Correlation of Weight Estimation in Large and Small Fetuses with Three-Dimensional Ultrasonographic Volume Measurements of the Fetal Upper-Arm and Thigh: A Preliminary Report

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Objective: *To determine the correlation of measuring fetal upper-arm and thigh volume using three-dimensional ultrasonography with weight estimation in large and small fetuses.*
Material and Method: *The authors included 46 pregnant women admitted for delivery in the Labor Room at Srinagarind Hospital, Khon Kaen University, between February 1 and September 30, 2004. Inclusion criteria were: 1) singleton pregnancy; 2) delivery within 48 hours after study; 3) estimation birthweight < 2,500 g (small fetuses group: n = 22) or > 3,500 g (large fetus group: n = 24). All patients received two- and three-dimensional ultrasound examinations by an experienced practitioner. The upper-arm and thigh volume were assessed using a three-dimensional ultrasound scanner.*
Results: *In the large fetus group, upper-arm and thigh volume measurements by three-dimensional ultrasound strongly correlated with birthweight, r = 0.805 (95%CI = 0.594-0.912) and r = 0.739 (95%CI = 0.478-0.880), respectively. In the small fetuses group, the upper-arm and thigh volume measurements, by three-dimensional ultrasound, strongly correlated with birthweight, r = 0.868 (95%CI = 0.689-0.946) and r = 0.835 (95%CI = 0.638-0.929), respectively.*
Conclusion: *Upper-arm and thigh volumes measured by three-dimensional ultrasound highly correlates with weight estimation in large and small fetuses and can be used as a new modality for estimating fetal weight.*

Keywords: *Upper-arm volumes, Thigh volumes, Birthweight estimation by three-dimensional ultrasound, Large fetuses and small fetuses*

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Both *small-for-gestational-age* (below the10th percentile)[1] and low birthweight (< 2,500 g)[2] infants are associated with an increased risk of complications during labor (attributable to preterm delivery, intrauterine growth restriction (IUGR), or both). Complications include intrapartum fetal distress, intrapartum asphyxia, meconium aspiration, hypoglycemia, hypocalcemia, hypothermia, and polycythemia. The consequent neonatal mortality rate for *small-for-gestational-age* infants born at 38 weeks is 1 percent *vs.* 0.2 percent in infants with appropriate birthweights[1].

For macrosomic infants (> 4,000 g), the potential complications associated with delivery include cephalopelvic disproportion, shoulder dystocia, protracted labor, arrest disorders, perinatal asphyxia, hypoglycemia, hyperbilirubinemia, polycythemia, and thrombocytopenia[3-5]. The maternal risks associated with the delivery of an excessively large fetus include birth canal and pelvic floor injuries and postpartum hemorrhage.

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The methods used for fetal weight estimation include clinical and sonographic measurements. Two-dimensional sonographic estimation is the most accurate way (mean error 7.6-9.1%) to measure various fetal parameters, particularly biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), transverse trunk diameter (TTD) and femur length (FL)[6-10] however, most studies documented poor accuracy among small and excessive fetal weight populations[11].

Now three-dimensional ultrasonography can be used for fetal weight estimation by measurement of the upper-arm and thigh volumes. Previous studies concluded that three-dimensional ultrasonographic estimation of fetal weight by upper-arm and thigh volume measurements were better than two-dimensional ultrasonographic estimation[12-15]. A paucity of data for small and excessive fetal weight fetuses limits any definitive conclusion. The authors therefore determined to test the correlation of fetal upper-arm and thigh volume with weight estimation in small and large fetuses.

Material and Method

The Ethics Committee of Khon Kaen University approved the following study protocols.

The authors enrolled 50 consecutive women, admitted to the Labor Room at the Srinagarind Hospital, Department of Obstetrics and Gynecology, Faculty of Medicine, Khon Kaen University, between February 1 and September 30, 2004.

The inclusion criteria were: 1) singleton pregnancy; 2) planned delivery or cesarean section within 48 hours of ultrasonography; and, 3) estimation of intrauterine fetal weight by two-dimensional ultrasound < 2,500 or > 3,500 g (using BPD and TTD parameters[10]) The exclusion criteria were: 1) fetal anomalies; 2) abnormal fetal karyotype; 3) amniotic fluid index < 5 cm; 4) delivery more than 48 hours after ultrasonography; and, 5) actual birthweight between 2,501 to 3,499 g.

After giving informed consent, all the participants received both a two- and three-dimensional ultrasound examination by an experienced practitioner. The upper-arm and thigh volume were assessed using a three-dimensional ultrasound scanner (Medison, Voluson 530 MT) with a 5.0-MHz transabdominal sector transducer. When the fetus was at rest, the transducer was placed in order to visualize the traditional plane of humerus and femur lengths. When the whole contour of the humerus or femur diaphysis was visualized, three-dimensional scanning was performed.

All image information, of the scanned volume of the whole upper-arm and thigh, was stored in the *three-dimensional ultrasound unit's* built-in computer or on magneto optical discs. Because measurements of the upper-arm and thigh volume were made slice by slice, at 5-mm intervals, complete assessments usually took between 10 and 20 min. Samples of upper-arm and thigh volume measurements, using three-dimensional ultrasound, are presented in Fig. 1 and 2.

All of the neonates were weighed after delivery on the same metric scale and the value recorded to the nearest gram.

Statistical analysis

After completion of the present study, the continuous data were analyzed and presented as means $\pm$ standard deviations. SPSS-PC Version 11.5 was used to perform all statistical analysis. Regression analysis with correlation coefficients with 95%CI was used to calculate the relationship between the independent and dependent variables. The scatter-grams, correlation, and regression analyses also illustrated their accuracy. $P < 0.05$ was considered statistically significant.

Results

Fifty pregnant women were recruited. Both two-dimensional ultrasonographic biometry and three-dimensional ultrasonographic acquisition were performed for upper-arm volume and thigh volume without difficulty in all of the presented patients. Two patients were excluded because they delivered more than 48 hours after the ultrasonography.

When using two-dimensional ultrasonography, one case in the large fetus group, the actual birthweight less than 3,500 g and one case in the small fetuses group, the actual birthweight more than 2,500 g were excluded from the presentstudy. The clinical data of the patients in the large fetuses groups (n = 24) and small fetuses groups (n = 22) are presented in Table 1. The authors entered the data for three-dimensional ultrasonographic upper-arm volume, thigh volume, actual birthweight and correlation analyses performed.

The upper-arm and thigh volume measurements by three-dimensional ultrasound in the large fetus group were strongly correlated with birthweight, r = 0.805 (95%CI = 0.594-0.912) and r = 0.739 (95%CI = 0.478-0.880) (Fig. 3). The upper-arm and thigh volume measurements by three-dimensional ultrasound in the small fetuse group were strongly correlated with birthweight, r = 0.868 (95%CI = 0.689-0.946) and r = 0.835 (95%CI = 0.638-0.929) (Fig. 4). The upper-arm volume

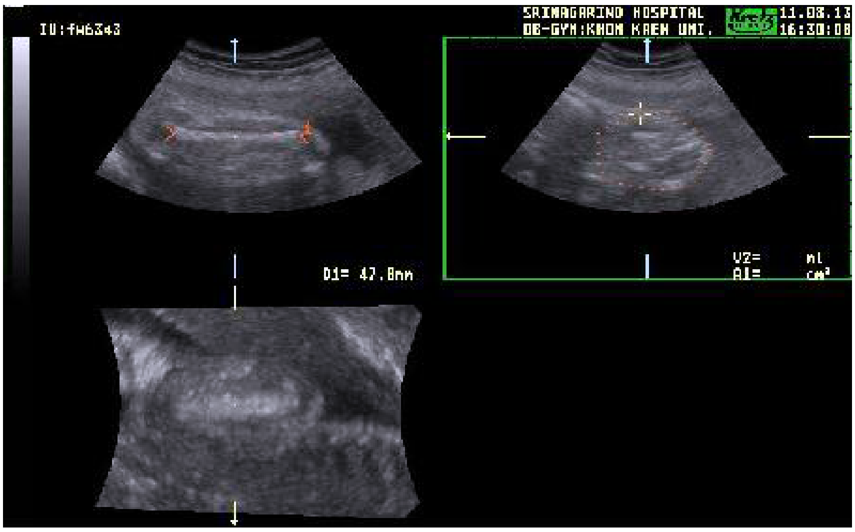

Fig. 1 Measurement volumetry of the upper-arm. The traditional plane for measuring the humerus length was used. The rendered volume was displayed in three orthogonal planes on the screen and rotated to a standard anatomic orientation with the sagittal, transverse and frontal views positioned in the upper left, upper right and lower left planes, respectively. Volume measurements were performed in the upper right plane with the humerus in the transverse plane. Starting from the left to the right end of the humerus shaft, the contour of the upper-arm was outlined with a cursor and stored. The contouring procedure was repeated whenever the shape of the upper-arm changed. The built-in computer calculated the volume of the upper-arm

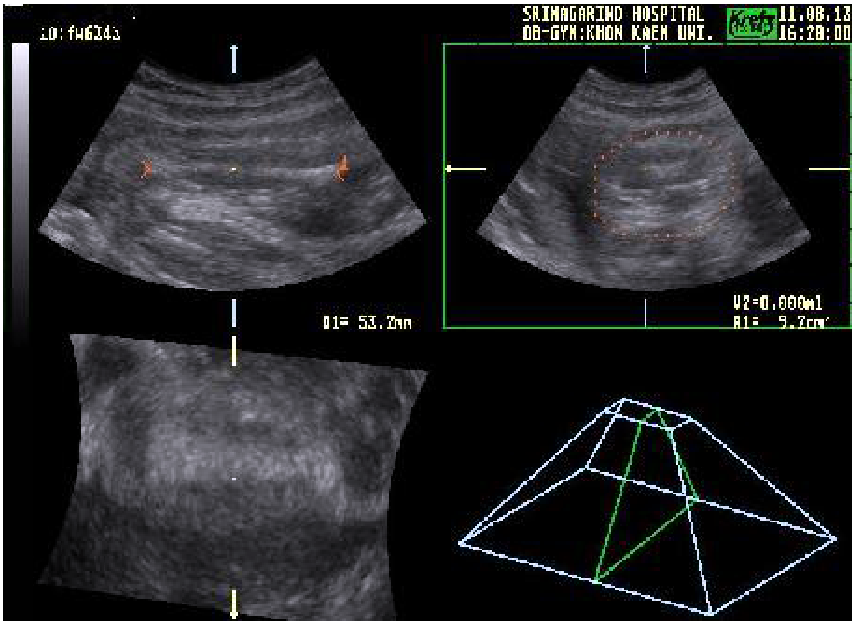

Fig. 2 Measurement volumetry of the thigh. The traditional plane for measuring the femur length was used. The rendered volume was displayed in three orthogonal planes on the screen and rotated to a standard anatomic orientation with the sagittal, transverse and frontal views positioned in the upper left, upper right and lower left plane, respectively. Volume measurements were performed in the upper right plane with the femur in the transverse plane. Starting from the left to the right end of the femoral shaft, the contour of the thigh was outlined with a cursor and stored. The contouring procedure was repeated whenever the shape of the thigh changed. The built-in computer calculated the volume of the thigh

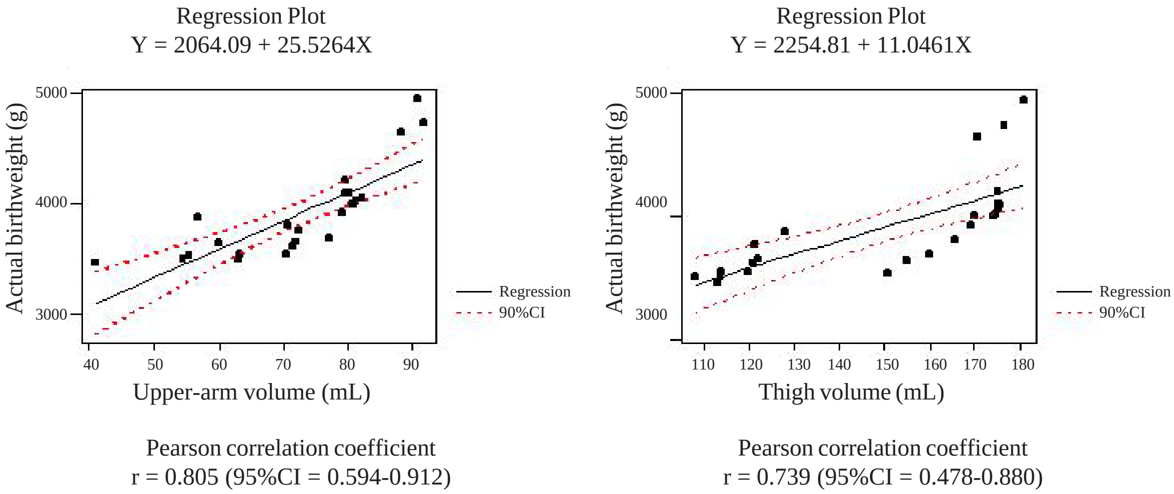

Fig. 3 Scattergrams of the upper-arm and thigh volume assessed using three-dimensional ultrasound vs birthweight in the large fetus group > 3500 g

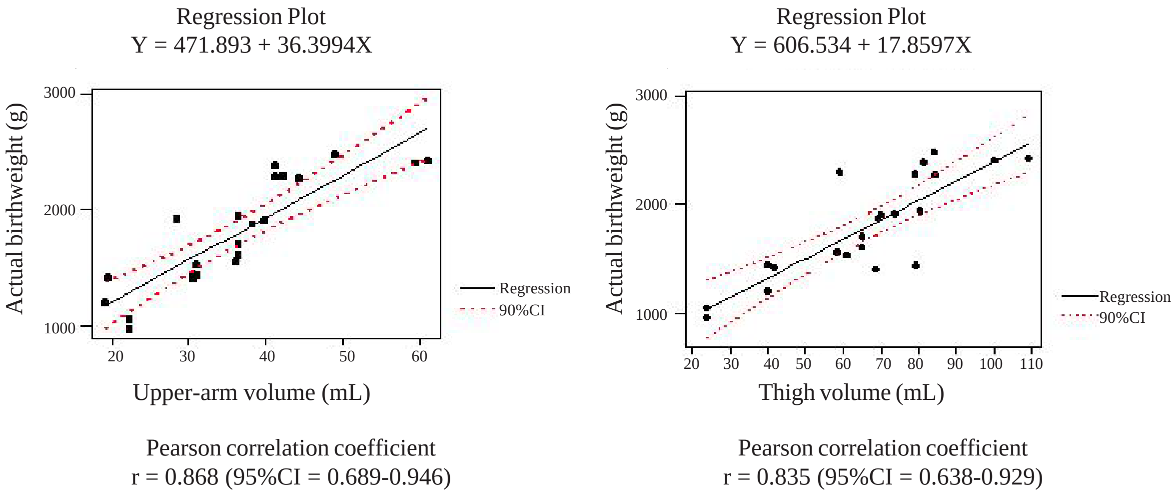

Fig. 4 Scattergrams of the upper-arm and thigh volume assessed with three-dimensional ultrasound vs birthweight in the small fetus group < 2,500 g

was more correlated than thigh volume in both the large and small fetus groups and the small fetus group was more correlated than the large fetus group.

By use of linear and multiple linear regressions in the large fetus group, a best-fit formula was derived: Birthweight (g) = 2031.28 + 15.30 upper-arm volume (mL) + 5.21 thigh volume (mL) (Table 2). The correlations between birthweight and upper-arm and/or thigh volume were significant in the large fetus group > 3,500 g (R^2 = 0.673).

By use of linear and multiple linear regressions in the small fetus group, a best-fit formula was derived: Birthweight (g) = 458.41 + 11.31 upper-arm volume (mL) + 14.27 thigh volume (mL) (Table 2). The correlations between birthweight and upper-arm and/or thigh volume were significant in the small fetus group < 2,500 g (R^2 = 0.786).

Discussion

A variety of formulae and models have been proposed in an attempt to achieve a more precise estimation of fetal weight. Although it is relatively convenient to predict fetal weight by two-dimensional formulae, many fetal conditions decrease their accuracy in predicting fetal weight. Examples include small and excessive fetal weights. Under these conditions,

Table 1. Demographic data for patients in the large and small fetus groups

Clinical Data	Large Fetus Group (n = 24)		Small Fetus Group (n = 22)	
Age (year) mean $\pm$ SD (range)	27.92$\pm$5.12 (20-37)		27.00$\pm$5.86 (16-40)	
Gravidity				
1	7 (29.2%)		12 (54.5%)	
2	13 (54.2%)		4 (18.2%)	
3	4 (16.6%)		6 (27.3%)	
GA (weeks) mean $\pm$ SD (range)	39.32$\pm$1.18 (38-42)		33.73$\pm$2.85(29-39)	
Total maternal weight gain (kg) mean $\pm$ SD (range)	18.37$\pm$3.60 (10-30)		8.57$\pm$3.04 (2-15)	
Actual birthweight (g) mean $\pm$ SD (range)	3915.00$\pm$402.66 (3500-4950)		1791.00$\pm$471.27 (960-2480)	
Upper-arm volume (mL) mean $\pm$ SD (range)	71.05$\pm$14.41 (40.82-91.71)		36.54$\pm$11.07 (19.11-61.21)	
Thigh volume (mL) mean $\pm$ SD (range)	148.00$\pm$28.91 (91.2-180.95)		64.53$\pm$21.44 (24.02-109.25)	
Total time to study (min) mean $\pm$ SD (range)	21.16$\pm$3.93 (15-29)		21.82$\pm$5.01 (15-35)	
Etiology	Unknown	16	Preterm	10
	GDM	5	IUGR	10
	DM class B	2	Severe PIH	1
	Chronic hypertension	1	Chronic hypertension	1

Table 2. Regression analysis with the individual volumetric parameters independent variable and actual birthweight as dependent variable, respectively

	Large Fetus Group (n = 24) Regression formula	R^2	Small Fetus Group (n = 22) Regression formula	R^2
Upper-arm volume (mL)	EBW = 2064.09 + 25.52 Upper-arm volume (mL)	0.648	EBW = 471.89 + 36.39 Upper-arm volume (mL)	0.754
Thigh volume (mL)	EBW = 2254.81 + 11.04 Thigh volume (mL)	0.546	EBW = 532.74 + 19.50 x Thigh volume (mL)	0.697
Upper-arm and Thigh volume (mL)	EBW = 2031.28 + 15.30 Upper-arm volume (mL) + 5.21 x Thigh volume (mL)	0.673	EBW = 458.41 + 11.37 Upper-arm volume (mL) + 14.27 x Thigh volume (mL)	0.786

EBW = estimated birthweight

the error in estimating fetal weight will be greater when using two-dimensional ultrasound, while three-dimensional ultrasound would be more accurate[12-15].

Schild et al[12] reported three-dimensional sonography allows superior fetal weight estimation by soft tissue volume. The fetal upper-arm and thigh volume was highly correlation with birthweight (R^2 = 0.940), (R^2 = 0.949) respectively and new formulae correlated with birthweight (r = 0.967). Chang et al[13] found fetal thigh volume was highly correlatied with birthweight (r = 0.89). The thigh volume had better accuracy in predicting birthweight than two-dimensional ultrasound. Song et al[14] found fetal thigh volume was highly correlatied with birthweight (R^2 = 0.921). Liang et al[15] reported fetal upper-arm volume was highly correlatied with birthweight (r = 0.921). The upper-arm volume had better accuracy in predicting birthweight than two-dimensional ultrasound and there was no difference between right-and left-side upper-arm volume.

The authors found the fetal upper-arm and thigh volume measurement by three-dimensional ultrasound were highly correlated with birthweight estimation in the large and the small fetus groups (R^2 = 0.673), (R^2 = 0.786) respectively, but the correlation coefficient was less than the appropriate for the gestational age fetus (AGA) group according to previous studies by Schild et al[12] (r = 0.967), Chang et al[13] (r = 0.89), Song et al[14] (R^2 = 0.92), Liang et al[15] (r = 0.92), because the authors studied the extreme weight fetuses (*i.e.* < 2,500 and > 3,500 g) which has not been published in a previous study.

By using two parameters in estimated birthweight there was more accuracy than using a single parameter. When using only a single parameter the authors prefer the upper-arm volume to estimate birthweight because it had higher accuracy than thigh volume. Furthermore, using a single parameter is less time consuming than studying the two parameters. The upper-arm volume was more correlated than thigh volume because thigh volumes assessed three-dimensionally were limited due to acoustic shadowing near the knee or hip joints which hinder accurate assessment of the soft tissue border which is necessary for reliable volume calculations of the fetal thigh[16].

In the present study, the effort was made to minimize measurement biases. All sonographic examinations were performed by an experienced practitioner. In addition, actual birthweight examinations were performed without prior knowledge of the sonographic measurements. The numbers in the sample sizes were adequate for calculating correlation.

In summary, the benefit of three-dimensional ultrasonography is now accepted as a reliable tool for prenatal diagnosis of fetal anomalies with the further benefit of accurate estimation of birthweight. The present study demonstrated that the three-dimensional assessments of the upper-arm and thigh volumes are highly correlated with birthweight estimation of large and small fetuses.

A large, prospective study may be needed to confirm the author' conclusions and suggest running comparisons of the three- and two-dimensional ultrasonography in estimating birthweight in the extreme weight fetuses.

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References

1. Cunningham FG, Gant NF, Leveno KJ, Gilstrap LC III, Hauth JC, Wenstrom KD. Fetal growth disorders. Williams obstetrics. 21st ed. New York: McGraw-Hill, 2001: 743-6.
2. Cunningham FG, Gant NF, Leveno KJ, Gilstrap LC III, Hauth JC, Wenstrom KD. Obstetrics in broad perspective. Williams obstetrics. 21st ed. New York: McGraw-Hill, 2001: 3-14.
3. Langer O. Fetal macrosomia: etiologic factors. Clin Obstet Gynecol 2000; 43: 283-97.
4. Ferber A. Maternal complications of fetal macrosomia. Clin Obstet Gynecol 2000; 43: 335-9.
5. Grassi AE, Giuliano MA. The neonate with macrosomia. Clin Obstet Gynecol 2000; 43: 340-8.
6. Campbell S, Wilkin D. Ultrasonic measurement of fetal abdomen circumference in the estimation of fetal weight. Br J Obstet Gynaecol 1975; 82: 689-97.
7. Hadlock FP, Harrist RB, Carpenter RJ, Deter RL, Park SK. Sonographic estimation of fetal weight. Radiology 1984; 150: 353-40.
8. Shepard MJ, Richards VA, Berkowitz RL, Warsof SL, Hobbins JC. An evaluation of two equations for predicting fetal weight by ultrasound. Am J Obstet Gynecol 1982; 142: 47-54.
9. Ott WJ, Doyle S, Flamm S, Wittman J. Accurate ultrasonic estimation of fetal weight. Prospective analysis of new ultrasonic formulae. Am J Perinatol 1986; 3: 307-10.
10. Ratanasiri T, Jirapornkul S, Somboonporn W, Seejorn K, Patumnakul P. Comparison of accuracy of ultrasonic fetal weight estimation by using the various equations. J Med Assoc Thai 2002; 85: 962-7.
11. Sherman DJ, Arieli S, Tovbin J, Siegel G, Caspi E, Bukovsky I. A comparison of clinical and ultrasonic estimation of fetal weight. Obstet Gynecol 1998; 9: 212-7.
12. Schild RL, Fimmers R, Hansmann M. Fetal weight estimation by three-dimensional ultrasound. Ultrasound Obstet Gynecol 2000; 16: 445-52.
13. Chang FM, Liang RI, Ko HC, Yao BL, Chang CH, Yu CH. Three-dimensional ultrasound-assessed fetal thigh volumetry in predicting birth weight. Obstet Gynecol 1997; 90: 331-9.
14. Song TB, Moore TR, Lee JY, Kim YH, Kim EK. Fetal weight prediction by thigh volume measurement with three-dimensional ultrasonography. Obstet Gynecol 2000; 96: 157-61.
15. Liang RI, Chang FM, Yao BL, Chang CH, Yu CH, Ko HC. Predicting birth weight by fetal upper-arm volume with use of three-dimensional ultrasonography. Am J Obstet Gynecol 1997; 177: 632-8.
16. Lee W, Deter RL, McNie B, Goncalves LF, Espinosa J, Chiworapongsa T, et al. Individualized growth assessment of fetal soft tissue using fractional thigh volume. Ultrasound Obstet Gynecol 2004; 24: 766-74.

ความสัมพันธ์ระหว่างการประเมินน้ำหนักทารกในครรภ์ตัวโตและตัวเล็กด้วยการวัดปริมาตรของต้นแขนและต้นขาทารกในครรภ์ด้วยคลื่นเสียงความถี่สูง 3 มิติ

สมศักดิ์ ประฏิภาณวัตร, รัตนา คำวิลัยศักดิ์, ถวัลย์วงค์ รัตนสิริ

วัตถุประสงค์: *หาความสัมพันธ์ระหว่างปริมาตรต้นแขนและต้นขาทารกในครรภ์ด้วยคลื่นเสียงความถี่สูง 3 มิติกับน้ำหนักทารกแรกคลอดในทารกตัวโตและทารกตัวเล็ก*

วัสดุและวิธีการ: *เป็นการศึกษาสตรีตั้งครรภ์ 46 รายที่มาคลอดบุตรที่ห้องคลอด โรงพยาบาลศรีนครินทร์ คณะแพทยศาสตร์ มหาวิทยาลัยขอนแก่น ตั้งแต่วันที่ 1 กุมภาพันธ์ พ.ศ. 2547 - 30 กันยายน พ.ศ. 2547 โดย 1) เป็นสตรีตั้งครรภ์เดี่ยว 2) คลอดภายใน 48 ชั่วโมงหลังทำการศึกษา 3) โดยทารกมีน้ำหนักแรกคลอดน้อยกว่า 2,500 กรัม (ในกลุ่มทารกตัวเล็ก จำนวน 22 ราย)หรือมากกว่า 3,500 กรัม (กลุ่มทารกตัวโต จำนวน 24 ราย) สตรีตั้งครรภ์ทุกรายได้รับการตรวจคลื่นเสียงความถี่สูง 2 มิติ และทำการตรวจหาค่าปริมาตรของต้นแขนและต้นขาทารกด้วยเครื่องตรวจคลื่นเสียงความถี่สูง 3 มิติโดยผู้ตรวจคลื่นเสียงความถี่สูงคนเดียว*

ผลการศึกษา: *ในกลุ่มทารกตัวโต ปริมาตรต้นแขนและต้นขาทารกในครรภ์ด้วยคลื่นเสียงความถี่สูง 3 มิติ มีความสัมพันธ์อย่างมากกับน้ำหนักทารกแรกคลอด r = 0.805 (95%CI = 0.594-0.912) และ r = 0.739 (95%CI = 0.478-0.880) ตามลำดับ ในกลุ่มทารกตัวเล็ก ปริมาตรต้นแขนและต้นขาทารกในครรภ์ด้วยคลื่นเสียงความถี่สูง 3 มิติมีความสัมพันธ์อย่างมากกับน้ำหนักทารกแรกคลอดเช่นกัน r = 0.868 (95%CI= 0.689-0.946) และ r = 0.835 (95%CI = 0.638-0.929) ตามลำดับ*

สรุป: *ปริมาตรต้นแขนและต้นขาทารกในครรภ์ด้วยคลื่นเสียงความถี่สูง 3 มิติมีความสัมพันธ์อย่างมากในการประเมินน้ำหนักทารกในครรภ์ที่ตัวโตและตัวเล็ก สามารถนำมาคำนวณน้ำหนักทารกในครรภ์ได้*