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Reliability of ultrasound estimation of fetal weight in term singleton pregnancies

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Abstract

Aim To assess the reliability of ultrasound estimation of fetal weight undertaken antenatally at Wellington Hospital (Wellington City, New Zealand) in women with a singleton pregnancy ≥37 weeks gestation.

Method Data were collected retrospectively for pregnant women who had undergone ultrasound estimation of fetal weight <7 days prior to a term delivery (≥37 weeks gestation) over the period of July 1998–June 2005. Stillbirths and multiple pregnancies were excluded. Ultrasound fetal weight estimations, calculated using a locally modified Woo formula, were compared with the infant's actual birth weight.

Results A total of 1177 infants were studied. The mean absolute error and mean signed error (±SD) of ultrasound fetal weight estimations were 7.0±5.7% and -0.2±9.0%, respectively (n=1177). Three-quarters of estimations were within 10% of birth weight. Ultrasonic estimation of fetal weight tended to overestimate the weight of small infants (<2500 g; mean signed error = +3.5%±9.1%, n=98) and underestimate the weight of large infants (≥4000 g; mean signed error = -3.3±8.7%, n=170). Both large and normal weight infants of women with diabetes tended to have their weight underestimated (mean signed error = -5.1±9.2%, n=48).

Sensitivity, specificity, positive predictive value, and negative predictive value for ultrasonic detection of fetal weight ≥4000 g in non-diabetic women were 61%, 96%, 69%, and 94%, respectively. For detection of fetal weight ≥4500, the figures were 50%, 98%, 47%, and 98%, respectively.

Conclusion The accuracy of ultrasound estimations of fetal weight performed at Wellington Hospital within 7 days of delivery in term singleton pregnancies was at least similar and sometimes better than that reported in other studies. For one in four women, however, the fetal weight estimation was more than 10% different from the actual birth weight of their infant. Ultrasound measurements had a tendency to overestimate the weight of small infants while underestimating the weight of both large infants and the infants of diabetic mothers. As the reliability of ultrasound estimation of fetal weight to detect larger babies was poor, the use of such an objective measurement in the management of suspected macrosomia in term singleton pregnancies should be avoided.

The ultrasound estimation of fetal weight in term pregnancies is used to determine growth, and this may affect the timing and route of delivery.[1–4] Although antenatal care has focused more on the diagnosis of fetal growth restriction, the delivery of macrosomic infants is associated with higher rates of adverse outcomes for both mother and infant in comparison to the delivery of normal weight infants. Increased risks to the large infant include shoulder dystocia, brachial plexus injury, perinatal

asphyxia, and neonatal death.[5–7] Adverse maternal outcomes include prolonged labour, genital tract trauma, postpartum haemorrhage, and a higher rate of caesarean delivery.[6–8]

Whilst early delivery is the obvious management option for growth-restricted term or near term infants,[9] management of suspected fetal macrosomia is less certain.[2,10] Macrosomia has variously been defined as birth weight >4000 g, >4500 g or >90th centile for weight by gestation.[11] One of the causes of fetal macrosomia is maternal diabetes.[7,8] Ultrasound fetal weight estimations are undertaken as part of the routine management of pregnant women with diabetes. Ultrasound estimations of fetal weight are also undertaken in cases where there is a clinical suspicion of abnormal growth. The appropriate clinical response to an ultrasound diagnosis of macrosomia is unclear, in part because the predictions have been considered unreliable.[2,10,12,13]

The aim of this study was to determine the reliability of ultrasound estimation of fetal weight performed antenatally at Wellington Hospital in singleton term pregnancies delivered within 7 days of the ultrasound assessment, including the particular accuracy of the diagnosis of fetal macrosomia when defined as >4000 g or >4500 g.

Method

Data were collected retrospectively for the 7-year period from 1 July 1998 to 30 June 2005. The study cohort consisted of term infants (≥37 weeks gestation) who had undergone an ultrasound estimation of fetal weight at the Wellington Perinatal Ultrasound Unit, and who delivered <7 days after the measurement. All multiple pregnancies and stillbirths were excluded. Estimated fetal weight data as recorded in the ultrasound database were matched with data derived from the hospital's Perinatal Information Management System, in which maternal and infant information, including the diagnosis of diabetes, was recorded perinatally. Where electronic information was incomplete or uncertain, individual patient records were obtained and viewed to affirm accuracy.

All ultrasound measurements were performed by trained sonographers or obstetric specialists. Estimation of fetal weight was determined using measurements of biparietal diameter (BPD), abdominal circumference (AC), and femur length (FL), which were applied within the formula:

Estimated fetal weight = EXP [2.3026*(1.385 + 0.06739*BPD + 0.03591*AC – 0.00006883*BPD*AC + 0.1312*FL – 0.002675*AC*FL)].

This is a local modification of a formula described by Woo[14] and used at Wellington Hospital since 1996. It was developed after analysis of 581 cases between 1990–1995, which showed this formula to have the best prediction of birth weight (Personal Communication, Paula Carryer, 2002).

Statistical analyses were performed using the Student's t-test and linear regression analysis for parametric data and the non-parametric Kruskal-Wallis, Mann-Whitney U tests, and Chi-squared tests with $p<0.05$ considered significant. Data are presented as mean ± standard deviation (SD).

Results

Of the 20,649 term live-born singleton infants delivered at Wellington Hospital during the study period, 1177 (5.7%) had undergone ultrasound estimation of fetal weight <7 days preceding birth.

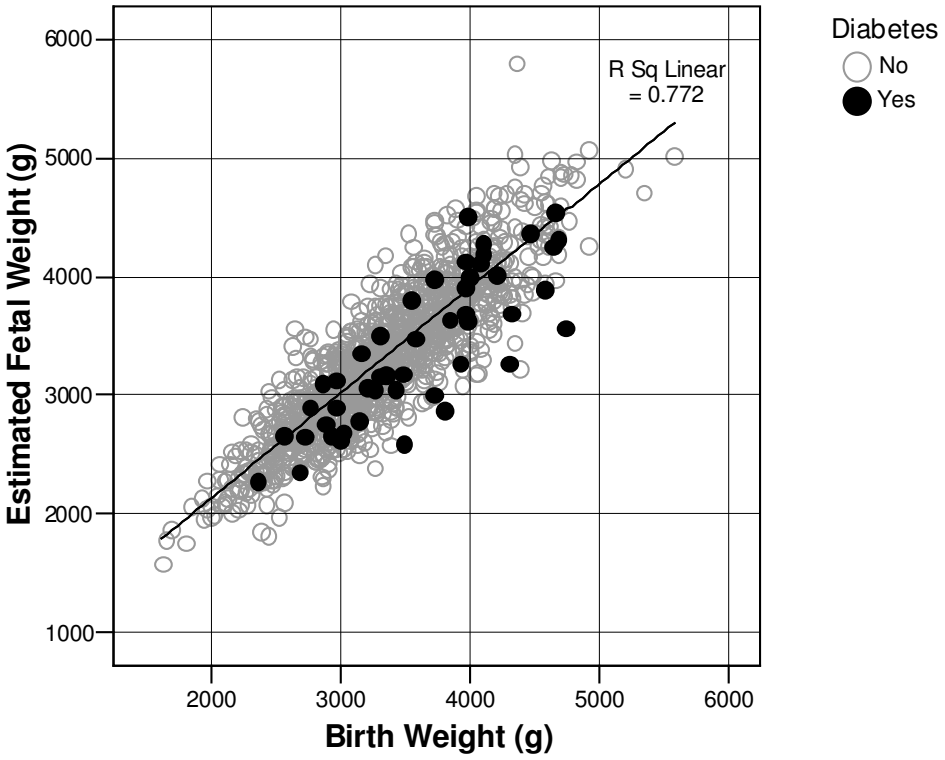
The mean actual birth weight within the study cohort was 3325 g (range 1620–5580 g). Ninety-eight infants (8%) weighed less than 2500 g, and 170 (14%) weighed more than 4000 g. Of the 170, 36 weighed more than 4500 g and three babies weighed more than 5000 g.

Forty-eight (4.1%) women in the study cohort had diabetes in pregnancy. The birth weight of the infants born to these women was significantly higher (3603±629 g) than in non-diabetic women (3314±604 g, n=1129) (p=0.001).

The mean time interval between ultrasound estimation of fetal weight and delivery was 2.9±1.8 days (n=1177) and did not differ significantly between diabetic and non-diabetic women, nor amongst infants in different birth weight categories. Within each birth weight category (<2500 g, 2500–4000 g and ≥4000 g), birth weight did not significantly differ between diabetic and non-diabetic women.

The ultrasonic estimation of fetal weight significantly correlated with actual birth weight for all infants (R=0.879, p<0.001) (Figure 1). Seventy-five percent of all fetal weight estimations were within 10% of actual birth weight; in one out of four women, the error was >10% (Table 1). The difference was >20% in 3% of the weight estimations.

Figure. 1 Scatter plot showing correlation between birth weight and the ultrasound estimation of fetal weight (R=0.879, R^2=0.772, p<0.001, n=1177)



The mean absolute error of fetal weight estimations was 7.0±5.7% (n=1177). This did not differ significantly between infants of different birth weights (<2500 g, 7.3±6.4%, n=98; 2500–3999 g, 6.9±5.6%, n=909; ≥4000 g, 7.3±5.8%, n=170) nor between diabetic and non-diabetic pregnancies (diabetic 8.3±6.5%, n=48; non-diabetic 6.9±5.6%, n=1129).

Table 1. Error distribution of estimated fetal weights

Ultrasound weight estimation	Birth weight (g)							
	<2500		2500–3999		≥4000		All weights	
	n	%	n	%	n	%	n	%
Non-diabetic women								
Within 10% of birth weight	71	73%	659	75%	116	74%	846	75%
>10% below birth weight	3	3%	101	12%	32	20%	136	12%
>10% above birth weight	23	24%	115	13%	9	6%	147	13%
Total	**97**	**100%**	**875**	**100%**	**157**	**100%**	**1129**	**100%**
Diabetic women								
Within 10% of birth weight	1	100%	24	71%	9	69%	34	71%
>10% below birth weight	0	0%	9	27%	4	31%	13	27%
>10% above birth weight	0	0%	1	3%	0	0%	1	2%
Total	**1**	**100%**	**34**	**100%**	**13**	**100%**	**48**	**100%**

Although the absolute percent errors for fetal weight estimation were similar in each of the birth weight categories, the direction of the error (i.e. underestimation vs overestimation) differed. The percentage of infants whose birth weight was underestimated by more than 10% rose from 3% of babies in the low birth weight group to 21% in the macrosomic group. Conversely, the incidence of ultrasound overestimation of weight by more than 10% dropped from 24% of infants in the low birth weight group to 5% in the macrosomic group. Infants in the normal weight group were equally likely to have their weight underestimated (12%) or overestimated (13%) by >10%. These trends remained the same even when non-diabetic pregnancies were analysed separately (Table 1).

Although the absolute percent errors for fetal weight estimation were similar for diabetic and non-diabetic pregnancies, infants of diabetic mothers showed a tendency towards marked underestimation of weight (27% of infants) rather than overestimation (2% of infants), and this trend was seen in both normal weight infants and macrosomic infants (Table 1). This underestimation of weight of infants of diabetic pregnancies (27% [CI: 17–41%]) was significantly more common in comparison to infants of non-diabetic pregnancies (12% [CI: 10–14%]) ($p<0.01$). Only one infant of low birth weight was born to a diabetic mother; its fetal weight estimation was within 10% of birth weight.

These trends were also evident when signed percent errors were examined in the different groups. The mean signed error for all fetal weight estimations was -0.2±9.0%—but when infants were analysed by weight category, the mean signed errors were as follows: <2500 g, +3.5±9.1% (n=98); 2500–3999 g, 0.0±8.8% (n=909); ≥4000 g, -3.3±8.7% (n=170).

Thus the calculation of weight based on ultrasound measurements tended to overestimate the weight of low birth weight infants while underestimating the birth weight of large babies. Mean signed error was 0.0±8.0% in non-diabetic women (n=1129) but was -5.1±9.2% in diabetic women (n=48), indicating that ultrasound tended to underestimate fetal weight in women with diabetes in pregnancy. Linear regression analysis showed that birth weight and diabetic status each had a significant and independent influence on mean signed error (birth weight, $p<0.001$; diabetes, $p=0.001$).

The data were examined to determine the influence of time interval between the ultrasound scan and delivery on accuracy of the fetal weight estimation. There was no significant difference in the absolute error between estimations made ≤3 days prior to delivery (7.0%±5.7, n=724) and those performed 4–6 days before delivery (7.0%±5.7, n=453). Ultrasound measurements carried out 4–6 days prior to delivery tended to result in a slight underestimation of fetal weight (mean signed error = -1.3%±8.9, n=453, p<0.01) whereas ultrasound examination performed ≤3 days before delivery resulted in a mean signed error that was not significantly different from zero (mean signed error = +0.5%±9.0, n=724).

The ability of ultrasound fetal weight estimation to predict fetal macrosomia in non-diabetic women when defined as ≥4000 g or ≥4500 g is shown in Tables 2 and 3, respectively. The cohort contained only 48 diabetic pregnancies, of which only 13 resulted in macrosomic deliveries; thus it was not possible to perform a meaningful analysis of macrosomia prediction in pregnant women with diabetes.

Table 2. Ultrasound prediction of birth weight greater than 4000 g in pregnancies of non-diabetic women

Estimated fetal weight (g)	Actual birth weight (g)		Total
	<4000	≥4000	
<4000	929	62	991
≥4000	43	95	138
Total	**972**	**157**	**1129**

Sensitivity: 61% (CI: 53–68%), specificity: 96% (CI: 94–97%), positive predictive value: 69% (CI: 61–76%), negative predictive value: 94% (CI: 92–95%); CI=confidence interval.

Table 3. Ultrasound prediction of birth weight greater than 4500 g in pregnancies of non-diabetic women

Estimated fetal weight (g)	Actual birth weight (g)		Total
	<4500	≥4500	
<4500	1073	18	1091
≥4500	20	18	38
Total	**1093**	**36**	**1129**

Sensitivity: 50% (CI: 34–66%), specificity: 98% (CI: 97–99%), positive predictive value: 47% (CI: 32–63%), negative predictive value: 98% (CI: 97–99%); C=confidence interval.

There were no cases of macrosomia in infants when the estimated fetal weight was <3000 g. In the non-diabetic women, 3% (10/349) of infants with fetal weight estimations of 3000–3499 g had actual birth weights of more than 4000 g and 19% (52/273) of infants with fetal weight estimations of 3500–3999 g had actual birth weights of more than 4000 g. Conversely, 41% (41/100) of infants of non-diabetic women with fetal weight estimations in the range 4000–4499 g actually weighed less than 4000 g at birth. Sixteen percent (16/100) of estimated fetal weights in the range 4000–4499 g resulted in infants weighing more than 4500 g, and 53% (18/34) of

estimated fetal weights in the range 4500–4999 resulted in infants weighing less than 4500 g.

Discussion

This analysis of 1177 pregnancies is the largest study of the reliability of ultrasound fetal weight estimation in New Zealand. The ultrasound estimation of fetal weight at Wellington Hospital was associated with a mean absolute error of 7%, a figure that compares favourably with other published data.[15–17]

Three out of four (75%) fetal weight estimations were within 10% of actual birth weight—this rate is as good or better than in most published studies (63%,[15] 74%,[16] 23–78%,[17] 52%,[18] 60%,[19] and 74%[20]).

Although the accuracy of our estimations was comparatively good, one out of every four fetal weight estimations was more than 10% different from actual birth weight. Ultrasound measurements give the appearance of precision, but the accuracy of ultrasonic estimations of fetal weight is limited by the fact that the mature fetus is an irregular, three dimensional structure of varying density, the weight of which cannot be calculated with certainty from biometric measurements.[12] It is therefore not surprising that the Australasian Society for Ultrasound in Medicine states that "No formula for estimating fetal weight has achieved an accuracy which enables us to recommend its use,"[21] despite the large number of formulae available.[17,22]

In our study there was an association between fetal size and the direction of the weight estimation error. Thus, for the one in four infants whose fetal weight estimation was more than 10% different from actual birth weight, the error was generally one of overestimation in the case of the small infants and an underestimation in the case of the macrosomic infants. These trends have previously been documented in a systematic review of ultrasonic estimation of fetal weight.[22]

However, our study did not confirm the findings of others[15,18] that the ultrasound estimation of fetal weight was less accurate in macrosomic infants than in non-macrosomic infants. In our study both the mean absolute percent error and the percentage of infants whose estimated fetal weight was within 10% of birth weight were similar in all three weight groups.

The tendency of the ultrasound estimation of fetal weight to err towards normal when the infant was subsequently found to be either <2500 g or ≥4000 g is important because the estimation of fetal weight is of relevance in clinical decision-making at these extremes. The relationship between birth weight and the direction of the estimation error was not due to a bias in the time interval between ultrasound and delivery (as might occur if smaller infants were scanned more regularly) as there was no relationship between infant birth weight and the time interval between ultrasound and delivery.

The reliable estimation of fetal weight is especially important in diabetic pregnancies because these pregnancies are at greater risk of macrosomia.[7,8] Amongst pregnancies complicated by fetal macrosomia, shoulder dystocia occurs more commonly in diabetic than non-diabetic women.[5] Fetal weight estimations have been reported to be less accurate in women with diabetes by some authors,[23,24] whereas others have found no difference in accuracy.[15]

In our study there was no significant difference in the accuracy of fetal weight estimation between women with diabetes and non-diabetic women. There was, however, a systematic underestimation (-5%) of fetal weight in the women with diabetes. This underestimation was also noted by Wong et al (2001),[24] who attributed it to the greater liver size and the increased subcutaneous fat that commonly occurs in fetuses of women with diabetes not being reflected in the formulae used in ultrasound fetal weight estimation.

In this study, the ultrasound estimations of fetal weight were performed <7 days prior to delivery. Although some authors studying reliability of ultrasound estimation of fetal weight have included estimations performed up to 14 days prior to delivery,[25] others have restricted their data to estimations performed within 7 days[24] or 3 days,[15,20] or have attempted to correct for the time elapsed between the ultrasound and delivery by the addition of 25 g per day[26] or 12.4 g or 13.0 g per day (Nahum et al, 2003).[17] Although fetal weight estimations made 4–6 days before delivery tended to slightly underestimate birth weight in our study, the error was small (-1.3±8.9%).

Amongst the non-diabetic cohort, ultrasound estimation of fetal weight detected only three out of every five infants weighing more than 4000 g and only half of the infants weighing more than 4500 g. Our findings thus confirm those of others,[10,13,20] that ultrasound does not reliably detect macrosomia, at least in non-diabetic mothers. Until more reliable methods are developed to determine fetal macrosomia, the use of ultrasound to assess fetal weight in singleton term pregnancies must be interpreted with caution.

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