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Original Article

Sonographic fetal weight estimation prior to delivery: analysis of accuracy and interobserver variability between obstetrician and radiologist

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Abstract: The aim of this study was to evaluate the interobserver reliability of sonographic fetal weight estimation between experienced obstetrician and radiologist immadiately prior to delivery and to compare the sonographic accuracies of estimated fetal weights (EFW) between the sonographers. This was a prospective study of singleton pregnancies that underwent sonographic fetal weight estimation prior to scheduled delivery. One obstetrician and one radiologist, performed all examinations prior to delivery. Sonographic fetal weight estimations were obtained from each ultrasonographic examination. EFWs were compared with the actual birth weight (ABW) and interobserver reliability of sonographic fetal weight estimation between two sonographers was assessed. A total of 245 subjects were included. Inter-observer reliability coefficient for EFW was 0.864 (95% confidence interval: 0.825-0.894, $P < 0.001$). Mean values of EFWs by radiologist and obstetrician did not significantly differ ($P = 0.480$) while both did significantly differ from the ABW ($P < 0.001$, for both comparisons). The mean absolute error for EFW obtained by radiologist and obsterician was 227 (± 160) and 197 (± 138), respectively ($P < 0.01$). The mean absolute percentage error for EFW obtained by radiologist and obsterician was 7.09 (± 5.17) and 6.15 (± 4.38), respectively ($P < 0.01$). EFWs measured by radiologists and obstetricians are similar but both are significantly distant from the ABW. However, obstetricians measure EFW significantly more accurate than the radiologists do.

Keywords: Interobserver reliability, fetal weight estimation, ultrasonography

Introduction

Sonographic estimation of the fetal weight (EFW) is an integral part of routine antenatal care and has a pivotal role in obstetric practice with a major impact on antenatal management [1]. The optimal practice of obstetrical care requires an optimal estimation of fetal weight. Many important clinical decisions depend upon a precise and accurate assessment of sonographic fetal weight estimation. The accuracy of EFW is also crucial for optimal delivery management and allows obstetrician to make management decisions [1]. Sonographic EFW prior to delivery is part of the daily routine obstetric practice worldwide; however, sonographic EFW has some limitations due to the subjective elements of this measurement [2, 3]. Various clinical factors such as maternal weight, amniotic fluid volume, fetal sex, multiple pregnancy, the presence of gestational diabetes mellitus, time interval from ultrasound examination to delivery, fetal size and gestational age have also potential to affect the accuracy of sonographic EFW [2, 4-8]. The majority of literature on this topic has focused on the maternal and fetal component in the accuracy of sonographic EFW. Technical factors related to the experience of the sonographer may further differentially impact the accuracy of sonographic EFW.

Technical factors regarding the operator himself have not been well investigated. There are quite few studies, which investigate the effect of operator-dependent subjective factors on accuracy of sonographic EFW [7, 9-12].

Although widely used in routine obstetric practice and numerous weight formulas have been suggested to compute the sonographic EFW, the accuracy of fetal weight estimation has not been achieved precisely [1, 13-16]. Despite these efforts to improve the accuracy of fetal weight prediction, ultrasonography provides weight estimates with errors of up to 15% when compared with actual birth weights [15, 17-20]. The operator-dependent subjective components of the method are the main cause of this high error in predicting fetal weight. Moreover, prenatal estimation of fetal weight is performed by either obstetricians or radiologists in many parts of Turkey, depending on the practices of health care provider, however, it has not been investigated whether these examinations do vary with regards to accuracy and reliability.

In spite of a long history of utilizing ultrasound to estimate fetal weight and the potential implications of these estimates, it is surprising that few interoperator variability studies have been published. Ultrasound examination is routinely performed in Turkey for all pregnancies prior to delivery. The aim of this study was to assess the reliability in reproducing sonographic EFW between radiologist and obstetricians prior to delivery and to compare the sonographic EFW accuracies of both operators.

Materials and methods

A prospective clinical study was conducted between December 2013 and September 2014 in Kayseri Education and Research Hospital of Medicine, a tertiary center where approximately 7,200 women deliver each year. The study was approved by the institutional ethics committee and all participants signed an informed consent form regarding to participate in the present study.

Singleton pregnant women who had admitted to our department for scheduled labor induction or scheduled elective cesarean section enrolled to the study. Two hundred and fourty-five singleton pregnant women who fulfilled the inclusion criteria were included in the study. Inclusion criteria include singleton third-trimester pregnancies with cephalic presentation and admission for scheduled delivery (vaginal or elective cesarean delivery). All pregnant participants were between 37-42th weeks of gestation with singleton cephalic presentation and none had any medical or obstetrical problems.

Our exclusion criteria were as follows: multiple pregnancies, abnormal presentations (breech, transverse and other noncephalic presentations), oligohydramnios, anhydramnios, congenital fetal anomalies, hydrops, intrauterine fetal deaths, active stage of labor, unstable patients, and obstetric emergencies such as antepartum hemorrhage, eclampticia and acute fetal distress. Moreover, patients who did not deliver within 48 hours after the sonographic fetal weight estimation were not included into study. After informed consent, the participant completed an enrollment questionnaire assessing sociodemographic characteristics and medical information. The final study group was composed of 245 subjects.

Gestational age was calculated according to last menstrual period and confirmed by in all cases by crown-rump length measurements done in the first trimester. Two experienced sonographers (one experienced radiologist and one experienced obstetrician with average knowledge in obstetric ultrasound) performed all examinations on the day of the patient's admission to clinic. Each measurement was performed once by each operator. The initial measurement was recorded by the first sonographer who is an experienced obstetrician (F.C). Subsequently, a second sonographer who is an experienced radiologist (S.T), blinded to the results of the first sonographer, performed the same measurements. The fetal biometric measurements and EFW of the first sonographer were always removed from the ultrasound screen, after a hard copy had been made, before the second sonographer entered the room. The operators were not allowed to present in the ultrasound room during each other's examinations to remove any possible influence by the second operator when generating the image and measuring the fetal biometry. Each operator was blinded to any pre-existing measurements. All ultrasound examinations were performed in a single room. Fetal biometrical measurements (biparietal diameter, head circumfe-

Table 1. Demographic characteristics of the patients included in the study (n = 245)

	Mean ± SD
Age, y	25.84 ± 5.46
BMI, kg/m^2	28.29 ± 5.23
Gravidity, n	2.59 ± 1.35
Parity, n	1.21 ± 1.01
Gestational age, w	39.59 ± 1.23

All data were expressed as mean ± standard deviation (SD). BMI, body mass index; y, years; n, numbers; w, weeks.

rence, abdominal circumference, and femur length) and EFW were obtained by each ultrasonographic examination. Fetal biometries and EFW calculations were performed by using the formula described by Hadlock [15, 21]. For BPD a transverse section of the head was used with both the lateral ventricles symmetrical in view with a horizontal midline. The BPD measurement was made perpendicular to the midline outer to inner at the widest point. The head circumference was measured at the same level as the biparietal diameter, around the outer perimeter of the calvarium. The FL was measured by including only the femoral diaphysis length, excluding the hypoechogenic cartilaginous structures at either end of the femur. Finally, abdominal circumference measurement was taken from a transverse section of the abdomen at the level of fetal liver and the umbilical vein complex. All measurements were obtained at the appropriate levels described elsewhere. Ultrasonographic fetal weight (EFW), in grams, was estimated with Hadlock formula using a combination of the BPD, AC, and FL using a formula that combines BPD, AC and FL [15]. In all cases, the sonographic fetal weight estimation was done 1-2 days before delivery to eliminate the possible impact of the time elapsed between ultrasound examination and delivery on the accuracy of the EFW. Actual birth weight was measured within 30 min after delivery by an experienced midwife on a weighing scale, which was standardized by monthly calibration. Ultrasound examinations were performed transabdominally using a commercially available ultrasound system, Toshiba Xario (Toshiba Medical Systems Corporation, Japan) equipped with a 4-7 MHz curved, high frequency, and curved array transducer for all attendants.

EFW was compared with the actual birth weight (ABW) and the difference between the EFW and the ABW (simple error) was recorded as error in grams. Interobserver reliability of sonographic fetal weight estimation between two sonographers were assessed. Estimated fetal weight (EFW) was compared with the actual birth weight (ABW) with respect to:

mean of absolute error (MAE) = absolute value of [EFW-ABW], and
mean of absolute percentage error (MAPE) = absolute value of [EFW-ABW] × 100/ABW.

Statistical analysis

Continuous variables were expressed as mean ± standard deviation and median (minimum-maximum) where appropriate. Kolmogorov-Smirnov Goodness of Fit test was used to test the distribution of data. For normally distributed data, paired samples T-test was used, whereas Wilcoxon signed ranks test was used to compare the non-parametric continuous variables. Inter-observer comparisons were done by reliability tests (Cronbach alpha and intraclass correlation coefficients). Two-way mixed effects model where people effects are random and measures effects are fixed (Absolute Agreement Definition) was used. The accuracy of actual and sonographic fetal weight estimation were compared using Wilcoxon Signed Ranks Test and Pearsons' correlation coefficient test for BMI of participants. All the analysis were done by Statistical Package for Social Sciences version 15.0 (SPSS Inc., Chicago, IL, USA). Two-tailed p value less than 0.05 was accepted to be statistically significant.

Results

A total of 468 patients who admitted to our department for scheduled delivery were evaluated for eligibility and 223 patients were excluded, of which 17 refused to participate in the study and 206 did not meet the inclusion criteria. The final study group was composed of 245 subjects.

Some demographic and clinical characteristics of patients are illustrated in **Table 1**. The mean of fetal weight estimated by radiologist and obstetrician were 3356 ± 375 g and 3344 ± 365 g, respectively. The mean actual birth weight was 3266 ± 366 g. Significant differences were found with respect to the comparison of EFW obtained by each operator and ABW ($P < 0.001$, for both observer). Mean EFW

Table 2. Descriptive statistics for EFW by observers and ABW and inter-observer reliability coefficients for EFW (n = 245)

	Radiologist	Obstetrician	P*	Inter-observer reliability coefficients	95% CI		P**
					Lower	Upper	
EFW-(Mean ± SD)	3356.20 ± 375.13	3344.59 ± 365.97	0.480	0.864	0.825	0.894	*< 0.0001*
EFW-Med (Min-Max)	3365 (2083-4391)	3356 (2345-4410)	0.660				
Actual Birth Weight ± SD	3266.64 ± 366.48						
p*	*< 0.001*	*< 0.001*					

EFW; Estimated fetal weight, CI; confidence interval. *Paired samples t-test, **Intraclass correlation coefficient test.

Table 3. Comparisons of observers for mean absolute and percentage errors (n = 245)

	Radiologist		Obstetrician		P*
	Mean	± SD	Mean	± SD	
MAE	227.32	160.98	197.51	138.54	< 0.01*
MAPE	7.09	5.17	6.15	4.38	< 0.01*

MAE; mean absolute error, MAPE; mean absolute percentage error. *Wilcoxon signed ranks test.

obtained by each operator and ABW of the participants are presented in **Table 2**. There was no significant difference between mean EFW obtained by radiologist and obstetrician.

Inter-observer reliability coefficients with 95% confidence intervals for sonographic EFW was 0.864 (0.825-0.894, P < 0.001). The reliability coefficient for sonographic fetal weight estimation for interclass observations was summarized in **Table 2**. Interobserver reliability and agreement in sonographic EFW measurement was high.

Table 3 demonstrates the median absolute and median absolute percentage errors of sonographic EFW for two operators. Significant difference was found between operators regarding absolute errors and absolute percentage errors (P < 0.01). The median absolute error for sonographic EFW obtained by radiologist and obsterician was 192 (5-862) and 160 (0-590) g, respectively (P < 0.01). The median absolute percentage error for sonographic EFW obtained by radiologist and obsterician was 5.7 (0.1-26.9) and 5.0 (0-19.4), respectively (P < 0.01). There was significant difference in the magnitude of the median absolute errors and absolute percentage errors between two operators.

Discussion

Prediction of fetal birth-weight by ultrasound in third-trimester is integral to the antenatal care and the accuracy of EFW is also crucial for optimal delivery management [1]. In this present study, we evaluated the interobserver reliability of sonographic fetal weight estimation between two experience sonographers in the third-trimester shortly before delivery. We also compared the sonographic EFW obtained by both sonographers with the ABW using the absolute error and percentage error data. Our study demonstrated that the interobserver reliability and agreement in sonographic EFW measurement was high. Despite this high interobserver agreement for measurement of EFW; absolute error and absolute percentage error between two operators were found significantly different. In parallel with high interobserver agreement, clinical evaluation of this significant difference between operators regarding absolute error and absolute percentage error makes this finding clinically insignificant.

Previous studies have mostly focused on the impact of different weight equations and various clinical factors on the accuracy of estimated fetal weight [2, 4-8, 18, 19, 22]. Despite the clinical importance of sonographic EFW in obstetrical care and delivery management, few interoperator variability studies have been published [9-12]. In 1993, the first in this issue was the study by Chang [12], which was a prospective study to assess intra and interobserver variability in a series of 40 third-trimester pregnancies. In that study, EFWs were obtained by two experienced sonographers and it was demonstrated that measurements of sonographic EFW were reproducible. They reported interobserver differences of less than 85 g, or approximately 3.5%, in EFW [12]. Our results were in agrement with the prior report of Chang [12]. The median absolute percentage error for sonographic EFW obtained by radiologist and obsterician in our study was 5.7 (0.1-26.9) and 5.0 (0-19.4), respectively (P < 0.01). This finding was also comparable with mean absolute percentage errors of 6.1 ± 4.2, 5.9 ± 3.8 and 6.3 ± 5.1% reported in a previous study [23]. In that study, the investigators analyzed the biometric measurements of 39 fetuses at term, which were independently measured by three experienced sonographers [23]. They investigated the contribution of additional examiners to prediction of fetal weight by ultrasound and it was found that averaging the measurement results of two sonographers reduced the mean absolute error in EFW by approximately 17% (from 6.1% to 5.1%). The overall accuracy of sonographic EFW, in terms of median absolute error, obtained by two operators in our study was 192 (5-862) and 160 (0-590) g, respectively and was consistent with a previously published report, in which 840 women undergoing ultrasound assessment for EFW shortly before induction of labor over a 2-year period had been evaluated and a mean absolute error of 227 ± 197 was reported [24].

Several studies compared the accuracy of different sonographic models for fetal weight estimation [22, 23]. In a retrospective cohort study, 26 different models using 3705 sonographic weight estimations performed less than 3 days before delivery were analyzed [22]. They found that mean absolute percentage error for EFW, obtained by using the combination of AC, FL and BPD weight equations, was 6.6%. This finding was also consistent with our study results. In 2003, the accuracies of 25 ultrasonic algorithms for the estimation of term fetal weight in 82 nondiabetic pregnant women at 35 to 42 weeks of gestation were investigated [24]. Mean absolute percentage error for EFW obtained by using the combination of AC, FL and BPD weight equations was reported to be approximately 8.1%. As compared to the results of the study by Nahum [26], the mean absolute percentage error for EFW in our study is lower. The main discrepancy between the results of two studies may be related to differences in the study protocols. Nahum [26] reviewed the medical records retrospectively and the mean interval between sonographic assessment and delivery was 8.2 ± 6.4. In our study, the sonographic assessment was done 1-2 days prior to delivery to eliminate the possible impact of the time elapsed between ultrasound examination and delivery on the accuracy of the EFW.

Operator experience is an important factor to provide accurate fetal weight estimates. A study investigating the learning curve for sonographic EFW reported that there were marked improvements in accuracy among residents in training up to 24 months, where the acceptable performance was achieved [10]. The major clinical concern with reliance on sonographic fetal weight prediction is that it has inherent inaccuracies [1, 16]. Our study focused on the interobserver variability of sonographic EFW. Due to clinical importance of operator-dependent subjective factors on accuracy of sonographic measurements; Dudley and Potter developed a simple audit method for improving the quality of fetal measurements [27]. A further five centers included in this audit strategy program for improving the quality of fetal measurements to determine whether quality varied significantly [28]. These audit studies demonstrated that there was significant variability in sonographic fetal measurement quality between centers and that sonographic measurement performance could be improved.

Our study is limited by a number of matters. Lack of different formulas for ultrasonographic fetal weight calculation. The EFWs were calculated by using the formula described by Hadlock. Ideally, the study would have different sonographic fetal weight estimation models. The absence of time required for ultrasound measurements is another limitation of this study. In this current study time required for ultrasound measurements was not measured, thus comparison between operators regarding the time required for ultrasound examination could not be made. This study has many strengths. The major strength of this study was its prospective nature. Other important strengths of the study include wide and strict exclusion and inclusion criteria and narrow gestational age range and. In addition, all ultrasound measurements were performed on the same ultrasound machine and in all cases, ultrasound assessment for EFW was done 1-2 days before delivery to eliminate the possible impact of the time elapsed between ultrasound examination and delivery on the accuracy of the EFW.

Precise estimation of fetal weight is critical in determining adequate and accurate obstetrical care to pregnant women. Accurate prediction of birth weight prior to delivery is a valuable tool for determining further obstetric and delivery management. Inaccurate measurements shortly before the delivery adversely affects delivery management performance and may lead to inappropriate or untimely intervention and perinatal compromise. Despite considerable technical advances in ultrasound equipment have been achieved and numerous weight formulas have been suggested over the past 30 years, there is still a lack of accuracy in sonographic fetal weight estimation. The importance of ascertaining the interobserver reliability of sonographic EFW is necessary to further improve the accuracy of sonographic EFW during pregnancy. Despite the widespread use of ultrasound to estimate fetal weight and the possible implications of these estimates, there is a relative paucity of literature evaluating interobserver reliability of sonographic EFW.

We suggest that sonographic EFW in third-trimester shortly before the delivery is highly reliable between the radiologists and obstetricians. EFWs measured by radiologists and obstetricians are similar but both are significantly distant from the actual birth weight. However, obstetricians measure EFW significantly more accurate than the radiologists do. Further studies are needed to clarify the reasons of the discrepancy between the two measurements and to guide clinicans with respect to sonographic estimation of fetal weight.

Disclosure of conflict of interest

None.

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