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Brief Report

Accuracy of emergency physicians using ultrasound to determine gestational age in pregnant women

Sachita Shah MD*, Nathan Teismann MD, Brita Zaia MD, Farnaz Vahidnia MD, PhD, Gerin River MD, Dan Price MD, Arun Nagdev MD

Department of Emergency Medicine, Alameda County Medical Center, Oakland, CA 94602, USA

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Abstract

Introduction: Rapid and accurate determination of gestational age may be vital to the appropriate care of the critically ill pregnant patient. Before the use of emergency ultrasound, physical examination of fundal height (FH) in the nonverbal patient was considered the quickest method to estimate gestational age. We conducted a prospective, observational study of the performance of bedside sonography to determine gestational age.

Methods: We enrolled a convenience sample of women in their second or third trimester of pregnancy. Emergency physicians (EPs) made ultrasound measurements of fetal biparietal diameter (BPD) and femur length, followed by a measurement of FH. These measurements were compared with true gestational age (TGA), sonography by an ultrasound technician, and measurement of FH performed by an obstetrician. Main outcome measures were the average time needed to complete measurements; correlation coefficients between EP measurements and those made by an ultrasound technician, an obstetrician, and TGA, and overall accuracy to determine fetal age greater than 24 weeks.

Results: The average time to complete ultrasound measurements was less than 1 minute. When physician-performed measurements were compared with TGA, the correlation coefficients were 0.947 (0.926-0.968) for BPD, 0.957 (0.941-0.973) for femur length, and 0.712 (0.615-0.809) for FH. When determining fetal viability, EP's overall accuracy was 96% using ultrasound and 80% using FH.

Conclusions: With brief training, EPs can quickly and accurately determine gestational age using ultrasound, and these estimates may be more accurate than those obtained through physical examination. Emergency physicians should consider using ultrasound in emergent evaluation of pregnant patients who are unable to provide history.

1. Introduction

1.1. Background

Accurate determination of gestational age is an important and potentially life-saving step in providing optimal medical care to a pregnant patient in the emergency department (ED). Critical management decisions, such as the use of emergent

* Corresponding author.
E-mail address: sachita.shah@gmail.com (S. Shah).

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cesarean section, can be made confidently only when fetal viability can be assessed reliably. Traditionally, estimates of gestational age are based on the patient's recollection of her last menstrual period (LMP); however, prior research suggests that this may be inaccurate [1]. Even if a reliable date for LMP is known, this information may be unobtainable because of a patient's acuity or inability to provide historical information. A physical measurement of the height of the uterine fundus above the pubic symphysis is frequently used to estimate gestational age; however, the reliability of this method in an ED setting has never been studied rigorously. Furthermore, in cases involving obese patients, previous cesarian delivery, or uterine rupture, this technique may yield inaccurate results [2].

1.2. Importance

Obstetrical (OB) ultrasound technicians routinely measure biparietal diameter (BPD), head circumference, abdominal circumference, and femur length (FL) to estimate gestational age in an outpatient setting [2]. In the ED, bedside ultrasound is a fast and readily available tool for a growing number of applications; however, the ability of emergency physicians (EPs) to assess gestational age using fetal biometry remains unstudied. If EPs are able to accurately and rapidly determine gestational age in second and third trimester pregnancies using ultrasound, this technique may prove to be a powerful tool in cases where fetal viability must be assessed on an emergent basis.

1.3. Goals of investigation

We hypothesized that EPs can rapidly and accurately determine gestational age in second and third trimester pregnancies using ultrasound measurements of fetal BPD and FL, as well as fundal height (FH) measurement. This report describes the results of the study.

2. Methods

2.1. Study design

We conducted a prospective, blinded observational study of women in their second or third trimester of pregnancy presenting to our hospital's OB clinic for a routine sonogram in December 2008. Written informed consent was obtained in all patients. The study was approved by our hospital's institutional review board.

2.2. Setting

This study was performed at a large urban teaching hospital with multiple residency training programs including emergency medicine.

2.3. Participants

A convenience sample of women older than 18 years were enrolled on days when study physicians trained in ultrasound and an ultrasound technician were available during daytime hours. Inclusion criteria were being healthy, adult, pregnant women between 14 and 40 weeks gestation presenting to their regular OB visit at Alameda County Medical Center. The 8 participating emergency sonographers included a senior medical student (GR) who had completed a 1-month emergency ultrasound elective, first year (LF) and fourth year (BZ and OW) emergency medicine residents who had completed a 1-month elective in emergency ultrasound, 2 emergency ultrasound fellows (SS and NT), and 2 ultrasound-trained faculty eligible for the Registered Diagnostic Medical Sonographer (RDMS) certification (DP and AN). Within the group, GR, BZ, and OW were considered novice users, with less than 5 OB ultrasound examinations before the study, whereas NT completed approximately 20 BPD measurements and 10 FL measurements before the study and AN completed approximately 50 BPD measurements but no FL measurements before the study. SS, LF, and DP were considered very experienced users, with more than 100 BPD and FL measurements performed before the study. Study sonologists inexperienced in estimating gestational age by ultrasound underwent didactic instruction given by author SS, who had prior experience with OB ultrasound, including a 1-month training course. Instruction included a 1-hour lecture with still images and video of measurement technique for BPD and FL, highlighting proper landmarks and planes of visualization, and 1 proctored examination on a 17-week pregnant model. The participating ultrasound technician is RDMS certified and has more than 10 years of experience in OB ultrasound. The ultrasound technician's scans were overread by radiologists, as is customary at our institution.

2.4. Study protocol

Each emergency sonographer measured the fetal FL and BPD twice. The average of the 2 measurements for BPD and the 2 measurements for FL were used in our statistical analysis. For blinding, the measurements displayed on the screen of the ultrasound machine were covered while the examinations were performed and recorded by a separate author not involved in the scanning process for that patient. The recording author noted the measurements and calculated the estimated gestational age (EGA) immediately after each examination. Time was measured from placement of the transducer on the patient's abdomen until the point at which each measurement was completed.

After each ultrasound study, a physical measurement of FH using a flexible obstetric tape measure was made by both the emergency sonographer and, if available, an attending obstetrician. This method was used because it is the method used in the OB clinic at our institution for determining FH. All study patients then underwent formal sonography by our

ultrasound technician. All emergency medicine participants and the OB ultrasound technician were blinded to each other's measurements and the true gestational age (TGA) of the pregnancy. TGA was determined by dating using first trimester ultrasound results, LMP, or both.

2.5. Ultrasound measurements

A 3.5-MHz curvilinear abdominal transducer was used to measure FL in the longitudinal plane. In standard fashion, the distal femoral epiphysis was excluded (Fig. 1B). The BPD was measured in a transverse (axial) plane at the level of the falx cerebri and the thalamus (Fig. 1A). The calipers were placed at the outer aspect of the skull in the near field and the inner table of the skull in the far field per convention. A SonoSite M-Turbo ultrasound machine (Bothell, WA) was used by the emergency sonographers, whereas the ultrasound technician used an Accuvix XQ ultrasound machine (Medison America Inc, Cypress, CA).

2.6. Fundal height measurements

Fundal height was measured in standard fashion using a tape measure from the symphysis pubis to the palpable superior portion of the uterus. Time was measured from placement of the clinician's hands on the patient until the measurement was completed.

2.7. Data analysis

We calculated Lin's [3] concordance correlation coefficients and 95% confidence intervals to evaluate the agreement between the following measurements: TGA compared with BPD, FL, and FH measurements taken by emergency medicine personnel; OB ultrasound technician measurements of BPD and FL compared with ultrasound measurements of BPD and FL taken by emergency medicine personnel; and FH measurements taken by obstetricians compared with FH measurements taken by emergency medicine personnel. We found concordance correlation coefficients identical to Pearson correlation coefficients to the second decimal place; thus, we report only concordance correlation coefficients.

We then calculated the average number of days that TGA was overestimated/underestimated by ultrasound measurements and FH measurements.

Finally, we calculated the sensitivity, specificity, and accuracy of the ultrasound measurements and FH measurements against the gold standard of TGA (based on reliable LMP and/or first trimester ultrasound dating) for the determination of fetal viability using 24 weeks as a cutoff value.

Data were entered into a Microsoft Excel spreadsheet (Redmond, WA). Data analysis was performed using Stata version 7.0 (StataCorp LP, College Station, TX).

3. Results

3.1. General results

Eight emergency sonographers performed 96 ultrasound examinations on 38 pregnant patients. Each patient underwent ultrasound by 2 to 5 of the emergency sonographers

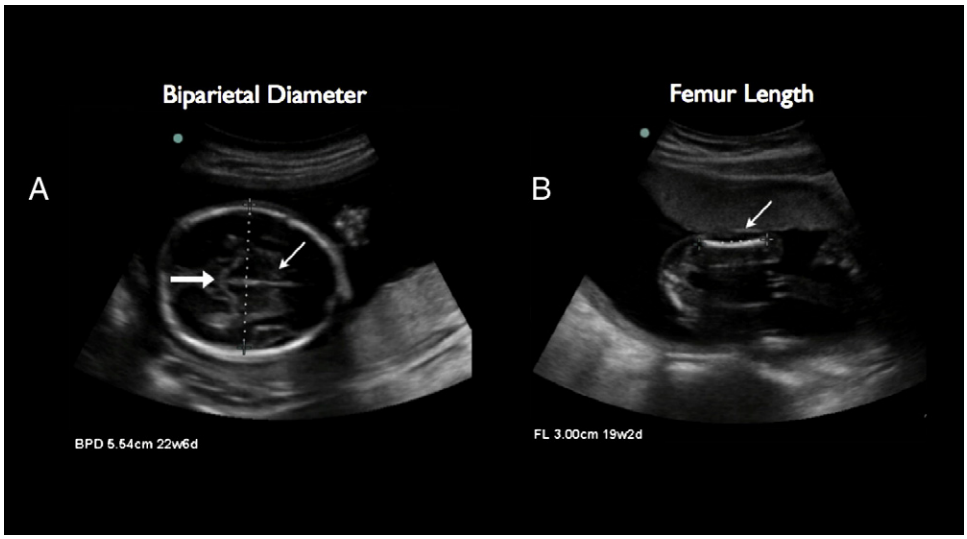

Fig. 1 A, BPD measurement. Note the level of the hyperechoic falx cerebri (thin arrow) and thalamus (thick arrow) shown as a central hypoechoic butterfly-shaped area. Ideally, the ultrasound waves penetrate the calvarium perpendicular to the sagittal plane. Biparietal diameter is measured from the inner table of the skull on one side to the outer table on the opposite side. Calipers are placed to cross the falx cerebri in a perpendicular plane. B, FL measurement. Femur length is measured with the femur perpendicular to the plane of the ultrasound beam for higher accuracy (arrow).

depending on sonographer availability. The patients enrolled in the study had an average age of 26 years (18-35 years), with a mean TGA of 27 weeks (17-38 weeks). Each sonographer performed ultrasound studies on at least 6 subjects (BZ, 24; SS, 66; AN, 8; NT, 28; LF, 20; DP, 16; OW, 6; and GR, 18). The average time required to measure BPD was 51 seconds (17-166 seconds), whereas the average time to measure FL was 59 seconds (18-180.5 seconds). Patients enrolled by individual emergency sonographers did not differ significantly in age or mean TGA. We excluded from analysis 1 ultrasound of a late third trimester twin gestation, which required more than 5000 seconds to complete. We felt exclusion was reasonable because in clinical practice, if the second twin could not be adequately visualized because of position, gestational age estimations would be derived from the more easily visualized twin. Six patients did not have FH measured by an obstetrician at the time of their visit and were thus not included in this portion of the data analysis.

3.2. Measurements

When measurements of BPD and FL made by emergency sonographers were compared with those made by our ultrasound technician, the correlation coefficient was 0.955 (0.937-0.973) for BPD and 0.973 (0.962-0.984) for FL. When measurements by emergency sonographers were compared with TGA, the correlation coefficient was 0.947 (0.926-0.968) for BPD and 0.957 (0.941-0.973) for FL. Each individual sonographer, from novice to expert, obtained similar correlation coefficients (for BPD: SS, 0.924; DP, 0.963; AN, 0.923; BZ, 0.981; NT, 0.941; OW, 0.980; LF, 0.941; and GR, 0.961; for FL: SS, 0.979; DP, 0.939; AN, 0.991; BZ, 0.978; NT, 0.955; OW, 0.995; LF, 0.916; and GR, 0.829). These data are shown in graph form in Fig. 2.

We found that emergency sonographers would have underestimated TGA by an average of 0.32 days (SD, 15.86 days) using BPD and by 2.096 days (SD, 13.79 days) using FL.

When measurements of FH made by ED sonographers were compared with those made by an obstetrician, we found a correlation coefficient of 0.808 (0.733-0.833). When FH measurements made by emergency sonographers were compared with TGA, the correlation coefficient was 0.712 (0.615-0.809). Our data show that emergency sonographers would have overestimated TGA by an average of 8.07 days (SD, 40.7 days) by using FH measurements.

When we determined the ability of EPs to detect fetal viability, we found that the use of BPD yielded a sensitivity of 98.4% and a specificity of 93.9% and that FL yielded a sensitivity of 95.1% and a specificity of 93.9%. The overall accuracy of ED sonographers in predicting TGA for 24 weeks was 96% (181 correct/189 total measurements of BPD and FL) using ultrasound measurements (Table 1).

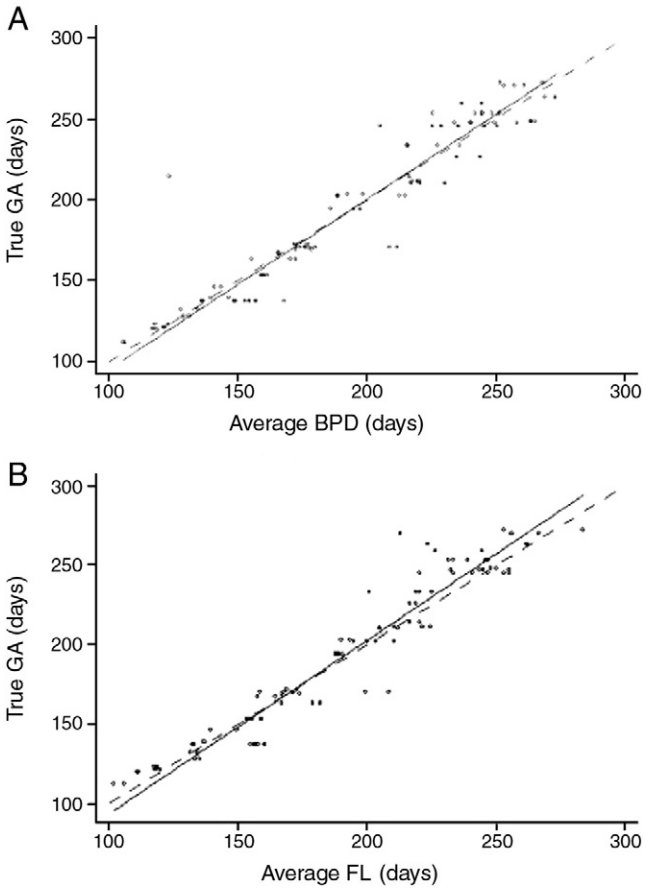

Fig. 2 Scatter plot representation of concordance correlation coefficient for agreement on a continuous measure obtained by 2 methods. Note that for perfect concordance, the data must overlay the dashed line. A, Concordance for all ED sonographer ultrasound measurements of BPD compared with TGA (concordance correlation coefficient, 0.947). B, Concordance for all ED sonographer measurements of FL compared with TGA (concordance correlation coefficient, 0.973).

When we examined the performance of emergency sonographer–performed FH measurement to determine fetal viability, we found a sensitivity of 88.5% and specificity of 63.6% for the detection of fetal viability. The overall accuracy was found to be 80% (75 correct/94 total

Table 1 Test characteristics for Ultrasound and Fundal Height Measurements using TGA >24 weeks as gold standard for viability

	BPD	FL	FH
Sensitivity (%)	98.4	95.1	88.5
Specificity (%)	93.9	93.9	63.6

Overall, ED sonographers accurately predicted gestational age >24 weeks in 96% of ultrasound measurement (181 correct BPD and FL measurements/189 total ultrasound measurements by all sonographers) compared with 80% accuracy for uterine fundal examination (75 correct/94 total measurements).

measurements of FH) for the detection of TGA for 24 weeks (Table 1).

4. Limitations

We identified several important limitations of our study. First, because we studied stable outpatients in a controlled setting, factors that may impact the performance of this technique in actual ED practice were not assessed. These might include additional time required to locate equipment and the need to prioritize other interventions, especially when caring for a critically ill patient.

Second, although providers with a wide range of experience (medical students through RDMS-certified ultrasound director) participated in the study, the relatively limited number of individual participants may not provide results that are widely applicable to physicians with varying levels of ultrasound expertise.

Third, differences in BPD and FL measurements for fetuses of the same gestational age are seen in normal pregnancy owing to parental and other factors, and this is a challenge for ultrasound estimation of gestational age in general.

Although we found BPD to be a similarly accurate but more rapidly measured parameter compared with FL, in any specific clinical situation, a clinician may achieve excellent visualization of one, both, or neither of these structures. In actual practice, emergency sonographers may need to tailor their practice on a case-by-case basis and avoid reliance on 1 measurement at the expense of the other. Future studies with a larger sample of patients may help to further define optimal practice of this technique in the ED.

5. Discussion

To the best of our knowledge, this is the first study that has evaluated the performance of EPs using ultrasound to estimate gestational age in second and third trimester pregnant patients. The high degree of correlation between EP measurements and those made by an ultrasound technician suggests that EPs can expect that their measurements will generally agree with those of formal sonography. Furthermore, the excellent correlation between EP measurements and TGA suggests that EPs can be confident that fetal dating using bedside sonography provides an accurate estimate of actual gestational age. Because the average time to complete a measurement of either BPD or FL measurements took less than 1 minute, our data indicate that these measurements can be made quickly and accurately.

When might EP-performed fetal dating be useful? In cases involving an unstable patient who is unable to provide any historical information, clinicians must rely on an immediate physical assessment to estimate gestational age. Without the use of emergency bedside ultrasound, the most immediate way to estimate gestational age in the nonverbal patient is through physical examination of the FH. Our data suggest that sonography is more accurate than FH measurement in this regard, albeit at a slightly greater time cost. Even when caring for patients who are able to provide a date for LMP, clinicians may choose to incorporate sonographic measurements into their final estimate of gestational age, as prior research suggests that the use of LMP to determine gestational age can be inaccurate [1] and that even a single second trimester sonogram may be more reliable [4,5].

Finally, we wish to emphasize the potential importance of ultrasound in cases where a fetus may be on the cusp of viability. In settings where emergent cesarean delivery is considered, an accurate estimate of gestational age is critical, as the consequences of both action and inaction are profound. Our study included a range of gestational ages above and below 24 weeks and found that ultrasound performed exceedingly well in differentiating between fetuses above and below this value. Conversely, the use of FH measurement also would have miscategorized one fifth of gestations, leading to potentially disastrous outcomes had actual management decisions been made with these findings. For this reason, we believe that, although a bedside ultrasound should never replace formal OB sonography, it should be available to EPs and obstetricians facing time-sensitive decisions when formal sonography is unavailable.

In conclusion, our study found that EPs with limited, goal-directed training in OB ultrasound were able to quickly and accurately estimate gestational age in second and third trimester pregnancies using ultrasound measurement of BPD and FL. These measurements were more accurate than FH estimations by both obstetricians and EPs. Given these data, EPs may wish to incorporate ultrasound into a strategy for evaluating fetal age in the ED.

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