Fractional Thigh Volume by Three-Dimensional Ultrasonography for Birth Weight Prediction

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Objective: *To determine the correlation between actual birthweight (BW) and fetal weight calculated from fractional thigh volume (ThiV).*
Material and Method: *The authors have conducted a prospective, cross-sectional study of normal Thai fetal thigh volume. There were 176 eligible pregnant women who met the criteria of singleton with no fetal anomaly were recruited into the present study. Prior to the present study, 3 operators had been trained and standardized for fractional ThiV measurement by an expert for the first 20 cases. To generate the fetal weight calculating formula, fetal ThiV data from the first 100 cases were employed. Then, the authors' new prediction formula was compared and validated with the Hadlock's and the Tongsong's formula in 56 normal late-third-trimester fetuses. All patients were assessed for 2D fetal biometry and 3D fractional ThiV within one week before delivery.*
Results: *A total of 176 fetuses underwent ultrasound at the gestational age of 38.5 ± 2.1 weeks. The reproducibility of fractional ThiV measurement technique showned very good correlation in both inter- and intra-observer reliability as observed by the high intraclass correlation (0.971-0.994). By using the regression model, fractional ThiV presents a superior correlation to actual BW (r = 0.965). The fitting formula is characterized by predicted fetal BW (g) = 774.744 + 32.658 x fractional ThiV (ml). The presented new formula shows the smallest absolute percentage error (APE) for BW estimation when compared to that of Hadlock's and Tongsong's.*
Conclusion: *Fetal 3D-fractional ThiV is consistent with actual BW. The measurement of fractional ThiV can improve the accuracy of fetal weight prediction especially in some eventful conditions.*

Keywords: *Three-dimensional ultrasound, Two-dimensional ultrasound, Birth weight prediction*

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Intrauterine growth restriction and macrosomia are not uncommon in obstetrics and carry an increased risk of perinatal mortality and morbidity[1-4]. Fetal growth restriction is the second leading contributor to the perinatal mortality rate. The incidence of intrapartum asphyxia in cases complicated by IUGR has been reported to be as high as 50 percent[2]. Identification of fetal weight is crucial because proper evaluation and management can result in a favorable outcome[5]. Several methods that are commonly used to predict fetal weight include fundal height measurement and ultrasonography[2].

To date, 2-dimensional ultrasound (2-D US) becomes an essential tool for fetal weight evaluation. Many birthweight formulas are consisting of common fetal growth indices derived from two dimensional ultrasound such as BPD (biparietal diameter), HC (head circumference), AC (abdominal circum-ference), and FL (femur length)[6]. None of these formulas took soft tissue into account.

Since development of three-dimensional ultrasound (3-D US), many investigators use fetal

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volume such as upper arm volume and thigh volume for improvement in birthweight prediction formula(7-10). Even though many studies have shown improvement in prediction, the use of three-dimensional ultrasound for calculated birthweight is not popular in general usage due to the technical difficulty such as obtaining the optimal plane for the measurement and it's time consuming process.

The recent development of computer software has extended the capabilities of three-dimension ultrasound to gain more appropriate pictures. To the authors' best knowledge, this is the first time fractional thigh volume (ThiV) generated from software has been conduced to evaluate the improvement on predicting fetal birth weight among a Thai population.

Material and Method

A total of 176 fetuses were enrolled into the present study. All of them were expected to deliver within 7 days after ultrasound measurement. Inclusion criteria consisted of singleton pregnancy without fetal anomaly and being planned to deliver at Siriraj Hospital.

Prior to the present study, three maternal fetal medicine (MFM) fellows underwent a 2-week intensive training course for fractional ThiV measurement under the supervision of an MFM expert.

Each operator had to complete the measure ThiV twice for 20 fetuses. Thereafter, the average of fetal ThiV data of all cases in each trainer were analyzed and evaluated. The reproducibility of the ThiV measuring technique was finally determined in terms of the intra-observer and Inter-observer variability.

To create a new formula using fetal ThiV for birthweight prediction, another 100 fetuses (formula finding group) were included. After delivery, actual birth weight of each fetus was recorded and used to generate a new formula. Lastly, fetal ThiV measurement was conducted in another 56 fetuses (formula evaluation group) to validate the precision of the authors' new formula.

The authors received approval for the present study from the human subjected committees at Faculty of Medicine, Siriraj Hospital, Mahidol University.

Technical Method

The measurement of 2-D ultrasound fetal biometry and 3-D fractional ThiV measurement were both achieved by using the Voluson 730 Expert machine (GE Medical system, USA) and 3-D trans-abdominal transducer (RAB4-8L H48621Z, 5.0-MHz annular array). The standard technique of 2-D ultrasound fetal biometry (BPD,HC,AC,and FL) has been described elsewhere. The fractional ThiV measurement was taken from a single sweep technique in the same plane as the femur length measurement. The 3-D volume data set recorded and digitally transferred to another computer work station for further offline analysis.

To obtain fractional ThiV value, the collected volume data was reopened by using 4D view program, version 12 (GE medical system) under the fractinal limb volume mode. After placing the caliper at both sides of the femur, the software automatically divided the femur into five transverse planes. By completely tracing the circumference of each slice, the fractional thigh volume will be calculated based on 50% of femur length (Fig. 1A, B).

Statistical analysis

Statistical analysis was performed by SPSS for Window version 13. The reproducibility (inter and

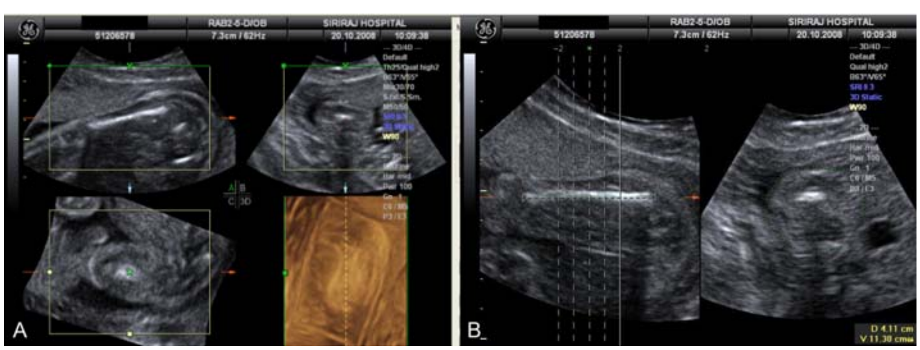

Fig. 1 Technique to obtain fetal fractional thigh volume (ThiV) (A) multiplanar views (saggital, axial and coronal sections) of fetal femur and (B) axial view of femur was selected to determine fractional ThiV by using 4-D view program

intraobserver reliability) was determined by intraclass correlation. The correlation between thigh volume and actual birthweight was assessed by Spearman's correlation coefficient and displayed in a scattergram. The validation of new 3-D ultrasound formula for fetal weight prediction was assessed and presented by Spearman's correlation, mean errors and standard deviation comparison between conventional 2-D and new 3-D formulas was performed in terms of absolute percentage error (APE).

Results

The fractional ThiV measurement of all 176 fetuses was successfully performed. The reproducibility of this technique has apparently been excellent in correlation in both inter-observer and intra-observer reliability. From Table 1, the intraclass correlation (ICC) in each operator ranged from 0.971 to 0.994 while the inter-observer reliability among the operators showed a very good reliability (0.994).

Demographic data of the patient in the formula finding group and formula evaluating group was comparable as shown in Table 2. The mean maternal age and geastaional age were 27.09 $\pm$ 5.75 years and 25.79 $\pm$ 5.12 years 38.13 $\pm$ 2.14 weeks and 38.96 $\pm$ 2.13 weeks in the former and the latter group, respectively. The average interval from the day of ultrasound until delivery was 1.8 day and 1.2 day respectively. The mean birthweight of the first group was slightly smaller than that of the second group (2,952 gm and 3,159 gm, respectively).

To generate a simple linear regression equation of birth weight on fractional ThiV, all data of 100 fetuses in formula finding Group were analyzed. The simple scatter plot of birth weight against thigh volume (Fig. 2) showed a very strong positive correlation between

Table 1. Intra-observer reliability amoung 3 operators (n = 20 fetuses)

Operators	Times	Mean $\pm$ SD	ICC (95% CI)
1st MFM fellow	1	68.37 $\pm$ 17.36	0.983 (0.958-0.993)
	2	68.47 $\pm$ 18.08	
2nd MFM fellow	1	68.62 $\pm$ 18.28	0.971 (0.928-0.988)
	2	67.42 $\pm$ 16.10	
3rd MFM fellow	1	67.77 $\pm$ 18.21	0.994 (0.986-0.997)
	2	68.35 $\pm$ 18.74	

ICC = intraclass correlation, MFM = maternal fetal medicine

Table 2. Patient's demographic data

Characteristic	Mean $\pm$ SD or number (%)	
	Formula finding group (n = 100)	Formula evaluating group (n = 56)
Age (yrs)	27.09 $\pm$ 5.75	25.79 $\pm$ 5.12
BMI (kg/m^2)	27.02 $\pm$ 3.59	28.48 $\pm$ 5.01
Nullipara/multiparity	62/38	34/16
GA (weeks)	38.13 $\pm$ 2.14	38.96 $\pm$ 2.13
Interval between USG and delivery (days)	1.8	1.2
Delivery mode		
Cesarean section	35	23
Vaginal birth	65	33
Operative obsteterics	0	0
Birthweight (gm)	2,952 $\pm$ 565.57	3,159.64 $\pm$ 589.20
< 1500	1	1
> 4000	2	1
Gender male:female	58:42	35:21

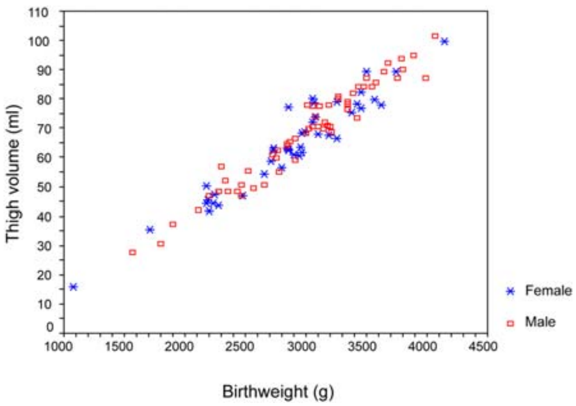

Fig. 2 Scatter plot of fractional thigh volume assessed by ThiV against actual birth weight using 100 subjects in the model fitting data set (formula finding group). There was a very good positive correlation between birth weight and thigh volume ($r = 0.965$, $p < 0.001$)

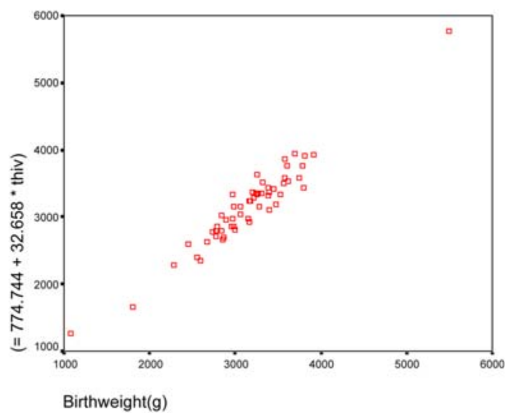

Fig. 3 Scattergram shows the correlation between the actual birthweight (X) and the predicted birthweight from the new fractinal ThiV formula (Y) (n = 56)

birth weight and thigh volume ($r = 0.965$, $p < 0.001$). The simple linear regression analysis revealed a regression equation of birth weight as: bodyweight (BW) = 774.744 + 32.568 x thigh volume (ThiV). This regression model had a very high coefficient of determination (R^2).

For formula validation, the authors evaluated whether the linear regression model derived from 100 fetuses in the model fitting set was able to be generalized to other fetuses. Therefore, fractional thigh volume measurement was conducted in another 56 fetuses of the formula evaluating group. Then, the retrieved data was applied to the new formula for birthweight prediction Scatter plot of the actual birthweight against the predicted birth weight is shown in Fig. 3.

To evaluate the precision of each formula in birthweight prediction, the comparison between the authors' new formula and other formulas has been conducted (Table 3). In the present study, two formulas based on 2-D ultrasound fetal parameters were selected including Hadlock's formula as the representative of Caucasian population and Tongsong's formula as the representative for Thai fetuses. The absolute percentage errors (APE) were 4%, 7% and 9%, respectively.

Discussion

Nowadays, ultrasound is the main diagnostic tool for fetal birthweight (BW) evaluation. The majority of birth weight prediction formulas rely on the fetal biometry data derived from 2-D ultrasound measurement. However, the precision of those conventional formulas remains unsatisfactory with a mean error of 7-10%[7]. Recently, several studies have shown that the subcutaneous fat is strongly correlated to the birthweight including fetal thigh volume[7-13].

Table 3. Comparison of the actual birthweight to the predicted birthweight from different formulas (n = 56)

Value	Fractional ThiV formula	Hadlock's formula	Tongsong's formula
Error (E)	2.86 ± 165.30	-94.00 ± 250.00	41.93 ± 386.00
Percentage error (PE)	0.15 ± 5.50	-3.10 ± 7.80	0.77 ± 11.30
Absolute error (AE)	131.51 ± 98.70	221.17 ± 148.6	298.00 ± 247.20
Absolute percentage error (APE)	4.34 ± 3.47	7.08 ± 4.50	9.12 ± 6.71

Error (E) = Predicted birthweight (PBW) - Actual birthweight (BW)
Percentage error (PE) = (PBW - BW) / BW x 100%
Absolute error (AE) = Absolute (PBW - BW)
Absolute perecentage error (APE) = Absolute (PBW - BW)/BW x 100%
PBW = Predicted birth weight
BW = Actual birth weight

According to the presented data, the reproducibility of ThiV measurement technique showed very good correlation in both inter- and intra-observer reliability. After 2 weeks of training course for thigh volume acquisition technique, one can capture the correct plane of thigh volume measurement in a short period of time. Compared to previous total thigh volume measurement[7-10] this fractional ThiV technique was superior to the former in terms of feasibility and better visualization. Since the error collection in both ends of diaphysis of fetal thigh was eliminated by using partial measurement. Nevertheless, the fractional ThiV technique cannot overcome the universal problems such as severe oligohydramnios, marked maternal obesity and improper position of the fetus.

In the present study, the regression model was applied to evaluate the relationship between fractional ThiV and the actual birth weight. The statistical analysis revealed that fractional ThiV was the best predictor for actual birthweight (the relation coefficient = 0.965). This result was similar to the previous finding of fractional thigh volume study by Lee et al in 2001 (14) (r = 0.86).

For evaluating improvement of the presented formula that generated from the presented regression model, the authors compared the error between the presented formula and other generally used formulas. The authors' new formula shows the smallest absolute percentage error (APE) for birth weight estimation when compared to that of Hadlock's and Tongsong's. Since this parameter is the best predictor of birth weight; the authors can use these single parameters (fractional ThiV) for superior birthweight prediction without any additional parameters.

In certain limited situations such as ventral wall defect. The authors usually cannot visualize truly abdominal circumference. However, by using the presented formula the authors can overcome this problem and predict the birthweight correctly.

Furthermore, with modern equipment, another advantage by using software is the creation of an offline workstation to manipulate and analyze volume ultrasound data later.

Due to the time constraint, there were some limitations of the present study. The presented population contained a small number of extreme fetal weight (< 1500 gm or > 4000 gm), thus the authors were unable to assume whether these extreme birth weight groups would be appropriate for these new formulas. Therefore, the authors suggested that further study is required and should include more of extreme weight such as macrosomia, IUGR, and preterm. Furthermore the next future research is evaluated nomogram for fetal ThiV.

In summary, the present study found that fractional ThiV is well correlated with actual birth weight. The authors' new fractional ThiV formula is practical on a routine basis.

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การทำนายน้ำหนักทารกแรกคลอดจากปริมาตรต้นขาเฉพาะส่วนด้วยคลื่นเสียงความถี่สูงสามมิติ

ณัฐฐิณี ศรีสันติโรจน์, พฤหัส จันทร์ประภาพ, จุฬาลักษณ์ โกมลตรี

เป็นการศึกษาหาความสัมพันธ์ระหว่างน้ำหนักทารกแรกคลอด กับน้ำหนักที่คำนวณได้จากการใช้ปริมาตรต้นขาเฉพาะส่วน ที่วัดด้วยคลื่นเสียง ความถี่สูงสามมิติ ในสตรีตั้งครรภ์ จำนวน 176 ราย ที่มีแนวโน้มว่าจะคลอดบุตรใน 7 วัน นับตั้งแต่วันที่ทำอัลตราซาวน์ โดยอัลตราซาวน์สามมิติเพื่อคำนวณปริมาตรของต้นขาทารกเฉพาะส่วนเปรียบเทียบกับค่าสัดส่วนของการอัลตราซาวน์แบบสองมิติ โดยแบ่งกลุ่ม การศึกษาเป็นสองกลุ่มคือ กลุ่มแรก จำนวน 100 คน เพื่อหาสมการที่เหมาะสมในการคำนวณน้ำหนักจากปริมาตรต้นขาเฉพาะส่วน กลุ่มที่สองจำนวน 56 คน เพื่อทดสอบสมการคำนวณน้ำหนักที่ได้จากกลุ่มที่ 1 จากการคำนวณด้วยสมการถดถอย พบว่าสูตรการคำนวณน้ำหนักด้วยปริมตรต้นขาเฉพาะส่วน มีความสัมพันธ์ที่ดีเมื่อเทียบกับน้ำหนักแรกคลอดจริง โดยสูตรความสัมพันธ์ คือ น้ำหนักทารก (กรัม) = 774.744 + 32.658 x ปริมตรต้นขาเฉพาะส่วน (กรัม) เมื่อเปรียบเทียบกับสูตรการคำนวณน้ำหนักทารกแบบสองมิติ พบว่าการคำนวณด้วยปริมาตรต้นขาเฉพาะส่วนนั้นมีค่าความผิดพลาดต่ำกว่า (Absolute percentage error) ดังนั้น การทำนายน้ำหนักทารกด้วยปริมาตรต้นขาเฉพาะส่วนสามารถนำมาใช้ทำนายน้ำหนักของทารกได้ดีเมื่อเทียบกับสูตรทำนายแบบสองมิติเดิม
