Fetal Assessment
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I. Pregnancy

A. Duration of pregnancy
1. Normal length of gestation is 280 days (40 weeks) from the first day of the woman’s last normal menstrual period.
2. Because the actual date of conception is often unknown, the expected date of delivery or confinement (EDC) is a range of +/- 2 weeks to account for variations in ovulation timing. With assisted reproduction, timing is more accurate.
3. Pregnancy is divided into three trimesters:
   a. First trimester: 0–12 weeks
   b. Second trimester: 13–26 weeks
   c. Third trimester: 27 weeks until term

B. First trimester: Fertilization through 12 weeks gestation
1. Fertilization – zygote formation
   a. Occurs in the upper third of the fallopian tube
   b. Cell division continues into inner cell mass, giving rise to germ layers; and outer cell mass, giving rise to placental tissue
2. Multiple gestation
   a. Monozygotic — division of a single ovum after fertilization
      (1) Separation and duplication at 2–3 days after fertilization forms dichorionic-diamniotic gestation.
      (2) Separation and duplication of the inner cell mass 4–7 days after fertilization forms monochorionic-diamniotic gestation.
         (a) Most common for monozygotic formations
         (b) Twin-to-twin transfusion possible
      (3) Separation and duplication at day 7–13 forms monochorionic-monoamniotic gestation.
         (a) Higher rate of mortality due to cord entanglement
         (b) Twin-to-twin transfusion possible
      (4) Separation at 14 days and after is usually incomplete, resulting in conjoined twins.
b. Dizygotic — simultaneous fertilization of two ova
   (70% twins are dizygotic)
   (1) Strong maternal familial tendency
   (2) Increased incidence with increased parity, maternal age, maternal body mass index (BMI)
   (3) Always dichorionic-diamniotic, placentas may be fused or separated

3. Period of the embryo — 2 weeks after fertilization until end of 8 weeks of gestation
   a. Organogenesis completed
   b. All major systems established, greatest period of vulnerability and susceptibility to malformations

4. Period of the fetus — from 9 weeks gestation to delivery
   a. Rapid growth and gradual increase in functional ability
   b. Fetal organ growth not synchronous, systems have varying degrees of susceptibility to malformations due to environmental or maternal conditions

5. Ultrasound measurements
   a. To date, there is no proof that diagnostic ultrasound exposure has adverse effects on the developing human fetus.
   b. The gestational sac can be measured at 5–6 weeks
   c. A fetal pole with movement and cardiac activity can be measured by 7–8 weeks. This provides an estimated gestational age with +/- 9 days accuracy.
   d. Crown-rump length (CRL) has greatest accuracy, +/- 4.7 days.

6. Uterine growth — at 12 weeks, uterus fills pelvis and fundus is at symphysis pubis

C. Second trimester: 13–26 weeks gestation
   1. Fetal growth
   a. From 20 weeks until term, further maturation of organ and body systems occurs, with a progressive increase in weight.
   b. Fetal anatomy may be evaluated and possible anomalies detected via ultrasound.
   c. By 24 weeks, 60% of the weight and 20% of the growth should be present.
   d. In the first half of pregnancy, the fetus grows by increasing the number of cells at a rapid rate (hyperplasia, or growth through increasing cell numbers).
2. Ultrasound measurements
   a. Fetal measurements, including biparietal diameter and femur length, may be used to estimate fetal age accurately.
   b. Biparietal diameter is a fairly accurate method of determining fetal age between 13 and 30 weeks of gestation, providing accuracy of +/- 10 days.
   c. An ultrasound in the mid-second trimester may be useful to evaluate fetal size and identify any size-date discrepancies.

3. Uterine growth provides a rough estimate of gestational age and is influenced by adiposity, variations in body shape, or presence of uterine fibroids.
   a. By 16 weeks, the uterine fundus is midway between the symphysis pubis and the umbilicus.
   b. At 20 weeks, the uterine fundus is expected at the umbilical level.
   c. Fundal height measurements, especially when confirmed by the onset of quickening and audible heart tones and an accurate menstrual history, can help to determine whether a size-date discrepancy exists.
   d. Maternal obesity, poor prenatal care, and uncertain menstrual history may confound assessment of fetal size-date measurements.
   e. Variations
      (1) Uterine size that is greater than expected may suggest multiple gestation, inaccurate dating, uterine anomalies, molar pregnancy, or polyhydramnios.
      (2) Uterine size that is less than expected may indicate inaccurate dating, intrauterine growth failure, or oligohydramnios, etc.

4. Fetal surveillance
   a. Goal is to prevent fetal death without false positive or false negative results that result in unexpected outcomes.
      (1) A false positive test implies that a condition exists when it actually does not exist.
      (2) A false negative test implies that a condition does not exist when it actually does exist.
b. Ultrasound may be used during the second half of pregnancy to assess blood flow changes in the fetal heart, aorta, cerebrum, and uterine and umbilical arteries.

5. Viability
   a. The ability or capacity to survive outside the uterus
   b. Not defined by a worldwide, uniform, gestational age

D. Third trimester: 27–40 weeks gestation
1. Fetal growth is governed by inherited genetic growth potential and can be influenced by maternal, placental, or uterine factors.
   a. Genetic determinants and environmental factors can play an important role in fetal development.
   b. Maternal nutrition, general maternal health, and exposure to legal and illicit drugs will influence fetal growth.
   c. Perfusion of the intervillous spaces and the availability of glucose, amino acids, and fats in maternal blood avail growth substrates to the fetus.
2. Fetal growth continues through cellular hyperplasia, but the fetus primarily grows through cellular hypertrophy (growth through the enlargement of individual cells). Fetal growth increases linearly; as the infant reaches term, the rate of fetal growth slows.
   a. The fetus gains 85% of its body weight during the last half of pregnancy.
   b. Throughout gestation, there is a gradual decrease in total body water and in extracellular water; intracellular water increases as gestation progresses (Fig. 1-1).
   c. Rates of growth vary for specific organs and tissues.
   d. Based on the ratio of organ size to body size, the brain is the largest contributor to body mass, making up 13% in infants vs. 2% in adults.
   e. Infants’ skin, kidneys, and liver are also twice as large in percentile as adults.
3. Gestational age definitions
   a. Early preterm: Birth at <34 weeks gestation
   b. Late preterm: Birth at 34 to 36-6/7 weeks gestation
   c. Early term: Birth at 37 to 38-6/7 weeks gestation
   d. Full term: Birth at 39 to 40-6/7 weeks gestation
   e. Late term: Birth at 41 completed weeks gestation
   f. Post term: Birth at ≥42 completed weeks gestation
4. Ultrasound measurements
   a. Ultrasounds are useful to detect other anomalies and to assess the volume of amniotic fluid (Fig. 1-2).
   b. Between 32 and 34 weeks, altered growth rates may be found in small for gestational age (SGA) and large for gestational age (LGA) fetuses.
   c. Growth curves are used in the third trimester.
      (1) SGA
         (a) Infants who are two standard deviations below the mean, or <10th percentile
         (b) Pathological or non-pathological factors may alter growth
      (2) Average for gestational age
      (3) LGA: ≥90th percentile
      (4) Intrauterine-growth restriction (IUGR)
         (a) Failure of a fetus to achieve its genetic growth potential in utero.
         (b) Occurs as a result of reduced growth potential or multiple maternal adverse effects, which places the fetus at increased risk for hypoxia.
         (c) Asymmetric growth restriction is usually due to extrinsic factors, such as maternal preeclampsia, placental insufficiency, and fetal malnutrition.

**FIGURE 1-1**
Changes in Body Water Throughout Gestation

The fetus gains 85% of its body weight during the last half of pregnancy. Throughout gestation, there is a gradual decrease in total body water and in extracellular water; intracellular water increases as gestation progresses.
(d) The terms IUGR and SGA are not equivalent.
(e) Only 50% of these infants are identified prior to birth.
(f) The neonate is at risk for conditions such as perinatal asphyxia, meconium aspiration, hypoglycemia, cold stress, and polycythemia.

II. The placenta and placental physiology
A. Implantation
1. Mediated by coordinated actions between maternal and embryonic cells.
2. Implantation and placentation requires communication between the developing embryonic cells and maternal uterine receptivity, which includes increased vascularity, edema, increased secretory activity, and microvilli trophoblastic development.
3. The ideal window for implantation occurs ~6–10 days after ovulation.
4. The location for attachment is usually on the upper posterior wall of the uterus, but can occur on various other intrauterine and extrauterine sites.

FIGURE 1-2
Using Ultrasound to Measure Amniotic Fluid

Ultrasounds are useful to detect anomalies and to assess the volume of amniotic fluid. Between 32 and 34 weeks, altered growth rates may be found in fetuses who are SGA or LGA.
5. Human chorionic gonadotropin (hCG) can be detected in maternal serum and urine 7–8 days after ovulation or around the time of implantation.
6. Slight bleeding may occur during implantation, which may be mistaken for a scanty, short menstrual period.
7. The endometrium following implantation is referred to as decidua. The decidua basalis forms the maternal portion of the placenta and is the site in which separation of the placenta occurs after delivery of the fetus.

B. Normal development
1. The placenta is a fetal organ and the maternal-fetal interface.
2. Development and function are directly related to the growth and well-being of the fetus; antenatal testing assesses the functionality.
3. By 21–22 days, a primitive fetoplacental circulation is established between blood in the chorionic villi and embryonic vessels.
4. The mature placenta is established at ~10–12 weeks of gestation, when maternal spiral arteries open and supply blood to the intervillous space.
5. The intervillous space surrounds numerous chorionic villi within the placenta.
   a. The intervillous space is the site for simple (passive) diffusion, facilitated diffusion, active transport, bulk flow, and pinocytosis; which allow for the exchange of gases and nutrients and the removal of waste.
   b. Oxygen and carbon dioxide diffuse readily across the thin blood-blood barrier.
   c. Restriction of fetal oxygenation may result from acute or chronic conditions that reduce maternal blood entering the intervillous space.

C. Abnormalities of the chorionic villi may occur with the initial invasion of maternal spiral arteries and villi or the secondary destruction by infarction, thrombosis, hemorrhage, or infection.
1. Hypoplasia may result in abortion or abruption and increase the risk of stillbirth, IUGR, and preterm delivery.
2. Hyperplasia is possibly due to suboptimal oxygenation and has been observed in women with hypertension and prolonged pregnancy. Large placentas are seen with severe erythroblastosis, some class A–C diabetic pregnancies, and cigarette smokers.
3. Preeclampsia is thought to be associated with abnormal vascular invasion and remodeling at the level of the spiral arteries, which leads to abnormal perfusion of nutrients into the intervillous space.

D. Fetal/placental circulation
1. Adequate blood flow to and through the placenta from both maternal and fetal circulation is essential for exchange of nutrients, gases, and waste products.
2. Fetal circulation
   a. Umbilical vein
      (1) Carries blood from the placenta to the fetus.
   b. Ductous venosus
      (1) Connects the umbilical vein with the inferior vena cava.
      (2) Less than one-third enters the fetal ductus venosus, while the remainder enters the liver proper from the inferior border.
      (3) Blood travels via the inferior vena cava to the right atrium of the heart.
   c. Foramen ovale
      (1) Blood passes through an opening between the right and left atrium (the foramen ovale), bypassing pulmonary circulation.
      (2) Blood flow continues into the left ventricle and is pumped through the aorta, primarily to the head and into the body.
      (3) Blood returns from the head via the superior vena cava into the right atrium, enters the right ventricle, and is pumped into the pulmonary artery.
   d. Ductus arteriosus
      (1) A connection between the pulmonary artery and the aorta with the purpose of bypassing the lungs.
      (2) 90% of the blood flow passes through this ductus, while 10% enters the lungs.
      (3) From the ductus arteriosus, the blood moves from the aorta through the internal iliac arteries.
   e. Two umbilical arteries
      (1) A branch of the hypogastric arteries that return deoxygenated blood to the placenta, where carbon dioxide and other waste products from the fetus are taken up and enter the maternal circulation.
3. Changes at birth  
   a. When the infant breathes for the first time, there is a decrease in the resistance in the pulmonary vasculature, which causes the pressure in the left atrium to increase relative to the pressure in the right atrium.  
   b. An increase in left-sided pressure leads to the closure of the foramen ovale.  
   c. The increase in the oxygen concentration in the blood leads to a decrease in prostaglandins, causing closure of the ductus arteriosus over 12–24 hours.  
   d. These closures prevent blood from bypassing pulmonary circulation, allowing the neonate’s blood to become oxygenated via the newly operational lungs.

E. Maternal circulation  
1. Blood flows to the uterus via the uterine arteries and reaches the placenta via the altered spiral arteries of the uterus.  
2. The intervillous space in the mature placenta contains ~150 mL of blood; the rate of flow increases during pregnancy, from 50 mL/min at 10 weeks to 500–600 mL/min by term.  
3. Uterine contractions limit the entry of blood into the intervillous space; oxygen transfer to the fetus may be decreased during a normal contraction.  
4. The blood flows around the chorionic villi, allowing exchange of materials between maternal and fetal circulation.  
5. Pressures within this system are low; increased blood flow is mediated by the low-resistance uteroplacental circuit, alteration in maternal cardiac output, system and peripheral vascular resistance, and hormonal/chemical influences.  
6. The spiral arteries underlying the placenta are almost completely dilated and become distended, flaccid, saclike structures with low resistance that are able to accommodate the blood needed to supply and provide reserve in the intervillous spaces. These arteries are no longer responsive to systemic circulatory pressor agents or influences of the autonomic nervous system.
F. Placental separation
1. Separation occurs normally during the third stage of labor. Delivery causes sudden emptying of the uterus, leading to a decrease in the support base for the placenta and the shearing of the placenta from the decidua basalis.
a. Gross examination for abruption, calcification, meconium staining, and infection of the placenta upon delivery is important and may yield the need for microscopic evaluation.
b. Retained fragments of the placenta and membranes can lead to uterine atony, hemorrhage, or infection.

III. Antepartum fetal surveillance
A. Initiation and frequency
1. Testing is initiated when individual clinical circumstances warrant fetal monitoring. Initiating testing at 32–34 weeks of gestation is appropriate for most pregnancies with increased risk of stillbirth.
2. A reactive test indicative of normal fetal acid-base balance should be repeated periodically (weekly or twice weekly) until delivery when a high-risk condition persists.
3. More frequent testing intervals, with individualization based on the high-risk clinical setting or any significant deterioration in the clinical status (e.g. worsening preeclampsia, decreased fetal activity) requires fetal reevaluation, regardless of the amount of time elapsed since the last test.

B. Maternal conditions that warrant antenatal testing
1. Antiphospholipid syndrome
2. Poorly controlled hyperthyroidism
3. Diabetes mellitus
4. Cyanotic heart disease
5. Systemic lupus erythematosus
6. Hypertensive disorders
7. Chronic renal disease
8. Hemoglobinopathies
9. Substance/environmental exposures
10. Decreased fetal movement
11. Oligohydramnios
12. Polyhydramnios
13. IUGR
14. Multiple gestation
15. Post-term pregnancies
16. Previous fetal demise
17. Isoimmunization
18. Prolonged premature rupture of membranes
19. Unexplained third trimester bleeding

C. Fetal movement counting
1. Fetal movement is usually perceived at 18–20 weeks of gestation.
2. Several methods of fetal movement counting are in place; neither the ideal number of kicks nor the duration for counting has been determined.
3. There is not enough evidence to influence practice. In particular, no trials have compared fetal movement counting vs. no fetal movement counting to determine morbidity.
4. Decreased fetal movement may be affected by:
   a. Placental location
   b. Maternal smoking, opioid or steroid use, alcohol
   c. Maternal perception
   d. Decreased uterine space
   e. Adiposity
   f. Hypoglycemia or hyperglycemia
5. The fetus has periods of sleep when activity is lower and movement decreased.
6. Fetal heart rate (FHR) usually increases with movement.

D. Non-stress test (NST)
1. Definition
   a. Non-invasive test to evaluate the presence of accelerations in the FHR that are either spontaneous or in association with fetal movement
   b. Common method of fetal surveillance
2. Physiologic basis
   a. Fetal movement and accelerations require an intact central nervous system (CNS) reflective of adequate fetal oxygenation and autonomic function.
   b. The normal fetus moves at various intervals; the CNS and myocardium respond to movement with acceleration of the FHR.
   c. Since 1975, fetal movements and FHR accelerations have been recognized indicators of fetal well-being.
3. Procedure
   a. An external fetal monitor is applied, including both a tocdynamometer and an ultrasound transducer.
   b. A baseline FHR tracing is obtained.
c. The mother presses a button to indicate fetal movement.

d. The FHR tracing is evaluated for the presence of accelerations with fetal movement.

e. An acceleration is considered to be present if detected on the monitor, even if the mother does not perceive a fetal movement.

4. Interpretation of results

a. Reactive NST (≥32 weeks gestation)
   (1) Presence of two or more accelerations reaching a peak of ≥15 beats/min (bpm) above the baseline rate and lasting for ≥15 sec from onset to return in a 20-min period
   (2) An indicator of normal fetal acid-base balance

b. Reactive NST (28 to 31-6/7 weeks gestation)
   (1) Presence of two accelerations ≥10 bpm lasting ≥10 sec over a 20-min interval
   (2) NST of non-compromised preterm fetus (24–28 weeks gestation) is frequently nonreactive

c. Nonreactive NST
   (1) Defined as one that does not show such accelerations over a 40-min period

5. Considerations with nonreactive NST

a. May be benign and temporary due to fetal immaturity, quiet fetal sleep, or maternal smoking

b. May be a sign of fetal hypoxemia or acidosis and thus necessitate additional testing

c. May be related to fetal neurological or cardiac anomalies, sepsis, or maternal ingestion of drugs with cardiac effects

d. Use of vibroacoustic stimulation
   (1) Decreases testing time and may be used for the term infant
   (2) Applies a vibratory sound stimulus to the abdomen over the fetal head for 1–3 sec
   (3) May be repeated at 1-min intervals for a total of three stimuli
   (4) Will elicit an acceleration due to fetal startle reflex

6. Follow-up

a. There is a <1% chance of fetal death within 1 week of a reactive NST.
b. FHR decelerations during the NST, regardless of reactivity, warrant consideration of further testing or delivery.

c. The nonreactive NST indicates a need for further testing and should be followed by a contraction stress test (CST) or biophysical profile (BPP).

d. False negative/false positive
   (1) False positive
      (a) Results in a nonreactive NST when the fetus is normal.
      (b) Between 28 and 32 weeks of gestation, 15% of normal fetuses have nonreactive NSTs.
      (c) 90% of these fetuses have a negative CST.
   (2) False negative
      (a) Results in reactive FHR when a hypoxic condition actually exists.
      (b) Rate is 6.8:1000.

E. CST

1. Definition
   a. Antepartum observation assessing for evidence of transient fetal hypoxemia, demonstrated by late decelerations when the fetus is exposed to the stress of uterine contractions
   b. An infrequently used test to determine how the fetus responds to relative hypoxemia during a contraction

2. Physiologic basis
   a. Fetal oxygenation will be transiently worsened by uterine contractions and, in the fetus with suboptimal oxygenation, the added stress will lead to late decelerations.
   b. Due to the state of hypoxemia with deteriorating reserves, the fetus may not withstand labor contractions without developing metabolic acidosis.
   c. Relative contraindications to the test include conditions that are associated with an increased risk of preterm labor and delivery, uterine rupture, or uterine bleeding. These include preterm labor, preterm premature rupture of the membranes (PPROM), history of extensive uterine surgery or prior classic cesarean birth, and known placenta previa.
3. Procedure
   a. May be performed by nipple stimulation or by administering an IV infusion with oxytocin. If at least three spontaneous contractions ≥40 sec are present in 10 min, no uterine stimulation is necessary.
   b. Nipple stimulation
      (1) With the mother in a semi-Fowlers position with a lateral tilt, apply external monitor and establish FHR baseline.
      (2) Assess maternal blood pressure every 15 min during the test.
      (3) Instruct the mother to brush the palmar surface of her fingers over the nipple of one breast through her clothes; continue 4 cycles of 2 min on and 2–5 minutes off; stop when contraction begins and re-stimulate when contraction ends. If not effective, she may brush both nipples simultaneously.
      (4) Discontinue nipple stimulation when three or more spontaneous contractions ≥40 sec occur in a 10-min period.
      (5) If nipple stimulation does not produce the desired uterine activity, an oxytocin-stimulated CST may be necessary.
   c. Oxytocin challenge
      (1) With the mother in a semi-Fowlers position with a lateral tilt, apply external monitors, establish FHR baseline, and begin mainline IV infusion.
      (2) Assess maternal blood pressure every 15 min during the test.
      (3) Piggyback oxytocin into the primary IV line in the port nearest the IV insertion site.
      (4) Begin oxytocin at 0.5–2.0 mU/min and increase the dosage by 0.5–1.0 mU/min at 15-min intervals until three contractions of ≥40 sec duration have occurred within 10 min.
      (5) Discontinue the oxytocin when three contractions have occurred within a 10-min period of interpretable data.
      (6) Discontinue the oxytocin with tachysystole, a prolonged deceleration, or recurrent late decelerations.
      (7) Terbutaline may be required for tocolysis.
(8) Continue to monitor until uterine activity and FHR return to baseline status.

4. Interpretation of results
   a. Negative: No late decelerations
   b. Positive: Late decelerations with 50% or more of contractions
   c. Equivocal
      (1) Suspicious: Intermittent late decelerations are present, but at a frequency of ≤50% of uterine contractions.
      (2) Tachysystole: FHR decelerations occur in the presence of contractions that occur more frequently than every 2 min or with a duration of ≥90 sec.
      (3) Unsatisfactory: Fewer than three contractions occur in 10 min or a tracing that is not interpretable.

5. Follow-up
   a. Negative CST predicts continued fetal well-being for 7 days and needs only to be repeated weekly, provided maternal well-being is the same.
   b. Equivocal CST should be followed with another form of fetal assessment (e.g. BPP).
   c. Positive CST should be followed by an assessment of variability to help determine the need for immediate delivery. A category-3 pattern requires an urgent management plan.
   d. False-positive rate is >50% and may be due to supine hypotension during the test (tachysystole, etc.). False negative is <1%.

F. BPP

1. Definition
   a. Combines reactive NST with ultrasonography to evaluate fetal well-being over a 30-min observation period

2. Physiologic basis
   a. Implies absence of significant CNS hypoxemia/acidemia at the time of testing
   b. Presence of five biophysical variables: FHR reactivity, fetal movement, tone, and breathing reflect acute fetal state; amniotic fluid volume serves as marker of chronic state of placental function
3. Procedure
   a. Ultrasound examination performed over a 30-min period to assess fetal tone, movement, breathing, fetal reactivity, and amniotic fluid
      (1) Gross body movements: Four or more discrete body or limb movements
      (2) Fetal muscle tone: One or more episodes of active extension with return to flexion of limb or trunk and/or opening and closing hand
      (3) Fetal breathing: Intermittent, multiple episodes of hiccups or rhythmic fetal breathing movements of ≥30-sec duration
      (4) Amniotic fluid index >5 cm total or at least one pocket >2 cm
      (5) Reactive FHR

4. Interpretation of results
   a. Each component is assigned a score of 2 if present, 0 if not, for a total of 10.
      (1) Score of 8–10 with normal amniotic fluid is normal and indicates a 0.8% chance of fetal death. Repeat test in 3–4 days.
      (2) Score of 6 is considered equivocal; the test should be repeated. A persistent score of 6 indicates delivery of a mature fetus. If the fetus is immature, repeat the test in 24 hours.
      (3) Score of ≤4 is abnormal. Unless extenuating circumstances exist, consider delivery by obstetrically appropriate method.
      (4) Score of 0–2 means immediate delivery is necessary and indicates a 40% chance of fetal death.
   b. Oligohydramnios (amniotic fluid index ≤5) constitutes an abnormal biophysical assessment, regardless of the overall score.
      (1) Increases risk of preterm delivery or low birth weight, lower Apgar scores, intrauterine fetal death, meconium-stained amniotic fluid, more admissions to NICU, and cesarean delivery.
      (2) Prolonged oligohydramnios may result in severe pulmonary hypoplasia, as seen in infants with renal aplasia.
   c. False negative rate is superior to that of the NST alone and compares with the CST 0.6/1000.
5. Factors affecting test results
   a. Administration of antenatal corticosteroids
      (1) Can be associated with transient FHR and behavioral changes that typically return to baseline by day 4 after treatment.
      (2) The most consistent FHR finding is a decrease in variability on days 2 and 3.
      (3) Fetal breathing and body movements are also commonly reduced, which may result in a lower BPP score or nonreactive NST.
   b. Onset of labor
      (1) Although fetal breathing and body movements decrease before the onset of spontaneous labor, other parameters that make up the BPP are present at early gestational ages and are useful in the evaluation of a very immature fetus.
   c. Sedation, stimulants, indomethacin, cigarette smoking
   d. Maternal hyperglycemia and hypoglycemia

G. Modified biophysical profile
   1. Definition
      a. An evaluation of fetal well-being
   2. Physiologic basis
      a. The NST is a short-term indicator of fetal hypoxemia.
      b. The amniotic fluid volume is an indicator of long-term placental function. Decrease in placental perfusion results in decreased blood flow and less oxygen to fetus, which diverts blood flow away from non-vital organs, including the kidneys. Decreased renal perfusion results in decreased fetal urine output, leading to decreased amniotic fluid.
   3. Procedure
      a. Combines the NST and ultrasonic evaluation of amniotic fluid volume (AFV)
      b. Performed once to twice weekly
   4. Interpretation of results
      a. Normal: Reactive NST, amniotic fluid volume >5 cm, and absence of variable or late decelerations
      b. Abnormal: Any of the following require complete BPP or CST
         (1) Nonreactive NST
         (2) Variable or late decelerations
         (3) AFV ≤5 cm
5. Follow-up
   a. Test is repeated twice weekly.
   b. False negative rate is 0.8/1000; false positive rate is 60%.

H. Umbilical Doppler velocimetry
1. Definition
   a. A noninvasive method to assess the uteroplacental blood flow in the umbilical arteries.
   b. Umbilical artery, fetal aorta, and middle cerebral artery velocimetry is a relatively new antepartum fetal surveillance method used to assess placental function in women who may have fetal growth restriction.

2. Physiologic basis
   a. Normally, the end-diastolic velocity in the umbilical arteries increases with advancing gestation secondary to decreased resistance in the placenta as more tertiary vessels develop.
   b. The velocity of blood flow through the umbilical artery can be detected with Doppler waveform analysis.

3. Procedure
   a. Assist the mother into a supine position with a left tilt to facilitate adequate blood flow and reduce maternal positional side effects.
   b. A pulsed Doppler device is positioned over the fetus.
   c. The umbilical artery blood flow is distinguished from other blood flow by its characteristic waveform.
   d. The directed blood flow within the umbilical arteries is calculated using the difference between the systolic and the diastolic flow.
   e. Measurements are averaged from at least five waveforms.

4. Interpretation of results
   a. Absent or reversed flow can occur when more of the vessels are abnormal.
      (1) Absent or end-flow velocity is an indication for preparation for delivery in consideration with other clinical factors.
      (2) Reversed end-flow velocity is an indication for immediate delivery.
b. Elevations of the systolic/diastolic ratio are seen in hypertensive disorders of pregnancy, fetal growth restriction, or other causes of uteroplacental insufficiency.

c. Abnormal flow in the ductus venosus indicates serious compromise and increased morbidity and mortality.

5. Implications for management
   a. Abnormal Doppler flow precedes FHR abnormalities by 7 days.
   b. Doppler flow velocities of maternal and fetal circulation detect vascular resistance before onset of IUGR.
   c. Maternal uterine artery notching indicates preeclampsia and IUGR.
   d. Doppler flow velocity of the fetal middle cerebral artery has been used as a surrogate measure of fetal anemia; peak systolic velocity is inversely correlated to fetal hemoglobin.

IV. Intrapartum fetal monitoring
   A. Overview
      1. Electronic heart rate monitoring has been used since the early 1970s; no decrease in intrapartum fetal deaths, morbidity, or cerebral palsy has been proven, despite several randomized controlled trials and retrospective studies.
      2. Labor is metabolically stressful to the fetus; a progressive decrease in fetal pH and oxygenation develops.
      3. Healthy fetuses tolerate and recover from labor.
      4. Continuous or intermittent monitoring is equally effective. The effect of electronic fetal monitoring on the perinatal death rate is unclear. Most obstetric units cannot provide the level of nursing care that intermittent auscultation requires.
      5. FHR monitoring is not a specific technique for identifying the compromised fetus. The high false positive rate (category 2 and 3) may induce clinicians to perform unnecessary interventions, with the intention of preventing of fetal neurologic injury.
      6. The NICHD convened a series of workshops to develop a standardized definition for FHR tracings to improve communication and allow evidence-based clinical management of intrapartum fetal compromise.
a. FHR patterns are produced by an external Doppler device detecting fetal cardiac motion or with a direct fetal electrode detecting the fetal EKG.
b. Patterns are categorized as baseline, periodic, or episodic.
   (1) Baseline patterns include baseline rate and variability.
   (2) Periodic and episodic patterns include FHR accelerations and decelerations.
      (a) Periodic patterns are those associated with uterine contractions.
      (b) Episodic patterns are those that occur spontaneously and are not associated with uterine contractions.
c. Abrupt shape is defined as the onset of the change in the FHR from the baseline to the nadir or peak in <30 sec (acceleration or variable deceleration).
d. Gradual shape applies to a deceleration that has a change in the FHR from the baseline to the nadir in ≥30 sec.
e. There are five basic components of a fetal heart rate tracing:
   (1) Uterine activity
   (2) Baseline rate
   (3) Baseline variability
   (4) Periodic or episodic changes (accelerations or decelerations)
   (5) Changes or trends over time (categories of FHR)

B. Uterine activity
1. Definition
   a. The number of contractions present in a 10-min window, averaged over 30 min.
   b. Duration, intensity, and relaxation time between contractions are important in clinical practice.
2. Terms
   a. Normal: Five contractions in 10 min, averaged over a 30-min window
   b. Tachysystole: More than five spontaneous or induced contractions in 10 min, averaged over a 30-min window
3. Interpretation
   a. External (indirect) tocodynamometer
      (1) Determines contraction frequency and duration.
(2) Intensity requires palpation, which is described as mild, moderate, or strong, depending on the ability to indent the fundus with the fingertips.
(3) Resting tone should be palpated in between uterine activity.

b. Internal (direct) intrauterine pressure catheter
   (1) Determines contraction frequency, duration and intensity
   (2) Intensity measured in mmHg for baseline tonus and peak intensity

C. Baseline FHR
   1. Definition
      a. The approximate mean FHR rounded to increments of 5 bpm during a 10-min segment (excluding periodic or episodic changes), periods of marked variability, and segments of baseline that differ by >25 bpm.
      b. A period of at least 10 min is required to determine baseline and at least 2 min of (not necessarily contiguous) information is required to establish a baseline.
      c. Baseline is reported as a single number, e.g., 145 bpm.
      d. The baseline is used as a reference point to determine variability and if accelerations or decelerations are present.
   2. Underlying physiology
      a. Regulated by the sinoatrial node, atrioventricular (AV) node, catecholamine release, and autonomic innervation (parasympathetic and sympathetic branches).
         (1) Sympathetic innervation and catecholamine release increases baseline FHR.
         (2) Parasympathetic innervation, carried by the vagus nerve, reduces the baseline rate.
      b. Chemoreceptors and baroreceptors located in the aortic arch and carotid arteries regulate the heart rate in response to changes in fetal partial pressure of oxygen (PO₂), partial pressure of carbon dioxide (PCO₂), and blood pressure.
   3. Rate
      a. Normal FHR baseline
         (1) Ranges from 110 to 160 bpm
         (2) Decreases with advancement of gestational age due to maturation of the parasympathetic pathway
b. Tachycardia – baseline >160 bpm
   (1) Any baseline FHR >160 bpm must be explained on some basis other than fetal prematurity.
   (2) Potential maternal conditions causing tachycardia:
      (a) Fever
      (b) Chorioamnionitis
      (c) Dehydration
      (d) Hyperthyroidism
      (e) Illicit substance use
      (f) β-sympathomimetic medications (terbutaline)
   (3) Potential fetal conditions causing tachycardia:
      (a) Anemia
      (b) Heart failure
      (c) Hypoxia
      (d) Infection or sepsis
      (e) Tachyarrhythmia
   (4) Implications
      (a) Increases myocardial oxygen demand, which utilizes fetal reserve.
   (5) Management
      (a) Base on the associated baseline FHR variability and the presence or absence of accelerations.
      (b) Maximize uteroplacental perfusion and identify if tachysystole exists.
      (c) Notify provider of fetal tachycardia.

c. Bradycardia – FHR <110 bpm
   (1) A sudden, profound bradycardia is a medical emergency.
   (2) Bradycardia that occurs during the second stage of labor following a previously normal FHR pattern may be due to increased vagal tone (head compression, rapid fetal descent) or, occasionally, umbilical cord occlusion.
   (3) Potential maternal conditions causing bradycardia:
      (a) Uterine rupture
      (b) Beta-blockers (propranolol [Inderal])
      (c) Hypoglycemia
      (d) Hypothermia
      (e) Urosepsis
      (f) Magnesium sulfate infusion
   (4) Potential fetal conditions causing bradycardia:
      (a) Dominance of AV node innervation with heart block arrhythmia
(b) Chronic or acute hypoxemia
(c) Prolapsed cord

(5) Implications
(a) Bradycardia must be quickly distinguished from continuation of a prolonged deceleration.
(b) In the absence of a known cardiac condition, e.g., congenital heart block, bradycardia is a serious finding.

(6) Management
(a) Differentiate maternal vs. fetal heart rate.
(b) Immediate delivery is usually required.

D. Baseline variability
1. Definition
   a. Fluctuations in the baseline FHR of ≥2 cycles/min
   b. Fluctuations irregular in amplitude and frequency, quantitated in bpm, and measured from peak to trough in a single cycle
   c. Reflection of the interaction of the sympathetic and parasympathetic reflexes

2. Categories
   a. Absent: Amplitude range undetectable
      (1) When associated with recurrent late or variable decelerations, it is most consistently associated with newborn acidosis and neonatal morbidity.
      (2) When present, it is an indication for obstetric evaluation and possible intervention.
   b. Minimal: Amplitude range detectable but ≤5 bpm
      (1) May be seen in states of fetal sleep, following administration of general anesthesia, and in response to maternal drugs (magnesium sulfate, opioids given for relief of labor pain, corticosteroids).
      (2) Minimal variability is a very nonspecific finding and must be interpreted in the context of other indicators of hypoxia; other causes of reduced variability must be considered.
      (3) Minimal variability without concomitant decelerations is almost always unrelated to fetal acidemia.
   c. Moderate: Amplitude range 6–25 bpm
      (1) Reliably indicates the absence of metabolic acidemia.
(2) Most important indicator of anatomic and functional integrity of pathways regulating cardiac function; reflects adequate cerebral oxygenation.

d. Marked: Amplitude range >25 bpm
   (1) May occur with sympathetic stimulation in response to acute but temporary hypoxemia.
   (2) May also occur following administration of larger doses of ephedrine.

E. Periodic and episodic changes

1. Accelerations (Fig. 1-3)
   a. Definition
      (1) Abrupt (onset to peak <30 sec) increase in FHR above baseline calculated from most recently determined portion of baseline
         (a) At ≥32 weeks of gestation, peak is ≥15 bpm above the baseline and entire event is ≥15 sec from onset to return to baseline.
         (b) At <32 weeks of gestation, peak is ≥10 bpm above the baseline and duration is ≥10 sec.
      (2) Prolonged if acceleration lasts 2–10 min in duration

FIGURE 1-3
Fetal Heart Monitor Strip Showing Accelerations

An abrupt (onset to peak <30 sec) increase in FHR above the baseline, calculated from the most recently determined portion of baseline, is thought to occur as a result of stimulation of peripheral proprioceptors, increased catecholamine release, and autonomic stimulation of the heart.
b. Physiologic mechanism
   (1) Thought to occur as a result of stimulation of peripheral proprioceptors, increased catecholamine release, and autonomic stimulation of the heart

c. Clinical significance
   (1) Indicator of normal fetal acid-base status when observed with fetal movements
   (2) Not required during active labor, but when present, denote a well-oxygenated fetus

d. Interventions
   (1) In the absence of spontaneous accelerations, fetal scalp stimulation or vibroacoustic stimulation performed when the fetus is at baseline can provoke fetal movement and FHR accelerations.

2. Early decelerations (Fig. 1-4)
   a. Definition
      (1) Gradual (>30 sec from onset to nadir) decrease in FHR from baseline and subsequent return to baseline associated with uterine contraction
      (2) Recurrent if occurring with ≥50% of uterine contractions in any 20-min segment
      (3) Decrease usually not >40 bpm
   b. Physiologic mechanism
      (1) Result of physiologic chain of events that begins with head compression during uterine contraction

**FIGURE 1-4**
Fetal Heart Monitor Strip Showing Early Decelerations

A gradual (>30 sec from onset to nadir) decrease in FHR from the baseline and subsequent return to the baseline is the result of a physiologic chain of events that begins with head compression during a uterine contraction. These are recurrent if they occur with ≥50% of uterine contractions in any 20-min segment.
(2) Caused by reduction in cerebral blood flow, hypoxemia, and hypercapnia
   (a) Hypercapnia results in hypertension that triggers a baroreceptor response mediated by the parasympathetic nervous system and a decrease in the FHR.

c. Clinical significance
   (1) Do not appear to be associated with poor outcome, therefore considered clinically benign.
   (2) May be included in the category-1 grouping.

d. Interventions
   (1) None required

3. Late decelerations (Fig. 1-5)
   a. Definition
      (1) Gradual (≥30 sec from onset to nadir) decrease in FHR associated with uterine contractions
      (2) Deceleration begins after peak of contraction, gradual in shape
   b. Physiologic mechanism
      (1) Believed to reflect fetal response to transient or chronic disruption of oxygen transfer from the environment to the fetus, resulting in transient fetal hypoxemia
      (2) Interruption in uteroplacental blood flow sufficient to impair oxygen transfer to the fetus

**FIGURE 1-5**
Fetal Heart Monitor Strip Showing Late Decelerations

Late decelerations begin after the peak of the contraction and are gradual in shape. These are believed to reflect fetal response to transient or chronic disruption of oxygen transfer from the environment to the fetus, resulting in transient fetal hypoxemia.
(3) Reflex fetal response to transient hypoxemia during uterine contraction
(a) Uterine contractions compress maternal blood vessels and disrupt maternal perfusion of the intervillous space.
(b) Decreased oxygenation in the intervillous space can reduce the diffusion of oxygen into the fetal capillary blood, leading to a decline in fetal PO$_2$ below the normal range of 15–25 mmHg.
(c) Chemoreceptors detect the change and initiate a protective reflex response of peripheral vasoconstriction, which redistributes perfusion to the brain, heart, and adrenal glands.
(d) Vasoconstriction leads to an increase in fetal blood pressure, leading to a baroreceptor stimulation and gradual slowing of the FHR.
(e) After the contraction, these reflexes subside.

(4) Risk to a fetus with decreased placental reserve

(5) Maternal factors potentially related to uteroplacental insufficiency:
(a) Hypotension
(b) Hypertension
(c) Placental concerns: post-term, previa, abruption, or small or malformed placenta
(d) Cardiopulmonary disease
(e) Severe anemia
(f) Tachysystole
(g) Other high-risk conditions of pregnancy: preexisting chronic disease, maternal smoking, poor maternal nutrition, multiple gestation

c. Clinical significance
(1) Baseline variability will determine if category 2 or 3.
(2) Recurrent or sustained disruption may progress to metabolic acidemia.

d. Intervention
(1) Must correlate with variability
(a) If moderate variability occurs with late decelerations, it is believed to reflect a chemoreceptor-mediated response to a transient hypoxemic event.
(b) Late decelerations with absent variability occur when the amount of oxygen in blood coming from the placenta cannot support fetal myocardial function.

4. Variable decelerations (Fig. 1-6)
   a. Definition
      (1) Abrupt (onset to nadir <30 sec) decrease of ≥15 bpm below the baseline with a duration of ≥15 sec and <2 min
      (2) May occur with (recurrent) or without (episodic) uterine contractions and not necessarily associated with uterine contraction
      (3) Recurrent if occurring with >50% of uterine contractions in any 20-min segment
   b. Physiologic mechanism
      (1) Results from transient mechanical compression of umbilical blood vessels within the umbilical cord.
      (2) Results from baroreceptor detection of abrupt rise in blood pressure and signals abrupt decrease in heart rate.
      (3) Parasympathetic stimulation may result in AV rhythm that appears as relatively stable rate of 60–80 bpm at the base of a variable deceleration.
      (4) As cord is decompressed, this sequence of events occurs in reverse.

**FIGURE 1-6**
Fetal Heart Monitor Strip Showing Variable Decelerations

Variable decelerations are abrupt (onset to nadir <30 sec) decreases of ≥15 bpm below the baseline with a duration of ≥15 sec and <2 min. These may occur with (recurrent) or without (episodic) uterine contractions, but are not necessarily associated with uterine contractions.
c. Clinical significance
   (1) Recurrent variable decelerations can result in recurrent disruption of fetal oxygenation and lead to a cascade of changes; including hypoxemia, hypoxia, respiratory acidosis; and may progress to mixed acidosis.
   (2) This is a common type of deceleration that varies in depth, shape, and duration.

d. Intervention
   (1) Position change, fluid bolus
   (2) Category 2, may deteriorate to category 3 if accompanied by absent variability

5. Prolonged deceleration
a. Definition
   (1) Abrupt or gradual deceleration of ≥15 bpm lasting 2–10 min
   (2) Characterized by duration of the event

b. Physiologic mechanism
   (1) Prolonged interruption of oxygenation from cord compression, tachysystole, uterine tetany, etc.

c. Clinical significance
   (1) If duration exceeds 10 min, it is a bradycardia.
   (2) The fetus may become academic, followed by myocardial depression.

d. Intervention
   (1) Intrauterine resuscitation
   (2) Prepare for expeditious delivery if unresolved

6. Abnormal patterns
a. Sinusoidal pattern (Fig. 1-7)
   (1) Visually apparent, smooth, sine wave-like undulating pattern above and below the baseline, with a cycle of ~2–5 times/min and an amplitude of 5–15 beats above and below the baseline that persists for >20 min
   (2) Actual baseline is indeterminate
   (3) Not a type of variability
   (4) Classically associated with fetal anemia due to Rh isoimmunization, massive fetomaternal hemorrhage, twin-to-twin transfusion syndrome, ruptured vasa previa, and fetal intracranial hemorrhage
(5) Other associated fetal conditions include fetal hypoxia or asphyxia, fetal infection, cardiac anomalies, gastroschisis
(6) Classified as category-3 tracing
(7) Will not resolve spontaneously and may become complicated by additional elements, such as late, variable, or prolonged decelerations

b. Arrhythmia
(1) Defined as any irregularity of the fetal cardiac rhythm
(2) Specific arrhythmias named according to anatomic site of aberrant impulse formation or conduction
(3) Usually not associated with uterine contractions, but characteristic of the baseline
(4) Rarely seen; may be detected during prenatal visit, NST, or labor
(5) Important to differentiate between arrhythmia and artifact
(a) Arrhythmias may impair interpretation of intrapartum heart rate tracings. Direct fetal monitoring with a fetal scalp electrode will assist in determination of baseline.

FIGURE 1-7
Fetal Heart Monitor Strip Showing Sinusoidal Pattern

A sinusoidal pattern appears as a smooth, sine wave-like undulating pattern above and below the baseline, with a cycle of ~2–5 times/min and an amplitude of 5–15 beats above and below the baseline that persists for >20 min. It is classically associated with fetal anemia due to Rh isoimmunization, massive fetomaternal hemorrhage, twin-to-twin transfusion syndrome, ruptured vasa previa, and fetal intracranial hemorrhage.
(6) Significance
(a) Arrhythmias usually disappear in the immediate neonatal period, although some are associated with structural cardiac defects.
(b) Ultrasonic survey of fetal anatomy, as well as echocardiography, may be useful.

c. Supraventricular tachycardia (SVT)
(1) Rate disorder that presents after 15 weeks of gestation and is most commonly seen at 30–32 weeks.
(2) Atrial arrhythmia is sustained, rapid, and regular.
(3) Rate may range upwards from 210 and increases workload on the fetal heart, resulting in decreased cardiac output.
(4) May progress to hydrops, depending on the severity of hemodynamic compromise.
(5) Management ranges from observation to prenatal medication therapy, including digoxin.

d. Atrioventricular block
(1) Thought to be due to a failure of union of the AV node and bundle of His in early fetal development; complete congenital heart block may also result from damage to the conducting system after it has been normally formed.
(2) Categorized according to the severity of the block: first, second, and third (complete). Impulse conduction is through the AV node and is abnormally slow.
(3) May be associated with maternal collagen vascular disease, fetal cardiac structural defects, fetal cytomegalovirus, antiphospholipid antibody syndrome, and maternal lupus.

e. Premature atrial contractions (PAC) and premature ventricular contractions (PVC)
(1) Comprise more than half of the cases of fetal dysrhythmia.
(2) Generally considered benign, but warrant observation.
(3) With direct monitoring, vertical spikes above and below the baseline are characteristic.
(4) Indirect (external) monitoring reveals irregular rhythm.
F. Categories of FHR

1. Normal (category 1)
   a. Characteristics
      (1) Exhibit baseline rate of 110–160 and moderate variability with no late, variable, or prolonged decelerations
      (2) May or may not exhibit accelerations or early decelerations
   b. Significance
      (1) Almost always associated with non-acidotic fetus and vigorous newborn at delivery; high predictability of a normally oxygenated fetus
   c. Management
      (1) Routine measures to support labor progress, maternal coping, and fetal oxygenation

2. Indeterminate (category 2)
   a. Characteristics
      (1) All FHR tracings that do not meet criteria for category 1 or 3
      (2) Includes tracings such as moderate or minimal variability and recurrent late or variable decelerations, tachycardia, prolonged decelerations, absent variability without decelerations
   b. Significance
      (1) Requires heightened surveillance and ongoing reevaluation
      (2) FHR patterns nonspecific; cannot reliably predict whether fetus will be well-oxygenated, depressed, or acidotic at birth
   c. Management
      (1) Supportive actions to promote maternal and fetal adaptation to labor
      (2) Intrauterine resuscitation measures (noted under category 3) may be used as appropriate

3. Abnormal (category 3)
   a. Characteristics exhibit any of the following:
      (1) Absent variability with bradycardia
      (2) Absent variability with recurrent late or variable decelerations
      (3) Sinusoidal pattern
b. Significance
   (1) Abnormal FHR patterns may be associated with fetal acidemia.
   (2) The following conditions may indicate neurologic injury:
      (a) Profound acidemia (determined by umbilical artery pH of <7 and base deficit ≥12 mmol/L)
      (b) Five-minute Apgar scores of 0–3
      (c) Early onset of severe or moderate neonatal encephalopathy in infants born ≥34 weeks gestation
      (d) Multi-organ system involvement within 72 hours of birth
         i. The kidney is a very sensitive organ and renal damage may occur as a result of altered blood flow patterns adopted by the fetus when hypoxia is present.
      (e) Cerebral palsy of the spastic quadriplegic or dyskinetic type
   (3) Exclusion of other identifiable etiologies: trauma, coagulation disorders, infectious conditions, genetic disorders

c. Management
   (1) Initial assessment may include a cervical examination to rule out cord prolapse or imminent delivery.
   (2) One or more intrauterine resuscitation techniques should be used:
      (a) Maternal repositioning to a lateral position
      (b) Reduction of excessive uterine activity noted as hypertonus (basal tone >20–25 mmHg) or tachysystole
         i. Removal of pharmacologic agents used with cervical ripening
         ii. Decreasing or discontinuing oxytocin infusion
         iii. Lateral positioning
         iv. Administration of an IV fluid bolus of lactated Ringers solution
         v. Consideration of a subcutaneous dose of terbutaline (0.25 mg)
Golden Hours: Care of the VLBW Infant

(c) IV fluid bolus
   i. Correction of maternal hypotension with bolus or ephedrine
   ii. 500- to 1,000-mL lactated Ringer’s solution
   iii. Caution with repeated IV fluid boluses
      1) Caution with preeclampsia, preterm labor
      2) IV boluses of glucose-containing solutions should generally be avoided due to transfer of glucose to the fetus, which can cause fetal hyperglycemia and subsequent reactive hypoglycemia due to hyperinsulinism.

(d) Oxygen administration
   i. Provide 100% oxygen via a non-rebreather face mask at 10 L/min and discontinue as soon as possible, based on fetal response.
   ii. Oxytocin should not be infused concurrently with maternal oxygen administration.

(e) Amnioinfusion
   i. Transcervical instillation of fluid into the amniotic cavity
   ii. Used to resolve variable decelerations

(f) Modification of maternal pushing efforts during second-stage labor
   i. Continuation of coached pushing in the presence of category 2 and 3 patterns can lead to iatrogenic fetal stress.
   ii. Shortening the active pushing phase, temporarily discontinuing pushing, and limiting pushing to every other or every third contraction can be effective methods to minimize risk of progression fetal oxygen desaturation.

V. Conditions affecting pregnancy that may impact fetal growth
   A. Maternal nutrition
      1. Maternal metabolic changes in pregnancy ensure that nutrients are continuously provided to the fetus.
         a. Substrates are delivered to the maternal side of the placenta for transport to the fetus.
b. If nutrient restriction occurs only during the first trimester, infant birth weights tend to be within normal limits. Restricted protein intake in early pregnancy has a detrimental effect on both fetal and placental development.
c. Caloric restriction in third trimester may affect fetal weight.

2. Due to the release of human placental lactogen (hPL) and increase in maternal insulin resistance, providing glucose to the fetus causes the following to occur:
   a. Hypoinsulinemia reduces glucose uptake in insulin-dependent tissues, preserving glucose for fetal use.
   b. Alternative substrates, such as ketones, cross the placenta and can be utilized by the fetus for lipid or protein synthesis.

3. During maternal fasting, adaptive mechanisms preserve fetal growth.
   a. Fuel mobilization results in increased maternal ketones and free fatty acids.
   b. Mobilization of maternal adipose tissue stores is facilitated by a rapid decline in maternal insulin levels and enhanced secretion of human placental somatomammotropin.
   c. Somatomammotropin has lipolytic activity and directly diminishes maternal glucose utilization, allowing greater fetal glucose transport.
   d. Maternal glucose utilization decreases because free fatty acids and ketones replace glucose as a maternal energy source.
   e. Prolonged periods of starvation have adverse consequences on fetal outcome.

B. Insulin and fetal-growth hormone

1. Maternal insulin does not cross the placenta; fetal insulin is from fetal pancreatic origin.

2. Fetal insulin and insulin-like growth factors are critical to fetal health.
   a. Increase deposition of adipose tissue in fetus
   b. Increase fetal glycogen stores
   c. Stimulate fetal amino acid uptake and protein synthesis in the muscle
   d. Govern fetal growth
3. Fetal-growth hormone does not significantly influence growth; there are few fetal-growth hormone receptors in the liver.
   a. Infants with growth-hormone deficiency (panhypopituitarism) have birth weights that are similar to those of normal fetuses.
   b. In cases of IUGR, placental-derived growth hormone levels in maternal serum are low.
   c. Placental-derived growth hormone increases maternal nutrient provision to the fetus and enhances mobilization of maternal substrates for fetal growth.

C. Maternal conditions
1. If the mother was small or large at her own birth, genetic factors may result in large or growth-restricted infants.
2. Chronic maternal diseases may influence fetal growth.
   a. Hypertensive disorders
      (1) Gestational hypertension
      (2) Preeclampsia-eclampsia
      (3) Chronic hypertension
      (4) Chronic hypertension with superimposed preeclampsia
   b. Maternal hypoxemia from cyanotic heart disease or living at high altitude
   c. Diabetes mellitus, particularly if vascular complications are present
   d. Autoimmune diseases
   e. Sickle cell anemia
3. Maternal ingestion of legal or illegal drugs
   a. Teratogens: isoretinoin, warfarin, toluene, methylmercury
   b. Pharmaceuticals: propranolol, prednisone
   c. Recreational: amphetamines, cocaine (may cause abruption from vasoconstriction), alcohol, heroin, phencyclidine
4. Other factors
   a. Cigarette smoking and lower socioeconomic status have been linked to IUGR.
      (1) These conditions may actually be related to poor maternal nutrition or drug abuse.
   b. History of previous infant with either IUGR or SGA
   c. Low pre-pregnancy weight
D. Fetal conditions

1. Chromosomal abnormalities, such as trisomy 8, 13, 18, and 21
2. Deletion or addition syndromes
3. Triplet sex-chromosome abnormalities
4. Agenesis of the pancreas
5. Other known syndromes
   a. Cornelia de Lange
   b. Potter syndrome
   c. Radial aplasia
   d. VACTERL syndrome
   e. Williams syndrome
   f. TORCH infectious syndromes
      (1) Toxoplasmosis
      (2) Other (syphilis, varicella)
      (3) Rubella
      (4) Cytomegalovirus
      (5) Herpes simplex

VI. Preterm labor and delivery

A. Definition and incidence

1. Defined by the World Health Organization as any delivery that occurs between 20 and 37 weeks of gestation
2. Account for 60%–80% of infant deaths worldwide
3. Rate of preterm delivery has not changed in last 40 years; may actually have increased in recent decades
4. Rate in United States is 12%

B. Risk factors

1. Race
   a. Preterm delivery rate is 16%–18% for African Americans; 7%–9% for Caucasians.
2. Socioeconomic factors
   a. Mother’s age; <17 and >35 at higher risk
   b. Lower income
3. Stress
4. Previous preterm delivery most significant risk factor
   a. Risk ranges from 17% to 40%, depending on number of prior preterm deliveries
   b. Greater number and earlier time frame of prior preterm deliveries increases risk
   c. Spontaneous abortion prior to second trimester
5. Uterine abnormalities and fibroid presence
6. Cervical incompetence (painless dilation at 12–20 weeks), may be associated with previous cervical biopsies or traumatic deliveries

7. Multiple fetus gestation
   a. One of the highest risk factors for preterm delivery and low birth weight
   b. 26% of infants with birth weight <2,500 g are twins
   c. 50% of twins and triplets are preterm

8. Placental factors: placenta previa or abruption

C. Management of preterm labor

1. Determination of underlying cause, if possible
   a. PPROM
   b. Maternal underlying condition
   c. Fetal underlying condition

2. Ultrasound to determine cervical length
   a. Dynamic changes of cervix over time
   b. Cervical funneling or wedging

3. Goals of preterm labor management
   a. The initial goal of management is to delay delivery long enough using tocolytics to allow three adjunctive interventions that have been shown to reduce the neonatal morbidity and mortality related to prematurity.
      (1) Transfer of mother and fetus to a hospital equipped to care for a premature infant
      (2) Administration of glucocorticoids
      (3) Administration of antibiotic prophylaxis to decrease neonatal group B *Streptococcus* (GBS) infection

4. Tests for lung maturity (*Table 1-1*)
   a. Overview
      (1) Tests of lung maturation are based on the premise that amniotic fluid accurately reflects the degree of differentiation of the type II cell population in the fetal lung.
      (2) Amniotic fluid phospholipids are far downstream in distance and time from the type II alveolar cell.
      (3) Surfactant secretion and the flow of fetal lung fluid are influenced by preterm labor and delivery.
   b. Ratio of lecithin (phosphatidylcholine) to sphingomyelin (L/S ratio)
      (1) Introduced by Gluck and associates in 1971.
(2) Standard against which all other tests are compared.
(3) Depends on sufficient flow of fetal lung fluid into amniotic fluid to change amniotic fluid phospholipid composition in a timely manner.
(4) Sphingomyelin is a membrane lipid, a nonspecific component of amniotic fluid not related to lung maturation.
(5) Sphingomyelin tends to decrease from ~32 weeks gestational age to term.
(6) Phosphatidylcholine, a large part of which is produced by the fetal lung, increases to a value of 2 by 35 weeks of gestation.
(7) In the normal fetus, values of 1.5–2 are considered immature; however, risk of respiratory distress syndrome (RDS) is low.
(8) If L/S ratio <1, incidence of RDS is high.

c. Phosphatidylglycerol (PG)
(1) Normally appears in amniotic fluid at the time of lung maturity, ~35 weeks gestation
(2) Absent from the amniotic fluid of tracheal aspirates of infants with RDS, appears as disease resolves
(3) Can be detected <30 weeks gestation in infants with early lung maturation
(4) Present in appreciable amounts only in lung tissue and surfactant

d. TDx-FLM II
(1) Measures relative concentrations of surfactant and albumin in the amniotic fluid

<table>
<thead>
<tr>
<th>Test</th>
<th>Normal</th>
<th>Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>L/S ratio</td>
<td>&gt;2: normal</td>
<td>1.5–2: immature, incidence of RDS low &lt;1: incidence of RDS high</td>
</tr>
<tr>
<td>PG</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>TDx-FML II</td>
<td>≥55 mg/g: likelihood of RDS small</td>
<td>40–54 mg/g: intermediate risk for RDS &lt;39 mg/g: likelihood of RDS high</td>
</tr>
</tbody>
</table>

L/S ratio = ratio of lecithin to sphingomyelin; PG = phosphatidylglycerol; RDS = respiratory distress syndrome

**TABLE 1-1**

**Fetal Lung Maturity**
(2) Has several advantages over L/S ratio:
   (a) Less technical expertise required
   (b) Can be performed more easily
   (c) Results obtained faster
(3) Interpretation of results:
   (a) <39 mg/g: Risk for immature lungs, other conditions may weigh more heavily on decision to deliver early
   (b) 40–54 mg/g: Intermediate risk for development of RDS
   (c) ≥55 mg/g: Likelihood of RDS small
(4) Measures ratio of amniotic fluid surfactant to albumin
(5) Equivalent to L/S ratio for prediction of RDS
(6) Used less frequently today
   (a) Virtually all women at risk for preterm delivery are treated with antenatal corticosteroids.
   (b) The availability of postnatal surfactant administration has changed the nature of surfactant deficiency disease.
5. Glucocorticoid recommendations from the NICHD and the American College of Obstetricians and Gynecologists (ACOG)
   a. Antenatal steroids are recommended for mothers expected to deliver at <32 weeks of gestation to reduce mortality and the incidence of RDS and intraventricular hemorrhage, regardless of the status of the fetal membranes.
   b. At 32–34 weeks, both recommend antenatal steroid treatment for mothers with intact membranes who are likely to deliver within 7 days, but noted that the benefit for infants born to women with ruptured membranes after 32 weeks is still controversial.
   c. Corticosteroids have greatest effect if delivery occurs 24 hours after starting treatment or <7 days after the last dose. However, if delivery occurred <24 hours after administration, steroid administration provided benefits.
   d. Anticipate transient FHR changes that typically return to baseline by 4–7 days after treatment.
      (1) The most consistent FHR finding is a decrease in variability on days 2 and 3.
(2) Fetal breathing and body movements are also commonly reduced, which may result in a lower BPP score or nonreactive NST.

e. Corticosteroid treatment decreases the tendency of the preterm lung to develop pulmonary edema.

f. Effects between corticosteroid and surfactant treatments are synergistic and additive. Because of increased lung volume, corticosteroid-treated fetuses have improved responses to postnatal surfactant.

D. Fetal neuroprotection

1. Pooling the results of the available clinical trials of magnesium sulfate for neuroprotection suggests that prenatal administration of magnesium sulfate reduces the occurrence of cerebral palsy when given with neuroprotective intent.

2. It is believed that magnesium sulfate not only reduces the risk of all levels of cerebral palsy (mild, moderate, severe), but also decreases the combined outcome of cerebral palsy on both fetal and infant death.

3. Use during 24–31 weeks of gestation, when risk of delivery is high.
   a. 6 g magnesium sulfate load followed by 2 g/hour up to 12 hours
   b. May be resumed when delivery is imminent
References


