

SONOGRAPHIC DETERMINATION OF GESTATIONAL AGE

Robin B. Kalish, Frank Chervenak

ABSTRACT

Appropriate assessment of gestational age is paramount in obstetric care. Making appropriate management decisions requires accurate appraisal of gestational age. Accurate pregnancy dating may assist obstetricians in appropriately counseling women who are at risk of a preterm delivery about likely neonatal outcomes and is also essential in the evaluation of fetal growth and the detection of intrauterine growth restriction. Accurate gestational age is also important in the interpretation of biochemical serum screening test or for counselling patients regarding the option of pregnancy termination. Since clinical data such as the menstrual cycle or uterine size often are not reliable, the most precise parameter for pregnancy dating should be determined by the obstetrician by ultrasound early in the pregnancy. Ultrasound is an accurate and useful modality for the assessment of gestational age in the first and second trimester of pregnancy and, as a routine part of prenatal care, can greatly impact obstetric management and improve antepartum care.

Key Words: Gestational age assessment, Clinical data, Ultrasound measurements, Estimated Date of Confinement

REZUMAT

Datarea exactă a vârstei gestaționale este un element fundamental în îngrijirea obstetricală. Stabilirea deciziilor corecte în obstetrică necesită cunoașterea exactă a vârstei gestaționale. Datarea corectă a sarcinii ajută obstetricianul în consilierea gravidei asupra nașterii premature și riscului fetal, fiind de asemenea importantă și pentru evaluarea creșterii fetale și a detectării restricției intrauterine de creștere. Calcularea exactă a vârstei gestaționale este importantă pentru interpretarea testelor biochimice de screening pentru aneuploidii și pentru consilierea pentru întreruperea de sarcină. Deoarece datele clinice precum data ultimei menstruații sau mărimea uterului nu sunt întotdeauna exacte, cel mai precis parametru este datarea ecografică cât mai precoce în sarcină. Ecografia este o metodă acurată și utilă pentru evaluarea vârstei gestaționale în primul și al doilea trimestru. Ecografia este o parte inclusă în îngrijirea prenatală ce îmbunătățește considerabil managementul și îngrijirea obstetricală.

Cuvinte cheie: Datarea sarcinii, date clinice, măsurători ecografice, data probabila a nasterii

INTRODUCTION

Importance of accurate gestational age assessment

Appropriate assessment of gestational age is paramount in obstetric care. Uncertain gestational age has been associated with adverse pregnancy outcomes including low birth weight, spontaneous preterm delivery and perinatal mortality, independent of maternal characteristics.¹ Making appropriate management decisions and delivering optimal obstetric care requires accurate appraisal of gestational age. For example, proper diagnosis and management of preterm labor and post-term pregnancy requires an accurate estimation of fetal age. Many pregnancies considered to be preterm or post term are wrongly classified. Unnecessary testing such as fetal monitoring

and unwarranted interventions including induction for supposed postterm pregnancies may lead to an increased risk of maternal and neonatal morbidity. In addition, pregnancies erroneously thought to be preterm may be subject to avoidable and expensive hospitalization stays as well as excessive and potentially dangerous medication use including tocolytic therapy. In one study by Kramer *et al* that assessed over 11,000 pregnant women who underwent early ultrasound, one fourth of all infants who would be classified as premature and one eighth of all infants who would be classified as postterm by menstrual history alone would be misdiagnosed.² Accurate pregnancy dating may also assist obstetricians in appropriately counseling women who are at risk of a preterm delivery about likely neonatal outcomes.

Accurate gestational age assessment is also essential in the evaluation of fetal growth and the detection of intrauterine growth restriction. During the third trimester, fundal height assessment may be helpful in determining appropriate fetal growth by comparing the measurement to a known gestational age. In addition, dating a pregnancy is imperative for scheduling invasive diagnostic tests such as chorionic villus sampling or amniocentesis, as appropriate timing can influence the safety of the procedure. Accurate

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Received for publication: Mar. 29, 200. Revised: Jun. 22, 2009.

gestational age is also important in the interpretation of biochemical serum screening test results and may help avoid undue parental anxiety from miscalculations and superfluous invasive procedures, which may increase the risk of pregnancy loss. Gestational age is also crucial for counseling patients regarding the option of pregnancy termination.

Assessing gestational age using LMP

The first day of the last menstrual period (LMP) traditionally has been used as a reference point, with a predicted delivery date 280 days later. The estimated date of confinement (EDC) can also be calculated by Nägele's rule by subtracting three months and adding seven days to the first day of the last normal menstrual period. However, assessing gestational age using the menstrual cycle can often be inaccurate. One obstacle in using the LMP is the varying length of the follicular phase and the fact that many women do not have regular menstrual cycles. Walker et al evaluated 75 ovulatory cycles using luteinizing hormone levels as a biochemical marker and found that ovulation occurred within a wide range of 8-31 days after the LMP.³ Similarly, Chiazze et al collected over 30,000 recorded menstrual cycles from 2316 women and found that only 77% of women have average cycle lengths between 25 and 31 days.⁴ Another barrier in using a menstrual history is that many women do not routinely document or remember their LMP. Campbell *et al* demonstrated that of more than 4000 pregnant women, 45% were not certain about their LMP as a result of poor recall, irregular cycles, bleeding in early pregnancy or oral contraceptive use within two months of conception.⁵

Clinical methods for determining gestational age

Aside from ultrasound, other methods used to assess gestational age have included uterine size assessment, time at quickening and fundal height measurements. However, these clinical methods are often suboptimal. Robinson noted that uterine size determination by bimanual examination produced incorrect assessments by more than two weeks in over 30% of patients.⁶ Similarly, fundal height estimation does not provide a reliable guide to predicting gestational age. Beazly et al found up to eight weeks variation in gestational age for any particular fundal height measurement during the second and third trimesters.⁷ In addition, quickening, or initial perception of fetal movement can vary greatly among women. While these modalities may be useful adjuncts, they are unreliable as the sole tool for the precise dating of a pregnancy.

ULTRASOUND ASSESSMENT OF GESTATIONAL AGE

Ultrasound assessment of gestational age has become an integral part of obstetric practice in recent times.⁸ Correspondingly, assessment of gestational age is a central element of obstetric ultrasonography. Fetal biometry has been used to predict gestational age since the time of A-mode ultrasound.⁹ Currently, the sonographic estimation is derived from calculations based on fetal measurements and serves as an indirect indicator of gestational age. Over the past three decades, numerous equations regarding the relationship between fetal biometric parameters and gestational age have been described and have proven early antenatal ultrasound to be an objective and accurate means of establishing gestational age.¹⁰⁻¹⁵

First trimester ultrasound

Gestational age assessment can be predicted with ultrasound most accurately in the first trimester of pregnancy.¹⁶ During this time, biological variation in regards to fetal size is minimal. The gestational sac is the earliest sonographic sign of pregnancy.¹⁷⁻²⁰ Historically, gestational sac size and volume had been used as a means to estimate gestational age.^{21,22} This structure sonographically resembles a fluid filled sac surrounded by a bright echogenic ring, the developing chorionic villi, within the endometrial cavity. This sac can be visualized as early as five menstrual weeks using transvaginal sonography.²³⁻²⁵ However, studies have shown that fetal age assessment by gestation sac measurement is not reliable, with a prediction error up to two weeks.^{6,26} Another imprecise yet often used modality is the sonographic visualization of distinct developing structures.²⁷ During the fifth menstrual week, the yolk sac, the earliest embryonic structure detectable by sonography, can be visualized prior to the appearance of the fetal pole. And, by the end of the sixth menstrual week, a fetal pole with cardiac activity should be present. Subsequently, the presence of limb buds can be seen at approximately 8 weeks gestation. However, these developmental landmarks can only provide rough estimates to the actual fetal age.

In 1973, Robinson reported using the crown rump length (CRL) for determining gestational age.²⁸ Since that time, ultrasound equipment, techniques and prediction formulas have substantially improved and allow for more precise measurement of the crown rump length and determination of gestational age.^{29,30} For the best results, the fetus should be imaged in a longitudinal plane. The greatest embryonic length should be measured by placing the calipers at the

head and rump of the fetus. Three adequate CRL measurements should be taken and the average used for gestational age determination.³¹ The accuracy of the CRL measurement has been well documented in the medical literature. Specifically, gestational age can be estimated safely with a maximal error of three to five days in the first trimester.^{6,16,32,33}

In summary, first trimester ultrasound is a useful and reliable modality for assessment of gestational age. In particular, sonographic measurement of the CRL during the first trimester is the best parameter for estimating gestational age and is accurate within five days of the actual conception date.^{16,32}

Second trimester ultrasound

Routine ultrasonography at 18-20 weeks gestation, while historically somewhat controversial, it is currently practiced by most obstetricians in the United States.^{34,35} In addition to screening for fetal anomalies, sonographic gestational age assessment is of clinical value in that it has been shown to decrease the incidence of post-term as well as preterm diagnoses and thus the administration of tocolytic agents.^{36,37} In addition, uncertain gestational age has been associated with higher perinatal mortality rates and an increase of low birth weight and spontaneous preterm delivery.¹

Ultrasound parameters

When choosing the optimal parameter for estimating gestational age, it is essential that the structure has little biologic variation, and can be measured with a high degree of reproducibility.³⁸ In the past, the biparietal diameter (BPD) had been described as a reliable method of determining gestational age.^{9,12} While the BPD was the first fetal parameter to be clinically utilized in the determination of fetal age in the second trimester, more recent studies have evaluated the use several other biometric parameters including head circumference (HC), abdominal circumference (AC), femur length (FL), foot length, ear size, orbital diameters, cerebellum diameter and others.³⁹⁻⁴⁷ In a large study by Chervenak et al that evaluated pregnancies conceived by *in vitro* fertilization and thus had known conception dates, head circumference was found to be the best predictor of gestational age compared with other commonly used parameters.⁴⁸ (Table 1) This finding is in agreement with that of Hadlock, Ott and Benson who compared the performance of HC, BPD, FL and AC in different populations.^{10,11,49}

The fetal head circumference should be measured sonographically in a plane that is perpendicular to the parietal bones and traverses the third ventricle and thalami.³¹ The image should demonstrate smooth and

symmetrical calvaria and the presence of a cavum septum pellucidum. The calipers should be placed on the outer edges of the calvaria and a computer-generated ellipse should be adjusted to fit around the fetal head without including the scalp. The biparietal diameter can be taken in the same plane by placing the calipers on the outer edge of the proximal calvarium wall and on the inner edge of the distal calvarium wall.⁵⁰ The BPD, while highly correlated with HC, is less accurate as a predictor of gestational age as a result of variation in head shape.⁴⁸

Table 1. Comparison of stepwise multiple linear regression in estimation of fetal age for singletons using different second trimester biometric parameters by Chervenak et al (Adapted from Chervenak FA, Skupski DW, Romero R, et al. How accurate is fetal biometry in the assessment of fetal age? American Journal of Obstetrics and Gynecology 1998;178:678-87).⁴⁷

Biometric parameters	Random error (days)
HC	3.77
AC	3.96
BPD	4.26
FL	4.35
HC+AC	3.44
HC+FL	3.55
HC+AC+FL	3.35

Using multiple parameters, the accuracy of gestational age assessment can be improved.⁴⁸ Along with head circumference, the addition of one parameter (AC or FL) or two parameters (AC and FL) is slightly superior to head circumference alone in the assessment of fetal age. Table 1 demonstrates the relative error associated with the use of different biometric parameters. The use of multiple parameters also reduces the effect of outliers caused by biologic phenomena (*i.e.* congenital anomalies or growth variation) or technical error in measurement of a single structure. Still, with multiple parameters, it is essential to take the images in the proper plane and place the calipers appropriately. For example, when assessing FL, the long axis of the femur should be aligned with the transducer measuring only the osseous portions of the diaphysis and metaphysis of the proximal femur. While not included in the FL measurement, the proximal epiphyseal cartilage (future greater trochanter) and the distal femoral epiphyseal cartilage (future distal femoral condyle) should be visualized to assure that the entire osseous femur can be measured without foreshortening or elongation.^{31,51} Similarly, the AC must be measured appropriately in order to obtain an accurate estimate. The image should be taken in a

plane slightly superior to the umbilicus at the greatest transverse abdominal diameter, with the liver, stomach, spleen and junction of the right and left portal veins visualized.³¹

Modern ultrasound machines are equipped with computer software that will automatically calculate the estimated gestational age based on the entered measurements. Using a large singleton in vitro fertilization (IVF) population from 14-22 weeks, Chervenak et al. derived an optimal gestational age prediction formula using stepwise linear regression with a standard deviation (SD) of 3.5 days between the predicted and true gestational age.⁴⁸ This formula was compared it to 38 previously published equations. Nearly all equations produced a prediction within one week demonstrating that fetal biometry in the midtrimester for assessment of gestational age is applicable and accurate across populations and institutions. Clinically, when a discrepancy greater than seven days (2SD) exists between the menstrual and ultrasound dating in the second trimester, the biometric prediction should be given preference.

In addition, we published a study evaluating and comparing the accuracy of first- and second-trimester ultrasound assessment of gestational age using pregnancies conceived with in vitro fertilization.¹⁶ Our data showed that first- and second-trimester estimates of gestational age had small differences in the systematic and random error components for an estimated gestational age that was based on fetal crown-rump length or biometry. On the basis of this data derived from pregnancies with known conception dates, ultrasound scanning can determine fetal age to within <5 days in the first trimester and <7 days in the second trimester in >95% of cases. This data further confirms the findings of Wisser et al and Chervenak et al, regarding the precision of ultrasound scans to assess gestational age in the first and second trimester, respectively.^{32, 48}

Third trimester ultrasound

While ultrasound has proven to be useful in the assessment of gestational age in the first and second trimesters, accuracy in the third trimester is not as reliable. Biologic variation can be a major factor that affects accuracy in gestational age prediction, and this variability greatly increases with advancing pregnancy. Doubilet and Benson evaluated late third trimester ultrasound examinations of women who had also received a first trimester exam and found the disparity in gestational age assessments to be three weeks or greater.⁵² However, more recent data has revealed that ultrasound estimation of gestational

age in late pregnancy may be better than indicated in older publications.⁵³ Still, third trimester sonographic estimates of gestational age should be used with caution, if at all.

Multifetal Pregnancies

Ultrasound can also be used to accurately date multifetal pregnancies. In fact, dating equations generated for singletons can be applied to twins and triplets in order to accurately predict gestational age. Chervenak et al used multiple linear regression to determine an optimal dating formula for multiple gestations.⁴⁸ In twin pregnancies, a single averaged prediction of the gestational age of each fetus is appropriate and was found to yield the most accurate results. This approach of averaging the two fetal age estimates is reasonable as the combined biologic and measurement variability among twins is larger than the decrease in average size of twins relative to singletons. In contrast, using the maximum or minimum estimate in a twin set yielded a slightly larger systematic error than an averaged prediction. (Table 2) In the case of triplets, one day can be added to the average of the largest and shortest gestational age prediction among these fetuses for the most accurate gestational age assessment.

Table 2. Application of a singleton multiple linear regression formula for estimation of fetal age to multiple gestations by Chervenak et al (Adapted from Chervenak FA, Skupski DW, Romero R, et al. How accurate is fetal biometry in the assessment of fetal age? American Journal of Obstetrics and Gynecology 1998;178:678-87).

Pregnancy type	Prediction type	Mean error (days)
Twins	GA of larger twin	0.8
	GA of smaller twin	-1.3
	Mean GA of both fetuses	-0.3
	GA of larger twin- GA of smaller twin	2.2
Triplets	GA of largest triplet	0.8
	GA of smallest triplet	-3.4
	Mean GA of all fetuses	-1.3
	GA of largest triplet- GA of smallest triplet	4.2

GA=gestational age

In twins or triplets, slightly larger deviations in the predictions are not unexpected as the formulae have been derived from a singleton population. However, this imprecision is partially compensated for by the fact that multiple pregnancy predictions are based

Table 3. Discrepancies between ultrasound estimates and true gestational age for the first and second trimester in singleton, twin, and triplet pregnancies (Adapted from Kalish RB, Thaler HT, Chasen ST, Gupta M, Berman SJ, Rosenwaks Z, Chervenak FA. First- and second-trimester ultrasound assessment of gestational age. *Am J Obstet Gynecol* 2004;191:975-8.)

	Systematic Errora		Random Errorb		Absolute Errora		
	First Trimester	Second Trimester	First Trimester	Second Trimester	First Trimester	Second Trimester	Secondl - lFirstlc
Singleton	+1.3 ± 0.2 days	-0.1 ± 0.4 days	2.4 days	3.5 days	2.3 ± 0.1 days	2.8 ± 0.2 days	0.5 ± 0.3 days
Twin	+1.4 ± 0.2 days	-0.6 ± 0.3 days	1.7 days	2.7 days	1.8 ± 0.1 days	2.1 ± 0.2 days	0.3 ± 0.3 days
Triplet	+0.8 ± 0.4 days	-0.6 ± 0.5 days	2.1 days	2.8 days	1.7 ± 0.2 days	2.2 ± 0.3 days	0.5 ± 0.3 days

on more information, namely two or three times as many measurements as for singletons. As singleton and multiple gestations grow at similar rates during the second trimester, the difference in the uncertainty of the prediction for gestational age is small using a singleton gestation formula. Using IVF pregnancies with known conception dates, we have published data confirming that gestational age predictions for twin and triplet gestations have similar accuracy as singleton gestations.¹⁶ (Table 3)

Choosing a Due Date

The estimated date of confinement should not be changed based on ultrasound when the date of conception is unequivocal, as in cases of in vitro fertilization. However, oftentimes the date of conception is not certain. In the first trimester, an estimated date of confinement (EDC) based on the LMP that is greater than five days different from the crown-rump length measurement should be changed to the sonographically derived EDC.^{28,32,33} (Fig.1). In the second trimester, a combination of biometric parameters that includes the head circumference should be used to predict the EDC. In cases with a discrepancy of more than 7 days in the second trimester, the sonographic biometric prediction should be given preference, provided there is no anomaly or severe growth delay.⁴⁸ (Fig. 2) In fact, some authors argue that biometric prediction in the first and second trimesters should be given preference in every case.⁵⁴⁻⁵⁷

When determining gestational age, the due date either derived or confirmed by an ultrasound exam should not be changed based on a second or subsequent ultrasound exam. The inaccuracy of ultrasound dating increases with gestational age. If the LMP and clinical findings suggest a gestational age within 5 days of a first trimester scan or within 7 days of a second trimester scan, no further investigation is necessary. If the initial first or second trimester sonographically determined gestational age is outside these ranges,

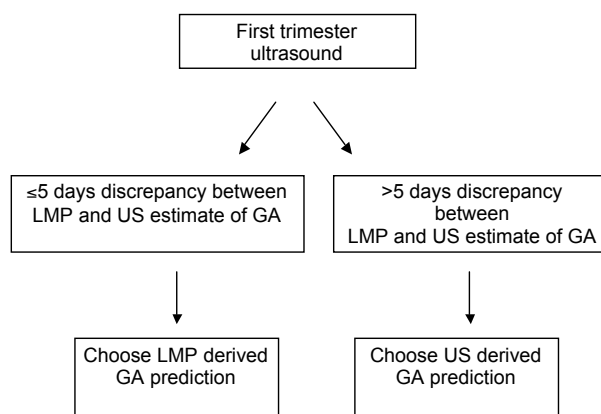


Figure 1. Gestational age assessment using first trimester ultrasound (LMP=last menstrual period, US=ultrasound, GA=gestational age)

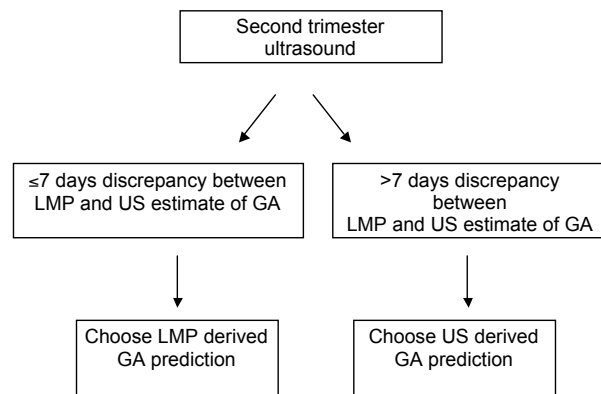


Figure 2. Gestational age assessment using second trimester ultrasound (LMP=last menstrual period, US=ultrasound, GA=gestational age)

the due date should be changed. However, as the pregnancy progresses, revision of a due date that was based on a previous ultrasound is not warranted. If there is a discrepancy between the gestational age assessments of two ultrasound examinations, considering explanations such as intrauterine growth restriction (IUGR), macrosomia or other pathological conditions may be appropriate.

Ultrasound pitfalls

Modern improvements in ultrasound image quality and the wide availability of accurate biometric formulas have greatly improved physicians' ability to calculate gestational age. However, properly dating a pregnancy sonographically still depends on adherence to good ultrasound technique. Obtaining a clear and precise image of each biometric indicator is essential. Errors in estimation may arise from technical difficulties including obtaining the proper axis for measurement, movement of the mother or fetus, machine sensitivity settings or caliper placement. If a certain biometric indicator is not well visualized or is difficult to measure, it is better to use an alternative indicator rather than include a suboptimal measurement. In addition, it is helpful to obtain several measurements of each indicator and use an average to ensure a more precise calculation of fetal age.

CONCLUSIONS

Accurate gestational age assessment is of great importance in obstetric practice. Appropriate estimation of gestational age requires good judgment by the obstetrician caring for the patient. Since clinical data such as the menstrual cycle or uterine size often are not reliable, the most precise parameter for pregnancy dating should be determined by the obstetrician early in the pregnancy. Ultrasound is an accurate and useful modality for the assessment of gestational age in the first and second trimester of pregnancy and, as a routine part of prenatal care, can greatly impact obstetric management and improve antepartum care.

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