ROLE OF VOLUME(THREE DIMENSIONAL) ULTRASOUND IN ESTIMATION OF FETAL WEIGHT IN APPROPRIATE AND INAPPROPRIATE FETAL GROWTH

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ABSTRACT

This observational prospective study was approved by the council of the gynecology and obstetric department 2009 to evaluate the role of volume (3D) ultrasound as a new method for more accurate estimation of fetal weight than conventional 2D ultrasound.

Research methodology: One hundred and thirty-five women prospectively underwent two-dimensional and three-dimensional ultrasonography within 7 days of delivery. Birth weights (BWs) ranged from 1700 to 4550 g. Fetal measurements were extracted using volume datasets for biparietal diameter, abdominal circumference, femur diaphysis length, and fractional thigh volume. Fractional limb volumes were manually traced from a central portion of the femur diaphysis. Median percentage differences were calculated for EFW. The sensitivity of EFW within 10% of BW were calculated for the following formulas Hadlock (AC), Hadlock (BPD, AC, FDL), Tvol, Lee1and Lee 2.

Results: Ultrasound scans were performed between 30 and 41weeks' menstrual age. Optimal model sensitivity (87.7%) resulted from using a combination of biparietal diameter, abdominal circumference and fractional thigh volume (Lee2). The precision of this model was superior to results obtained using a Hadlock model (83.1%), although accuracy of these predictions was slightly decreased by decreased aminiotic fluid index and placental anterior position. For all fetuses, the prediction model that incorporated fractional thigh volume except for model (Tvol) correctly classified a greater proportion of EFW within 10% of BW when compared with the Hadlock model.

Conclusion: Fractional thigh volume can be added to two-dimensional sonographic measurements of the head and trunk to improve the precision of fetal weight estimation. This approach permits the inclusion of soft tissue development as part of a weight estimation procedure.

Keywords: fetal weight**,** volume ultrasound, 3D ultrasound; birth weight, fractional thigh volume, 2Dultrasound**.**

INTRODUCTION

One of the main tasks of antenatal care is the early detection of fetal growth abnormalities. In pregnancies with intrauterine growth restriction (IUGR) the fetus is at increased risk of hypoxia and prenatal death, and delivery of macrocosmic fetus is associated with increased rate of cesarean section, postpartum hemorrhage, and maternal and fetal injury[1].

Knowledge of fetal size is of great clinical importance in order to minimize the risks associated with abnormal fetal growth.

If diagnosed antenatal, an IUGR fetus can be submitted to intensify surveillance and for both IUGR and macrocosmic fetuses, antenatal diagnosis can enable optimization of delivery mode and timing [2].

For many years two –dimensional (2D) sonography has been used for fetal weight (FW) estimation and it has been useful in detection of IUGR and large for gestational age fetuses (Macrosomia) [3].

However, two dimensional ultrasound biometry is characterized by low sensitivity and low positive predictive value [4], and most of the 2D formula have tendency to under estimate for example large fetuses, furthermore none of the established 2D formula consider soft tissue thickness despite evidence that abnormal tissue content may be reliable indicator of fetal growth aberration [5-6].

So the rationale for calculating fetal weight from volumetric measurement was that weight should be directly proportional to fetal volume also fetal growth is a complex fetal development process that involves fetal anatomical changes over time, suggesting that more complex measurement than diameters and circumferences might be needed to achieve greater precision in weight estimation [7-8-9].

Limb volume is a soft tissue parameter that has been described for the evaluation of fetal nutritional status [10].

Three-dimensional ultrasono-graphy (3DUS) provides a versatile method for evaluating the soft tissue of fetal limbs.

Nonetheless, earlier attempts to measure soft tissue by 3DUS were hampered by the extended time necessary to allow manual tracing of surface borders along the length of an entire limb[7].

Acoustic shadowing of these borders near the joints also posed additional technical limitations that hindered the practical implement-ation of this approach in obstetric care.

Lee et al. Examined the feasibility of using fetal volume measurement obtained with three dimensional (3D) sonography, including fractional thigh volume in the prediction of body weight (11).

The volume ultrasound based formulae showed good precision in predicting fetal body weight (12).

AIM OF THE WORK

The aim of this work was to study the role of volume ultrasound as new method of measuring fetal soft tissue in order to increase the accuracy of estimation of fetal weight.

PATIENTS AND METHOD

This study was carried out in the department of gynecology and obstetric department, zagazig university hospitals.

This was a prospective, cross-sectional study of 135 pregnant women with singleton fetuses in the third trimesters of pregnancy.

All patients had been enrolled in research protocols were approved by the council of the gynecology and obstetric department Zagazig University 2009.

The inclusion criterion consisted of singleton pregnancy with accurate gestational age based on sure menstrual date and confirmed by early ultrasound scan , that were delivered during the third trimesters of pregnancy within 7 days of ultrasound scan .

Exclusion criteria were pregnancies with poor menstrual dating data, Multiple gestations and fetuses with congenital anomalies.

Maternal age, gravidity, menstrual age at time of scan, fetal gender and ethnicity were also documented.

Women were prospectively scanned by 2D and 3D ultrasonogra-phy (GE Voluson pro v) within 7 days of delivery.

The study population consisted of 135 pregnancies; all fetal measurements were obtained from 3D volume datasets for the following parameters: BPD, AC, FDL and TVol.

BPD measured from the outer edge of the proximal parietal bone to the inner edge of the the distal skull table in a line perpendicular to the orientation of the cerebral falx obtained in the axial view at the level of the cavum septum pellucidum, where both thalami could be seen symmetrically (13).

AC measured in a transverse circular view of the abdomen at the level of the stomach and the portoumbilical vein complex (13).

(FDL) was measured from one end of the diaphysis to the other in a plane in which the full femoral diaphysis was almost parallel to the transducer surface (13).

Fractional thigh volume measured by using Three-dimensional multiplanar imaging was used to identify a midpoint of the thigh, this midpart of the volume was split into four equal sections and each of the five cross-sectional images was traced manually. Electronic calipers were used to measure the FDL (11).

The software automatically defined a cylindrical limb volume that was based on 50% of total diaphysis length. Limb circumfer-ence measurements were performed in the five sections on the outer skin margin to include the subcutaneous fat and skin (11) .(4D View 9.0, GE Healthcare Ultrasound)(14).

Models that were used to estimate fetal weight in this study:

1-Log EFW = 1.4787-0.003343(AC)(FDL)+0.001837(BPD)(BPD)+0.0458(AC)+0.158(FDL) (13).

2- Ln EFW=2.695+0.253(AC) – (0.000275(AC) (13)

3-FW = 34.649 (TVol) + 604.227 (11).

4-FW= 20.953 (TVol) + 113.571 (AC) – 2375.068 (11).

5-Log FW = 11.1372 × BPD2 − 67.2281 × BPD + 1.217 × AC2 − 17.3004 × AC − 0.0490 × Tvol2 + 25.3052 × Tvol + 285.429 (14).

Study group divided into three groups according to the actual birth weight grouP 1 (<2000g), group2 (2000 g- <4000g), group3 (≥ 4000g)

Chi-square test (Fisher’s exact test) was used to examine the relation between qualitative variables. For quantitative data, paired sample t-test, Student t test, Mann-Whitnney u test ,Analysis Of Variance (ANOVA) F test and Krusskall –Wallis test was used to compare 2D and 3D estimates.

McNemar test was used to compare sensitivities of 2D and 3D US. A p-value <0.05 considered significant and confidence interval 95% were considered.

Multiple logistic linear regressions used to find three equations for prediction fetal birth weight from (AC, BPD, Tvol).

Sensitivity used for detecting the accuracy of equations to predict actual birth weight. Confidence intervals for differences in sensitivities were also calculated.

All statistical calculations were performed using Stata SE 10.1 (Stata Corporation, College Station, TX, USA) [15].

RESULTS

The study population comprised 135 pregnant women who were prospectively scanned within 7 days of delivery between January 2011 and December 2012.

Sonographic examinations were performed between 30 and 41weeks' menstrual age.

Most fetuses were scanned after 35weeks gestation (30–34weeks, n=20; 35–39weeks, n=96; 40–41weeks, n=14). The mean maternal age was 25.1±4.7 years, 2 was the median number of parity.

Newborn infants (54.1% female, 45.9% male) were delivered at a mean±SD gestational age of 36.1±2.9 weeks.

BWs were normally distributed with a mean±SD of 2962.6±847.5 (range, (1700-4550) g).

Study group divided into three groups According to the actual birth weight Group1 (<2000g), Group2 (2000g-<4000g) and Group3 (≥4000g).

Table (1): summarize the number and percentage of newborn in each group according to the actual birth weight.

Fetal Weight	Number	%
<2000 (gm)	20	14.2%
≥2000-<4000 (gm)	88	67.9%
≥4000 (gm)	22	15.9%

gm, grams

Table (2): shows the estimated fetal weight by Hadlock equations and its correlation with actual birth weight.

	Mean ±SD	Range	R	FP
AC (hadlock)	2846.7±796.4 (gm)	(1620-4600)	0.93	0.00*
Hadlock (BPD,AC,FL)	2820.2±860.1 (gm)	(1480-4420)	0.94	0.00*

*p<0.05 gm, gram

Table (3): shows the estimated fetal weight by Tvol, Lee (1) and Lee (2) equations and its correlation with actual birth weight.

	Mean ±SD	Range	R	P
Tvol (equation)	3572.4±525.9 (gm)	(2320-4600)	0.92	0.00*
Lee (1)	2951.8±813.1 (gm)	(1450-4450)	0.96	0.00*
Lee (2)	2933.1±830.4 (gm)	(1450-4500)	0.98	0.00*

*p<0.05 r, correlation Tvol, fractional thigh volume

Table 2,3 summarize the mean ±SD and range of estimation of fetal weight by the five formula used in the study and its coefficient correlation with the actual birth weight according to tables all the formula have significant positive correlation with the actual birth weight also we can see that formulas based on multible variables had better correlation with actual birth weight Lee2 has more correlation than lee1, addition of fractional thigh volume improve correlation with the birth weight, lee 2 formula showed higher correlation with birth weight (0.98).

Table (4): shows the kappa segment between 2D and volume ultrasound.

2D and volume agree	Different	K	P
98	27	287.3	0.00*

*p<0.05 K, kappa

Table (4) showed The agreement between 2D equations (Hadlock(AC), Hadlock(AC,BPD,FDL) and Tvol based equations(Tvol,Lee1,Lee2) within 130 gm were 98 and difference were in 27 .

Table (5): shows the median percent error between actual /estimated birth weight by 2D and 3D equation in the three groups.

Actual birth weight (gm)	**<2000gm N=20**	**2000-<4000 gm N=88**	**≥4000 gm N=22**
Hadlock (AC)	110 (-370/250)	-140 (-220/300)	-250 (-600/300)
Hadlock (BPD,AC,FL)	95 (-200/210)	-95 (-230/233)	-170 (-530/290)
Tvol	140 (-200/350)	180 (-150/300)	180 (-140/350)
Lee(1)	84 (-70/270)	75 (-100/230)	110 (-150/250)
Lee(2)	63 (-80/220)	63 (-100/180)	90 (-118/100)

N, number AC, abdominal circumference BPD, biparietal diameter FDL,femur diaphysieal length Tvol, fractional thigh volume median percent error =actual birth weight – estimated birth weight.

Table (5) summarize the performance of each formula in the study in each study group it showed that Hadlock(AC) and Hadlock (BPD,AC,FDL) overestimate in the <2000 gm group and its median were 110gm and 95gm respectively while it showed underestimation in the other 2 groups .
Tvol,Lee(1) and Lee(2) showed overestimation across all groups .
This table also showed that lee1 and lee2 accuracy were much better than hadlock(BPD,AC,FDL)in (≥4000) group while it was comparable in (2000g-<4000g) group ,in (<2000g) group all formulas showed decrease in its accuracy.

Table (6): the sensitivity of equations in predicting fetal weight in three study groups.

Fetal weight percentile	<2000 (gm)	≥2000-<4000 (gm)	≥4000 (gm)
Hadlock (AC)	78%	84.2%	82.6%
Hadlock (BPD, ACBPD)	80%	86%	84%
Tvol	79%	83%	82%
Lee(1)	81%	87%	88%
Lee(2)	82%	88%	90%

AC, abdominal circumference BPD, biparietal diameter FDL, femur diaphysieal length Tvol, fractional thigh volume

Table6: summarize the sensitivity of each equation in the three study groups within 10% percent of actual birth weight as previous table it showed increase sensitivity of Lee1and Lee2 over other equation used in the study, especially in (≥4000g) **group** while in (2000g-<4000g)group Lee1 and Lee2 were close to Hadlock (BPD,AC,FDL) sensitivity, in(<2000g) group sensitivities

Multiple logistic linear regressions used to find three equations for prediction fetal birth weight from (AC,BPD,Tvol) based on studied population in this study.

1- EFW= 26.5(Tvol)+1087.5
(r2=0.93, SE of estimation= 225.8)
2- EFW=20.89(Tvol)+6.15(AC)-502.65
(r2=0.93, SE of estimation =227.91)
3- EFW=18.1(BPD)+5.72(AC)+17.7 (Tvol)-1793.8
(r2=0.94, SE of estimation = 275.11)

DISCUSSION

Birth weight prediction has traditionally relied on anatomic measurements of the fetal head, limbs, and abdomen circumference [7].

Hadlock et al. (1984) have reported predictive accuracy within 15% (±2 SD) of actual BW using functions containing fetal head biparietal diameter, AC, and FDL. The hadlock systematic error
Increased with BWs greater than 4000 g [13].

Other investigators, however, have suggested that an estimation of soft tissue mass (e.g., skin, fat, and muscle) may improve our ability to evaluate fetal intrauterine nutritional status and growth **(Jeanty et al., 1985)**. **Catalano et al. (1992)** supported the concept that soft tissue, particularly fat mass, contributes significantly to BW [16-17].

Although neonatal fat mass constituted only 14% of BW, it explained 46% of its variance. The percentage of fat mass was strongly correlated with the degree of BW error on 2DUS. Unfortunately, weight-estimating formulas are presently based on 2DUS measurements that do not consider the contribution of soft tissue to BW [18].

Three-dimensional ultrasonography (3DUS) has the potential for allowing more accurate volume measurements compared to two-dimensional ultrasonography (2DUS) [19].

However, delaying the practical implementation of these volume-based prediction models into clinical practice was for the following.

First, the technique has typically required a large number of manual tracings to calculate thigh volumes. Second, it is not always possible to clearly visualize soft tissue borders around the proximal and distal ends of the volume studied, especially if the arm or leg is pressed against the body.

This study addresses these technical limitations by introducing fractional limb volume as a new sonographic parameter for BW prediction. The goal of this study is to determine the practical utility of fractional limb volume for BW prediction during pregnancy. Our method has 2 distinct advantages over earlier approaches to BW prediction by 3DUS [22].

Fractional volume measurements require only about 1 to 2 minutes performing and reducing the amount of time that would otherwise be required to manually trace multiple sections.

The examiner no longer needs to manually trace indistinct soft tissue borders that often result from acoustic shadowing at the extreme ends of the diaphysis. Prospective testing earlier reports regarding the use of fetal volume measurements in BW prediction by 3DUS have been encouraging [(22)].

A new fetal weight prediction model, using fractional limb volume and AC, can be reliably used to estimate BW during the late pregnancy [(22)].

Initial observations suggest that a volume-based model may provide improved BW predictions when compared with conventional 2DUS [(11)].

five equation included in this study for estimation of fetal weight, two based on the parameters taken by 2D scanning and those were the commonly used and widely accepted Hadlock fetal weight estimation models , one using (AC) ,and the other use (BPD, AC and FDL) ,those equations were used as a basis of comparison. And one equation based on fractional Tvol as described by Lee et al and two equation (Lee1and Lee 2) used the (Tvol and AC) and the (Tvol, AC and BPD) respectively**.**

We divided the study group into three groups according the actual birth weight, the three groups were as follow (<2000gm, 2000-<4000gm, ≥4000gm), the value of this groups is to evaluate each equation in different weight group beside general evaluation of each equation all over the studied groups [(20-21)].

The Hadlock (AC) and Hadlock (AC, BPD, FDL) equations used in this study showed under estimation of fetal weight in all groups of the study , while Tvol, Lee1, Lee2 showed over estimation all over the studied groups , the over or under estimation was less in equations used more than one parameter than equations used single parameter as shown in table (8).

The Lee2 equation (Tvol, AC, BPD) showed the least overestimation among all studied groups.

As regard the performance of the five formulas according to the three groups of fetal weight the following formulas Tvol ,Lee(1) ,Lee(2)) showed over-estimation of fetal weight across all over the three groups the overestimation was less with the Lee(2) formula, also the Hadlock(AC) and Hadlock (BPD,AC,FDL) showed over estimation in (<2000gm) group while it showed under estimation of fetal weight in the following groups (2000gm-<4000gm, ≥4000gm).

The sensitivity of formulas used in the study within 10% of the actual birth weight were as follow the Lee2 has the best sensitivity (87.7%) followed by Lee1 (86.9%), while the Hadlock(AC)and Hadlock (BPD, AC,FDL) sensitivity was (82%)and (83.1%) respectively , the (Tvol) formula was (81.5%).

As regard groups Lee1 and Lee2 in (≥4000gm) group had better sensitivity (90%) and (88%) respectively compared to Hadlock (BPD,AC,FDL) sensitivity (84%), in (2000gm -<4000gm)group the sensitivity of (Lee1, Lee2) and hadlock (BPD, AC, FDL) were comparable, Tvol and Hadlock (AC) equations showed less sensitivity allover and in each group than other equations (Lee1, Lee2, Hadlock (BPD, AC, FDL).

In a study done by **Lee et al. (2009)**, the Hadlock model (AC, FDL)correctly classified 30.5% and 53.1% of newborns within 5% and 10% of birth weight, respectively the three-parameter Hadlock models of the head, trunk, and limb were also correctly classified 35.7% and 63.6% of newborns within 5% and 10% of birth weight, respectively[(22).]

In a study done by **Lee et al. (2009)** (27)on 271 pregnant women ,The Hadlock(AC and FDL) weight estimation functions it showed over estimation of fetal weight ranged between 7.7 and 8.8% of actual birth weight also it showed that Hadlock (BPD , FDL, AC) was more accurate than Hadlock (AC , FDL) and it overestimation ranged from 7.6% to 8.3% . The original Hadlock formula was based on Houston population and lee conduct it on Michigan population [(22)].

General cause of difference This overestimation may be related to multicollinearity(is a statistical phenomenon in which two or more predictor variables in a multiple regression model are highly correlated) .

In the study done by **Lee et al. (2009)**, Lee 2 had the lowest mean percent differences (Mean percent difference = (estimated weight − birth weight)/birth weight × 100.) ranging from 0.12 to 0.18%, which were not significantly different from zero (*P* < 0.0001, Student's *t*-test).and lee1 and Tvol their mean percent difference were 0.27and0.45 respectively, and their SD percent difference were 9.5 for Tvol and 7.2 for Lee1 [(22)].

Lindell and Marsal (2009) reported fetal weight estimation using fractional thigh volume for a Swedish population. They studied 176 pregnant women at ≥287 days of gestation within 4 days of delivery [(23)].

Results obtained using the formula of Persson and Weldner (using BPD, abdominal diameter and FDL) 53 were compared to those obtained using Lee 2 models (using BPD, AC and TVol) **[23]**.

A new formula employing HC, abdominal diameter, abdominal volume and TVol was developed for their population sample. Both the Persson and Weldner model 53 and Lee2 using TVol 55 yielded the smallest random weight estimation errors of 6.3%, although the latter led to underestimated mean percent differences of 6.0% [23].

in a study done by **Yang et al. (2013)** conducted on 290 pregnant Chinese women the Hadlock showed under estimation of fetal weight its mean percentage error -2.93, SD was 7.03 and correlation was r 0.653, while the Lee2 performance was much better it showed underestimation of fetal birth weight and its MPE was −3.29* , its SD was 4.93and it showed high correlation with fetal birth weight it was 0.808. Mean while the Tvol formula showed comparable result to Hadlock (AC, BPD ,FL) with MPE 0.38 , SD 6.08 and correlation 0.717. The prediction rates within 5 and 10% of accuracy by Lee2 were (74.2%, 95.8%), and Hadlock (BPD, AC, FL) were (46.3%, 82.6%) [24].

This result can be explained by different population and Femur length is greater in Caucasian fetuses than in Chinese fetuses **(Leung et al., 2008)** **[25]**.

Yang et al. (2013) found that precise results were obtained in this Chinese population when the TVol parameter was used and concluded that that precision of birth weight prediction within 5% and 10% of actual birth weight in a Chinese population at term gestation can be improved by adding 3D thigh volume to conventional 2D fetal biometric measurements [24].

Lee et al. (2013) conducted study on 164 pregnant women of multiethnic origin the study consisted of uncomplicated pregnancies but included women with gestational diabetes ,hypertension and tobacco exposure pregnant women , this study divided the scanned women into three groups according to fetal weight (<2000 gm ,2000gm-4000gm, >4000gm) ,the Hadlock in this study showed MPE 4.9 • with SD 8.8 all over the studied group and the performance of Hadlock formula was lowest in (>4000gm)group it showed MPE 6.7 and SD 8.6 [21] .

Lee2 showed best performance among all models used in this study and on all groups of with the most precise weight estimates and the lowest random errors for all fetuses (6.6%) as well as for infants with BW<2000 g (7.8%), BW 2000–4000 g (6.4%) and BW>4000 g (5.8%) [21].

Lee 1 formula showed comparable result to Lee 2 formula it showed MPE 2.3 and SD 7.9. Tvol formula showed close result to Hadlock formula with its MPE 5.3 • SD 11.7 [21].

CONCLUSION

both 2D and 3D ultrasonographic fetal weight estimation have acceptable precision for prediction of neonatal birth weight especially for the average weight range 2000-<4000g.

Both methods have less precise estimation when fetuses <2000g .

On the larger fetus side above and especially above 4 kg, 3D ultrasonography seems to be more precise compared to 2D. However, larger samples of the two extremes of fetal weight

Need to be investigated to draw more reliable conclusions.

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