Ultrasound of Fetal Biometrics and Growth

Contents:

- Section 1: Ultrasound Measure of Fetal Size: Biometrics
- Section 2: Individual Measurement Characteristics and Techniques
- Section 3: Strategies for Ultrasound Detection of Fetal Growth Retardation
- Section 4: Types and Causes of Fetal Growth Retardation

Section 1: Ultrasound Measurement of Fetal Size: Biometrics

The development of ultrasound scanning of the obstetric patient includes the ability to make measurements of various fetal structures. By evaluating large groups of fetuses found to be normal at birth, it has been possible to create standard tables and curves of fetal growth. Shown below is such a curve outlining the length of the femur in a normal fetal population:

![Femur Length Curve](image)

Notice the large r value, in this case 0.987, indicating over 97% of the change in femur length is explained by gestational age. Using such curves, accurate conclusion can be drawn regarding gestation age or fetal growth.

Biometric Interpretation:

There are two basic approaches to biometric data:
1.) If we assume a fetus is growing normally, biometric measurements are determined by gestational age, and we can estimate the gestational age and thus the due date (EDC - estimated date of confinement). The accuracy of this estimation is about 8% (± 8% of estimate includes 95% of population), or at 20 weeks age, 8% = 1.6 week or ±11 days (2 Standard Deviation).

When the date of the last menses preceding conception is known, it is usually a more accurate estimate (±5 days) of EDC, however when the menstrual age is unknown, or if confounding factors are present (i.e. inconsistent menses, recent pregnancy or oral contraceptives) ultrasound biometry represents a useful estimate.

When using ultrasound to estimate gestational age, remember that we are assuming the fetus is growing normally. Conditions which alter fetal growth will make the estimates less reliable.

2.) If we have an accurate menstrual age (or sometimes an earlier ultrasound) which establishes gestational age, we can recognize deviation from the normal growth pattern, as a sign of disease in the fetus. This is conceptually similar to the recognition of growth failure (failure to thrive), as a non-specific indicator of pediatric disease.

Section 2: Individual Measurement Characteristics and Techniques

Obstetrical Ultrasound Measurements:

The although many embryonic and fetal structures can be measured, only a few measurements easy and repeatable enough for widespread use. The most common are:

Gestational Sac: The first element to be measurable is the gestation sac of the early pregnancy. The gestational sac is measured in three dimensions, and the average, the Mean Sac Diameter (MSD) used for estimating gestational age. It is useful between 5 and 8 menstrual weeks with accuracy of ± 0.5 week (95% CI). As a rough rule of thumb, the MSD + 30 = Menstrual Age in days.

Embryonic Crown-Rump Length:

The length of the embryo on the longest axis (excluding the yolk sac) constitutes the crown-rump length. This is among the best documented parameters to date the embryo, with accuracy of ± 3-5 days. As a rough rule of thumb, the CRL + 6.5 = Menstrual Age in Weeks.
Biparietal diameter (BPD):

The transverse width of the head at its widest, usually recognized by a symmetric demonstration of the fetal thalamus. We measure from the leading edge to leading edge of the bones, because this leading interface is most distinct. Since the head is oval, the error induced by small errors in positioning is small, making for a repeatable, robust measure.

Head size is determined largely by brain growth which is relatively independent of nutritional (maternal/placental insufficiency) growth retarding processes, and head growth is often relatively "spared" in such growth retardation. When the head growth is retarded, it is often the result of non-nutritional "symmetric growth retardation" associated with genetic, toxic, or infectious damage to the fetus.

The BPD best used after 12 weeks. Accuracy is +/- 1.1 week 14-20 weeks, +/- 1.6 weeks 20-26 weeks, +/- 2.4 week 26-30 weeks, and +/- 3-4 weeks after 30 weeks.
Head Circumference:

The accuracy of the Biparietal diameter is affected by the shape of the fetal head however. Although brain growth and volume that determine head size, in some babies, the head will develop a more oval shape, in which the same brain volume is held by a narrower BPD. In this situation, a measurement which considers both transverse (BPD) and front to back (APD) will be more accurate. This combined measurement is called the head circumference. A true circumference is not actually measured though. The BPD and APD (anterior/posterior diameter) are measured and the circumference of the resulting oval calculated. If your machine does not calculate Head Circumference, you can do it easily with the formula

\[(\text{APD} + \text{BPD})/2 \times 3.14 = \text{Head Circumference}\]

In essence this averages the BPD and APD to correct for variations in head shape, but since it was standardized as a "circumference", it requires the conversion formula before you can use the standard tables. It's accuracy is a little better than the BPD.

Femur Length

The femur length is a repeatable measurement with accuracy similar to the BPD. It is effected by skeletal dysplasias, but since these are rare, it is a reliable measurement which confirms measurements of the head. It is best measured after 14 weeks.

Femur length is determined largely by growth which is relatively independent of nutritional (maternal/placental insufficiency) growth retarding processes, and femur growth is often relatively "spared" in "nutritional growth retardation. As with the head measures, retardation of femur growth is more often of a symmetric category associated with intrinsic problems in the fetus.

Abdominal circumference

The abdominal circumference is another circumference estimate made by averaging the anterior-posterior and transverse diameters times 3.14. It is made at the widest point in the abdomen, through the liver at the level of the left portal vein or stomach.
The abdominal measurement is special because it is determined not only by growing tissues (especially liver), but also nutrient storage as subcutaneous fat and liver glycogen. Because of this nutrient storage, the abdominal size is substantially reduced in nutritional growth retardation (starvation) related to maternal/placental insufficiency. In this setting, small abdominal circumference will be seen with normal head and femur length (thus asymmetric growth retardation). This category of growth retardation is important because it involves a normal fetus in an abnormal environment. The timely early delivery from this environment may save the life of the otherwise normal fetus.

The ratio of the Head Circumference to Abdominal circumference (HC/AC) is used to identify asymmetric growth retardation, and when HC/AC is increased, nutritional growth retardation should be suspected.

The abdominal circumference (AC) also changes in diabetic macrosomia, where elevated blood glucose levels lead to increased metabolic storage, increased AC, and decreased HC/AC.

**Composite measurement:**

It is common to make at least 2 and often 4-5 measurements to estimate gestational age. In most cases, BPD, Head Circumference, Femur length, and Abdominal circumference are used.

Since all of these measurements are strongly related to gestational age, it is not usually important how they are combined. In the setting where one measure is misleading however, care must be taken not to overestimate the effect of the misleading value. This is a possibility when the parameters a combined using the results of a multiple variable linear regression equation. In these equations, the "best" variable receives very strong weight (equivalent to it's strong correlation in normal populations), and other value receive weak weighting equivalent to the small additional improvement in estimation provided by additional variables.

If the "best" variable is misleading in a regression equation, the minimal weight allotted the additional values does not correct the error. Because of this mathematical anomaly, it is better and easier to use a simple average of the gestational age estimates from each measured variable, rather than the more complex regression equations.

**Reports:**

Most modern ultrasound machines include computerized biometric analysis programs used to easily calculate and standardize measured and calculated biometric parameters. These reports are useful, but represent extrapolation from a limited data set. Below is a typical report (this one generated by an Acuson® machine), although a large number of calculated values are shown, all values derive from the four measurements in the upper left for BPD,HC,AC,FL. You must take care not to over interpret such reports.
**Section 3: Strategies for Ultrasound Detection of Fetal Growth Retardation**

**Fetal Growth Assessment:**

Rational: Fetal growth is a linear, predictable process in the normal fetus which is analogous to growth in childhood. Delay or retardation of growth is a fairly reliable indicator of a fetus at high risk for stillbirth or significant post-natal handicaps.

Because the fetus is not directly available to physical examination and laboratory analysis, the relatively non-specific sign of growth retardation may be the earliest or only sign of serious fetal compromise.

Intrauterine growth retardation is analogous to pediatric "failure to thrive" in that it is a non-specific sign which may result from a wide variety of congenital or acquired conditions.

In addition to conditions directly effecting the fetus, an important group of normal fetuses will show growth retardation caused by insufficient oxygenation or nutrition due to maternal/placental insufficiency. In this group, if the fetus can be monitored for acute compromise until it is old enough for safe delivery, an normal fetus can be salvaged when serious compromise or stillbirth would otherwise have occurred. Since early delivery is dangerous in itself (due to the effects of prematurity) the timing of such early deliveries is critical and is discussed in the section on assessment of fetal wellbeing.

Although growth retardation can occur throughout pregnancy, it is the later part (third trimester) when nutritional demands are high, that growth retardation is most important. Growth retardation occurring in the first and second trimester tends to occur in fetuses with severe congenital or acquired conditions, for which fetal morbidity cannot be avoided. It is during the later second and third trimester when nutritional growth retardation puts otherwise healthy fetuses at risk, and when timely delivery can be life saving.

**Methods of fetal growth assessment:**

Growth assessment is a simple matter of comparing the observed fetal size to the size expected. When the observed size is less than the 10th percentile of normal expected population (usually expressed as estimated fetal weight found from standard tables), growth retardation is said to be present.

Expected fetal size for this gestational age is read from a normal table, and fetuses below the 10th percentile a labeled growth retarded, and assigned to high risk care, usually careful serial monitoring of fetal wellbeing.
beginning at 26 weeks. Monitoring is most often by non-stress test (NST) or biophysical profile (BPP). There are three ways to determine the expected fetal size to be compared to measured size.

1.) Expected size of fetus based on historical menstrual age: In this setting, the menstrual history and clinical measurement of uterine fundus height are used to establish the gestational age.

The advantage of this method is that a single ultrasound is sufficient to make the diagnosis, and evaluation can begin anytime during pregnancy.

The disadvantages are that the method is only as accurate as the clinical and historical gestational age estimate. If the expected gestational age is too advanced, the normal fetus may be falsely placed in the high risk category, and if it is too early, a growth retarded fetus may be overlooked.

2.) Expected size based on earlier ultrasound measurements. Because growth retardation occurs prominently in later pregnancy, early ultrasound measurement, especially in the first trimester can be used to verify the gestational age in most fetuses that later develop growth retardation. This information is then used to more accurately establish the expected fetal size at a later examination, reducing uncertainty regarding the expected fetal size.

A variation of this method involves both the historical menstrual age and the early ultrasound. In this method, fetuses which appear larger than expected on the early ultrasound are assumed to be constitutionally large (big babies), and smaller fetuses are assumed to be constitutionally small (small babies).

This amounts to dividing the normal fetal weight chart into quartiles, and assigning the upper (75-100) and lower (0-25) percentiles as large and small babies. On subsequent third trimester examinations, the large babies are expected to stay in the upper quartile and the small in the lower quartile.

The value of this method lies in the time required for a growth retarded fetus to "fall off" the curve. When a "naturally" large baby starts off at the 90 percentile and begins to undergo growth retardation, it will take many weeks to fall all the way down to the 10 percentile, and during those weeks, the unrecognized "starvation" may lead to permanent damage. If the fetus is plotted on a growth curve using an early ultrasound, it is possible to observe a fall from higher to lower quartile much sooner, improving the detection rate.

In practice this can be implemented by plotting serial estimates of fetal weight onto a fetal growth curve, and looking for unexplained drops from upper to lower ranges of the normal curve. Such fetuses can then be identified as high risk candidates for monitoring of fetal wellbeing.

3.) Assessment of interval growth:

The most straightforward assessment of growth is to take two ultrasound studies separated by a specific period of time, and determine if the expected amount of growth for that time period actually occurs. This method is useful if the first study is early in pregnancy and compared to a much later study.

The weakness of this approach is that serial growth measurements are somewhat variable, and in the second half of pregnancy, 3-4 weeks must pass before an accurately measurable amount of growth occurs.

In the late second and third trimester, growth retardation can easily progress to permanent damage in 3 to 4 weeks. Therefore, if an early study is suspicious, it is unwise to wait for 3-4 weeks to check growth. Instead, weekly evaluation of fetal wellbeing should be initiated. These checks are non-invasive, and guard against missing a rapidly progressive situation, and if carefully interpreted, result in no danger to the fetus.
Section 4: Types and Causes of Fetal Growth Retardation

Causes of Intrauterine Growth Retardation (IUGR)

The definition of intrauterine growth retardation is a fetus below the the 10 percentile of estimated (or actual) fetal weight. There are three recognized groups which fit this definition.

1.) Constitutionally small infants: Small for gestational age infants are the group of normal infants making up the lower 10 percentiles. They are generally healthy fetuses, and in particular, they have normal findings on carefully repeated tests of fetal wellbeing. These fetuses have outcomes similar, but slightly less favorable the the average normal infant.

2.) Hypoplastic intrauterine growth retardation:

Synonyms - intrinsic, non-nutritional, symmetric growth retardation.

In this group, an intrinsic fetal problem limits cellular division (hypoplasia) and growth. A wide range of causes can create this type.

Genetic: Triploidy, Trisomy 21,18,13, Turner's, various autosomal syndromes.

Syndromes: Renal agenesis, and others.

Fetal Exposure: Radiation, heroin, methadone, alcohol, aminopterin, coumadin, dilantin, and others.

Fetal Infection: Rubella, cytomegalovirus, Herpes simplex, toxoplasmosis, malaria, syphilis.

In these fetuses, outcome is determined at least in part by the underlying problem.

They may benefit from careful monitoring and timely early delivery, but they will carry the often permanent stigmata of the original disease process.

Because these problems usually begin early in pregnancy, growth retardation may be detected as early as the first trimester.

Because most of the causes are pervasive, the ultrasound measurements of the head, femur, and abdomen growth are often equally effected, giving rise to the term symmetric growth retardation.

3.) Hypotrophic intrauterine growth retardation:

Synonyms: nutritional, symmetric, extrinsic growth retardation.

This group of fetuses are intrinsically normal, but suffer from insufficient oxygenation and nutritional support through the placental circulation. Essentially this is a starvation syndrome. The cause lies outside the fetus in the maternal circulation or placenta.

Because stored nutrients are depleted rapidly, this syndrome often shows disproportional decrease in abdominal circumference due to decreased storage of glycogen in the liver and subcutaneous tissues, with relative sparing of head and extremity growth (normal biparietal diameter and femur length).

In most cases, the smaller demands of early growth do not cause early growth retardation. In later pregnancy
when growth demands increase, growth retardation and the risk of permanent damage or still birth develop.

This type of growth retardation is progressive, with mild changes seen first, which progress to more severe damage and finally stillbirth. Tests of fetal neural reflex activities can usually detect the developing disease before the effects are severe. These tests of fetal wellbeing are the NST (Cardiac Acceleration with Movement), and the BPP (Breathing, Movement, Tone, Amniotic Fluid). When carefully evaluated these tests can provide reassurance of fetal health, or indicate the need for early delivery.

Causes of hypotrophic growth retardation may be:

*Maternal (Common):*

Pregnancy induced hypertension/pre-eclampsia
Severe chronic hypertension
Severe maternal diabetes mellitus
Chronic renal disease
Collagen vascular disease (vasculitis)
Heart disease

??? Poor Nutrition

??? Smoking

*Placental (uncommon):*

Placental infarct
Hemangioma
Partial abortion
Multiple gestation
## Summary Table:

<table>
<thead>
<tr>
<th>Manifestation</th>
<th>Hypoplastic IUGR (intrinsic IUGR)</th>
<th>Hypotrophic IUGR (Nutritional IUGR)</th>
<th>Small for Gestational Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>&lt; 10%ile estimated. fetal weight</td>
<td>&lt; 10%ile estimated. fetal weight</td>
<td>&lt; 10%ile estimated. fetal weight</td>
</tr>
<tr>
<td>Biometrics</td>
<td>Symmetric head, femur abdomen small</td>
<td>Asymmetric, head, and femur spared, abdomen small</td>
<td>Symmetric, all measurements small</td>
</tr>
<tr>
<td>Doppler</td>
<td>Increased umbilical SD ratio if fetal distress, uterine SD normal</td>
<td>Increased umbilical SD ratio if fetal distress, uterine SD may be abnormal</td>
<td>Normal umbilical and uterine Doppler</td>
</tr>
<tr>
<td>NST/BPP</td>
<td>May be predictive of fetal distress, but not reliable</td>
<td>Reliable prediction of fetal distress</td>
<td>Usually reassuring, may need to repeat in 1-2 hours</td>
</tr>
<tr>
<td>Cause</td>
<td>Early fetal exposure, infection, genetic abnormality</td>
<td>Utero-placental insufficiency, mostly maternal</td>
<td>Normal, just a constitutionally small baby</td>
</tr>
<tr>
<td>Course</td>
<td>Fetal distress common, NST/BPP may not predict</td>
<td>Fetal distress common, NST/BPP usually predictive</td>
<td>Fetal distress uncommon</td>
</tr>
<tr>
<td>Prognosis</td>
<td>Survivors bear stigmata of causative process</td>
<td>Survivors may suffer from prematurity, otherwise normal</td>
<td>Essentially normal</td>
</tr>
</tbody>
</table>

**Basic Radiology Imaging Lectures**