Superior Vena Cava Diameters in Normal Thai Fetuses

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Objective: *Establish the normative data of fetal superior vena cava (SVC) diameters from 20 to 38 weeks' gestation in Thai fetuses.*

Material and Method: *Thai pregnant women with normal fetuses were enrolled for 2-dimensional echocardiographic measurements of SVC diameters. All women had good menstrual history and a confirmed gestational age with first or second trimester ultrasound. The SVC diameters were obtained in caval long-axis view in both systolic and diastolic periods. The measurements were plotted against gestational age. The best-fit regression equations were obtained. The 5th, 50th, and 95th percentile were then calculated for each gestational age.*

Results: *Three hundred three measurements were obtained. Regression analysis demonstrated a linear correlation between SVC diameter and gestational age in both early ventricular systolic and end ventricular diastolic periods. The best-fit equations were SVC maximum diameter (mm) = -1.379 + 0.183GA (week), r = 0.889 (p < 0.001), SVC minimum diameter (mm) = -1.194 + 0.134GA (week), r = 0.826 (p < 0.001) at early systolic and end diastolic periods respectively. The calculated values of the SVC diameters across gestational age were presented as 5th, 50th, and 95th percentile.*

Conclusion: *SVC diameter increases linearly across gestational age in both ventricular systolic and diastolic periods. These could be a basis for assessment of fetuses with abnormal cardiovascular physiology such as hydrops fetalis and intrauterine growth restriction.*

Keywords: *Fetal echocardiography, Nomogram, Superior vena cava*

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Fetal echocardiography has been a sonographic tool used in evaluation of the human fetal cardiovascular system for a few decades. Caval long-axis view is a component of cardiac imaging used to assess the right cardiac inflows, the superior vena cava (SVC), and the inferior vena cava (IVC). The caval long-axis view is obtained with the imaging plane parallel to the caval connections to the right atrium (RA). Continuity of the IVC as it passes through the liver will also be demonstrated. Structures viewed in this view include SVC, IVC, eustachian valve, foramen ovale, and right pulmonary artery[1]. The SVC is formed by the confluence of the left and right brachiocephalic veins, which drain blood from the arms, head, and brain. Approximately 80% of this blood is estimated to be returning from the brain in infants[2].

Impaired fetoplacental circulation in intrauterine growth restriction (IUGR) is characterized by a high placental resistance, an increase in umbilical artery impedance, and a compensatory vasodilatation of the cerebral vascular system, so called "brain-sparing phenomenon". This arterial blood flow redistribution has been demonstrated by Doppler ultrasound to pose a potential rise in the cerebral and SVC blood flows[3]. The authors' speculate that in uteroplacental insufficiency, the increase in cerebral blood flow to the brain and consequently a return of more blood flow to SVC may have an effect on the size of SVC diameter. Thus, SVC diameter could be a potential marker in evaluation of fetuses with uteroplacental insufficiency. This implies a need for a standard nomogram of SVC diameter in

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normal population. To the authors' knowledge, there is no standard nomogram of SVC diameter available in normal Thai fetuses. Therefore, the purpose of the present study was primarily to establish the normative data of SVC diameters in normal fetuses at 20-38 weeks' gestation.

Material and Method

The present study was approved by the Ethical Committee of the Faculty of Medicine, Chulalongkorn University.

Patient population

A cross-sectional descriptive study was established for a nomogram of fetal SVC diameter between January 2007 and November 2007. Three hundred and fifteen normal Thai singleton pregnancies with gestational age from 20 to 38 weeks who registered at antenatal clinic of King Chulalongkorn Memorial Hospital were enrolled. Inclusion criteria were:

1. Accurate gestational age based on good menstrual history and verified by first or early second trimester scan
2. Absence of maternal diseases (e.g. diabetes, chronic hypertension, preeclampsia)
3. Normal fetuses with estimated fetal weight within 10^{th} and 90^{th} percentiles for the Thai population

Exclusion criteria were:

1. Uncertain gestational age
2. Fetus with structural or chromosomal abnormalities at birth
3. Unable to obtain SVC diameter (e.g. inappropriate fetal position or maternal obesity)

SVC measurement

Three hundred fifteen normal pregnant women underwent sonographic study with a curvilinear 3.5 or 5.0 MHz transabdominal transducer. The ultrasound machines employed were an Aloka Prosound 5000 (Aloka Co., Ltd., Tokyo, Japan) or a Voluson 730 Expert (GE Medical system, WI, USA). Standard ultrasonography was performed to obtain general data and to search for fetal anomalies. Each patient was examined once by one operator (SD). SVC measurements were performed in caval long-axis view, which was obtained by sliding the transducer along the long axis and to the right of fetal vertebra. With the imaging plane parallel to the caval connection to the RA, relationship with the IVC as it passes through the liver was established. SVC, RA, and IVC were readily demonstrated. The images were usually enlarged to fill at least 70% of the screen to minimize the measurement error. The SVC diameters were measured at the point where SVC connects with the RA (Fig. 1).

The internal diameters were obtained at the period of early ventricular systole and end ventricular diastole by frozen image (Fig. 2, 3). Three measurements were obtained in each fetus and the mean diameters were determined.

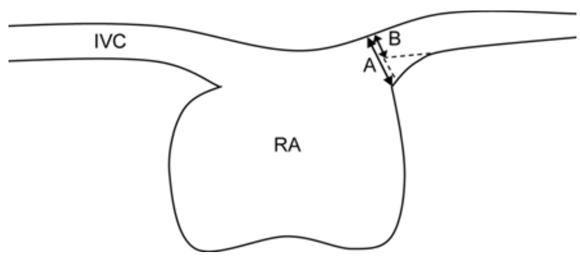

Fig. 1 Caval long-axis view
A: SVC diameter at early ventricular systole
B: SVC diameter at end ventricular diastole

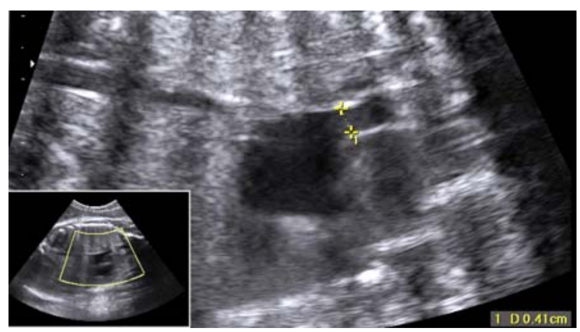

Fig. 2 SVC diameter at early ventricular systole

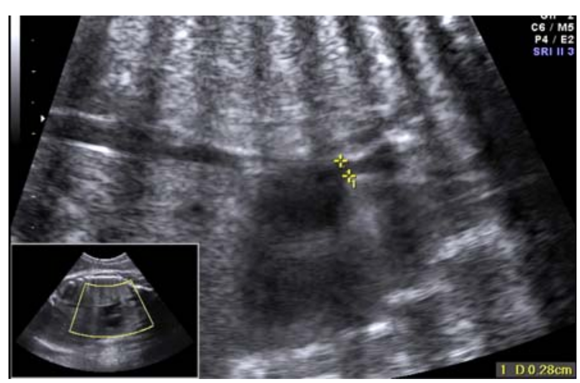

Fig. 3 SVC diameter at end ventricular diastole

Statistical analysis

The statistical analysis was carried out by using SPSS software package version 15. Obstetric characteristics were presented as mean and standard deviation (SD). SVC diameters were plotted against gestational age and the best-fit regression equations were determined by using Pearson's correlation. The normal values of SVC diameters were presented as 5^{th}, 50^{th}, and 95^{th} percentile ranks. A p-value < 0.05 was considered statistically significant. Intraobserver reliability with 95% confidence internal (95% CI) was determined using intraclass correlation coefficient.

Sample size calculation was based on the data from the pilot study of three fetuses for each gestational age. The authors found that the SD of SVC diameters was 0.80 mm. With an acceptable error of less than 0.1 mm from each measurement, the sample size of at least 13 subjects per gestational age were required to obtain the power of the test over 80%.

Results

Three hundred fifteen fetuses were initially enrolled. One fetus was excluded for trisomy, 21 discovered at amniocentesis, three could not have the SVC diameters obtained due to maternal habitus and eight had fetal suboptimal position. This left 303 fetuses in the present study. The mean ($\pm$ SD) maternal age was 31 ($\pm$ 6.5) years. Most were multiparous (54%). The mean ($\pm$ SD) gestational age at delivery was 38.6 ($\pm$ 1.3) weeks and mean ($\pm$ SD) birth weight was 3,266.1 ($\pm$ 335.9) g.

The SVC demonstrated maximum diameter (SVCmax) at early ventricular systole and demonstrated minimum diameter (SVCmin) at end ventricular diastole. The anterior wall of SVC had more movement than the posterior wall.

The best-fit regression equations for SVCmax and SVCmin were:

SVCmax (mm) = -1.379 + 0.183GA (week), $r = 0.889$ ($p < 0.001$) (Fig. 4)

SVCmin (mm) = -1.194 + 0.134GA (week), $r = 0.826$ ($p < 0.001$) (Fig. 5).

With the use of these regression equations, the predicted SVC diameters for the 5^{th}, 50^{th}, and 95^{th} percentile were calculated for each gestational age (Table 1). Intraobserver reliability was 0.93 (95% CI, 0.82-0.98). Graphic presentation of 5^{th}, 50^{th}, and 95^{th} percentile of SVC diameters at both early ventricular systole and end ventricular diastole are presented in Fig. 6 and 7 respectively.

Discussion

Our study has shown that fetal SVC diameter can be reliably measured by 2-dimensional ultrasound. The caval long-axis view is the most favorable view as it clearly depicts SVC connecting to the RA. It is necessary that SVC, RA, and IVC be seen simultaneously to obtain the optimal view for measurement of SVC diameter. The anterior wall of SVC has much more movement than the posterior wall and is generally used as the landmark to distinguish the lumen of SVC from RA at the point they are connecting. This point should be clearly viewed before the image is frozen for measurement.

The present study has demonstrated that SVC diameter varies along the cardiac cycle. The internal diameter is largest at early ventricular systole and smallest at end ventricular diastole. The present results have shown that SVC diameter increases significantly in a linear fashion with advancing gestational age in both early ventricular systole and end ventricular diastole. It is likely that an increase in venous back-pressure at early systolic period may contribute to an

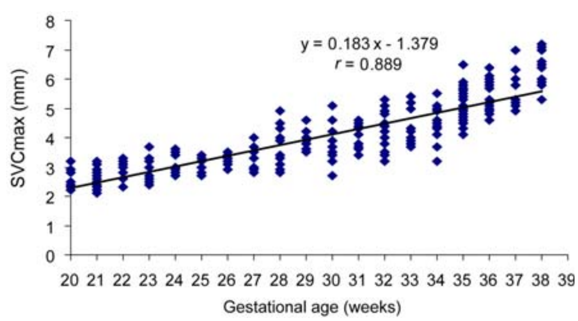

Fig. 4 Scatter gram of SVC diameter at early ventricular systole (mm) in relation to gestational age (weeks)

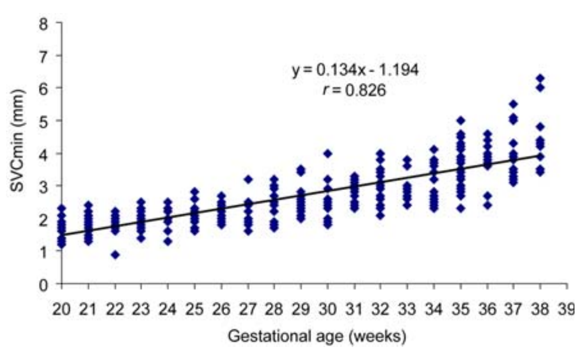

Fig. 5 Scatter gram of SVC diameter at end ventricular diastole (mm) in relation to gestational age (weeks)

Table 1. SVC diameters at the 5th, 50th, and 95th percentile across gestational age

GA (weeks)	n	SVCmax (mm)			SVCmin (mm)		
		5th percentile	50th percentile	95th percentile	5th percentile	50th percentile	95th percentile
20	18	1.9	2.2	2.7	1.1	1.5	1.8
21	23	2.1	2.4	2.9	1.2	1.6	2.0
22	20	2.2	2.5	3.1	1.4	1.8	2.1
23	14	2.4	2.7	3.3	1.5	1.9	2.3
24	13	2.5	2.9	3.5	1.6	2.0	2.5
25	13	2.7	3.1	3.7	1.7	2.1	2.7
26	13	2.9	3.3	4.0	1.8	2.3	2.9
27	13	3.0	3.5	4.2	1.9	2.4	3.1
28	13	3.2	3.7	4.4	2.0	2.5	3.2
29	13	3.4	3.9	4.6	2.1	2.7	3.4
30	14	3.5	4.1	4.8	2.2	2.8	3.6
31	14	3.7	4.3	5.0	2.3	2.9	3.8
32	16	3.8	4.5	5.2	2.4	3.1	4.0
33	16	4.0	4.7	5.4	2.5	3.9	4.1
34	15	4.2	4.9	5.6	2.6	3.3	4.3
35	26	4.3	5.1	5.9	2.7	3.4	4.5
36	17	4.5	5.3	6.1	2.8	3.6	4.7
37	19	4.6	5.5	6.3	2.9	3.7	4.9
38	13	4.8	5.6	6.5	3.0	3.8	5.0

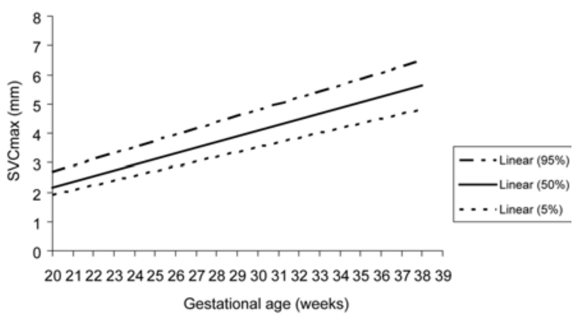

Fig. 6 Lines presentation of 5th, 50th, and 95th percentile of SVC diameter at early ventricular systole

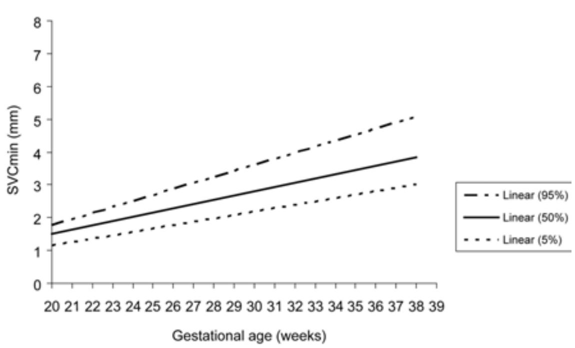

Fig. 7 Lines presentation of 5th, 50th, and 95th percentile of SVC diameter at end ventricular diastole

increase in SVC diameter. In contrast, a decrease in venous pressure at end diastolic period may cause a decrease in SVC diameter.

The American College of Obstetricians and Gynecologists (ACOG) defines an IUGR fetus as a fetus with an estimated weight below the 10th percentile[4]. Ideally, a growth-restricted fetus is a fetus that fails to reach its growth potential and is at risk for adverse perinatal morbidity and mortality. IUGR can be classified as symmetrical and asymmetrical. Uteroplacental insufficiency is known to be the main cause of asymmetrical IUGR and is characterized by high placental resistance and an increase in the umbilical artery resistance. This renders an increase in aortic resistance and eventually an increase in the right ventricular pressure load. To alleviate the increase in the pressure of fetal right ventricle, the fetal heart inherits a magic mechanism to reroute the blood from right chambers to left chambers through the existing intra and extracardiac shunt. This in turn augments the blood volume in left ventricular system and finally a redistribution of more blood flow to the brain and the heart so called "brain-sparing and cardiac sparing phenomena" as evidenced by an increase in blood flow in the middle cerebral and coronary artery respectively[5]. It has been demonstrated in an ovine fetus that 70% of the circulating blood returns to the heart through the IVC[6]. A decrease in umbilical blood flow resulting from uteroplacental insufficiency may significantly alter the redistribution of uteroplacental blood flow through the IVC. A study by Fouron et al[7] showed that in the absence of umbilical artery diastolic flow, a reciprocal shift was observed in the systemic venous return towards the heart, characterized by a fall in most IVC velocity parameters and a rise in the velocities of the SVC. These reciprocal changes in flow pattern between the two vena cava in favor of more venous blood flow through the SVC are thus another hemodynamic marker for the presence of placental insufficiency. Nevertheless, in documentation of all these reciprocal hemodynamic alterations, there is a need for a sophisticate Doppler technology as well as an expert in operating the system. The authors assume that the hemodynamic alteration that results in more returning venous blood flow through SVC proved by Fouron et al may have an effect on the size of SVC diameter. If this is true, the SVC diameter can be a simple marker of placental insufficiency as there is no need for sophisticated Doppler technology. Since SVC diameter can be more easily approached by 2-dimensional echocardiography and should be more readily accessed by physicians in rural areas of the country.

In conclusion, the authors have demonstrated that the SVC diameter is readily assessed by 2-dimensional ultrasound. The SVC diameter increases linearly across gestational age in both ventricular systolic and diastolic periods. These can be the basis for assessment of fetuses with an alteration in hemodynamic status such as IUGR or hydrops fetalis. Further study is needed to verify this postulation.

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ความกว้างของหลอดเลือดดำ superior vena cava ของทารกไทยในครรภ์ปกติ

เด่นนพพร สุดใจ, บุญชัย เอื้อไพโรจน์กิจ

วัตถุประสงค์: *เพื่อหาค่าปกติของความกว้างของหลอดเลือดดำ superior vena cava (SVC) ของทารกไทยในช่วงอายุครรภ์ 20 ถึง 38 สัปดาห์*

วัสดุและวิธีการ: *วัดความกว้างของหลอดเลือดดำ SVC ของทารกปกติในสตรีตั้งครรภ์ด้วยเครื่องตรวจคลื่นเสียงความถี่สูงในช่วงหัวใจบีบตัว (systole) และช่วงหัวใจคลายตัว (diastole) โดยใช้ระนาบ caval long-axis โดยสตรีตั้งครรภ์ทุกรายมีประวัติประจำเดือนที่เชื่อถือได้ และได้รับการตรวจยืนยันอายุครรภ์ด้วยเครื่องตรวจคลื่นเสียงความถี่สูงในช่วงไตรมาสแรกหรือต้นไตรมาสที่สอง ข้อมูลที่ได้นำมาวิเคราะห์สมการถดถอยเพื่อหาค่าความสัมพันธ์ระหว่างความกว้างของหลอดเลือดดำ SVC กับอายุครรภ์ในช่วงหัวใจบีบตัวและช่วงหัวใจคลายตัว และหาค่าความกว้างของหลอดเลือดดำ SVC ในระดับเปอร์เซนไทล์ที่ 5, 50, และ 95 ในแต่ละอายุครรภ์*

ผลการศึกษา: *พบว่าสตรีตั้งครรภ์จำนวน 303 รายที่เข้าร่วมการศึกษาวิจัย มีค่าความกว้างของหลอดเลือดดำ SVC ในช่วงหัวใจบีบตัวและคลายตัวเพิ่มขึ้นตามอายุครรภ์ โดยมีความสัมพันธ์เป็นแบบเส้นตรง สมการถดถอย และค่าสัมประสิทธิ์ของความสัมพันธ์ระหว่างความกว้างของหลอดเลือดดำ SVC กับอายุครรภ์ในช่วงหัวใจบีบตัวและคลายตัวมีค่าเท่ากับ -1.379 + 0.183GA (week), $r = 0.889$ ($p < 0.001$) และเท่ากับ -1.194 + 0.134GA (week), $r = 0.826$ ($p < 0.001$) ตามลำดับ และได้แสดงค่าความกว้างของหลอดเลือดดำ SVC ที่ระดับเปอร์เซนไทล์ที่ 5, 50, และ 95 ในแต่ละอายุครรภ์*

สรุป: *ความกว้างของหลอดเลือดดำ SVC มีค่าเพิ่มขึ้นตามอายุครรภ์ทั้งในช่วงหัวใจบีบตัวและคลายตัว ข้อมูลนี้อาจเป็นประโยชน์ในการนำมาใช้เป็นพื้นฐานในการประเมินความผิดปกติของระบบไหลเวียนโลหิตของทารกในครรภ์ เช่น ภาวะบวมน้ำ และทารกโตช้าในครรภ์ เป็นต้น*