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Full Length Research Paper

Sonography in fetal birth weight estimation

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The estimation of fetal birth weight is an important factor in the management of high risk pregnancies. The information and knowledge gained through this study, comparing a combination of various fetal parameters using computer assisted analysis, will help the obstetrician to screen the high risk pregnancies, monitor the growth and development, and determine the gestational age and weight of fetuses more accurately. A prospective ultrasonic study of 120 booked pregnant patients, with singleton pregnancies, at term, without any chronic illness was done 1 - 20 days prior to delivery. Measurements of their head and abdominal circumference (HC and AC), biparietal diameter (BPD) and femur length (FL) were obtained to calculate the fetal birth weight. Computerized statistical evaluation was done using various internationally recognized models and results were compared with actual birth weight at delivery. The gestational age at delivery was between 37 - 42 weeks. The age range of patients was between 16 - 41 years, with a mean of 30.7 years. The actual range of birth weights was 2500 - 4700 g, with a mean of 3390 g (SD 381). This study showed that regression models incorporating HC and AC were not as good as those using AC and BPD. The use of femur length and abdominal circumference, AC/FL, did not improve accuracy. The use of multiple parameters, gives the most accurate prediction of fetal weight.

Key words: Sonography, birth weight, head, abdominal circumference, biparietal diameter, femur length.

INTRODUCTION

It has long been established that birthweight is a major determinant of infant mortality in the first year of life (Steer et al., 1995), and that mortality rates are more sensitive to birthweight than gestational age (Williams et al., 1982). Hence the importance attached to antenatal birthweight determination. The use of ultrasound for determination of fetal weight spans over three decades now, with varied attempts at the use of different biophysical parameters, (Ben-Haroush et al., 2004; Chauhan et al., 1998). Initial attempts to estimate fetal weight by ultrasound were made on the basis of measurements of individual single fetal parameters such as the Biparietal Diameter (BPD) or Abdominal Circumference (AC), (Campbell and Wilkin, 1975). Weight estimates obtained by these parameters were found to have high standard deviation up to 11.9% (Hadlock et al., 1984). Subsequent reports demonstrated that accuracy of the estimate was improved by the use of multiple fetal parameters (Ben-Haroush et al., 2004; Chauhan et al., 1998; Campbell and Wilkin, 1975; Hadlock et al., 1984; Scioscia et al., 2008). The methods that gave reasonably accurate results and the simplest to apply are those based on the use of two parameters, namely, abdominal circumference (AC) in combination with biparietal diameter (BPD) or femur length (FL) (Ben-Haroush et al., 2004; Hadlock et al., 1984).

Further attempts to improve the predictive value of sonography in fetal weight estimation have resulted in the use of more parameters combined. Hadlock et al. (1984) showed that using FL in addition to head measurements and abdominal measurements significantly improved fetal weight estimation (Chauhan et al., 1998; Hadlock et al., 1984; Salomon et al., 2007; Peregrine et al., 2007). More recently, the addition of thigh circumference to head, abdominal and femur length measurements gave even better predictive value and hence better identification of high risk pregnancies (Hadlock et al., 1984).

This study is done to obtain an estimated fetal weight from the fetal parameters of HC-AC, BPD-AC and FL-AC,

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Table 1. Distribution of patients by ultrasound gestational age.

Weeks	No of fetuses Scanned (%)	BPD (Mean ± SD)	AC (Mean ± SD)	HC (Mean ± SD)	FL (Mean ± SD)	GA (Mean ± SD)	Wt (Mean ± SD)
37	16(13.3)	9.0±0.2	33.5±1.7	32.9±0.1	7.2±0.1	36.3±0.2	3081.3±303.8
38	54(45)	9.2±0.2	34.4±1.8	33.9±1.2	7.3±0.1	37.0±0.2	3338.9±384.6
39	44(36.7)	9.4±0.2	35.1±1.9	34.4±1.2	7.4±0.1	37.8±0.3	3520.5±336.6
40	6(5)	9.7±0.1	36.1±1.8	34.5±1.6	7.5±0.1	38.7±0.3	3683.3±213.7

and to highlight the predictive value of this procedure, by comparing the estimated fetal weight with the actual birth weight.

MATERIALS AND METHODS

One hundred and fifty booked pregnant patients at the Antenatal Clinic of the Lagos State University Teaching Hospital (LASUTH) were recruited counselled and informed consent obtained. The hospital research and ethics committee approved the study protocol. Inclusion criteria in the study were term pregnancy (37 and 42 weeks), reliable date of last menstrual period, regular menstrual cycle, close correlation between menstrual age and clinical gestational age measurements. Patients with malpresentation, maternal diseases such as gestational diabetes, pulmonary tuberculosis, multiple pregnancy, antenatal diagnosis of congenital fetal malformation or advanced labour were excluded. All patients were asked to present early on noticing signs of labour and examined by the obstetrician. Once the diagnosis was confirmed, the ultrasound examination was carried out.

All examinations were performed using a Dynamic Imaging Concept MC real time ultrasound machine with a 3.5 MHz curvilinear transducer. Measurements were made with calibrated caliper on the machine on frozen images using the mapping method. Computer assisted analysis was performed using SPSS statistical soft ware after collation of data.

Head circumference measurement was made at the fetal plane described by Campbell and Thomas (1977).

Biparietal diameter measurement was made on the same frozen image for the head circumference, at the level of the thalami, from outer to the inner table of the skull (Campbell and Thomas, 1977), (Figure 1).

Abdominal circumference was made on the fetal plane described by Campbell and Wilkin (1975). Circumferences were measured on the outer margin of the abdomen using internal calipers by direct tracing (mapping) (Campbell and Wilkin, 1975), (Figure 2).

Femur Length measurements are made using the method described by O'Brien et al. (1981) and Peregrine et al. (2007), (Figure 3). To forestall error of measurement due to shadowing of their structures, superimposition and poor alignment, three images were measured and measurements within range of 2 mm were accepted (O'Brien et al., 1981).

Head circumference, abdominal circumference, biparietal diameter and femur length measurements were obtained from each fetus scanned and recorded in centimeters (cm). All measurements were made within 1 - 20 days to delivery.

Estimated fetal weights (EFW), in grams, were calculated using various models that combine two parameters of AC, BPD; AC, FL; and AC, HC; also various models that combine the three parameters of AC, BPD and FL.

These models did not consider the scan delivery interval (SDI). The formulae (models) used for obtaining the estimated fetal weight are (Two parameters), (Hadlock et al., 1984; Shepard et al., 1982).

i. AC/BPD = EFW (Shepard) = $10^{1.25-0.00265BPD*AC+0.046AC+0.166BPD}$

ii. AC/FL – EFW (Hadlock) = $10^{1-3598-0.0037ac *FL + 0.051AC + 0.1844FL}$

iii. AC/HC – EFW (Hadlock) = $10^{1.182+0.0273(HC) + 0.07057(AC) - 0.00063 (AC)2 - 0.0002184(HC*AC)}$

(Three parameters of AC/BPD/FL) (Hadlock et al., 1984; Deter et al., 1981; Nzeh, 1992).

Deter model – $Log_{10}BW$ = 1.335-0.0034 AC* FL + 0.0416BPD + 0.0457 + 0.12623FL

i. Nzeh model – Log_{10} BW = 0.470 + 0.488 $Log_{10}BPD$ + 0.554 $Log_{10}FL$ + 1.377 $Log_{10}AC$

ii. Hadlock model – $Log_{10}BW$ = 1.4787 – 0.003343 (AC*FL) + 0.001837 $(BPD)^2$ + 0.0458 $(AC)^2$ + 0.518 (FL).

Mean deviation measurements

The expected fetal weight values using the different models (formulae) were compared in two different categories, those utilizing two parameters, involving the abdominal circumference and either the biparietal diameter, head circumference or the femur length, and those utilizing three parameters of abdominal circumference, biparietal diameter and femur length.

The mean standard deviation and correlation of each week group was calculated by computer statistical evaluation for all the models and the mean difference between the predicted (expected) and the actual weight was calculated for each model using standard methods and expressed as a percentage of the actual weight, calculated by the formula below (Hadlock et al., 1984).

Mean deviation percentage = predicted weight/ actual weight x 100.

Level of significance was set at $p < 0.05$ (5%)

The mean value of the fetal parameters obtained by ultrasound at different gestational age groups was recorded in cm and the mean of the actual birth weight at delivery, recorded in grams.

RESULTS

Only one hundred and twenty patients met the inclusion criteria for the study. The age range of the patients was between 16 - 41 years with a mean of 30.7 years. The actual range of birth weights was 2500 – 4700 g, with a mean of 3390 g (SD 381). The distribution of patients by ultrasound gestational age grouping is shown in Table 1.

The mean of the expected weights of the different models utilizing two parameters only, with the standard deviation in various week groups and the mean of the actual weights in these groups is shown in Table 2A.

Table 2B shows the mean deviation percentage of the week groups and the p value. For 37 weeks, the least bias is Shepard model incorporating the BPD/AC with a

Table 2A. Estimated fetal weight using two parameters.

Gestational age (weeks)	EFW (Shepard) BPD/AC Mean ± SD	EFW (Hadlock) FL/AC Mean ± SD	EFW (Hadlock) HC/AC Mean ± SDD	Actual weight Mean ± SD
37	3088±275	3192±309	3301±139	3081±303
38	3342±334	3405±345	3424±154	3338±384
39	3599±342	3599±389	3506±163	3525±336
40	3943±339	3827±398	3577±224	3683±213

Table 2B. Mean deviation (expressed as % of actual weight) and the p value using two parameters.

Gestational age (weeks)	EFW (Shepard) BPD/AC mean deviation %	P value	EFW(Hadlock) FL/AC mean deviation %	P value	EFW (Hadlock) HC/AC mean deviation %	P value
37	0.23	0.473	3.60	0.003	7.14	0.006
38	0.11	0.481	2.00	0.066	2.57	0.087
39	2.09	0.142	2.09	0.389	-0.53	0.347
40	7.06	0.971	3.91	0.209	-2.88	0.218

Table 3A. Estimated fetal weights using three parameters.

Gestational age (weeks)	EFW (Deter) AC/BPD/FL Mean ± SD	EFW (Hadlock) AC/BPD/FL mean ± SD	EFW (Nzeh) AC/BPD/FL mean ± SD	Actual weight Mean ± SD
37	3161±266	3290±123	3510±30	3081±303
38	3389±308	3392±136	3533±32	3338±384
39	3609±337	3488±143	3555±32	3525±336
40	3886±358	3607±150	3581±34	3683±213

mean deviation percentage of 0.23 and p value of 0.47 indicating that there is no significant difference in the means. The FL/AC and HC/AC models by Hadlock significantly overestimated the weight, with a mean deviation percentage value of 3.60; 7.14 and a p value of 0.003; 0.006 respectively.

For 38 weeks, the Shepard model demonstrated the least bias though overestimates by the other models were not significant.

At 39 weeks the mean deviation percentage for AC/BPD and AC/FL by Shepard and Hadlock is 2.09 with p value of 0.142 and 0.398 respectively suggestive of insignificant overestimation while the AC/HC model underestimated the weight, mean deviation percentage of -0.53, though not significantly ($p > 0.05$).

At 40 weeks both AC/BPD and AC/FL models overestimated the weight, though insignificantly, while AC/HC model underestimated the weight insignificantly.

The mean of the expected weights of different models utilizing three parameters of AC/BPD/FL, with the standard deviation in various week groups and the mean of the actual birth weights in these groups is shown in Table 3A while Table 3B shows the difference in the means, expressed as percentage of actual birth weight.

At 37 weeks, the Deter model shows the least bias (mean deviation % 2.60; $p = 0.218$) with an insignificant overestimation. Both Hadlock and Nzeh models signifycantly overestimated the weights ($p < 0.05$)

Both Deter (mean deviation % 1.53; $p = 0.228$) and Hadlock (mean deviation % 1.61; $p = 0.169$) models, at 38 weeks showed minimal insignificant overestimate. Though the least bias is still the Deter model. The Nzeh model, Nzeh et al. (1992), significantly overestimated the weight.

The Nzeh model showed the least bias at 39 weeks, with a very minimal overestimation, which is not signifycant (mean deviation % 0.85; $p = 0.351$). The Hadlock model, Hadlock et al. (1984) under estimated while the Deter model, Deter et al. (1981), overestimated; though insignificantly.

At 40 weeks, both Nzeh (mean deviation % -2.77; $p = 0.135$), and the Hadlock (mean deviation % -2.06; $p = 0.246$) model underestimated the weight though insignificantly ($p > 0.05$). The Deter model largely overestimated the weight (mean deviation percentage 5.51; $p = 0.131$). Table 4 compares several models considered in this study, the mean, mean deviation, percentage correlation and the corresponding p values. All models overestima-

Table 3B. Mean Deviation (expressed as % of actual weight) and the p value using three parameters.

Gestational age (weeks)	EFW (Deter) AC/BPD/FL mean deviation%	p value	EFW (Hadlock) AC/BPD/FL mean deviation%	p value	EFW(Nzeh) AC/BPD/FL mean deviation%	P value
37	2.60	0.218	6.78	9.998	13.92	0.000
38	1.53	0.228	1.61	0.169	5.84	0.000
39	2.38	0.112	-1.05	0.261	0.85	0.251
40	5.51	0.131	-2.06	0.246	-2.77	0.135

Table 4. Comparison of all models in this study.

Parameters	Model	Mean ± SD	Mean deviation %	Correlation	P value
AC/BPD	Shepard	3430±387	1.1	0.72	0.208
AC/FL	Hadlock	3469±391	2.3	0.71	0.056
AC/HC	Hadlock	3444±173	1.5	0.71	0.078
AC/BPD/FL	Deter	3463±361	2.1	0.72	0.063
AC/BPD/FL	Nzeh	3540±036	4.4	0.71	0.000
AC/BPD/FL	Hadlock	3424±157	1.0	0.72	0.181

ted the birth weight to varying degrees, the least bias is shown by the AC/BPD/FL, Hadlock model, utilizing three parameters (mean deviation percentage 1.0; p = 0.181)

Three models, Hadlock (AC/BPD/FL), Deter and Shepard showed high correlation of 0.72 each while other models show a lower correlation of 0.71. All models overestimated the weight but only in the Nzeh model was the bias significant.

DISCUSSION

Accurate estimation of fetal weight has been shown to reduce perinatal morbidity and mortality associated with high risk pregnancy such as intrauterine growth retardation, macrosomia and prematurity (Williams et al., 1982).

Regression equation incorporating AC and BPD offer a better model for weight estimation than AC and FL. AC and BPD model by Shepard showed the least bias among the models utilizing two parameters. These findings were in agreement with the study of Nzeh et al. (1992). The model also gives a good result for fetuses between 36 and 37 weeks and a weight range of 2778 and 3722 g with a mean deviation range of 0.11 to 0.23%. Jordan and Jordaan (1983), evaluating regression model utilizing HC and AC, got a better result than using AC and BPD with a systemic error of 2.5%.

This is not corroborated by this study where the mean deviation is 1.5% using HC and AC compared with 1.1% of AC and BPD. The difference observed between this study and that of Jordan (Hadlock et al., 1984; Jordaan, 1983), may be due to anthropological differences between the two populations studied.

This study agrees with Hadlock's, Hadlock et al. (1984) findings which showed that regression models incorporating HC and AC, were not as good as AC and BPD as observed in the Shepard model, (Hadlock et al., 1984; Peregrine et al., (2007). This does not rule out that weight estimate may be adversely affected by shape of the fetal head.

Thurnau et al. (1987), using a simple linear regression equation incorporating BPD and AC observed good results in fetuses less than 2,500 g reporting a random error of 9.3%. Although their work was limited to fetuses below 2,500 g, Hadlock et al. (1984) found that using this regression model resulted in significant overestimation below 1,500 g and significant underestimation above 2,000 g, (Salomon et al., 2007; Peregrine et al., 2007). This was however not corroborated in this study as the fetal weight in this study were above 2,500 g yet only a systemic error of 1.1% was observed.

The addition of FL to head and abdominal parameters is expected to significantly improve the estimated fetal weight results, (Hadlock et al., 1984), because femur length is directly related to the crown-heel length (Fakeka and Kosa, 1978).

However in this study, the addition of femur length to abdominal circumference, AC/FL, did not improve accuracy. This is in agreement with the observation of Nzeh et al. (1992) and contrary to Hadlock et al. (1984) that concluded that AC/FL is more accurate than AC/BPD, (Hadlock et al., 1984; Salomon et al., 2007).

The FL and AC model will give acceptable results in situation where the head cannot be properly imaged; it also shows a narrow range of mean deviation between 2.0 to 3.91% and good results between 3000 to 3800 g (37 to 39 weeks) fetuses.

The use of multiple parameters especially those utilizing abdominal circumference, biparietal diameter and femur length gives the most accurate prediction of fetal weight (Chauhan et al., 1998; Hadlock et al., 1984; Nzeh et al., 1992). This is in agreement with the finding of this study using the Hadlock model, Hadlock et al. (1984).

The formula found most useful for estimating fetal birth weight among the models studied was the Hadlock model, (Hadlock et al., 1984; Salomon et al., 2007; Peregrine et al., 2007), utilizing three parameters of abdominal circumference, biparietal diameter and femur length.

Measurement of AC has been found to be less accurate in cases of oligohydramnious because the fetal skin edge may be difficult to identify when liquor volume is diminished (Nzeh et al., 1992).

Conclusion

This study demonstrates that multiple parameters especially those utilizing AC, BPD and FL give the most accurate prediction of fetal weight. In situations where the head is deeply engaged making adequate head measurement difficult, as found in about 22% of cases, models not using head measurements but incorporating femur length may be adopted.

Accuracy of a given formula decreases as the model deviates from the population from which it is derived, therefore, population specific measurements should be done since anthropological variations may change the various coefficients.

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