Evaluation of Ventricular Myocardial Velocities and Heart Motion of the Fetal Heart by Tissue Doppler Image†

VACHARA JAMJUREERUK, M.D.*

Abstract

Fetal echocardiogram has developed into a reliable tool for prenatal diagnosis of congenital heart disease. It is also used to evaluate ventricular function. Recently, Tissue Doppler Imaging (TDI) has been introduced to evaluate ventricular functions especially in ischaemic heart disease. The objective of this study was to evaluate myocardial velocities and heart motions of the normal fetal heart by using TDI. The TDI was preformed in 28 fetal hearts with a gestational age of 20-35 wks (Mean 29±3.7 wks) to evaluate myocardial velocities and heart motion. The Toshiba, Power Vision, machine with 3.75 and 5 MHz transducers was used with an appropriate setting of colour-coded tissue velocities. The apical four chamber and apical or parasternal long axis views were the standard planes for measuring myocardial velocities and evaluating the heart motions. The results showed the myocardial velocities of the posterior wall of the left ventricle during the early, mid, and late systolic phases were 1.5±0.2, 2.1±0.9, and 1.0±0.5 cm/sec and early, mid, and late diastolic phases were 1.3±0.7, 1.9±0.8, and 1.1±0.7 cm/sec respectively. The myocardial velocity of the anterior wall of the right ventricle during the early, mid, and late systolic phases were 1.7±0.9, 1.7±0.6, and 1.0±0.6 cm/sec and early, mid, and late diastolic phases were 1.1±0.6, 1.8±0.7, and 1.5±1.0 cm/sec respectively. The myocardial velocity of the interventricular septum could not be measured due to the abnormal septal motion and the total fetal heart movement during the cardiac cycle. The fetal heart had anterior displacement during systole and posterior translation during diastole and also had counter-clockwise rotation during the systolic phase. Conclusion: Using the TDI to evaluate myocardial velocities of the fetal heart is limited by the angle of ultrasound beam and the total fetal heart motion. The fetal heart movement is similar to the newborn or young adult heart.

Key word : Tissue Doppler Image (TDI), Fetal Echocardiogram, Myocardial Velocities

JAMJUREERUK V
J Med Assoc Thai 2001; 84: 1158-1163

* Bangkok Heart Institute, Bangkok General Hospital, Bangkok 10230, Thailand.

† Part of this paper was presented during the 4th World Congress of Echocardiography and Vascular Ultrasound, Cairo, Egypt 2000.

Fetal echocardiogram has been accepted as a reliable tool for prenatal diagnosis of congenital heart diseases due to much improvement in the resolution of the 2-D Echo picture and Doppler Colour Flow Imaging[1-7]. Recently, the Tissue Doppler Imaging (TDI) method which is a non-invasive modality, has been developed[8-10]. It is based on the conventional colour Doppler imaging, which makes it possible to measure cardiac wall motion velocity as a parameter for quantitative evaluation of heart disease including ischaemic heart disease, myocardial infarction[11-21], cardiomyopathy[22] and ventricular pre-excitation (WPW syndrome)[23] in adults. In children, TDI has been used to evaluate the myocardial velocities in normal and abnormal structural heart diseases[24,25] especially in the abnormal origin of the left coronary artery, myocarditis and congestive cardiomyopathy. However, there have been no reports using TDI to evaluate the ventricular function of both the normal and abnormal fetal hearts.

The objective of this study was to evaluate the myocardial wall velocities and the heart motion of normal fetal hearts for the purpose of establishing base line data to provide beneficial parameters to detect or diagnose abnormal ventricular function of the fetal heart.

PATIENTS AND METHOD

From 1998 to 1999, we performed trans-abdominal fetal echocardiograms in 85 cases prospectively to study the TDI. Twenty-eight of eighty-five cases with normal fetal hearts with proper cut and appropriate colour - coded tissue velocity were recruited. The gestational ages of these 28 fetal hearts were 20-35 wks (mean 29±3.7 wks). The Toshiba, Power Vision machine with 3.75 and 5 MHz transducers were used with the appropriate setting of colour-coded tissue velocity to evaluate myocardial velocity and heart motion. The apical four chamber view and apical or parasternal long axis views with the M-mode superimposed were the standard planes for measuring myocardial velocity of the posterior wall of the left ventricle, interventricular septum and anterior wall of the right ventricle. The myocardial velocity interogation was focused on the posterior wall of the left ventricle, interventricular septum and the anterior wall of the right ventricle at the tip or just below the tip of the mitral valve. Endomyocardial velocity was measured during the early, mid and late phase of systolic (contraction) and diastolic phases (relaxation) of the posterior wall of the left ventricle, interventricular septum and anterior wall of the right ventricle (Fig. 1). The fetal heart motion was evaluated by direct observation and by drawing the fetal heart contour during each cardiac cycle (Fig. 2).

RESULTS

The myocardial velocities of the posterior wall of the left ventricle during the early, mid, and late systolic phases (contraction) were 1.5±0.6, 2.1±0.9, 1.0±0.5 cm/sec and early, mid, and late diastolic phases (relaxation) were 1.3±0.7, 1.9±0.8, 1.1±0.7 cm/sec respectively. The myocardial velocities of the anterior wall of the right ventricle during the early, mid, and late systolic phases (contraction) were 1.7±0.9, 1.7±0.6, 1.0±0.6 cm/sec and early, mid, and late diastolic phases (relaxation) were 1.1±0.6, 1.8±0.7, 1.5±1.0 cm/sec respectively. The myocardial velocity of both systolic and diastolic phases of the posterior wall of the left ventricle and anterior wall of the right ventricle were scattered and had no correlation with the fetal gestational ages. The myocardial velocity of the interventricular septum could not be measured due to the abnormal septal motion and the whole fetal heart movement during the cardiac cycle. The fetal heart had anterior displacement during systole and posterior translation during diastole and also had counter-clockwise rotation during the systolic phase.

DISCUSSION

The principle and application of the TDI system has been reported in detail elsewhere[8-10]. The wall motion toward the transducer was coded red and that away from the transducer was coded blue. Real-time image was stored in cineloop memory, permitting frame-by-frame review. The quality and appropriate cuts of the apical four chamber view and apical or parasternal long axis view of the fetal heart were very important in order to get good 2- D Echo and TDI pictures. These were necessary for a reliable M-mode superimposed picture with the appropriate colour-coded tissue velocities and gain control to obtain optimal colour-coded signals for measuring myocardial velocities of the posterior wall of the left ventricle and the anterior wall of the right ventricle. The fetal position, frequently, was not in a good position to obtain a good picture. The angle between the beam of the ultrasound and the area measuring in addi-

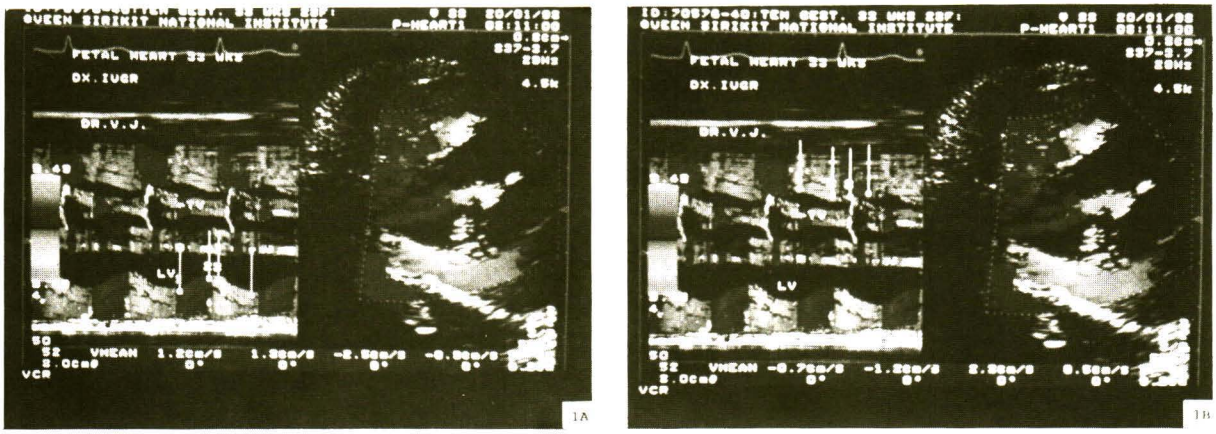

Fig. 1. Tissue Doppler Imaging with the colour - coded M-mode of a normal fetal heart with a gestational age of 33 weeks : normal endomyocardial velocity during systole and diastole of the posterior wall of the left ventricle (A) and the anterior wall of the right ventricle (B). The interventricular septum was incorrectly colour-coded due to abnormal interventricular septal motion and fetal heart motion.

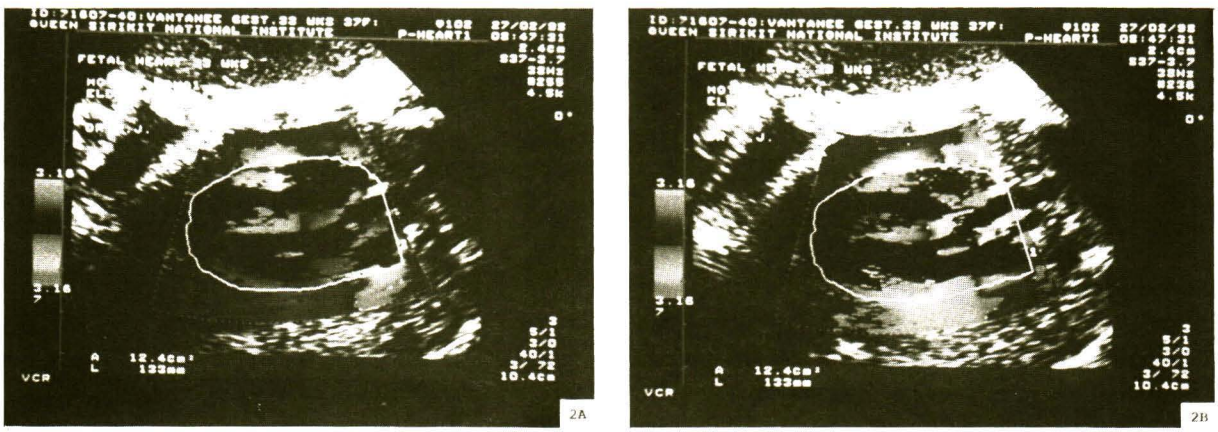

Fig. 2. Tissue Doppler Imaging of the whole fetal heart motion by directly drawing of the whole heart during systole (A) and diastole (B).

tion with the fetal heart motion were the main factors which influenced the real value of the myocardial velocities of both the posterior wall of the left ventricle and the anterior wall of the right ventricle. Before taking the measurements, standard plane cuts with the M-mode superimposed including the angle between the beam of the ultrasound and the target area of the myocardium must be in the proper position and good TDI pictures, otherwise there would be a lot of error. The appropriate colour-coded tissue setting was also very important in order to visualize and evaluate myocardial velocities accurately. The myocardial velocities of the distal areas of both the posterior wall of the left ventricle and anterior wall of the right ventricle could not be measured due to angle between the beam of the ultrasound and the area of measurement was too wide. New specialized software that can eliminate the whole heart motions and automatically correct the angle between the beam of the

ultrasound and the area of measurement is needed. The author hopes the results of these studies would be the base-line data of the normal fetal heart myocardial velocities of the anterior wall of the right ventricle and posterior wall of the left ventricle and could be used to determine the myocardial dysfuntion of an abnormal fetal heart. It may be used to grade the severity of the myocardial dysfuntion if new software programs are available. The right atrial wall and the left atrial wall contractions produced weak signals and it was difficult to get good pictures of wall contraction for measuring myocardial velocities by TDI. The anterior wall of the right ventricle seemed to have more vigorous contractions than the posterior wall of the left ventricle but there was no statistical difference in the measurements. The fetal heart motion is similar to the adult heart[26] which has anterior displacement during systole and posterior translation the during diastole and a counter-clockwise rotation during the systolic phase.

In conclusion, the use of TDI to evaluate myocardial velocities of the fetal heart is limited due to the angle between the beam of the ultrasound and the area of measurement as well as the whole fetal heart motion. The myocardial velocity of the posterior wall of the left ventricle and the anterior wall of the right ventricle are not related to the gestational age. The fetal heart movement is similar to that in the newborn or young adult.

ACKNOWLEDGEMENT

The author wishes to thank Dr. Vilai Ratrisawadi, Director of the Queen Sirikit National Institute of Child Health and Dr. Yingdao Krairiksk, Director of Bangkok General Hospital, for kindly supporting this study and Mr. Steve Hahman for kindly preparing the manuscript.

(Received for publication on January 16, 2001)

REFERENCES

1. Allan LD. Fetal cardiac anomalies. Prog Pediatr Cardiol 1996; 5: 103-12.
2. Eronen M. Outcome of fetuses with heart disease diagnosed *in utero*. Arch Dis Child 1997; 77: F41-F46.
3. Shraland G. Changing impact of fetal diagnosis of congenital heart disease. Arch Dis Child 1997; 77: F1-F3.
4. Allan LD. Echocardiographic detection of congenital heart disease in the fetus: Present and future. Br Heart J 1995; 74: 103-6.
5. Simpson LL, Marx GR. Diagnoisis and treatment of structural fetal cardiac abnormality and dysrhythmia. Semin Perinatol 1994; 9: 215-27.
6. Tegnander E, Eik-Nes SH, Johansen OJ, Linker DT. Perinatal detection of heart defects at the routine fetal examination at 18 weeks in a non selected population. Ultrasound Obstet Gynecol 1995; 5: 364-5.
7. Wladimiroff JW, Splunder PV. Doppler assessment of the fetal circulation in early and late fetal development. Prog Pediatr Cardiol 1996; 5: 35-140.
8. Yamazaki N. Pricipal of Doppler tissue measurement. In: Erbel R. Nesser HJ, Drozdz J. eds. Atlas of Tissue Doppler Echocardiography-TDE. Heidenberg; Germany, Springer 1995: 9-15.
9. Sutheran GR, Stewart MJ, Groundstrom KWE, et al. Color Doppler myocardial imaging: A new technique for the assessment of myocardial function. J Am Soc Echocardiogr 1994; 7: 441-58.
10. Miyatake K, Yamagishi M, Tanaka N, et al. New method for evaluating left ventricular wall motion by color-coded tissue Doppler imaging: *In vitro* and *in vivo* studies. J Am Coll Cardiol 1995; 25: 717-24.
11. Brodin LA, van der Linden J, Olstad B. Echocardiographic functional images based on tissue velocity information. Herz 1998; 23: 491-8.
12. Rambaldi R, Poldermans D, Vletter WB, et al. Tissue Doppler imaging and the quantification of myocardial function. Int J Card Imaging 1998; 4: 241-50.
13. Donovan CL, Armstrong WF, Bach DS. Quantitative Doppler tissue imaging of the left ventricular myocardium: Validation in normal subjects. Am Heart J 1995; 130: 100-4.
14. Gorcsan J, Katz WE, Mandarino WA, Pimsky MR. Heterogenous left ventricular septal and posterior wall velocities: Quantitation temporal assessment by myocardial color Doppler imaging. (abstract). Circulation 1994; 90: I-327.
15. Uematsu M, Miyatake K, Tanaka N, et al. Myocardial velocity gradient as a new indicator of regional left ventricular contraction: Detection by a two-dimentional tissue Doppler imaging technique. J Am Coll Cardiol 1995; 26: 217-23.
16. Fleming AD, Xia X, Mcdicken WN, Sutherland GR. Myocardial velocity gradients detected by Doppler imaging. Br Heart J Radiol 1994; 67: 679-88.
17. Pasquet A, Armstrong G, Beachler L, et al. Use of segmental tissue Doppler velocity to quantitate exercise echocardiography. J Am Soc Echocardiogr 1999; 12: 901-12.
18. Hunziker PR, Picard MH, Jander N, et al. Regional wall motion assessment in stress echocardiography by tissue Doppler bull's eye. J Am Soc Echocardiogr 1999; 12: 196-202.
19. Bach DS, Armstrong WF, Donovan CL, et al. Quantitative Doppler tissue imaging for assessment of regional myocardial velocities during transient ischemia and reperfusion. Am Heart J 1996; 132: 721-5.
20. Katz WE, Gulati VK, Mahler CM, Gorcsan J. Quantitative evaluation of the segmental left ventricular response to dobutamine stress by tissue Doppler echocardiography. Am J Cardiol 1997; 79: 1036-42.
21. Gorcsan J, Gulati VK, Mandario WA, Katz WE. Color-coded measures of myocardial velocity throughout the cardiac cycle by tissue Doppler imaging to quantify regional left ventricular function. Am Heart J 1996; 131: 1203-13.
22. Wallbridge DR. Hypertrophic cardiomyopathy. In: Erbel R. Nesser HJ, Drozdz J. eds. Atlas of Tissue Doppler Echocardiography-TDE. Heidenberg; Germany, Springer 1995: 95-9.
23. Nakayama K, Miyatake K, Uematsu M, et al. Application of tissue Doppler imaging technique in evaluating early ventricular contraction associated with accessory atrioventricular pathways in Wolff-Parkinson-White Syndrome. Am Heart J 1998; 135: 99-106.
24. Rychik J, Tian ZY. Quantitative assessment of myocardial tissue velocities in normal children with Doppler tissue imaging. Am J Cardiol 1996; 77: 1254-7.
25. Sutherland GR. Colour Doppler myocardial imaging: Potential applications in acquired and congenital heart disease. Acta Paediatr (Suppl) 1995; 410: 40-8.
26. Drozdz J. Movement of the total heart. In: Erbel R. Nesser HJ, Drozdz J. eds. Atlas of Tissue Doppler Echocardiography- TDE. Heidenberg; Germany, Springer 1995: 45-51.

การวิเคราะห์วัดความเร็วของกล้ามเนื้อหัวใจและการเคลื่อนของหัวใจทารกในครรภ์มารดาด้วย Tissue Doppler Image†

*วัชระ จามจุรีรักษ์, พ.บ.**

ปัจจุบัน Fetal Echocardiogram เป็นเครื่องมือในการตรวจความผิดปกติของหัวใจทารกในครรภ์มารดาได้อย่างถูกต้องและแม่นยำ เนื่องจากมีการปรับปรุงเครื่องมือให้มีคุณภาพมากยิ่งขึ้นมีภาพที่ชัดเจนและมี resolution ดีขึ้นมากตลอดจนสามารถดูถึงการทำงานของกล้ามเนื้อหัวใจได้อย่างคร่าว ๆ ด้วย ระยะหลังได้มีการนำ Tissue Doppler Imaging (TDI) มาใช้ในการ evaluate การทำงานของกล้ามเนื้อหัวใจในผู้ใหญ่และเด็ก โดยเฉพาะในผู้ป่วย Myocardial infarction หรือ ischemia ผู้รายงานจึงนำวิธีการนี้มาศึกษาการทำงานของกล้ามเนื้อหัวใจของทารกในครรภ์มารดา (fetal heart) โดยวัดความเร็วของกล้ามเนื้อหัวใจตอนหดตัว และคลายตัวของ anterior wall ของ right ventricle และ posterior wall ของ left ventricle เพื่อใช้เป็นข้อมูลเบื้องต้นเพื่อหวังว่าจะสามารถใช้วิเคราะห์โรคกล้ามเนื้อหัวใจของหัวใจทารกในครรภ์มารดาได้ โดยใช้เครื่อง Toshiba, Power Vision และ Transducer ขนาด 3.75–5 MHz โดยวัดในท่า apical four chamber view หรือ parasternal long axis view โดย super-imposed ด้วย colour-coded M-mode แล้ววัดหาความเร็วของการหดตัวและคลายตัวของกล้ามเนื้อหัวใจทารกในครรภ์มารดา ผลการศึกษาพบว่าความเร็วของกล้ามเนื้อหัวใจของ posterior wall ของ left ventricle ตอนช่วงหดตัว : early, mid, late : 1.5±0.2, 2.1±0.9, 1.0±0.5 ซม/วินาที และ early, mid, late ตอนช่วงคลายตัว : 1.3±0.7, 1.9±0.8, 1.0±0.7 ซม./วินาทีตามลำดับ ส่วนความเร็วของ anterior wall ของ right ventricle ตอนช่วงหดตัว : early, mid, late : 1.7±0.9, 1.7±0.6, 1.0±0.6 ซม/วินาที และ early, mid, late ตอนช่วงคลายตัว : 1.1±0.6, 1.8±0.7, 1.5±1.0 ซม/วินาทีตามลำดับ ส่วนความเร็วของการหดตัวและคลายตัวของ interventricular septum วัดไม่ได้เนื่องจากมี abnormal interventricular septal motion และมีการเคลื่อนไหวของ fetal heart ด้วย โดยพบ fetal heart มีการเคลื่อนไปข้างหน้าและหมุนตัวในทิศทางทวนเข็มนาฬิกาตอนช่วงหดตัว และเคลื่อนไปข้างหลังตอนช่วงคลายตัว จากการศึกษานี้สรุปได้ว่า TDI อาจใช้ evaluate myocardial function ของหัวใจทารกในครรภ์มารดาได้แต่มีข้อจำกัดจากมุมระหว่าง ultrasound beam กับบริเวณกล้ามเนื้อที่ต้องการวัด และการเคลื่อนไหวของหัวใจทำให้ค่าการวัดผิดพลาดได้ การเคลื่อนไหวของหัวใจทารกในครรภ์มารดาจะคล้ายกับในเด็กแรกเกิดและเด็กโต

คำสำคัญ : Tissue Doppler Image (TDI), Fetal Echocardiogram, Myocardial Velocities

วัชระ จามจุรีรักษ์
จดหมายเหตุทางแพทย์ ฯ 2544; 84: 1158–1163

* ศูนย์โรคหัวใจ, โรงพยาบาลกรุงเทพ, กรุงเทพ ฯ 10230

† ส่วนหนึ่งของผลงานนี้เสนอในที่ประชุม 4th World Congress of Echocardiography and Vascular Ultrasound ณ กรุงไคโร ประเทศอียิปต์