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Mercer,J.P.; Brenner,W.E.; Bolan,J.C.; Dingfelder,J.R.; Edelman,D.A.; Staurovsky,L.G.

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PRACTICABILITY OF ULTRASONOGRAPHY FOR ASSESSING FETAL AGE AND WEIGHT IN EARLY PREGNANCY

By

Jack P. Mercer, M. D.*+

William E. Brenner, M. D.*

Jean C. Bolan*

James R. Dingfelder, M. D.*

David A. Edelman, Ph.D.**

Linda G. Staurovsky, C.N.M.*

*Department of Obstetrics and Gynecology, University of North Carolina School of Medicine, Chapel Hill, North Carolina 27514

**International Fertility Research Program, Research Triangle Park, North Carolina 27709

+Deceased

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ABSTRACT

To assess the feasibility and accuracy of the B-Scan technique for measuring biparietal diameter (BPD) in utero, the accuracy of B-Scanning for predicting fetal age and weight, and determining parameters of fetal growth in pregnancies prior to 21 weeks' gestation, 41 subjects underwent diagnostic ultrasonography prior to induction of therapeutic abortion with Prostaglandin $F_{2\alpha}$. Following abortion, fetal crown to rump length (CRL), crown to heel length (CHL), BPD and fetal weight were measured directly. After 13 menstrual weeks' gestation the BPD could be accurately measured by ultrasound. The relationship of BPD to gestational age and fetal weight, and fetal growth indices as measured by the CRL and CHL were established with 90 percent confidence. It was concluded that ultrasound was a useful adjuvant to our clinical assessment of fetal age and weight in patients from 13 to 21 menstrual weeks' gestation.

INTRODUCTION

Estimates of fetal growth, size, age, and maturity are important factors for the clinical assessment and care of both patients who continue their pregnancies to term and occasionally for patients who request second trimester therapeutic abortions. Using ultrasound, pregnancy can be diagnosed as early as the fifth week of gestation,[5] fetal weight can probably be estimated during the second trimester, and serial ultrasound measurements can be used throughout pregnancy to evaluate fetal growth, size, and maturity.[9,12]

Several investigators[1,5,6,10,11] have reported the direct measures of crown-rump length, crown-heel length, biparietal diameter (BPD), and fetal weight after delivery. The BPD at each gestational age and its relationship to fetal weight have been documented in pregnancies after 20 menstrual weeks' gestation.[3,11] However, the estimates of BPD prior to 20 menstrual weeks and correlations with fetal weight have been derived by either extrapolating from values obtained after 20 weeks' gestation or from only a few subjects.[3,6] Results obtained from patients undergoing saline abortion may be misleading because fetal death usually occurs rapidly after saline administration, and there are probably significant weight and size changes in the fetus and placenta after exposure to hypertonic saline.[1] Fetuses fixed in formalin or embalmed also have significant weight changes.[10]

Since it has been reported that the fetal BPD can usually be measured by ultrasound from about the thirteenth week of gestation, the in utero measurement of BPD may be useful as a predictor of fetal age and size. Fetuses aborted with the intraamniotic administration of Prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) probably do not change in weight or size significantly since they usually die late in labor and they are not exposed to a hypertonic environment.

This study was conducted to evaluate 1) the feasibility and accuracy of the B-Scan for measuring the BPD in utero, 2) the accuracy of the B-Scan technique for predicting fetal age and weight, and 3) parameters of fetal growth in pregnancies prior to 21 menstrual weeks' gestation.

METHODS AND MATERIALS

Forty-one patients who requested a therapeutic abortion underwent diagnostic ultrasonography by one author (J.M.) prior to induction of abortion, using the Compound B sonographic scanning technique according to the method of Donald.[4] After completion of the abortion, fetal crown-rump length (CRL), crown-heel length (CHL), biparietal diameter (BPD), and weight were measured. When the fetus was distorted during the abortion and accurate measurement of one or more of the parameters was not possible, the case was eliminated from a specific analysis.

For each subject gestational age was based on the following: 1) the number of completed weeks from onset of their last normal menstrual periods (LMP), 2) fundal size, and 3) physical examination.

Among patients who requested a therapeutic abortion, and who could not be followed to term, there was no best method of determining the patient's gestational age when the estimates based on LMP, fundal size, and physical examination did not agree. All three estimates were subject to various errors, and parameters of fetal growth did not appear to correlate better with either LMP, fundal size, or estimation from physical examination. There, a composite gestational age for each patient was computed as follows:

1) If the three estimates of gestational age were within three weeks of each other, the patient's gestational age was calculated as the

average of the three estimates rounded to the nearest week.

2) If two estimates of gestational age were within two weeks of each other, but the third estimate differed by more than three weeks from either of the other two estimates, the patient's gestational age was calculated as the average of the two estimates rounded to the nearest week.

The data were analyzed using linear regression methods.[7]

RESULTS

Ultrasonography

Feasibility

After 16 menstrual weeks' gestation the BPD could be measured in all patients (Figure 1). Prior to 11 weeks' gestation only a yolk sac was identified. Only after 13 weeks' gestation was the BPD accurately measurable in more than 50 percent of the subjects.

Accuracy

The biparietal diameter measured indirectly in utero by B-Scan correlated well with the BPD measured directly on the fetus after delivery (Figure 2).

The variability between the two measurements (mean difference 0.96 mm) was small and was not significantly different from zero ($P > 0.10$). Differences did not appear to be larger at any specific size and one means of measurement did not appear to be consistently larger than the other. Differences between the two BPD measurements did not depend on gestational age.

Fetal Age and BPD

The relationship of sonar BPD and gestational age was not linear, particularly below 18 weeks' gestation (Figure 3). The regression of

BPD on gestational age is given by

$$\ln_e (\text{BPD}) = 2.431 + 0.071 \text{ (Gestational Age)} \quad s = 0.075$$

The 90 percent lower and upper confidence limits on a future BPD are 24.9, 33.0 mm at 13 weeks' gestation, and 44.2, 58.0 at 21 weeks' gestation.

The 50 and 90 percent confidence limits on gestational age for a given BPD are presented in Table I for selected BPD values. These limits show that for a given BPD, gestational age can be estimated within $\pm$0.8 weeks with a confidence of 50 percent and within $\pm$2.0 weeks with a confidence of 90 percent. Either 50 or 90 percent confidence limits for a BPD value other than shown in Table I can be obtained by linear interpolation of the tabular values.

Fetal Weight and BPD

For ultrasound derived BPDs in the range of 32-53 mm, fetal weight appears to be linearly related to BPD. The regression equation of fetal weight on BPD is given by

$$\text{Fetal weight} = -441.1 + 15.26 \text{ (BPD)} \quad s = 31.3 \text{ gms}$$

The 90 percent confidence limits for a fetal weight for a specific BPD are obtained by the expected fetal weight, calculated from the above equation, $\pm$57 gms (Figure 4). However, the lower confidence limit is obviously not valid for BPDs of less than 32 mm since the corresponding fetal weight is negative. The relationship between fetal weight and BPD is curvilinear when BPD is less than 32 mm.

Fetal Growth

Crown-to-Rump Length

Crown-to-rump length (CRL) appears to be linearly related to fetal age in the 13 to 21 menstrual week gestational age period (Figure 5). The calculated regression from the 34 pairs of coordinate values of gestational age and CRL are given by

$$CRL = -6.73 + 1.3 \text{ (Gestational Age)} \quad s = 1.82 \text{ cm}$$

For a patient of a specific gestational age (13 to 21 weeks), the expected CRL is obtained by the above equation, and the 90 percent confidence limits on a future CRL are given by the expected CRL $\pm$3.5 cm.

Crown-to-Heel Length

Crown-to-heel length (CHL) appears to be linearly related to fetal age in the 13 to 21 menstrual week gestational age period (Figure 6). The calculated regression from 31 pairs of coordinate values of gestational age and CHL are given by

$$CHL = -10.25 + 1.68 \text{ (Gestational Age)} \quad s = 2.93 \text{ cm}$$

For a patient of a specific gestational age (13 to 21 weeks), the expected CHL is obtained by the above equation and the 90 percent confidence limits on a future CHL are given by the expected CHL $\pm$ 5.3 cm.

DISCUSSION

While B-Scanning appears to be feasible and accurate enough to be clinically useful for determining fetal age and fetal weight during the initial 21 weeks of gestation, there appear to be specific limitations.

After 13 weeks the BPD was measurable and accurate by B-Scan in more than one-half of the patients and after 16 weeks' gestation, the BPD was reliably measurable in all subjects. It appears that the 90 percent confidence limits for using BPD to establish fetal age are ± two weeks and for fetal weight ±57 grams in the 13 to 21 weeks' gestational age group.

Although it would be desirable to determine ultrasonic measurement of the BPD, fetal age, and fetal weight in early pregnancy more precisely, measurement of the BPD appears to be useful for the clinical management of many patients. Not only is there some variation of fetal weight at each gestational age but there appears to be variation attributable to inaccuracy of correctly establishing gestational age in all patients. To care for his patient properly the physician must be aware of the limitation of ultrasonography and interpret the derived estimate of fetal age and weight within the context of all of the other pertinent clinical data. Hopefully, improved methods of fetal monitoring and measurement of other determinants of fetal size such as CRL[8] or a combination of measurements will significantly improve the estimate of gestational age and weight based on BPD alone.

Ultrasound assessment of fetal age and size during early pregnancy would be useful for clinical and research purposes. Among patients undergoing therapeutic abortion, a potentially viable fetus is occasionally delivered because estimates of gestational age and fetal size by the patient's last normal menstrual period and uterine size were inaccurate. This problem may be less frequent if ultrasound assessment is performed in cases where gestational age by conventional parameters is in doubt. Occasionally amniocentesis is attempted in a first trimester patient who has unrecognized gynecological pathology or a hydatidiform mole that the physician interprets to be a uterus of a minimum of 16 weeks' size. Such cases may be less

frequent if ultrasound is used to assess fetal age in selected patients. Similar assessment would be useful in patients undergoing amniocentesis as part of genetic counseling since the optimal time for diagnostic amniocentesis appears to be about 16 menstrual weeks' gestation. Failed amniocentesis, failure to grow cells, and having to delay the abortion in affected cases may be less frequent if ultrasound is used in cases where gestational age based on conventional methods is in doubt. In patients with high risk pregnancies, the ultrasonic assessment of fetal age in early pregnancy and repeated examinations in later pregnancy may allow for better planning of therapy and assessment of an appropriate time for intervention in those cases where early delivery is appropriate. Ultrasound in early pregnancy with serial examinations in later pregnancy appears to be an important research method to study fetal growth in normal and high risk pregnancies. Growth responses to specific therapy in patients with growth retardation can be assessed.

While these results of the relationship of BPD and gestational age during this period of pregnancy are similar in magnitude with those reported by other investigators, the rate of growth is different. Campbell and Newman[3] using B-Scan values obtained throughout pregnancy from patients delivered at term reported a linear rate of BPD change (Figure 7). In contrast the values derived in the present study during the thirteenth to twenty-first menstrual week appeared to be curvilinear.

Four differences between the two studies are apparent. There were different 1) operators, 2) sonar equipment, 3) patient population, and 4) study techniques in the two studies. Although it cannot be determined how much of the difference can be attributed to the operators and equipment,

in the present study B-Scan BPD measurements correlated well with the directly measured BPD after termination of pregnancy. In this study the BPD may be slightly higher because not all BPDs could be measured in patients below 16 weeks' gestation and those that were measured may have been the larger fetuses of that specific age group. Some of the differences may have been in the manner gestational age was established and data was selected. In Campbell and Newman's study only BPD values from uncomplicated pregnancies delivered at term of babies within the fifth percentile of weight were selected. Since the present study values were derived from patients undergoing therapeutic abortion, no selection was made. This difference between the studies may have accounted for the slightly higher but statistically insignificant differences in BPD values reported by Campbell and Newman after 16 weeks' gestation.

In spite of there being differences between the two studies, it is doubtful that the relationship of BPD to gestational age is linear throughout early pregnancy. If the linear line is extrapolated to 0.0 mm BPD, it would cross at about 10 menstrual weeks' gestation. In contrast, when the curvilinear line is extrapolated to 0.0 mm BPD it crosses at about six menstrual weeks' gestation; an observation that is more compatible with direct BPD measurements at this gestational age.

The mean BPD in relationship to weight appears to increase more rapidly in early pregnancy than it does in later pregnancy (Figure 8). Based on data reported by Thompson and Makowski[11] the relationship of BPD is also linear at higher fetal weights but at a different slope from that observed in the present study at lower fetal weights. These two slopes would be anticipated by the known relationships between fetal BPD[11] and fetal

weight[2] with gestational age. Unfortunately, data are not available to complete the relationship between BPD and fetal weight with direct measurements.

Fetal length as measured by crown-to-rump length and crown-to-heel length appear to increase linearly during pregnancy while fetal skull si: as measured by BPD appears to increase in a curvilinear manner during the period from 13 to 21 menstrual weeks' gestation. Crown-to-heel length has more variability than crown to rump length[10] as might be anticipated since crown-to-heel length is more subject to slight errors in measurement. While there is probably some variation in these parameters of fetal growth at different weeks gestation, some of the variation in this and other studies is due to errors in establishing gestational age in all patients. Since estimates of gestational age from either last normal menstrual period, uterine size, or the physician's estimate alone were grossly inaccurate, a composite estimate was derived based on all of these traditional parameters to provide a more accurate measure of gestational age to evaluate BPD, CRL, and CHL. This method of computing menstrual age and the small distortion of the fetus that occurred during $PGF_{2\alpha}$-induced abortion resulted in similar mean values for CHL, CRL, and BPD as those reported after spontaneous or saline-induced abortion or pregnancies followed to term[1,6,9,10] but often resulted in smaller ranges within the 90 percent confidence limits.

Ultrasound appears to be both a feasible, and a useful adjuvant to clinical practice in early pregnancy. The fetal BPD, gestational age, fetal weight, CRL and CHL can be estimated within specific limits of confidence. Parameters of fetal growth during the 13 to 21 menstrual weeks'

gestational age have been documented. Hopefully, investigators will conduct additional studies in which ultrasound is used to obtain in utero measurements of fetal size in addition to BPD so that improved estimates of fetal age and growth may be obtained.

TABLE I

FIFTY AND NINETY PERCENT CONFIDENCE LIMITS ON GESTATIONAL AGE FOR A GIVEN BIPARIETAL DIAMETER

Biparietal Diameter (mm)	Confidence Limits On Gestational Age (Weeks)			
	50 Percent		90 Percent	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit
25	10.1	11.8	8.9	13.1
30	12.8	14.4	11.6	15.6
35	15.0	16.5	13.9	17.7
40	17.0	18.5	15.8	19.6
45	18.7	20.2	17.5	21.3
50	20.2	21.7	19.0	22.8
55	21.5	23.1	20.3	24.3

TITLES AND LEGENDS

Table I — Title: Fifty and Ninety Percent Confidence Limits on Gestational Age for a Given Biparietal Diameter

Figure 1 — Title: Ultrasound Results

Legend: The proportion of 41 subjects with yolk sac, a fetal head not identifiable or an identifiable fetal head that the physician believed an accurate BPD could be measured at each week of gestation are graphed.

Figure 2 — Title: Actual Biparietal Diameter Versus B-Scan Measured Biparietal Diameter

Legend: The biparietal diameter (BPD) in millimeters as measured directly on the delivered fetus versus the BPD as measured in utero by B-Scan are graphed.

Figure 3 — Title: Biparietal Diameter By Gestational Age

Legend: The mean biparietal diameter in millimeters as measured by B-Scan among the patients at different gestational ages in menstrual weeks (•—•) with upper and lower 90 percent confidence limits (•---•) are graphed.

Figure 4 — Title: Biparietal Diameter By Fetal Weight

Legend: The mean fetal weight in grams for subjects with various B-Scan measured biparietal diameters

(⟵) with 90 percent confidence limits (---) are graphed.

Figure 5

Title: Crown-Rump Length By Gestational Age

Legend: The mean direct crown to rump length in centimeters (⟵) with 90 percent confidence limits (---) at different menstrual weeks' gestation are graphed.

Figure 6

Title: Crown-Heel Length By Gestational Age

Legend: The mean crown to heel length in centimeters (⟵) with 90 percent confidence limits (---) at different menstrual weeks' gestation are graphed.

Figure 7

Title: Biparietal Diameter By Gestational Age

Legend: The mean biparietal diameter as measured by ultrasound at different menstrual weeks' gestation as reported by Campbell, S. and Newman, G. B. J. Obstet. Gynaec. Brit. Commonw. 78: 513-519, 1971 in 574 patients who delivered at term are portrayed with the results of values obtained in the present study from 25 subjects between 13 and 21 weeks' gestation who were aborted.

Figure 8

Title: Biparietal Diameter By Fetal Weight

Legend: The mean biparietal diameter among 1079 fetuses of different weights above 1,400 gms as reported by Thompson, H. E. and Makowski,

Figure 8
(continued)

E. L. in Obstet. Gynec. 37: 44-47, 1971 and among 26 fetuses less than 400 gms in the present study.

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