Doppler Study of Umbilical Artery in Thai Fetus

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Objective: *Create reference centile charts for Doppler study of Pulsatile index (PI), Resistance index (RI) and Systolic to Diastolic (S/D) ratio of umbilical artery in Thai fetus throughout gestation.*
Material and Method: *Six hundred fifty eight pregnant women between 13-40 weeks gestation who attended the antenatal clinic at Siriraj Hospital, Mahidol University, Bangkok, were recruited. Each fetus was measured only once for the purpose of the present study. The mean and fitted centiles were estimated at each week of gestation using linear regression modeling.*
Results: *Doppler study of Pulsatile index (PI), Resistance index (RI), and Systolic to Diastolic (S/D) ratio of umbilical artery were measured in 658 fetuses. The mean 95% confidence intervals for Doppler study of Pulsatile index (PI), Resistance index (RI), and Systolic to Diastolic (S/D) ratio of umbilical artery at each gestational age were fitted to estimate by linear regression models. The centile chart of this parameter was also presented.*
Conclusion: *Reference centile chart for Doppler study of Pulsatile index (PI), Resistance index (RI) and Systolic to Diastolic (S/D) ratio of umbilical artery of Thai fetuses was presented.*

Keywords: *Pulsatile index (PI), Resistance index (RI), Systolic to Diastolic (S/D) ratio, Umbilical artery, Centile chart*

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Doppler measurements, the pulsatility index (PI) and resistance index (RI) using for the arteries, can be obtained from the umbilical artery (UA). Abnormal umbilical artery Doppler flow velocity is defined as a pulsatility index (PI) >2 standard deviations (SD) above the mean for gestational age and/or absence or reversal of end-diastolic flow[1]. Umbilical artery Doppler reflects downstream placental vascular resistance, correlated with intrauterine growth restriction and the multi-system effects of placental deficiency. To assess fetal intrauterine growth restriction by using common parameter include head circumference (HC), abdominal circumference (AC), biparietal parameter (BPD), femur length (FL), transverse cerebellar diameter (TCD) and umbilical artery Doppler waveforms with flow velocity have been published in several papers[2-4]. Recent meta-analysis of randomized controlled trials suggests that incorporation of umbilical artery Doppler waveform analysis into management protocols for high risk pregnancies significantly decreases perinatal mortality[5]. Unfortunately, there was no reference value for the umbilical artery Doppler flow velocimetry in Thai fetuses. The purpose of the present study was to establish the reference values for umbilical artery Doppler flow velocimetry in Thai fetuses throughout pregnancy from 13-40 weeks of gestation for clinical utilization in Siriraj Hospital.

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Material and Method

The present study was performed before April 2007 therefore, ethic consideration was not presented. Six hundred fifty eight pregnant women that attended the antenatal clinic at Siriraj Hospital between January and December 2004, were recruited in the present study. Pregnant women had no underlying medical and surgical complications and were in the first trimester. Their last menstrual periods (LMP) and crown rump length (CRL) measurements were obtained and performed to confirm gestational age. The gestational age was based on LMP if the gestational age from LMP and CRL measurement was different less than seven days. The gestational age was based on the CRL measurement if the differentiation was up from seven days.

The umbilical artery Doppler flow velocity study for PI, RI and S/D ratio were obtained at the first visit and at 18-20 weeks along with fetal anomaly scan. The other fetal biometric measurements including

biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur length (FL) were also recorded during every scan. If fetal structural abnormality and fetal chromosomal abnormality was detected, the case was excluded from the analysis. The intraobserver and interobserver variabilities were excluded by measuring three times at each location.

The umbilical artery Doppler flow velocity measurement

The ultrasonographic measurement of those measurements was made by ALOKA, Dynaview 2, SSD 1,700 with 3.5 MHz convex transducer. The patient was placed in a semi-recumbent position, with lateral tilt to avoid maternal inferior vena caval compression. The wall filter settings for pulsed Doppler are kept at the lowest level (50 to 100 Hz) to prevent any false depiction of low or absent end-diastolic flow. An initial ultrasound examination is performed to confirm that the fetus is not active, breathing, or hiccupping and to identify a free-floating loop of cord for sampling. Color Doppler may assist in identifying the sampling site. The Doppler sample volume is then placed in the vascular lumen encompassing it and the waveforms are recorded. The peak systolic and end diastolic frequency shifts are then identified with cursors and the Doppler indices are generated. Many devices can automatically perform these functions (Fig. 1).

Statistical analyses

Mean and centiles were calculated in each week of gestation. Linear regression analysis and ANOVA to test the regression line was used to estimate the predicted values and their 95% confidence intervals of those measurements for each gestational age. This was based on the assumption that the data in each gestational age are normally distributed.

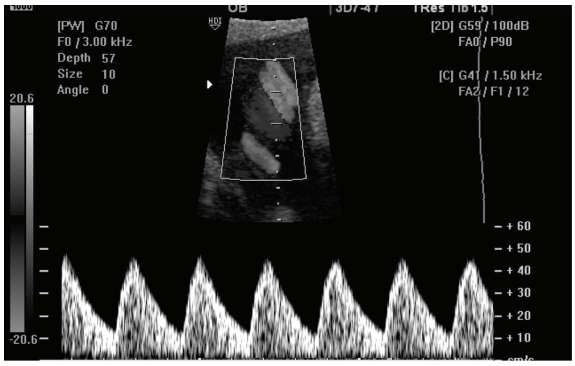

Fig. 1 Doppler study of umbilical artery

Results

Seven hundred pregnant women participated in the present study. The measurements included the umbilical artery Doppler flow velocimetry study for PI, RI and S/D ratio could be obtained in 658 pregnant women. Forty-two cases were excluded due to fetal malposition that the measurement plane could not be obtained. The anomaly fetuses described above were also excluded from the present study. The number of the fetuses measured at each gestational age is presented in Table 1.

Predictive values from the regression analysis and their 95% confidence intervals were estimated and plotted against the actual data as shown in Fig. 2-4.

Table 1. Number of fetuses measured at each week of gestation

Gestational age (weeks)	Number of fetus	Percentage
13	10	1.5
14	24	3.6
15	22	3.4
16	21	3.2
17	21	3.2
18	24	3.6
19	22	3.4
20	24	3.6
21	30	4.6
22	27	4.1
23	27	4.1
24	34	5.2
25	29	4.4
26	22	3.4
27	20	3.0
28	22	3.4
29	24	3.6
30	21	3.2
31	27	4.1
32	22	3.4
33	28	4.2
34	23	3.5
35	22	3.4
36	23	3.5
37	34	5.1
38	33	5.0
39	15	2.3
40	7	1.0
Total	658	100

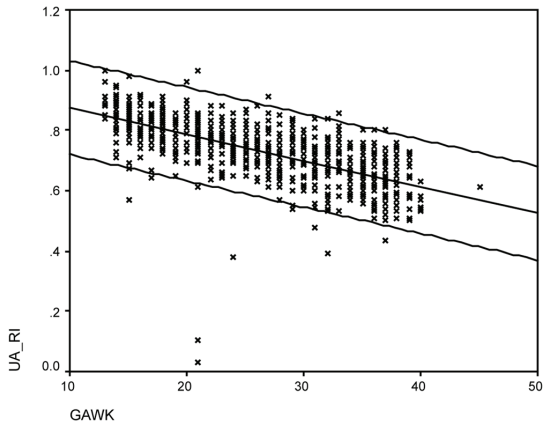

Fig. 2 The umbilical artery Doppler flow velocimetry study for resistance index was presented

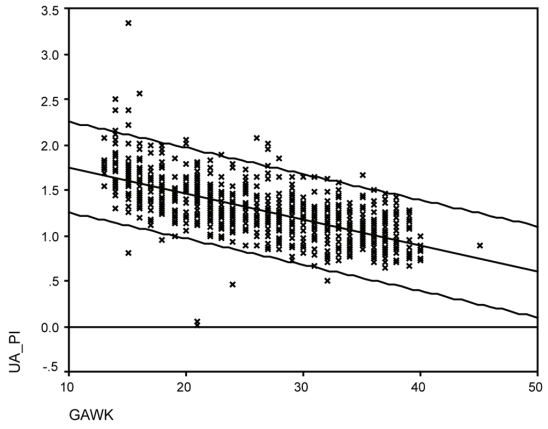

Fig. 3 The umbilical artery Doppler flow velocimetry study for pulsatile index (PI) was presented

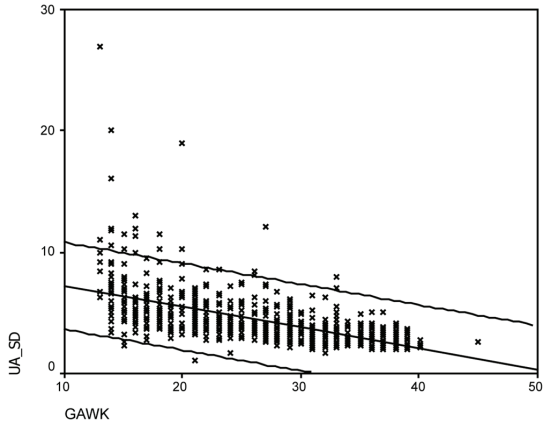

Fig. 4 The umbilical artery Doppler flow velocimetry study for systolic/diastolic (S/D) ratio was presented

Discussion

Assessment of umbilical artery Doppler is most useful for monitoring fetuses with early-onset growth restriction due to uteroplacental insufficiency. Surveillance tool for monitoring these pregnancies with Doppler velocimetry is recommended[6]. Investigation with Doppler can identify the fetal cardiovascular response to progressive hypoxia and acidosis. Many randomized trials present that Doppler velocimetry can be used to reduce perinatal death significantly as well as unnecessary induction of labor in the preterm growth restricted fetus.

Clinical implementations of Doppler ultrasound technology include continuous wave (CW), pulsed wave (PW) and color Doppler. CW and PW Doppler modes are also known as spectral Doppler. Doppler ultrasound waveforms reflect blood velocity; therefore, they potentially can yield information on various aspects of blood flow in a circulation, including the presence and direction of flow, velocity profile, volume of flow, and impedance to flow. In general practice, Doppler of the umbilical artery has been used extensively for assessing downstream circulatory impedance (*i.e.*, resistance to pulsatile flow).

The most commonly used obstetrical applications are the peak systolic frequency shift to end-diastolic frequency shift ratio, (S/D)[7] and the resistance index (RI), which represents the difference between the peak systolic and end-diastolic shift divided by the peak systolic shift[8]. The interobserver and intraobserver variances of these measurements for the S/D ratio are 9.8% and 11.1%, respectively, and for the RI interobserver and intraobserver, variances are 4% and 8%, respectively[9]. The pulsatility index (PI = S-D/A) is also used.

The progressive decline in fetoplacental blood flow impedance from fetal and placental vascular and hemodynamic changes is compatible with the increased end diastolic velocity with advanced gestational age. This is reflected by a progressive decline in the S/D ratio and RI as pregnancy progresses as presented in the present study. Fetal heart rate, fetal breathing, uteroplacental insufficiency, and location where the cord in sampled can affect the waveform. Normal fetal heart rate, 110-160 beats per minute, cannot significantly affect the waveform[10,11]. Intrathoracic pressure during fetal breathing can affect the waveform therefore, Doppler study of umbilical artery should be performed during fetal apnea and the location where the cord in sampled should be at the mid level of free floating loop of umbilical artery[12].

Occlusion of small muscular arteries in the tertiary stem villi results in an elevated S/D ratio[13]. Recent studies presented that abnormal fetal placental angiogenesis resulted from sparse, elongated, uncoiled, and less ramified terminal capillary loops complicated growth restriction and abnormal umbilical arterial Doppler[14]. Therefore, fetoplacental vascular maldevelopment results in an increase in impedance that is reflected in the abnormal Doppler waveforms and indices. The non-stress test (NST), biophysical profile (BPP) with simultaneously with the normal umbilical artery Doppler can be used as fetal surveillance once every two weeks[15].

In conclusion, Doppler study of the umbilical artery can be used as a noninvasive measure of the fetoplacental hemodynamic state. Umbilical artery Doppler indices indirectly reflect impedance of downstream circulation. Normal umbilical artery Doppler can reassure the normal fetal circulation. However, abnormality of the Doppler index has been correlated to fetoplacental vascular maldevelopment. Significant association was found between abnormal Doppler indices and fetal hypoxia, fetal acidosis, and adverse perinatal outcome. The use of umbilical artery Doppler ultrasound in high risk pregnancies presented improved in perinatal outcome.

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Potential conflicts of interest

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References

1. Bricker L, Neilson JP. Routine doppler ultrasound in pregnancy. Cochrane Database Syst Rev 2000; (2): CD001450.
2. Hashimoto K, Shimizu T, Shimoya K, Kanzaki T, Clapp JF, Murata Y. Fetal cerebellum: US appearance with advancing gestational age. Radiology 2001; 221: 70-4.
3. Malik R, Pandya VK, Shrivastava P. Gestational age estimation using transcerebellar diameter with grading of fetal cerebellum and evaluation of TCD/AC (Transcerebellar diameter/abdominal circumference) ratio as a gestational age independent parameter. Indian J Radiol Imaging 2003; 13: 95-7.
4. Degani S. Fetal biometry: clinical, pathological, and technical considerations. Obstet Gynecol Surv 2001; 56: 159-67.
5. Neilson JP, Alfirevic Z. Doppler ultrasound for fetal assessment in high risk pregnancies. Cochrane Database Syst Rev 2000; (2): CD000073.
6. American College of Obstetricians and Gynecologists. Intrauterine growth restriction. ACOG practice bulletin no. 12. Washington, DC: ACOG; 2000.
7. Stuart B, Drumm J, FitzGerald DE, Duignan NM. Fetal blood velocity waveforms in normal pregnancy. Br J Obstet Gynaecol 1980; 87: 780-5.
8. Pourcelot L. Applications clinique de 1'examen doppler transcutane. In: Pourcelot L, editor. Velocimetric ultrasonore doppler 34, Serminaire. Paris: INSERM; 1974; 213-40.
9. Maulik D, Yarlagadda AP, Youngblood JP, Willoughby L. Components of variability of umbilical arterial Doppler velocimetry—a prospective analysis. Am J Obstet Gynecol 1989; 160: 1406-12.
10. Mires G, Dempster J, Patel NB, Crawford JW. The effect of fetal heart rate on umbilical artery flow velocity waveforms. Br J Obstet Gynaecol 1987; 94: 665-9.
11. Yarlagadda P, Willoughby L, Maulik D. Effect of fetal heart rate on umbilical arterial Doppler indices. J Ultrasound Med 1989; 8: 215-8.
12. Abramowicz JS, Warsof SL, Arrington J, Levy DL. Doppler analysis of the umbilical artery. The importance of choosing the placental end of the cord. J Ultrasound Med 1989; 8: 219-21.
13. Giles WB, Trudinger BJ, Baird PJ. Fetal umbilical artery flow velocity waveforms and placental resistance: pathological correlation. Br J Obstet Gynaecol 1985; 92: 31-8.
14. Kingdom J, Huppertz B, Seaward G, Kaufmann P. Development of the placental villous tree and its consequences for fetal growth. Eur J Obstet Gynecol Reprod Biol 2000; 92: 35-43.
15. McCowan LM, Harding JE, Roberts AB, Barker SE, Ford C, Stewart AW. A pilot randomized controlled trial of two regimens of fetal surveillance for small-for-gestational-age fetuses with normal results of umbilical artery doppler velocimetry. Am J Obstet Gynecol 2000; 182: 81-6.

การศึกษา umbilical artery ในทารกไทยโดยใช้ Doppler

อนุวัฒน์ สุตัณฑวิบูลย์, สายฝน ชวาลไพบูลย์

วัตถุประสงค์: *ค่า Doppler study of pulsatile index (PI), Resistance index (RI) and Systolic to Diastolic (S/D) ratio of umbilical artery ของทารกไทยได้ถูกทำการศึกษา*

วัสดุและวิธีการ: *ทำการศึกษาสตรีตั้งครรภ์ปกติ อายุครรภ์ระหว่าง 13-40 สัปดาห์ จำนวน 658 ราย ทำการวัดค่า pulsatile index (PI), Resistance index (RI) และ Systolic to Diastolic (S/D) ratio ของ umbilical artery ของทารกในครรภ์ด้วยการใช้ Doppler จากคลื่นเสียงความถี่สูง ในแต่ละรายที่อายุครรภ์ต่าง ๆ กัน โดยการสุ่มเพื่อการศึกษาครั้งนี้โดยเฉพาะ ทำการวิเคราะห์ข้อมูลโดยการหาค่าเฉลี่ยของ pulsatile index (PI), Resistance index (RI) และ Systolic to Diastolic (S/D) ratio ของ umbilical artery ในช่วงอายุครรภ์ต่าง ๆ*

ผลการศึกษา: *สามารถวัดค่า pulsatile index (PI), Resistance index (RI) และ Systolic to Diastolic (S/D) ratio ของ umbilical artery ได้ทั้งหมด 658 ราย จากนั้นจึงทำการหาค่าเฉลี่ยและส่วนเบี่ยงมาตรฐานของค่าต่าง ๆ ดังกล่าวข้างต้นของทารกในครรภ์ ในช่วงอายุครรภ์ต่างๆ ตามกราฟ*

สรุป: *pulsatile index (PI), Resistance index (RI) และ Systolic to Diastolic (S/D) ratio ของ umbilical artery ของทารกในครรภ์ได้แสดงในการศึกษานี้*