be performed, including intravenous fluids, oxygen, position changes, and close observation maintained of the FHR tracing to determine if the patient needs to be delivered emergently.

The nurse is at the patient’s bedside and the physicians are called to the bedside. The patient is placed in the left lateral decubitus position. Ultrasound is performed to confirm the presence of the FHR. A sterile vaginal examination is performed, and the patient’s cervix is noted to be closed with no evidence of rupture of membranes. Maternal pulse oximeter is again applied as the FHR recovers and is noted to be 90 beats per minute, definitively separate from the FHR. The FHR returns to baseline after 5 minutes of bradycardia.

Prolonged decelerations or fetal bradycardia should be evaluated for identifiable causes such as maternal hypotension (eg, post-epidural), umbilical cord prolapse or occlusion, rapid fetal descent, tachysystole, placental abruption, or uterine rupture. Bradycardia due to these conditions often occurs in labor and usually is preceded by an initially normal FHR at baseline. Rarely, bradycardia also may occur in fetuses with congenital heart abnormalities or myocardial conduction defects, such as those associated with maternal collagen vascular disease. Most often, the onset of bradycardia associated with congenital heart block occurs in the second trimester; it is extremely unlikely that new-onset intrapartum bradycardia would be due to this condition. FHR variability during baseline periods should be evaluated to better assess the risk of fetal academia. (12) If bradycardia with minimal or absent variability or prolonged decelerations (or both) do not resolve, then prompt delivery is recommended.
Close observation with continuous fetal monitoring is continued for the next 12 hours on labor and delivery with no further variables or late decelerations for 12 hours, consistent with a Category I tracing. The patient remains hemodynamically stable with minimal contractions. Approximately 13 hours after the last prolonged deceleration, the fetal monitoring alarm notifies the nurse of fetal bradycardia. The FHR tracing is shown in Fig 5.

Findings on EFM Strip #5 are:

- Variability: Minimal
- Baseline rate: 130 beats per minute
- Episodic pattern: None
- Periodic pattern: Moderate variable deceleration followed by prolonged deceleration to 60 seconds
- Uterine contractions: None
- Interpretation: Category II tracing concerning for Category III tracing
- Differential diagnosis: The differential diagnosis includes intrauterine cord compression, umbilical cord prolapse, and uteroplacental insufficiency. If there is no evidence of an umbilical cord prolapse, then the most likely cause is umbilical cord compression; this is particularly true when the patient is not having significant abdominal pain and/or vaginal bleeding, which are usually present in the setting of placental abruption.
- Action: Resuscitative measures should be performed, including intravenous fluids, oxygen, position changes, and close observation maintained of the FHR tracing to determine if the patient needs to be delivered emergently. It is imperative to expeditiously perform a sterile vaginal examination in the setting of prolonged bradycardia after variable decelerations to rule out umbilical cord prolapse.

The nurse presents to the patient’s bedside where the patient is noted to be lying completely supine. The nurse quickly physicians places in the left lateral decubitus position and notifies the physicians to come to her bedside. The nurse applies oxygen (10 L/min) via facemask and gives another intravenous fluid bolus. The patient is changed from the left lateral decubitus position to a “hands and knees” position with no resolution of the severe variables that are becoming prolonged fetal deceleration. Resuscitative measures are attempted for approximately 6 minutes from the start of the variable
deceleration, with no resolution. Given the now pro-
longed deceleration at 6 minutes with the FHR at 60
beats per minute, the decision is made to proceed to
the operating room (OR) for an emergent cesarean de-
livery. The OR staff and anesthesia team are notified of
the emergent cesarean delivery as the patient is being
moved. The patient is moved to the OR in 1 minute
and placed back on the fetal monitor once she is moved
to the operating room table. The FHR tracing from the
operating room is shown in Fig 6.

Findings on EFM Strip #6 are:

- Variability: Minimal
- Baseline rate: Unclear, intermittent tracing
- Episodic pattern: None
- Periodic pattern: Prolonged deceleration, return to
  150 seconds, prolonged deceleration from 150 sec-
  onds back to 60 seconds
- Uterine contractions: None
- Interpretation: Category II tracing, concerning for
  Category III tracing
- Differential Diagnosis: Unchanged
- Action: Quickly reassess the FHR tracing once the pa-
tient has been moved to the OR to determine how rap-
idly the cesarean delivery needs to be performed and to
help anesthesia staff determine if they have time to
dose the patient’s epidural, place a spinal, or if they
need to place the patient under general endotracheal
anesthesia.

The patient is moved from the labor room to the OR,
and the FHR is again noted to be 55 beats per minute
according to external fetal monitoring and ultrasound.
However, the FHR briefly returned to 150 beats per min-
ute while the patient was being prepared for delivery be-
fore there was another deceleration from 150 to 60
seconds over 4 minutes. The patient is prepared and sur-
geons proceed with emergent cesarean delivery. The time
from the decision in the labor room to incision was 14
minutes. The time from incision to delivery of the viable
female infant was 1 minute.

Outcome

A viable infant girl at 32 5/7 weeks weighing 1.615 kg
(3 lb 9 oz) is delivered via emergent cesarean delivery
with Apgar scores of 8 at 1 minute and 9 at 5 minutes.
The blood gas results are consistent with respiratory ac-
idosis shown (Table 2). The umbilical cord was noted to
be wrapped around the leg multiple times at the time of
delivery. The infant requires 10 to 15 minutes of

Table 2. Arterial Umbilical Cord Gas Values

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<td>Mixed acidosis</td>
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<td>Variable</td>
<td>≥10</td>
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<td>Patient readings</td>
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<td>13</td>
<td>–0.1</td>
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supplementary oxygen for respiratory distress with an excellent response. She is transferred to the NICU in stable condition, is noted to have good air movement bilaterally, and has no further need for continuous positive airway pressure (CPAP). Surfactant is not given.

On transfer to the NICU, there are no retractions, has excellent air movement bilaterally, and no need for CPAP. The infant is stable on room air after transfer; she is started on total parenteral nutrition initially and then transitioned to tube feeds. Phototherapy is needed for hyperbilirubinemia for 3 days. On day of life 8, she develops new apnea/bradycardia episodes, is noted to have residual in her tube feeds, and a low normal white blood cell count (WBC) and thrombocytopenia, concerning for sepsis, meningitis, urinary tract infection, and possibly necrotizing enterocolitis. Blood and urine cultures are collected, and a lumbar puncture is done after thrombocytopenia resolves. The infant is started on broad-spectrum antibiotics. Antibiotics are discontinued on hospital day 4, tube feeds are continued, and she is observed in the NICU for 6 days. She is discharged from the hospital on day 10.

There are several mechanical and vascular umbilical cord abnormalities that are capable of impeding fetoplacental blood flow, including knots, loops, torsion, strictures, hematomas, and cysts. The cord frequently becomes coiled around portions of the fetus, usually the neck (ie, a nuchal cord). Not surprisingly, this occurrence is more likely with longer cords. Several large studies have reported one loop of nuchal cord in 20% to 34% of deliveries; two loops in 2.5% to 5%; and three loops in 0.2% to 0.5%. (11)(13) Nuchal cords are usually not clinically significant. (13) However, it is clear that they can have devastating results. Coiling of the cord around the neck is an uncommon cause of antepartum fetal death and/or neurologic damage. (14)(15) As ultrasound imaging techniques improve, nuchal cords (or cords around the body or extremity) are often being identified before labor, as it was in this patient’s case. Nuchal cords may be associated with abnormal fetal activity and testing, but there is often no clinical warning of a nuchal cord during pregnancy, labor, or delivery. (13) Nuchal cords (and/or body/extremity cord) can cause intrapartum complications. As labor progresses and there is fetal descent, contractions may compress the umbilical cord vessels, resulting in FHR variable decelerations that often persist until the contraction ceases. In a study of 110 newborns with nuchal cords, Hankins et al (16) reported that newborns with nuchal cords had an increased prevalence of variable FHR decelerations in the first and second stages of labor and with an increased incidence of umbilical artery acidemia (pH <7.20). In a large prospective study in India of cord problems at birth in 12,000 singleton deliveries, nearly 30% had fetal distress during labor and 20.5% had a 1-minute Apgar score <6. (17) The perinatal mortality rate with cord problems was 85.3/1000 births. Neonatal problems noted were septicemia (4.56%), asphyxiation syndromes (13.48%), hypoxic ischemic encephalopathy (7.50%), neonatal convulsions (2.14%), and hyperbilirubinemia (2.14%). Although mean hemoglobin and hematocrit values were lower in those infants with a nuchal cord compared with normal controls, this difference was not significant. It is clear from this study that neonates born with a cord around the neck or with other cord abnormalities should be carefully followed up for morbidity. (17) Prenatal ultrasonography assists in the diagnosis of nuchal cord(s), true knot of the umbilical cord, cord entanglement in monoamniotic twin gestations, and other unusual etiologies that may lead to umbilical cord compression. Supplementary ultrasonographic measures, including color Doppler imaging, Doppler flow velocimetry, and possibly three-dimensional ultrasound, may further prenatal diagnosis of these conditions. Doppler flow velocimetry may also assist in detecting impaired or deteriorating umbilical artery flow reflecting increasing cord compression before the onset of adverse and potentially nonreversible effects on the fetus. (18)

References
7. Antepartum Fetal Surveillance. ACOG Practice Bulletin Number 9, October 1999