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OBSTRETRICS

Combined 3-D fractional thigh volume with 2-D ultrasonographic biometry for estimating fetal weight

Siraprapa Tantechasatid MD.

Department of Obstetrics and Gynecology, Bhumibol Adulyadej Hospital, Bangkok 10220, Thailand

ABSTRACT

Objective: To generate a new equation for birthweight estimation in the Thai population using fractional thigh volume (Tvol) with a conventional two dimensional ultrasound (2D US).

Materials and methods: A prospective, cross-sectional study was conducted. 123 normal fetuses from 37-42 weeks of gestation were examined within 48 hours before delivery. 2D US was performed for conventional fetal biometry and Tvol was collected by three dimensional ultrasound (3D US). The ultrasound was performed by the author who is an US trained, second year obstetric resident. Intra-observer reliability was analyzed using intraclass correlation coefficient (ICC). Stepwise regression analysis was used to generate a new equation.

Results: ICC 0.994 for Tvol has showed good intra-observer reliability in this study. Two strong biometries correlated with birthweight are Tvol (r=0.96) and biparietal diameter (r=0.044). Birthweight estimation equation from the study was birthweight (grams) = 1241.285 + 22.908 Tvol + 43.741 BPD (r^2 = 0.949).

Conclusion: The Tvol fetal biometry showed a good correlation with fetal birthweight and it could be combined with biparietal diameter to estimate fetal weight.

Keywords: Fractional thigh volume, 2-D ultrasonographic biometry, estimated fetal weight

Introduction

An extreme birth weights (BW), both macrosomia and fetal growth restriction (FGR), is one of the major obstetric issues. Macrosomia infants significantly increase risk of shoulder dystocia, maternal obstetric maneuvers and complications as third and fourth degree laceration especially when vaginal delivery was complicated by shoulder dystocia[1-2]. FGR is an important determinant of numerous neonatal outcomes including stillbirth, fetal hypoxia, hypoglycemia, hypocalcemia, polycythemia, and severe depression at birth[3]. Accurate estimation of fetal BW is a major concern in prenatal care. Not only assessment of fetal growth, it has been used along with other techniques to make a favorable plan of management and delivery by both obstetricians and neonatalogists[4].

According to the American College of Obstetricians and Gynecologists (ACOG), primary methods for clinical estimation of fetal BW are Leopold's maneuver and fundal height measurement. These methods are considered to be a poor predictor[5]. Two-dimensional ultrasonography (2D US) is one of the tools provided for predicting fetal BW. Fetal BW was calculated based on an equation derived from biometric measurements of the fetus-biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), femur length (FL)[6]. In term pregnancy BW estimation that uses 2D US is generally no more accurate than predictions based solely on maternal and pregnancy specific characteristics[7]. Ultrasound measurements in term pregnancies tend to overestimate in small infants while underestimating in large infants by more than 10% different from actual BW[8].

To date, three-dimensional ultrasonography (3D US) has been used for prediction of fetal BW. Soft tissue volume parameters included upper arm and thigh volume was measured by 3D US. These volume parameters allow more accuracy in fetal BW estimation[9]. However there are technical limitations due to unconfidently trace soft tissue borders near limb joints due to acoustic shadowing. To decease this limitation, fractional thigh volume (Tvol) was introduced[10]. Tvol is a parameter derived from the central portion of limb's diaphysis. It displays the sharpest soft tissue borders for tracing[11]. Khoury FR et al have described Tvol to be a better parameter correlated with BW compared to fractional arm volume[12]. Srisantiroj N et al have described Tvol as only one biometry for estimating fetal BW. Their equation has a smaller percentage error compared to Hadlock's and Tongsong's[13]. In Caucasian and Chinese populations, adding Tvol to conventional 2D US biometry equation can improve precision of fetal BW estimation[14-15]. Appropriate equations for estimating fetal BW should be developed for all populations[16]. No equation that combined 3D Tvol with 2D US biometry for estimating fetal BW was developed for Thailand.

This study was conducted to generate an equation for BW prediction by adding Tvol to conventional 2D US biometry in for the Thai population.

Methods

A prospective, cross-sectional study was conducted at Bhumibol Adulyadej Hospital between April 2012 and February 2013. A total of 123 pregnant Thai women were enrolled into the study. Informed consent was given to all women in this study. The study was approved by the Institutional Review Board of Bhumibol Adulyadej Hospital. Inclusion criteria included singleton pregnancies at 37-42 weeks of gestation and expected to deliver at Bhumibol Adulyadej Hospital within 48 hours after US scans were performed. Exclusion criteria were multifetal gestations, infants with major structural or chromosomal abnormalities. All fetal BWs was measured at the nursery care unit on the same calibrated scale.

Gestational age was based on the first day of the last menstrual period (LMP) and confirmed by either first or second trimester ultrasound scan. A normal LMP was defined as regular cyclic menses without antecedent oral contraceptive use. In the first trimester, gestational age was based on crown-rump length measurements. Gestational age in the second trimester was confirmed by measurements of BPD, HC, AC, and FL[17].

Both 2D and 3D ultrasonography were performed by a second year obstetric resident (Tantechasatid S.) who underwent a training course for 2D and 3D ultrasound measurement with an experienced sonographer and maternal-fetal medicine (MFM) staff.

2D fetal biometric examinations and 3D fractional thigh volume (Tvol) were acquired by Voluson 730 Pro (GE, Medical system, USA), with hybrid mechanical and curved array abdominal ultrasonic transducers (RAB 4-8P, RAB 2-5P). The standard 2D fetal biometry (BPD, HC, AC and FL) were collected. Fractional Tvol was taken from a sagittal sweep in the same plane as FL. All 2D and 3D data were recorded.

The fractional Tvol was obtained by measurement offline using 4D view (version 10.5 BT12 Ext1, GE Medical system). Image of Tvol was reopened and magnified to fill at least 2/3 of the screen. Color filtering, system brightness and contrast were adjusted to gain fine image quality and distinct soft tissue border. Then, both calipers were placed at the proximal and distal end of the femur. Five transverse planes of the femur were systematically divided from the center of the mid thigh.

All planes were manually traced. Tvol was automatically calculated from the volume obtained by the tracing. (Fig. 1).

The intra-observer reliability on measuring technique was calculated by 20 randomized cases. Both 2D and 3D parameters were measured twice in each of the 20 cases. The data in each measurement was analyzed to assess intra-observer reliability.

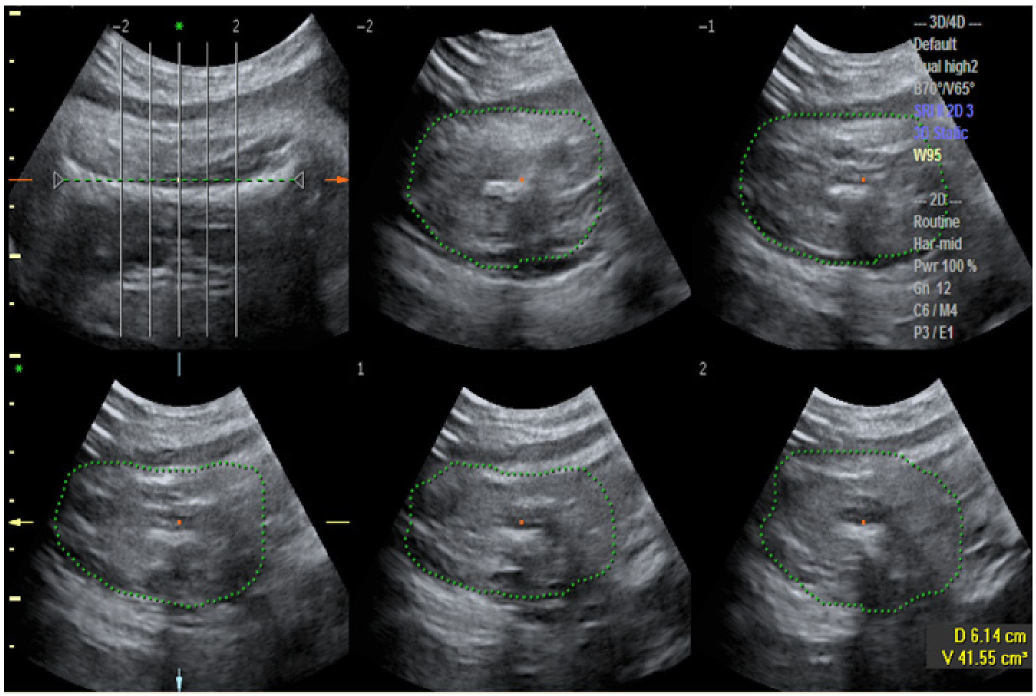

Fig. 1. Fractional thigh volume measurement using 4D view software.

Statistical analysis

Statistical analysis was performed by Statistical Package for the Social Sciences (SPSS 16.0, SPSS Inc., USA). Intraclass correlation coefficients (ICCs) was used to examine intra-observer reliability. An ICCs of 1 indicates that all of the observed variances are due to variations between the subjects, whereas an ICCs of 0 indicates that all of observed variances are due to variations within observers[18]. An ICCs >0.7 is commonly used to indicate sufficient reliability.

To develop weight estimation equation, stepwise regression analysis was used by including fractional Tvol and 2D fetal biometry. Correlation coefficient (R) and coefficient of determination (R^2) are used to measure the strength of relationship between BW and fetal biometry. A value of R and R^2 close to 1 indicated strong correlation. An α level of $p < 0.05$ was considered as statistical significant.

Results

All 123 pregnancies were successfully scanned within 48 hours before delivery from April 2012 to February 2013. Demographic data was shown in Table 1. The mean maternal age was 30.48 years with an average gravidity of 1.82 pregnancies. The mean interval between the ultrasound date and delivery date was 1.11 days. There were 3 fetuses born with a birth weight of more than 4000 grams and one fetus with birth weight of less than 2500 grams.

Intra-observer reliability of ultrasonography measurement was studied in 20 of 100 cases. The ICCs were high for all fetal biometry measurement (ICCs >0.7) except HC (ICCs 0.620) as shown in Table 2. No statistical significance was shown in intra-observer mean differences for all biometry (Table 2).

Birth-weight prediction equation had been generated by using stepwise regression analysis. The correlation between birth weight and fractional Tvol was very strong positive (r=0.96, p=0.00). Another positive correlation was correlation between birth weight and BPD (r=0.044, p=0.042) as shown in Table 3. AC, HC and FL were excluded from the equation because of no statistical significant correlation with birthweight (p>0.05) (Table 3). When combining both positive correlated parameters, regression equation for birth-weight prediction was BW (gram) = 1241.285 + 22.908 Tvol + 43.741 BPD. This equation has a high R^2 value (0.949).

Table 1. Demographic data (n=123)

Characteristic	Mean ± SD or number (%)
Age (yrs)	30.48 ± 6.21
Parity	1.82 ± 0.7
BMI (kg/m2)	27.82 ± 4.16
GA (days)	270.97 ± 6.23
Interval between US and delivery date (days)	1.11 ± 0.32
Delivery mode	
Vaginal birth	2 (1.63%)
Caesarean section	121 (98.37%)
Presentation	
Head	114 (92.7%)
Breech	9 (7.3%)
Sex (Male:Female)	
Male	69 (56.1%)
Female	54 (43.9%)
Birthweight (gm)	3214.84 ± 383.48
< 2500 gm	1 (0.81%)
> 4000 gm	3 (2.44%)

The prediction percentages of 123 studied cases were analyzed using this equation. Mean percentage error for this equation is 0.06%±2.65%. The prediction percentages within 5 and 10% of actual weight is 94.3 and 99.2% respectively.

Table 2. Intra-observer reliability of fractional thigh volume (Tvol), biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur length (FL)

Fetal biometry	Mean difference (95% CI)	ICC (95% CI)	p
Tvol (ml)	-0.22 (-0.87 to 0.44)	0.994 (0.986 to 0.998)	0.503
BPD (cm)	0.01 (-0.06 to 0.08)	0.881 (0.724 to 0.951)	0.747
HC (cm2)	0.00 (-0.31 to 0.31)	0.620 (0.256 to 0.830)	0.997
AC (cm2)	-0.02 (-0.40 to 0.37)	0.872 (0.706 to 0.948)	0.935
FL (cm)	0.01 (-0.08 to 0.09)	0.822 (0.603 to 0.925)	0.890

p = paired sample t-test, ICC = intraclass correlation coefficient

Table 3. Coefficients correlation between ultrasonographic parameter and birth weight

Fetal biometry	r	t	p
Tvol	0.960	44.541	0.00
BPD	0.044	2.052	0.04
HC	-0.008	-0.298	0.77
AC	0.019	0.655	0.51
FL	-0.006	-0.252	0.80

Tvol = fractional thigh volume, BPD = biparietal diameter, HC = head circumference, AC = abdominal circumference, FL = femur length, statistical significant $p < 0.05$

Discussion

In this study, we attempted to construct a new birth weight prediction equation for the Thai population. From a total of 123 cases studied, demographic data shows the mean age was 30.48 years. All cases were term pregnancies. Average birth weight was 3214.84 grams. The study group can well represent reproductive-aged women and fetuses born with birth weight appropriate for gestational age (AGA).

The correlation between actual birth weight and ultrasonographic parameters (BPD, HC, AC, FL and Tvol) were evaluated by stepwise regression analysis. The analysis showed a strong correlation between Tvol and fetal weight (r = 0.96). This correlation was similar to Lee W.et al study in 2001 (r = 0.86) and Nattinee S. et al who studied the Thai population (r = 0.965). Besides Tvol, another statistically significant correlation with fetal weight is BPD (r = 0.044).

Two strong correlated parameters which are Tvol and BPD are combined and are used to generate the equation to estimate fetal weight. From the analysis, our equation has a prediction rate at 94.9% (R2 = 0.949). Trials using this equation found that prediction of birth weight within 5% of actual birth weight was 94.3%. This equation has more accuracy and is simpler compared to previous studies. In 2009, Lee W.et al has generated model based on BPD, Tvol and AC (LnBW = -0.8297+4.0344 (lnBPD) - 0.7820 (lnBPD) 2 + 0.7853 (lnAC) + 0.0528 (lnTvol) 2). The prediction of birth weight within 5% of actual birth weight was 57.3%. Yang F. et al have studied and found the most reliable equation was combination of BPD, AC, FL and Tvol (BW = - 2797.107 + 188.708 x BPD + 176.42 x FL + 13.906 x Tvol + 57.152 x AC). Prediction rate was 69.5% of birth weight to within 5% of actual birth weight in the Chinese population.

Both 2D and 3D US measurements were performed by one operator who is a second-year obstetric resident. Intra-observer ICCs were high. The correlation between Tvol and fetal weight is similar to other studies. According to previous studies, the US data were collected by maternal-fetal medicine (MFM) fellows or staff. This Tvol measurement technique and equation developed in this research can be more feasible for a general obstetric practitioner. However, there are some issues to be considered to achieve an accurate Tvol. As discussed by Lee W. et al, adequate abdominal transducer pressure should be obtained because amniotic fluid volume decreased by excessive pressure can make Tvol measurements more difficult. Some artifacts from maternal respiration and inadequate sweep from fetal size, these can be minimized by acquiring serial images and identifying artifacts before saving the data. Therefore a general obstetric practitioner should have adequately trained and gain some experience before performimg this US parameter measurement.

Since this study is a prospective study, with no drop outs and we gain 123 cases to develop the equation. All the cases studied were Thais which made this equation specific to the Thai population. However, due to limitation of times, we did not perform the validation of this equation in another study group. Thus we can only show the prediction rate from the analysis but unable to show the accuracy or validation of our equation and whether this new equation can best predict birth weight compared to other studies. Another limitation is patient recruitment, all patients were term pregnancies. Further study for validation of this equation is suggested. Besides, the other area of interest is estimation of birth weight in the extremely high and low birth weight groups.

In conclusion, the combination 2D and 3D US parameters to estimate fetal weight yielded a good high prediction rate (94.9%). We found that actual birth weight is well correlated with both Tvol and BPD. Our new birth weight predicted equation is BW = 1241.285 + 22.908Tvol + 43.741BPD.

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การใช้ปริมาตรต้นขาเฉพาะส่วนด้วยอัลตราซาวน์สามมิติร่วมกับการใช้อัลตราซาวน์สองมิติในการทำนายน้ำหนักทารกแรกคลอด

ศิรประภา ตันเตชสาธิต

วัตถุประสงค์ : *เพื่อหาสมการคำนวณน้ำหนักทารกแรกคลอด โดยการใช้ปริมาตรต้นขาเฉพาะส่วน ซึ่งวัดจากการใช้อัลตราซาวน์สามมิติ ร่วมกับการใช้ตัวแปรที่วัดจากอัลตราซาวน์สองมิติแบบเดิม*

วิธีการวิจัย: *เป็นการศึกษาไปข้างหน้าแบบ cross sectional ทำการศึกษาในสตรีตั้งครรภ์เดี่ยวอายุครรภ์ 37-42 สัปดาห์ ที่มีแนวโน้มจะคลอดภายใน 48 ชั่วโมง หลังการทำอัลตราซาวน์ จำนวน 123 ราย ผู้เข้าร่วมวิจัยได้รับการวัด และเก็บข้อมูลอัลตราซาวน์สองและสามมิติ โดยแพทย์ประจำบ้านปีที่สอง นำค่าที่ได้มาวิเคราะห์ความน่าเชื่อถือในตัวผู้ทำการอัลตราซาวน์ (Intra-observer reliability) ด้วยค่าสัมประสิทธิ์สหสัมพันธ์ (Intraclass correlation coefficient) จากนั้นวิเคราะห์หาสมการสำหรับทำนายน้ำหนักทารกโดยใช้การวิเคราะห์การถดถอยแบบขั้นตอน (Stepwise regression analysis)*

ผลการวิจัย: *การคำนวณความน่าเชื่อถือในการวัดอัลตราซาวน์ของแพทย์พบว่า มีความน่าเชื่อถืออยู่ในเกณฑ์สูง (ความน่าเชื่อถือ = 0.994) และจากการวิเคราะห์ข้อมูลด้วยวิธีการถดถอยแบบขั้นตอนพบว่า ปริมาตรต้นขาเฉพาะส่วนและความยาวระหว่างกระดูกข้างขม่อม (Parietal bone) เป็นตัวแปรสองตัวที่มีความสัมพันธ์แปรผันตามน้ำหนักทารก ทำให้ได้สูตรการคำนวณน้ำหนักทารกแรกคลอด คือ น้ำหนักทารก (กรัม) = 1241.285 + 22.908 ปริมาตรต้นขาเฉพาะส่วน + 43.741 ความยาวระหว่างกระดูกข้างขม่อม*

สรุป: *ปริมาตรต้นขาเฉพาะส่วนเป็นตัวแปรที่มีความสัมพันธ์ที่ดีกับน้ำหนักทารก และสามารถนำมาใช้ร่วมกับการวัดความยาวระหว่างกระดูกข้างขม่อม เพื่อใช้ในการคำนวณทารกแรกคลอดได้*