بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ
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(Reference: up to date)
The five fetal parameters used for determining the BPP score are heart rate accelerations in response to movement (NST), breathing movement, body and limb movement, tone, and amniotic fluid volume, as described in the table.
A parameter may be assigned a normal score as soon as it is observed. The acute parameters (movement, tone, breathing) are subject to fetal sleep-wake cycles; therefore, the fetus should be observed continuously for at least 30 minutes before the parameter is assigned 0 points.
A score of 10/10 or 8/10 without oligohydramnios is reassuring of fetal well-being; 6/10 without oligohydramnios is an equivocal test result and should be repeated within 24 hours if the patient is not delivered; and 0 to 4/10 suggests a high risk of fetal asphyxia within one week if the patient remains undelivered or no therapeutic intervention is undertaken.
Scores of 6/10 or 8/10 with oligohydramnios (0 points for amniotic fluid) are abnormal tests, as the risk of fetal asphyxia within one week is 89/1000 with expectant management. These scores should be interpreted within the context of gestational age (eg, neonatal morbidity and mortality if the fetus is delivered) and maternal and obstetric factors (eg, risk of fetal death related to maternal, fetal, or obstetric disorder if the fetus is not delivered; whether cervix is favorable; maternal risks from continuing the pregnancy
The minimum gestational age for initiating testing should reflect the lower limit that intervention with delivery would be considered. We repeat a normal BPP score (10/10 or 8/10 without oligohydranmios) weekly or twice weekly until delivery when the high-risk condition persists and appears stable, and more frequently when there is significant deterioration in the clinical status (eg, worsening preeclampsia, decreased fetal activity) or in selected very high-risk settings (severe fetal growth restriction with abnormal Doppler velocimetry).
The predictive value of the four ultrasound biophysical parameters (movement, tone, breathing, amniotic fluid volume) is equivalent to that of the four ultrasound parameters plus a nonstress test when the four ultrasound parameters are normal (2 points for each).

A nonstress test can be omitted if the BPP score is 8/8 after ultrasound alone, but should always be performed if any ultrasound monitored parameter is 0.
The modified BPP simplifies the examination and reduces the time necessary to complete testing by focusing on those components of the BPP that are most predictive of outcome. Assessment of both amniotic fluid volume and the nonstress test appears to be as reliable a predictor of long-term fetal well-being as the full BPP.
Fasting – There are sparse data on the effect of maternal fasting on fetal biophysical activities. A study that performed a BPP one hour after a meal and 10 to 12 hours after abstaining from food and drink in 30 women with uncomplicated pregnancies reported scores of \( \geq 8/10 \) for all postprandial tests, but two fasting tests were 4/10 and 6/10; both tests rose to 10/10 after the mother ate a meal.
Point reductions during fasting were primarily due to nonreactive nonstress tests and inadequate fetal breathing movements. Some sites give the patient juice or another type of food/drink if a BPP shows inadequate breathing or the nonstress test is nonreactive, but this has not been proven to be effective.
Antenatal corticosteroids – Administration of antenatal corticosteroids can be associated with transient fetal heart rate and behavioral changes, but these changes typically return to baseline by day 4 after treatment. The most consistent fetal heart rate change is a decrease in variability on days 2 and 3 after administration. FBM and FMss are also commonly reduced, which may result in a lower BPP score or nonreactive nonstress test. These findings should be considered within the total clinical picture when assessing a fetus for possible delivery because of a nonreassuring fetal evaluation (NST or BPP) after corticosteroid administration.
The degree of fall in oxygen concentration necessary to abolish a given central nervous system regulatory center output varies by center.

The two most oxygen-sensitive centers are (1) the cardioregulatory neurons, which control the coupling of fetal movement and heart rate acceleration, and (2) the fetal breathing center neurons, which control fetal breathing movements.

The centers regulating FM have a higher threshold for hypoxemia than those for FBM or fetal heart rate accelerations; the FT center has the highest threshold.

Thus, acute fetal biophysical activities respond to hypoxemia in a predictable, physiologically based cascade: loss of FBM and fetal heart rate accelerations, followed by decreased FM, and finally loss of FT.

This sequence is of clinical value since it allows for estimation of both the presence and severity of hypoxemia.
## Components of second and third trimester ultrasound examinations

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<td>Presence or absence of fetal cardiac activity, fetal heart rate and rhythm</td>
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<td>Fetal biometry (biparietal diameter, head circumference, femoral length, abdominal circumference)</td>
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Biometry can be used to estimate gestational age (if not previously determined), fetal weight, and fetal growth (by comparing two or more examinations over an appropriate time interval).

* Fetal anatomic survey can include the following assessments: head (intact cranium, cavum septi pellucidi, midline falx, thalami, cerebral ventricles, cerebellum, cisterna magna, choroid plexus); face (orbits, mouth, upper lip intact); neck (absence of masses); chest/heart (shape/size of chest and lungs, cardiac activity present, four-chamber view of heart, aortic and pulmonary outflow tracts, diaphragmatic hernia); abdomen (stomach in normal position, bowel not dilated, both kidneys present, cord insertion site, bladder); skeletal (spine, masses, arms and hands, legs and feet); genitilia.

**Data adapted from:**

2. Executive Summary of a Joint Eunice Kennedy Shriver National Institute of Child Health and Human Development, Society for Maternal-Fetal Medicine, American Institute of Ultrasound in Medicine, American College of Obstetricians and Gynecologists, American College of Radiology, Society for Pediatric Radiology, and Society of Radiologists in Ultrasound Fetal Imaging Workshop. Obstet Gynecol 2014; 123:1070.
Doppler velocimetry — Doppler velocimetry of the UA is a good tool for fetal assessment in FGR when the etiology is placental dysfunction related to progressive obliteration of the villus vasculature. Placental vascular changes lead to fetal hemodynamic changes that can be evaluated by umbilical artery Doppler.

Doppler of the ductus venosus and middle cerebral artery, as well as other fetal vessels, also provide information about fetal hemodynamic status, but the clinical utility of Doppler interrogation of vessels other than the umbilical artery has not been validated.
Umbilical artery — Doppler velocimetry of the umbilical artery is the primary surveillance tool for monitoring pregnancies in which FGR is suspected.

It has been well established by numerous randomized trials that monitoring umbilical artery Doppler can significantly reduce perinatal death, as well as unnecessary induction of labor in the preterm growth restricted fetus.
Abnormal Doppler was defined as a pulsatility index >95th centile or absent/reversed end-diastolic flow. When 30 percent of the villous vasculature ceases to function, an increase in umbilical artery resistance leading to reduced end diastolic flow is consistently seen and is a weak predictor of adverse outcome. When 60 to 70 percent of the villous vasculature is obliterated, umbilical artery diastolic flow is absent or reversed and fetal prognosis is poor. Reversed diastolic flow is associated with poorer neonatal outcomes than absent diastolic flow.
We perform weekly Doppler velocimetry of the umbilical artery upon diagnosis of FGR. If consecutive Doppler results are normal, we decrease the frequency of Doppler examination to two-week intervals. The two-week interval is reasonable for the fetus with estimated fetal weigh ≥5th percentile, progressive growth, normal AFV, and no maternal risk factors for placental dysfunction. The Society for Maternal-Fetal Medicine suggests umbilical artery Doppler studies every one to two weeks initially, and if normal, the interval between examinations can be lengthened.
If umbilical artery diastolic flow is present but decreased (pulsatility index >95th percentile), we perform weekly Doppler evaluation to look for progression to absent or reversed flow. Absent or reversed end diastolic flow in the umbilical artery can be a sign of impending fetal cardiovascular and metabolic deterioration.
The absence of abnormal flow patterns in the ductus venosus has been used to support the decision to extend such a pregnancy, and may enable the pregnancy to be prolonged for as long as two weeks; however, clinical use of this test is controversial.
Ductus venosus — Doppler interrogation of the ductus venosus provides information about the hemodynamic status of the fetus, but there is no convincing evidence that this information is useful for guiding clinical decisions about timing of delivery.
Changes in the venous circulation, including flow reversal in the DV or pulsatile umbilical venous flow, generally occur later than those observed in the arterial circulation. With progressively increasing umbilical arterial resistance, fetal cardiac performance can become impaired and central venous pressure increases, resulting in reduced diastolic flow in the DV and other large veins.

Vasodilatation of the ductus venosus further diverts nutrient and oxygen rich blood to the heart but enhances retrograde transmission of atrial pressure. The DV resistance index increases, ultimately with loss of the a wave. An absent or reversed DV a-wave indicates cardiovascular instability and can be a sign of impending acidemia and death.
S = Ventricular systole
D = early diastole
a = atrial contraction
Ductus Venosus Waveform

11 wks GA

Absent A wave
Although overall sensitivity and specificity for fetal pH <7.20 are only 65 and 95 percent, respectively, the duration of the absent or reversed ductus venous a-wave needs to be taken into account and appears to impact outcome independently of gestational age. Each day of this Doppler abnormality doubles the odds of stillbirth, and fetal survival for more than one week is unlikely
Although the use of venous Doppler interrogation remains largely investigational, an increasing number of maternal-fetal medicine specialists are using this tool to avoid very preterm delivery in fetuses with absent or reversed end-diastolic arterial flow in the umbilical artery and reassuring antepartum fetal testing (nonstress test, BPP). In these pregnancies, the absence of abnormal flow patterns in the ductus venosus has been used to support the decision to extend the pregnancy to 32 to 34 weeks, if other tests of fetal well-being remain reassuring.
Middle cerebral artery — Doppler interrogation of the MCA also provides information about the hemodynamic status of the fetus. The fetal brain in uncomplicated pregnancies has a high resistance circulation. With progressive hypoxia, blood flow increases to compensate for the decrease in available oxygen (brain-sparing effect).

This results in a reduction in the Doppler parameters used to assess blood flow through the MCA: the peak systolic to end diastolic blood flow velocity ratio (S/D), resistance index, and pulsatility index.
There is no convincing evidence that interrogation of the MCA Doppler alone is useful in guiding clinical decisions about timing of delivery, although MCA Doppler alterations may be useful as an adjunct to umbilical artery Doppler interrogation for assessing the severity of hypoxia and predicting neonatal outcome.
Cerebroplacental ratio — The cerebroplacental Doppler ratio (CPR) is the MCA pulsatility index (or resistance index) divided by the umbilical artery pulsatility index (or resistance index).

A low CPR indicates fetal blood flow redistribution (brain sparing) and is predictive of adverse neonatal outcome. Adverse outcome was a composite of intraventricular hemorrhage, periventricular leukomalacia, hypoxic ischemic encephalopathy, necrotizing enterocolitis, bronchopulmonary dysplasia, sepsis, and death.
CPR was most useful for predicting adverse neonatal outcome when the umbilical artery Doppler pulsatility index was >95th centile. The additional finding of an abnormal CPR in these cases improved the prediction of an adverse neonatal outcome to a level similar to that found with absent or reversed umbilical artery end diastolic flow.
glucocorticoid administration
Three studies observed that growth restricted fetuses with absent end diastolic flow often show transient improvement in blood flow after glucocorticoid administration. Fetuses that did not show increased end diastolic flow appeared to have poorer neonatal outcomes.
The reason sicker fetuses are unable to mount a vascular response to glucocorticoid administration is unclear.
One action of glucocorticoids is to enhance the tropic effect of catecholamines on heart muscle. It is hypothesized that inotropy does not improve in sicker fetuses because they have impaired cardiac wall compliance.
Our approach — We time the delivery of the growth restricted fetus based on a combination of factors, including: GA, Doppler ultrasound of the UA, BPP score (or NST), and the presence or absence of risk factors for, or signs of, uteroplacental insufficiency. The goal is to maximize fetal maturity and growth while minimizing the risks of fetal or neonatal mortality and short-term and long-term morbidity.
REDF UA is a strong precursor of fetal demise. We deliver fetuses ≥32 weeks of gestation with reversed diastolic flow.

Morbidity and mortality related to PTL is relatively high before 32 weeks of gestation, between 26 and 29 weeks of gestation, each day in utero has been estimated to improve survival by 1 to 2%.

Therefore, before 32 weeks, we perform daily fetal monitoring using a BPP score in an attempt to delay delivery until 32 weeks or until the BPP score becomes abnormal.
Absent diastolic flow in the UA is also predictive of fetal death, but the risk is less imminent than with reversed diastolic flow.

We deliver fetuses ≥34 weeks of gestation with absent diastolic flow. Before 34 weeks, we perform daily fetal monitoring using a BPP score in an attempt to delay delivery until 34 weeks or until the BPP score becomes abnormal.
Decreased diastolic flow (pulsatility index >95th percentile) in the UA is a weak predictor of fetal death.

We perform a BPP twice per week and deliver these fetuses at term or when the BPP score becomes abnormal. Delivery at 37 to 38 weeks is reasonable if UA flow is decreased and risk factors for, or signs of, uteroplacental insufficiency are present, such as oligohydramnios, preeclampsia or hypertension, renal insufficiency, fetal growth arrest, estimated weight <5th percentile, or prior birth of a SGA infant.
Normal umbilical artery Doppler provides strong evidence of fetal well-being, especially in the absence of risk factors for, or signs of, uteroplacental insufficiency.

We deliver these fetuses at 39 to 40 weeks of gestation.
RECURRENCE RISK — There is a tendency to repeat SGA deliveries in successive pregnancies. As an example, a prospective national cohort study from the Netherlands reported that the risk of a non-anomalous SGA birth (<5th percentile) in the second pregnancy of women whose first delivery was “SGA” versus “not SGA” was 23 and 3 percent, respectively. Furthermore, uteroplacental insufficiency may manifest in different ways in different pregnancies. Growth restriction, preterm delivery, preeclampsia, abruption, and stillbirth can all be sequelae of impaired placental function.
Second and third trimester — The four standard biometric parameters commonly used to estimate gestational age and/or fetal weight in the second and third trimesters are BPD, HC, AC, and FL. They are typically obtained by TAS examination.
Biparietal diameter —

The BPD is the best-studied biometric parameter because it is highly reproducible and can predict gestational age within ±7 days when measured between 14 and 20 weeks of gestation. We agree with guidelines from national organizations that recommend using BPD for gestational age assessment when the CRL is >84 mm (14 weeks of gestation) and CRL for gestational age assessment when the measurement is ≤84 mm.

BPD test performance diminishes as the gestation progresses beyond 14 to 20 weeks. By the mid- to late-third trimester, the margin of error is three to four weeks.
The BPD is measured on a plane of section that intersects both the third ventricle and thalami. To further enhance test performance, the calvarium should appear smooth and symmetrical in the plane of section.

The cursors are then placed on the outer edge of the proximal skull and the inner edge of the distal skull.
Cephalic index — The fetal cranium may not always display a traditional shape, particularly with breech presentations, oligohydramnios, premature rupture of the membranes, and neural tube abnormalities. Head compression or distortion from these conditions may result in an abnormal cranial conformation (eg, dolichocephaly) that lowers test performance of the BPD for gestational age estimation.
In these cases, the cephalic index (CI) should be measured. CI refers to the ratio of the BPD and the OFD multiplied by 100. The standard CI range for normal-shaped craniums approximates one standard deviation from the mean (>74 or <83). Therefore, if the CI measurement approaches the outer limits of the normal range, the use of the BPD for estimation of gestational age is not accurate.
Head circumference — Measurement of the fetal HC provides a good estimate of gestational age on routine sonograms.

In most fetuses, a HC more than two standard deviations below the mean represents the lower end of the distribution in a normal population, while HC more than three standard deviations below the mean is more strongly associated with a pathological condition.
The correct plane for the image passes through the thalami and third ventricle, and is similar to the plane for the BPD. However, additional intracerebral landmarks that must be visualized to obtain the appropriate measurement include the cavum septum pellucidum anteriorly and the tentorial hiatus posteriorly.
The calvarium should always appear symmetrical in the image.

HC measurements are obtained by placing the cursors on the outer margins of the calvarium bilaterally. By using the computerized ellipse function, the ultrasound machine will assist in the approximation of the outer perimeter of the calvarium.

It is important to avoid measuring the outer margin of the skin overlying the scalp since doing so will falsely increase the HC.
Femur length — The FL can be measured as early as 10 weeks of gestation because of its size and echogenicity. Correlation with true GA is within one week prior to 20 weeks of gestation, but falls to within 2.1 to 3.5 weeks in the third trimester.

The transducer should be aligned along the long axis of the femoral bone.

The proper view is obtained by visualizing either the femoral head or the greater trochanter at the proximal end of the femur and the femoral condyle at the distal end.

The calipers should be placed at the junction of bone and cartilage to measure only ossified bone. They should not contain the femoral head. Including nonossified portions of the femur and not visualizing the full femur...
Average FL appears to vary slightly among ethnic groups. Short femurs may be a normal finding or a marker of aneuploidy (trisomy 21). Severely shortened (<5th percentile) or abnormal appearing femurs in the second trimester suggest a skeletal dysplasia or early-onset fetal growth restriction.
Measurement of fetal biparietal diameter

Axial image of the fetal head of a second trimester fetus at the level of the thalami. The thalami are symmetrical and the midline of the fetal brain is identified. The calipers are placed on the leading portions of the cranium for measurement of the biparietal diameter. This level is generally the largest transverse diameter of the cranium and is used for estimation of gestational age and fetal weight.

Courtesy of Thomas Shipp, MD.
Fetal femur length

Longitudinal view of a fetal femur of a second trimester fetus. The femur is hyperechoic with shadowing as compared with the surrounding soft tissue. The length of the femur is indicated by the calipers, which are placed on the proximal and distal diaphyseal borders.

Courtesy of Thomas Shipp, MD.
Image of abdominal circumference

Courtesy of Jacques Abramowicz, MD.
Abdominal circumference
— The AC appears to have a slightly lower ability to predict GA early in the second trimester than the BPD, HC, and FL. Some of the variability may be due to error in ultrasound technique, along with natural biologic variations.

In the second trimester, GA assessment is accurate within two weeks. In the late third trimester, variability increases, so accuracy falls to within three to four weeks.
positioning the transducer perpendicularly to the fetal abdominal wall and visualizing the symmetrical appearance of the lower ribs. The fetal stomach is typically visualized on the AC view.

The measurement is taken by placing four calibration points around the abdomen on the skin edge, not the rib cage.