Estimation of Fetal Weight by Ultrasonic Measurement of Several Fetal Growth Parameters

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SATO, A., LIOU, S., YAMAGUCHI, Y., SATO, M. and SUZUKI, M. *Estimation of Fetal Weight by Ultrasonic Measurement of Several Fetal Growth Parameters.* Tohoku J. exp. Med., 1985, **146** (3), 349-361 — Fetal biparietal diameter (BPD) and head, chest and abdominal circumferences (HC, CC, AC) were measured by means of real-time B-scan echography. The study population consisted of 198 patients who were hospitalized at Tohoku University Hospital. All live-born infants were delivered within 48 hr after ultrasonic examination. This study was intended to establish criteria for diagnosis of fetuses weighing more than 2,500 g by means of a single ultrasonic measurement of several different fetal growth parameters. When estimated diameter of BPD exceeded 9.0 cm, 96.1% of the infants weighed more than 2,500 g. In all cases in which HC, CC and AC exceeded 30 cm, the infants weighed more than 2,500 g. Finally, a multiple regression equation was constructed for estimation of birth weight by the values of fetal BPD, HC, CC and AC. The prediction error between prospective birth weight given by this formula and actual birth weight was ± 200 g. The present method for estimation of fetal weight is simple and useful in obstetrical clinic. ——— ultrasonic measurement; biparietal diameter; head circumference; chest circumference; abdominal circumference

The major advances that have occurred in ultrasonography have been technological, particularly with regard to real-time instrumentation. The use of real-time ultrasonography in obstetrics has increased rapidly in the last decade. Although the utilization of ultrasonography in obstetrics has been based on the confirmation of pregnancy, estimation of gestational age, diagnosis of placenta previa, detection of congenital malformation, observation of fetal behavior and condition, and many other purposes, the most essential use in obstetrics is the evaluation of normal fetal growth and detection of intrauterine growth retardation (IUGR). The representative parameters for fetal growth are diameter of gestational sac and crown-rump length in the first trimester, and biparietal

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diameter (BPD) and femur length (FL) in the second and third trimesters. These parameters are very significant when measured serially during pregnancy. However, it is usually difficult to measure these parameters consistently for out-patients. This study is intended to establish criteria for diagnosis of fetuses weighing more than 2,500 g with a single measurement, and to give a formula of estimation of fetal weight from several parameters measured by ultrasonography.

MATERIALS AND METHODS

Instruments

All the measurements of biparietal diameter (BPD), head circumference (HC), chest circumference (CC) and abdominal circumference (AC) were performed with real-time B-scanners; U-Sonic RT-100 and 2000 (Yokogawa Medical System Co.) and Sonovista-P (Mochida Co.), all of them being equipped with transducers of 3.5 MHz in frequency. The ultrasonic velocity was set at 1,540 m/sec for the scanners except for the Sonovista-P which was set at 1,500 m/sec.

Measurement procedure

Biparietal diameter. Multiple scans were performed at the right angle to longitudinal axis of a fetus until a picture was obtained of an elliptic-shaped skull as well as the cavum septum pellucidum anteriorly and the falx cerebri posteriorly located in the midline of the profile. Using an electronic caliper, BPD was determined as a length from the outer edge of the anterior skull wall to the inner table of the posterior skull (Fig. 1).

Head circumference. The plane for HC measurement was the same as the plane for BPD measurement. Assuming a shape of a fetal head to be an ellipse, head circumference was calculated using the formula for an ellipse.

$$HC = \frac{BPD + \text{occipito-frontal diameter}}{2} \times \pi \quad (\text{Fig. 1})$$

Chest circumference. First, a longitudinal B-mode ultrasonogram of a sagittal section of a fetus was obtained. Fetal spine was then located. Subsequently, the transverse section at the right angle to the spine immediately caudal to the heart pulsations was obtained and could be demonstrated on a transverse section. At this level, the fetal spine,

Fig. 1. Representative photographs of fetal head, chest and abdomen.

Fig. 2. Correlation between the circumference value obtained from diameter caliper and curvimeter. Measurements by ellipic approximation ("Caliper") and that measured directly with a curvimeter ("Curvimeter").

heart, and liver can always be visualized. The transverse and the anteroposterior diameter of fetal chest were then measured with an electronic caliper. A fetal chest circumference was calculated as well as BPD (Fig. 1).

Abdominal circumference. Ultrasonic real-time B-scans were first made at different angles to the midline of the maternal abdomen to identify the position of a long axis of a fetal body. Where there was marked flexion of a fetal body, it was helpful to identify a significant length of the fetal aorta or fetal dorsal spine. Scans were then made orthogonal to the long axis of the fetal body and a section across the upper abdomen was selected. This plane was recognized by the typical appearance of the umbilical vein as it passed under the fetal liver. Usually the umbilical vein could be easily confirmed. Under this section, we have sometimes found the fetal stomach. This method of abdominal circumference measurement is the same as that described by Campbell and Wilkin (1975). The calculation of abdominal circumference was performed in the same way as head and chest circumferences (Fig. 1).

In order to evaluate the present measurement process by the elliptic approximation, each circumference was measured on a polaroid photograph by a curvimeter. After that, each circumference was calculated with reduced scale. The correlation between the value obtained from the formula of elliptic approximation by a caliper and the value determined by a curvimeter is as follows:

$$Y = 1.0067X + 0.2119$$

Y = value of AC by using a curvimeter,

X = value of AC by using the formula of elliptic approximation by caliper.

Correlation coefficient $r = 0.997$.

There was a good correlation between the value using a caliper and the value using a curvimeter (Fig. 2). From this result, the present measurement method was considered reliable.

Patients

The study population consisted of 198 patients who were hospitalized at Tohoku University Hospital. The live-born infants consisted of 172 appropriate-for-gestational-age (AGA) infants and 26 small-for-gestational-age (SGA) infants, and they were classified according to definition previously reported (Sato et al. 1982). The fetal growth parameters were measured in all the live-born cases delivered within 48 hr after the latest ultrasonic examination. Data processing and statistical analysis were carried out at Tohoku University Computer Center.

RESULTS

Correlation between BPD and birth weight

There was a good correlation between BPD and birth weight in cases in which BPD was 8 to 10 cm. Coefficient of correlation was 0.769 and the regression line between these two factors was expressed by an equation as follows:

$$Y = 854.8X - 4911.9,$$

where Y is birth weight in grams and X is BPD in cm (Fig. 3). In 89% of the

Fig. 3. Correlation between BPD and birth weight, in 198 cases divided into four categories as indicated in the figure. "Premature" means infants whose gestational age ≤ 36 weeks and "SGA" was defined as described in the text.

TABLE 1. *Correlation between measurements of biparietal diameter (BPD) and birth weight exceeding 2500 g*

BPD (cm)	<2500 g cases	≥2500 g cases	Accumulation rate for infants weighing more than 2500 g	
8.0>	6			
8.0	1			
8.1	1			
8.2	4			
8.3	4			
8.4	3			
8.5	3	2	159/179	88.8%
8.6	1	4	157/174	90.2%
8.7	3	1	153/169	90.5%
8.8	7	2	152/165	92.1%
8.9		3	150/156	96.1%
9.0	6	21	147/153	96.1%
9.1		10	126/126	100 %
9.2		17		
9.3		10		
9.4		9		
9.5		24		
9.6		16		
9.7		10		
9.8		11		
9.9		5		
10.0		7		
10.0<		7		
Total	39	159		

cases in which BPD was above 8.5 cm, the birth weight exceeded 2,500 g, and in 96.1% of the cases with BPD above 9.0 cm, the birth weight was more than 2,500 g (Table 1).

Correlation between birth weight and HC

The regression line between birth weight and HC was expressed by an equation: $Y = 286.4X - 5717.6$, where Y is birth weight and X is HC. Coefficient of correlation (r) was 0.789. There was a good correlation between these two factors in the AGA cases. But there was no significant correlation in the SGA cases (Fig. 4).

In all cases in which HC was below 26 cm, the infants weighed less than 2,500 g. In all cases in which HC exceeded 30 cm these infants weighed more than 2,500 g.

Fig. 4. Correlation between head circumference and birth weight. Categorization and symbols are as in Fig. 3.

Correlation between birth weight and CC

The regression line between birth weight and CC was expressed by a following equation :

$$Y = 200.5X - 2852.6,$$

where Y is birth weight and X is CC.

Coefficient of correlation (r) was 0.887 (Fig. 5).

In all cases in which HC exceeded 30 cm, the infants weighed more than 2,500 g (Table 3).

Correlation between birth weight and AC

There was a good correlation between birth weight and AC. Coefficient of correlation was 0.891. The regression line between these two factors was expressed by a following equation :

$$Y = 208.7X - 3409.5,$$

where Y is the birth weight and X is AC (Fig. 6). In all cases in which AC was

TABLE 2. *Correlation between measurements of head circumference (HC) and birth weight exceeding 2500 g*

HC (cm)	< 2500 g cases	≥ 2500 g cases	Accumulation rate for infants weighing more than 2500 g	
20				
21	1			
22				
23				
24	2			
25	5			
26	11	2	159/190	83.7%
27	7	7	157/177	88.7%
28	11	15	150/163	92.0%
29	2	60	135/137	98.5%
30		43	75/ 75	100 %
31		26		
32		5		
33		1		
34				
35				
36				
Total	39	159		

below 26 cm, the infants weighed less than 2,500 g. In all cases in which AC was greater than 30 cm, the infants weighed more than 2,500 g (Table 4).

Estimation of fetal body weight

A multiple regression equation for estimation of birth weight by using values of BPD, HC, CC and AC measured by ultrasonography, fundal height of uterus, and gestational age was as follows:

$$Y = 47.227X_1 + 103.939X_2 + 63.848X_3 + 105.109X_4 + 9.082X_5 \\ + 49.228X_6 - 7702.901.$$

X_1 : BPD, X_2 : HC, X_3 : CC, X_4 : AC,

X_5 : gestational age (weeks)

X_6 : fundal height (cm)

Correlation coefficient: $r=0.943$

Correlation between birth weight and estimated birth weight

Prospective study of 122 cases was done by using the equation for estimating birth weight. There was an excellent correlation between actual birth weight and the estimated birth weight (correlation coefficient: $r=0.943$). Prediction error

Fig. 5. Correlation between chest circumference and birth weight. Categorization and symbols are as in Fig. 3.

was ± 200 g (Fig. 7).

DISCUSSION

Recently, several authors have attempted to evaluate fetal growth by ultrasonic measurement of a number of different fetal growth parameters (Thompson et al. 1965; Hellman et al. 1967; Campbell 1968). These parameters have been used to detect IUGR. It has been shown in the infant with IUGR that there is a 3- to 8-fold increase in perinatal mortality, markedly increased perinatal morbidity and many long-term problems in growth and development. It is, therefore, essential that such an IUGR fetus is recognized antenatally. Ultrasonography should provide an ideal means of detecting such a fetus. The purpose of this study was to detect a fetus weighing more than 2,500 g by a simple ultrasonic measurement. Finally, a formula was proposed for estimation of fetal weight by means of ultrasonic measurements of BPD, HC, CC and AC.

Kohorn (1967) reported that neonatal weight exceeded 2,500 g in 96% of the patients studied, if estimated BPD exceeded 8.5 cm. Thompson et al. (1965) reported that in 91% of the infants in which BPD was 8.5 cm or greater, the fetal

TABLE 3. *Correlation between measurements of chest circumference (CC) and birth weight exceeding 2500 g*

CC (cm)	< 2500 g cases	≥ 2500 g cases	Accumulation rate for infants weighing more than 2500 g	
20 >	1			
20	2			
21	1			
22	4			
23	4			
24	2			
25	9		159/184	86.4%
26	10	6	159/175	90.8%
27	6	13	153/159	96.2%
28		19	140/140	100 %
29		37		
30		41		
31		20		
32		13		
33		7		
34		2		
35		1		
Total	39	159		

weight was in excess of 2,500 g. When the estimated diameter exceeded 9.0 cm, 97% of the babies weighed more than 2,500 g. Nakazawa (1973) demonstrated that 95% of the babies weighed more than 2,500 g if their estimated diameter exceeded 8.5 cm. From the present results, it was possible to demonstrate that in 89% of the patients studied, neonatal weight exceeded 2,500 g if estimated BPD exceeded 8.5 cm. When the estimated diameter exceeded 9.0 cm, 96.1% of the neonates weighed more than 2,500 g. This result was similar to Thompson's.

Campbell and Wilkin (1975) has reported that AC determined by ultrasonic measurement is useful for detecting fetal growth, and that a single measurement of fetal AC would also appear to be more efficient in diagnosing a small-for-dates fetus than serial cephalometry and has a lower incidence of false positive diagnosis. They also demonstrated that neonatal birth weight was in excess of 2,500 g if an estimated AC was 29.0–32.0 cm. From the present results, it was possible to estimate fetal weight heavier than 2,500 g at a success rate of 100%, if AC from ultrasonic measurement was 30 cm or greater. The difference between our results and Campbell's may be due to the difference in calculating AC. Campbell and Wilkins (1975) stated that circumference measurements were made on a polaroid photograph by means of a map measurer with appropriate correction for picture

Fig. 6. Correlation between abdominal circumference and birth weight. Categorization and symbols are as in Fig. 8.

size. We measured long and short diameters of the abdomen on the same plane as in Campbell's method, and calculated AC from the data as an ellipse. Clinically, it is very complicated to measure AC on a polaroid photograph consistently. Our calculation is simple and more useful than Campbell's method.

There are a few reports concerning the correlation between birth weight of an infant and ultrasonic measurement of fetal HC and CC (Thompson et al. 1965; Issel and Prenzlau 1974). The reason for this is thought to be that an anteroposterior diameter of the head cannot be measured accurately because a contour line of the head cannot be clearly identified on a screen. Another reason is that CC cannot be measured accurately because it is very difficult to obtain constantly the same chest section. It is thought, however, that this difficulty may be dissolved by practice.

A number of authors have attempted to estimate fetal weight by ultrasonic measurement of a number of different fetal growth parameters (Higginbottom et al. 1975; Lunt and Chard 1976; Warsof et al. 1977). Willocks and associates (1964) reported that estimation of birth weight by BPD alone had standard deviation of a prediction error ± 350.36 g and correlation coefficient was 0.77. From our

TABLE 4. Correlation between measurements of abdominal circumference (AC) and birth weight exceeding 2500 g

AC (cm)	< 2500 g cases	≥ 2500 g cases	Accumulation rate for infants weighing more than 2500 g	
20				
21				
22	3			
23	2			
24	4			
25	5			
26	3		159/184	86.4%
27	9	2	159/181	87.8%
28	7	6	157/170	92.4%
29	6	16	151/157	96.2%
30		35	135/135	100 %
31		37		
32		26		
33		22		
34		10		
35		4		
36		1		
Total	39	159

Fig. 7. Correlation between birth weight and estimated birth weight. ●, non premature and non SGA infants; ×, premature infants; ○, SGA infants.

results, correlation coefficient was also 0.77 using BPD alone. However, the correlation between these parameters is not sufficiently reliable to be of a clinical value.

Campbell and Wilkin (1975) gave a formula for estimating birth weight using ultrasonic measurement of AC. From their results, the error was ± 9.1 percent. Thompson and Makowski (1971) measured both biparietal and anteroposterior chest in newborn infants and made an equation to predict birth weight from these two parameters. They found that estimated birth weight had a standard deviation of 290 g, which was less than that obtained from either diameter alone. Since this report, a number of authors have attempted to estimate fetal weight using ultrasonic measurement of several fetal growth parameters (Suzuki et al. 1974; Picker and Saunders 1976; Wladimiroff et al. 1977). Minoura et al. (1976) gave a multiple regression equation for estimation of birth weight using maternal age, parity, maternal height, gestational age, fundal height, circumference of maternal abdomen, maternal weight and fetal BPD. From their results, their prediction error had standard deviation of 250 g. In this study, we constructed a multiple regression equation for estimation of birth weight using values of fundal height, gestational age, and fetal BPD, HC, CC and AC which were measured by real-time ultrasonography. In the prospective study using these formula, prediction error was ± 200 g. Our method for estimation of fetal weight is simple and we believe it will be useful in obstetric practice.

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