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The Effect of Amniotic Fluid Index on the Accuracy of Sonographic Estimated Fetal Weight

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The objective of this study was to investigate whether there is a relationship between the amniotic fluid index (AFI) and the accuracy of the sonographic estimated fetal weight (EFW) as substantiated by the actual birth weight. This is a retrospective study where data of the sonographic estimated fetal weight and the birth weight at delivery were collected to calculate range of error when the amniotic fluid index was indicative of polyhydramnios or oligohydramnios, with normal amniotic fluid volumes as a control group. Results revealed significant, fairly strong to strong correlations between the variables within each group. Further analysis compared the mean scores of the three groups. Although differences in the mean values exist, large overlaps existed. This questions the usefulness of the correlation of the EFW and AFI in clinical use.

Key words: amniotic fluid index, birth weight, estimated fetal weight, ultrasound estimated fetal weight, biparietal diameter, head circumference, abdominal circumference, femur length

In late pregnancy, obstetrical management is often influenced by the sonographic estimation of fetal weight, especially in the case of macrosomic or growth-restricted fetuses. Sonographic estimated fetal weight (EFW) should be within the accepted accuracy range of less than 10% in comparison to actual birth weight (BW). This should hold true with 75% of the estimates. The sonographic estimated fetal weight should be within 5% of the birth weight in as many as 40% of estimates.[1] This study set out to determine if either high or low levels of amniotic fluid affected the accuracy of the sonographic estimated fetal weight at the time of term pregnancy.

Specifically, we sought to investigate whether a relationship existed between amniotic fluid index (AFI) and the accuracy of the sonographic mea-

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surement of EFW, with increased AFI showing an overestimation of EFW and decreased AFI showing an underestimation of EFW. The predictive value of sonographic EFW would be enhanced with the use of the AFI as a modifying factor in sonographic EFW. An improvement in the accuracy of EFW calculation will permit obstetric intervention to be undertaken more assertively, with the aim of minimizing risks for both mother and fetus.

A review of literature demonstrated conflicting data in regard to the effects of amniotic fluid volume on the estimation of sonographic fetal weight. Two large studies[2,3] suggested that the finding of oligohydramnios or polyhydramnios made no difference in the percentage of errors in fetal weight estimation. In 1988, Benacerraf et al[2] studied the impact of amniotic fluid volume on the accuracy of predicted birth weights with a research study involving 1301 women. The study concluded that the "presence of oligohydramnios or polyhydramnios made no difference in the percent errors."

In 1995, Meyer et al[3] evaluated the relationship between the amniotic fluid index and sonographic estimated fetal weights with a study involving 664 patients. These authors concluded that the accuracy of sonographic EFW is independent of the AFI. A study done by Edwards et al[4] in 2001 showed that oligohydramnios did, indeed, result in a trend toward underestimating the sonographic EFW. In 2002, Owen et al[5] found no relevant correlation between amniotic fluid volume and EFW in their research, stating that it is not necessary to make adjustments for EFW based on the AFI. More recently, in 2004, Perni et al[6] completed a research study that showed no relationship between AFI and EFW in the third trimester until 38 weeks gestation. Furthermore, they concluded there was a relationship between the AFI and EFW after 38 weeks gestation—the similar sample group we studied. The aim of our study was to determine if a correlation truly existed between EFW and the AFI with term pregnancies, as determined by sonograms done within our women's health ultrasound department.

Methods

Sonographic records for the years 2002-2003 at our women's health ultrasound department were reviewed retrospectively for quality assurance purposes in relation to EFW. The inclusion criteria for this study were a pregnancy with a sonogram for EFW at term with delivery within approximately 72 hours of the sonogram, along with an AFI that indicated oligohydramnios, polyhydramnios, or normal amniotic fluid as determined by the standards within the Digisonics reporting system using Moore and Cayle's[7] gestational reference range for the AFI. Oligohydramnios is defined as an AFI below the 5th percentile for gestational age. This value varies between 7.9 cm at 16 weeks and 6.3 cm at 40 weeks gestation. Polyhydramnios is defined as an amniotic fluid index above the 95th percentile. The mean AFI for normal pregnancies is approximately 11 to 16 cm.[7]

The technical quality of the sonographic images was assessed in relation to diagnostic accuracy and degree of difficulty in relation to maternal obesity and oligohydramnios. Exclusion criteria included those images demonstrating poor anatomical landmarks due to maternal body habitus, extreme oligohydramnios, or fetal lie, particularly of the fetal head.

The study sample included three groups of 30 patients, each stratified into the following three categories: EFW with oligohydramnios, EFW with polyhydramnios, and EFW with normal amniotic fluid index. Only normal, full-term, singleton fetuses were included in our study, irrespective of any risk factors such as diabetes, hypertension, intrauterine growth restriction (IUGR), and so on.

Measurements were obtained by a single sonographer using an ATL Phillips HDI 3500 ultrasound machine with a 3.5-MHz curved-array transducer. Head measurements were obtained from a cross section of the cranium, using the cavum of the septum pellucidum and the thalami as anatomical landmarks, with the measurement taken from leading edge (outer) to leading edge (inner). Abdominal circumference was measured on a cross section of the abdomen at the level of the fetal liver, using the umbilical portion of the portal vein as a landmark, placing the ellipse at the outer edge of the abdominal soft tissues. Femur length was measured from the large trochanter to the distal metaphysis.

EFW was calculated using the Hadlock B formula, which contains four sonogram-obtained

measurements: biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL):

$Log_{10}EFW = 1.3596 - 0.00386(AC)\ (FL) + 0.0064(HC) + 0.00061(BPD)\ (AC) + 0.0424(AC) + 0.174(FL)$.[8]

The AFI is the sum of the largest vertical pocket of amniotic fluid, free of umbilical cord, within each quadrant of the uterus in centimeters. The AFI is determined by mentally dividing the pregnant abdomen into four quadrants by using the umbilicus as a reference point. The linea nigra divides the uterus into left and right halves, and the umbilicus separates the uterus into upper and lower halves. The four sonographic measurements are summed to obtain the AFI in centimeters. The Digisonics reporting system uses Moore and Cayle's[7] table of the normal limits for AFI, based on the gestational age. The norms established by Moore and Cayle were used in this study to reflect oligohydramnios or polyhydramnios. Each newborn weight was done immediately after birth and taken from the delivery summary dictation. A study done by Chien et al[9] reported previous research demonstrating that the average weight gain of a fetus between 37 and 40 weeks is 25 grams per day. The sonographic estimated fetal weight was adjusted accordingly. Consequently, 25 grams was added to the EFW for every day between the scan and the actual delivery date. The difference between the sonographic EFW and the actual birth weight is an estimate of the error ascertained by the measurements.

Systematic error was calculated by a formula using BW and ultrasound EFW (uEFW). Determining the percentage of error was calculated as a percentage of the difference divided by the birth weight. Each result was then compared with the corresponding BW to quantify the error intrinsic in each measurement. The data analysis and values can be summarized as follows: BW – uEFW/BW × 100.

Statistical Analysis

Statistical analysis was done by SPSS, a statistical package, at Clemson University through the statistical analysis department. For each group, Spearman's rho correlation coefficient was computed to assess the relationship between adjusted uEFW and BW. Results revealed significant, fairly strong to strong (.76 to .90) correlations between the variables within each group. Correlations were judged statistically significant when the corresponding *P* value was < .05 (see Table 1).

TABLE 1.
Spearman's Correlation Coefficients

Group	Spearman's Rho	*P* Value
Normal	.83	< .0005
Oligohydramnios	.90	< .0005
Polyhydramnios	.76	< .0005

TABLE 2.
Analysis of Variance (ANOVA)

Groups	Count	Sum	Average	Variance
ANOVA: Single factor (*P* = .000014)				
Adjusted uEFW-Oligo	30	104604	3487	446671.6
Adjusted uEFW-Norm	30	116144	3871	223171.5
Adjusted uEFW-Poly	30	125165	4172	162370.6
ANOVA: Single factor (*P* = .0097)				
Difference Poly	30	–5285	–176.2	71246.4
Difference Norm	30	–2309	–77.0	59591.9
Difference Oligo	30	550	18.3	43189.0

uEFW = ultrasound estimated fetal weight.

Further analysis, using ANOVA, compares the mean scores of the three groups. Although differences in the mean values exist, large overlaps exist. This questions the usefulness of the correlation of the EFW and AFI in clinical use (see Table 2).

Results

Ninety women, scanned within the women's health ultrasound department, were included in this retrospective analysis. All women delivered within 72 hours of sonographic assessment of fetal weight. To maximize the results, 25 grams was added to the EFW for every day between the scan and the actual delivery date. These 90 fetuses were then grouped into three categories of 30: those with normal amniotic fluid index, those with polyhydramnios, and those with oligohydramnios. The

TABLE 3.
Summary of Data

	Normal AFI	Oligohydramnios	Polyhydramnios
Mean (SD) gestational age at time of uEFW (weeks)	40.2 ± 1.0	39.2 ± 1.6	39.7 ± 1.4
Mean (SD) uEFW (g)	3871 ± 472.4	3487 ± 668	4172 ± 403
Mean (SD) birth weight (g)	3794 ± 472.4	3504 ± 622	3996 ± 401
Mean (SD) AFI	14.2 ± 4.0	5.3 ± 1.3	26.6 ± 4.4
Average difference (SD) (g)	–77 ± 244.1	18.3 ± 207.8	–176 ± 267
Mean (SD) percentage of error	–22 ± 6.5	1.08 ± 6.3	–4.6 ± 6.7
Results in accuracy of obtaining uEFW	Overestimation of uEFW in 19/30 or 63% of fetuses	Underestimation of uEFW in 19/30 or 63% of fetuses	Overestimation of uEFW in 24/30 or 80% of fetuses
n and percentage of uEFW within 10% of actual BW	27/30 or 90%	27/30 or 90%	24/30 or 80%
n and percentage of uEFW within 5% of actual BW	18/30 or 60%	16/30 or 53%	17/30 or 57%

A negative value under difference and percentage of error is an overestimation by the ultrasound EFW formula. A positive value is indicative of an underestimation. uEFW = ultrasound estimated fetal weight; AFI = amniotic fluid index; BW = birth weight.

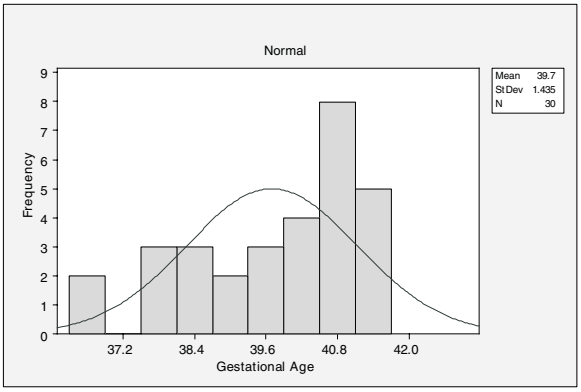

FIG. 1. Histogram of gestational age.

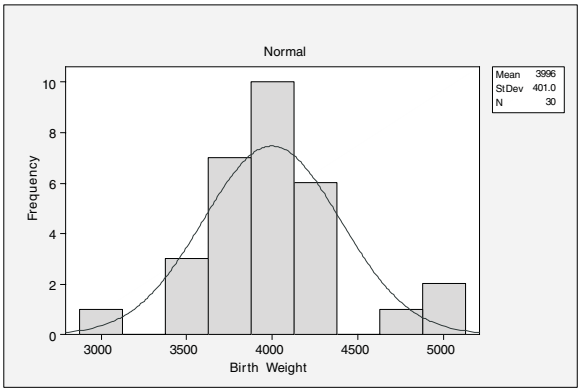

FIG. 3. Histogram of birth weight.

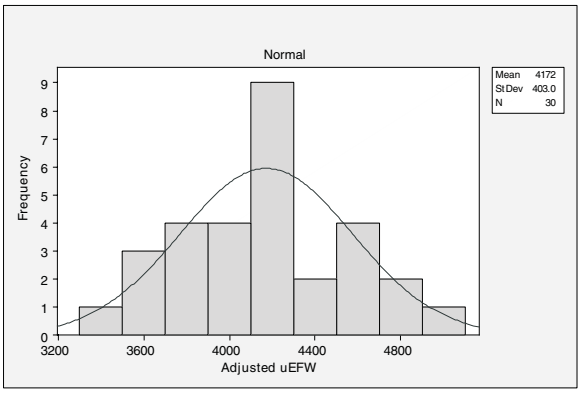

FIG. 2. Histogram of adjusted ultrasound estimated fetal weight (uEFW).

normal amniotic fluid index group acted as our control group.

Of the 90 women involved in this study, all were between 39.2 to 40.2 weeks gestation at the time of obtaining the uEFW. The mean birth weight of the three groups ranged from 3504 grams in the oligohydramnios group to 4172 grams in the polyhydramnios group. There is a wide range in the mean AFI of each group, with the oligohydramnios group showing a mere 5.3 cm. The polyhydramnios group had a mean AFI of 26.6 cm. The normal AFI group had a mean AFI of 14.2 cm. Mean percentage of error is calculated with either a positive or negative value, showing overestimation with a negative value and underestimation with a positive value.

In reviewing the data in the three varying amniotic fluid groups, there appears to be a correlation between the amniotic fluid index and esti-

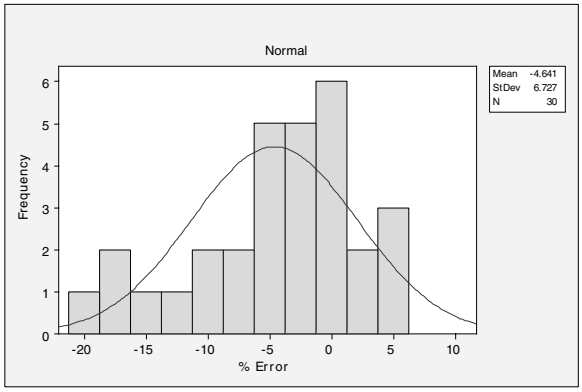

FIG. 4. Histogram of percent error.

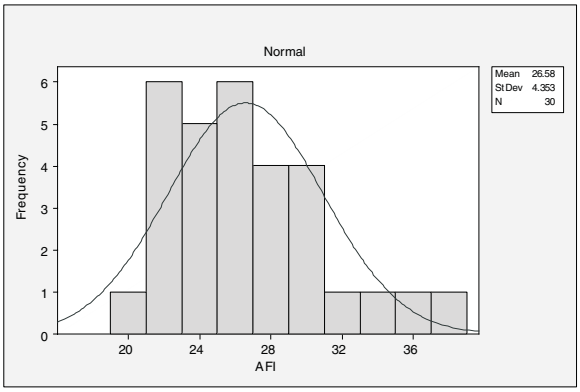

FIG. 5. Histogram of amniotic fluid index (AFI).

mated fetal weight. In the sample group with oligohydramnios, uEFW is underestimated 63% of the time. Our control group, with the normal AFI, is equally underestimated at 63%. In the sample group with polyhydramnios, uEFW is overestimated 80% of the time. These data appear to relate to our original hypothesis that a relationship exists between the amniotic fluid index and the accuracy of the sonographic measurement of estimated fetal weight, with the increased amniotic fluid index showing an overestimation of EFW 80% of the time and decreased amniotic fluid index showing an underestimation of EFW 63% of the time. Because normal AFV also shows underestimation 63% of the time, one would question the validity of the oligohydramnios group. Further investigation yields that the EFWs fall within the accepted norms of accuracy for EFW assessment. Sonographic EFW within our women's health ultrasound department is within the accepted accuracy range of less than 10% with 75% of the estimates and within 5% of the birth weight in as many as 40%.[1]

Discussion

Accurate sonographic EFW can be an intangible objective for any sonographer because the endpoint or the ultrasound estimated fetal weight will lead to a management decision that will have a direct impact on the mother and fetus. Polyhydramnios, oligohydramnios, fetal macrosomia, and intrauterine growth restriction can lead to potential complications affecting management decisions for patients presenting for labor and delivery. Fetal weight estimations that are frequently determined by sonography play a major role in obstetric decision making and management. Both low birth weight and excessive fetal weight at delivery are associated with an increased risk of newborn complications during labor and delivery.

Fetal macrosomia is a common obstetric term that implies fetal growth beyond a specific weight. According to the American College of Obstetricians and Gynecologists, all newborn infants weighing 4500 grams (9 lb, 4 oz) are considered macrosomic.[10] However, some use 4000 grams (8 lb, 13 oz) to denote macrosomia. It is well known that macrosomia is a significant risk factor for shoulder dystocia, cesarean section, birth trauma, perinatal asphyxia, and significant perineal lacerations.[11] Although sonography can identify a group of fetuses with increased risk for macrosomia, there is no current formula with an accurate predictive value. The fact that the amniotic fluid volume could overestimate the sonographic fetal weight adds another dimension to the accuracy of the fetal weight and could affect the course of labor and delivery.

Accurate estimation of fetal weight is often needed in obstetric practice, especially for the very low birth weight infants, because it is associated with perinatal mortality and later neurodevelopmental problems.[12] Those infants with EFWs that fall below the 10th percentile for their gestational age are classified as being small for gestational age.[10] These infants are often consid-

ered to manifest IUGR, although some are simply small due to constitutional factors. Again, knowing that sonography has underestimated the fetal weight could have a bearing on decision making during labor.

The sonographic technique of obtaining EFW represents the most technologically innovative method of obtaining birth weight estimations. Initial reactions concluded that the use of sonography for determining fetal weight might provide an objective standard for identifying fetuses of abnormal size for gestational age. However, research studies have since proven that sonographic EFWs are no better than clinical palpation for predicting fetal birth weight.[13] Furthermore, Baum et al[14] concluded that sonographic estimation of fetal weight showed no statistically significant difference in weight accuracy when compared with maternal estimates. More recently, in 2004, Perni et al[6] concluded that a relationship existed between the AFI and EFW at 38 weeks gestation or later. Furthermore, they stated, "In female fetuses, there was a significant positive relationship between the EFW percentile and AFI in the entire group as well as in earlier gestational age ranges." They speculated a possible link to higher estrogen levels in heavier female fetuses, which affected fetal urination.

Overall, these findings suggest that the prediction of fetal weight is not an exact science and requires additional modification. Our data suggest that the knowledge of amniotic fluid volume could add only a limited component to increase the reliability of the sonographic estimated fetal weight. Because the precision of predicting actual birth weight can be critical for proper obstetric management, we felt obligated to analyze our data despite the contrary findings. The fact that the ultrasound estimated fetal weight is underestimated 63% of the time with oligohydramnios is comparable to the control group—the normal AFI group. However, knowing that the EFW is overestimated with polyhydramnios 80% of the time adds another parameter to the obstetrician's management variables. Sonography can provide a relatively good estimation of fetal weight, whereas the range of error changes to a limited extent with the rise of the amniotic fluid index.

Further speculation focuses on the fact that increasing amniotic fluid volumes correlate linearly with increasing birth weight or macrosomia. Oligohydramnios correlates with fetuses that are small for gestational age and intrauterine growth restriction. The degree of precision of the uEFW could be a function of the actual fetal weight as there is a tendency to either overestimate or underestimate EFW at the extremes of the fetal weight range. Predantic et al,[1] in their study of sonographic estimation of fetal weight, stated that "the best results for ultrasonographic determination of fetal weight are encountered if the fetus weighs between 2500 and 3500 grams and the worse are obtained with fetuses weighing more than 4000 grams." The mean birth weight in the oligohydramnios group was 3504 grams, whereas the mean birth weight in the polyhydramnios group was 3996 grams.

Then again, the correlation could simply be a factor inherent of Hadlock's formula. Pinette et al[15] produced results that "showed that when the actual birth weight was in the low range (500-999 grams) all formulas significantly underestimated fetal weight by an average 30 to 100 grams. When the actual birth weight was in the high range (<3500 grams) the EFW formulas overestimated the weight by 100-200g." This was seen with the use of Hadlock's BPD:FL:AC formula. Some of the inaccuracy of the sonographic EFW to predict birth weight could be due to the properties of the formula itself, even though we used Hadlock's formula, which included all four biometrics—BPD:HC:AC:FL. Further investigation led us to a study by Edwards et al,[4] which studied four EFW equations: Shepard, Hadlock A, Hadlock B, and Combs, all of which produced a similar accuracy range of 8.6% to 9.5% for EFW. Edwards et al also concluded that oligohydramnios (AFI < 5) resulted in a statistically significant underestimation of mean fetal weight by 5.9%.

Our results appear to suggest a link between amniotic fluid volume and estimated fetal weight in the polyhydramnios group. In conclusion, our findings imply that one should consider the amniotic fluid volume when looking at the sonographic estimated fetal weight. Combining sonographic estimates of fetal weight with the

amniotic fluid volume will enable one to identify a subset of EFWs that have a significant probability of overestimating the fetal weight in the polyhydramnios group. Because accurate estimates of fetal weight have a bearing on perinatal outcomes, this knowledge provides another parameter that the obstetrician could integrate into obstetrical decisions.

References

1. Predanic M, Cho A, Ingrid F, Pellettieri J: Ultrasonographic estimation of fetal weight: acquiring accuracy in residency. *J Ultrasound Med* 2002;21:495–500.
2. Benacerraf BR, Gelman R, Frigoletto FD Jr: Sonographically estimated fetal weights: accuracy and limitation. *Am J Obstet Gynecol* 1988;159:1118–1121.
3. Meyer WJ, Font GE, Gathier DW, et al: Effect of amniotic fluid volume on ultrasonic fetal weight estimation. *J Ultrasound Med* 1995;14:193–197.
4. Edwards A, Goff J, Baker L: Accuracy and modifying factors of the sonographic estimation of fetal weight in a high-risk population. *Aust N Z Obstet Gynecol* 2001;41:187–190.
5. Owen P, Osman I, Farrell T: Is there a relationship between fetal weight and amniotic fluid index? *Ultrasound Obstet Gynecol* 2002;20:61–63.
6. Perni SC, Predanic M, Cho JE, Kalish RB, Chasen ST: Association of amniotic fluid index with estimated fetal weight. *J Ultrasound Med* 2004;23:1449–1452.
7. Moore TR, Cayle JE: The amniotic fluid index in normal human pregnancy. *Am J Obstet Gynecol* 1990;162:1168–1173.
8. Hadlock FP, Harrist RB, Sharman RS, Deter RL, Park SK: Estimation of fetal weight with the use of head, body and femur measurements: a prospective study. *Am J Obstet Gynecol* 1985;151:333–337.
9. Chien PF, Owen P, Khalid KS: Validity of ultrasound estimation of fetal weight. *Obstet Gynecol* 2000;95:856–860.
10. Cunningham F, MacDonald P, Leveno K, Gant N, Gilstrap L III: *Williams Obstetrics*. 19th ed. Norwalk, CT: Appleton & Lange, 1993.
11. Myles TM, Nguyen TM: Relationship between normal amniotic fluid index and birth weight in term patients presenting for labor. *J Reprod Med* 2001;46:685–690.
12. Owen P, Donnet ML, Ogston SA, Christie AD, Howie PW, Patel NB: Standards for ultrasound fetal growth velocity. *Br J Obstet Gynaecol* 1996;103:60–69.
13. Hendrix N, Grady C, Chauhan S, Suneet CP: Clinical versus sonographic estimate of weight in term parturients. *J Reprod Med* 2000;45:317–322.
14. Baum J, Gussman D, Wirth J III: Clinical and patient estimation of fetal weight vs. ultrasound estimation. *J Reprod Med* 2002;20:61–63.
15. Pinette M: Estimation of fetal weight: mean value from multiple formulas. *J Ultrasound Med* 1999;18:813–817.