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Accuracy of Antenatal Ultrasound in High Risk Obstetrical Unit in Predicting Neonatal Actual Birth Weight

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Abstract

Objectives: In this study we will evaluate the accuracy of antenatal ultrasound in predicting Actual Birth Weight (ABW) and identify any contributing factors that might be modified to improve our accuracy rate in our high risk ultrasound department. Furthermore, we aim to assess the ultrasound department's performance in comparison to international figures and to demonstrate the need for providing additional training if required.

Setting: King Faisal Specialist Hospital and Research Center (Maternal Fetal Medicine Section), Riyadh, Saudi Arabia.

Design: Retrospective cohort study from January 2011 till August 2014.

Material and Method: Total of 680 pregnant ladies were collected using chart review data from KFSHRC's delivery book as well as electronic data from Viewpoint® (comprehensive data management software) aimed at patients who followed up and delivered at KFSHRC and had U/S within 7 days of delivery. The main outcome measures were to evaluate our official ultrasound accuracy in KFSHRC in predicting Estimated Fetal Weight (EFW) by comparing it to actual postnatal birth weight.

Result: In our study, we observed that the most accurate EFW were obtained among deliveries with birth weights of <2500 gm. On the other hand, fetal weights were overestimated among fetuses >4000 gm.

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Introduction

It is often difficult to know when most developments in medicine actually begin. They tend to evolve and many people will claim the credit for being the first to make a certain breakthrough. With Ultrasound in Obstetrics and Gynecology there is no such doubt for it had a very definite beginning with the1958 classic Lancet paper [1]. The history of Sonography in Obstetrics and Gynecology dates from the classic 1958 Lancet paper of Ian Donald and his team from Glasgow. Fifty years on it is impossible to conceive of practicing Obstetrics and Gynecology without one of the many forms of ultrasound available today. Technological developments such as solid state circuitry, real time imaging, color and power Doppler, transvaginal sonography and 3/4D imaging have been seized by clinical researchers to enhance the investigation and management of patients in areas as diverse as assessment of fetal growth and wellbeing, screening for fetal anomalies, prediction of pre-eclampsia and preterm birth, detection of ectopic gestation, evaluation of pelvic masses, screening for ovarian cancer and fertility management. Ultrasound guided procedures are now essential components of fetal therapy and IVF treatment. This concise history is written by someone who has witnessed each of these advances throughout the ultrasound era and is able to give perspective to these momentous happenings

The ease with which the probe could be manipulated meant that many fetal structures were measured and a great number of charts of different planes and organs were developed. For example charts of inter-orbital diameter [2] long bones, foot length, ear length, the sizes of virtually every fetal organ and multiple ratios between parameters like femur to foot were produced within a space of a few years. However the standard measurements CRL, BPD, head circumference and abdomen circumference which were developed during the static era remained the standard fetal biometric measurements for assessing growth with only the addition of the femur length (which was now easier to measure) incorporated into equations for fetal weight and growth predictions [3].

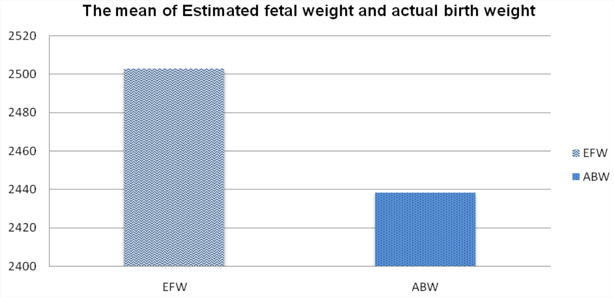

Figure 1: The mean of estimated fetal weight and actual birth weight.

Many researchers have attempted to estimate fetal weight using single or combined ultrasound measurements of the fetus. Knowledge of expected birth weight is attractive to clinicians as it is an important variable affecting perinatal mortality [4].

Fetal weight estimation is thought to be helpful in predicting fetal survival and making decision in very high risk population and in managing the delivery of the large baby, where complications may occur [5].

Numerous methods for the sonographic prediction of fetal birth weight have been proposed over the past few decades. These methods incorporate either single or combinations of biometric parameters measured on ultrasound into mathematical equations. Several mathematical formulas can be used to calculate estimated fetal weight (EFW) [6]. Among them, Hadlock's formula [3] which includes measurements of Biparietal Diameter (BPD), Abdominal Circumference (AC) and Femur Length (FL) - has been shown to provide the best accuracy and is thus frequently used. More recently, fetal thigh soft-tissue thickness [7,8] and Thoracic diameter [9]. Measurements have also been used to calculate fetal weight. Birth weight is an important predictor of neonatal morbidity and mortality. There is no international consensus on the definition of macrosomia, but the most common definition is birth weight ≥ 4000 g, which occurs in 0.5 % to 15% of all pregnancies. Macrosomia is associated with an increased risk for a number of perinatal complications including prolonged labor, shoulder dystocia with brachial palsy, facial nerve palsy, fractures of the clavicle and humerus, perinatal mortality and asphyxia [10]. Low-birth-weight fetuses have higher rates of adverse perinatal outcomes. An accurate prediction of birth weight can be an extremely valuable tool in clinical decision-making regarding perinatal strategies, including elective caesarean delivery, [6] especially in extreme gestational age, i.e. near viability and post-term pregnancy. The main aim of antenatal care is the prevention of morbidity and mortality. Prevention requires intervention in those patients at risk. If identification of the risk group lacks sensitivity and specificity, any trial of intervention will be compromised [11]. Various clinical and technical factors may affect the accuracy of the EFW. These factors may or may not include maternal factors such as body mass index (BMI); pregnancy factors such as fetal sex, multiple pregnancy, and amniotic fluid volume, ethnicity and technical factors related to the experience and fatigue of the ultrasonographer [12] as well as technically advanced equipment. When EFW is calculated prior to delivery in order to help in decision- making, it can be compared to birth-weight reference charts and, in experienced hands, nearly 80% of EFWs are within 10% of the actual birth weight, with most of the remainder being within 20% of actual birth weight [13]. Many reviews and studies were conducted regarding the accuracy of ultrasound in estimating fetal weight: Melissa et al. published a retrospective study in 2013 demonstrating less observers' source of error in a well trained ultrasound department. In addition to that, their study showed that absolute error in gm was significantly higher in males [6]. Another study by N.J. Dudley published a systematic review of the ultrasound estimation of fetal weight concluded that Population differences, maternal factors and variations in fetal composition are probably minor issues in the context of the current large random errors in EFW. Image quality is an issue that may be overcome, at least in part, by technological developments such as harmonic imaging [11] demonstrated the learning curve in estimating fetal weight; there were significant improvements in accuracy amongst residents in training up to 24 months, where the best performance was achieved [14].

Table 1: Subject's Characteristics.

	Minimum	Maximum	Mean	Standard Deviation
Mother's age	16	48	31	5.7
Mother's height	141	178	158	5.8
Mother's weight	39	133	78.4	15.8
Mother's BMI	16	53	31.4	6

Materials and Methods

Retrospective cohort study from January 2011 till August 2014. A total of 680 pregnant ladies were collected using chart review data from KFSHRC's delivery book as well as electronic data from Viewpoint® (comprehensive data management software) aimed at patients who followed up and delivered at KFSHRC and had ultrasound scan within 7 days of delivery.

Main outcome measures

To evaluate our official ultrasound accuracy in KFSHRC in predicting Estimated Fetal Weight (EFW) by comparing it to actual postnatal birth weight.

Secondary outcome

To identify any contributing factors that might be modified to improve our accuracy rate in our high risk ultrasound department. Furthermore, we aim to assess the ultrasound department's performance in comparison to international figures and to demonstrate the need for providing additional training if required.

Exclusion criteria

Chromosomal abnormal fetus, Presence of fetal abnormality, incomplete record, Neonate without immediate post-partum birth weight, inaccurate gestational age.

Descriptive analysis

The design of the study is a cross-sectional one and for which primary interest is on quantifying how accurately the Viewpoint ultrasound system can predict eventual birth weight. To that extent, the statistical analyses will be one of estimation-estimating the difference between the predicting birth weight and the actual together with 95% confidence intervals. The eventual parameter of interest is the population mean delta between the two birth weights (predicted and actual). A few other concomitant items of information will also be collected (e.g. operator, type of pregnancy, maternal co-morbidities, etc.) to investigate the extent to which these may be related to the level of accuracy of prediction.

In terms of sample size, it is know that since 2009 when the

Table 2: The mean and standard deviation of the fetal estimated weight.

Type of pregnancy	N	Mean		Standard Deviation	Gender F=Female; M=Male
Singleton	563	1st	2597.4	832.54	273 F 290 M
Twin (Di-Di)	2X 89	1st	2008.2	455.57	84 F 94 M
		2nd	2059.39	599.3	
Twin (Mono-Di)	2X 15	1st	2000.2	386.13	21 F 9 M
		2nd	1865.6	459.2	
Twin (Mono-Mono)	2X 2	1st	2117.5	144.96	2 F 2 M
		2nd	2032.5	413.65	
Triplet	3X 1	1st	1689	.	2 F 1M
		2nd	1576	.	
		3rd	1775	.	
Total	778	2502.96		812.33	382 F
					396 M

Table 3: The mean and standard deviation of the actual birth weight.

Type of pregnancy	N	Mean	Standard Deviation	Gender Boys	Gender Girls
Singleton	563	2537	787.2	396	382
Twin (Di-Di)	89	1934	414.8		
Twin (Mono-Di)	15	1900	341		
Twin (Mono-Mono)	2	1925	275.8		
Triplet	1	1010	.		
Total	670	2438	773.4	778	

Viewpoint device was acquired, over 7000 births have happened at KFSH & RC, and it is thought that several hundred of those will be relevant to this study. A level of precision for estimating (i.e. confidence intervals) the accuracy (to within 5% of birth weight) would require approximately 110 births. Many more than this will be included in the study and surpassing the minimal requirements.

Results of accuracy will be summarized as mean plus/minus standard error. Calculations of the confidence intervals will be done assuming normality (an assumption that will be tested with the data).

Ethical considerations

It is chart review (paper and electronic charts). To ensure confidentiality research data will be collected only by the authors, subjects names will not be collected, a study ID which will be used to identify subjects data will be collected on excel sheets and kept in file with PI. File will be encrypted. No consent is required from the patients as they all will have expected routine prenatal care during pregnancy and delivery. No financial cost or compensation will be expected for this study.

Statistical analysis

The design of the study is a cross-sectional one and for which primary interest is on evaluating how accurately the Viewpoint ultrasound system can predict eventual birth weight. To that extent, Paried sample t-test was used to estimating the difference between the predicting birth weight and the actual birth weight for the whole group. Factorial repeated measures ANOVA test was conducted to determine whether there was an effect of the gestational age and fetal weight on the accuracy of estimating the fetal weight.

The eventual parameter of interest is the population mean delta between the two birth weights (predicted and actual). A few other concomitant items of information was collected (e.g. operator, type of pregnancy, maternal co-morbidities, etc.) Descriptive analysis was used to investigate the extent to which these may be related to the level of accuracy of prediction.

Results of accuracy will be summarized as mean plus/minus standard deviation (an assumption that will be tested with the data).

Results

Six hundred and seventy pregnant women were recruited in this study. The data were collected from the maternal fetal medicine department at King Faisal Specialist Hospital and Research Center in Riyadh, Saudi Arabia. Mean and standard deviation of their age, height, weight and body mass index (BMI) were 31 years (5.7), 158 (5.8), 78.4 (15.8) and 31.4 (6), respectively. Subjects' characteristics are summarized in (Table 1).

Five hundred and sixty three (84%) women had singleton pregnancy while 89 (13.3%) women had dichorionic-diamniotic (Di-Di) twin pregnancy, fifteen (2.2%) had monochorionic-diamniotic (Mono-Di) twin, two (0.3%) had monochorionic-monoamniotic (Mono-Mono) twin, and only one (0.1%) had triplet pregnancy. Fourteen (2.1%) women had hypertension and twenty-two (3.1%) had diabetes. The maximum gravida reported in all included women in this study was 16 and it was related to one woman only. Most included women (n=517) had five or less gravida. Three women had twelve parity and 626 (93.4%) women had five or less parity.

Seven sonographers estimated the fetal weight of 670 pregnant women using the ultrasound Phillips IU22 machine. Means and standard deviations of the estimated fetal weights for the singleton, twin (Di-Di), twin (Mono-Di), twin (Mono-Mono) and triplet were 2597 (832), 2008.2 (455.5), 2000.2 (386.1), 2117.5 (144.9) and 1689 (0) grams respectively (Table 2).

The weight of seven hundred and seventy eight (778) babies were measured at birth and the means and standard deviations of the singleton, Twin (Di-Di), Twin (Mono-Di), Twin (Mono-Mono) and Triplet were 2536.9 (787), 1933.5 (414), 1900 (341),

Table 4: Frequency and percentage of the AFI.

	AF1		AF2		AF3	
	Frequency	Percent (%)	Frequency	Percent (%)	Frequency	Percent (%)
Normal	502	74.9	97	14.3	1	0.1
Oligohydramnios	104	15.5	2	0.3	0	0
Polyhydramnios	56	8.4	6	0.9	0	0
Anhdramnios	8	1.2	2	0.3	0	0

Table 5: Frequency and percentage of fetuses' presentation.

	AF1		AF2		AF3	
	Frequency	Percent (%)	Frequency	Percent (%)	Frequency	Percent (%)
Cephalic	589	87.9	48	7.2	0	0
Breach	74	11	44	6.6	1	0.1
Transverse	7	1	14	2.1	0	0

Table 6: Estimated fetal weight versus actual birth weight according to the gestational age.

Gestational age categories	N	Mean (SD)			Paired sample t-test		
		EFW	ABW	Mean difference (SD)	Standard error	df	p-value
Group 1 (24-28 weeks)	29	904.7 (279.5)	865 (238.3)	39.5 (94.2)	17.5	28	0.032
Group 2 (28-32 weeks)	82	1625.2 (231.6)	1619 (441.4)	6.2 (231.6)	25.5	81	0.809
Group 3 (32-36 weeks)	270	2265.5 (470.6)	2218 (455)	47.5 (227.2)	13.8	269	0.001
Group 4 (>36 weeks)	289	3134.2 (581)	3034.5 (541)	99.7 (260.8)	15.3	288	0

Table 7: Descriptive data and p-values for the estimated fetal weight and actual birth weight in according to the baby weight categories.

Weight categories	N	Mean (SD)		Paired sample t-test			
		EFW	ABW	Mean difference (SD)	Standard error	df	p-value
Group 1<1000 grams	21	738.8 (142.3)	741.9 (156.6)	3.1 (82.7)	18	20	0.864
Group 2 1001-1500 grams	52	1285.2 (140.6)	1303.4 (222.35)	18.2 (174.8)	24.2	51	0.457
Group 3 1501 – 2000 grams	102	1746.1 (138)	1759.7 (243.2)	13.6 (196.2)	19.4	101	0.487
Group 4 2001-2500 grams	165	2253.6 (143.1)	2232.3 (277.8)	21.3 (230.2)	17.9	164	0.235
Group 5 2501-3000 grams	45	2686.4 (133.7)	2566.9 (245.2)	119.5 (221.8)	33	44	0.001
Group 6 3001-3500 grams	211	3004.4 (267.3)	2907 (317.5)	97.4 (234.3)	16.1	210	0
Group 7 3501- 4000 grams	46	3741.7 (141.3)	3605.9 (329.7)	135.8 (300)	44.3	45	0.004
Group 8 >4000 grams	28	4204.9 (153.9)	3848 (331.7)	356.5 (298.8)	56.5	27	0

1010 (0) respectively (Table 3). The average number of days between estimating the fetal weight by ultrasound and measuring the actual weight at birth was 3.3 days. The mean and standard deviation of the gestational age of all included women was 35.3 (3.2) weeks.

Six hundred fetuses were with normal AFI, 106 Oligohydramnios, 62 Polyhydramnios and 10 Anhydramnios (Table 4).

Sixty hundred and thirty seven fetuses presented in cephalic position, 119 in breech presentation, and 21 in transverse lie (Table 5).

Estimated fetal weight versus actual birth weight

Paired sample t-test was used to compare the estimated fetal weight to the actual birth weight and to determine if there were any changes. Since assumptions of normality and equality of variances do not apply to paired t-tests, data were not transformed. The paired sample t-test results showed that there is a statistically significant difference between the estimated fetal weight measured by sonographer and the actual birth weight measured at baby birth as p-value was less than 0.05 (P=0.000). Figure 1 illustrates the means of the estimated fetal weight and actual birth weight. Results indicate that the mean of the estimated fetal weight are significantly higher than that of actual birth weight. The mean difference between the estimated fetal weight and actual birth weight is 64.6 with standard deviation of 240.8.

Estimated fetal weight versus actual birth weight according to the gestational age

The factorial repeated measures ANOVA test was used to measure the effect of the gestational age on the repeated measure of estimated and actual weight. The results of the analysis of the factorial repeated measures ANOVA: 2 (weight measurements) ×4 (groups of gestational age; 1 ≥ 24-28 weeks, 2 >28-32 weeks, 3 > 32-36 weeks and 4 > 36 weeks), shown in table 6, implied that the main effect of the gestational age on estimating the fetal weight is significant (p=005).

Considering that the interaction between the gestational age and fetal weight is significant, for the purpose of investigating the gestational age on each of the estimated and actual birth weight, paired sample t-test was used for each category of the gestational age. The results of the analysis showed a significant difference between the estimated fetal weight and actual weight if the gestational age between 24-28 weeks (group 1), 33 to 36 weeks (group 3) and more than 36 weeks (group 4) and the p-values were 0.032, 0.001 and 0.000 respectively (Table 6).

Estimated fetal weight versus actual birth weight according to the fetal weight categories

The factorial repeated measures ANOVA test was used to measure the effect of the fetal weight on the repeated measure of estimated and actual weight. The results of the analysis of the factorial

Table 8: The number of cases each operator (sonographer) perform in the significant and non-significant group.

Operators	Significant group n=330		Non-significant group n=340	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Operator 1	45	13.6	44	12.9
Operator 2	41	12.4	49	14.4
Operator 3	42	12.7	31	9.1
Operator 4	59	17.9	41	12.1
Operator 5	87	26.4	108	31.8
Operator 6	5	1.5	4	1.2
Other operator	51	15.5	63	18.5

Table 9: Fetal presentation on both significant and non-significant group.

	Significant group n=330		Non-significant group n=340	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Breach	16	4.8	58	17.1
Cephalic	311	94.2	278	81.8
Transverse	3	0.9	4	1.2

repeated measures ANOVA: 2 (weight measurements) × 8(groups of fetal weight; 1 <1000 grams, 2= 1001 grams to 1500 grams, 3=1501 grams – 2000 grams, 4= 2001 grams – 2500 grams, 5 = 2501grams – 3000 grams, 6= 3001grams –3500 grams, 7=3501 grams – 4000 grams and 8 more than 4000 grams), are shown in Table 7, implied that the main effect of the fetal weight on estimating the fetal weight using the ultrasound compared to the actual weigh at birth is significant (p=0036).

Considering that the interaction between the baby weight on estimating the weight of the fetus is significant, and for the purpose of investigating the effect of each fetal weights' category on the accuracy of estimating the fetal weight by compare it to the actual birth weight, paired sample t-test was used. The results of the analysis showed a significant difference between the estimated fetal weight and actual weight if the baby weight was higher than 2500 grams. More details and p-values reported in (Table 7).

For the purpose of investigating the effect of the period between the ultrasound being taken and the birth date and the AFI, sonographers and fetal presentation on estimating the fetal weight, a descriptive analysis was used for those babies whom their weights were more than 2500 grams as they showed a significant difference between the estimated weight and actual birth weight and compare the result to the group of women whom showed no significant difference.

The mean and standard deviation of the period in days between the ultrasound and birth day in both groups were almost similar (significant group 3.5 days (2.2) and non-significant group 3.1 days (2.2)). This finding indicates that there is no effect of the period between the ultrasound and birthday on the accuracy of estimating the fetal weight. (Table 8) indicates that the number and percentage of cases reported by each operator in this study. Result shows that there is no different between the number each operator performed in each group. Though, no significant effect of the operator would be expected.

For the purpose of investigating the effect of fetal presentation on the accuracy of estimating the fetal weight, a descriptive analysis was used. Table 9 indicates that the fetal presentation observed in both groups were almost similar and there is no expected effect of fetal presentation on estimating the fetal weight.

For the purpose of investigating the effect of the AFI, on the accuracy of estimating the fetal weight, a descriptive analysis was used. Table 10 indicates that the AFI almost similar in both groups and there is no expected effect of AFI on the accuracy of estimating the fetal weight.

Discussion

In our study we found that there is a statistically significant difference between the estimated fetal weight and the actual birth weight in 3 out of 4 groups. In the first group (group 1 ≥ 24 weeks –28 weeks), the mean difference was 39.5 gm and SD 94.2 with P-value=0.032, with a range of error in EFW between 227.9 gms–148.9 gms at 95% CI. When this result is applied clinically it is unlikely to have a significant clinical effect. While in the other groups: group 3 (GA > 32–36) and group 4 (GA> 36 weeks), the mean difference was 47.5 and 99.7 gm, SD (227.2), (260.8), P-value (0.001) and (0.000) respectively. This result gives a range of error between (501.9 – 406.9) with 95% CI in group 3, and (619.7-421.9) with 95% CI in group 4.

In experienced hands, nearly 80% of EFWs were within 10% of the ABW while most of the remaining EFWs were within 20% of the ABW. When EFW is calculated prior to delivery in order to assist in the decision making process, any statistically significant difference between the EFW and the ABW will have a negative influence on the decision. On the other hand, we observed that the most reliable EFW were obtained among delivery within the GA of >28-32 weeks with statistically non-significant p value (0.809).

Due to the presence of a statistically significant difference

Table 10: AFI on both significant and non-significant group.

	Significant group n=330		Non-significant group n=340	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Anhdramnios	1	0.3	7	2.1
Normal	248	75.2	254	74.7
Oligohydramnios	41	12.4	63	18.5
Polyhydramnios	40	12.1	16	4.7

between EFW and ABW in 3 groups based on GA, we had to look to different variable in order to correlate the effect of each variable in the accuracy of ultrasound estimation. First we evaluated each of the fetal weight categories and we observed that the most reliable EFWs were obtained among deliveries with birth weights of <2500 gm with very high accuracy, whereas the group of EFW>4000gm, the effects were more pronounced with a high tendency to overestimate the weight with a mean of (356.5) and SD (298.8) range of error (3964 – 5156) with 95% CI. In the latter group, we had 28 fetuses with a mean EFW of (4204.9) and SD (153.9) and a mean ABW of (3848) and SD (331.7).

We then evaluated other variables in order to find additional factors that would affect the accuracy of the U/S EFW such as the period between the ultrasound being taken and the birth date, the AFI, the performing sonographers and finally fetal presentation on estimating the fetal weight. The findings indicated that there are no effects from any of the previous variables when a comparison was made between the two groups, one for those babies whose weights were more than 2500 gm which showed a significant difference between EFW and ABW when the results were compared to the group of women who showed no significant difference.

Conclusion

Restricting study samples to births within seven days of the last ultrasound examination helped to obtain the most accurate EFW. We highlighted the importance of improving the predictions of birth weights in the tails of the birth weight continuum especially in cases of large fetuses. Finally we demonstrated that the majority of the errors in EFW are unexplained by fetal characteristics or operators. More training on cases of large fetuses might be needed.

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