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Original Article

Fetal weight estimation and prediction of fetal macrosomia in non-diabetic pregnant women

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Abstract

In the present study we investigated the accuracy of Shepard's formula in the sonographic diagnosis of macrosomic fetus of non-diabetic pregnant women. Three hundred and eighty-one macrosomic and 450 appropriate for gestational age (AGA) fetuses born to non-diabetic mothers between 37–42 weeks of gestation were included in the study. Ultrasonographic fetal weight estimation within two days of delivery was made using Shepard's formula in all patients. The estimated fetal weights were compared with the actual birth weights of the same subjects. We did not observe any macrosomic newborn birth in pregnant women with 3200 g or less fetal weight estimation. However, in patients with 3400–3499 g fetal weight estimation, a statistically significant increase in macrosomic newborn birth was observed. Only 3.2% of newborns having actual birth weights greater than or equal to 4000 g had sonographic birth weight estimation less than 4000 g. Accuracy of weight estimations using the Shepard's formula was found to be low in macrosomic fetus. On the other hand, increased incidence of macrosomic newborn birth was observed in subjects with ultrasonographic fetal weight estimations above 3400 g and this level may be useful as a cut-off value for prediction of macrosomic fetus in non-diabetic pregnant women.

Keywords: Macrosomia; Ultrasound; Fetal weight estimation

1. Introduction

Fetal macrosomia is an important obstetric condition that has significant impact on perinatal morbidity and mortality. Obstetric complications such as shoulder dystocia, fetal asphyxia, brachial and facial nerve injury, cranial skeletal injury, genital lacerations, uterine atony or rupture are commonly encountered during delivery of macrosomic infants [1]. Ten to twenty percent of births between 38–41 weeks gestation are newborns above 4000 g, thus clearly indicating the high incidence of fetal macrosomia [2]. Maternal diabetes mellitus (DM) is the major cause of this condition. The incidence of fetal macrosomia increases by five-fold in maternal DM; however it must be remembered that maternal DM is absent in the majority of cases with fetal macrosomia [3]. Proper antenatal surveillance of these patients requires frequent evaluation of both the mother and fetus. Therefore, early detection and management of fetal macrosomia has significantly reduced the incidence of both fetal and maternal complications related to this condition. Diabetic women are now followed-up more intensively compared to recent decades, and only a limited number of diabetic patients are allowed to continue their pregnancy beyond the onset of fetal macrosomia. Routine antenatal follow-up of pregnant women without risk factors such as DM and obesity is usually performed at longer intervals and they may have enough time to develop macrosomic fetus. Hence, we expect the problem of fetal macrosomia will relatively increase in non-diabetic pregnant women.

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The diagnosis of fetal macrosomia can be made in only 40% of the cases when maternal risk factors are taken into consideration [4]. Many investigators have advocated the use of ultrasonographic fetal biometry for the early detection of fetal macrosomia. However, it is worthy to mention that the predictive accuracy of fetal weight estimation varies significantly with the equation or formula used for calculation and the results are far from been desirable [5,6]. Also, the ultrasonographic cut-off values for the diagnosis of fetal macrosomia have not been clearly identified. Furthermore, these studies have generally concentrated on diabetic pregnant women and non-diabetic pregnant women have not been thoroughly investigated [7–12]. In our study, we investigated the predictive accuracy of the Shepard's formula, for estimating fetal weight at labour in non-diabetic pregnant women. We also tried to identify cut-off values for diagnosis of fetal macrosomia in the same patient group.

2. Materials and methods

Our study was conducted prospectively in the Department of Obstetrics and Gynaecology at Cerrahpasa Medical Faculty Hospital between January 1993 and July 1996. This study consisted of 381 macrosomic and 450 appropriate for gestational age (AGA) fetuses born to non-diabetic mother between 37–42 weeks of gestation. Macrosomic and AGA fetuses were collected consecutively as study and control cases in respect to the actual birth weight. Fetal macrosomia was defined as actual birth weights over 4000 g. The patients diagnosed as DM and/or gestational carbohydrate intolerance, multiple pregnancy and fetal anomaly were not included in the study. All pregnant women were screened for gestational diabetes according to the American Diabetes Association criteria [13]. At 24–28 gestational weeks, 50 g glucose load was given orally and 1-h plasma glucose level was obtained. A 1-h plasma glucose level exceeding 140 mg/dl was accepted as abnormal and the patient was advised to take the 3-h oral glucose tolerance test with 100 g glucose. The 3-h test was deemed abnormal when two or more values were elevated according to the criteria of the National Diabetes Data Group (NDDG) [14]. If these criteria were not met the diagnosis of gestational DM was excluded.

A Siemens Imager 2380 scanner with a 3.5 MHz linear-array transducer was used for sonographic examinations. Ultrasonographic examinations and fetal weight estimations were performed by the authors within 48 h of delivery and therefore accepted as estimated birth weights (EBWs). Inter-observer and intra-observer variability were found to be comparable and less than 3%. To minimise errors derived from single measurements, all measurements were repeated at least two times, and the average was accepted as the final value of the related parameter. The delivery room doctors were informed of the estimated birth weights and labour was induced when fetal macrosomia was suspected. Pregnant women who did not apply to our clinic until fetal macrosomia had developed constituted the control group.

Biparietal diameter (BPD) measurements were obtained at the horizontal plane transversing the thalami, the septum cavum pellucidum and the third ventricle by placing the callipers at the outer echodense side of the proximal parietal bone to the inner echodense side of the distal parietal bone. In the presence of dolichocephaly, occipito–frontal diameter (OFD) measurements were obtained at the same plane used for the BPD; the corrected BPD values obtained from the cephalic index formula were used for fetal weight estimations in these patients [15]. The abdominal circumferences (ACs) were measured directly along the outer perimeter including the subcutaneous fatty tissue with a digitiser from a transverse axial section of the fetal abdomen at the level of the fetal stomach and portal–umbilical venous complex. When both or any one of these measurements could not be measured according to criteria described above, the subject was excluded from the study. Estimated births weights were obtained from the nomogram prepared according to Shepard's formula using the BPD and AC values. The newborns were weighed immediately after delivery within 10–15 min and the actual birth weights (ABWs) were recorded. Patients' age, parity and estimated gestational age (according to Naegele's formula) were recorded for every patient. Student's *t*-test, chi-square test and discriminant analyses were used and the level of 0.05 was accepted to assess statistical significance. The results were analysed using the Epi Info (Version 5.01b) program.

3. Results

Of the 831 deliveries, 381 cases (group 1) had a birth weight greater than 4000 g (macrosomic newborn) and 450 cases (group 2) had normal birth weights of 2500–3999 g. Maternal age, gestational age, parity and the distribution of fetal sex were similar in both groups (Table 1). The relationship between actual birth weights and estimated birth weights are shown in Table 2. According to this table, no macrosomic newborn birth was seen among cases with estimated birth weights between 2500–2999 g. However, the incidence of macrosomic newborn birth was 2.5% (3/121), 12% (17/140), 50% (64/127) and 79.7% (114/143) for cases with birth weight estimations of 3000–3249 g, 3250–3499 g, 3500–3749 g and 3750–3999 g, respectively. A significant increase in the incidence of macrosomic newborn birth was observed above the level of 3500 g EBW. Therefore, 3500 g seems to be a good cut-off level for macrosomic birth when estimations are made using the Shepard's formula. Discriminant analysis of the data revealed a significant increase in the incidence of macrosomic birth between 3400 and 3499 g EBWs (Table

Table 1
Gestational week, patient age and parity of the groups studied

Variable	Macrosomic subjects (Group 1) (n=381)	Control subjects (Group 2) (n=450)	p
Gestational week (mean±S.D.) (min–max)	40.37±1.22 (36–43)	39.58±1.43 (36–43)	NS[a]
Age (mean±S.D.) (min–max)	27.64±5.11 (18–42)	25.92±4.97 (16–46)	NS[a]
Parity (n, %)			
Nulliparous	162 (42.5)	255 (56.7)	NS[b]
Primiparous	134 (35.2)	124 (27.6)	
Multiparous	76 (19.9)	69 (15.3)	
Grandmultiparous	9 (2.4)	2 (0.4)	
Fetal Sex (male/female)	192/189	222/228	NS[b]

NS: No significant difference.
[a] Student's t-test.
[b] Chi-square test.

Table 2
Macrosomic birth rates in patients with previously performed ultrasonographic birth weight estimations

Estimated birth weight (g)	n	Macrosomic newborn birth rate (%)				
		4000–4249	4250–4499	4500–4749	4750–4999	≥5000
2500–2749	50	0	0	0	0	0
2750–2999	61	0	0	0	0	0
3000–3249	121	25	0	0	0	0
3250–3449	140	7.1	4.3	0.7	0	0
3500–3749	127	34.6	15.0	0.8	0	0
3750–3999	143	46.2	23.1	7.0	2.8	0.7
4000–4249	128	43.8	37.5	7.8	4.7	2.3
4250–4499	42	16.7	31.0	28.6	14.3	7.1
4500–4999	19	0	31.6	15.8	31.6	21.0

3). The sensitivity for detecting fetuses with birth weights above 4000 g was significantly high, only 3.2% of these cases had actual birth weights under 4000 g. Negative and positive error values in every actual birth weight interval are shown in Table 4. Negative error values show a parallel rise with increasing fetal weight, whereas positive error values fall with increasing fetal weight. When both negative and positive error values are taken into considera-

Table 3
Discriminant analysis results for estimated birth weight and macrosomic fetus

Estimated birth weight (g)	AGA		Actual birth weight			p[a]
	n/N	(%)	Macrosomia		Macrosomia % $<\Sigma a$	
			n/N	(%)		
3000–3099	40/40	(100)	0/40	(0)	–	
3100–3199	44/44	(100)	0/44	(0)	–	
3200–3299	57/61	(93.5)	4/61	(6.5)	–	
3300–3399	50/55	(90.9)	5/55	(9.1)	4/61	0.73
3400–3499	50/61	(82.0)	11/61	(18.0)	9/116	0.04
3500–3599	30/57	(52.6)	27/57	(47.4)	20/177	0.0000
3600–3699	22/41	(53.7)	19/41	(46.3)	47/234	0.0003
3700–3799	15/44	(34.1)	29/44	(65.9)	66/275	0.0000
3800–3899	18/66	(27.3)	48/66	(72.7)	95/319	0.0000
3900–3999	7/62	(11.3)	55/62	(88.7)	143/385	0.0000

AGA=Appropriate for gestational age.
[a] Level of significance was accepted as 0.05.
a: Estimated body weight index (BWI) observed in macrosomic newborn at birth.

Table 4
The error rates of ultrasonographic birth weight estimation in every actual birth weight interval

Actual birth weight (g)	*N*	Accurate measurement	Negative error/positive error (n_{NE}/n_{PE})		Negative error (mean±S.D., %)	Positive error (mean±S.D., %)
			n/*n*	NE/PE ratio		
2500–2749	36	1	15/20	(75)	6.43±3.90	8.52±5.59
2750–2999	49	2	19/28	(68)	8.62±7.22	7.91±5.62
3000–3249	99	6	47/46	(102)	7.74±6.64	5.06±3.86*
3250–3499	110	6	69/35	(197)	7.33±6.19	4.86±4.79*
3500–3749	108	3	79/26	(304)	7.63±5.44	4.90±2.87**
3750–3999	48	1	32/15	(213)	8.67±4.08	3.22±2.58***
4000–4249	186	12	156/18	(867)	7.81±5.07	2.81±2.48***
4250–4449	125	4	113/8	(1412)	9.21±5.65	3.42±3.06**
4500–4749	37	1	34/2	(1700)	10.35±5.43	2.16±1.51*
4750–4999	22	0	21/1	(2100)	11.20±5.47	1.66
≥5000	11	0	11/0	∞	16.59±5.14	–

* $p<0.05$, ** $p<0.02$, *** $p<0.001$.

Table 5
The relation between actual birth weight and estimated birth weight in association to estimated birth weight increments

Estimated birth weight intervals	*n*	Actual birth weight (g) (mean±S.D.)	Estimated birth weight (g) (mean±S.D.)
2500–2749	50	2813±255	2530±183
2750–2999	61	3069±288	2863±63
3000–3249	121	3222±276	3119±76
3250–3499	140	3523±342	3361±68
3500–3749	127	3870±347	3597±77
3750–3999	143	4122±310	3866±69
4000–4249	128	4272±240	4081±70
4250–4499	42	4487±340	4338±61
4500+	19	4729±303	4619±145

tion, negative error values show a higher increase in comparison to positive error values as ABW values reach macrosomic levels.

ABW estimation rates were similar in both group 1 (17/382; 0.045) and group 2 (19/450; 0.042) patients. As shown in Table 5, ABW values were consistently higher than the EBW values in every estimated weight interval, including intervals under macrosomic levels. Using the Shepard's formula EBWs were nearly always lower than the ABW in every subject. Furthermore, the absolute error in grams increased due to underestimation of birth weight as the ABW increased, making the prediction of fetal macrosomia even less likely. Specificity and positive predictive values of ultrasonographic weight estimations were fairly good for estimations made above 3200 g (Table 6).

Table 6
The predicability of sonographic birth weight estimation for detection of fetal macrosomia

Estimated birth weight (g)	Actual birth weight	
	<4000 g	≥4000 g
<4000	249	198
≥4000	6	183

Birth weight estimations above 3200 g were taken into consideration. Sensitivity: 48%, specificity: 97.6%, positive predictive value: 96.8%, negative predictive value: 55.7%, total accuracy rate: 67.9%.

4. Discussion

Various mathematical models have been offered to predict fetal birth weight [16]. A formula that consists of maternal characteristics and fetal gender may be especially useful in studies having dissimilar groups. In the present study, the study and control groups were found to be similar with regard to gestational age, maternal age, parity and fetal sex. The authors of this study accept the possibility that a fetus weighing more than 4000 g could be normal and appropriate for gestational age. However, a definition is needed to define macrosomia. Although cut-off levels have not been clearly defined in the literature, many studies accept the level of 4000 g, the 90th percentile for weight values [4,17]. Others have used 4500 g, a birth weight that occurs in only 1% of all pregnancies [18]. Shoulder dystocia is the most important complication of fetal macrosomia encountered during labour; it has been reported in 12% of non-diabetic deliveries of neonates weighing over 4000 g, compared to only 2% of neonates weighing less than 4000 g [1]. Therefore, the authors accepted 4000 g as the cut-off level for the definition of macrosomia in the present study.

Our study has demonstrated that ultrasonographic fetal weight estimation of non-diabetic pregnant women with Shepard's formula has limited clinical benefits for detection of fetal macrosomia (sensitivity=48%, false negative rate=52%). On the other hand, since the incidence of actual birth weight values above 4000 g were significantly higher in subjects which were defined as having fetal macrosomia ultrasonographically, our findings support the beneficial role of ultrasound in this respect. The fact that fetal weight estimations of macrosomic newborns were

usually under 4000 g, necessitates the need to identify a cut-off value that should alert the obstetrician of a macrosomic fetus. We did not observe any macrosomic newborn birth among subjects with fetal weight estimations under 3200 g (Table 3). The incidence of true macrosomia in subjects with fetal weight estimations between 3200–3299 and 3900–3999 g increased from 6.5% to 88.7%, respectively. According to the results of discriminant analysis, the cut-off value for suspicion of macrosomia was determined to be at a relatively low level around 3400 g. The reason for this was that fetal weight estimation using Shepard's formula generally resulted in underestimation of the actual fetal weight. These findings are consistent with previously reported studies [11]. In a study investigating the accuracy of three different equations for estimated birth weight, no statistically significant difference was observed in the predicability of fetal macrosomia between the formulas; and estimated birth weights were lower than actual birth weights in all groups [12]. In another study performed on 160 diabetic pregnant women investigating the accuracy of various formulas (including Shepard's formula) for estimated fetal weight, no significant difference was detected among the formulas [19]. Tamura et al. reported a detection rate of 74% for fetal macrosomia in a study performed on 147 diabetic pregnant women and 40 control cases using Shepard's formula [20]. The positive predictive value of this study performed on diabetic pregnant women is very low when compared with the positive predictive value of our study on non-diabetic pregnant women. A reasonable explanation may be the difference in growth patterns of macrosomic fetuses of diabetic and non-diabetic pregnant women. At term, weight increments of the macrosomic fetus are similar in both diabetic and non-diabetic subjects, and show a linear increase with progression of pregnancy [21]. Fetal BPD measurements of diabetic and non-diabetics normal patients are similar for the same gestational age; however, due to the subcutaneous fatty tissue accumulation mainly of the abdomen and thorax (centripetal) of fetus of diabetic subjects, abdominal circumference measurements show dissimilarity [22,23]. Therefore, thoracic circumference or bi-acromial diameter measurements have been proposed for calculation of birth weight estimations [23]. The increase in fetal subcutaneous fatty tissue of non-diabetic subjects is more homogeneous; thus the increase in abdominal circumference may not be accentuated as in fetuses of non-diabetic pregnant women compared with diabetic ones. This variance is not noted in BPD measurements because there is no relationship between fetal hyperinsulinemia and enhanced brain growth [24]. Some investigators have proposed to use other parameters such as femur length–abdominal circumference ratio (FL/AC) for weight estimation of fetuses of diabetic mothers, thereby disregarding BPD measurements [25]. The sensitivity for detection of macrosomia secondary to maternal diabetes was 78% when FL/AC was above 1.385; however this ratio was not valuable for non-diabetic subjects [26]. Again, this can be explained with the centripetal fatty tissue distribution of fetuses of diabetic mothers.

In conclusion, the results of our study has demonstrated that a cut-off level of 3400 g can be used for prediction of fetal macrosomia in the non-diabetic pregnant population between 37–42 weeks gestation. It must be remembered that the possibility of a macrosomic fetal birth is more likely in a fetus within normal weight range when the EBW is above 3500 g. Our study was performed in a large series of non-diabetic patients and therefore provides good information for this specific group of patients. Future studies concentrating on ultrasonographic birth weight estimations in more specific groups such as DM, obesity, prolonged pregnancy etc., will clear the clouding over this issue and provide sufficient information to the obstetrician.

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